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Ishita Luharch
Department of Agriculture, Maharishi Markandeshwar University, Sadopur Ambala, Haryana, India

Dr. Vikas Tomar
Department of Agriculture, Maharishi Markandeshwar University, Sadopur Ambala, Haryana, India

Diksha Sharma
Department of Agriculture, Maharishi Markandeshwar University, Sadopur Ambala, Haryana, India

Dr. Sandeep Kaur
Microbiologist, Satpaul Mittal School, Ludhiana, Punjab, India

Corresponding Author:
Ishita Luharch
Department of Agriculture, Maharishi Markandeshwar University, Sadopur Ambala, Haryana, India

Effect of planting methods and nutrient management on growth, yield and economics of mustard (*Brassica rapa L.*)

Ishita Luharch, Dr. Vikas Tomar, Diksha Sharma and Dr. Sandeep Kaur

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Abstract
Planting methods and nutrient management are the most important factors in increasing the productivity of crop plants. Broadcasting and line sowing are common planting methods for rapeseed-mustard. Among nutrients, nitrogen (N), phosphorus (P) and potassium (K) are vital nutrients along with sulphur (S) and boron (B) that play key roles in plants. In present research the effect of planting methods and nutrient management in mustard (*Brassica rapa* L.) was studied. A field experiment was conducted in the Research Field of the Department of Agriculture at Maharishi Markandeshwar University, Sadopur (Haryana) during the Rabi season 2020-21. A treatment combination of line sowing + T_5 gave results with maximum benefits in most of the parameters. At the same time it was also observed that boron and sulphur can also influence most of the traits if applied in an optimum dose. On the basis of the experimental findings, it may be concluded that the application of RDF along with boron and sulphur in deficient areas is recommended to increase the growth and productivity of mustard along with line sowing as an appropriate method of sowing.

Keywords: Economics, mustard, nutrient management, sowing method, yield

1. Introduction

Brassica rapa is an upright winter annual or biennial that is used for the production of both industrial and vegetable oil and fodder production. It shows flowering and physiological maturity in comparison to other alternative oilseed crops making it a better option for short season growing areas (Kayacetin *et al.*, 2021) [7]. *Brassica rapa* L. can provide important genetic diversity for crop improvement with rotation benefits to dryland wheat as it can also be cultivated on marginal areas and can serve as a source of bio-fuel production. (Kayacetin *et al.*, 2021) [7]. In India, rapeseed and mustard are the major oilseed crops, traditionally grown everywhere in the country due to their high adaptability in conventional farming systems.

Brassica crops are the second most cultivated after groundnut, with 3.5 million hectares area under cultivation with production of about 2 million tonnes of seed annually in India. Around 16.2 million tonnes of rapeseed are produced annually in India accounting for about 18% of the total oilseed production of the country. Rapeseed– mustard is the third most important source of edible oil next to soybean and groundnut in India and is a cold-season crop produced in certain tropical and subtropical areas (Thakur *et al.*, 2021) [22]. Rajasthan leads the Indian states in terms of production of mustard contributing more than 50% of total production of crop in the country (Kaur *et al.*,2019) [6].

Planting methods and nutrient management are the most important factors in improving the productivity of crop plants. Planting methods depend mainly on the farmer's resources, management conditions and soil conditions. Furrow method, broadcast, line sowing and broad bed are common planting methods for rapeseed-mustard (Mir *et al.*, 2010) [11]. According to Rahman *et al*. (2019) [14] sowing method has main influence on productivity of crop. The broadcasting and line sowing methods were undertaken in present research. Seeds were spread in distinct lines in line sowing with plant to plant spacing maintained. Line planting ensures an optimal plant population per unit area improving mustard production. Seeds are planted randomly in broadcasting. As a result, maintaining the optimal plant density per unit space, which is critical for greater production, is challenging (Hossain *et al.*, 2013) [3].

Among macro-nutrients, nitrogen (N), phosphorus (P) and potassium (K) are vital nutrients that play key roles in plants. Nitrogen triggers chlorophyll synthesis, cell division and protein synthesis in plants. Phosphorus application strengthen the plant roots, improves grain partitioning and crop quality. Potassium triggers enzyme activation, stomatal activity and starch synthesis within plants including the oilseed crops. Hence, the role of NPK fertilizers in enhancing the productivity of field crops is paramount (Sher *et al.* 2019) [19].

Sulphur is essential for increasing oil content (%) and oil yield and sulphur application influences chlorophyll synthesis, carbohydrate as well as protein metabolism. Boron is among the essential micronutrient which helps in translocation of photosynthates and growth regulators from source to sink and growth of pollen grains thereby increasing seed yield of crops. Functions of plant like cell wall formation, cell wall strength, cell division, fruit and seed development and sugar transport are related to boron (Sharma *et al.*, 2020) [17].

In view of above facts the present investigation entitled "Effect of planting methods and nutrient management on growth and yield of mustard (*Brassica rapa* L.) was conducted to find the appropriate fertilizer dose and best planting method suitable for obtaining maximum out-put out of all the parameters related to growth and yield of mustard.

2. Materials and methods

The research was conducted during *rabi* season 2020-2021 in the Research Field, Department of Agriculture, Maharishi Markandeshwar University, Sadopur (Haryana). The experimental location is located at latitude 30º42'39" N and 76º77'69" E longitude and 264 meters above sea level. The climate of the area is tropical and semi-arid, with hot and dry summers (April to June), hot and humid monsoon period (July to September) and cold winter (December to February). The maximum temperature surpasses 17-45 ^{0}C during January-June and the lowest temperatures varies between 4-25 ^{0}C during the winter months of December-June. The average annual rainfall in the region is 919 mm. Mustard is a rabi crop and grows best between 15-25 ^{0}C. It is cultivated in areas where the yearly rainfall is between 750 and 1000 mm. The soil of this region is alkaline in nature. Soil samples were collected from the depth of 0-15 cm before the experiment was laid out and after the crop was harvested and pH, available nitrogen, phosphorus and potassium were measured in the samples.

The experiment was laid out in factorial randomized block design with three replications. Variety Pioneer 45S46 was used for cultivation. Main plots were referred as two planting systems namely line sowing and broadcasting and subplots were referred as nutrient management practices with 5 fertilizer treatments namely 100% RFD, 130% RFD, 130% RFD + S, 130% RDF + B and 130% RFD + B + S. Recommended fertilizer dose (RFD) contained 80:40:40 kg ha^{-1} of N: P_2 O_5 : K_2O , respectively. Sulphur (S) treatment was 25 kg ha^{-1} through agricultural gypsum and Boron (B) treatment was 1.5 kg ha^{-1} through boric acid. The size of each plot was 10m (2.5m x 4m). Spacing between main plots was 30cm and sub plots was 10cm. The weeds were controlled manually and removed from the field at regular intervals. Line sowing and broadcasting are by far the most often used sowing methods. The plots of first half were sown by following line sowing methods and the plots of second half were sown following broadcasting with a seed rate of 2.5 kg ha^{-1}. In case of line sowing, spacing was maintained as 30 x 10 cm.

The specific quantity of each fertilizer was calculated on the basis of gross plot size and as per treatment taken per plot. During the experiment, all the fertilizers comprising of nitrogen, phosphorus, potassium, sulphur and boron were administered according to the treatments. During sowing, a complete dosage (80:40:40, N: P: K kg ha^{-1}) of nitrogen, phosphorous and potassium was given as a basal dose. The fertilizers urea, single super phosphate and potash muriate were used to apply nitrogen, phosphorus and potassium respectively. Gypsum and boric acid were used as a base coat. Pre-sowing irrigation was given a week before sowing, followed by two subsequent irrigations, one at 15 days after sowing and second one was given at flowering stage. To maintain the spacing between the plants and encourage complete canopy development, thinning was done 4 weeks after sowing. To prevent crop weed competition and encourage optimal plant growth, weeding was done 40 and 60 days after sowing. Plant protection measures were implemented at required times. To control the aphid population, imidachloprid was sprayed @ 0.2% in the field.Harvesting was done when the siliquae turned completely brown. Harvesting was done manually and the harvested crop was kept in their respective plot. The products of each net plot were gathered and threshed. Manual cleaning and weighing of the seeds was done. The weight of the seeds recorded in kilograms for each treatment was then converted to quintal per hectare.

3. Results

3.1. Growth parameters

3.2 Plant height (cm)

Plant height was found to be influenced by different planting methods and nutrient management practices at all stages of crop growth. Table 1 shows the plant height recorded at 30, 60, 90, 120 days interval and at harvest of mustard crop. Line sowing was significantly superior to broadcasting in all stages of crop growth. Line sowing produced the highest plant height (33.78 cm) at 30 DAS, whereas the maximum height attained in broadcasting method was 32.95 cm. Tallest plants (34.95 cm) were recorded in plots treated with T_5 (130% RDF + S @ 25 kg ha^{-1} + B @ 1.5 kg ha^{-1}) and minimum plant height was recorded (31.52 cm) in plots treated with T_1 (100% RDF). At 60, 90 and 120 DAS, as well as at harvest, similar patterns in plant height were observed. The maximum plant height of mustard (36.38 cm) was recorded at 30 DAS, indicating a strong interaction between planting methods and nutrient management in plots having line sowing method with a treatment application of T_5 (130% RDF + S @ 25 kg ha^{-1} + B @ 1.5 kg ha^{-1}) which was followed by plots applicated with treatment T_3 (34.69 cm) with line sowing and the minimum plant height was recorded in plots with treatment T_1 (31.41 cm) with line sowing.

Table 1: Effect of planting methods and nutrient management on plant height of mustard

Nutrient management	30 DAS			60 DAS			90 DAS			120 DAS			At harvest		
	Line sowing	Broadcasting	Mean	Line sowing	Broadcasting	Mean	Line sowing	Broadc-asting	Mean	Line sowing	Broadcasting	Mean	Line sowing	Broadc-asting	Mean
T_1-100% RDF	31.41	31.64	31.52	71.61	71.59	71.60	130.83	127.84	129.33	170.86	170.65	170.55	209.58	206.89	208.24
T_2-130% RDF	33.03	34.09	33.56	73.96	72.56	73.25	133.30	131.99	132.65	174.24	172.75	173.499	213.34	210.30	211.82
T_3-130% + S	34.69	33.09	33.89	74.26	72.46	73.36	133.74	133.51	133.63	175.18	173.83	174.51	215.25	212.92	214.08
T_4-130% RDF + B	33.42	32.40	32.91	72.07	71.86	71.97	132.37	132.06	132.21	172.60	171.26	171.93	211.76	211.11	211.43
T_5-130% RDF + S + B	36.38	33.52	34.95	75.33	73.57	74.45	136.19	134.81	135.49	177.38	174.24	175.81	216.36	215.97	216.16
Mean	33.78	32.95		73.45	72.41		133.29	132.04		174.05	172.55		213.26	211.44	
SEm± (Interaction)	0.25			0.14			0.44			0.32			0.49		
CD (P=0.05)(Inte raction)	0.74			0.43			1.31			0.97			1.49		

3.2 Number of primary branches (no.), number of secondary branches (no.) and dry matter accumulation (g plant^{-1})

Table 1.1 displays information on the number of primary branches plant^{-1} as a function of planting methods and nutrient levels. Maximum mean number of branches per plant were recorded in line sowing and minimum (8.69) were recorded in broadcasting. The primary branches plant^{-1} were maximum (9.67) in plots applicated with treatment T_5 (130% RDF + S @ 25 kg ha^{-1} + B @ 1.5 kg ha^{-1}). However minimum primary branches plant^{-1} (8.48) were recorded in plots with a treatment application of T_1 (100% RDF). A significant interaction between planting methods and levels of nutrient indicated that maximum number of primary branches plant^{-1} (9.90) were recorded in line sowing + T_5 (130% RDF + S @ 25 kg ha^{-1} + B @ 1.5 kg ha^{-1}) which was significantly at par with line sowing + T_3 (9.73), line sowing + T_4 (9.43) and broadcasting + T_5 (9.43) while minimum number of primary branches plant^{-1} (8.27) were recorded in broadcasting + T_1 (100% RDF). In closer plant population at broadcasting method, there was competition for light, space, nutrients and environment and therefore, lowest number of branches plant^{-1} were recorded in mustard.

In line sowing, the mean number of secondary branches plant^{-1} was highest (19.23). Broadcasting method of sowing generated the lowest mean number of secondary branches plant^{-1} (18.54). Likewise, maximum number of secondary branches plant^{-1} (19.55) were recorded in plots given treatment T_5 (130% RDF + S @ 25 kg ha^{-1} + B @ 1.5 kg ha^{-1}) and minimum secondary branches plant^{-1} (18.43) were recorded in plots with a treatment application of T_1 (100% RDF). A significant interaction between planting methods and levels of nutrients was observed with line sowing + T_5 (19.90) giving maximum number of secondary branches plant^{-1}. This treatment was followed by line sowing + T_3 (19.40). Whereas minimum secondary branches plant^{-1} (18.23) were recorded in a treatment combination of broadcasting + T_1 (100% RDF).

The maximum dry matter accumulation (113.00 g plant^{-1}) was recorded in line sowing while minimum dry matter accumulation (110.65 g plant^{-1}) was recorded in broadcasting. The dry matter accumulation was highest (119.87 g plant^{-1}) in plots receiving treatment T_5. While the lowest dry matter accumulation (97.56 g plant^{-1}) was observed in plots with treatment application of T_1 (100% RDF). The interaction between planting methods and levels of nutrient showed that maximum dry matter accumulation (120.56 g plant^{-1}) in plots having a treatment combination of line sowing + T_5 which was followed by broadcasting with treatment application of T_5 with 119.17 g plant^{-1}.

Table 1: Effect planting methods and nutrient management on number of branches plant^{-1} and dry matter accumulation in mustard at harvest

Nutrient management	Number of primary branches			Number of secondary branches			Dry matter accumulation (g plant^{-1})		
	Line sowing	Broadcasting	Mean	Line sowing	Broadcasting	Mean	Line sowing	Broadcasting	Mean
T_1- 100% RDF	8.70	8.27	8.48	18.63	18.23	18.43	98.41	96.71	97.56
T_2-130% RDF	9.37	8.40	8.88	18.97	18.30	18.63	115.04	110.61	112.83
T_3-130% RDF + S	9.73	8.67	9.20	19.40	18.53	18.97	116.24	114.38	115.31
T_4-130% RDF + B	9.43	8.70	9.07	19.23	18.43	18.83	114.75	112.39	113.57
T_5-130% RDF + S + B	9.90	9.43	9.67	19.90	19.20	19.55	120.56	119.17	119.87
Mean	9.43	8.69		19.23	18.54		113.00	110.65	
SEm± (Interaction)	0.17			0.03			0.43		
CD(P=0.05) (Interaction)	0.51			0.11			1.28		

4. Yield attributes

4.1 Plant population (10 m^2)

The final plant population was found to be significantly influenced by different planting methods as presented in Table 2. The highest mean plant population (87.57 plants) was observed in line sowing method. Whereas lowest (83.96 plants) were obtained in broadcasting method. Likewise, maximum plant population (91.13 plants) was recorded in plots provided with a treatment application of T_5 and minimum plant population (79.90 plants) was observed in the plots treated with T_1 (100% RDF). The interaction of planting methods and different levels of nutrients was found to be maximum (95.23 plants) with a treatment combination of line sowing + T_5. Whereas minimum plant population was recorded in plots where line sowing was followed with a treatment application of T_1 (79.60 plants).

4.2 Length of siliqua (cm), number of siliqua plant^{-1} (no.) and number of seeds siliqua^{-1} (no.)

The maximum mean length of siliqua (5.15 cm) was recorded in line sowing and minimum (4.81 cm) in broadcasting. Maximum length of siliqua (5.37 cm) was recorded in plots treated with an application of treatment T_3 (130% RDF + S @ 25 kg ha^{-1}) and minimum (4.35 cm) was recorded in plots treated with T_1 (100% RDF). A significant interaction was recorded between planting methods and levels of nutrients where maximum length of siliqua (5.67 cm) was recorded in line sowing with a treatment application of T_3 (130% RDF + S @ 25 kg ha^{-1}).

The highest mean number of siliquae plant^{-1}(368.84) was recorded in line sowing, while the lowest (361.57) was observed in broadcasting. It was also discovered that plots treated with treatment T_5 had the highest number of siliquae plant^{-1} (382.27) followed by plots treated with treatment T_4. Minimum number of siliquae plant^{-1} (344.57) were recorded in plots treated with T_1 (100% RDF). The highest number of siliquae plant^{-1} (385.63) were found in plots provided with line sowing + T_5 (130% RDF + S @ 25 kg ha^{-1} + B @ 1.5 kg ha^{-1}) treatment. In plots with broadcasting + T_1 (100% RDF), the lowest number of siliquae plant^{-1} (342.67) were reported.

Data pertaining to number of seeds siliqua^{-1} has been presented in table 2. The highest mean value (15.32) was registered in line sowing. Whereas minimum (14.51) value was recorded in broadcasting. Likewise, the higher number of seeds siliqua^{-1} (15.92) was registered in plots treated with T_5. Whereas minimum (14.27) value was registered in plots treated with T_1 (100% RDF). The interaction recorded that the treatment combination of line sowing + T_5 recorded the highest number of seeds siliqua^{-1} (16.97).

4.3 Test weight (g)

The highest test weight (5.43 g) was attained by line sowing and lowest (4.41 g) was recorded in broadcasting. In case of different treatments, the highest test weight (5.72 g) was recorded in plots treated with T_5 (130% RDF + B @ 1.5 kg ha^{-1}) followed by treatment T_5 (5.63 g). Whereas minimum test weight (5.10 g) was recorded in treatment T_1 (100% RDF). The interaction effect of planting methods and nutrient management showed that the highest test weight (5.77 g) was registered in plots provided with a treatment combination of line sowing with T_4.

Table 3: Effect of planting methods and nutrient management on yield parameters of mustard

Nutrient management	Plant population (10 m^2)			Length of siliqua (cm)			Number of siliqua plant^{-1}			Number of seeds siliqua^{-1}			Test weight (g)		
	Line sowing	Broad casting	Mean	Line sowing	Broad casting	Mean	Line sowing	Broadcasting	Mean	Line sowing	Broadcasting	Mean	Line sowing	Broadcasting	Mean
T_1-100% RDF	80.20	79.60	79.90	4.47	4.23	4.35	346.47	342.67	344.57	14.47	14.07	14.27	5.13	5.07	5.10
T_2-130% RDF	82.40	82.30	82.35	4.80	4.53	4.67	353.20	349.80	351.50	15.08	14.40	14.73	5.27	5.20	5.23
T_3-130% RDF + S	86.63	84.73	85.68	5.67	5.07	5.37	375.93	359.23	367.58	15.03	14.70	14.87	5.37	5.50	5.43
T_4-130% RDF + B	93.37	86.13	89.75	5.43	5.03	5.23	382.97	377.23	380.10	15.07	14.50	14.78	5.77	5.67	5.72
T_5-130% RDF + S + B	95.23	87.03	91.13	5.37	5.17	5.27	385.63	378.90	382.27	16.97	14.87	15.92	5.63	5.63	5.63
Mean	87.57	83.96		5.15	4.81		368.84	361.57		15.32	14.51		5.43	5.41	
SEm± (Interaction)	0.57			0.07			0.76			0.29			0.04		
CD (P=0.05) (Interaction)	1.71			0.20			2.28			0.87			0.11		

5. Yield

5.1 Seed yield (q ha^{-1}) and straw yield (q ha^{-1})

The maximum mean seed yield (21.74 q ha^{-1}) was registered in line sowing and minimum seed yield (19.65 q ha^{-1}) was recorded in broadcasting. The seed yield of mustard was also found to be significantly influenced by different levels of nutrients. The maximum seed yield (24.22 q ha^{-1}) was registered in plots provided with treatment T_5 (130% RDF + S @ 25 kg ha^{-1} + B @ 1.5 kg ha^{-1}). Whereas, minimum seed yield (16.12 q ha^{-1}) was registered from plots provided with application of treatment T_1 (100% RDF). A significant interaction between planting methods and nutrient management was observed with a treatment combination of line sowing with T_5 giving maximum seed yield (25.13 q ha^{-1}) which was at par with a treatment combination of line sowing + T_4 (130% RDF + B @ 1.5 kg ha^{-1}) giving seed yield of 24.72 q ha^{-1}.

Like in seed yield the maximum straw yield (30.74 q ha^{-1}) was recorded from line sowing and minimum straw yield (28.89 q ha^{-1}) was recorded from broadcasting. The maximum mean straw yield (33.23 q ha^{-1}) was registered from plots provided with treatment T_5 (130% RDF + S @ 25 kg ha^{-1} + B @ 1.5 kg ha^{-1}). While minimum straw yield (26.38 q ha^{-1}) reported in the plots provided with treatment T_1 (100% RDF). The interaction that gave maximum straw yield (34.53 q ha^{-1}) was recorded in plots applicated with treatment combination of line sowing with treatment T_5 (130% RDF + S @ 25 kg ha^{1} + B @ 1.5 kg ha^{-1}) which was significantly at par with treatment combination of line sowing + T_4 giving straw yield of 34.21 q ha^{-1}.

5.2 Biological yield (q ha^{-1}) and harvest index (%)

Line sowing produced the highest biological output (52.72 q ha^{-1}) whereas broadcasting produced the lowest biological yield (48.89 q ha^{-1}). Likewise, maximum biological yield (26.38 q ha^{-1}) was registered from plots provided with a treatment of T_5 (130% RDF + S @ 25 kg ha^{-1} + B @ 1.5 kg ha^{-1}). Whereas minimum biological yield (50.97 q ha^{-1}) was registered from plots with treatment application of T_1 (100% RDF). A significant interaction was observed with a treatment combination of line sowing + T_5 (130% RDF + S @ 25 kg ha^{-1}+ B @ 1.5 kg ha^{-1}) giving maximum biological yield i.e. 59.99 q ha^{-1} which was at par with treatment combination of line sowing + T_4 (130% RDF + B @ 1.5 kg ha^{1}) giving biological yield of 59.71 q ha^{-1}.

The maximum harvest index (41.69%) was registered from line sowing while minimum (40.00%) was recorded in broadcasting method. The harvest index of mustard was significantly influenced by different levels of nutrients. Maximum harvest index (43.82%) was registered from plots provided with treatment T_2 (130% RDF) while minimum (38.41%) was obtained from plots with treatment T_1 (100% RDF). A non-significant interaction of planting methods and levels of nutrient was observed with respect to harvest index. The results are found to be in an agreement with the findings of Rahman *et al.* (2019) [14] as they recorded an increase in the harvest index of mustard where line to line spacing of 30 cm was followed. However, least harvest index was observed in broadcasting.

Table 3: Effect of planting methods and nutrient management on yield of mustard

Nutrient management	Seed yield (q ha^{-1})			Straw yield (q ha^{-1})			Biological yield (q ha^{-1})			Harvest index (%)		
	Line sowing	Broadcasting	Mean	Line sowing	Broadcasting	Mean	Line sowing	Broadcasting	Mean	Line sowing	Broadcasting	Mean
T_1- 100% RDF	17.38	14.86	16.12	27.35	25.42	26.38	44.72	40.28	50.97	38.84	36.90	38.41
T_2-130% RDF	19.23	15.77	17.50	28.09	27.23	27.66	47.32	43.00	56.73	40.64	36.66	43.82
T_3-130% + S	22.26	21.22	21.74	29.54	27.99	28.76	51.79	49.21	55.23	42.97	43.12	42.01
T_4-130% RDF + B	24.72	23.30	24.02	34.21	31.89	33.05	59.71	55.90	58.88	44.09	41.69	41.45
T_5-130% RDF + S + B	25.13	23.31	24.22	34.53	31.94	33.23	59.99	55.99	60.82	41.89	41.63	40.98
Mean	21.74	19.65		30.74	28.89		52.71	48.89		41.69	40.00	
SEm± (Interaction)	0.17			0.20			0.23			0.90		
CD (P=0.05) (Interaction)	0.53			0.60			0.68			NS		

6. Economics

6.1 Cost of cultivation (□ha^{-1})

Data pertaining to cost of cultivation has been given in table 4. Maximum cost of cultivation (□19313.82ha^{-1}) was recorded in line sowing**.** Whereas minimum (□18713.82ha^{-1}) was recorded in broadcasting. Among levels of nutrients, maximum cost of cultivation was observed in plots with treatment T_5 (130% RDF + S @ 25 kg ha^{-1} + B @ 1.5 kg ha^{-1}) and minimum (□17911.14ha^{-}1) was observed in plots with treatment T_1 (100% RDF).

The results are in an agreement with the findings of Verma *et al.* (2018) [23] where they recorded maximum cost of cultivation under line sowing method and least under broadcasting in mustard.

In case of levels of nutrients, the results are in an agreement with the findings of Satyanarayan *et al.* (2020) [16] where they recorded highest cost of cultivation under the treatment where boron and sulphur were applied in combination in mustard. Also, Kumar *et al.* (2017) [8] recorded maximum cost of cultivation under the application of maximum doses of NPK in mustard. Changes in marginal seed yield of the crop with consecutive increases in fertilizer nutrient and relative costs of inputs in proportion to output caused such behavior of economic parameters owing to S and B levels.

6.2 Net returns (□ha^{-1})

Data pertaining to net return has been given in table 4. The maximum mean net return (□19313.82ha^{-1}) was obtained from line sowing while minimum (□83903.02ha^{-1}) was obtained from broadcasting. Among levels of nutrients, maximum net return (□105991.80ha^{-1}) was obtained from the plots with treatment T_4 (130% RDF + B @ 1.5 kg ha^{-1}). While minimum (□67340.12 ha^{-1}) was obtained from plots with treatment T_1 (100% RDF).

The results are in an agreement with the findings of Verma *et al.* (2018) [23] where they recorded maximum net return under line sowing method and least under broadcasting in mustard.

In case of levels of nutrients, the results are in an agreement with the findings of Satyanarayan *et al.* (2020) [16] where they recorded highest net returns under the treatment where boron and sulphur were applied in combination in mustard. Also, Sharma *et al.* (2020) [17] recorded higher net return when higher doses of NPK was applied as a treatment in mustard.

6.3 Gross returns (□ha^{-1})

Data pertaining to gross return has been given in table 4. Maximum mean gross return (□113682.90ha^{-1}) was obtained from line sowing method. Minimum gross return (□103094.70ha^{-1}) was recorded in broadcasting. Among levels of nutrients, maximum gross return (□125924.80ha^{-1}) was registered from plots with treatment T_5 (130% RDF + S @ 25 kg ha^{-1} + B @ 1.5 kg ha^{-1}) whereas lowest (□86178.09ha^{-1}) was observed in treatment T_1 (100% RDF).

The results are in an agreement with the findings of Verma *et al.* (2018) [23] where they recorded maximum gross return under line sowing method and least under broadcasting in mustard.

In case of levels of nutrients, the results are in an agreement with the findings of Satyanarayan *et al.* (2020) [16] where they recorded highest gross return under the treatment where boron and sulphur were applied in combination in mustard. Also, Kumar *et al.* (2017) [8] recorded maximum gross return under the application of maximum doses of NPK in mustard.

6.4 Benefit cost ratio

Data pertaining to benefit cost ratio has been given in table 4. Line sowing was found to be superior in terms of benefit cost ratio giving maximum BCR of 5.89. Minimum benefit cost ratio (5.49) was recorded in broadcasting. Likewise, maximum benefit cost ratio (6.29) was observed in plots with treatment T_5 (130% RDF + S @ 25 kg ha^{-1} + B @ 1.5 kg ha^{-1}). While minimum was obtained from plots with treatment T_1 (4.89).

The results are in an agreement with the findings of Verma *et al.* (2018) [23] where they recorded maximum BCR under line sowing method and least under broadcasting in mustard.

In case of levels of nutrients, the results are in an agreement with the findings of Satyanarayan *et al.* (2020) [16] where they recorded highest benefit cost ratio under the treatment where boron and sulphur were applied in combination in mustard.

Table 4: Effect of planting methods and nutrient management on economics of different treatments

Nutrient management	Cost of cultivation (□ ha^{-1})			Gross return (□ ha^{-1})			Net return (□ ha^{-1})			BCR		
	Line sowing	Broadcasting	Mean	Line sowing	Broadcasting	Mean	Line sowing	Broadcasting	Mean	Line sowing	Broadcasting	Mean
T_1-100% RDF	17899.64	17299.64	17911.14	93073.50	79282.66	86178.09	75083.89	59596.34	67340.12	5.20	4.58	4.89
T_2-130% RDF	19041.36	18441.36	18741.72	100655.50	83712.64	92183.91	81614.14	65268.31	73441.23	5.29	4.54	4.91
T_3-130% RDF + S	19973.36	19373.36	19673.36	115323.50	109884.50	112604	95348.14	90511.15	92929.65	5.77	5.67	5.72
T_4-130% RDF + B	19361.36	18761.36	19061.36	128694	121412.30	125053.20	109332.66	102651	105991.80	6.64	6.49	6.57
T_5-130% RDF + S + B	20293.36	19693.36	19993.36	130667.80	121181.70	125924.80	110374.50	101488.30	105931.40	6.43	6.15	6.29
Mean	19313.82	18713.82		113682.90	103094.70		94350.66	83903.02		5.87	5.49	

RDF= Recommended dose of fertilizer; S= Sulphur; B= Boron; BCR= Benefit cost ratio

7. Discussions

7.1 Growth parameters

Maximum plant height was obtained by line sowing method in plots treated with T_5 and plots with T_1 recorded minimum height. Similarly, line sowing method gave maximum branches per plant while minimum were reported in broadcasting method. Hossain *et al.* (2013) [3] recorded maximum plant height and maximum branches per plant in line sowing method and shortest plants and minimum branches were recorded in broadcasting in mustard. Oad *et al.* (2001) reported that row spacing had a substantial impact on plant height and broader spacing i.e. 60 cm row spacing was given as optimal for mustard. In case of nutrient management, Sharma *et al.* (2020b) [18] recorded tallest plants in mustard with a combination of RDF with sulphur and boron. Similar results were obtained by Kumar *et al.* (2011) [9] where they stated that application of increased doses of nitrogen and sulphur fertilizers produced taller plants in mustard as compared to other treatments.

The interaction between planting methods and levels of nutrient showed that maximum dry matter accumulation (120.56 g plant^{-1}) in plots having a treatment combination of line sowing + T_5 which was followed by broadcasting with treatment application of T_5 with 119.17 g plant^{-1}.

Rahman *et al.* (2019) [14] recorded an increase in branches plant^{-1} and maximum dry matter accumulation in mustard with a row to row spacing of 30 cm and minimum dry matter accumulation was recorded in broadcasting methods. Sharma *et al.* (2020b) [18] observed that the application of RDF with sulphur and boron gave maximum primary branches plant^{-1} and maximum dry matter accumulation in mustard. Negi *et al.* (2017) [12] also recorded an increase in number of primary branches plant^{-1} with sulphur application in mustard along with RDF. The final plant population was found to be significantly influenced by different planting methods as presented in Table 2. Better spacing and light in line sowing method helped in proper germination of seeds of mustard. With proper spacing and no competition for light space and nutrients resulted in the maintenance of plant population in line sowing method. Whereas in broadcasting uneven spacing resulted in lesser plant population. Hossain *et al.* (2013) [3] observed maximum plant population in line sowing methods in comparison to broadcasting in mustard. The results are contrary to the findings of Rahman *et al*. (2019) [14] where broadcasting proved to be the best method in maintaining plant population in mustard.

8. Yield attributes

Maximum mean length of siliqua and number of seeds per siliqua were recorded in line sowing method and minimum in broadcasting method similar to findings of Rahman *et. al.* (2019) [14], who recorded maximum length of siliqua in line sowing method with a row to row spacing of 30 cm in mustard. In case of nutrient management, Yadav *et al*. (2018) [24] observed that application of higher fertilizer dose of RDF along with sulphur had a positive influence on increasing length of siliqua of mustard. Sharma *et al.* (2020b) [18] stated an increase in the length of siliqua with the application of RDF along with sulphur and boron in their study based on mustard.

Hossain *et al.* (2013) [3] recorded highest number of siliquae plant^{-1} in line sowing and the lowest in broadcasting in mustard. The reason for this can be that line sowing method is helpful in the complete absorption of more nutrients, light and moisture than broadcasting.They also reported the number of seeds per siliqua being significantly affected by sowing method. In case of nutrient management, Sharma *et al.* (2020 a,b) [17, 18] observed that increased doses of sulphur along with boron resulted in increased number of siliquae plant^{-1} and increased number of seeds per siliquae as well. Application of increased dose of N, P and K contributes promoting yield attributing characters resulting in overall development of mustard (Jat *et al*., 2017; Sharma *et al.,* 2020a) [5, 17]. Also, increase in seeds siliqua^{-1} can be due to optimum dose of boron and sulphur which significantly increases the number of seeds siliqua^{-1} of mustard Sharma *et al.* (2020b) [18]. Nutrient requirement increases from initial to developed stages of grain filling in mustard and providing the required amount of nutrients results in good yield. Application of boron and sulphur helps in photosynthesis and their translocation to sink. The highest test weight (5.43 g) was attained by line sowing and lowest (4.41 g) was recorded in broadcasting. The results are in agreement with the findings of Hossain *et al.* (2013) [3] where they observed the maximum test weight of mustard in line sowing method and least in broadcasting.According to Masum *et al.* (2019) [10] test weight is influenced by the application of boron along with RDF. Hossain *et al.* (2012) [3] also reported increased test weight in plants sown in boron supplemented plots in comparison to those where boron treatment was not given.These results are in contradiction with the findings of Sharma *et al.* (2020b) [18] reported that application of RDF along with sulphur and boron even individually or in a combined form showed no effects on test weight of mustard.

9. Yield

The seed yield of mustard was also found to be significantly influenced by different levels of nutrients. The maximum seed yield (24.22 q ha^{-1}) was registered in plots provided with treatment T_5 (130% RDF + S @ 25 kg ha^{-1} + B @ 1.5 kg ha^{-1}). Whereas, minimum seed yield (16.12 q ha^{-1}) was registered from plots provided with application of treatment T_1 (100% RDF). Similar results were obtained for straw yield with line sowing and broadcasting method. Alam *et al.* (2015) [1] stated that sowing method has significant influence on seed yield of mustard and reported highest seed yield from line sowing method and the lowest from broadcasting method. According to Hossain *et al.* (2013) [3], line sowing is the best method for obtaining higher seed and straw yield in mustard. The results similar to findings of Singh *et al*. (2003) [20]. In case of nutrient management, the enhancement of seed yield in mustard due to the application of sulphur have also been reported by Suresh *et al*. (2002) [21] and Raut *et al*. (2003) [15]. This improvement might be due to the translocation of photosynthates leading to improvement in higher seed yield (Sharma *et al.*, 2020a) [17]. They also stated that increased straw yield is due to the translocation of photosynthates. Also, Jaiswal *et al.* (2015) [4] stated that application of RDF along with sulphur and boron was found to be increasing the dry matter accumulation and seed yield, ultimately causing an increase in the straw yield of mustard.

Hossain *et al.* (2013) [3] recorded highest biological yield in line sowing method. Also, Jaiswal *et al.* (2015) [4] stated that application of RDF along with sulphur and boron was found to be increasing the straw and seed yield ultimately causing an increase in the biological yield of mustard. Rahman *et al.* (2019) [14] recorded an increase in the harvest index of mustard where line to line spacing of 30 cm was followed. However, least harvest index was observed in broadcasting.

10. Economics

Analysis of economics factors like cost of cultivation, gross return, net return, and BCR ratio are important to evaluate the effect of the treatment from practical point of view to the farming community as well as to the planner. Line sowing was found to be superior in terms of all the economic parameters such as cost of cultivation (□19313.82ha^{-1}), gross return (□113682.90ha^{-1}), net return (□19313.82ha^{-1}) and benefit cost ratio (5.89) in comparison to broadcasting method of sowing. Among levels of nutrient maximum cost of cultivation (□ 19993.36) , gross return (□125924.80ha^{-1}) and benefit cost ratio (6.29) was recorded in treatment T_5 (130% RDF + S @ 25 kg ha^{-1} + B @ 1.5 kg ha^{-1}). Maximum net return (□105991.80ha^{-1}) was observed in treatment T_4 (130% RDF + B @ 1.5 kg ha^{-1}). The results are in an agreement with the findings of Verma *et al.* (2018) [23] where they recorded maximum cost of cultivation, net return, gross return and BCR under line sowing method and least under broadcasting in mustard. In case of levels of nutrients, the results are in an agreement with the findings of Satyanarayan *et al.* (2020) [16] where they recorded highest cost of cultivation, net return, gross return and benefit cost ratio under the treatment where boron and sulphur were applied in combination in mustard. Also, Kumar *et al.* (2017) [8] recorded maximum cost of cultivation and gross return under the application of maximum doses of NPK in mustard. Sharma *et al.* (2020a) [17] recorded higher net return when higher doses of NPK was applied as a treatment in mustard.

11. Conclusion

On the basis of the experimental findings, it may be concluded that application of recommended doses of fertilizers with optimum doses of boron and sulphur increases the growth and yield of mustard. Meanwhile the methods of planting were also found to influence the growth and yield parameters. Maximum seed yield of mustard was recorded when line sowing was followed with the application of 130% RDF + S @ 25 kg ha^{-1} + B @ 1.5 kg ha^{-1}. Maximum net return was obtained from the combination of line sowing + T_4 (130% RDF + B @ 1.5 kg ha^{-1}) treatment. . Thus, the application of RDF along with boron and sulphur in deficient areas is recommended to increase the growth and productivity of mustard along with line sowing as an appropriate method of sowing.

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13. References

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