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Effect of Liquid Biofertilizer and Variable Source of Nutrients on Growth and Yield of Indian Mustard (*Brassica juncea L.*) in Western U.P., India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted during *Rabi* season of 2021-22 at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.). The experiment consisted of twenty treatment combinations with variable source of nutrients and biofertilizer. The treatment consisted of four sources of nutrients and five Biofertilizer levels were tested in RCBD (Factorial) with three replications. Results revealed that the application of 75% RDF (NPKS 90:45:45:30 kg/ha) +2-ton Vermicompost ha^{-1} gave higher plant height (203.55 cm), LAI (2.929), branches $plant^{-1}$, dry matter accumulation (66.65 g $plant^{-1}$), and seed (1854), stover (7193) & biological (9047) yield (kg ha^{-1}) of mustard crop. Similarly, application of Azotobacter + PSB + KMB + Zn SB each @20 ml kg^{-1} seed treatment gave higher plant height (201.46 cm), LAI (2.702), branches $plant^{-1}$, dry matter accumulation (64.98 g $plant^{-1}$), and seed (1735), stover (6888) & biological (8623) yield (kg ha^{-1}) of mustard crop. Thus, it may be concluded that the application of 75% RDF (NPKS 90:45:45:30kg/ha) + 2-ton Vermicompost/ha +Biofertilizers *(*Azotobacter + PSB + KMB + ZnSB each @ 20 ml/kg Seed treatment) found economical in obtaining higher growth and yield of mustard.

Keywords: Liquid biofertilizer; NPKS; PSB; KMB; seed treatment.

1. INTRODUCTION

Rapeseed and Mustard are the major *rabi* oilseed crops of India. Indian mustard [*Brassica juncea (L.) Czern & Coss*] is commonly known as *rai.* Crop is grown under a wide range of agro-climatic conditions. During the growing season, it requires somewhat cool temperatures with a good supply of soil moisture and a dry harvest period. Mustard is typically grown in temperate areas. It is also grown as a cold season crop in select tropical and subtropical climates. Indian mustard is an important oilseed crop in the world. Rapeseed and mustard are members of the genus Brassica and the family Brassicaceae. This plant is grown for vegetable, oil, fodder, condiment, and green manure. With the passage of time, this crop has evolved into one of the most important suppliers of vegetable oil. Vegetable oils are a high-value agricultural commodity. Globally, the total area under Rapseed-Mustard crop is 35.95 Mha with 71.49 MT production and 1990 kg/ha productivity. However, India continues to be rank 2nd after Canada in acreage 6.86 Mha (19.81%) and rank 4th after Canada, European Union and China in production 9.12 MT (10.37%) with productivity 1331 kg/ha. Rapseed-Mustard crop in india are grown in diverse agro climatic conditions. In india, Rajasthan have rank 1st with 2.84 Mha (41.44%) area and 4.10 MT (45.03%) production. Uttar Pradesh contributed 0.77 Mha (11.29 %) to the total area and 0.98 MT (10.79 %) to the production with 1090 kg/ha productivity [1]. “It is the most important edible oil seed crops of India next to groundnut and soybean. India has 12-15% of the world’s area under oilseed but account for less than 6-7 % of world’s production to meet the need of about 16% of world population” [2].

“The oil content of Indian mustard varies between 30 to 49%. The seed and oil are used as condiment and for flavouring various food items such as curries and pickles. The oil is utilized for human consumption throughout the Northern India, in cooking and frying purposes. The oilcake is used as feed and manure. It is also used as vegetable where the fresh leaves of young plants serve as a good source of Sulphur and minerals in the human diet. Population of India is increasing rapidly and consequently edible oil demand is also going up day by day. Hence, it has become necessary to enhance the present production by developing superior varieties of Indian mustard. Indian mustard requires optimum weather conditions for its good growth and development. Since, it is mostly grown after the harvest of long duration varieties of rice and late recession of moisture from rice fields in Uttar Pradesh. The sowing of mustard crop gets delayed and the growth and vigour of mustard is not good as timely sown crop. It is important to increase the productivity of Indian mustard, which still has a greater scope to exploit the yield potential of existing cultivars with agronomic manipulations. Among the various agronomic factors that are known to augment crop production, fertilizer and nutrient management play a significant role. The efficiency of fertilizer nitrogen is only 40-50%, phosphorous 15-20% and Sulphur 10-12% in Indian soils and this could be enhanced by efficient use of inputs” [3].

For sustainable crop production, integrative effect of organic, inorganic and bio-fertilizers is important. Biofertilizers and organic manures play a significant role in sustainable agriculture. Bio-fertilizer contains selective strains of nitrogen fixing bacteria, PSB, and potash mobilizing Bacteria which helps to improve availability of NPK to crops. It mobilizes & converts insoluble plant nutrients to soluble and makes it available to plants. Farmyard manure with rich organic matter can be supplemented with N, P & K fertilizers. FYM improves soil structure through binding effect on soil aggregates, cation exchange capacity and water holding capacity, fertilizer use efficiency, microbial activity and nutrient availability in soil besides supplying the essential plant nutrients. There is a great scope for increasing the production of Indian mustard by bringing more area under cultivation and increasing its productivity by applying organic manures (FYM) & liquid biofertilizers (Azotobacter, PSB, KMB, ZnSB) with balanced fertilization (N:P:K:S) and maintaining soil fertility status. Though some information about mustard nutrition is available but the role of nutrient use efficiency on effecting the productivity of crop under the influence of different organic, inorganic nutrients and biofertilizers needs to be worked out. The suitable treatment of different nutrient with appropriate dosages is to be worked out to understand nutrient uptake, availability and achieve maximum yield.

2. MATERIALS AND METHODS

The experiment was carried out at Crop Research Centre, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.) located in Indo – Gangetic plains of Western Uttar Pradesh at 29 13' 96" N latitude and University is situated at 77 68' 43" E longitude with an elevation of 228 metres above the mean sea level. Meerut lies on national highway 58 and is at a distance of 70 km from Delhi. The climate of this region is subtropical and semi-arid climate characterized with hot summers and extremely cold winters. The normal period for of onset of the monsoon in this region is third week of June and, it lasts up to end of September or sometimes extends to the first week of October. The average annual rainfall is about 1073 mm and out of which about 80 percent is received by south-west monsoon while annual potential evapo-transpiration is about 1667 mm. Thus, the area falls under soil moisture deficit. The rainfall during the experimental period was recorded from the Meteorological observatory of the IIFSR, Modipuram, Meerut. The temperature begins to rise from the month of February and reaches its maximum in March month, minimum and maximum temperature ranged between (4.7 ^{0}C to 38.70 ^{0}C), respectively, whereas minimum and maximum relative humidity ranged between 28.4 % and 92.6 % percent during crop period. Mean weekly temperature, relative humidity, sunshine hours, evaporation and rainfall as recorded at nearby located meteorological observatory of Indian Institute of Farming Systems Research, Meerut.

The experiment consisted of twenty treatment combinations with variable source of nutrients and biofertilizer. The treatment consisted of four sources of nutrients i.e., Control, 100% RDF (NPKS 120:60:60:40 kg/ha), 75% RDF (NPKS 90:45:45:30 kg/ha) + 6-ton FYM/ha and 75% RDF (NPKS 90:45:45:30 kg/ha) + 2-ton Vermicompost/ha and five Biofertilizer levels i.e., No biofertilizers, Azotobacter @20 ml/kg seed treatment, Azotobacter + PSB each @20 ml/kg seed treatment), Azotobacter + PSB + KMB each @20 ml/kg seed treatment, Azotobacter + PSB + KMB + ZnSB each @20 ml/kg seed treatment were tested in RCBD (Factorial) with three replications. The mustard variety Pusa Vijay (NPJ-93) was grown and growth & yield, nutrient uptake, soil properties as influenced by different treatments were assessed. The height of the mustard plant was measured from the base to the top of the plant at harvesting, with the help of meter scale. The mean of plant height was worked out on the basis of total height of five randomly selected plants in each plot which was divided by the number of plants. Number of primary and secondary branches per plant were counted from five plants selected randomly at harvest and their mean value was taken. Five plants were randomly selected from border rows at harvest stage and after sun drying, materials were dried in oven (65 °C) till the constant weight was attained. The average value obtained was recorded as the dry matter of the plant (g/plant). The samples collected for dry matter estimation, leaves of five plants was packed at 90 DAS and leaf area was measured with the help of leaf area meter.

$$\text{LAI} = \frac{\textbf{Leaf area (cm)}}{\textbf{Land area (cm)}}$$

Mean crop growth rate of a plant for a time "t" is defined us the increase in dry weight of plant material from a unit area per unit of time.

$$\text{CGR (g/m}^2\text{/day)} = \frac{W2-W1}{T2-T1} \times \frac{1}{A}$$

W_1 = Total dry weight of plant at time t_1
W_2= Total dry weight of plant at time t_2
t_1=Time at first observation
t_2=Time at second observation
A= ground area (m^2)

From the individual plot, the net plot area was harvested separately and produce was sun dried. After sun drying, the crop was threshed and produce cleaned. The final weight was recorded in kg $plot^{-1}$ and finally converted into kg ha^{-1}. Stover yield of mustard was calculated with subtraction of seed yield from biological yield and reported in kg ha^{-1}. After 3-4 days sun drying, all above the ground plant parts of the net plot were dried and weighed in kg $plot^{-1}$ to represent the biological yield and finally converted into kg ha^{-1}. The harvest index will be computed by calculate the harvest index.

$$\text{H.I (\%)} = \frac{\text{Economic yield (kg/ha)}}{\text{Biological yield (kg/ha)}} \times 100$$

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

Perusal of data given in Table 1 Showed that Plant height was significantly influence by the application of liquid biofertilizer and variable source of nutrients at harvest. In case of variable source of nutrients, treatment N_4 (75% NPKS + 2-ton VC ha^{-1}) recorded highest plant height (203.55 cm) as compared to other source of nutrients. However, the lowest plant height was recorded under N_1 (Control) at harvest. These results are in conformity with the findings of Shivendu et al. (2019). Similarly, it was indicated from the data in the table that plant height also differs with application of different biofertilizers. Amongst, all the treatments, application of B_5 treatment (Azotobacter + PSB + KMB + Zn SB each @ 20 ml/kg ST) recorded superior plant height (201.40 cm) at harvest. The lowest plant height was recorded under the treatment B_1 (No biofertilizers) at harvest. However, the non-significant effect was found in respect to biofertilizer treatments at harvest. These results are in conformity with the findings of Krishna et al. [4] in mustard and Dhaka et al. [5] in raya. Number of branches increased with advancement of crop age and reached maximum at harvest. The number of primary and secondary branches at different stages was influenced by the application of liquid biofertilizer and variable source of nutrients. The treatment, N_4 (75% NPKS + 2-ton VC ha^{-1}) recorded significantly higher number of primary branches $plant^{-1}$ (5.87) at harvest. The lowest primary branches $plant^{-1}$ were observed in N_1 (Control). Similar findings were also reported by Kansotia et al. [6]. Data indicated that number of primary branches also significantly influenced by different treatments of biofertilizers. Amongst the treatments, the B_5 treatment (Azotobacter + PSB + KMB + Zn SB each @ 20 ml/kg ST) recorded higher number of primary branches $plant^{-1}$(5.82), which was significantly superior then remaining treatments of biofertilizers. However, the significantly lowest number of primary branches were recorded under B_1 treatment (No biofertilizer). Similar findings were also reported by Singh et al. [7]. The treatment, N_4 (75% NPKS + 2-ton VC ha^{-1}) recorded significantly higher number of secondary branches $plant^{-1}$ (13.20) at harvest stage, respectively. which was statistically at par with N_2 (100% NPKS @ (120:60:60:40) kg ha^{-1}) at harvest. However, The lowest number of secondary branches $plant^{-1}$recorded with N_1 (Control). Similar findings were also reported by Thakur et al., [8]. Data indicated that number of secondary branches also influenced by different treatments of biofertilizers. Amongst the treatments, the B_5 treatment (Azotobacter + PSB + KMB + Zn SB each @ 20 ml/kg ST) recorded higher number of secondary branches $plant^{-1}$ (12.96), at harvest stage and the lowest number of secondary branches were recorded under B_1 (No biofertilizer). However, the non-significant effect in respect to number of secondary branches under the different treatment of biofertilizer. These findings are conformed with the findings of Sahoo et al., [9]. plant dry weight was significantly influenced by the application of liquid biofertilizer and variable source of nutrients. Amongst variable source of nutrients, the treatment N_4 (75% NPKS + 2-ton VC ha^{-1}) recorded the significantly higher plant dry weight (66.65 g $plant^{-1}$) at harvest, as compared to other source of nutrients. However, the significantly lowest dry matter accumulation was noticed in N_1 (Control) treatment. Similar results were also reported by Meena et al., [10] and Thakur et al., [8]. Plant dry weight significantly varied with the treatments of different biofertilizer. Amongst all the treatments, the B_5 treatment (Azotobacter + PSB + KMB + Zn SB each @ 20 ml/kg ST) recorded significantly higher dry matter accumulation (64.98 g $plant^{-1}$) at harvest. which was statistically at par with B_4 (Azotobacter + PSB + KMB each @20 ml/kg ST) at 30 DAS and at harvest. However, the significantly lowest plant dry weight was found under treatment B_1 (No biofertilizer). These results were in agreement with the findings of Singh and Singh [11]. Maximum LAI (2.929) was recorded with the application of N_4 (75% NPKS + 2-ton VC ha^{-1}) at 90 DAS, which was significantly superior than rest of the source of nutrients. However, minimum LAI was recorded under N_1 (Control) at harvest. Similar findings were also reported by Kashved et al*.,* [12] and Krishna et al., [4]. Similarly, application of B_5 (Azotobacter + PSB + KMB + Zn SB each @ 20 ml/kg ST) recorded significantly higher (2.702) leaf area index than B1. The lowest leaf area index was recorded under B_1 (No biofertilizers). Similar findings were also reported by Krishna et al., [4]. The maximum Crop growth rate (4.903 g m^{-2} day) was recorded in the application of N_4 (75% NPKS + 2-ton VC ha^{-1}) at harvest. However, the minimum crop growth rate was recorded under N_1 (Control). Similar findings were also reported by [13,14]. Similarly, in case of biofertilizers, the application of B_5 (Azotobacter + PSB + KMB + Zn SB each @ 20 ml/kg ST) recorded significantly higher Crop growth rate (4.563 g m^{-2} day) at harvest as compare to B1. While the lower Crop growth rate was recorded under B_1 (No biofertilizers). Similar findings were also reported by Saikia et al., [15].

Perusal of data given in Table 2 Showed that seed yield of mustard influenced significantly with the application of variable source of nutrients. The significant highest value of seed yield (1854 kg ha^{-1}) was recorded under the treatment N_4 (75% NPKS + 2-ton VC ha^{-1}) followed by N_3 (75% NPKS + 6-ton FYM ha^{-1}) and lowest (632 *kg ha^{-1})* in control treatment. Similar results were also reported by Kansotia et al*.* [6] and Singh et al*.* [7]. Similarly, with the application of different biofertilizer influenced significantly in the seed yield of mustard. The highest seed yield (1735 kg ha^{-1}) recorded under the treatment B_5 (Azotobacter + PSB + KMB + Zn SB each @ 20 ml/kg ST) which was followed by B_4 (Azotobacter + PSB + KMB each @20 ml/kg ST) and the lowest seed yield (1123 kg ha^{-1}) was recorded under the treatment B_1 (No biofertilizer). These results are confirmed with the findings of Kumar et al., [16] and Singh and Singh [11]. The significant highest value of stover yield (7193 kg ha^{-1}) was recorded under the treatment N_4 (75% NPKS + 2-ton VC ha^{-1}) followed by N_3 (75% NPKS + 6-ton FYM ha^{-1}) and lowest (4242 kg ha^{-1}) in control treatment [13,14]. Similarly, with the application of different biofertilizer influenced significantly in the stover yield of mustard. The highest stover yield (6888 kg ha^{-1}) under the treatment B_5 (Azotobacter + PSB + KMB + Zn SB each @ 20 ml/kg ST) followed by B_4 (Azotobacter + PSB + KMB each @20 ml/kg ST) and the lowest stover yield (5136 kg ha^{-1}) was recorded under the treatment B_1 (No biofertilizer). The results are in close conformity with the findings of Krishna et al*.,* [4] and Kumar et al*.,* [17]. The biological yield of mustard significantly influenced with the application of variable source of nutrients. The significant highest value of biological yield (9047 kg ha^{-1}) was recorded under the treatment N_4 (75% NPKS + 2-ton VC ha^{-1}) followed by N_3 (75% NPKS + 6-ton FYM ha^{-1}) and lowest (4875 kg ha^{-1}) in control treatment. Similar results were also reported by Kansotia et al*.* [6] and Singh et al*.* [7]. Similarly, with the application of different biofertilizer influenced significantly in the biological yield of mustard. The highest biological yield (8623 kg ha^{-1}) under the treatment B_5 (Azotobacter + PSB + KMB + Zn SB each @ 20 ml/kg ST) followed by B_4 (Azotobacter + PSB + KMB each @20 ml/kg ST) and the lowest biological yield (6260 kg ha^{-1}) was recorded under the treatment B_1 (No biofertilizer). The results are in close conformity with the findings of Krishna et al*.,* [4] and Kumar et al*.,* [17]. From the table it is clear that in comparison to N_1 control, the significantly higher value of harvest index (20.48) was observed by the application of N_4 (75% NPKS + 2-ton VC ha^{-1}), which is statistically at par with the treatment N_3 (75% NPKS + 6-ton FYM ha^{-1}). The lowest value of harvest index (12.97) was noticed in N_1 (Control) [18,19]. Similar results were also reported by Tripathi et al*.*, [14]. Application of different biofertilizer influenced in harvest index of mustard. The significantly higher value of harvest index (19.45) recorded under the treatment B_5 (Azotobacter + PSB + KMB + Zn SB each @ 20 ml/kg ST) followed by B_4 (Azotobacter + PSB + KMB each @20 ml/kg ST) and the lowest value of harvest index (17.43) was recorded under the treatment B_1 (No biofertilizer). The results are in close conformity with the findings of Kumar et al*.,* [17].

Table 1. Effect of liquid biofertilizers and variables source of nutrients on the growth parameters of mustard at harvest stage

Treatments		Plant height (cm)	Primary branches plant^{-1}	Secondary branches plant^{-1}	Dry matter accumulation (g plant^{-1})	Leaf area index	Crop Growth Rate (g m^{-2} day^{-1})
Factor A (Source of nutrients)							
N_1	Control	186.32	5.20	12.26	56.40	2.383	3.858
N_2	100% NPKS @ (120:60:60:40) Kg ha^{-1}.	197.43	5.54	12.90	62.22	2.466	4.783
N_3	75% NPKS + 6 ton FYM ha^{-1}.	202.46	5.72	12.78	64.36	2.689	4.593
N_4	75% NPKS + 2 ton VC ha^{-1}.	203.55	5.87	13.20	66.65	2.929	4.903
SEm ±		**2.23**	**0.07**	**0.09**	**0.70**	**0.077**	**0.273**
CD (P= 0.05)		**6.41**	**0.20**	**0.25**	**2.02**	**0.221**	**0.784**
Factor B (Biofertilizers)							
B_1	No biofertilizers	193.91	5.50	12.56	59.76	2.587	4.416
B_2	Azotobacter @ 20 ml/kg ST	195.37	5.54	12.80	61.32	2.622	4.498
B_3	Azotobacter + PSB each @ 20 ml/kg ST	197.26	5.46	12.70	62.32	2.574	4.518
B_4	Azotobacter + PSB + KMB each @20 ml/kg ST	199.25	5.60	12.89	63.65	2.598	4.676
B_5	Azotobacter + PSB + KMB + Zn SB each @ 20 ml/kg ST	201.40	5.82	12.96	64.98	2.702	4.563
SEm ±		**2.39**	**0.07**	**0.10**	**0.78**	**0.036**	**0.04**
CD (P= 0.05)		**6.90**	**0.22**	**0.30**	**2.26**	**0.091**	**0.12**

ST: Seed treatment, PSB: Phosphorus solubilizing bacteria, VC: Vermi-compost, KMB: Potassium mobilizing bacteria, Zn SB: Zinc solubilizing bacteria

Table 2. Effect of liquid biofertilizers and variables source of nutrients on seed, stover, biological yield (kg ha^{-1}) and Harvest index of mustard

Treatment		Yield (kg ha^{-1})			
		Seed	**Stover**	**Biological**	**H.I (%)**
Factor A (Source of nutrients)					
N_1	Control	632	4242	4875	12.97
N_2	100% NPKS @ (120:60:60:40) Kg ha^{-1}.	1363	5901	7264	18.71
N_3	75% NPKS + 6 ton FYM ha^{-1}.	1743	6740	8483	20.48
N_4	75% NPKS + 2 ton VC ha^{-1}.	1854	7193	9047	20.39
SEm ±		**8.13**	**47.10**	**45.84**	**0.17**
CD (P= 0.05)		**23.36**	**135.35**	**131.74**	**0.50**
Factor B (Biofertilizers)					
B_1	No biofertilizers	1123	5136	6260	17.43
B_2	Azotobacter @ 20 ml/kg ST	1250	5613	6863	17.61
B_3	Azotobacter + PSB each @ 20 ml/kg ST	1388	6072	7460	17.90
B_4	Azotobacter + PSB + KMB each @20 ml/kg ST	1496	6387	7883	18.28
B_5	Azotobacter + PSB + KMB + Zn SB each @ 20 ml/kg ST	1735	6888	8623	19.45
SEm ±		**9.08**	**52.66**	**51.25**	**0.19**
CD (P= 0.05)		**26.12**	**151.35**	**147.29**	**0.56**

ST: Seed treatment, PSB: Phosphorus solubilizing bacteria, VC: Vermi-compost, KMB: Potassium mobilizing bacteria, Zn SB: Zinc solubilizing bacteria

4. CONCLUSION

Thus, the application of 75% NPKS (90:45:45:30) + 2-ton VC ha^{-1}) + B_5 (Azotobacter + PSB + KMB + Zn SB each @ 20 ml/kg Seed treatment) seems to best option for maximum plant growth and higher yield under western UP. The study is to be continuing for few more years to draw definite conclusion for application of liquid biofertilizers and variable source of nutrients in mustard.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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