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Effect of biofertilizers and nitrogen levels on growth, yield, oil content and economics of mustard (*Brassica juncea* L.) in north central plateau zone of Odisha

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Abstract
A field experiment was conducted at Regional Research and Technology Transfer Station, OUAT, Keonjhar under North Central Plateau Agro climatic Zone of Odisha during *rabi* 2020-21 and 2021-22 under irrigated condition. The soil of the experimental plot was sandy loam in texture with pH 6.9, organic carbon 4.72 g kg^{-1} soil and available N, P and K of 225, 18.4 and 140 kg ha^{-1}, respectively. Inoculation of biofertilizers and application of different levels of nitrogen significantly influenced the growth, yield attributes, yield, oil content and economics of Indian mustard. The seed yield and net returns were highest (1317 kg ha^{-1} and Rs.12,312 ha^{-1}, respectively) for *Azotobacter* + 80 kg N ha^{-1}, which were at par with *Azospirillum* + 60 kg N ha^{-1} (1234 kg ha^{-1} and Rs.11,157 ha^{-1}, respectively) and no biofertilizer with 80 kg N ha^{-1} (1223 kg ha^{-1} and Rs.10801 ha^{-1}, respectively). The oil yield also followed similar trend as of yield. The result of the experiment suggests that seed inoculation of *Azotobacter* along with application of 80 kg N ha^{-1} can be recommended for Indian mustard in the irrigated tracts of northern Odisha. However, in order to reduce inorganic nitrogen use, it can also be advocated to use *Azospirillum* seed inoculation with 60 kg N ha^{-1}.

Keywords: Indian mustard, biofertilizer, nitrogen & economics

Introduction
Oilseed crops are the most important commercial crops in India. Indian mustard (*Brassica juncea* L.) is the most popular one among different species of rapeseed and mustard grown in India. Mustard oil production in India is estimated to increase by 28.5% (8.2 lakh tons) to 3.67 million tonnes in the 2021-22 crop year, whereas in 2020-21, 2.85 million tonnes was produced (Pyare *et al*., 2022) [1]. The country produces about 41.4 million tonnes of oilseeds in 29.4 million hectare of land (2022-23), which is still lower by about 12 million tonnes required to achieve self-sufficiency. The contribution of Indian mustard to this production pool is 11.35 million tonnes. In Orissa, mustard is grown over an area of 145 thousand hectare with total production of 63.22 thousand tonnes at a meagre average productivity of 436 kg ha^{-1} (OAS, 2021-22) [2]. The nutrient requirement of Indian mustard is high, which needs to be supplied in adequate quantity to augment production from unit area. Application of nitrogen in Indian mustard results in higher photosynthetic activity leading to accumulation of carbohydrates, proteins and their translocation to the reproductive organs which, in turn, improves over all growth, yield attributing characters and yields (Yadav *et al*., 1995) [3]. Bio fertilizers such as *Azotobacter* and *Azospirillum* have proved themselves as partial substitutes of nitrogenous fertilizers. These microbial inoculants have attained special significance in recent times. These are low cost and non-bulky agricultural inputs, which could play a significant role in plant nutrition as a supplementary or complimentary factor. Use of the microbial inoculants can increase crop yields while contributing towards soil health and sustainability of agriculture (Pyare *et al*., 2022) [1]. Keeping in view the judicious use of nitrogenous fertilizer in terms of chemical and biofertilizers, the present investigation was conducted to study the effect of biofertilizers and levels of nitrogen on Indian mustard.

Materials and Methods

The experiment was undertaken during *rabi* 2020-21 and 2021-22 at Regional Research and Technology Transfer Station, OUAT, Keonjhar under North Central Plateau Agro climatic Zone of Odisha taking Indian mustard variety 'Pusa Mahak' as test crop. The soil of the experimental site was sandy loam in texture with pH 6.9, organic carbon 4.72 g kg^{-1} soil and available N, P and K of 225, 18.4 and 140 kg ha^{-1}, respectively. The experiment with 12 treatments was laid out in randomised block design with three replications. The treatments were combinations of three levels of seed inoculation with biofertilizers namely no biofertilizers (control), *Azotobacter* and *Azospirillum* and four levels of nitrogen *i.e.*, 20, 40, 60 and 80 kg ha^{-1}. Nitrogen was applied in two equal splits at sowing and 30 days after sowing (DAS). *Azotobacter* and *Azospirillum* were applied as seed inoculation at the rate of 20 g kg^{-1} of seed. The crop was sown on 18th and 24th October and harvested on 14th and 19th February in respective years. Application of phosphorous and potassium at the rate of 30 kg each per hectare were common to all treatments. Biometric observations like plant height (cm), number of branches per plant, leaf area, dry matter accumulation (g plant $^{-1}$), crop growth rate (CGR) and net assimilation rate (NAR) were taken at 15 days interval starting from 30 DAS. Leaf area index (LAI), dry matter accumulation, CGR, NAR and harvest index (HI) were computed by using standard formula. Oil content was determined by ether extraction method. The data were statistically analysed. Economics of the crop was calculated as per the prevailing market price.

Result and Discussion

Biometric observations like plant height, number of primary branches $plant^{-1}$, LAI, dry matter accumulation, CGR and NAR were significantly influenced either by inoculation of biofertilizers or levels of nitrogen or both (Table 1). Seed inoculation with *Azospirillum* produced the highest plant height (121.5 cm), LAI at 60 DAS (4.35), dry matter accumulation at harvest (13.43 g plant $^{-1}$), CGR at 45-60 DAS (0.37 g plant $^{-1}$ day^{-1}) and NAR at 45-60 DAS (4.4 g m^{-2} leaf area day^{-1}). However, these were at par with those of *Azotobacter* inoculation. No biofertilizer inoculation registered the lowest values for the above parameters. This might be due to increased nitrogen supply in inoculated plots because of nitrogen fixing ability of these bacteria (Chaurasia *et al.*, 1919) [4], production of phytohormones like IAA, GA, Cytokinin and antifungal antibiotics (Tien *et al.*, 1979) [5], and greater excretion of the root exudates and enhanced activity of various rhizospheric bacteria (Odu, 1997) [6]. Similarly, the levels of nitrogen also influenced the biometric observations significantly. Application of 80 kg N ha^{-1} produced the highest plant height (127.7 cm), number of primary branches per plant (4.1), LAI (4.92), dry matter accumulation (14.57 g plant $^{-1}$), CGR (0.41 g $plant^{-1}$ day^{-1}) and net assimilation rate (3.7 g m^{-2} leaf area day^{-1}). However, these were at par with application of 60 kg N ha^{-1} except LAI. This might be due to better utilization of photosynthates (Patel *et al.* 2022, Gora *et al.* 2022) [7, 8] and enhanced meristematic activity leading to cell multiplication, cell elongation and ultimately increased all the growth parameters (Chaurasiya *et al.* 2019) [4]. Again application of balanced P and K along with nitrogen improves root ramification, thereby increasing the total absorbing area and helps in translocation and partitioning of dry matter produced in the leaf resulting in expansion of photosynthetic site, in turn, photosynthetic activity and ultimately expansion of growth characters and higher biomass production (Kumar *et al.* 2019) [9].

Data presented in Table 2 reveal significant influence of biofertilizers and nitrogen on yield attributes and yield of Indian mustard. Yield attributes of Indian mustard like number of siliquae per plant (93.16), number of seeds per siliqua (12.27), 1000-seed weight (4.44 g), seed yield (1073 kg ha^{-1}), stover yield (2215 kg ha^{-1}) and harvest index (32.38%) were the highest for *Azospirillum* inoculation. However, these were at par with those of *Azotobacter* inoculation except seed yield. The crop without biofertilizer inoculation registered the lowest values for the above parameters. This might be due to the ability of *Azotobacter* and *Azospirillum* to produce phytohormones and antifungal antibiotics in addition to fixing nitrogen which is made available to plants for higher yield. Inoculation of nitrogen fixing bacteria resulted in greater leaf area index and higher crop growth particularly at active growth stage which suggest that more pods and seeds were developed because of greater supply of carbon assimilates and nitrogen to the pods due to presence of a large photosynthetic surface (Reddy *et al.* (2018) [10], Vijayeswarudu *et al.* (2021) [11]. The result also reveals that although the oil content was not affected, the oil yield was significantly influenced by inoculation of biofertilizers. Similarly, nitrogen also influenced the yield attributes and yield. Application of 80 kg N ha^{-1} produced highest number of siliquae $plant^{-1}$ (110.72), number of seeds $siliqua^{-1}$ (13.36), 1000-seed weight (4.56 g), seed yield (1245 kg ha^{-1}), stover yield (2286 kg ha^{-1}) and harvest index (34.19%) and oil yield (457 kg ha^{-1}). However, these were at par with 60 kg N ha^{-1} except in number of siliquae $plant^{-1}$, seed yield, stover yield and oil content. The reduction in oil content with incremental supply of nitrogen can be ascribed to accelerated synthesis of amino acids, the building block of proteins in seeds, ultimately reducing the synthesis of fats. The inverse relationship between nitrogen supply and oil content in seed has been reported by Meena *et al.* (2013) [12] and Chaurasiya *et al.* (2019) [4]. Interaction effect of nitrogen levels and biofertilizer (Table 3) revealed that inoculation of *Azotobacter* along with 80 kg N ha^{-1} produced the highest seed yield (1317 kg ha^{-1}) and was at par with that of *Azospirillum* alongwith 60 kg N ha^{-1} (1234 kg ha^{-1}) and 80 kg N ha^{-1} without biofertilizer (1223 kg ha^{-1}). Meena *et al.* (2013) [12], Janaki *et al.* (2022) [13] reported that higher levels of nitrogen inhibit the growth and ability of the nitrogen fixing bacteria.

Bacterial inoculation with *Azospirillum* recorded highest gross returns of Rs.17,832 ha^{-1} with returns per rupee invested of 1.93 as compared to *Azotobacter* (Rs.16,906 ha^{-1} and Rs.1.82, respectively). Similarly, highest gross returns of Rs.20,616 ha^{-1} was obtained in 80 kg N ha^{-1} followed by Rs. 18,204 ha^{-1} in 60 kg N ha^{-1}. The net returns per rupee invested was highest in 80 kg N ha^{-1} (2.18) followed by 60 kg N ha^{-1} (1.96). The interaction effect of biofertilizer and levels of nitrogen on net returns, however, reveal that maximum net returns of Rs.12,312 was obtained from 80 kg N ha^{-1} with *Azotobacter*, which was at par with 60 kg N ha^{-1} along with *Azospirillum* (Rs.11,157) and 80 kg N ha^{-1} without biofertilizer (Rs.10,801).

Table 1: Effect of biofertilizers and levels of nitrogen on biometrics of Indian mustard

Particular	Plant height (cm)	Primary branches plant^{-1}	Leaf area index at 60 DAS	Dry matter accumulation at harvest (g plant^{-1})	Crop growth rate at 45-60 DAS (g plant^{-1} day^{-1})	Net assimilation rate at 45-60 DAS (g m^{-2} leaf area day^{-1})
Biofertilizers						
No biofertilizer	119.4	3.5	3.50	12.25	0.31	3.3
Azotobacter	121.0	3.6	4.34	13.37	0.36	4.3
Azospirillum	121.5	3.7	4.35	13.43	0.37	4.4
S.Em±	0.49	0.13	0.09	0.30	0.008	0.07
CD (0.05)	1.5	NS	0.26	0.89	0.02	0.2
Nitrogen levels (kg ha^{-1})						
20	108.3	2.7	3.16	11.40	0.24	2.8
40	120.1	3.7	3.65	12.53	0.33	2.9
60	126.5	4.0	4.50	13.56	0.40	3.6
80	127.7	4.1	4.92	14.57	0.41	3.7
S.Em ±	0.57	0.14	0.10	0.35	0.01	0.08
CD (0.05)	1.7	0.4	0.30	1.02	0.03	0.2

Table 2: Effect of biofertilizers and levels of nitrogen on seed, oil yield and economics of Indian mustard

Particular	Siliquae Plant^{-1}	Seeds siliqua^{-1}	1000, seed weight (g)	Seed yield (kg ha$^{-1)}$	Stover yield (kg ha^{-1})	Harvest index (%)	Oil content (%)	Oil yield (kg ha^{-1})	Gross returns (Rs ha^{-1})	Net returns per rupee invested (Rs)
Biofertilizers										
No biofertilizer	73.61	11.37	4.34	931	2016	30.81	37.09	344	15,499	1.68
Azotobacter	93.38	12.24	4.38	1014	2192	31.59	37.13	376	16,906	1.82
Azospirillum	93.16	12.27	4.44	1073	2215	32.38	37.22	398	17,832	1.93
S.Em±	0.94	0.18	0.02	16	17	0.40	0.06	15	-	-
CD (0.05)	2.75	0.52	0.07	48	49	1.18	NS	43	-	-
Nitrogen levels (kg ha^{-1})										
20	60.15	10.56	4.15	825	1991	28.29	37.49	309	13,805	1.54
40	75.32	11.08	4.30	857	2075	30.11	37.36	320	14,356	1.57
60	100.68	12.84	4.53	1095	2211	33.80	37.00	409	18,204	1.96
80	110.72	13.36	4.56	1245	2286	34.19	36.74	457	20,616	2.18
S.Em ±	1.23	0.21	0.03	19	20	0.46	0.07	17	-	-
CD (0.05)	3.61	0.61	0.09	56	56	1.36	0.22	50	-	-

Table 3: Interaction effect of biofertilizers and levels of nitrogen on seed yield and net returns of Indian mustard

Biofertilizer	Nitrogen levels (kg ha^{-1})				
	20	40	60	80	Mean
No biofertilizer	750 (3634)	780 (3966)	970 (6867)	1223 (10,801)	931 (6317)
Azotobacter	823 (4859)	837 (4932)	1085 (8770)	1317 (12,312)	1014 (7718)
Azospirillum	903 (6154)	958 (6875)	1234 (11,157)	1197 (10,394)	1073 (8645)
Mean	825 (4882)	8.57 (5258)	1095 (8931)	1245 (11,169)	
SEm±	33 (530)				
CD (0.05)	97 (1552)				

Figures in parentheses indicate the net returns (Rs ha^{-1})

Conclusion

Based on the result acquired under the study it can be concluded that seed inoculation of *Azotobacter* with application of 80 kg N ha^{-1} or *Azospirillum* inoculation with 60 kg N ha^{-1} along with each of 30 kg P_2O_5 & K_2O per hectare can be recommended in the irrigated situations of northern Odisha for maximum output in Indian mustard.

Conflict of Interest

None.

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