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Influence of bio and chemical fertilizers on vegetative growth, flowering and fruiting response of black mustard (*Brassica nigra* (L.)) cv. Rohani for sustainable cropping system

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Abstract
The present investigation was carried out at Research Farm of Department of Agronomy, Monad University during *Rabi* seasons 2022-2023 and 2023-2024. In order to standardize the suitable treatment of Black mustard (*Brassica nigra* (L.)) cv. Rohani, the sources of nitrogen, phosphorus, potassium and sulphur were Urea, DAP, MOP and elemental sulphur. The rest half nitrogen was top dressed through urea at one month stage. Bio fertilizers such as RDF (Refuse-derived-fuel), Azotabactor and PSB (Phosphate solubilizing bacteria)applied in the soil as per the treatment just before sowing were replicated thrice with sixteen treatment combinations in a Split plot design (SPD). The present investigation that the present study of black mustard variety Rohani treating with bio and chemical enhanced the Vegetative growth (Plant height(cm), Numbers of primary and secondary branches per plant, Number of leaves, leaf area index (LAI), Dry matter accumulation at 30, 60, 80, 120 DAS) and Floral and Fruiting characters (Days taken to first flower, No of flowers per plants, Days taken to first fruit, Fruit length (mm), Fruit width (mm), Crop growth rate (g/plant/day) and Relative growth rate (g/plant/day)). Observed maximum plant heights (167.50, 167.23 and 167.37 cm), number of leaves per plant **(**29.91, 29.44 and 29.68),leaf area (516.91, 513.44 and 515.18 cm^2),leaf area index (0.57, 0.57 and 0.57), number of branches (6.89, 6.84 and 6.87), earliest flowering (60.94, 60.80 and 60.87 days),highest number of flowers per plants (647.94, 647.80 and 647.87) and maximum Crop Growth Rate (17.67, 14.97 and 16.32) in T_{15} (100% RDF+ Azotobacter + PSB), at 120 DAS for the years 2022-23, 2023-24 and pooled respectively. So, the amelioration of soil condition and yield potentiality can achieve by applying combination of bio and chemical fertilizers rather than only chemical fertilizers. This research elucidates the efficacy of different fertilizers' (Bio and Chemical) application on growth attributes, yield potentialand oil quality of mustard which encourages farmers to adopt the combined application of Bio and Chemical fertilizers to increase the yield and quality of crops.

Keywords: Mustard seeds, split plot design, bio-fertilizers, RDF, Azotobacter and PSB

Introduction
Agriculture continues to be the backbone of the Indian economy. After seventy five years of Indian independence, it is appropriate to look at the agricultural development process-the success achieved areas where India could have done better, the challenges it faces and the required reorientation in the development process.
India is blessed with a favourable agro-ecological condition for growth of different crops. India is considered to be a paradise of oil seed crops having 19% of the total Worlds oil seed area and 10% of the World's oil seed production, with seven edible oil seed *viz*., groundnut, rapeseed - mustard, Soybean, sunflower, sesame, niger and two non-edible sources *viz*., castor and linseed. India is the World's largest producer of castor and sesame and the second largest producer of groundnut and rape-seed mustard.
Due to a rich source of fats and vitamins, Oilseed crops are the pillar of Indian agricultural economy and occupy an important position in daily diet. Oilseeds play a vital role in Indian economy, accounting for 5% of gross national product and 10% of the value of agricultural product.

In India, oilseeds are the second largest agricultural commodity after cereals, which occupy about 13.5% of the gross cropped area in the country. India is the fourth largest oilseed producer in the world next to USA, China and Argentina. Hence; this crop plays the important role in the Indian agricultural economy after food grains with respect to area and production. The country accounts for 15 percent of global oilseeds area, 7 percent of vegetable oils production and 10 percent of the total edible oils consumption (Jha *et al.*, 2012) [2]. Rapeseed mustard is the third important oilseed crop in the world after soybean (*Glycine max*) and palm (*Elaeis guineensis* Jacq.). They occupy a distinct position after cereals constituting 13% gross cropped area of the country. They occupy an area of 27.86 M ha with 32.98 MT of production and registering the productivity level of 1004 kg ha^{-1}. Rapeseed-mustard is the third important oilseed crop in the world after soybean (*Glycine max* L. Merr.) and palm (*Elaeis guineensis* Jacq.). Among the seven edible oilseeds cultivated in India, rapeseed-mustard (*Brassica* spp.) contributes 28.6% to the total production of oilseeds. It ranks second in oilseeds production after groundnut, sharing 27.8% in the India's oilseed economy. Mustard seeds (*Brassica nigra*) nutrition value per l00 gram. Energy 508 Kcal, Carbohydrates 28.09 g, Protein 26.08 g, Total Fat 36.24 g, Cholesterol 0 mg, Dietary Fiber 12.2 g, Vitamins Folates 162 meg, Niacin 4.733 mg, Pantothenic acid 0.810 mg, Pyridoxine 0.397 mg, Riboflavin 0.261 mg, Thiamin 0.805 mg, Vitamin A 31 IU, Vitamin C 7.1 mg, Vitamin E-y 19.82 mg, Vitamin K 5.4 meg, Electrolytes Sodium 13 mg, Potassium 738 mg, Minerals Calcium 266 mg, Copper 0.645 mg, Iron 9.21 mg, Magnesium 370 mg, Manganese 2.448 mg, Selenium 208.1 meg, Zinc 6.08 mg, Phyto-nutrients Carotene-B 18 meg, Crypto-xanthin-13 0 meg, Lutein Zeaxanthin 508 meg. (USDA National Nutrient data base, 2016).

In 'Rape seed and Mustard' group of oil seeds, mustard [*Brassica juncea* (L.) Czernj. & Cosson] occupies the prime position in India. Mustard is predominantly cultivated in Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh, and Gujarat. It is also grown under some non-traditional areas of South India including Karnataka, Tamil Nadu, and Andhra Pradesh. It is cultivated both under irrigated (79.2%) and rainfed (20.8%) conditions. Black mustard accounts for about 75-80% of the 5.8 m ha of rapeseed and mustard with the productivity of 1142 kg ha^{-1} in the country. Mustard seed has 36% protein content with a high nutritive value. The oil content varies from 37 to 42%. It is a winter (*Rabi*) season crop that requires relatively cool temperature, a fair supply of soil moisture during the growing season and a dry harvest period (Banerjee *et al.*, 2010) [1]. Agronomical achievements for increasing yield, use of chemical fertilizers has badly affected the soil microflora and soil health. Excessive use of nitrogenous fertilizers has reduced the natural availability of many micronutrients which are difficult to provide chemically. Biofertilizers have potential to solubilize / mobilize major nutrients such as nitrogen and phosphorus in addition to micronutrients and thus act as nutrient flow regulator in nature. *Azotobacter* is non-symbiotic nitrogen fixing agro-microbe having potential to fix considerable quantities of atmospheric nitrogen in the rhizosphere of non-legumes. Besides nitrogen fixation, *Azotobacter* inoculation may improve the crop productivity up to 25% over the control in the absence of any amendment and by 8.75% in the presence of NPK. Phosphate solubilizing bacteria (PSB) provides alternative biotechnology solution in sustainable agriculture to meet the P demand of the plant. These organisms in addition to providing P to the plants also facilitate plant growth by different mechanism. Sulphur, now recognized as the 4th major nutrient after 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 sulphur is present in these amino acids. Sulphur improves protein and oil content in seeds and is also associated with special metabolism in plant and the structural characteristics of protoplasm. Adequate supply of sulphur has been reported to enhance photosynthetic efficiency and productivity of *Brassica* genotypes. Black mustard markedly responded to sulphur fertilization in oilseeds. The chemical fertilizers being used for supplementing the major nutrient are generally either deficient or low in sulphur content.

The chemical fertilizers give an immediate effect on crop production for small duration but creates long term ill effects on both ecosystem and soil health. Intensive use of chemical fertilizers and other chemicals has produced environmental problems and increased production costs.

On one hand chemical fertilizers alone do not provide all the nutrients in balanced quantities needed by the plants and on the other hand encourage depletion of soil organic matter content, adversely affect biological and physical properties of soil, also their increasing prices, soil health deterioration, sustainability and pollution consideration in general have led to renewed interest in the use of organic manures. The Use of organic manure not only helps to sustain crop yields but also plays a key role by exhibiting both direct as well as indirect influence on the nutrient availability in soil by improving the physical, chemical and biological properties of soil and also improves the use efficiency of applied fertilizers.

The present investigation entitled "Effect of Chemical and Bio Fertilizers on Productivity and Quality of Black mustard (*Brassica nigra* (L.)) cv. Rohani" has been carried out to assess the Vegetative growth, flowering and fruiting response of Black mustard (*Brassica nigra* (L.)) cv. Rohani to Bio and chemical fertilizers.

Materials and Methods

This study was conducted at the Research Farm, Department of Agronomy, Monad Universityfor the year 2022-2023 and 2023 - 2024.The experimental farm situated in the river basin of the Ganga. One year old healthy seeds of black mustard (*Brassica nigra* (L.)) Rohani were brought out from Indian Agricultural Research Institute (IARI), New Delhi.

Seed rate and sowing of seeds

Thinning must be done three weeks after sowing and keep only healthy seedlings. The sowing of seeds was carried out by the sowing method. There is already enough mist in the soil when mustard seeds are planted. For better mustard seed germination, plant the seeds a maximum of 6 cm deep into the soil. After the final field preparation, black mustard seeds 'Rohani' were sown at a rate of 5 kg ha^{-1} at a row distance of 40 cm. Sowing was carried out in furrows, which were opened with a harrow and covered after sowing.

Application of fertilizers and organic manure

Furrows were opened in each plot at a distance of 40 cm. Half of N and full doses of phosphorus and potassium as per treatment were applied in furrows after mixing with moist soils. The sources of nitrogen, phosphorus, potassium and sulphur were Urea, DAP, MOP and elemental sulphur, respectively. The rest half nitrogen was top dressed through urea at one month stage. Bio fertilizers such as RDF (Refuse-derived-fuel), Azotabactor and PSB (Phosphate solubilizing bacteria) were applied in the soil as per the treatment just before sowing.

Treatment combination

T_0	**Control**
T_1	50% RDF
T_2	75% RDF
T_3	100% RDF
T_4	Azotobacter
T_5	Phosphate Solubilizing bacteria (PSB)
T_6	Azotobacter +PSB
T_7	50% RDF + Azotobacter
T_8	50% RDF +PSB
T_9	50% RDF+ Azotobacter +PSB
T_{10}	75% RDF + Azotobacter
T_{11}	75% RDF +PSB
T_{12}	75% RDF+ Azotobacter +PSB
T_{13}	100% RDF + Azotobacter
T_{14}	100% RDF +PSB
T_{15}	100% RDF+ Azotobacter +PSB

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 randomly and tagged and their observation were recorded at 30, 60, 90 and 120 DAS (harvest). Yield and yield attributing character were recorded after harvest.

Vegetative characters

1. Plant height (cm) at 30, 60, 80, 120 DAS and at harvest
2. Number of leaves at 30, 60, 80, 120 DAS and at harvest
3. Leaf Area Index (LAI) at 30, 60, 80, 120 DAS and at harvest
4. Number of primary and secondary branches/plant at 30, 60, 80, 120 DAS and at harvest
5. Dry matter accumulation at 30, 60, 80, 120 DAS and at harvest

Floral and Fruiting characters

1. Days taken to first flower
2. No of flowers per plants
3. Days taken to first fruit
4. Fruit length (mm)
5. Fruit width (mm)
6. Crop growth rate (g/plant/day)
7. Relative growth rate (g/plant/day)

Statistical analysis: The observations recorded during the course of investigation were tabulated and analyzed statistically to draw a valid conclusion. The data were analyzed as per the standard procedure for "Analysis of Variance" (ANOVA).

Analysis of variance: The analysis of variance was used to test significance of F tests according to the procedure of Randomized Block Design for each character as per methodology suggested. The total variance and degree of freedom were partitioned in to three components *viz.* replications, treatments and error.

Table 1: Analysis of variance

Source of variance	Degree of freedom	Sum of square	Mean sum of square	F value	
				Calculated	Tabulated at 1% and 5%
Replication	(r-1)	SSr	MSr	MSr/MSe	*significant at 5%
Treatment	(t-1)	SSt	MSt	MSt/MSe	**significant at 1%
Error	(r-1)(t-1)	Sse	MSe		
Total	(rt-1)				

Where –
r = replication
t = treatment
SSr = replication of sum square
SSt=treatment Sum of Sqaure
SSe= Error of Sum Square
MSt=Treatment Mean Sum of Square
MSr =Replication Mean Sum of Square

The significance of treatments was tested by 'F' test (Variance ratio). Standard error of mean was computed in all cases. The difference in the treatment mean were tested by using Critical Difference (CD) at 5% level of probability where 'F' test showed significant differences among means by the following formula:

$$CD = \sqrt{\frac{2 \times error\ \ sum\ \ of\ \ square}{N}} \times t\ (error\ \ d.f.\ 5\%)$$

The results have been presented in the tabular form and depicted in figure wherever necessary.

Coefficient of Variation (CV)

Coefficient of variation was estimated by the following formula:

$$CV(\%) = \frac{\sqrt{\sigma_0^2}}{\bar{x}} \times 100$$

Where,
σ_0^2 = error variance, x = mean

Results and Discussion

Observations has been found during both year treatments on the different levels of the bio and chemical fertilizers and shown in the Tables 2A, B and 2C.

It was clearly evident from the table that there were significant differences among the treatments at 30, 60, 90 and 120 days after planting (DAS) in 1st year, 2nd year and their pooled data. Increasing growth rate was observed from 30 DAS to 120 DAS in both the years. Data presented in Table 2A revealed that the plant growth was very slow till 30th days stage and thereafter it increased at faster rates between 60th to 90th day reaching the highest at 120th, day stage (harvest stage).

According to their data significantly the maximum plant heights 167.50 cm, 167.23 cm and 167.37 cm were recorded in T_{15} (100% RDF+ Azotobacter +PSB) at 120 DAS for the years 2022-23, 2023-24 and pooled respectively and followed by 163.28 cm, 163.84 cm and 163.56 cm were recorded in T_6 (Azotobacter +PSB) at 120 DAS for the years 2022-23, 2023-24 and pooled respectively which were at par with each other. The minimum plant heights 149.12 cm, 149.87 cm and 149.62 cm were recorded in T_0 (Recommended dose of nutrients through chemical fertilizers) at 120 DAS for the years 2022-23, 2023-24 and pooled respectively followed by 154.65 cm, 154.97 cm and

154.81 cm were recorded in T_1 (50% RDF) at 120 DAS for the years 2022-23, 2023-24 and pooled respectively.

According to their data significantly the maximum number of leaves per plant29.91, 29.44 and 29.68 were recorded in T_{15} (100% RDF+ Azotobacter +PSB)) at 120 DAS for the years 2022-23, 2023-24 and pooled respectively and followed by 28.26, 27.43 and 27.85 in T_{14} (100% RDF +PSB) at 120 DAS for the years 2022-23, 2023-24 and pooled respectively which were at par with each other. The minimum number of leaves per plant20.21, 20.33 and 20.27 were recorded in T_0 (Recommended dose of nutrients through chemical fertilizers) at 120 DAS for the years 2015-16, 2016-17 and pooled respectively followed by 22.49, 21.25 and 21.87 in T_1 (50% RDF) at 120 DAS for the years 2022-23, 2023-24 and pooled respectively.

The effect of nutrition is to bring changes in the vegetative growth attributes of any crop. The number of leaves per plant of black mustard was significantly influenced by the integrated nutrient management. Azotobactor has resulted in significant improvement in the quality of agricultural produce in terms of siliqua size and colour, enhancement in yield and increased plant biomass. It has also resulted in reduction in the frequency of irrigation, reduction in the dosage of fertilizers and improvement in hydrophysical environment of soil and high benefit cost ratio. PSB Increase plant or crop yield, Enhance photosynthesis and plant metabolism, Induce the production of flower buds and flowering, Allow the production of bigger leaves, and bigger root system, Increase cell growth in roots, and used to produce thicker foliage and flowers, Production of robust plants more resistant to disease and pathogens, Increase basal branching of rosette plants, and allow more basal breaks, Improve establishment and growth of young plants produced from cuttings, seed or plugs and Used to help plants suffering nutrient and growth deficiencies.

The beneficially effect of the RDF, Azotobacter and PSB are clearly shown in T_{15} (100% RDF+ Azotobacter +PSB) and further affected in vegetative growth of plant. Apart from the reasons mentioned earlier, enhanced growth parameter like plant height per plant due to 100% RDF+ Azotobacter +PSB may also be attributed to the influence of nitrogen, the chief constituent of protein – essential for formation of protoplasm, which enhances cell division and cell enlargement. Positive effect of 100% RDF+ Azotobacter +PSB on plant growth has also been reported earlier in black mustard. The interaction effect of different fertilizer treatments on plant number of leaves per plant was found to be significant and similar finding observed.

According to their data significantly the maximum leaf area 516.91 cm^2, 513.44 cm^2 and 515.18 cm^2 were recorded in T_{15} (100% RDF+ Azotobacter +PSB) at 120 DAS for the years 2022-23, 2023-24 and pooled respectively and followed by 515.40 cm^2, 512.73 cm^2 and 514.07 cm^2 in T_6 (Azotobacter +PSB) at 120 DAS for the years 2022-23, 2023-24 and pooled respectively which were at par with each other. The minimum leaf area 412.49 cm^2, 411.25 cm^2 and 411.87 cm^2 were recorded in T_0 (Recommended dose of nutrients through chemical fertilizers) at 120 DAS for the years 2022-23, 2023-24 and pooled respectively.

The beneficially effect of the RDF, Azotobacter and PSB are clearly shown in T_{15} (100% RDF+ Azotobacter +PSB) and further affected in vegetative growth of plant. Apart from the reasons mentioned earlier, enhanced growth parameter like plant height per plant due to 100% RDF+ Azotobacter +PSB may also be attributed to the influence of nitrogen, the chief constituent of protein – essential for formation of protoplasm, which enhances cell division and cell enlargement.

According to their data significantly the maximum leaf area index 0.57, 0.57 and 0.57 were recorded in T_{15} (100% RDF+ Azotobacter +PSB) and T_6 (Azotobacter +PSB) at 120 DAS for the years 2022-23, 2023-24 and pooled respectively and followed by 0.56, 0.56 and 0.56 in T_{11} (Triacontanol (150 ppm) +Pusahydrogel (25g)) at 120 DAS for the years 2022-23, 2023-24 and pooled respectively which were at par with each other. The minimum leaf area index 0.46, 0.46 and 0.46 were recorded in T_0 (Recommended dose of nutrients through chemical fertilizers) at 120 DAS for the years 2022-23, 2023-24 and pooled respectively.

The beneficially effect of the RDF, Azotobacter and PSB are clearly shown in T_{15} (100% RDF+ Azotobacter +PSB) and further affected in vegetative growth of plant. Apart from the reasons mentioned earlier, enhanced growth parameter like plant height per plant due to 100% RDF+ Azotobacter +PSB may also be attributed to the influence of nitrogen, the chief constituent of protein – essential for formation of protoplasm, which enhances cell division and cell enlargement.

Positive effect of 100% RDF+ Azotobacter + PSBon plant growth has also been reported earlier in black mustard.

Table 2A: Effect of different treatments on vegetative growth at different level of bio and chemical fertilizers

Treatment	Plant Height (cm)			Number of leaves			Leaf Area (cm^2)			Leaf area index		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_0	149.37	149.87	149.62	20.21	20.33	20.27	412.21	418.33	415.27	0.46	0.46	0.46
T_1	154.65	154.97	154.81	22.49	21.25	21.87	412.49	411.25	411.87	0.46	0.46	0.46
T_2	158.42	158.00	158.21	23.14	23.55	23.35	463.14	468.55	465.85	0.51	0.52	0.52
T_3	161.06	161.89	161.48	23.48	24.67	24.08	483.48	481.67	482.58	0.54	0.54	0.54
T_4	156.16	156.95	156.56	22.36	23.41	22.89	452.36	454.41	453.39	0.50	0.50	0.50
T_5	162.62	162.69	162.66	24.11	24.99	24.55	484.11	484.99	484.55	0.54	0.54	0.54
T_6	163.28	163.84	163.56	26.40	26.73	26.57	515.40	512.73	514.07	0.57	0.57	0.57
T_7	156.51	156.86	156.69	24.52	23.31	23.92	454.52	445.31	445.42	0.51	0.51	0.51
T_8	159.84	159.31	159.58	25.9	25.13	25.52	476.90	465.13	471.02	0.53	0.52	0.52
T_9	161.31	161.11	161.21	26.46	26.43	26.45	496.46	493.43	494.95	0.55	0.55	0.55
T_{10}	157.04	157.51	157.28	24.42	23.33	23.88	464.42	462.33	463.38	0.52	0.51	0.51
T_{11}	160.96	160.29	160.63	27.59	26.82	27.21	487.59	484.82	486.21	0.54	0.54	0.54
T_{12}	162.81	162.69	162.75	27.67	26.97	27.32	507.67	504.97	506.32	0.56	0.56	0.56
T_{13}	161.19	159.67	160.43	26.16	26.41	26.29	476.16	463.41	469.79	0.53	0.51	0.52
T_{14}	163.12	163.57	163.35	28.26	27.43	27.85	495.26	492.43	493.85	0.55	0.55	0.55
T_{15}	167.50	167.23	167.37	29.91	29.44	29.68	516.91	513.44	515.18	0.57	0.57	0.57
CD value	2.79	2.16	2.52	2.79	2.16	2.52	2.79	2.16	2.52	2.79	2.16	2.52
F Value	7.84**	2.41**	4.37**	7.84**	2.41**	4.37**	7.84**	2.41**	4.37**	7.84**	2.41**	4.37**

The data on number of branches of black mustard as influenced by bio and chemical fertilizers (RDF, Azotobacter and PSB) is given in the Table 2B.According to their data significantly the maximum number of branches 6.89, 6.84 and 6.87 were recorded in T_{15} (100% RDF+ Azotobacter +PSB) at 120 DAS for the years 2022-23, 2023-24 and pooled respectively and followed by 6.59, 6.58 and 6.56 in T_6 (Azotobacter +PSB) at 120 DAS for the years 2022-23, 2023-24 and pooled respectively which were at par with each other. The minimum number of branches 5.01, 5.03 and 5.02 were recorded in T_0 (Recommended dose of nutrients through chemical fertilizers) at 120 DAS for the years 2022-23, 2023-24 and pooled respectively. Positive effect of 100% RDF+ Azotobacter +PSB on nuber of branches per plant has also been reported earlier in black mustard.

According to their data significantly the maximum Crop Growth Rate 17.67, 14.97 and 16.32 were recorded in T_{15} (100% RDF+ Azotobacter +PSB) at 120 DAS for the years 2022-23, 2023-24 and pooled respectively and followed by 17.59, 14.82 and 16.21 in T_{14} (Azotobacter +PSB) at 120 DAS for the years 2022-23, 2023-24 and pooled respectively which were at par with each other. The minimum Crop Growth Rate 12.21, 8.33 and 10.27 were recorded in T_0 (Recommended dose of nutrients through chemical fertilizers) at 120 DAS for the years 2022-23, 2023-24 and pooled respectively.

According to their data significantly the maximum Relative Growth Rate 0.57, 0.57 and 0.57 were recorded in T_{15} (100% RDF+ Azotobacter +PSB) and T_6 (Azotobacter +PSB) at 120 DAS for the years 2022-23, 2023-24 and pooled respectively and followed by 0.56, 0.56 and 0.56 in T_{11} (Triacontanol (150 ppm) +Pusahydrogel (25g)) at 120 DAS for the years 2022-23, 2023-24 and pooled respectively which were at par with each other. The minimum leaf area index 0.46, 0.46 and 0.46 were recorded in T_0 (Recommended dose of nutrients through chemical fertilizers) at 120 DAS for the years 2022-23, 2023-24 and pooled respectively. It was clearly evident from the Table 2B that there were significant differences among the treatments in 1st year, 2nd year and their pooled data. According to their data significantly earliest flowering 60.94 days, 60.80 days and 60.87 days were recorded in T_{15} (100% RDF, Azotobacter and PSB) for the years 2022-23, 2023-24 and pooled data respectively and followed by 61.00 days, 61.40 days and 61.20 days in T_6 (Azotobacter and PSB) for the years 2022-23, 2023-24 and pooled respectively which were at par with each other. However, maximum number of days taken for first flowering 69.27 days, 69.87 days and 69.57 days were recorded in T_0(Recommended dose of nutrients through chemical fertilizers) for the years 2022-23, 2023-24 and pooled respectively.

Table 2B: Effect of different treatments on vegetative, flowering and fruiting growth at different level of bio and chemical fertilizers

Treatment	No. of branches per plant			Crop Growth Rate			Relative Growth Rate			days taken to first flower		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_0	5.01	5.03	5.02	12.49	11.25	11.87	0.46	0.46	0.44	69.27	69.87	69.57
T_1	5.39	5.35	5.37	13.14	8.55	10.85	0.46	0.46	0.50	64.80	64.53	64.67
T_2	5.66	5.57	5.62	13.48	11.67	12.58	0.52	0.52	0.53	63.33	63.93	63.63
T_3	6.02	5.99	6.01	12.36	14.41	13.39	0.54	0.54	0.55	61.53	61.47	61.50
T_4	5.49	5.46	5.48	14.11	14.99	14.55	0.50	0.50	0.50	65.60	65.93	65.77
T_5	6.04	6.02	6.03	15.40	12.73	14.07	0.54	0.54	0.54	64.00	64.87	64.44
T_6	6.59	6.56	6.58	14.52	13.31	13.92	0.57	0.57	0.57	61.00	61.40	61.20
T_7	5.41	5.29	5.35	16.90	15.13	16.02	0.05	0.28	0.50	66.13	66.33	66.23
T_8	5.71	5.72	5.72	16.46	13.43	14.95	0.52	0.52	0.53	65.33	65.07	65.20
T_9	6.09	6.11	6.10	14.42	12.33	13.38	0.55	0.55	0.55	64.40	64.13	64.27
T_{10}	5.76	5.75	5.76	15.26	12.43	13.85	0.51	0.51	0.51	66.03	66.27	66.15
T_{11}	6.08	6.02	6.05	16.91	13.44	15.18	0.54	0.54	0.54	64.00	64.87	64.44
T_{12}	6.39	6.41	6.40	16.16	13.41	14.79	0.56	0.56	0.56	63.60	63.73	63.67
T_{13}	5.84	5.87	5.86	17.59	14.82	16.21	0.51	0.52	0.53	64.17	64.93	64.55
T_{14}	6.34	6.32	6.33	17.67	14.97	16.32	0.55	0.55	0.55	62.87	62.93	62.90
T_{15}	6.89	6.84	6.87	2.79	2.16	2.52	0.57	0.57	0.57	60.94	60.80	60.87
CD value	2.79	2.16	2.52	7.84**	2.41**	4.37**	2.79	2.16	2.52	3.13	3.14	3.12
F Value	7.84**	2.41**	4.37**	12.49	11.25	11.87	7.84**	2.41**	4.37**	11.91**	14.61**	12.35**

Table 2C: Effect of different treatments on flowering and fruiting growth at different level of bio and chemical fertilizers

Treatment	No. of flowers per plant			Number of days taken first Siliqua			Siliqua length (cm)			Siliqua width (cm)		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_0	469.27	469.87	469.57	74.27	74.87	74.57	4.48	4.49	4.49	0.27	0.27	0.27
T_1	564.80	569.53	567.17	69.80	69.53	69.67	4.69	4.67	4.68	0.30	0.29	0.30
T_2	569.33	567.93	568.63	68.33	68.93	68.63	4.81	4.79	4.80	0.33	0.31	0.32
T_3	575.00	568.47	571.74	66.53	66.47	66.24	5.09	5.04	5.07	0.34	0.33	0.34
T_4	565.60	568.93	567.27	70.60	70.93	70.77	4.75	4.75	4.75	0.30	0.31	0.31
T_5	596.00	567.87	581.94	69.00	69.87	69.44	4.88	4.85	4.87	0.33	0.32	0.33
T_6	635.53	629.40	632.47	66.00	66.40	66.20	5.11	5.10	5.11	0.35	0.34	0.35
T_7	564.13	569.33	566.73	71.13	71.33	71.23	4.76	4.72	4.74	0.30	0.30	0.30
T_8	575.33	569.07	572.20	70.33	70.07	70.20	4.86	4.83	4.85	0.32	0.33	0.33
T_9	594.40	568.13	581.27	69.40	69.13	69.27	5.06	5.01	5.04	0.33	0.33	0.33
T_{10}	566.73	555.27	561.00	71.03	71.27	71.15	4.89	4.86	4.88	0.31	0.32	0.32
T_{11}	587.00	568.87	577.94	69.00	69.87	69.44	5.04	5.08	5.06	0.33	0.33	0.33
T_{12}	615.60	618.73	617.17	68.60	68.73	68.67	5.13	5.10	5.12	0.34	0.33	0.34
T_{13}	586.27	587.93	587.10	69.17	69.93	69.55	4.96	4.99	4.98	0.31	0.32	0.32
T_{14}	617.87	614.93	616.40	67.87	67.93	67.90	5.08	5.14	5.11	0.34	0.34	0.34
T_{15}	647.94	647.80	647.87	65.94	65.80	65.87	5.21	5.20	5.21	0.35	0.36	0.36
CD value	3.13	3.14	3.12	3.13	3.14	3.12	2.79	2.16	2.52	3.13	3.14	3.12
F Value	11.91**	14.61**	12.35**	11.91**	14.61**	12.35**	7.84**	2.41**	4.37**	11.91**	14.61**	12.35**

According to their data significantly highest number of flowers per plants 647.94, 647.80 and 647.87 were recorded in T_{15} (100% RDF, Azotobacter and PSB) for the years 2022-23, 2023-24 and pooled data respectively and followed by 635.53, 629.40 and 632.47 in T_6 (Azotobacter and PSB) for the years 2022-23, 2023-24 and pooled respectively which were at par with each other. However, maximum number of days taken for first flowering 469.27, 469.87 and 469.57 were recorded in T_0(Recommended dose of nutrients through chemical fertilizers) for the years 2022-23, 2023-24 and pooled respectively Plants receiving T_{15} (100% RDF, Azotobacter and PSB) in combination had taken significantly highest number of flower in comparison to other treatment combinations. Azotobacter has resulted in significant improvement in the quality of agricultural produce in terms of siliqua size and colour, enhancement in yield and increased plant biomass. It has also resulted in reduction in the frequency of irrigation, reduction in the dosage of fertilizers and improvement in hydro physical environment of soil and high benefit cost ratio. Positive effect of RDF, Azotobacter and PSB on plant growth has also been reported earlier in black mustard.

According to their data significantly earliest siliquaing 65.94 days, 65.80 days and 65.87 days were recorded in T_{15} (100% RDF, Azotobacter and PSB) for the years 2022-23, 2023-24 and pooled data respectively and followed by 66.00 days, 66.40 days and 66.20 days in T_6 (Azotobacter and PSB) for the years 2022-23, 2023-24 and pooled respectively which were at par with each other. However, maximum number of days taken for first flowering 74.27 days, 74.87 days and 74.57 days were recorded in T_0(Recommended dose of nutrients through chemical fertilizers) for the years 2022-23, 2023-24 and pooled respectively.

According to their data significantly highest length of siliqua 5.21 cm, 5.20 cm and 5.20 cm were recorded in T_{15} (100% RDF, Azotobacter and PSB) for the years 2022-23, 2023-24 and pooled data respectively and followed by 4.12 mm, 4.18 mm and 4.15 mm in T_6 (Triacontanol Azotobacter and PSB) for the years 2022-23, 2023-24 and pooled respectively which were at par with each other. However, lowest length of siliquas 3.32 mm, 3.51 mm and 3.42 mm were recorded in T_0(Recommended dose of nutrients through chemical fertilizers) for the years 2022-23, 2023-24 and pooled respectively.

It was clearly evident from the table that there were significant differences among the treatments in 1st year, 2nd year and their pooled data. According to their data significantly highest width 3.43 mm, 3.38 mm and 3.41 mm were recorded in T_{15} (100% RDF, Azotobacter and PSB) for the years 2022-23, 2023-24 and pooled data respectively and followed by 4.12 mm, 4.18 mm and 4.15 mm in T_6 (Azotobacter and PSB) for the years 2022-23, 2023-24 and pooled respectively which were at par with each other. However, lowest length of siliquas 3.32 mm, 3.51 mm and 3.42 mm were recorded in T_0(Recommended dose of nutrients through chemical fertilizers) for the years 2022-23, 2023-24 and pooled respectively. The beneficially effect of the RDF, Azotobacter and PSB are clearly shown in T_{15} (100% RDF, Azotobacter and PSB) and further affected in vegetative growth of plant. Apart from the reasons mentioned earlier, enhanced growth parameter like plant height per plant due to Azotobacter and PSBmay also be attributed to the influence of nitrogen, the chief constituent of protein – essential for formation of protoplasm, which enhances cell division and cell enlargement.

Positive effect of RDF, Azotobacter and PSB on plant growth has also been reported earlier in black mustard.

Conclusion

The present research concluded that only the chemical fertilizer application is not influential elements for yield and quality of mustard seed. So improving soil condition and increasing yield potential by applying a combination of bio and chemical fertilizers rather than just chemical fertilizers. This study shows that black mustard variety Rohini treating with bio and chemical enhanced the Vegetative growth (Plant height(cm), Numbers of primary and secondary branches per plant, Number of leaves, leaf area index (LAI), Dry matter accumulation at 30, 60, 80, 120 DAS) and Floral and Fruiting characters (Days taken to first flower, No of flowers per plants, Days taken to first fruit, Fruit length (mm), Fruit width (mm), Crop growth rate (g/plant/day) and Relative growth rate (g/plant/day)). Observed maximum plant heights (167.50, 167.23 and 167.37 cm), number of leaves per plant **(**29.91, 29.44 and 29.68),leaf area (516.91, 513.44 and 515.18 cm^2),leaf area index (0.57, 0.57 and 0.57), number of branches (6.89, 6.84 and 6.87), earliest flowering (60.94, 60.80 and 60.87 days),highest number of flowers per plants (647.94, 647.80 and 647.87) and maximum Crop Growth Rate (17.67, 14.97 and 16.32) in T_{15} (100% RDF+ Azotobacter + PSB), at 120 DAS for the years 2022-23, 2023-24 and pooled respectively. So, the amelioration of soil condition and yield potentiality can achieve by applying combination of bio and chemical fertilizers rather than only chemical fertilizers.

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References

1. Akbari KN, Sutaria GS, Vora VD, Hirpara DS, Padmani DR. Response of oilseed crops to enriched vermicompost on Verticustochrept under rainfed conditions. An Asian J Soil Sci. 2010;5:172-174.
2. Kumar R, Sharma N, Jamwal M, Sharma RM, Parmar AM. Production and economic studies of PBRs treated strawberry cv. Sweet Charlie. J Agric Environ Sci. 2012;12(12):1543-1547.
3. Das BH, Krisha NA, Ahamad N, Atlri BL, Ranjan JK. Protected strawberry culture at high altitude temperate climate as influenced by planting time, mulching and soil moisture. Indian J Hort. 2013;70(4):506-511.
4. Lal N, Das RP, Verma LR. Effect of plant growth regulators on flowering and fruit growth of guava (*Psidium guajava* L.) cv. Allahabad Safeda. Asian J Hort. 2013;8(1):54-56.
5. Mukunda Lakshmi L, Venkata Ramana KT, Sivarama Krishna VNP, Yuvaraj KM, Naga Lakshmi T, Sarada G, *et al*. Effect of growth regulators and chemicals on fruit yield and quality of Hasta Bahar flowering in acid lime (*Citrus aurantifolia* Swingle) cv. Balaji. J Agric Allied Sci. 2014:2119-9857.
6. Benett KS, Benett CGS, dos Santos GG, Costa E. Effects of hydrogel and nitrogen fertilization on the production of arugula in successive crops. Afr. J Agric. Res. 2015;10(26):2601-2607.
7. Singh AK, Singh SK, Pandey A, Rajan K, Sharma V, Sharma BL, *et al*. Studies on impact of sulphur with and without FYM on yield, uptake and methionine content in mustard. Int. J Curr Microbiol Appl. Sci.; c2018. p. 723-731.
8. Potdar AM, Narayan DG, Kengond S, Mulla MM.

Performance evaluation of docker container and virtual machine. Procedia Comput Sci. 2020;171:1419-1428.
9. Vijayeswarudu CY, Singh R, Khan W. Effect of biofertilizers and Sulphur on yield, yield attributes and economics of yellow mustard (Sinapisalba). Pharma Innov J. 2021;10(9):321-323.
10. Cahigas MM, Prasetyo YT, Persada SF, Nadlifatin R. Examining Filipinos' intention to revisit Siargao after Super Typhoon Rai 2021 (Odette): An extension of the theory of planned behavior approach. International Journal of Disaster Risk Reduction. 2023 Jan 1;84:103455.