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RESEARCH ARTICLE

Production potential and influence of chemical fertilizers, organic manures and bio-fertilizers on growth, yield and economics of mustard

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ABSTRACT

Mustard (*Brassica juncea* L.),) is an important oilseed crop in the Indian subcontinent and it provides around27 % So, to elucidate the effect of INM in mustard growth and yield a field experiment was conducted during Rabi season 2018-19 at Agricultural Research Farm in faculty of Agricultural sciences and Allied Industries Rama University, Mandhana, Kanpur (U.P.). The mustard variety cv. Varuna was laid out in a randomized block design with twelve treatment replicated in thrice and treatment details are T1 (Control), T2 (100% RDF), T3 (100% RDF + Vermicompost @ 5t ha-1), T4 (100% RDF + Vermicompost @ 5t ha-1 + PSB), T5 (100% RDF + Poultry manure @ 2t ha-1), T6 (100% RDF + Poultry manure @ 2t ha-1 + PSB), T7 (75% RDF), T8 (75% RDF + Vermicompost @ 5t ha-1), T9 (75% RDF + Vermicompost @ 5t ha-1 + PSB), T10 (75% RDF + Poultry manure @ 2t ha-1) and T11 (75% RDF + Poultry manure @ 2t ha-1 + PSB).The application of 100% RDF + Poultry manure @ 2t ha^{-1} + PSB was recorded significantly highest plant growth viz. plant height, dry matter accumulation, primary and secondary branches and leaf area index as well as yield attributes viz., number of siliqua $plant^{-1}$ (g), number of seed $siliquae^{-1}$ and test weight as compared to the rest of the treatment.The treatment T_6 (100%RDF+Poultry manure @ 2t ha^{-1} + PSB)was recorded maximum 22.93 qha^{-1} (grain yield), 52.66 qha^{-1} (Stover yield) with Rs. 67138.00 ha^{-1} net return and B: Cratio (2.55) in comparison to rest of the treatment.

Keywords: Growth, Indian mustard (Brassica juncea L.), INM, treatments, yield

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INTRODUCTION

Mustard or rapeseed are important oilseed crops grown in the Indian subcontinent specially in the winter season and provide 27.% of share in the edible oil production. These crops are highly important for Indian economy, since India imports large quantities of edible oils despite having the largest area of cultivated oilseeds in the world (Hegde and Sudhakara, 2011). The predicted oilseed production in India should reach 58 million tonnes by 2020 for sustaining minimum edible oil requirement of

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12 kg capita^{-1} annum^{-1}(Mittal, 2008). .The only option left in our hand is to increase the productivity under this limited area involving good agriculture practices such as, nutrient management, water management, resource conservation technologies, residue recycling and good quality breeding materials (Ref.) Among, the fore mentioned strategies, the most important among all of these is integrated nutrient management which can restore soil health and boost crop productivity (Randhawa, 1992, Prasad et al., 2010). Three primary functions of INM, as stated by FAO in 1998, are to maintain or improve soil productivity through the balanced application of fertilisers along with organic and biological sources of plant nutrients. increase the soil's supply of plant nutrients Enhance the effectiveness of plant nutrients while reducing environmental losses. Recent research has shown that the intense cropping system's ongoing use of suboptimal nutrient dosages has severely depleted the soil's nutrient reserves, leading to a variety of nutritional shortages. The use of high-analysis fertilizers devoid of micronutrients has also aggravated micronutrient deficiencies causing significant decline in crop productivity. Use of chemical fertilizers/organic manures alone are unable to sustain the desired levels of crop production under intensive farming practices. So, the integrated nutrient management is found to be a very promising option for elevating crop performance and nourishing our degrading soil condition. Integrated nutrient management can be defined as a combination of synthetic fertilisers, manures and microbial culture. Farmyard manure (FYM) itself contains reasonable amounts of nutrients which become available to plants upon decomposition besides enhancing availability of native as well as applied nutrients (Chander et al., 2010).The phosphate solubilizing microorganisms (Pseudomonas) play an important role in conversion of unavailable inorganic P (Ca-P, Fe-P and Al-P) into available inorganic P forms through secretion of organic acids and enzymes (Singh et al., 2011).In INM, not only major nutrients but also, secondary and micronutrient are given importance such as, Sulphur, now recognized as forth major nutrient with nitrogen, phosphorus and potassium, is a constituent of three sulphur containing amino acids (cysteine, cystine and methionine), which are the building blocks of protein and about 90% of plant S is present in these amino acids. Adequate supply of sulphur has been reported to enhance photosynthetic efficiency and productivity of Brassica genotypes (Ahmed & Abdin, 2000).(Verma et al., 2010). Experimental evidences showed, (Raj Singh et al.,2014) Integrating organic manure (FYM @ 10-15 ton/ha) with 100% recommended NPK fertilizer doses not only sustain high productivity but also maintain fertility in most of the intensive cropping systems and soil types. The results further revealed that soil type is on the most important factors affecting fertilizer use efficiency and crop yields. In the intensive agriculture, importance of integrated management of nutrient resources is being magnified to inorganic overall soil health (Prasad et al., 2002). Cruciferous crops like mustard, raya etc needs sulphur generally as much of phosphorus and one tenth of nitrogen as it can be represented bu its seed S content (1.1-1.7%), . Average removal of sulphur by one tone of oilseeds ranges between 8-12 kg, by pulses 4-8 kg as compared to 3-5 kg sulphur by cereal crops (ref.). But, there is lack of information regarding response of mustard in Inceptisol of northern India under integrated nutrient management practices. So, keeping in view to the above facts, present study was designed to study the effect of chemical fertilizers, organic manures and bio-fertilizers on growth and yield of mustard.

MATERIALS AND METHODS

Experimental site

Present investigation was conducted in Agricultural Research Farm, faculty of Agricultural sciences and Allied Industries at Rama University, Kanpur (U.P.) during rabi season of 2018-19. The experimental farm falls under the Indo-gangetic alluvial tract of Central Uttar Pradesh.

Climate and meteorological data

Geographically, Kanpur is situated in the central part of U.P. and subtropical tract of North India between latitude ranging from 25^0 56' to 28^0 58' North and longitude 79^0 31' to 80^0 34' East and is located at an elevation of about 125.9 meters above mean sea level in gangetic plain. The seasonal rainfall of about 629.5 mm received mostly from IInd Fortnight of June or first Fortnight of July to mid-October with a few showers in winter season. The maximum and minimum temperature in the Rabi season usually occurs 35˚C and 10˚C, respectively. The mean weather data such as weekly average temperature, relative humidity (R.H.), wind speed, evaporation rate and total rainfall etc. were recorded during crop season from meteorological observatory located at student Instructional Farm of the university and the data have been presented in Table 1.

Table 1. Weekly weather data recorded during crop growth period in (2018-19).

SMW	Months	Temperature (^{0}C)		Relative humidity (mm/day)		Wind speed (km/hr)	Rainfall (mm)
		Max.	Min.	Max.	Min.		
43	Oct. 22-28, 2018	33.1	14.2	70	30	2.0	0.0
44	Oct. 29- Nov. 04, 2018	32.0	14.4	76	36	1.7	0.0
45	Nov. 05-11, 2018	28.3	12.8	82	44	2.6	0.0
46	Nov. 12-18, 2018	29.5	10.6	84	34	2.7	0.0
47	Nov. 19-25, 2018	28.5	11.3	80	34	2.7	0.0
48	Nov. 26- Dec. 02, 2018	26.6	10.3	90	43	1.8	0.0
49	Dec. 03- Dec. 09, 2018	24.8	8.8	89	38	1.3	0.0
50	Dec. 10- Dec. 16, 2018	22.8	8.3	90	46	2.6	0.0
51	Dec. 17- Dec. 23, 2018	22.5	5.3	87	35	1.9	0.0
52	Dec. 24- Dec. 31, 2018	21.6	4.6	87	34	5.8	0.0
1	Jan. 01-07, 2019	22.4	7.3	88	48	3.2	0.0
2	Jan. 08-14, 2019	21.4	7.6	87	43	3.2	0.0
3	Jan. 15-21, 2019	23.1	6.0	83	39	3.3	0.0
4	Jan. 22-28, 2019	19.6	10.6	84	61	5.2	1.9
5	Jan. 29-Feb. 04, 2019	21.3	8.3	85	50	4.7	0.0
6	Feb. 05-11, 2019	22.1	10.0	90	55	5.3	0.0
7	Feb. 12-18, 2019	23.5	11.6	89	57	4.6	0.2
8	Feb. 19-25, 2019	26.1	12.8	87	50	5.2	0.0
9	Feb. 26- Mar. 04, 2019	22.7	10.5	87	52	4.5	1.3
10	Mar. 05-11, 2019	27.4	12.0	79	41	4.2	0.0
11	Mar. 12-18, 2019	29.2	13.2	80	38	4.1	0.0
12	Mar. 19-25, 2019	32.2	15.8	63	39	6.4	0.0
13	Mar. 26- Apr. 01, 2019	34.4	17.5	77	41	4.0	0.1
	Total	-	-	-	-	-	3.5
	Avg.	25.9	10.6	83	43	3.6	-

Source: Observatory of CSA University, Kanpur

Soil of experimental field

The soil of the experimental field was well leveled. The fertility status and textural class of the soil were judged by chemical, physical and mechanical analysis. For purpose, soil samples were taken randomly from 5 places of experimental plot from the depth of 15 cm. just before sowing and fertilizer application. The soil of these samples was mixed thoroughly and a representative soil sample was drawn. The quantity of soil sample was reduced to about one kg through quartering technique. This sample was subjected to mechanical, and chemical analysis. The method employed in both the analysis and results so obtained are presented in Table 2. The soil sample was then subject to mechanical and chemical analysis in order to determine the textural classes and fertility status. The representative sample so drawn was dried and made free from inert and foreign material by passing through 2 mm standard sieve before analysis. The sample so drawn was subjected to physical and chemical analysis using standards methods of analysis given in Table 2.

Table 2. Physico-chemical properties of experimental field

S.No.	Soil Properties	Values	Method of determination	Reference
(A)	**Mechanical Analysis**			
1.	Coarse sand (%)	0.75	International Pipette Method	Piper 1950
2.	Fine sand (%)	55.80	International Pipette Method	Piper 1950
3.	Silt (%)	23.50		
4.	Clay (%)	21.80	International Pipette method	Piper 1950
5.	Texture class	Sandy loam	USDA, Triangle	Soil survey staff 1975
(B)	**Physical Analysis**			
1.	Bulk density (mg m^{-3})	1.367	Core Cutter Sampler Method	USDA Handbook (LA Richards 1954)
(C)	**Chemical Analysis**			
1.	Organic Carbon (%)	0.27	Walkley and Block Rapid Titration Method	Jackson 1967
2.	Available N (kg ha^{-1})	60.75	Alkaline Potassium Per magnate Method	
3.	Available P_2O_5 (kg ha^{-1})	17.86	Olsen's Method	Olsen et al. 1954
4.	Available K_2O (kg ha^{-1})	113	Flame Photometer Method	
5.	pH	7.1	Electronic Glass Electrode Method	Piper 1950
6.	EC (dsm^{-1})	0.94	Electrical Conductivity Meter	
7.	Zn (mg-ha-^{1})	1.16		
8.	S (ppm)	11.0		
9.	B (ppm)	0.60	Extracted by DTPA & Analysed on	
10.	Fe (ppm)	1.54	AAS	
11.	Mn (ppm)	0.32		
12.	Cu (ppm)	0.37		

Crop variety

For the present investigation variety "Varuna" was selected. This variety was released by CSAUAT, Kanpur, U.P. in 1976 for irrigated as well as rainfed condition. The yield potential of Varuna is 20-25 q/ha in irrigated condition and 15 to 20 q/ha in dryland condition and oil content of 39.8 %. It has bold seed size and suitable for cultivation in the country. It has moderate tolerance to soil salinity as well as stress conditions and high responsiveness to fertilizer application. Its maturity period ranges between 125-130 days.

Experimental design and layout

Considering the nature of factors under study and the convenience of agricultural operation and efficiency, the experiment was laid out in Randomized Block Design (RBD) comprised of eleven treatments combination along with three replications (Table 3). Each replication was divided into eleven equal plots and the treatments were randomly allocated within them. The details of layout are given in Table 4.

Table 3: Details of Treatments

Treatments	Symbol used
Control	T_1
100% RDF	T_2
100% RDF + Vermicompost @ 5t ha^{-1}	T_3
100% RDF + Vermicompost @ 5t ha^{-1} + PSB	T_4
100% RDF + Poultry manure @ 2t ha^{-1}	T_5
100% RDF + Poultry manure @ 2t ha^{-1} + PSB	T_6
75% RDF	T_7
75% RDF + Vermicompost @ 5t ha^{-1}	T_8
75% RDF + Vermicompost @ 5t ha^{-1} + PSB	T_9
75% RDF + Poultry manure @ 2t ha^{-1}	T_{10}
75% RDF + Poultry manure @ 2t ha^{-1} + PSB	T_{11}

*RDF (Recommended dose of fertilizer-120 kg N, 60 kg P2O5,60 kg K2O and 60 kg S per hectare)

Table 4: Details of layout plan

Particulars	
Design	Randomized Block Design (RBD)
Treatment	11
Replication	03
Total number of plots	33
Plot Size (Gross)	4 x 3 m^2
Plot Size (Net)	3.8 x 2.80 = 10.64 m^2
Spacing	30 x 10 cm
Main irrigation Channel	1 m
Sub irrigation channel	0.5 m
Variety	Varuna (T-59)

Field operations

The details of the field operations performed during the period of experimentation are described in Table 5.

Table 5: Schedule of cultural operations

Operations	Date
Ploughing and planking	23.10.2018
Orgnaic application	23.10.2018
Layout of the experimental field	24.10.2018
Fertilizers application	25.10.2018
Sowing	25.10.2018
Germination	01.11.2018
Thinning	12.11.2018
Treatment application	19.12.2018
Weeding : (i) First	30.12.2018
(ii) Second	20.01.2019
Spraying of insecticide	26.01.2019
Harvesting	23.03.2019
Threshing	29.03.2019

Cultural operations

Proper field preparation and fine seed bed are essential for good germination and growth of mustard in order to have a suitable field for sowing. The experimental field was ploughed criss-cross with a tractor drawn disc and dry weeds as well as stubbles were removed. The field was again ploughed by cultivator and finally planking was done to obtain a good tilth. The block borders and plots were made manually as per the layout plan. The experimental plots were levelled before sowing of seeds. Full dose of recommended fertilizer (120 kg N, 60 kg P_2O_5, 60 kg K_2O and 60 kg S ha^{-1}) in the form of Urea (46% N), DAP (18% N, 46% P_2O_5), Murate of Potash (60% K_2O), Gypsum (18% S) was applied as basal dose. Fertilizers are placed in between the 30 cm row spacing for better germination and plant stand.

After the final field preparation, the seeds of 'Varuna' Indian mustard were sown at the rate of 5 kg ha^{-1} at a row distance of 30 cm. The sowing was done on 25th October 2018 in the fertilized row, opened with the help of kudal and covered after sowing. Thinning of plants was done after 15 days of sowing in order to keep only one robust and healthy plant at a distance of 10 cm to maintain proper plant population. Each plot accommodated 12 rows. Two weeding was done manually at 30 and 45 DAS. As the experiment was conducted under irrigated condition, two irrigation were applied at approximately 45 and 70 days after sowing. To protect crop from aphids (*Lipaphis erysimi*) Imidachlropid (17.8 SL) was sprayed @ 0.3 ml L^{-1} during flowering to pod formation stage. The crop was harvested as soon as 80 per cent siliquae turn yellowish brown to prevent shattering. First of all border rows were harvested. Thereafter, plants from each net plot area were harvested carefully, bundled, tagged and were taken to threshing floor and kept separately. After proper sun drying the bundles were threshed separately.

Observations recorded

For recording biometric observation at regular interval, two sampling area i.e. one for destructive and other for non- destructive were marked. The observations like plant height and branches were taken from non-destructive sampling area i.e. net plot area while the observation like dry matter accumulation per plant were taken from destructive area i.e. area apart from net plot. For recording growth parameter of 5 plants from net plot area were selected out randomly and tagged and their observation were made at 30, 60, 90 DAS and at harvest. Yield and yield attributing character were recorded after harvest.

Initial Plant Population and Plant height (cm)

Five plants from each plot were randomly selected for recording initial plant population at 20 days after sowing. Plant height of five randomly tagged plants was measured from base of plant up to the growing tips of main stem and expressed as average plant height per plant in cm.

Dry matter accumulation plant^{-1} (g)

For recording dry matter accumulation, 5 plants from each plot were cut from the ground level of border rows. Sampled plants were sun dried first then dried in an oven for 24 hours to get constant dry weight. Thereafter, the average dry weight was recorded in g $plant^{-1}$.

Leaf Area Index (LAI)

The leaf area index of two plants from each plot was determined by using leaf area meter. In order to that, entire leaves were grouped into four group's i.e. large, medium, small and very small. Two leaves from each group were put on the leaf area meter to measure the leaves which in tern, was multiplied with number of leaves to total leaf area of the two plants. The leaf area then divided by the land area covered by the plants to get leaf area index (LAI).

Leaf are index was obtained by selecting plants of 1 m^2 and then dividing total leaf area of plants selected in area by 1 m^2.

$$\text{Leaf area index} = \frac{\text{Leaf area}}{\text{Land area}}$$

No. of Primary and Secondary branches plant^{-1}

Five randomly tagged plants were used for counting the number of branches. All primary and secondary branches were counted at 30, 60, 90 DAS and at harvest of crop growth. The average number of branches per plant was worked out.

Siliquae/ plant, Seeds/siliqua

Total number of siliquae on five tagged plant were counted and average number of siliquae per plant was recorded. Ten siliquae were split open and number of seed was counted and the mean was expressed.

Test weight (1000-seed weight)

From the representative sample of each plot one thousand seeds were counted and weighed to record 1000 seeds weight in gram.

Seed yield (kg ha^{-1})

The seed yield of net plot after cleaning and proper drying was recorded in grams and converted into kilogram per hectare by multiplying with appropriate conversion factor.

Stover yield (kg ha^{-1})

After threshing stem and chaff weight per plot were recorded and added treatment wise. These were converted to kilogram per ha by multiplying with appropriate conversion factor.

Harvest index (%)

Harvest index was calculated by the formula (Donald and Hamblin, 1978):

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield (Seed + Stover)}} \times 100$$

Where,

Economic yield = seed yield (kg ha^{-1})

Biological yield = seed yield + stover yield (kg ha^{-1})

Nitrogen uptake by seed (kg ha^{-1})

The similar method followed as mentioned above in N content of the seed was multiplied by seed yield (q ha^{-1}) and to find out the N uptake by seed in kg ha^{-1}

Phosphorus and potassium uptake by seed (kg ha^{-1})

Phosphorus and potassium concentration of seed (%) was multiplied by seed yield (q ha^{-1}) of the respective plots to get the P & K uptake by the seed of that plot and expressed in kg ha^{-1}

Sulphur uptakes by seed (kg ha^{-1})

Sulphur content of seed (%) was multiplied by seed yield (q ha^{-1}) of the respective plots to get the S uptake by the seed of that plot and expressed in kg ha^{-1}.

Oil content in seed

Oil content in seed was estimated by Soxhlet method given by Sankaran (1966).

$$\text{Oil content (\%)} = \frac{\text{Weight of oil}}{\text{Weight of seed sample}} \times 100$$

Oil yield (kg ha^{-1})

Oil yield was obtained from oil content multiplied by seed yield and expressed in kg per hectare.

$$\text{Oil yield (kg ha}^{-1}\text{)} = \frac{\text{Oil content (\%) in seed x seed yield (kg ha}^{-1}\text{)}}{100}$$

Protein content of seed (%)

It was calculated by multiplying the total nitrogen content of seed by a factor (6.25) since protein contains 16% nitrogen (w/w). The unit expressed was in per cent.

Cost of cultivation

Cost of cultivation of the mustard crop was worked out separately for each treatment in Rs ha^{-1} taking into account all types of expenses incurred in the production process.

Gross and net return

Seed and stover yields were multiplied by prevailing market prices of the respective products to calculate the gross return in Rs. for each plot. Gross return (Rs ha^{-1}) minus cost of cultivation (Rs ha^{-1}) gave the net return per hectare in Rs. separately for each plot. Net return (Rs ha^{-1}) was divided by cost of cultivation (Rs ha^{-1}) to get the net return per rupee of investment in Rs. for each plot separately.

Statistical studies

The experimental data were subjected to statistical analysis in order to find out as a how the different treatments affected the various characters. The usual method of analysis of variance (ANOVA) enunciated by Fisher (1938) was followed to calculated the nature and magnitude of treatment effects revealed by 'F'-test. Approximate standard errors along with critical differences, wherever needed, were calculated for statistical interpretation of the results (Table 6).

Table 6: Skeleton of analysis of variance of mustard.

Sources of variation	d. f.	S.S.	M.S.S.	F.cal.	F-value	
					5%	1%
Replication	2					
Treatment	10				2.35	3.40
Error	20					
Total	32					

RESULTS AND DICSCUSSON

Effect of INM on growth attributes

Plant population

The data pertaining to plant population (m^{-2}) at 20 DAS as influenced by various treatments are presented in Table 7.

Table 7: Effect of integrated nutrient management practices on plant population (m^{-2}).

Treatment	Treatment combination	Plant population (m^{-2}) 20 DAS
T_1	Control	21.08
T_2	100% RDF	25.62
T_3	100% RDF + Vermicompost @ 5t ha^{-1}	25.89
T_4	100% RDF + Vermicompost @ 5t ha^{-1} + PSB	26.49
T_5	100% RDF + Poultry manure @ 2t ha^{-1}	26.01
T_6	100% RDF + Poultry manure @ 2t ha^{-1} + PSB	27.02
T_7	75% RDF	23.41
T_8	75% RDF + Vermicompost @ 5t ha^{-1}	25.16
T_9	75% RDF + Vermicompost @ 5t ha^{-1} + PSB	24.20
T_{10}	75% RDF + Poultry manure @ 2t ha^{-1}	24.54
T_{11}	75% RDF + Poultry manure @ 2t ha^{-1} + PSB	25.35
	SE(m)	1.16
	C.D. @ 5%	NS

It is perusal the data given in Table 7 indicate that plant population did not affected significantly by integrated nutrient management practices during the observation period. The plant population was noticed highest 27.02 doses of 100% RDF + Poultry manure @ 2t ha^{-1} + PSB while lowest (21.08) in control treatment during experimental period.

Plant height

The data pertaining to plant height (cm) at 30 60, 90 DAS and at harvest as influenced by different integrated nutrient management treatments were statistically analysed and presented in Table 8.

Table 8: Effect of integrated nutrient management practices on plant height (cm) and dry matter accumulation (g plant^{-1}) at different growth stages of mustard.

Treatment	Treatment combination	Plant height (cm)				Dry matter (g plant^{-1})			
		30 DAS	60 DAS	90 DAS	at harvest	30 DAS	60 DAS	90 DAS	at harvest
T_1	Control	13.81	98.86	116.4	123.83	1.59	19.26	32.41	48.26
T_2	100% RDF	18.41	116.09	128.1	137.62	2.37	30.01	54.26	73.74
T_3	100% RDF + Vermicompost @ 5t ha^{-1}	19.36	118.71	129.73	138.96	2.81	31.23	55.3	74.09
T_4	100% RDF + Vermicompost @ 5t ha^{-1} + PSB	20.22	119.70	133.13	143.15	2.89	33	57.87	76.34
T_5	100% RDF + Poultry manure @ 2t ha^{-1}	19.76	119.23	130.13	142.09	2.87	31.80	56.96	76.15
T_6	100% RDF + Poultry manure @ 2t ha^{-1} + PSB	20.51	122.55	134.83	144.44	3.04	35.87	61.46	80.48
T_7	75% RDF	16.07	102.36	120.73	123.11	1.76	20.24	39.34	52.86
T_8	75% RDF + Vermicompost @ 5t ha^{-1}	16.87	104.33	125	128.65	1.84	26.23	43.92	55.18
T_9	75% RDF + Vermicompost @ 5t ha^{-1} + PSB	18.23	115.11	127.6	134.38	2.17	27.23	47.66	71.56
T_{10}	75% RDF + Poultry manure @ 2t ha^{-1}	17.95	111.74	126.4	131.03	2.14	22.26	44.16	65.65
T_{11}	75% RDF + Poultry manure @ 2t ha^{-1} + PSB	18.28	115.22	127.73	137.13	2.28	28.29	53.3	73.04
	SE(m)	**0.91**	**1.18**	**1.05**	**1.95**	**0.01**	**0.89**	**1.06**	**1.26**
	C.D. @ 5%	**2.71**	**3.37**	**3.13**	**5.24**	**0.03**	**2.65**	**3.16**	**3.52**

Irrespective of different treatments, it is evident from the data (Table 8) that plant height increased with the advancement in the age of the plant and reached the maximum at harvest. Plant height at 30, 60, 90 DAS and at harvest was significantly affected by different integrated nutrient management treatments. Plant height at harvest (144.44 cm) was recorded significantly higher under treatment T_6 (100% RDF + Poultry manure @ 2t ha^{-1} + PSB) as compared to other treatments and found statistically at par with T_4 (100% RDF + Vermicompost @ 5t ha^{-1} + PSB)(143.15 cm) and T_5 (100% RDF + Poultry manure @ 2t ha^{-1})(142.09 cm). The lowest plant height (cm) was recoded in control plot (123.83 cm) during the study period.

Dry matter accumulation

The data pertaining to dry matter accumulation (g plant^{-1}) at 30 60, 90 DAS and at harvest as influenced by different integrated nutrient management treatments were statistically analysed and presented in Table 8. The dry matter accumulation was increased with increasing advancement of crop growth stages. The dry matter accumulation was observed significantly highest with the treatment T_6 (100% RDF + Poultry manure @ 2t ha^{-1} + PSB) (80.48g) followed by T_4 (100% RDF + Vermicompost @ 5t ha^{-1} + PSB) (76.34g) and T_5 (100% RDF + Poultry manure @ 2t ha^{-1}) (76.15h) which was significantly superior over rest of the treatments and statistically at par with each other. The Lowest dry matter accumulation was noticed with the control plots during the study period.

Number of primary and secondary branches

The data pertaining to number of primary branches plant^{-1} at 30 60, 90 DAS and at harvest as influenced by different integrated nutrient management practices were statistically analysed and presented in Table 9.

Table 9: Effect of integrated nutrient management practices on number of primary and secondary branches plant^{-1} at different growth stages

Treatment	Treatment combination	Primary Branches plant^{-1}				Secondary branches plant^{-1}			
		30 DAS	60 DAS	90 DAS	at harvest	30 DAS	60 DAS	90 DAS	at harvest
T_1	Control	2.44	3.25	6.93	2.38	2.38	2.99	6.93	7.83
T_2	100% RDF	3.08	5.08	8.16	2.92	2.92	4.8	8.16	9.46
T_3	100% RDF + Vermicompost @ 5t ha^{-1}	3.10	5.15	8.26	2.95	2.95	4.92	8.26	9.72
T_4	100% RDF + Vermicompost @ 5t ha^{-1} + PSB	3.15	5.74	8.93	3.03	3.03	5.06	8.93	9.97
T_5	100% RDF + Poultry manure @ 2t ha^{-1}	3.11	5.19	8.59	3.01	3.01	4.96	8.59	9.73
T_6	100% RDF + Poultry manure @ 2t ha^{-1} + PSB	3.20	5.92	9.03	3.11	3.11	5.64	9.03	10.81
T_7	75% RDF	2.71	3.91	7.07	2.41	2.41	3.34	7.07	7.09
T_8	75% RDF + Vermicompost @ 5t ha^{-1}	2.88	4.15	7.17	2.76	2.76	3.94	7.17	8.22
T_9	75% RDF + Vermicompost @ 5t ha^{-1} + PSB	3.07	4.82	7.95	2.78	2.78	4.62	7.95	8.92
T_{10}	75% RDF + Poultry manure @ 2t ha^{-1}	2.98	4.79	7.53	2.77	2.77	4.08	7.53	8.82
T_{11}	75% RDF + Poultry manure @ 2t ha^{-1} + PSB	3.08	4.89	8.05	2.82	2.82	4.67	8.05	9.07
	SE(m)	**0.02**	**0.02**	**0.01**	**0.03**	**0.03**	**0.05**	**0.01**	**0.06**
	C.D. @ 5%	**0.05**	**0.06**	**0.04**	**0.10**	**0.10**	**0.16**	**0.04**	**0.17**

It is perusal from the data given in Table 4.4 indicate that number of primary branches was influenced significantly by various integrated nutrient management practices during experimental periods. The maximum (11.01) number of primary branches was produced with the treatments T_6 (100% RDF + Poultry manure @ 2t ha^{-1} + PSB) at all crop growth stages which was at par with T_4 (100% RDF + Vermicompost @ 5t ha^{-1} + PSB)(10.92)and T_5 (100% RDF + Poultry manure @ 2t ha^{-1})(10.62) and found significantly over rest of the treatments. The statically minimum number of primary branches was noticed in control plot which was not received any integrated nutrient management. The data pertaining to number of secondary branches plant^{-1} at 30 60, 90 DAS and at harvest as influenced by different integrated nutrient management practices were statistically analysed and presented in Table 9. It is perusal from the data given in Table 11 indicate that number of secondary branches was influenced significantly by various integrated nutrient management practices on mustard crop during experimental periods. The highest number of secondary branches (10.81) was recorded with the treatments T_6 (100% RDF + Poultry manure @ 2t ha^{-1} + PSB) at all crop growth stages as compared to all other integrated nutrient management treatment and statistically at par with T_4 (100%

RDF + Vermicompost @ 5t ha^{-1} + PSB)(9.97) and T_5 (100% RDF + Poultry manure @ 2t ha^{-1})(9.73)while lowest number of secondary branches was noticed in control plot which was not received any integrated nutrient management.

Leaf area index

The data pertaining to leaf area index at 30 60, 90 DAS and at harvest as influenced by different integrated nutrient management practices were statistically analysed and presented in Table 10.

Table 10. Effect of integrated nutrient management practices on leaf area index and yield attributes at harvest stages

Treatment	Treatment combination	Leaf area Index				No. of siliquae/plant	No. of seed/siliquae	Test weight (g)
		30 DAS	60 DAS	90 DAS	at harvest			
T_1	Control	0.51	2.11	4.04	1.88	145.22	8.36	4.30
T_2	100% RDF	0.68	3.10	6.01	2.32	183.33	10.25	5.88
T_3	100% RDF + Vermicompost @ 5t ha^{-1}	0.70	3.06	6.05	2.39	190.00	10.36	6.16
T_4	100% RDF + Vermicompost @ 5t ha^{-1} + PSB	0.79	3.41	6.28	2.49	195.00	11.27	6.33
T_5	100% RDF + Poultry manure @ 2t ha^{-1}	0.76	3.34	6.19	2.45	194.00	11.04	6.32
T_6	100% RDF + Poultry manure @ 2t ha^{-1} + PSB	0.82	3.47	6.59	2.73	196.67	11.91	6.54
T_7	75% RDF	0.56	2.42	4.93	2.04	164.85	9.06	4.95
T_8	75% RDF + Vermicompost @ 5t ha^{-1}	0.60	2.55	5.05	2.10	171.22	9.11	5.10
T_9	75% RDF + Vermicompost @ 5t ha^{-1} + PSB	0.62	2.95	5.45	2.23	181.33	9.91	5.65
T_{10}	75% RDF + Poultry manure @ 2t ha^{-1}	0.61	2.63	5.65	2.19	179.00	9.68	5.20
T_{11}	75% RDF + Poultry manure @ 2t ha^{-1} + PSB	0.65	2.98	5.92	2.25	181.67	10.11	5.80
	SE(m)	**0.02**	**0.03**	**0.04**	**0.05**	**0.89**	**0.01**	**0.02**
	C.D. @ 5%	**0.06**	**0.08**	**0.12**	**0.14**	**2.46**	**0.04**	**0.06**

Irrespective of different treatments, it is evident from the data (Table 10) that leaf area index increased at 30, 60 and 90 DAS and decreased at harvest. Leaf area index at 30, 60, 90 DAS and at harvest was significantly affected by different integrated nutrient management treatments. Leaf area index at harvest (2.73) was recorded significantly greater under T_6 (100% RDF + Poultry manure @ 2t ha^{-1} + PSB) as compared to other treatments and found statistically at par with T_4 (100% RDF + Vermicompost @ 5t ha^{-1} + PSB)(2.49) and T_5 (100% RDF + Poultry manure @ 2t ha^{-1})(2.45). The lowest leaf area index was recoded in control plot (1.88) during the study period.

Number of siliquae, seed siliquae and test weight

It is perusal from the data given in Table 10 indicates that number of siliquae plant^{-1} was marked significant variation due to integrated nutrient management practices. The number of siliquae plant^{-1} was recorded significantly highest (196.67) under the treatment T_6 (100% RDF + Poultry manure @ 2t ha^{-1} + PSB) as compared to all other nutrient management practices during the study period. The treatment T_4 (100% RDF + Vermicompost @ 5t ha^{-1} + PSB)(195.00) and T_5 (100% RDF + Poultry manure @ 2t ha^{-1})(194.00) was also obtained higher number of siliquae plant^{-1} which was significantly superior over rest of the treatments and statistically at par with T_6. The lowest number of siliquae plant^{-1} (101.00) was noted with control plot which was not received any nutrient management practices.

It is evident from the Table 10 that the number of seed siliquae^{-1} was affected significantly by integrated nutrient management practices of mustard crop. The number of seed siliquae^{-1} was noticed significantly highest (11.91) with the treatment T_6 (100% RDF + Poultry manure @ 2t ha^{-1} + PSB) followed by T_4 (100% RDF + Vermicompost @ 5t ha^{-1} + PSB)(11.27) and T_5 (100% RDF + Poultry manure @ 2t ha^{-1}) (11.04) and found significantly superior over the rest treatments was also exhibited significantly at par with T_6 (100% RDF + Poultry manure @ 2t ha^{-1} + PSB).

It is perusal the data given in Table 10 indicates that marked significantly by integrated nutrient management practices in respect of test weight of mustard crop. The test weight of mustard crop was highest (6.54g) under the treatment T_6 which received 100% RDF + Poultry manure @ 2t ha^{-1} + PSB as compared to control plot (4.30g) during the study period. The treatment T_6, T_4 and T_5 was significantly 6.54g, 6.33g and 6.32g significantly superior over control plot, respectively. These treatments were also exhibited significantly at par with each other.

Yield, seed yield, straw yield, biological yield, and harvest index

The data pertaining to yield viz., seed yield, straw yield, biological yield (q ha^{-1}) and harvest index (%) as influenced by different integrated nutrient management practices were statistically analysed and presented in Table 13. It is clear from the data given in Table 15 which indicated that seed yield (qha^{-1}) was influenced significantly by various integrated nutrient management practices of mustard crop. The seed yield was observed significantly highest (22.93 qha^{-1}) under T_6 (100% RDF + Poultry manure @ 2t ha^{-1} + PSB) followed by T_4 (100% RDF + Vermicompost @ 5t ha^{-1} + PSB) and T_5 (100% RDF + Poultry manure @ 2t ha^{-1}) viz., 22.46 and 21.76 qha^{-1}, respectively. *These three treatments were also statistically close to T_3 (21.65 qha^{-1}), T_2 (21.13 qha^{-1}), T_{11} (20.27 qha^{-1}), T_9 (20.20 qha^{-1}). The lowest yield was noticed under control plot i.e. 16.58 qha^{-1} which was surprisingly however close to T_7 (18.27 qha^{-1}), T_8 (19.32 qha^{-1}).

It is clear from the data of straw yield marked significant due to integrated nutrient management practices on mustard crop during 2018. The highest straw yield (52.66 qha^{-1}) was observed under the treatment T_6 which was received 100% RDF + Poultry manure @ 2t ha^{-1} + PSB found significantly superior and statistically at per with T_4 (100% RDF + Vermicompost @ 5t ha^{-1} + PSB)(52.12)and T_5 (100% RDF + Poultry manure @ 2t ha^{-1})(51.74) as compared to all other treatments during the observation period. The lowest yield was noted with control plot (49.33qha^{-1}).

It is evident from the data given in Table 11 that the biological yield was influenced significantly by various integrated nutrient management practices of mustard crop during the study period. The treatment T_6 (100% RDF + Poultry manure @ 2t ha^{-1} + PSB) was produced significantly highest biological yield (75.12 qha^{-1}) as compared to control treatment. The treatment T_4 (100% RDF + Vermicompost @ 5t ha^{-1} + PSB) (75.12 qha^{-1}) and T_5 (100% RDF + Poultry manure @ 2t ha^{-1}) (73.38 qha^{-1}) was statistically at par with T_6. The lowest biological yield was obtained under control plot (65.91 qha^{-1}).

It is evident from the data given in Table 11 showed that harvest index (%) was influenced significantly by integrated nutrient management practices of mustard crop. The harvest index was recorded significantly highest in T_6 (100% RDF + Poultry manure @ 2t ha^{-1} + PSB)(30.56%) as compare to other treatment combinations. The lowest harvest index was recorded under control plot (25.10%).

Table 11: Effect of integrated nutrient management practices on seed, straw and biological yield (qha^{-1}) and harvest index (%) at harvest stages

Treatment	Treatment combination	Seed yield (q/ha)	Stover yield (q/ha)	Biological yield (q/ha)	Harvest Index (%)
T_1	Control	16.58	49.33	65.91	25.10
T_2	100% RDF	21.13	51.42	72.55	29.10
T_3	100% RDF + Vermicompost @ 5t ha^{-1}	21.65	51.67	73.44	29.62
T_4	100% RDF + Vermicompost @ 5t ha^{-1} + PSB	22.46	52.12	75.05	29.88
T_5	100% RDF + Poultry manure @ 2t ha^{-1}	21.76	51.74	73.38	29.46
T_6	100% RDF + Poultry manure @ 2t ha^{-1} + PSB	22.93	52.66	75.12	30.56
T_7	75% RDF	18.27	50.00	68.27	26.75
T_8	75% RDF + Vermicompost @ 5t ha^{-1}	19.32	50.47	69.94	27.80
T_9	75% RDF + Vermicompost @ 5t ha^{-1} + PSB	20.20	50.92	71.19	28.48
T_{10}	75% RDF + Poultry manure @ 2t ha^{-1}	19.47	50.74	70.06	27.53
T_{11}	75% RDF + Poultry manure @ 2t ha^{-1} + PSB	20.27	51.00	71.19	28.36
	SE(m)	**0.92**	**1.03**	**1.04**	**1.15**
	C.D. @ 5%	**2.76**	**2.89**	**3.09**	**3.36**

Available N, P, K and S in soil

The data pertaining to available nitrogen, phosphorus, potassium and sulphur (kg ha^{-1}) as influenced by different integrated nutrient management practices were statistically analysed and presented in Table 12. It is evident from the data given in Table 14 showed that the available NPKS was marked with significant variation due to integrated nutrient management practices during 2018. The highest availability of N, P, K, and S was observed under treatment T_6 i.e. 315.7, 24.7, 215.6 and 13.7 kg ha^{-1}, respectively which was significantly superior over rest of integrated nutrient management treatments. The lowest available N, P, K, and S was found in control treatment which was not received integrated nutrient.

N, P, K and S content

The data pertaining to nitrogen, phosphorus, potassium and sulphur content (%) as influenced by different integrated nutrient management practices were statistically analysed and presented in Table 13.

Table 12: Effect of integrated nutrient management practices on available N,P, K and S at harvest stages.

Treatment	Treatment combination	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Available S (kg ha^{-1})
T_1	Control	287.9	18.8	199.1	9.8
T_2	100% RDF	295.8	21.9	208.0	11.5
T_3	100% RDF + Vermicompost @ 5t ha^{-1}	299.8	22.1	208.9	12.0
T_4	100% RDF + Vermicompost @ 5t ha^{-1} + PSB	303.3	22.7	212.2	13.4
T_5	100% RDF + Poultry manure @ 2t ha^{-1}	301.7	22.2	211.9	12.2
T_6	100% RDF + Poultry manure @ 2t ha^{-1} + PSB	315.7	24.7	215.6	13.7
T_7	75% RDF	288.3	20.5	202.1	10.7
T_8	75% RDF + Vermicompost @ 5t ha^{-1}	290.1	20.7	204.0	10.8
T_9	75% RDF + Vermicompost @ 5t ha^{-1} + PSB	299.8	21.4	208.9	11.5
T_{10}	75% RDF + Poultry manure @ 2t ha^{-1}	290.3	20.7	204.5	11.0
T_{11}	75% RDF + Poultry manure @ 2t ha^{-1} + PSB	295.5	21.5	205.9	11.4
	SE(m)	**1.58**	**0.92**	**1.66**	**0.83**
	C.D. @ 5%	**4.37**	**2.74**	**4.92**	**2.55**

Table 13. Effect of integrated nutrient management practices on N,P, K and S content (%) at harvest stages in seed.

Treatment	Treatment combination	N content (%)	P content (%)	K content (%)	S Content (%)
T_1	Control	1.55	0.50	1.30	0.46
T_2	100% RDF	1.60	0.58	1.40	0.53
T_3	100% RDF + Vermicompost @ 5t ha^{-1}	1.61	0.60	1.42	0.54
T_4	100% RDF + Vermicompost @ 5t ha^{-1} + PSB	1.62	0.62	1.45	0.55
T_5	100% RDF + Poultry manure @ 2t ha^{-1}	1.61	0.61	1.44	0.55
T_6	100% RDF + Poultry manure @ 2t ha^{-1} + PSB	1.63	0.63	1.46	0.58
T_7	75% RDF	1.56	0.53	1.34	0.48
T_8	75% RDF + Vermicompost @ 5t ha^{-1}	1.57	0.54	1.35	0.51
T_9	75% RDF + Vermicompost @ 5t ha^{-1} + PSB	1.59	0.56	1.37	0.52
T_{10}	75% RDF + Poultry manure @ 2t ha^{-1}	1.58	0.55	1.37	0.52
T_{11}	75% RDF + Poultry manure @ 2t ha^{-1} + PSB	1.60	0.57	1.39	0.53
	SE(m)	**0.01**	**0.01**	**0.02**	**0.01**
	C.D. @ 5%	**0.03**	**0.04**	**0.05**	**0.04**

It is clear from the data given in Table 17 indicate that nutrient content viz., N,P, K and S was influenced significantly by various treatment of mustard crop. The highest nutrient content N, P, K and S viz., 1.63%, 0.63%, 1.46% and 0.58%, respectively was analyzed under treatments T_6 which received 100% RDF + Poultry manure @ 2t ha^{-1} + PSB doses followed by T_4 and T_5 as compared to control treatment during the study period. These treatments was also exhibited significantly at par with each other.

Nutrient uptake

The data pertaining to nitrogen, phosphorus, potassium and sulphur uptake (kg ha^{-1}) in seed as influenced by different integrated nutrient management practices were statistically analysed and presented in Table 14.

Table 14: Effect of integrated nutrient management practices on N, P, K and S uptake (kg ha^{-1}) by seed

Treatment	Treatment combination	N uptake (kgha^{-1})	P Uptake (kgha^{-1})	K uptake (kgha^{-1})	S uptake (kgha^{-1})
T_1	Control	25.63	8.25	21.54	7.62
T_2	100% RDF	33.94	12.34	29.56	11.19
T_3	100% RDF + Vermicompost @ 5t ha^{-1}	34.93	12.94	30.77	11.74
T_4	100% RDF + Vermicompost @ 5t ha^{-1} + PSB	36.29	13.94	32.55	12.38
T_5	100% RDF + Poultry manure @ 2t ha^{-1}	35.05	13.36	31.33	11.98
T_6	100% RDF + Poultry manure @ 2t ha^{-1} + PSB	37.37	14.35	33.49	13.38
T_7	75% RDF	28.58	9.70	24.39	8.74
T_8	75% RDF + Vermicompost @ 5t ha^{-1}	30.28	10.38	26.07	9.90
T_9	75% RDF + Vermicompost @ 5t ha^{-1} + PSB	32.07	11.36	27.75	10.60
T_{10}	75% RDF + Poultry manure @ 2t ha^{-1}	30.84	10.66	26.75	10.18
T_{11}	75% RDF + Poultry manure @ 2t ha^{-1} + PSB	32.35	11.61	28.10	10.70
	SE(m)	**1.47**	**0.70**	**1.39**	**0.69**
	C.D. @ 5%	**4.16**	**2.07**	**3.85**	**2.06**

It is perusal from the data given in Table 18, the highest nutrient uptake viz., N, P, K and S was found in the treatment T_6 i.e. 37.37 kg ha^{-1}, 14.35 kg ha^{-1}, 33.49 kg ha^{-1} and 13.38 kg ha^{-1}, respectively as compared to all other integrated nutrient management practices. The lowest N, P, K and S uptake was noted with control treatment i.e. 25.63 kg ha^{-1}, 8.25 kg ha^{-1}, 21.54 kg ha^{-1} and 7.62 kg ha^{-1}**.**

Quality parameter

The data pertaining to quality parameter of mustard crop viz., oil yield (kgha^{-1}), oil content (%) and protein content (%) as influenced by different integrated nutrient management practices were statistically analysed and presented in Table 20. It is clear from the data showed that oil yield was influenced significantly by integrated nutrient management practices of mustard crop during experimental period. The oil yield was observed highest (42.13 q ha^{-1}) under T_6 (100% RDF + Poultry manure @ 2t ha^{-1} + PSB) followed by T_4 and T_5, respectively which was statistically at par with each other. The lowest oil yield (35.83 q ha^{-1}) was noted with control treatment.

Table 15. Effect of integrated nutrient management practices on oil yield (kg ha^{-1}), oil content (%) and protein content (%)

Treatment	Treatment combination	Oil yield (q/ha)	Oil content (%)	Protein content (%)
T_1	Control	35.83	5.91	18.33
T_2	100% RDF	40.40	8.35	23.06
T_3	100% RDF + Vermicompost @ 5t ha^{-1}	40.74	8.88	23.44
T_4	100% RDF + Vermicompost @ 5t ha^{-1} + PSB	41.11	9.13	24.60
T_5	100% RDF + Poultry manure @ 2t ha^{-1}	41.01	8.94	24.28
T_6	100% RDF + Poultry manure @ 2t ha^{-1} + PSB	42.13	9.67	25.45
T_7	75% RDF	39.07	7.16	20.96
T_8	75% RDF + Vermicompost @ 5t ha^{-1}	38.86	7.49	21.86
T_9	75% RDF + Vermicompost @ 5t ha^{-1} + PSB	39.66	8.11	22.53
T_{10}	75% RDF + Poultry manure @ 2t ha^{-1}	39.41	7.68	22.06
T_{11}	75% RDF + Poultry manure @ 2t ha^{-1} + PSB	40.20	8.16	23.16
	SE(m)	**0.87**	**0.40**	**0.91**
	C.D. @ 5%	**2.38**	**1.18**	**2.71**

The data was synthesized that oil content (%) was recorded maximum (9.67%) under T_6 (100% RDF + Poultry manure @ 2t ha^{-1} + PSB) which was significantly superior over control treatment (5.91%). The oil content was also higher with the treatment T_4 and T_5 as compared to other integrated nutrient management. Both of the treatments were also exhibited significantly at par with T_6 during the observation period.

It is evident from the data given in Table 15 was marked significant variation with the integrated nutrient management practices of mustard crop. The protein content was noticed highest with the application of 100% RDF + Poultry manure @ 2t ha^{-1} + PSB (T_6) 25.45% as compared to control treatment (18.33%). The treatment T_4 and T_5 was also received higher protein content which was significantly over rest of the integrated nutrient management treatment.

Economics (Cost of cultivation (Rs ha^{-1}), gross return, net return, B:C ratio)

The data pertaining to economics of mustard crop viz., Cost of cultivation (Rs ha^{-1}), gross return (Rs ha^{-1}), net return (Rs ha^{-1}) and B:C ratio as influenced by different integrated nutrient management practices were statistically analysed and presented in Table 16. It is perusal from the data given in Table 16 showed that cost of cultivation was higher under the treatment T_4 (Rs 27782.00 ha^{-1}) which received 100% RDF + Vermicompost @ 5t ha^{-1} + PSB doses followed by T_3 (Rs 27582.00 ha^{-1}), T_6 (Rs 26282.00 ha^{-1}) and T_5 (Rs 26082.00 ha^{-1}), respectively during the observation period. The lowest cost of cultivation was noticed in control (Rs 14789 ha^{-1}) treatment. It is clear from the data given in Table 19 was indicate that gross return in respect of mustard crop was recorded maximum Rs 93420.00 ha^{-1} with the application of 100% RDF + Vermicompost @ 5t ha^{-1} + PSB

(T_6) followed by T_4 and T_5, respectively during study period. The least value of gross return was recorded with control plot (Rs 70363.00 ha^{-1}).

It is evident from the data showed that highest net return was found with the application of 100% RDF + Vermicompost @ 5t ha^{-1} + PSB (T_6) Rs 67138.00 ha^{-1} as compared to control treatment (Rs 55574.00 ha^{-1}). The treatment T_4 (Rs 63858.00 ha^{-1}), T_5 (Rs 63013.00 ha^{-1}) and T_2 (Rs 63013.00 ha^{-1}) was also recorded higher as compared to other treatments. It is clear from the data given in Table 19 showed that B:C ratio was higher 3.76 with the application of Control (T_1) followed by T_2 which received 100% RDF alone (2.60) as compared to treatment T_8 (75% RDF + Vermicompost @ 5t ha^{-1}) i.e. 2.18 followed with application of 100% RDF + Vermicompost @ 5t ha^{-1} (2.22).

Table 16. Effect of integrated nutrient management practices on economics (Rs ha^{-1}) iat harvest stages of mustard

Treatment	Treatment combination	Cost of cultivation (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rsha^{-1})	B:C ratio
T_1	Control	14789.00	70363	55574	3.76
T_2	100% RDF	24082.00	86810	62728	2.60
T_3	100% RDF + Vermicompost @ 5t ha^{-1}	27582.00	88693	61111	2.22
T_4	100% RDF + Vermicompost @ 5t ha^{-1} + PSB	27782.00	91640	63858	2.30
T_5	100% RDF + Poultry manure @ 2t ha^{-1}	26082.00	89095	63013	2.42
T_6	100% RDF + Poultry manure @ 2t ha^{-1} + PSB	26282.00	93420	67138	2.55
T_7	75% RDF	21699.00	76445	54746	2.52
T_8	75% RDF + Vermicompost @ 5t ha^{-1}	25199.00	80238	55039	2.18
T_9	75% RDF + Vermicompost @ 5t ha^{-1} + PSB	25399.00	83430	58031	2.28
T_{10}	75% RDF + Poultry manure @ 2t ha^{-1}	23699.00	80830	57131	2.41
T_{11}	75% RDF + Poultry manure @ 2t ha^{-1} + PSB	23899.00	83695	59796	2.50

DISCUSSION

Since time immemorial man has been harvesting very low yields under dryland and irrigated conditions because of various constraints in crop production. They have generated various indigenous technologies as correction measures but they have not proved too effective. Various methods of application of various nutrient sources have been carried out in this particular experiment on mustard, an important crop in the irrigated areas. Thus, this investigation not only aimed at identifying an effective method application of nutrients but also to generate information on the feasibility of increasing nutrients use by the crop plants so as to make the technology sound effective in economic terms. The relationship between cause and effect associated with various results of the present investigation are discussed in this chapter in the light of established physiological and biochemical processes. Efforts have been made to explain the pertinent findings with the support of experimental findings wherever possible.

The growth and development of plant are influenced by inherited genetical characters as well as external environment. A set of favourable environmental conditions is essential for proper growth and development of crop plant. Matching the crop phenology to the climatic environment which prevails during the growing season is an important aspect to maximize genetic yield potential. Mustard is a monocarpic annual in which growth and phenology are climate dependent. Rate of vegetative growth as well as floral initiation and anthesis, the vitally important components are easily affected by fluctuation in climatic parameters and may change the effectivity of agronomic management. Genetic responsiveness to photoperiod, temperature and humidity, affects the duration of flowering period, time of flower initiation and date of anthesis in mustard crop. Duration of crop growth is one of the main determinants of cumulative energy intercepted by the crop. Thus, sensitivity to photo-thermal regime establishes the time limit for energy input in crop. In general, conditions of field environment during course of investigation remained mostly conducive and within the normal photo-thermal responsive plane. Consequently, the expected response of experimental variables was not affected by any of the climatic parameters except rainfall.

Growth attributes

Growth of plant can be measured vertically in terms of plant height and horizontally in terms of leaf area index, number of branches, dry matter production, etc. Dry matter production is more important because all other vegetative characters are contained in it. Further, the growth of characters viz. plant height, leaf area index, dry matter production and number of branches plant^{-1} increased with advancement in age of mustard crop irrespective of the treatments differential response.

100% RDF + Poultry manure @ 2t ha^{-1} + PSB brought about marked improvement in plant height, number of leaves, number of branches and production of dry matter at all the stages of plant growth. Fully recommended (120-60-60-60 kg N-P_2O_5-K_2O-S per hectare) basal dose of fertilizer with poultry manure of nutrients and Multiplex provided ample quantities of nitrogen, phosphorus, potassium and sulphur for the growth and development of the crop. The superiority of treatment may be accounted to the higher uptake of nitrogen, phosphorus, potassium and sulphur. Nitrogen is an essential constituent of all living matter including proteins, amino acids, nucleic acids, nucleotides, enzymes, alkaloids, vitamins, chlorophyll etc. It is involved in photosynthesis, respiration and protein synthesis. Likewise, phosphorus is a structural component of the membrane system of the cell, the chloroplast and the mitochondria. It is a constituent of ATP, ADP, nucleic acids, phospholipids, the co-enzyme NAD, NADP. It stimulates early root development and growth, thus helps in plant development. It enhances the development of reproductive parts, thus bringing about maturity. However, potassium works as a catalyst in a number of physiological processes, for e.g. carbohydrate metabolism, nitrogen metabolism and synthesis of proteins etc. It imparts hardiness and disease resistance in plants.

From the results, it appears that combined application of organic and inorganic, in general, favorably influenced the growth attributes, supporting its well established role in proper growth and development. Balanced nutrition to growing mustard plant resulted in vigorous amount of nutrient absorbed by the plant is governed by nutrient supply intensity and capacity of soil, in addition to, potentiality of crop plant to utilize it. It is evident that with increasing incorporation of nutrients, the intensity and capacity of soil to supply adequate nutrients increased, enabling its greater uptake and utilization. As a result, plant height and production of branches also increased which increased the total dry matter production. Dinesh et al. (2006), Antil and Narwal (2007) and Singh et al. (2011) found the same trend.

The initial rate of growth remained very slow, but under high nutrients supply, it markedly increased with production of more branches. Greater protein synthesis under adequate nutrient supply induced more production of primary and secondary branches which is one of the basic factors for increased height and dry matter production. With the stimulated increase in height and production of branches, LAI is bound to increase, capturing more radiant energy. This made the plant more photosynthetically efficient for higher assimilate production and dry matter accumulation. Branching is related with the formation and development of axillary or lateral buds which physiologically is the function of tissue differentiation, multiplication and development. Pal et al. (2008), Theunissen et al. (2010) and Yadav et al. (2018) found increased branching due to adequate nutrient supply.

In the present investigation, the LAI was lower at harvest in comparison to 90 DAS irrespective of the treatments proving senescence of lower leaves and photosynthetically inactive. Combined nutrient application registered significant variation in LAI at both the stages of observation. Combination of all nutrient management practices registered maximum LAI, while lowest with control. More leaf area as a result of more number of functional leaves per plant was noted due to combined nutrients dose. Supply of adequate nutrients results in better utilization of carbohydrates to form protoplasm leading to the production of large cells with thin walls which increased the leaf area. Higher leaf area with adequate nutrition under irrigated condition was reported by Pal et al. (2008), Kashved et al. (2010), Theunissen et al. (2010), Kumar et al. (2017), Mahata and Sinha (2018), and Yadav et al. (2018) in Indian mustard.

Yield and yield attributes

In accordance with vegetative growth, every increment in nutrient dose brought about significant increase in production of siliqua, seeds per siliqua and test weight of seeds as well as seed yield per hectare. Higher amount of nutrients through combined organic and inorganic showed greater efficiency over control. As discussed, marked improvement in various vegetative attributes and overall effective vegetative growth performance under adequate nutrient supply appears to be basic factor for improvement in maturity attributes. The basic vegetative phase has a significant role in shaping the reproductive organs, which is most important from point of view of obtaining high yield. Some studies have shown positive correlation with number of branches and siliquae number. Mobilization of nutrients from vegetative parts to developing siliquae and seeds depends on its pre-assimilated content. Under adequate nutrient supply, plants are expected to utilize it more effectively has been revealed in this investigation in terms of increase dry matter accumulation. In addition, under adequate nutrients more efficient mobilization of nutrients to reproductive attributes is bound to occur. Improvement in siliqua and seed production per plant as well as test weight could be ascribed to this phenomenon.

Seed yield per hectare significantly increased with adequate supply of nutrient. In most of the studies, it was inevitably noticed that siliquae number and seed weight are related to seed yield. Among the various yield attributes, positive correlation between the number of siliqua and seed weight per plant with seed yield of mustard has been reported by Premi et al. (2004), Ramesh et al. (2009), Chandan et al., (2018) Seed yield and other yield parameters were higher with the application of both poultry manure and basal dose of nutrients rather than fully recommended dose of fertilizer as basal. Saha et al. (2010), Singh et al., (2014) and Mahata and Sinha (2018) assessed poultry manure superior towards seed and stover yield of mustard. Harvest index a parameter of determining the economic yield from the total biological yield showed almost the same trend and remained higher with adequate nutrient supply through organic application and 100% RDF. It is an indicative that plants supplied with adequate nutrients had better potential to translocate food material from vegetative part to reproductive part in comparison to single nutrient spray.

Effect on quality

Quality parameter includes oil percentage, oil yield, protein content etc. Synthesis of oil by plant organs is a complicated series of bio-chemical reactions. Certain intermediate compounds which formed as a result of oxidation of carbohydrates are utilized in the synthesis of oil and fats. Rapid inter conversion takes place in living cell, the glycerol and fatty acids are final components which are derived from carbohydrates during respiration. During maturation of oilseeds, an increase in oil content occurs concurrently with a decrease in the quantity of carbohydrate present which suggests that carbohydrates in seeds are being converted in fat. When the nutrients are supplied in adequate amount, the oil content and oil yield also increased in mustard seed. Combined poultry manure recorded in enhancing the oil content leading to higher oil yield as a result of enhanced seed yield. Similar findings were reported by Nagdive et al. (2007), Pal et al. (2008) and Rundala et al. (2012) reported total edible oil production was higher with higher fertilizer rates compared to normal recommended rates of fertilizer. Same trend was observed for oil yield also in the investigation.

Nutrient uptake by seed

Application of adequate poultry manure induced marked improvement in nitrogen phosphorus, potassium and sulphur content and uptake. Nitrogen phosphorus, potassium and sulphur uptake were positively influenced by adequate supply of nutrients. The release of nutrient in soil solution depends upon intensity and capacity of soil to supply these nutrients. Adequate supply of nutrient increased nitrogen phosphorus, potassium and sulphur content for their effective uptake. Proper application of nutrient, in general, leads to more uptakes of nutrients by crop and this was true with present experiment also. Application of nutrients is not done only to the soil, but organic application is also very effective. It helped the crop in uptake of nutrient as it was observed in seed and stover of crop. Maximum nitrogen phosphorus, potassium and sulphur uptake was noticed with combined application of recommended dose, poultry manure and biofertilizer which was followed by vermicompost with recommended dose and biofertilizer. Similar result was recorded by Kumar et al. (2011), Upadhyay (2012), Majumder et al. (2017) and Singh et al. (2018).

Comparative economics

In modern agriculture, feasibility of any method can be judge on the basis of additional return due to that practice over the established one. The results of present investigation indicate appreciable variation in net return due to different combination of application of nutrients. Data computed on economic return (Table 17) revealed that combined application of 100% RDF, poultry manure and PSB gave the maximum net return of Rs. 67138.00 per ha^{-1}. The B: C ratio was however highest (3.76) with the application of Control (T_1) followed by T_2 which received 100% RDF alone (2.60) as compared to treatment T_8 (75% RDF + Vermicompost @ 5t ha^{-1}) i.e. 2.18 followed with application of 100% RDF + Vermicompost @ 5t ha^{-1} (2.22). Similar results were found by Singh et al. (2014), Saha et al. (2015), Mukharjee (2016) and Debasis and Sinha (2018). The experiment with mustard cv. Varuna was laid out in a randomized block design with three replications. The eleven treatments involved viz., Control, 100% RDF, 100% RDF + Vermicompost @ 5t ha^{-1}, 100% RDF + Vermicompost @ 5t ha^{-1}, 100% RDF + Vermicompost @ 5t ha^{-1} + PSB, 100% RDF + Poultry manure @ 2t ha^{-1}, 100% RDF + Poultry manure @ 2t ha^{-1} + PSB, 75% RDF, 75% RDF + Vermicompost @ 5t ha^{-1}, 75% RDF + Vermicompost @ 5t ha^{-1} + PSB, 75% RDF + Poultry manure @ 2t ha^{-1} and 75% RDF + Poultry manure @ 2t ha^{-1} + PSB. Application of N, P_2O_5 and K_2O were made through the urea, di-ammonium phosphate and muriate of potash to the crop as basal dose and response to various nutrients application were measured in terms of various quantitative and qualitative expressions. Growth and yield attributes and yield viz. plant height (cm), dry matter production(g), number of primary and secondary branches $plant^{-1}$, leaf area index, number of siliquae $plant^{-1}$, seeds $siliqua^{-1}$, test weight (g), seed yield (q ha^{-1}), stover yield (q ha^{-1}) and harvest index (%), quality parameters viz. seed oil content (%), oil yield (q ha^{-1}), protein content (%) and nutrient content and uptake (N, P, K and S) by seed (kg ha^{-1}) were recorded and finally the comparative economics of various treatments was computed.

CONCLUSION

On the basis of one-year field experiment during Rabi 2018, it could be concluded that the application of 100% RDF + Poultry manure @ 2t ha^{-1} + PSB, which was found statistically at par with T_4 (100% RDF + Vermicompost @ 5t ha^{-1} + PSB) and T_5 (100% RDF + Poultry manure @ 2t ha^{-1}) was more remunerative as it resulted into significantly higher seed yield (22.93 q ha^{-1})

over other treatments. The overall results of the study showed that the application of poultry manure, Vermicompost and biofertilizer in combination i.e., integrated nutrient management would be useful to enhance the productivity of mustard.

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