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Effect of Integrated Nutrient Management on Soil Properties, Yield and Quality of Indian Mustard (*Brassica juncea* L.)

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Abstract: A field experiment was conducted at research farm of Tirhut College of Agriculture, Dholi, Bihar during winter (*Rabi*) season of 2016-17 on sandy loam soil to study the effect of integrated nutrient management on soil properties, yield and quality of Indian mustard (*Brassica juncea* L.). The experiment was laid out in randomized block design (RBD) with eleven treatments and three applications. The results indicated that application of 75% RDF+40kg S+ 5t vermicompost ha^{-1}+*Azotobacter*+PSB produced the highest grain (1.79 t ha^{-1}), stover yield (6.17t ha^{-1}), oil content (40.86%) and protein content in seed (14.60 %). The free fatty acid content ranged from 1.28 to 1.59%, in different treatments which did not crossed the permissible limit of 2% while erucic acid varied from 44.66 to 51.34% in the mustard oil.

Key words: *INM, yield, nutrient uptake, oil content, erucic acid*

Introduction

Rapeseed -mustard are the major *Rabi* oilseed crops of India and contributes 28.6 per cent in the total production among the seven edible oils cultivated in India. Domestic production of edible oils meets only 50% of the total requirements and rest need to be fulfilled by imported oilseeds. The gap between the consumption and domestic production of edible oils can be filled up by either increasing the area under oilseed crops like rapeseed and mustard, sunflower and soybean or increasing production per unit area. The imbalanced and inadequate supply of fertilizers along with restricted use of organic manures not only leads to limit the yield potential but soils also get deficient in the nutrients which deteriorate the soil health with decline in crop response (Anonymous 2006). The use of organic fertilizers and their proper management can supply the nutrients to crop for longer period of time. Among the organic sources, poultry manure is also a good source of nutrients particularly nitrogen and phosphorus (Zamil *et al.* 2004), which enhances the seed yield of mustard. Nutrient management is very essential approach which maintains soil quality and sustains high crop production over the years (Prasad *et al*. 2010; Pal and Pathak 2016). Application of sulphur was reported to increase yield attributes and yield of Indian mustard (Patel *et al*. 2009) and also increased S uptake (Sharma *et al.* 2009) as well as oil content (Kumar and Trivedi 2012). Application of sulphur had reported a significant effect on oil, fatty acid

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(Ahmad and Abdin 2000) and glucosinolates content in mustard seed (Falk *et al*. 2007). It is now time to explore the possibility of supplementary organics with chemical ones that are eco-friendly and cost effective.

The major fatty acids of rapeseed-mustard oil are oleic, linoleic, linolenic, ecosenoic and erucic acid in oil of Indian mustard variety is quit high (Chauhan *et al.* 2007). The objective of this study were examined the effect of integrated nutrient management on yield and yield attributes, oil content and quality of Indian mustard.

Materials and Methods

Experimental site and observations method

A field experiment was conducted during winter (*Rabi*) season at research farm of Tirhut College of Agriculture, Dholi, Muzaffarpur, a campus of Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar situated on the southern bank of the river Burhi Gandak (25.98^{0}N; 85.60^{0}E) at, an elevation of 52.18 meter above mean sea level. It has semi-arid, sub-tropical climate with hot dry summer, moderate rainfall and cool winter. The experimental sandy loam occurs on flat topography and had pH (8.4), EC 0.44 dSm^{-1} and organic carbon 5.3 g kg^{-1}, available nitrogen 162 kg ha^{-1}, phosphorus 8.6 kg ha^{-1}, potassium 96.4 kg ha^{-1} and available sulphur 10.8 kg ha^{-1}. The experiment was laid out in randomized block design (RBD) comprising eleven treatments *i.e.* T_1-Absolute Control: T_2-RDF (N, P, K) @ 80:40:40+40 kg S ha^{-1}; T_3-RDF+40 kg S ha^{-1}+ 5 t vermicompost ha^{-1}; T_4-RDF+40 kg S ha^{-1}+5 t vermicompost ha^{-1}+ *Azotobacter* +PSB; T_5-RDF+40 kg S ha^{-1}+2 t poultry manure ha^{-1}; T_6-RDF+40 kg S ha^{-1}+2 t poultry manure ha^{-1}+ *Azotobacter*+PSB; T_7-75% RDF+40 kg S ha^{-1}; T_8-75% RDF+40 kg S ha^{-1}+5 t vermicompost ha^{-1}; T_9-75% RDF+40 kg S ha^{-1}+5 t vermicompost ha^{-1}+ *Azotobacter* +PSB; T_{10}-75% RDF +40 kg S ha^{-1}+2 t poultry manure ha^{-1}; T_{11}-75% RDF+40 kg S ha^{-1}+2 t poultry manure ha^{-1}+*Azotobacter*+PSB with three replications. The mustard seeds (Rajendra Suphlam) were inoculated with Rhizobium and PSB as per treatments. Plant height was measured from base of the plant to tip of the main shoot randomly at 30, 60 and 90 days after sowing (DAS) and average height was expressed in centimeters (cm).

Number of siliquae was counted from the tagged plants express as number of siliqua plant^{-1} and total length measured in centimeter. The leaf area index of two plants from each plot was determined by using leaf area meter.1000 seeds from bulk seed yield of each treatment were taken for measured test weight. Nitrogen, phosphorus, potassium and sulphur of seeds were analysed following standard procedure and uptake was computed for respective treatments.

Oil content in grains was determined by using Soxhlet units according to A.O.A.C. (1995). The fatty acid composition were determined using oil samples for methyl esters preparation (IUPAC 1979) with boron trifloride and it was quantified by GC 5765 Gas-Chromatograph (NUCON) equipped with Flame Ionization Detector (FID). Free fatty acid was determined by titrating the oil in an alcoholic medium against standard NaOH solution. The acid value was calculated by multiplying the per cent fatty acid (as oleic) x 1.99.

The processed soils were analysed for pH (using potentiometric method) and total soluble salts by electrical conductivity (Jackson 1973). The oxidizable soil organic carbon content (g kg^{-1}) were analyzed by the method proposed by Walkley and Black (1934). The available N, P, K and S in soils were analyzed (Subiah and Asija 1956) for available N, 0.5 *M* $NaHCO_3$ (pH 8.5) extractable P (Olsen's *et al.* 1954), 1 *N* NH_4OA extractable K by Flame Photometer and 0.15% $CaCl_2$ extractable sulphur (Chesnin and Yien 1951) respectively.

Results and Discussion

Yield and yield attributes

The influence of different treatments on plant height (Table 1) was non- significant at 30 DAS but plant height at 60 DAS it ranged from 88.0 to 108.16cm being

Table 1. Effect of integrated nutrient management on plant height at 30, 60 and 90 DAS

	Plant height (cm)			Plant weight $gplant^{-1}$					
	Days after sowing								
Treatments	30	60	90	30		60		90	
				Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight
T_1	12.07	79.83	100.83	7.02	1.01	46.05	5.38	119.49	10.68
T_2	12.92	104.00	125.83	8.80	1.06	68.34	6.26	162.16	14.48
T_3	13.19	105.34	114.33	9.80	1.21	78.78	6.88	180.11	15.72
T_4	12.66	88.00	115.34	10.43	1.26	79.30	6.86	192.60	16.02
T_5	11.26	101.67	121.33	10.43	1.22	71.44	6.56	178.60	15.68
T_6	11.15	102.17	118.00	10.38	1.24	82.73	6.82	210.82	16.42
T_7	12.74	97.00	121.50	9.58	1.18	69.67	6.49	186.56	15.28
T_8	14.19	108.17	123.67	10.41	1.25	78.96	6.58	191.20	16.12
T_9	11.89	90.40	131.83	10.16	1.23	81.90	7.03	201.06	16.32
T_{10}	12.29	98.67	126.00	10.09	1.11	81.28	6.72	178.68	15.73
T_{11}	12.31	93.67	117.39	10.08	1.20	78.06	6.70	185.42	15.74
SEm°	0.99	2.03	2.03	0.30	0.04	0.63	0.17	1.57	0.28
C.D (P=0.05)	NS	10.21	6.18	0.88	0.11	1.87	0.50	4.67	0.84

79.83 cm in control. The treatments comprising of 100% RDF+S@40 kg ha^{-1}+vermicompost @ 5 t ha^{-1}+ *Azotobacter*+PSB and 75% RDF+S @ 40 kg ha^{-1}+vermicompost @ 5 t ha^{-1} had 10.23 to 35.49 per cent increase in plant height at 60 DAS over control. Application of sulphur might have promoted the cell division resulting in increased height of shoot in mustard.

The maximum plant height (131.83cm) at 90 DAS and was observed with treatment 75% RDF+S@ 40 kg ha^{-1}+Vermicompost @5t ha^{-1}+*Azotobacter*+PSB over control. Rundala *et al.* (2013) reported that the integrated nutrient management gave significant impact on all growth parameters including plant height. The increase in fresh and dry weight of plant was closely associated with plant height.

Nutrient uptake differed significantly due to application of different treatments. The recommended dose of fertilizers increased nitrogen uptake up to 35.19 (kg ha^{-1}) over absolute control 18.39 (kg ha^{-1}) in seed. The seed of mustard utilized higher amount of N than of stover. The highest nitrogen uptake was recorded with the application of 60 Kg S ha^{-1} at all the growth stages and by seeds. Phosphorus, potassium and sulphur uptake in grain and stover increased significantly with application of recommended dose of fertilizers or with conjunctive use of organic and inorganic fertilizers (Table 2).

The effect of integrated nutrient management on length of siliqua was not significant. The siliqua length ranged from 4.37 to 4.63cm (Table 3) in different treatments organics, involving chemical fertilizers and bio-fertilizers, Piri *et al.* (2012) reported that the increasing level of sulphur not only increased the siliqua length but also gave higher yield of straw, more leaf area index, high growth rate and higher assimilation rate at all the growth stages of crop growth. The highest number of siliqua plant^{-1} (275.0) was recorded in treatment having 75% RDF+S@40kg ha^{-1}+vermicompost @5t ha^{-1}+*Azotobacter*+PSB, followed by 75% RDF+ S@ 40 kg ha^{-1} + vermicompost @ 5 t ha^{-1}. The highest no. of seeds siliqua^{-1} (12.48) was recorded with 75% RDF+S @40 kg ha^{-1}+vermicompost @ 5 t ha^{-1}+*Azotobacter*+PSB was 15.51% more than 100% RDF+S @ 40 kg ha^{-1}. The results are in conformity with the finding of Rundal *et al.* (2013) and Bhati *et al.* (2014)

The test weight of seeds varied from 4.78 to 5.70g in the treatments having of organics, inorganic fertilizers and bio-inoculants (Table 3). The maximum test weight was recorded with application of 100% RDF + S @ 40 kg ha^{-1}+ poultry manure @ 5 t ha^{-1} +*Azotobactor* + PSB followed by 100% RDF+S @ 40 kg ha^{-1}+poultry manure @ 2 t ha^{-1}. The grain yield ranged from 0.87 to 1.79 tonnes and the highest yield was found with 75% RDF+ S @ 40 kg ha^{-1}+vermicompost @ 5 t ha^{-1}+*Azotobacter*+PSB which was 1.7 per cent than control. The conjunctive use of organics, inorganic fertilizers and bio-fertilizer also had significant effect on Stover yield and also on harvest index (Table 3). The harvest index ranged from 21.32 to 23.77 per cent and it was significant over to absolute control. Lepcha *et al.* (2015) evaluated the combined effect of organic and inorganic sources of N and observed similar results for harvest index. The maximum (2.44) LAI was reported in the treatment having 75% RDF+S @ 40kg ha^{-1}+vermicompost @ 5 t ha^{-1}+*Azotobacter*+PSB followed by 75% RDF+ S @ 40kg ha^{-1}+poultry manure @ 2 t ha^{-1} while lowest (1.86) was associated with control.

Quality parameters

The oil content in seed significantly increased with each treatments over control might be due to the application of sulphur fertilizer with organics and bio-fertilizes. The highest oil content (40.0%) was recorded with the application of 75% RDF+40kg S ha^{-1}+5t vermicompost ha^{-1}+ *Azotobacter* +PSB, followed by T_6 and T_5 treatments. Application of nutrients through vermicompost and poultry manures produced seed with significantly higher protein content as compared to recommended dose of fertilizers. The maximum protein in seed (14.60 %) was recorded with the treatment having 75% RDF+S @ 40 kg ha^{-1}+Vermicompost @ 5 t ha^{-1}+*Azotobacter*+PSB than others treatments.

The content of free fatty acid always is an increase in acidity with time during transport and storage.

Table 2. Effect of integrated nutrient management on yield and yield attributes

	Length of siliqua (cm)	Siliqua plant^{-1}	Seeds siliqua^{-1}	1000 -seed weight (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	1000 - seed weight (g)	Stover yield (kg ha^{-1})	Harvest index (%)	Leaf area index	Oil content (%)	Protein content in seed (%)
T_1	4.34	166.60	10.20	4.77	0.87	3.27	4.78	3268	21.32	1.86	36.20	13.22
T_2	4.41	219.36	10.78	5.12	1.58	5.31	5.11	5302	23.09	2.22	38.40	13.82
T_3	4.46	265.00	10.85	5.31	1.67	5.54	5.30	5534	22.43	2.25	39.60	14.22
T_4	4.61	267.46	11.34	5.33	1.71	5.85	5.35	5766	23.16	2.32	39.26	14.12
T_5	4.58	262.00	11.34	5.56	1.64	5.58	5.57	5539	23.12	2.42	40.08	14.31
T_6	4.56	263.75	11.82	5.71	1.68	5.81	5.70	5832	23.12	2.33	40.68	14.38
T_7	4.39	233.83	11.74	5.16	1.57	5.33	5.13	5344	23.01	2.25	39.50	13.78
T_8	4.53	269.00	11.35	5.18	1.71	5.93	5.14	5923	22.89	2.30	39.75	14.34
T_9	4.61	275.00	12.48	5.20	1.79	6.17	5.10	6150	22.94	2.44	40.86	14.60
T_{10}	4.45	243.00	11.89	5.12	1.64	5.60	5.10	5604	23.22	2.37	39.33	14.08
T_{11}	4.55	255.87	12.21	5.21	1.66	5.62	5.23	5642	22.90	2.28	39.51	14.13
SEm°	0.08	5.02	0.41	0.16	0.043	0.18	0.15	91.51	0.04	0.07	0.27	0.10
C.D (P=0.05)	NS	14.86	1.19	0.47	0.058	0.27	0.45	0.11	1.87	0.21	0.84	0.29

Table 3. Effect of integrated nutrient management on uptake of N, P, K & S (kg ha^{-1}) in seed and stover of Indian mustard

Treatments	N uptake (kg ha^{-1})		P uptake (kg ha^{-1})		K uptake (kg ha^{-1})		S uptake (kg ha^{-1})	
	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover
T_1	18.392.11	13.05 (0.04)	3.27 (0.38)	5.57 (0.17)	7.19 (0.83)	43.83 (1.34)	4.40 (0.51)	9.14 (0.28)
T_2	35.19 (--2.23	24.35 (0.46)	5.99 (0.38)	11.16 (0.21)	13.42 (0.85)	77.93 (1.47)	9.78 (0.62)	15.88 (0.30)
T_3	38.19 (2.29)	26.59 (0.48)	6.54 (0.39)	12.20 (0.22)	14.74 (0.88)	82.44 (1.49)	10.73 (0.64)	17.18 (0.31)
T_4	38.97 (2.28)	29.96 (0.51)	7.20 (0.42)	14.37 (0.25)	14.93 (0.87)	83.60 (1.43)	12.86 (0.75)	18.43 (0.32)
T_5	37.65 (2.30)	26.00 (0.47)	7.22 (0.44)	12.71 (0.23)	13.97 (0.85)	80.88 (1.45)	12.80 (0.78)	18.81 (0.34)
T_6	38.66 (2.30)	30.33 (0.52)	6.68 (0.40)	15.15 (0.26)	14.40 (0.86)	86.31 (1.49)	13.37 (0.80)	19.81 (0.34)
T_7	34.55 (2.20)	24.06 (0.45)	6.61 (0.42)	11.72 (0.22)	12.89 (0.82)	77.52 (1.45)	11.20 (0.71)	17.05 (0.32)
T_8	39.22 (2.29)	30.73 (0.52)	8.17 (0.48)	13.61 (0.23)	14.49 (0.85)	87.09 (1.47)	11.23 (0.66)	17.73 (0.30)
T_9	41.70 (2.33)	33.18 (0.54)	8.90 (0.50)	15.32 (0.25)	15.15 (0.85)	91.64 (1.49)	12.29 (0.69)	17.15 (0.28)
T_{10}	36.94 (2.25)	28.60 (0.51)	7.20 (0.44)	11.78 (0.21)	14.38 (0.88)	82.37 (1.47)	11.62 (0.71)	14.59 (0.26)
T_{11}	37.65 (2.27)	29.93 (0.53)	8.77 (0.53)	14.68 (0.26)	14.09 (0.85)	82.36 (1.47)	11.45 (0.69)	18.07 (0.32)
SEm°	0.59	0.86	0.13	0.60	0.24	1.65	0.23	0.37
C.D (P=0.05)	1.75	2.55	0.39	1.79	0.71	4.91	0.68	1.09

Table 4. Effect of integrated nutrient management on oil quality, yield in seed and stover of Indian mustard

Treatments	Free fatty acid (%)	Acid value (%)	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Linolenic acid	Arachidic acid	Ecosenoic acid	Erucic acid
T_1	1.53	3.04	2.44	0.47	10.30	15.46	11.48	1.05	6.00	49.20
T_2	1.44	2.87	2.36	0.45	8.86	15.74	11.64	0.95	6.42	50.32
T_3	1.29	2.58	2.46	0.93	12.88	17.38	10.60	0.97	7.04	46.45
T_4	1.42	2.82	2.16	0.85	11.12	16.92	13.14	0.94	6.36	47.06
T_5	1.28	2.56	1.94	0.53	9.58	16.79	13.12	0.79	6.14	48.92
T_6	1.59	3.17	1.83	0.66	9.76	15.58	11.56	0.54	6.98	51.34
T_7	1.58	2.98	1.69	0.54	10.97	17.30	12.20	0.76	6.42	48.60
T_8	1.55	3.06	2.14	0.62	11.91	17.48	11.12	0.78	7.85	46.52
T_9	1.44	2.87	2.46	0.35	11.68	16.32	12.52	1.13	6.80	48.21
T_{10}	1.46	2.91	2.72	0.78	11.78	18.53	12.64	1.08	5.71	47.76
T_{11}	1.45	2.89	2.33	0.63	12.86	16.92	10.12	0.99	7.43	44.66
SEm°	0.07	0.14	0.21	0.26	1.09	0.84	1.23	0.14	0.68	1.43
C.D (P=0.05)	NS	NS	0.44	0.08	2.28	NS	NS	0.29	NS	3.01

Table 5. Effect of integrated nutrient management on soil physicochemical properties

Treatments	pH	EC (d Sm^{-1})	O.C (%)	Available nutrients (kg ha^{-1})			
				N	P	K	S
T_1	8.58	0.45	0.52	165.00	9.50	96.30	10.12
T_2	8.44	0.43	0.69	175.60	10.68	104.70	13.36
T_3	8.46	0.47	0.74	183.10	13.45	110.20	12.90
T_4	8.55	0.40	0.78	185.50	13.86	115.28	14.70
T_5	8.48	0.41	0.74	184.60	12.48	106.75	13.60
T_6	8.51	0.45	0.75	185.60	13.26	113.50	12.40
T_7	8.53	0.43	0.67	181.40	10.60	108.18	12.60
T_8	8.47	0.42	0.68	177.20	13.48	110.20	13.40
T_9	8.46	0.44	0.69	198.40	14.54	111.90	14.98
T_{10}	8.52	0.43	0.71	184.20	12.88	102.50	11.12
T_{11}	8.54	0.39	0.75	192.60	12.93	107.28	14.98
SEm°	0.03	0.02	0.02	1.28	0.24	0.49	0.12
C.D (P=0.05)	0.08	NS	0.04	3.94	0.68	1.48	0.36

Variations in free fatty acid content of mustard oil as influenced by the different treatment is show in table 4. The International specifications for top grade edible oils usually are set at 2% free fatty acids for human health purposes. The minimum value of free fatty acid (1.28%) was recorded with treatment, having 100% RDF+S @ 40 kg ha^{-1} +poultry manure @ 2 t ha^{-1}, however it ranged from 1.28 to 1.59%.

The content of saturated fatty acids includes palmitic, stearic acid and arachidic acid in mustard oil ranged from 1.69 to 2.72, 0.35 to 0.93 and 0.54 to 1.13 per cent. Maximum saturated fatty acid content (4.20%) was recorded in treatment involving 75% RDF +40 kg S ha^{-1}+2 t poultry manure ha^{-1}, while minimum (2.26%) was obtained with application of 75% RDF+40 kg S ha^{-1}. The mustard oil is nutritionally good quality oil because it has almost balance proportion of all fatty acid composition. The mustard oil contained erucic acid as a major monounsaturated fatty acid, followed by oleic, and eicosanoid acid. On the other hand, mustard oil contained high amount of erucic acid which ranged from 44.66 to 51.34 oleic acid percentage. The highest amount of erucic acid (51.3%) was recorded with treatment comprising of 100% RDF+40 kg S ha^{-1}+2 t poultry manure ha^{-1}+ *Azotobacter* +PSB which was at par with RDF+40kg S ha^{-1} .

Soil parameters

The soil pH at harvest ranged from 8.46 to 8.55(100% RDF+40 kg S ha^{-1}+2 t poultry manure ha^{-1}+ *Azotobacter*+PSB). The decrease in pH might be due to the application of sulphur along with vermicompost and poultry manures. This result is in conformity with Yadav *et al.* (2010). The treatments did not have significant effect on electrical conductivity of soil: water suspension (1:2.5 w/v) at crop harvest (Table 5). The organic carbon in soil ranged from 0.52 to 0.78 per cent and variation was due to types of organics applied. Pathak *et al.* (2015) also reported the integrated use of nutrients helps to increase the organic carbon. The treatments brought significant increase in available nitrogen and maximum nitrogen content (198.40 kg ha^{-1}) was recorded in 75% RDF+S @ 40 kg ha^{-1}+vermicompost @ 5 t ha^{-1}+*Azotobacter*+PSB while minimum (168.0 kg ha^{-1}) was associated with control.

The highest quantity of available phosphorus (14.54 kg ha^{-1}) and potassium and (111.90 kg ha^{-1}) were observed with the application of 100% RDF+S @ 40 kg ha^{-1}+ vermicompost @ 5 t ha^{-1}+*Azotobacter*+PSB followed by 75% RDF+S @ 40kg ha^{-1}+vermicompost @ 5 t ha^{-1}+*Azotobacter*+PSB. The higher available phosphorus was noticed in those plots which had bio-fertilizers (PSB).

The buildup of P might also be due to the release of organic acids during microbial decomposition of organic matter leading to increased solubility of native phosphorus. Similar results were reported by Balaguravaiah *et al*. (2005). The combined use of chemical and organic fertilizers inoculated with bio-fertilizer recorded significantly higher amount of potassium in soil after harvest than recommended dose of fertilizers. Shilpa and Dongale (2011) reported significant increase in available nutrients (NPK) with the application of organic and inorganic source of nutrients. Application of NPK and S along with vermicompost and poultry manure had positive influence on available S in soil at harvest content over control.

Conclusion

It may concluded that the yield of grain and stover, oil and protein content in Indian mustard were found maximum with the application of 25% reduced amount of NPK combined with sulphur, FYM and microbial inoculants. The minimum free fatty acid was noticed with treatments having 100% RDF, sulphur and poultry manure.

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