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Effect of integrated nutrient management on productivity, quality, nutrient uptake and economics of mustard (*Brassica juncea*)

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ABSTRACT

A field experiment was carried during winter season of 2005-06 and 2006-07 to study the effect of integrated nutrient management on productivity, quality, economics and nutrient uptake of mustard [*Brassica juncea* (L.) Czernj & Cosson] in Indo-Gangetic plains of India. The plant height, total dry matter accumulation, leaf area index and seed and stover yields were recorded significantly higher when recommended dose of fertilizers (RDF) i.e.120:17.6:16.6:40, N:P:K:S kg/ha was applied along with FYM 10t/ha, 25kg $ZnS0_4$/ha and seed treatment with *Azotobacter*. On an average, seed yield of mustard increased by 41.2 % over alone application of RDF. Application of either FYM or Zn or seed treatment along with RDF enhanced the mustard seed yield by 12.0, 11.5 and 13.0%, respectively over RDF alone. The inorganic fertilization had adverse effect on oil as well as glucosinolate contents and highest values were recorded at 50% RDF. Additional application of either of FYM or Zn further increased the oil and glucosinolate contents. Azotobacter seed treatment reduced the glucosinolate but improved the oil content. The highest values of N, P, K, S and Zn content and its uptake were recorded with combined application of RDF with FYM, Zn and *Azotobacter.*

Key words : Bio-fertilizers, Economics, Farm yard manure, Glucosinolate, Oil content

Presently, rapeseed-mustard is the third most important oilseed crops after groundnut and soybean in India occupying 6.18 Mha acreage, 7.36 Mt production and 1109 kg/ha productivity (2008-09). The productivity is quite lower than other developed countries mainly due to sub-optimal application of fertilizers and cultivation on marginal lands under rainfed conditions. Further the quality of mustard oil and its cake is an important aspect affected greatly by mineral nutrition (Tripathi *et al*, 2010). The researchers are working on the quality of rapeseed–mustard to evolve '*zero*' and '*double zero'* type varieties having internationally accepted level of glucosinolate content < 30 µ moles/g free fat meal and erucic acid < 2% of total fatty acids (Malhi *et al*., 2007 and Tripathi *et al*. 2010).

The gap between production and demand of oilseeds is progressively widening, therefore, the production of oilseed is to be increased for self sufficiency. Mustard is a major oilseed crop and its oil is consumed mainly in north India. It is mainly grown in *rabi* season under poor management with imbalanced fertilization. The cost of production is increasing due to high prices of inorganic fertilizers. Therefore, the alternatives of chemical fertilizers are to be looked into just to reduce the cost of cultivation. The organic manures being cheaper and eco-friendly, like FYM, compost and also biofertilizers are available and could be the alternatives of chemical fertilizers for improving both crop productivity and sustainability of the systems. The research findings also indicate that both micronutrients and bio-fertilizers also reduce the glucosinolate and erucic acid in the mustard seed (Tripathi *et al* 2010). Therefore, the present study was carried out with objective to study the effect of integrated nutrient management on seed yield, seed quality, economics and nutrient uptake of mustard in Indo Gangetic plains of India.

MATERIALS AND METHODS

The field experiments were carried out at Lakhaoti, Bulandshahr, Uttar Pradesh during *rabi* season of 2005-06 and 2006-07. Geographically, Lakhaoti is situated in between 28^0 40'N latitude and 77^0 10'E longitude with 207 meter above msl. The experimental site was sandy loam with 0.41 organic carbon and soil pH 7.6. The available nitrogen (N), phosphorus (P), potassium (K), zinc (Zn) and sulphur (S) were 186.8, 10.6, 260.3 kg/ha, 0.45 and 12.0 ppm, respectively. The available N, P, K, S and Zn content in farmyard manure (FYM) were 0.42, 0.20,

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0.48%, 0.14% and 0.70 ppm, respectively. The FYM was applied 15 days before crop sowing. The total rainfall received during *rabi* season of 2006 and 2007 was 90 and 101 mm, respectively. The preceding crops were sorghum in 2005-06 and maize in 2006-07.

The field experiment consisted of 12 treatments, i.e. $T_{1:}$ Recommended dose of fertilizer (RDF) i.e. 120:17.6:16.6:40::N:P:K:S kg/ha), $T_{2:}$ RDF + FYM 10 t/ha, $T_{3:}$ RDF + FYM 10 t/ha + $ZnS0_4$ 25 kg/ha, $T_{4:}$ RDF + FYM 10 t/ha + $ZnS0_4$ 25 kg/ha + *Azotobacter* 10 g/kg seed, $T_{5:}$ 75% of RDF, $T_{6:}$ 75% of RDF + FYM 10 t/ha, $T_{7:}$ 75% of RDF + FYM 10 t/ha + $ZnS0_4$ 25 kg/ha, $T_{8:}$ 75% of RDF + FYM 10 t/ha + $ZnS0_4$ 25 kg/ha + *Azotobacte*r 10 g/kg seed), $T_{9:}$ 50% RDF, $T_{10,}$ 50% RDF + FYM 10 t/ha, $T_{11:}$ 50% RDF + FYM 10 t/ha + $ZnS0_4$ 25 kg/ha and $T_{12:}$ 50% RDF + FYM 10 t/ha + $ZnS0_4$ 25 kg/ha + *Azotobacter* 10 g/kg seed, were arranged in randomized block design with three replications during both the years. Mustard '*Varuna*' was sown on 10 and 16 October of 2005 and 2006 and harvested on 18 and 28 February of 2006 and 2007, respectively.

The field observations on plant height, dry matter accumulation, leaf area, number of branches, number of siliquae, siliqua length, 1000 seed weight, seed weight/plant, seed yield, stover yield, harvest index, oil content, glucosinolate content, economics and nutrient uptake in seed and stover were recorded. The five randomly selected plants from each plot were uprooted and later cleaned and observations like plant height, dry matter, leaf area at peak growth stages (60 DAS) were recorded and averaged. The yield attributes were recorded at harvest to assess the contribution to yield. The branches of five randomly selected plants were counted and reported as number of branches/plant. Similarly, the total siliquae of five sample plants were counted and expressed as number of siliquae/plant. The siliqua length was the average of 10 randomly selected siliquae from five plants. The 1000 seeds were counted from the lot, weighed and expressed as 1000 seed weight. The average seed weight/plant was calculated from five randomly selected plants. The seed and stover yield was computed from the harvest of net plots and expressed in kg/ha.

The seed from the seed lot was taken for the estimation of seed quality, like oil, protein and glucosinolate contents. The oil content was estimated with the help of 'Soxhlet's extraction method'. The glucosinolate was estimated in deffated seed samples received after oil extraction by determining the glucose released by 'Myrosinase hydrolysis (Wang and Mcgregor, 1991). The glucosinolate content was expressed in µ moles/g seed. The economics was calculated on the basis of costs involved and output received at prevailing market rates. The nutrient uptake (N, P, K, S and Zn content) were estimated from both seed and stover, separately during both years and its uptake were estimated with the help of total seed and stover yield multiply with respective nutrient content. In pooled nutrient uptake analysis, the values of both years was pooled and averaged for each nutrient and analyzed. The total uptake was estimated by adding the values of each nutrient for seed and stover both and finally expressed in kg/ha. The experimental data were analyzed statistically by applying the technique of analysis of variance (ANOVA) prescribed for the design to test the significance of over all difference among treatments by the F test and conclusions were drawn at 5% probability levels.

RESULTS AND DISCUSSION

Growth attributes

The growth parameters like plant height, dry matter accumulation and leaf area index were affected significantly by inorganic and organic fertilization during both the years except the plant height in 2005-06 (Table 1). The tallest plants were observed at application of RDF + FYM + Zn + seed treatment with *Azotobacter,* followed by 75% RDF + FYM + Zn + seed treatment with *Azotobacter* and 50% RDF + FYM + Zn + seed treatment with *Azotobacter* during both years. The plant height was increased by applying FYM, zinc and seed treatment with *Azotobacter* along with chemical fertilizers. Total plant dry matter accumulation was recorded significantly highest at integrated application of RDF + FYM + Zn + seed treatment with *Azotobacter* during both years but it was found on par with 75% RDF + FYM + Zn + seed treatment with *Azotobacter* and 50% RDF + FYM + Zn + seed treatment with *Azotobacter*. The lowest values were recoded at 50% RDF level during both years. The balanced nutrient application made higher nutrient available to plants resulted into more height and dry matter accumulation and it was also supported by Shukla *et al.* (2002).

The treatment consisted of RDF + FYM + Zn + seed treatment gave the highest leaf area index followed by treatments 75% RDF + FYM + Zn + seed treatment and 50% RDF + FYM + Zn + seed treatment, respectively. Further the RDF had, however, higher leaf area index than 75 and 50% RDF levels but did not differ each other significantly during both the years. The leaf area index increased significantly at application of FYM at all three RDF levels only in 2005-06. Higher availability of essential nutrients particularly nitrogen increased the plant height, vigor, dry matter accumulation, leaf area and number of branching per plant (Giri *et al*. 2002 and Kumar, 2006).

Yield attributes

All yield parameters including number of branches, number of siliquae, number of seeds/siliqua, 1000 seed weight and seed weight/plant differed significantly with different nutrient management treatments during both years. In general, the higher values of yield parameters were recorded during 2005-06 than 2006-07 and lower values were observed with reduced fertility levels (Table 2). Number of branches increased with fertility levels and significantly higher value was recorded at application of RDF with additional application of FYM, Zn and seed treatment, that did not vary significantly with treatments RDF + FYM + Zn, 75% RDF + FYM + Zn, 75% RDF + FYM + Zn + seed treatment and 50% RDF + FYM + Zn + seed treatment during both years. Similarly, the treatment with RDF + FYM + Zn + seed treatment gave significantly higher number of siliquae/plant during both the years, however, it remained significantly similar with treatments RDF + FYM + Zn, 75% RDF + FYM + Zn, 75% RDF + FYM + Zn + seed treatment and 50% RDF + FYM + Zn + seed treatment with *Azotobacter* during both years. Seeds/siliqua was also found maximum at maximum fertility level i.e. RDF + FYM + Zn + seed treatment during both years but treatments RDF + FYM + Zn, 75% RDF + FYM + Zn, 75% RDF + FYM + Zn + seed treatment and 50% RDF + FYM + Zn + seed treatment in 2005-06 and RDF + FYM + Zn, 75% RDF + FYM + Zn + seed treatment and 50% RDF + FYM + Zn + seed treatment during 2006-07. 1000 seed weight was also found maximum at RDF + FYM + Zn + seed treatment during both years. In 2005-06, the treatments 75% RDF and 50% and in 2006-07, 75% RDF + FYM + Zn + seed treatment and 50% RDF + FYM + Zn + seed treatments' RDF' had significantly lower and similar test weight, respectively. The seed weight/plant was recorded with significantly maximum value at RDF + FYM + Zn + seed treatment during both years, however it remained significantly similar to RDF + FYM + Zn, 75% RDF + FYM + Zn + seed treatment and 50% RDF + FYM + Zn + seed treatment. The higher values of yield attributes is the result of higher fertility levels resulted in to better growth and more translocation of photosynthates from source to sink (Tripathi *et al*. 2005 and Rana *et al*. 2005). Further, the positive effect of supplementary nutrients on yield attributes of Indian mustard was observed by Rana *et al.* (2005) and Kumar (2006).

Seed and stover yield

Mustard seed yield differed significantly with different nutrient levels during both the years (Table 2). The yield was reduced with reduction in recommended dose of inorganic fertilizers (RDF) i.e. 75 and 50% RDF but increased with successive addition of supplementary nutrients like FYM and zinc at both levels. Treatment with RDF + FYM ± Zn + seed treatment gave the highest seed yield in both the years, however, it remained significantly at par with treatments 75% RDF + FYM + Zn + seed treatment, 50% RDF + FYM + Zn + seed treatment and RDF + FYM + Zn in 2005-06 and 75% RDF + FYM + Zn + seed treatment, 50% RDF + FYM + Zn + seed treatment, RDF + FYM, RDF + FYM + Zn, 75% RDF + FYM and 50% RDF +

Table 1. Effect of integrated nutrient management on growth of mustard

Treatment	Plant height (cm)		Total dry matter (g/plant)		LAI (60DAS)		Branches/plant	
	Y_1*	Y_2**	Y_1*	Y_2**	Y_1*	Y_2**	Y_1*	Y_2**
Recommended dose of fertilizer (RDF)	165	154	47.8	36.6	0.74	0.62	11.9	9.5
RDF + FYM 10 t/ha	168	156	49.0	39.4	0.88	0.70	12.4	11.1
RDF + FYM 10 t/ha + $ZnSO_4$ 25 kg/ha	172	162	52.8	47.4	1.26	0.74	16.2	12.4
RDF + FYM 10 t/ha + $ZnSO_4$ 25 kg/ha + *Azotobacter* 10 g/kg seed	177	172	62.8	50.6	1.80	0.95	20.8	16.7
75% RDF	163	139	45.1	31.9	0.71	0.53	9.7	8.8
75% RDF + FYM 10 t/ha	167	143	46.5	33.7	0.84	0.56	10.2	9.9
75% RDF + FYM 10 t/ha + $ZnSO_4$ 25 kg/ha	170	149	55.1	40.3	1.25	0.71	15.1	12.2
75% RDF + FYM 10 t/ha + $ZnSO_4$ 25 kg/ha + *Azotobacter* 10 g/kg seed	174	169	59.4	45.8	1.67	0.94	18.9	14.5
50% RDF	162	148	41.7	24.9	0.68	0.40	9.2	7.7
50% RDF + FYM 10 t/ha	165	151	44.0	26.1	0.81	0.43	10.0	10.1
50% RDF + FYM 10 t/ha + $ZnSO_4$ 25 kg/ha	170	156	51.4	32.9	1.18	0.52	13.3	11.2
50% RDF + FYM 10 t/ha + $ZnSO_4$ 25 kg/ha + *Azotobacter* 10 g/kg seed	173	170	57.2	32.5	1.61	0.90	17.3	13.2
SEm±	03	05	2.0	1.8	0.22	0.11	1.4	1.2
CD (P =0.05)	NS	14	5.9	5.3	0.63	0.32	4.1	3.4

Y_1*: 2005-06 and Y_2**: 2006-07; RDF: 120 kg N, 17.6 kg P, 16.6 kg K, 40 Kg S/ha

FYM + Zn in 2006-07. The mean mustard yield was significantly higher at RDF + FYM + Zn that had 6.5 and 11.7% higher values than 75% RDF + FYM + Zn and 50% RDF + FYM + Zn, respectively. The treatment consisted of RDF gave significantly higher average mean seed yield than reduced fertility levels at 75% and 50% RDF levels with 5.4 and 10.6% lower seed yield, respectively (Fig 1). Application of either FYM or Zinc or in combination with inorganic fertilizers improved the seed yield of mustard during both years. Additional application of FYM 10t/ha increased seed yield by 11.8, 9.7 and 13.9% in 2005-06 and 12.2, 12.4 and 12.5% in 2006-07 over 100, 75 and 50% RDF levels, respectively. Further, the supplementation of Zinc 25kg/ha along with FYM to different inorganic fertilizer levels improved the seed yield by 26.5, 26.6 and 34.3% in 2005-06 and 22.8, 15.7and 18.9% in 2006-07 at 100, 75 and 50% RDF levels, respectively. Similarly, the treatments consisted of seed treatment with *Azotobacter* and FYM and Zinc application gave 43.5, 43.2 and 49.7% in 2005-06 and 38.1, 36.5 and 31% higher seed yield than 100, 75 and 50% RDF levels, respectively. The results also revealed that mustard yield was increased by more than 10% by alone application of either zinc or seed treatment with *Azotobacter*. Higher mustard yield was attributed to improved availability of essential nutrient and growth hormones that led to enhanced N metabolism and protein synthesis (Kumar, 2006 and Tripathi *et al*. 2010).

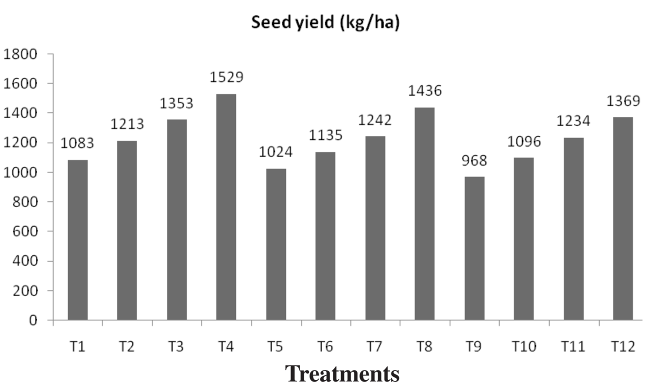

Fig. 1. Effect of integrated nutrient management on seed yield of mustard

(Average value of two years i.e. 2005-06 and 2006-07)

Stover yield did not influence significantly by different fertility levels during both years (Table 2). Stover yield was recorded higher at RDF level and reduced greatly with reduced RDF with average reduction of 3.1 and 11.8% at 75 and 50% RDF levels, respectively. The highest stover yield was found when RDF was applied with FYM + Zn + *Azotobacter* seed treatment during both years as evidenced with average increase of 17.6% in 2005-06 and 14.6% in 2006-7 over the 75 and 50% RDF levels. The treatments RDF + FYM 10 t/ha+ Zn 25 kg/ha, 75% RDF + FYM 10 t/ha + Zn 25 kg/ha and 50% RDF + FYM 10 t/ha + Zn 25 kg/ha gave 12.2, 9.3 and 12.1% higher average stover yield, respectively than alone application of RDF. The greater stover yield at higher fertility was attributed to increased plant height and leaf area and finally dry matter accumulation per plant and this was also concluded by Kumar (2006).

The harvest index varied from 19.8 to 23.5 in 2005-06 and 17.8 to 22.3 in 2006-07 but remained non significant among different nutrient management practices, however, the highest values were recorded at higher fertility levels during both the years (Table 2). Higher average values were also observed at higher fertility levels as it was 22.5, 21.9 and 21.8 at RDF + FYM + Zn, 75% RDF + FYM + Zn and 50% RDF + FYM + Zn, respectively. The higher fertility improved the growth and development of the plants by improving the uptake of essential nutrients and translocation of sink to source, resulting in to higher harvest index**.**

Quality parameters

Integrated application of RDF, 75 and 50% RDF along with FYM, Zn and seed treatment had significantly higher oil content compared to alone application of any of the chemical fertilizers, however, the highest oil content was recorded at 50% RDF + FYM + Zn + seed treatment during both years, (Table 3). The lowest oil content was noticed at application of alone RDF during both years. The increase in oil content under FYM, zinc and *Azotobacter* seed treatment might be attributed to the increased availability of S and Zn that involved in an increased conversion of primary fatty acids metabolites to the end products of fatty acid as supported by Tripathi *et al*. (2010). Further, higher levels of chemical fertilization improved N availability that helped to more protein production and made potential deficiency of carbohydrates vis – a vis '*acetyle co-enzyme A'*, precursor of fatty acid resulted in to low oil content (Shukla *et al.* 2002)

The glucosinolate content is one of the important aspects related to seed quality of mustard. The glucosinolate content decreased with increasing fertility levels either from 50% RDF to 75% RDF and RDF levels alone or with additional application of FYM and $ZnSO_4$ but seed treatment with *Azotobacter* further lowered down the values during both the years. However, variable response of FYM, $ZnS0_4$ and seed treatment on glucosinolate content was noticed (Table 3). Significantly highest glucosinolate content was recorded at 50% RDF level during both the years but it did not differ with treatment 50% RDF + FYM in 2006-07. The lowest glycosinolate was noticed in treat-

Table 2. Effect of integrated nutrient management on yield attributes, seed yield and harvest index of mustard

Treatment	Siliquae/ plant		Siliqua length (cm)		Seeds/ siliqua		1000 seed weight (g)		Seed weight/ plant (g)		Seed yield (t/ha)		Stover yield (t/ha)		Harvest index (%)	
	Y_1*	Y_2**	Y_1*	Y_2**	Y_1*	Y_2**	Y_1*	Y_2**	Y_1*	Y_2**	Y_1*	Y_2**	Y_1*	Y_2**	Y_1*	Y_2**
Recommended dose of fertilizer (RDF)	209	154	3.63	3.17	11.9	6.9	10.41	6.63	6.4	5.0	1.22	0.95	4.48	4.40	21.4	17.8
RDF + FYM 10 t/ha	206	167	3.7	3.37	11.4	8.3	10.43	6.62	6.8	5.4	1.36	1.06	4.96	4.50	21.6	19.1
RDF + FYM 10 t/ha + $ZnSO_4$ 25 kg/ha	236	208	3.87	3.93	13.4	10.4	10.45	6.80	8.1	6.4	1.54	1.16	5.31	4.64	22.5	20.0
RDF + FYM 10 t/ha + $ZnSO_4$ 25 kg/ha + *Azotobacter* 10 g/kg seed	272	258	4.30	4.47	14.7	12.8	12.31	7.82	10.4	8.2	1.75	1.31	5.71	4757	23.5	21.5
75% RDF	190	142	3.63	3.30	11.4	6.5	9.60	6.10	6.1	4.7	1.11	0.94	4.43	4.30	20.0	17.9
75% RDF + FYM 10 t/ha	196	154	3.67	3.37	11.9	7.9	10.50	6.35	6.5	5.4	1.22	1.06	4.62	4.35	20.8	19.5
75% RDF + FYM 10 t/ha + $ZnSO_4$ 25 kg/ha	221	195	3.83	3.77	12.9	10.2	11.01	6.49	7.8	5.8	1.40	1.09	5.12	4.43	21.0	19.7
75% RDF + FYM 10 t/ha + $ZnSO_4$ 25 kg/ha + *Azotobacter* 10 g/kg seed	237	234	4.03	4.23	14.0	11.7	11.93	7.16	9.0	6.9	1.58	1.28	5.54	4.46	22.2	21.6
50% RDF	188	123	3.30	2.70	11.3	7.3	10.14	5.89	5.7	4.4	1.04	0.89	4.21	3.63	19.8	19.8
50% RDF + FYM 10 t/ha	198	147	3.63	3.23	11.8	8.3	10.35	6.25	6.3	4.9	1.19	1.01	4.47	3.72	21.1	19.8
50% RDF + FYM 10 t/ha + $ZnSO_4$ 25 kg/ha	214	191	3.80	3.53	12.3	10.8	10.82	6.55	7.6	6.0	1.40	1.06	4.97	3.81	22.0	20.6
50% RDF + FYM 10 t/ha + $ZnSO_4$ 25 kg/ha + *Azotobacter* 10 g/kg seed	230	227	4.00	4.20	13.8	13.2	11.69	7.06	83.5	6.7	1.56	1.18	5.17	4.10	21.3	22.3
SEm±	20	23	0.20	0.3	0.7	0.8	0.68	0.34	0.8	0.8	0.09	0.10	0.43	0.41	2.6	2.7

Y_1^*: 2005-06 and Y_2^{**}: 2006-07

ment RDF + FYM + Zn + seed treatment' in both the years followed by the treatments RDF, RDF + FYM and RDF + FYM + Zn. The higher fertility reduced the glucosinolate content in mustard seed mainly because of dilution effect as higher fertility enhanced the growth and dry matter production. On other hand, higher glucosinolate content with application of FYM and $ZnS0_4$ is attributed to increased availability of S containing amino acids which are precursors for biosynthesis of glucosinolates (Krishna *et al*. 2005 and Tripathi *et al.* 2010).

Nutrient uptake

Nutrient uptake differed significantly with varying fertility levels during both years (Table.4 and fig 2). The nutrient uptake increased with successive increase in fertility levels from 50% RDF to 75% and RDF levels and also with combined application FYM, $ZnS0_4$ and seed treatment under different levels of chemical fertilization. The highest uptake of N, P, K, S and Zn in seed as well as in stover was recorded at RDF + FYM + Zn + seed treatment during both the years. The lowest uptake values of different nutrients in seed and stover were noticed at 50% RDF levels during both years (Table 4). The higher values of nutrient uptake in seed and stover of mustard was mainly attributed to different fertility levels as the nutrient uptake was increased with successive increase in chemical fertilization. Besides, the combined application of chemical fertilizers with FYM, Zn and seed treatment further improved the nutrient uptake mainly due to better growth and dry matter accumulation. The balanced nutrition also enhanced the synergistic effect on uptake of other plant nutrients (Ahmad *et al*. 2007).

Economics

The gross returns, net returns and net B:C ratio of the mustard were influenced significantly by integrated nutri-

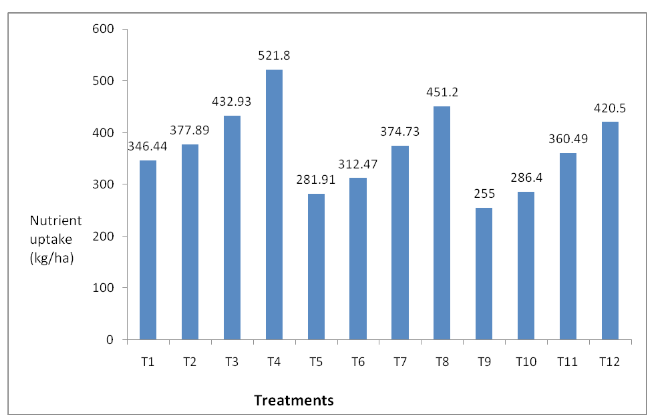

Fig 2. Effect of integrated nutrient management on total nutrient uptake (kg/ha).
(Average value of two years i.e. 2005-06 and 2006-07)

Table 3. Effect of integrated nutrient management on oil and glucosinolate content and economics (pooled data of two years) of mustard production

Treatment	Oil content(%)		Glucosinolate content (μ moles/g seed)		Economics (10^3 × ₹/ha)*		
	Y_1*	Y_2**	Y_1*	Y_2**	Cost of cultivation	Net returns	B:C ratio
Recommended dose of fertilizer (RDF)	38.2	38.7	106.6	110.7	10.89	16.16	1.48
RDF + FYM 10 t/ha	38.4	38.8	109.0	117.5	12.39	17.88	1.44
RDF + FYM 10 t/ha + $ZnSO_4$ 25 kg/ha	38.9	39.5	106.5	123.4	13.02	20.73	1.59
RDF + FYM 10 t/ha + $ZnSO_4$ 25 kg/ha + *Azotobacter* 10 g/kg seed	39.6	39.9	102.6	103.8	13.07	26.11	2.00
75% RDF	39.0	39.2	115.0	124.7	10.18	15.37	1.51
75% RDF + FYM 10 t/ha	39.2	39.4	118.0	123.7	11.68	16.67	1.43
75% RDF + FYM 10 t/ha + $ZnSO_4$ 25 kg/ha	39.9	40.2	115.3	128.3	12.31	18.69	1.52
75% RDF + FYM 10 t/ha + $ZnSO_4$ 25 kg/ha + *Azotobacter* 10 g/kg seed	40.5	40.6	108.9	109.0	12.36	23.49	1.90
50% RDF	39.5	39.8	142.4	137.2	9.44	14.77	1.56
50% RDF + FYM 10 t/ha	39.7	40.0	121.5	133.7	10.94	15.44	1.41
50% RDF + FYM 10 t/ha + $ZnSO_4$ 25 kg/ha	40.4	40.6	113.1	117.2	11.56	19.24	1.66
50% RDF + FYM 10 t/ha + $ZnSO_4$ 25 kg/ha + *Azotobacter 1*0 g/kg seed	40.9	41.5	117.0	114.5	11.61	22.57	1.94
SEm±	0.3	0.3	5.9	2.5	-	1.30	0.03
CD (P =0.05)	1.0	1.0	17.0	7.2	-	3.81	0.10

Y_1*: 2005-06; and Y_2*: 2006-07 & *[1] – Average values of 2005-06 and 2006-07.

Table 4. Effect of integrated nutrient management on nutrient uptake of mustard at harvest (Average values of 2005-06 and 2006-07)

Treatment	Nutrient uptake (kg/ha)									
	Seed					Stover				
	N	P	K	S	Zn	N	P	K	S	Zn*
Recommended dose of fertilizer (RDF)	80.2	17.2	22.9	12.3	134	40.9	22.2	131.0	19.2	410
RDF + FYM 10 t/ha	90.9	17.2	27.1	13.7	152	45.0	24.1	139.0	20.3	438
RDF + FYM 10 t/ha + $ZnSO_4$ 25 kg/ha	103.0	22.6	31.6	15.5	196	52.9	30.8	153.3	22.5	533
RDF + FYM 10 t/ha + $ZnSO_4$ 25 kg/ha + *Azotobacter 1*0 g/kg seed	117.8	28.4	36.8	17.6	236	66.6	39.9	186.7	27.1	663
75% RDF	73.7	14.1	19.6	11.4	107	29.0	15.1	102.7	15.9	303
75% RDF + FYM 10 t/ha	81.9	15.8	22.4	12.7	121	32.9	18.1	110.8	17.4	344
75% RDF + FYM 10 t/ha + $ZnSO_4$ 25 kg/ha	93.3	18.7	25.9	14.1	158	41.7	27.4	131.9	21.1	470
75% RDF + FYM 10 t/ha + $ZnSO_4$ 25 kg/ha + *Azotobacter 1*0 g/kg seed	110.1	23.0	33.0	16.35	197	53.5	35.4	155.2	23.9	557
50% RDF	66.8	9.8	15.5	10.65	88	26.4	12.6	97.5	15.4	261
50% RDF + FYM 10 t/ha	76.5	11.7	18.8	12.1	108	32.3	13.3	104.6	16.7	292
50% RDF + FYM 10 t/ha + $ZnSO_4$ 25 kg/ha	87.8	14.4	22.7	13.8	158	44.8	22.6	132.4	21.4	432
50% RDF + FYM 10 t/ha + $ZnSO_4$ 25 kg/ha + *Azotobacter* 10 g/kg seed	99.4	17.8	26.3	15.4	187	53.7	31.2	151.8	24.2	515
SEm±	7.0	1.6	2.0	1.55	12	2.8	2.2	7.4	1.1	43
CD (P =0.05)	20.2	4.6	5.7	3.55	35	5.0	6.4	21.2	3.2	133

*Zn uptake in g/ha

ent management during both years (Table 3). The mean cost of cultivation was observed maximum under treatment RDF + FYM + Zn + seed treatment followed by RDF + FYM + Zn, 75% RDF + FYM + Zn + seed treatment and 75% RDF + FYM + Zn but the lowest in 50% RDF, followed by 75% RDF and RDF treatment. The net return was significantly highest with nearly 11% higher at RDF + FYM + Zn + seed treatment but it remained at par with 75% RDF + FYM + Zn + seed treatment. The net B:C ratio was also noticed significantly highest at RDF + FYM + Zn + seed treatment. All other treatments except RDF + FYM, 75% RDF + FYM and 50% RDF + FYM gave higher net B:C ratio than alone application of RDF indicating more beneficial than application of recommended fertilizers.

Based on the study, it is concluded that application of

RDF (120:17.6:16.6:40, N:P:K:S kg/ha) along with 10 t FYM/ha, 25 kg $ZnSO_4$/ha and seed treatment with *Azotobacter* is the better option for realizing higher productivity, seed quality and net returns of mustard in Indo-Gangetic plains of India.

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