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Production potential, nutrient uptake and economics of Indian mustard (*Brassica juncea*) under integrated nutrient management practices

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ABSTRACT

A field experiment was conducted during the winter (*rabi*) seasons of 2009-10 and 2010-11 to study the production potential, nutrient uptake and economics of Indian mustard (*Brassica juncea* L.) under eight treatments of organic sources and three levels of inorganic nitrogen for integrated nutrient management practices. The organic sources comprising combined application of 5.0 tonnes/ha FYM along with PSM and *Azospirillum* or PSM being at par produced significantly higher yield attributes, yield, economics and nutrient uptake of mustard over sole application of 2.5 tonnes FYM/ha. Increasing application of inorganic nitrogen fertilizer from 0 to 80 kg N/ha significantly increased yield attributes, yield, economics and nutrient uptake of mustard. On an average, increase in seed yield due to the application of 80 kg N/ha was to the tune of 7.27 and 22.27 per cent over 40 and 0 kg N/ha, respectively. There was build up of available N, P, K and S in the soil after cropping. Integrated use of 5.0 tonnes FYM/ha along with PSM + *Azospirillum* and 80 kg N/ha is necessary for getting higher seed yield and is the most remunerative and effective integrated approach of Indian mustard after the completion of two years of experimentation.

Key words : *Azospirillum*, Economics, FYM, Mustard, Nitrogen, Nutrient uptake, Yield

Oilseed *Brassicas*, collectively known as rapeseed-mustard are important oilseed crops of India and stand second after soybean in production among the eight annual edible oilseeds cultivated in our country. Among oilseed *Brassica* species, major area is under *Brassica juncea* which contributes about 80% of the total rapeseed-mustard production in the country. All oilseed *Brassicas* are cultivated in about 6.18 million ha with 7.36 million tonnes production of oilseed contributing about 26.8% and 24.7% of the total oilseed production and acreage, respectively in the country with the average productivity of 1 190 kg/ha (AICRPRM 2009). Mostly they are cultivated for edible oils but used as condiments, spices, leafy vegetable and as fodder for livestock. The differential trends in seed yield of rapeseed-mustard under a particular agroclimatic condition have been noticed due to varying moisture and nutrient status of soil. *Brassica juncea* requires relatively large amount of nutrients for realization of yield potential but inadequate supply often leads to low productivity (Tripathi *et al.* 2010). Under such situation, organic resources such as farmyard manure (FYM) and biofertilizers like *Azospirillum* and phosphate solubilizing microorganism (PSM) can be exploited to boost the production and also to improve fertilizer use efficiency. In fact, fertilizers no doubt played a key role in agricultural production and changed country from a region of food scarcity to food sufficiency. But chemical fertilizers have also contributed significantly towards the pollution of water, air and soil. So the current trend is to explore the possibility of supplementing chemical fertilizers with organic ones which are eco-friendly and cost-effective (Datta *et al.* 2009). Farmyard manure improves soil quality apart from supplying all essential nutrients and enhancing the activity of microorganisms. The bioferitilzer inoculation by the way of nitrogen-fixation, solubilization of insoluble phosphate and production of growth hormones, vitamins and siderophores favourably effect crop growth. Sinha (2003) reported that higher seed yield of mustard with the highest level of organic matter enrichment along with biofertilizers. Seed inoculation of *Azotobactor* and *Azospirillum* in presence of partial application of fertilizer-N and farmyard manure yielded less grain by 12.7 and 8.3% and less stover yield by 10.6 and 17.1%, respectively while the combined seed inoculation of diazotrophs increase grain and straw yields by 4.5 and 5.9%, respectively than the optimum yields recorded in the soil treated with 100 kg N/ha only (Das and Saha 2007). Further, the activity of organic resources may also be influenced by

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supply of nutrients to the soil. Nitrogen is considered to be the most important nutrient for the crop to activate the metabolic activity and transformation of energy, chlorophyll and protein synthesis. Nitrogen also affects the uptake of other essential nutrients and it helps in the better partitioning of photosynthates to reproductive parts which increase the seed: stover ratio (Singh and Meena 2004). Hence, an attempt was made to assess the response of Indian mustard to integrated nutrient management.

MATERIALS AND METHODS

A field experiment was conducted during winter (*rabi*) seasons of 2009-10 and 2010-11 at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. The farm is located at 25° 18¢ North Latitude, 83° 03¢ East Longitude and altitude of 129 m above mean sea level. The soil was sandy clay loam in texture (43.2% sand, 18.1% silt and 38.7% clay) having *p*H 7.2, low organic carbon 0.34 and 0.37%, available nitrogen 187.5 and 191.3 kg/ha, available phosphorus 17.8 and 18.5 kg/ha, available potassium 178.4 and 182.1 kg/ha and available sulphur 11.9 and 12.6 kg/ha, respectively. The experiment consisting of eight organic sources were kept in main plots (two levels of farmyard manure, i.e. 2.5 and 5.0 tonnes FYM/ha and two biofertilizers, i.e. PSM and *Azospirillum*) and in sub-plots three levels of nitrogen (0, 40 and 80 kg/ha) was laid out in split-plot design with three replications. Maya Indian mustard variety was sown in 30 cm apart at a seed rate of 5.0 kg seed/ha on the first week of November. The crop was thinned 15 days after sowing to maintain a plant to plant spacing of 10 cm. Farmyard manure and biofertilizers such as PSM and *Azospirillum* were the organic sources and fertilizer urea for nitrogen was the inorganic source applied as treatment. The required amount of FYM containing 0.50% N, 0.25% P, 0.50% K and 0.15% S as per the treatments was incorporated into the soil one month before sowing of crop. The seeds were inoculated with biofertilizers (PSM and *Azospirillum*), a slurry was prepared by dissolving 200 g brown sugar in 250 ml water and then warming it for 15 min at 40°C. Inoculation was done by mixing the seeds with PSM or *Azospirillum* culture slurry. The seeds were then dried in shade for 24 hr and sown. A basal dose of phosphorus and potassium at 40 and 40 kg/ha through single super phosphate and muriate of potash were applied uniformly in the whole field at the time of sowing, respectively whereas schedules of nitrogen application varied according to the treatments. Half dose of nitrogen were applied uniformly as per treatments at the time of sowing and remaining half of the N was top dressed after the first irrigation (35 days after sowing) as per treatments through urea.

Soil samples at 0-0.15 m depth were collected from each plot before and after sowing of crop and analyzed for per cent available nitrogen by alkaline-$KMnO_4$ method, available phosphorus by 0.5 M $NaHCO_3$ (*p*H 8.5) extraction method followed by colour development by ascorbic acid method, available potassium extracted by 1 N neutral NH_4OAc and available sulphur by 0.15% $CaCl_2$ extraction method. The plant samples were collected at harvest and dried in oven (±70°C), processed and thoroughly mixed and analyzed for nitrogen, phosphorus, potassium and sulphur (N, P, K and S) content was estimated by Kjeldahl, Vanado-molybdate yellow colour, Flame-photometric and Turbidimetric method, respectively. N, P, K and S uptake were calculated by formula (Nutrient content/100 multiplied by seed/stover yield in kg/ha). Harvest index was calculated by using the formula (Economic yield/total biomass multiplied by 100). The economics of mustard crop was calculated by treatment wise in term of gross return (₹/ha), net return (₹/ha) and benefit: cost ratio, respectively. The curve estimation of nitrogen level (N kg/ha) and seed yield (kg/ha) mean data was done with the Microsoft office excels 2007 and optimum economic dose calculated by regression equation:

Optimum economic dose = (Output/Input)-b/2c

where, Output = Input b = X (regression equation value) and c = X^2 (regression equation value)

RESULTS AND DISCUSSION

Yield attributes

The yield attributes, viz. length of siliqua, siliquae/plant, seeds/siliqua and 1000-seed weight of Indian mustard differed significantly due to different treatments of organic sources during both the years (Table 1). Maximum length of siliqua was recorded in the combined application of 5.0 tonnes FYM/ha along with PSM and *Azospirillum* which was statistically at par with all the treatments comprising FYM along with PSM and *Azospirillum* or PSM/ *Azospirillum* but was found significantly superior over sole application of 2.5 tonnes FYM/ha. Treatment receiving 5.0 tonnes FYM/ha along with PSM and *Azospirillum* observed significantly more number of siliquae/plant and seeds/siliqua which were statistically at par with all the other treatments of FYM and biofertilizers, i.e. PSM and *Azospirillum* alone or in combination but proved significantly superior over the application of 2.5 tonnes/ha FYM, respectively. Further, the application of 5.0 tonnes FYM/ha along with seed inoculation of PSM and *Azospirillum* being at par with application of 2.5 tonnes FYM/ha with PSM and *Azospirillum*, and 5.0 tonnes FYM/ha with PSM or *Azospirillum* produced significantly heavier seed than the application of 2.5 tonnes/ha FYM with PSM, and FYM alone treated plots, respectively in both the years. The maximum values of yield attributes were recorded in the combined application of FYM and biofertilizers, i.e. PSM and *Azospirillum*, could be ascribed to better growth and more photosynthate accumulation as a result of adequate nutrients availability to the crop.

Table 1 Effect of integrated nutrient management on yield attributes of mustard

Treatment	Length of siliqua (cm)		Siliquae/plant		Seeds/siliqua		1 000-seed weight (g)	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Organic source								
2.5 tonnes FYM/ha	3.93	3.48	148.78	150.33	10.73	11.67	3.12	3.41
5.0 tonnes FYM/ha	4.10	4.22	154.44	170.84	11.88	14.28	3.37	3.77
2.5 tonnes FYM/ha + PSM	4.01	4.02	151.91	168.31	11.68	14.08	3.25	3.65
5.0 tonnes FYM/ha + PSM	4.30	4.52	159.13	175.53	12.20	14.60	3.73	4.19
2.5 tonnes FYM/ha + *Azospirillum*	4.00	4.12	149.33	165.73	11.38	13.78	3.21	3.61
5.0 tonnes FYM/ha + *Azospirillum*	4.28	4.40	155.68	172.08	12.07	14.47	3.37	3.77
2.5 tonnes FYM/ha + PSM + *Azospirillum*	4.10	4.22	154.33	170.73	11.79	14.19	3.36	3.76
5.0 tonnes FYM/ha + PSM + *Azospirillum*	4.56	4.66	162.08	178.62	12.57	16.00	3.83	4.25
SEm±	0.18	0.20	2.59	2.44	0.33	0.58	0.14	0.16
CD (*P*=0.05)	0.56	0.59	7.86	7.40	1.01	1.77	0.43	0.47
Nitrogen level (kg/ha)								
Control	3.59	3.52	121.50	132.90	9.94	11.79	2.97	3.22
40	4.28	4.38	156.26	172.10	12.09	14.49	3.40	3.87
80	4.60	4.71	185.63	202.08	13.33	16.12	3.85	4.32
SEm±	0.11	0.12	1.24	1.22	0.16	0.27	0.08	0.09
CD (*P*=0.05)	0.32	0.35	3.56	3.52	0.47	0.79	0.22	0.26

Successive increase in the nitrogen levels significantly improved the yield attributes of mustard during both the years of crop seasons (Table 1). Among different nitrogen levels, the application of 80 kg N/ha recorded maximum length of siliqua which was significantly longer than 40 kg N/ha and control (no nitrogen), respectively. Number of siliquae/plant and seeds/siliqua enhanced significantly corresponding with each increment of nitrogen from 0 to 80 kg N/ha. The highest siliqua length in 80 kg N/ha might be probable reason for higher number of seeds/siliqua. Further, 1000-seed weight was found to be significantly higher in 80 kg N/ha when compared with 40 kg N/ha and control. This might be due to the synergistic effect of nitrogen on cell division and photosynthetic rate of the crop, resulting higher uptake of nutrient and thereby increasing the yield attributes (Garanayak *et al*. 2000).

Yield

Increasing application of farmyard manures from 2.5 to 5.0 tonnes/ha and combined application of PSM or *Azospirillum* or both with farmyard manure also increased seed and stover yield of mustard (Table 2). Maximum seed yield (1 834 and 1 932 kg/ha) was recorded with the application of 5.0 tonnes FYM/ha along with PSM and *Azospirillum,* though it was at par with that of other treatments of organic sources comprising 5.0 tonnes FYM/ha alone and FYM in combination with PSM and *Azospirillum* or PSM/ *Azospirillum* but was found significantly superior over sole application of 2.5 tonnes FYM/ha. On an average, the combined application of 5.0 tonnes FYM/ha along with PSM and *Azospirillum* recorded 13.83 per cent higher seed yield than sole application of 2.5 tonnes FYM/ha. It seems that application of low dose of FYM alone could not supply sufficient nutrients at critical growth stages of the crop. Similar trends were observed in stover yield. Harvest index did not differ significantly, but was recorded the highest harvest index with combined application of 5.0 tonnes FYM/ ha along with PSM and *Azospirillum* and was the lowest harvest index with application of 2.5 tonnes FYM/ha during both the years. This has been due to enhanced nutrient availability. The results on seed yield thus confirmed the trend observed earlier in the yield attributing characters. 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 yield components and finally the yield. These results are in conformity with those of Singh and Sinsinwar (2006) and Datta *et al.* (2009).

There was a significant increase in seed yield of mustard with successive increment in each nitrogen level from 0 to 80 kg N/ha. The increase in seed yield due to 80 kg N/ha application was to the tune of 6.97, 20.77 and 7.56, 23.77 per cent over 40 kg N/ha and control, respectively. Stover yield showed trend similar to seed yield with the highest values recorded for the application of 80 kg N/ha. There was an increase of 7.04, 20.90 and 2.70, 13.23 per cent stover yield with 80 kg N/ha when compared with 40 kg N/ha and control, respectively. It may be attributed to the fact that the initial status of available nitrogen in the soil was low and under such condition a significant increase in the yield was expected.

Table 2 Effect of integrated nutrient management on yield, harvest index and economics of mustard

Treatment	Seed yield (kg/ha)		Stover yield (kg/ha)		Harvest Index (%)		Gross return (₹/ha)		Net return (₹/ha)		Benefit: cost ratio	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Organic source												
2.5 tonnes FYM/ha	1 673	1 651	5 000	5 450	25.07	23.20	33 118	33 277	19 969	20 128	1.5	1.5
5.0 tonnes FYM/ha	1 807	1 909	5 405	5 934	25.07	24.30	35 765	38 278	22 266	24 779	1.6	1.8
2.5 tonnes FYM/ha + PSM	1 799	1 878	5 379	5 878	25.09	24.20	35 605	37 689	22 448	24 530	1.7	1.8
5.0 tonnes FYM/ha + PSM	1 826	1 930	5 456	6 014	25.09	24.25	36 144	38 711	22 637	25 202	1.7	1.8
2.5 tonnes FYM/ha + *Azospirillum*	1 789	1 878	5 353	5 838	25.09	24.29	35 409	37 665	22 248	24 506	1.7	1.8
5.0 tonnes FYM/ha + *Azospirillum*	1 819	1 913	5 437	5 937	25.09	24.34	36 012	38 362	22 501	24 853	1.6	1.8
2.5 tonnes FYM/ha + PSM + *Azospirillum*	1 805	1 881	5 397	5 927	25.09	24.05	35 734	37 753	22 565	24 584	1.7	1.8
5.0 tonnes FYM/ha + PSM + *Azospirillum*	1 834	1 949	5 478	6 020	25.09	24.54	36 297	39 067	22 778	25 547	1.7	1.9
SEm±	30	33	91	86	0.00	0.43	596	626	596	627	0.05	0.05
CD (P=0.05)	91	101	275	262	NS	NS	1 808	1 903	NS	1 902	NS	0.16
Nitrogen level (kg/ha)												
Control	1 613	1 643	4 820	5 448	25.08	23.11	31 924	33 118	19 025	20 218	1.4	1.5
40	1 821	1 914	5 443	6 007	25.10	24.17	36 050	38 420	22 282	25 086	1.6	1.8
80	1 948	2 064	5 826	6 169	25.09	25.08	38 557	41 262	25 223	27 494	1.9	2.0
SEm±	24	26	74	53	0.01	0.34	480	483.49	449	483	0.04	0.03
CD (P=0.05)	70	75	213	152	NS	0.99	1 383	1 393	1 294	1 392	0.11	0.11

Further, physiological role of nitrogen in enhancing dry matter accumulation might have led to increased yield attributes and thereby yield of crop at higher rates of nitrogen (Kumar *et al.* 2011). The harvest index was found to increase with each increase in level of nitrogen but it differed significantly during second year of the study.

The interaction between organic sources and inorganic nitrogen levels on mustard seed yield was found significant at the end of the experiment. Similarly, combined application of FYM along with PSM and *Azospirillum* or PSM/ *Azospirillum* recorded significantly higher seed yield of Indian mustard under all the nitrogen levels. Further, application of inorganic nitrogen at 80 kg/ha produced the highest seed yield at each treatments of organic source. It seems that since the crop respond favourably to applied organic sources of nutrients and inorganic nitrogen, though combined sources of organic sources of nutrients as well as inorganic nitrogen remains unutilized in the first crop season due to interlocking of nutrients and slow mineralization of organic sources especially FYM, its application is invariably reflected in succeeding crop season. During second crop of mustard, interaction was reflected due to adequate availability of nutrients by organic sources at higher level of nitrogen application and keeping the field fallow for six months before sowing the second crop.

Economics

The economics data reveal that the net return and benefit: cost ratio was significantly influenced by sources of organic only during second year of study (Table 2). The highest net return and benefit: cost ratio was recorded under combined application of 5.0 tonnes FYM/ha along with biofertilizers, viz. PSM and *Azospirillum* which was found significantly higher as compared to remaining treatments. The lowest net return and benefit: cost ratio was noted in sole application of 2.5 tonnes FYM/ha. Singh and Sinsinwar (2006) also observed similar findings.

Net return and benefit: cost increased significantly with each successive increase in nitrogen level and on mean basis, net return and benefit: cost ratio were obtained the highest (26 359/ha and 1.95) with 80 kg N/ha. Singh *et al.* (2010) and Kumar *et al.* (2011) observed similar results that the highest net return and benefit: cost ratio were due to higher application of nitrogen.

Nutrient content and uptake

Nutrient content and uptake by crop varied significantly due to organic sources and nitrogen levels during both the years (Table 3 and 4). The highest nutrient (N, P, K and S) content and uptake of seed as well as stover by mustard was noted with application of 5.0 tonnes FYM/ha along with PSM and *Azospirillum*. The combined application of FYM with biofertilizers could stimulate the uptake of nutrients due to increased microbial activity and apparent availability of

Table 3 Effect of integrated nutrient management on N, P, K and S content (%) of mustard

Treatment	N content (%)				P content (%)				K content (%)				S content (%)			
	Seed		Stover		Seed		Stover		Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Organic source																
2.5 tonnes FYM/ha	2.45	2.53	0.41	0.44	1.20	1.25	1.03	1.02	1.63	1.79	0.93	1.00	1.77	1.87	0.21	0.29
5.0 tonnes FYM/ha	2.61	2.72	0.43	0.48	1.22	1.28	1.04	1.05	1.70	1.90	1.01	1.15	1.80	1.93	0.28	0.37
2.5 tonnes FYM/ha + PSM	2.50	2.61	0.42	0.46	1.21	1.27	1.04	1.05	1.67	1.87	0.97	1.11	1.77	1.91	0.24	0.33
5.0 tonnes FYM/ha + PSM	2.84	2.95	0.47	0.52	1.25	1.32	1.04	1.05	1.79	2.00	1.14	1.27	1.82	1.95	0.28	0.37
2.5 tonnes FYM /ha + *Azospirillum*	2.46	2.57	0.41	0.45	1.21	1.28	1.04	1.02	1.67	1.87	0.98	1.11	1.77	1.90	0.22	0.31
5.0 tonnes FYM /ha + *Azospirillum*	2.65	2.76	0.44	0.49	1.23	1.29	1.04	1.05	1.71	1.91	1.03	1.17	1.80	1.94	0.28	0.37
2.5 tonnes FYM /ha + PSM + *Azospirillum*	2.55	2.66	0.42	0.47	1.22	1.28	1.04	1.05	1.69	1.90	1.01	1.15	1.78	1.92	0.27	0.36
5.0 tonnes FYM /ha + PSM + *Azospirillum*	2.88	2.95	0.48	0.52	1.26	1.32	1.04	1.06	1.82	2.02	1.17	1.31	1.82	1.98	0.29	0.37
SEm±	0.07	0.06	0.010	0.011	0.01	0.01	0.00	0.01	0.03	0.037	0.04	0.047	0.01	0.016	0.01	0.012
CD (*P*=0.05)	0.20	0.19	0.030	0.032	0.03	0.03	0.01	0.03	0.10	0.113	0.12	0.141	0.04	0.048	0.04	0.036
Nitrogen level (kg/ha)																
0	1.64	1.74	0.27	0.31	1.16	1.22	1.03	1.02	1.49	1.68	0.75	0.87	1.62	1.74	0.19	0.27
40	2.75	2.86	0.46	0.50	1.23	1.28	1.04	1.05	1.71	1.89	1.03	1.14	1.82	1.96	0.28	0.36
80	3.46	3.56	0.58	0.62	1.30	1.36	1.05	1.07	1.93	2.15	1.31	1.47	1.93	2.08	0.31	0.40
SEm±	0.06	0.06	0.010	0.011	0.01	0.01	0.00	0.01	0.02	0.019	0.03	0.024	0.01	0.011	0.01	0.009
CD (*P*=0.05)	0.18	0.18	0.029	0.030	0.02	0.02	0.00	0.02	0.06	0.054	0.08	0.069	0.03	0.033	0.03	0.025

Table 4 Effect of integrated nutrient management on N, P, K and S uptake of mustard

Treatment	N uptake (kg/ha)				P uptake (kg/ha)				K uptake (kg/ha)				S uptake (kg/ha)			
	Seed		Stover		Seed		Stover		Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Organic source																
2.5 tonnes FYM/ha	42.98	44.98	21.38	25.26	20.24	20.92	51.79	55.84	27.67	30.48	47.89	56.63	29.93	31.56	10.93	16.32
5.0 tonnes FYM/ha	47.95	52.84	23.91	28.68	22.18	24.60	56.16	62.39	30.91	36.52	55.86	68.63	32.59	37.03	15.54	21.90
2.5 tonnes FYM/ha + PSM	46.01	50.30	22.96	27.30	21.89	24.02	55.80	61.89	30.18	35.33	53.38	65.80	32.08	36.08	13.38	19.55
5.0 tonnes FYM/ha + PSM	53.04	58.35	26.39	31.40	23.01	25.51	56.98	63.46	33.09	38.90	63.37	77.13	33.35	37.89	15.39	22.06
2.5 tonnes FYM/ha + *Azospirillum*	44.66	49.14	22.24	26.77	21.80	24.04	55.53	59.77	30.08	35.39	53.21	65.40	31.76	35.93	12.05	18.21
5.0 tonnes FYM/ha + *Azospirillum*	49.17	54.00	24.51	29.18	22.42	24.75	56.53	62.64	31.38	36.88	57.20	69.59	32.98	37.30	15.53	21.98
2.5 tonnes FYM/ha + PSM + *Azospirillum*	46.53	50.75	23.21	27.96	22.13	24.22	56.05	62.48	30.77	35.91	55.22	68.19	32.32	36.25	14.97	21.49
5.0 tonnes FYM/ha + PSM + *Azospirillum*	53.82	58.56	26.79	31.99	23.19	25.88	57.28	63.81	33.48	39.56	64.89	80.53	33.55	38.74	15.79	22.57
SEm±	1.27	1.33	0.63	0.74	0.40	0.48	0.94	0.99	0.75	0.96	2.47	3.36	0.56	0.68	0.66	0.83
CD (*P*=0.05)	3.86	4.04	1.90	2.24	1.21	1.46	2.85	2.99	2.28	2.92	7.49	10.18	1.71	2.07	2.01	2.52
Nitrogen level (kg/ha)																
0	26.52	28.81	13.20	17.22	18.70	20.01	49.51	55.51	24.17	27.82	36.61	47.37	26.19	28.77	8.99	14.71
40	50.06	54.80	24.93	30.28	22.34	24.55	56.54	63.12	31.08	36.20	55.84	68.84	33.14	37.44	15.27	21.92
80	67.48	73.48	33.64	38.21	25.28	28.16	61.24	65.98	37.59	44.35	76.68	90.75	37.63	42.83	18.33	24.90
SEm±	1.29	1.29	0.67	0.59	0.36	0.37	0.79	0.61	0.66	0.66	2.04	1.73	0.46	0.50	0.49	0.50
CD (*P*=0.05)	3.70	3.71	1.93	1.69	1.03	1.06	2.29	1.77	1.91	1.91	5.87	4.97	1.32	1.45	1.42	1.43

Table 5 Effect of integrated nutrient management on available N, P, K and S status of soil after harvest

Treatment	Available N (kg/ha)		Available P (kg/ha)		Available K (kg/ha)		Available S (kg/ha)	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Organic source								
2.5 tonnes FYM/ha	188.11	192.00	17.40	18.60	179.72	196.25	10.47	11.80
5.0 tonnes FYM/ha	195.07	198.07	18.41	19.80	188.48	207.38	12.20	13.70
2.5 tonnes FYM/ha + PSM	194.00	197.00	18.20	19.55	183.44	202.34	11.27	12.77
5.0 tonnes FYM/ha + PSM	198.33	201.33	19.07	20.58	193.40	212.30	13.11	14.61
2.5 tonnes FYM/ha + *Azospirillum*	193.73	196.73	18.15	19.49	181.16	200.06	10.84	12.34
5.0 tonnes FYM/ha + *Azospirillum*	196.20	199.20	18.64	20.07	188.72	207.62	12.24	13.74
2.5 tonnes FYM/ha + PSM + *Azospirillum*	194.80	197.80	18.36	19.74	187.88	206.78	12.09	13.59
5.0 tonnes FYM/ha + PSM + *Azospirillum*	205.47	206.80	20.16	21.36	195.44	213.00	12.73	14.22
SEm±	2.23	2.40	0.38	0.47	2.85	3.11	0.54	0.56
CD (P=0.05)	6.75	7.27	1.16	1.44	8.64	9.42	1.63	1.69
Nitrogen level (kg/ha)								
0	174.32	177.65	14.41	15.04	166.43	184.44	8.08	9.51
40	197.40	200.40	18.88	20.36	190.42	209.32	12.56	14.06
80	215.43	217.80	22.36	24.30	205.00	223.39	14.98	16.47
SEm±	1.44	1.51	0.31	0.36	1.68	2.05	0.31	0.32
CD (P=0.05)	4.16	4.35	0.89	1.03	4.83	5.91	0.89	0.93

native nutrients from the soil to crops under congenial soil physical condition created by farmyard manure. Singh and Sinsinwar (2006) observed that integrated application of FYM and biofertilizers along with 80 kg N/ha increased the uptake of nitrogen and sulphur both by seed and stover of mustard.

Different levels of nitrogen, in general, influenced the content and uptake of nitrogen, phosphorus, potassium and sulphur by seed and stover of mustard significantly and it increased gradually with increasing level of nitrogen. The highest nitrogen, phosphorus, potassium and sulphur content and uptake of seed as well as stover was noted with 80 kg N/ha which was significantly higher than 40 kg N/ha and control, respectively during both the years of experiment. This increase was mainly due to increased yield of seed and stover, and higher concentrations of respective nutrients (N, P, K and S). The findings of Singh *et al.* (2010) and Kumar *et al.* (2011) confirmed these results.

Soil fertility status

Soil samples analyzed after cropping indicated that available nutrients (N, P, K and S) in the soil were affected significantly due to organic sources of nutrients and inorganic nitrogen levels during both the years of study (Table 5). Significantly higher availability of N, P, K and S in the soil was observed in treatments receiving FYM along with PSM and *Azospirillum* or PSM over sole application of FYM during both the years. It might be due to indirect addition of partial nitrogen through FYM and enhanced microbial activity through *Azospirillum*, which convert organically bound nitrogen to inorganic form. The increase in phosphorus content may be ascribed to the capacity of FYM to form a cover of sesquioxide and PSM which reduces the phosphate fixation. Besides primary nutrients, organic sources contribute sizeable quantity of secondary nutrients also and found to improve the fertility of soil. This improvement in soil health resulted in better performance of Indian mustard under organic use of nutrients was reported by Panwar (2008).

Significant variation in available N, P, K and S content in soil was observed with each successive increase in nitrogen level and being the highest with application of 80 kg N/ha. With increase in the level of nitrogen also assured the availability of this nutrient to the crop in adequate amount and remained in soil in substantial quantity along with other major nutrients after fulfilling the crop requirement that ultimately improved the over all soil fertility.

Curve fitting, correlation study and optimum economic dose of nitrogen

Quadratic relationship between nitrogen level and seed

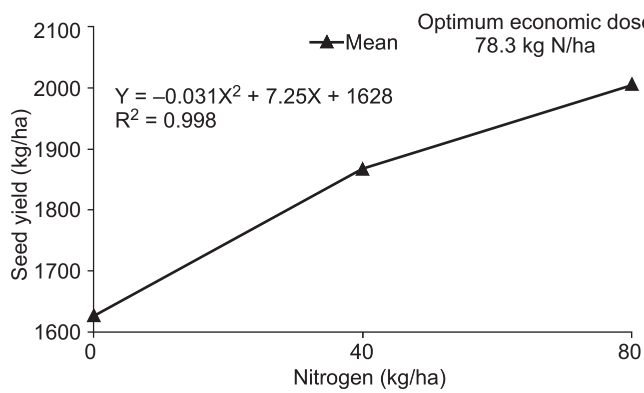

Fig. 1 Quadratic relationship between nitrogen level and seed yield

yield was observed (Fig 1). The correlation coefficient (r = 0.998) between nitrogen and seed yield showed that it was highly correlated. From the regression equation of mustard, the economic optimum level of nitrogen was estimated as 78.3 kg N/ha of the maximum seed yield.

Thus, it can be concluded that integrated use of 5.0 tonnes FYM/ha along with PSM + *Azospirillum* and 80 kg N/ha is essential for exploiting the production potential of mustard as well as for maintaining soil fertility.

REFERENCES

AICRPRM. 2009. All India Coordinated Research Project on Rapeseed-Mustard. *Annual Report* (2009), Directorate of Rapeseed-Mustard Research, Bharatpur, Rajasthan.

Das A C and Saha D. 2007. Effect of Diazotrophs on the mineralization of organic nitrogen in the rhizosphere soils of rice (*Oryza sativa*). *Journal of Crop and Weed* **3:** 69–74.

Datta J K Banerjee, Sikdar A, Saha M, Gupta S and Mondal N K. 2009. Impact of combined exposure of chemical, fertilizer, bio-fertilizer and compost on growth, physiology and productivity of *Brassica campestries* in old alluvial soil. *Journal of Environmental Biology* **30** (5): 797–800.

Garnayak L M, Singh N P, Singh S and Paikaray P K. 2000. Influence of irrigation and nitrogen on growth, yield and nutrient uptake by late-sown *Brassica* oilseed. *Indian Journal of Agronomy* **45** (2): 371–8.

Kumar Santosh, Verma S K, Singh K and Singh, Shyambeer. 2011. Effect of nitrogen and sulphur on growth, yield and nutrient uptake by Indian mustard (*Brassica juncea*) under rainfed condition. *Indian Journal of Agricultural Sciences* **81** (2): 145–9.

Panwar A S. 2008. Effect of integrated nutrient management in maize (*Zea mays* L.)- mustard *(Brassica campestris* var. *toria)* cropping system in mid-hills altitude. *Indian Journal of Agricultural Sciences* **78** (1): 27–31.

Rana K S, Rana D S and Gautam R C. 2005. Influence of phosphorus, sulphur and boron on growth, yield, nutrient uptake and economics of Indian mustard (*Brassica juncea*) under rainfed conditions. *Indian Journal of Agronomy* **50** (4): 314–6.

Singh A and Meena N L. 2004. Effect of nitrogen and sulphur on growth, yield attributes and seed yield of mustard (*Brassica juncea* L.) in eastern plains of Rajasthan. *Indian Journal of Agronomy* **49** (3):186–8.

Sinha S. 2003. Effect of different levels of farmyard manure on the growth of rapeseed. *Environment & Ecology* **21**: 741–3.

Singh Raju and Sinsinwar B S. 2006. Effect of integrated nutrient management on growth, yield, oil content and nutrient uptake of Indian mustard *(Brassica juncea)* in eastern part of Rajasthan. *Indian Journal of Agricultural Sciences* **76** (5): 322–4.

Singh, Yogeshwar, Singh, Tarkeshwar, Singh U N and Rajput P K. 2010. Effect of nutrient management on yield, quality and economics of irrigated Indian mustard (*Brassica juncea*). *Indian Journal of Agricultural Sciences* **80** (8): 691–4.

Tripathi M K, Chaturvedi Sumit, Shukla D K and Mahapatra B S. 2010. Yield performance and quality in Indian mustard (*Brassica juncea*) as affected by integrated nutrient management. *Indian Journal of Agronomy* **55** (2): 138–42.