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GROWTH ATTRIBUTES, YIELD AND YIELD ATTRIBUTES AFFECTED BY ORGANIC BIOFERTILIZERS AND DIFFERENT GROWTH REGULATORS OF INDIAN MUSTARD (*BRASSICA JUNCEA* L.) FOR SUSTAINABLE AGRICULTURE

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ABSTRACT

A field experiment was conducted during 2019–20 and 2020-21 at Crop Research Farm at Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj, Uttar Pradesh, India. Sixteen treatments, comprising biofertilizer *viz.*, Azotobacter (B_1) Phosphate Solubilizing Bacteria + Azotobacter (B_2), Vesicular Arbuscular Mycorrhiza + Azotobacter (B_3) and Phosphate Solubilizing Bacteria + Vesicular Arbuscular Mycorrhiza + Azotobacter (B_4), growth regulators *viz.*, Water Spray(G_0), Gibberellic acid 50 ppm (0.05 g/l) (G_1), Salicyclic acid 100 ppm (0.01 g/l) (G_2) and Indole acetic acid 50 ppm (0.05 g/l) (G_3) and were replicated 3 times in split plot design. Growth attributes *viz.*, leaf area (269.172 and 266.250 at 80 DAS during 2019-20) and (267.213 and 266.496 at harvest during 2020-21) and Leaf Area Index (LAI)(0.897 and 0.888 at 80 DAS during 2019-20) and (0.891 and 0.888 at harvest during 2020-21) under the treatment (B_4) Phosphate Solubilizing Bacteria + Vesicular Arbuscular Mycorrhiza + Azotobacter, respectively. Crop yield *viz.*, seed yield (1.943 and 2.034 t/ha) and stover yield (6.747 and 6.964) significantly higher were recorded during the years 2019-20 and 2020-21 in treatment combination B_4 (PSB + VAM +Azotobacter), respectively. Growth regulators recorded the higher seed yield (1.842 and 1.978 t/ha) and stover yield (6.768 and 6.954 t/ha) during the years 2019-20 and 2020-21, respectively in the treatment G_1 [Gibberellic acid 50 ppm (0.05 g/l)]. Growth attributes *viz.*, leaf area (257.589 and 256.500 at 80 DAS during 2019-20) and (258.991 and 256.922 at harvest during 2020-21) and LAI (0.859 and 0.855 at 80 DAS during 2019-20) and (0.863 and 0.856 at harvest during 2020-21) under the treatment G_1 [Gibberellic acid 50 ppm (0.05 g/l)], respectively.

KEY WORDS: Gibberellic acid, Biofertilizer, Growth regulators, Growth attributes and leaf area

INTRODUCTION

Indian mustard (*Brassica juncea* L.) is predominantly cultivated in Rajasthan, UP, Haryana, Madhya Pradesh and Gujarat. The recent research findings indicate the use of bio-regulators for increasing productivity (Hayat and Ahmad, 2007).

In view of the escalating price of fertilizers and its ill effects on soil health, there is a need to focus on integrated nutrient supply system that may improve crop production with reduced cost of cultivation. Biofertilizers are reported to enhance the yield of Indian mustard, which is mainly attributed to better N nutrition through N_2 - fixation, enhancement of nutrient availability and uptake and production of growth hormones such as indol acetic acid, gibberellins etc. (Kalita *et al.,* 2019).

These bio -regulators acts as chemical catalyst in the plant and improve physiology and reproductive efficiency in the plant. These bio-regulators possibly improve the sucrose transport and increase dry matter partitioning for grain production. Thiourea and thioglycollic acid are such sulphydral bio-regulators. In arid areas, despite constraints imposed by lack of water and high temperatures, the crop plants mostly survive in average rainfall years (Hussain *et al.,* 2010).

In view of the above, it is conceivable to assume that if antioxidants are sprayed onto the crop plants, most of the damaging free radicals can be quenched and the crop plants can be able to maintain an improved metabolic energy status, which will then facilitate translocation and partitioning of assimilates for yield formation. Since sulphydryl compounds are strong antioxidants and also supply reactive sulphydryl group for the functioning of sucrose transport protein, they can more effectively improve assimilate partitioning and yield of crops under arid environment (Sharma *et al.*, 2005). Keeping in view the present investigation was conducted to role of biofertilizer and growth regulators on production of Indian mustard (*Brassica juncea* L.).

MATERIALS AND METHODS

The field experiment was conducted on the crop Indian mustard during the *rabi* season 2019-20 and 2020-21 at Crop Research Farm, SHUATS, Department of Agronomy, Naini Agricultural Institute, Prayagraj, Uttar Pradesh, India. The experimental site has sub humid climate and is located at 25^0 39 42" N latitude, $81^0$6756" E longitude and 98 m altitude above the mean sea level (MSL). This area is situated on the right side of the Yamuna River.

The experiment consisted of two factors, biofertilizers and growth regulators with water spray, there were 16 treatments each being replicated thrice and laid down in Split Plot Design with three replications. The data of two years were pooled and statistically analysed using analysis of variance (ANOVA) for Split Plot Design. The experimental data were analyzed statistically by applying the technique of analysis of variance prescribed for the design to test and conclusions were drawn at 5% probability levels. Days to maturity were recorded by counting the days from sowing to the date when 100% plants maturity in each subplot. The aboveground harvested crop biomass from each plot was tied in bundles, tagged, sun-dried and then weighed to have total biological yield. The crop was threshed treatment-wise with the help of the mini thresher and grain yield was recorded. The siliquae harvested from the net plot were weighted and expressed in t ha^{-1}. Stover yieldafter harvesting of siliquae, the left-over plants were harvested to the base from net plot was weighed and expressed in t ha^{-1}.

The leaf area of the plants was measured using leaf area meter and was used for calculating leaf area index (LAI) as per standard method.

The leaf index was calculated using the formula given by Watson (1947). LAI: Leaf area/land area

RESULTS AND DISCUSSION

Growth attributes

Based on the both year data (Table 1) of experiment significantly the highest leaf area (269.172 and 267.213cm^2 per plant at 80 DAS) and (266.250 and 266.496 cm^2 per plant at harvest) and leaf area index (0.897 and 0.891) (0.888 and 0.888) during both the year, respectively were recorded organic fertilized by biofertilizer treatment combination B_4 (PSB + VAM + Azotobacter) Days to maturity and days of 50 % flowering stage were recorded non-significant during first year crop fertilized by biofertilizers, respectively. Significantly maximum days of maturity and 50% flowering of days (134.79 and 58.917) was recorded during second year in treatment B_4 and growth regulators treatment G_1 significantly more day's requirement (131.97 and 133.55) and 50% flowering of days (56.250 and 57.917) during both the year, respectively. The LAI value showed a decreasing trend in all the treatments at the initial stage of development but gradually increased at the time of crop maturity, which might be due to stimulating effect of combined application of biofertilizer which improved the nutrient availability and their uptake. Our results are therefore consistent with the observations of Gorttappeh *et al.* (2000).

Significant and maximum leaf area (257.589 and 258.991cm^2 per plant at 80 DAS and 256.500 and 256.922cm^2 per plant at harvest) and leaf area index (0.859 and 0.863 at 80 DAS and 0.855 and 0.856 at harvest) during both the year, respectively were recorded treatment growth regulators G_1 [Gibberellic acid 50 ppm (0.05 g/l)]. This might be due to the adequate soil moisture increase the availability of the nutrient in the soil for the plant to increase in growth parameters by cell elongation

Table 1. Growth attributes affected by biofertilizer and growth regulators of Indian mustard (*Brassica juncea* L.)

Treatments	Days to maturity		50 % flowering stage (Days)		Leaf area cm² per plant				Leaf area index			
					80 DAS		At harvest		80 DAS		At harvest	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
Biofertilizer												
B_1: Azotobacter	129.56	131.37 b	51.167	54.583 b	237.857 d	237.710 d	235.917 d	237.081 d	0.793 d	0.792 d	0.786 c	0.790 d
B_2: PSB + Azotobacter	130.72	131.82 b	54.583	58.250 a	256.987 b	259.549 b	256.333 b	257.719 b	0.857 b	0.865 b	0.854 b	0.859 b
B_3: VAM + Azotobacter	128.30	130.72 c	52.650	53.150 b	253.969 c	253.330 c	251.667 c	252.644 c	0.847 c	0.844 c	0.839 b	0.842 c
B_4: PSB + VAM + Azotobacter	132.81	134.79 a	58.417	58.917 a	269.172 a	267.213 a	266.250 a	266.496 a	0.897 a	0.891 a	0.888 a	0.888 a
F-test	NS	S	NS	S	S	S	S	S	S	S	S	S
SEm±	0.67	0.28	1.128	0.795	0.419	1.472	2.113	0.298	0.001	0.005	0.007	0.001
CD (P = 0.05)	2.31	0.95	3.902	2.751	1.450	5.094	7.310	1.030	0.005	0.017	0.024	0.003
CV (%)	0.94	0.45	3.828	3.531	0.303	1.537	1.539	0.255	0.303	0.239	1.539	0.048
Growth Regulators												
G_0: Water Spray	125.98 b	128.51 b	50.900 c	52.817 c	248.487 b	246.383 b	242.833 a	246.231 c	0.828 b	0.821 b	0.809 b	0.821 c
G_1: Gibberellic acid 50 ppm (0.05 g/L)	131.97 a	133.55 a	56.250 a	57.917 a	257.589 a	258.991 a	256.500 a	256.922 a	0.859 a	0.863 a	0.855 a	0.856 a
G_2: Salicyclic acid 100 ppm (0.01 g/L)	131.96 a	133.32 a	54.167 b	56.667 b	254.904 a	255.355 a	255.083 a	254.434 b	0.850 a	0.851 a	0.850 a	0.848 b
G_3: Indole acetic acid 50 ppm (0.05 g/L)	131.47 a	133.32 a	55.500 a	57.500 a	257.006 a	257.074 a	255.750 a	256.352 a	0.857 a	0.857 a	0.853 a	0.855 a
F-test	S	S	S	S	S	S	S	S	S	S	S	S
SEm±	0.95	0.26	0.610	0.436	1.775	1.490	3.353	0.315	0.006	0.005	0.011	0.001
CD (P = 0.05)	2.69	0.75	1.735	1.241	5.050	4.240	9.541	0.896	0.017	0.014	0.032	0.003
CV (%)	1.34	0.43	2.071	1.937	1.284	1.556	2.444	0.270	1.284	0.242	2.444	0.051

and cell division this is ascribed to higher activity of auxin in plant tissues and photosynthesis activity of plant so they produced more food (Mandal *et al.,* 2006; Meena *et al.,* 2019; Singh and Meena, 2019). Increase in the leaf area and LAI by the spraying of PGRs might be due to stimulation, cell elongation, cell division and cell enlargement as GA_3 is known to enhance cell elongation (Jupe *et al.,* 1988) and (Sharma *et al.,* 2017).

The leaves of the plants receiving the exogenous GA_3 treatment had a higher chlorophyll content resulted maximum leaf area, which may be explained on the basis of the GA_3 generated enhancement of ultra-structural morphogenesis of plastids (Arteca, 1997), coupled with the retention of chlorophyll and delay of senescence due to hormone treatment (Ouzounidou and Ilias, 2005) and an efficient utilization of optimally available N- which is a key constituent of chlorophyll (Sharma *et al.,* 2017).

Yield

During the experiment data of both the year (Table 2) noticed that seed yield (1.943 t/ha during first year) and (2.034 t/ha during second year) significantly higherand stover yield 6.747 t/ha during first year) and (6.964 t/ha during second year), respectively were recorded organic fertilized by biofertilizer treatment combination B_4.

The microbial inoculants bring about improvement in the nutrients availability either by fixation of atmospheric nitrogen in the rhizosphere (Azotobacter) or transformation of native unavailable phosphorus (PSB) in to plant utilizable P. Bio-fertilizer, on the other hand, transform fixed and insoluble forms in to soluble forms and make them readily available to plants. Similar results were reported

Table 2. Seed yield and stover yield influenced by biofertilizers and growth regulators of Indian mustard (*Brassica juncea* L.)

Treatments	Seed yield (t/ha)		Stover yield (t/ha)	
	2019-20	2020-21	2019-20	2020-21
Biofertilizer				
B_1: Azotobacter	1.649 b	1.768 b	6.596 a	6.794 a
B_2: PSB + Azotobacter	1.818 a	1.941 a	6.702 a	6.873 a
B_3: VAM + Azotobacter	1.723 b	1.848 b	6.588 a	6.856 a
B_4: PSB + VAM + Azotobacter	1.943 a	2.034 a	6.747 a	6.964 a
F-test	S	S	S	S
SEm±	0.046	0.032	0.106	0.104
CD (P = 0.05)	0.161	0.111	0.366	0.358
CV (%)	4.794	1.318	2.926	2.421
Growth Regulators				
G_0: Water Spray	1.658 b	1.728 b	6.418 b	6.729 b
G_1: Gibberellic acid 50 ppm (0.05 g/L)	1.842 a	1.978 a	6.768 a	6.954 a
G_2: Salicyclic acid 100 ppm (0.01 g/L)	1.808 a	1.938 a	6.698 a	6.941 a
G_3: Indole acetic acid 50 ppm (0.05 g/L)	1.825 a	1.947 a	6.748 a	6.864 a
F-test	S	S	S	S
SEm±	0.045	0.049	0.072	0.061
CD (P = 0.05)	0.127	0.140	0.206	0.173
CV (%)	4.617	2.014	1.997	1.425

by Yadav *et al.* (2010); Jakhar *et al.* (2018) and Kumar and Singh, 2019)

This increase in yield may be attributed to increased seed yield due to dual inoculation of bio-fertilizers. Enhanced P availability increased better root growth and absorption of N and S. Increased N and S absorption is responsible for improved synthesis of protein and oil in mustard seed (Solanki

Table 3. Leaf area and leaf area index at harvest affected by interaction of biofertilizers and growth regulators of Indian mustard (*Brassica juncea* L.)

Treatment combination	Leaf areacm² per plant at harvest					Leaf area index at harvest				
					2019-20					
	G_0	G_1	G_2	G_3	Mean	G_0	G_1	G_2	G_3	Mean
B_1	219.000	247.667	246.000	231.000	235.917	0.730	0.826	0.820	0.770	0.786
B_2	271.000	241.667	267.333	245.333	256.333	0.903	0.806	0.891	0.818	0.854
B_3	230.333	255.000	247.000	274.333	251.667	0.768	0.850	0.823	0.914	0.839
B_4	251.000	281.667	260.000	272.333	266.250	0.837	0.939	0.867	0.908	0.888
Mean	242.833	256.500	255.083	255.750	252.542	0.809	0.855	0.850	0.853	0.842
F-test			S					S		
SEm±			6.707					0.022		
CD (P=0.05)			19.082					0.064		
					2020-21					
	G_0	G_1	G_2	G_3	Mean	G_0	G_1	G_2	G_3	Mean
B_1	223.355	246.344	243.754	234.870	237.081	0.745	0.821	0.813	0.783	0.790
B_2	270.014	246.602	266.920	247.341	257.719	0.900	0.822	0.890	0.824	0.859
B_3	236.603	255.217	245.266	273.490	252.644	0.789	0.851	0.818	0.912	0.842
B_4	254.953	279.528	261.796	269.706	266.496	0.850	0.932	0.873	0.899	0.888
Mean	246.231	256.922	254.434	256.352	253.485	0.821	0.856	0.848	0.855	0.845
F-test			S					S		
SEm±			0.630					0.002		
CD (P=0.05)			1.793					0.006		

Note: *Biofertilizer*: B_1: Azotobacter, B_2: PSB + Azotobacter, B_3: VAM + Azotobacter, B_4: PSB + VAM + Azotobacter, *Growth Regulators*: G_0: Water Spray, G_1: Gibberellic acid 50 ppm, G_2: Salicyclic acid 100 ppm, G_3: Indole acetic acid 50 ppm

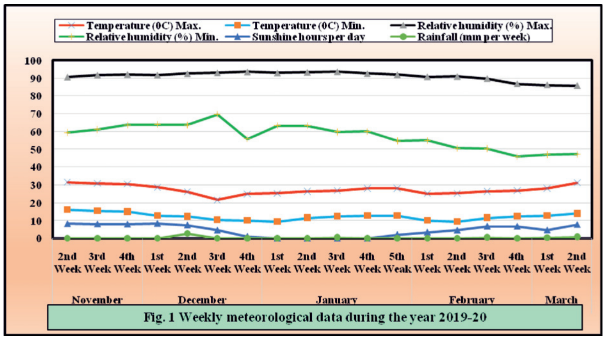

Fig. 1 Weekly meteorological data during the year 2019-20

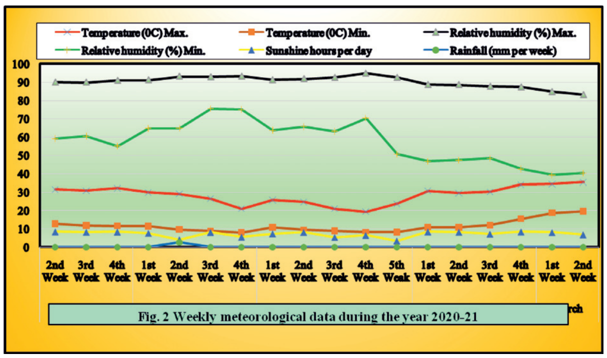

Fig. 2 Weekly meteorological data during the year 2020-21

et al. 2017)

Among the growth regulator experimental data from the treatment G_1 [Gibberellic acid 50 ppm (0.05 g/L)] recorded the significantly higher (seed yield (1.842 t/ha during first year) and (1.978 t/ha during second year) significantly higher and stover yield 6.768 t/ha during first year) and (6.954 t/ha during second year), respectively.

Interaction effect on the biofertilizers and growth attributes (Table 3) leaf area at harvest (281.667 cm^2 per plant during first year) and (279.528 cm^2 per plant during second year) significant and maximum recorded applied biofertilizers B_4G_1(PSB + VAM + Azotobacter) and gibberellic acid 50 ppm (0.05 g/ L)], respectively. LAI significant and maximum was recorded (0.939 and 0.932 during both the year similar treatment interaction combination.

CONCLUSION

This study indicated that growth attributes and productivity of mustard 'Varuna' under combination of (PSB, VAM and azotobacter) and growth regulators of gibberellic acid was found to be more yield and leaf area and leaf area index.

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