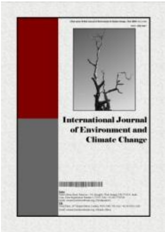

International Journal of Environment and Climate Change

12(10): 540-545, 2022; Article no.IJECC.87391
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Influence of Biofertilizers and Zinc on Growth and Yield of Mustard (*Brassica juncea* L.)

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Authors' contributions

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

Article Information

DOI: 10.9734/IJECC/2022/v12i1030828

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/87391

Original Research Article

Received 10 April 2022
Accepted 16 May 2022
Published 19 May 2022

ABSTRACT

A field experiment was conducted during *Rabi* 2021-2022 to study the "Effect of biofertilizers and zinc on growth and yield of mustard (*Brassica juncea*)'', at Central Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (U.P). Mustard variety of Varuna T-59 was used with biofertilizers like Azotobacter and PSB along with different levels of zinc at 5, 10 and 15 kg.ha^{1}. There were 9 treatments each replicated thrice. The result showed that growth and yield parameters *viz.,* plant height (191.33 cm), no of branches (10.40), Plant dry weight (34.99g), Number of siliquae/plant (283.93), Number of seeds/siliqua (14.99), seed yield (2.23t.ha^{1}) and stover yield(4.90t.ha^{1}) were recorded highest in treatment 9 with the application of Azotobacter 10 g/kg^{1} seeds+ PSB 10 g/kg seeds + Zinc 15 kg.ha^{1}. Gross return (1,33,800.00 INR/ha), Net return (93,921.00INR /ha). B:C ratio (2.35) were recorded superior with application of Azotobacter 10 g/kg^{1} seeds+PSB 10 g/kg seeds + zinc 15 kg.ha^{1}.

Keywords: Azotobacter; PSB; seed yield; stover yied.

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1. INTRODUCTION

Mustard {*Brassica juncea* (L.) Czern & Coss} belongs to the family Cruciferae popularly known as rai or raya and it is the most important rabi season crop of north India. It has a higher potential of production per unit area than other members of the family Cruciferae. Indian mustard is nutritionally very rich having 35-40% oil content and a protein range from 25-30%. Although the oil is the most valuable product of *Brassica* oilseeds, the seed and oil are used as a condiment in the preparation of pickles, flavoring curries and also used as vegetable. Mustard oil is used in tanning industry for softening of leather, preparation of hair oils, medicines, soap making and in manufacture of greases. The high protein meal that remains after the oil extraction and mustard cake are used for cattle feed and manure.

Globally rapeseed-mustard is grown in an area of 33.64 million hectares with a production of 62.84 million tones and productivity of 1856 kg ha^{-1} [1]. Mustard production is around 12- 14 million tones. European Union is the leading producer of mustard seed in the world accounting for 35% of the world production followed by Canada (21%), China (22%) and India (11%) [2].

India is one of the largest rapeseeds and mustard growing countries in the world, occupying the 1st rank in area and 2nd in production next to China. The total area under rapeseed and mustard in India is about 6.23 million hectares with a production of 9.34 million tones and productivity of 1499 kg.ha^{1} [2]. It is predominantly grown in the states of Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh and Gujarat and some of the non-traditional areas of South India including Karnataka, Tamil Nadu and Andhra Pradesh.

Biofertilizers are known to play a number of vital roles in soil fertility, crop productivity and production in agriculture as they are eco-friendly but cannot at any cost replace chemical fertilizers that are indispensable for getting maximum crop yields. Biofertilizers offer a low-cost, low capital intensive and eco-friendly route to boost the farm productivity depending upon their activity of mobilizing different nutrients.The use of biofertilizers in crops not only fixes the biological nitrogen but also solubilizes the insoluble phosphates in soil and thus improves fertilizer use efficiency. Biofertilizers also promote seed germination and give initial vigor of a plant by producing growth promoting substances [3].

Azotobacter is non-symbiotic nitrogen-fixing microorganism having the potential to fix considerable quantities of atmospheric Nitrogen in the rhizosphere of non-legumes. Besides nitrogen fixation, it synthesizes various growth promoting substances such as Vitamins of B group, Nicotinic acid, Gibberellins and anti-fungal compounds. Azotobacter inoculation improves the crop productivity by 0-25 percent over the control in the absence of any amendment and by 8.75 percent in the presence ofNPK [4].

Phosphate solubilizing bacteria (PSB) promotes seed germination and the initial vigor of the plants by producing growth promoting substances. Application of PSB results in increased mineral and water uptake, root development and nitrogen fixation (Gangwal et al., 2011). PSB solubilizes unavailable phosphorus in soil and makes it available to the plants.

Zinc is an essential micro-nutrient and plays an important role in plant system for the proper growth, development and in the production of biomass [5]. The Principle function of zinc in plants is as a metal activator of enzymes, about 10% of enzymes require zinc as a co-factor viz., in tryptophan synthetase, an enzyme responsible for tryptophan synthesis in indoleacetic acid (IAA) biosynthesis [6]. The application of zinc has a significant effect on seed yield, oil content of the seeds and test weight.It also helps in the utilization of phosphorus and nitrogen along with the physiology of seed formation [7]. Zinc deficiency also affects the carbohydrate metabolism, damages pollen structure and also decreases the yield [8]. So, it is very important to apply zinc fertilizer for increasing the yield and improving crop quality.

2. MATERIALS AND METHODS

The present examination was carried out during *Rabi* 2021-22 at Crop Research Farm, Department of Agronomy, Shuats, Prayagraj, UP, which is located at 25.28^{o}N latitude, 81.54^{o}E longitude and 98 m altitude above the mean sea level. The experiment was laid out in Randomized Block Design which consisting of nine treatments each replicated thrice. Mustard variety of Varuna T-59 was used with biofertilizers like Azotobacter and PSB along with different levels of Zinc at 5, 10 and 15 kg.ha^{1}. The experimental site was uniform in topography and sandy loam in texture, nearly neutral in soil reaction (PH 7.1), low in Organic carbon (0.38%), medium available N (225 kg.ha^{1}), higher available P (19.50 kg.ha^{1}) and medium available K (213.7 kg.ha^{1}). In the period from germination to harvest several plant growth parameters were recorded at frequent intervals along with it after harvest, several yield parameters were recorded those parameters are growth parameters, plant height, no. of branches/plant and plant dry weight are recorded. The yield parameters like No. of siliquea/plant, No. of seeds/siliqua, Test weight (g), seed yield(t.ha^{1}), stover yield (t.ha^{1}) and harvest index were recorded and statistically analyzed using analysis of variance (ANOVA) as applicable to Randomized Block Design.

2.1 Treatment Combinations

T_1 Azotobacter 20 g/kg seeds+ Zinc 5 kg.ha^{1}
T_2 Azotobacter 20 g/kg seeds+ Zinc 10 kg.ha^{1}
T_3 Azotobacter 20 g/kg seeds + Zinc 15 kg.ha^{1}
T_4 PSB -20 g/kg seeds+ Zinc 5 kg.ha^{1}
T_5 PSB -20 g/kg seeds+ Zinc 10 kg.ha^{1}
T_6 PSB -20 g/kg seeds+ Zinc 15 kg.ha^{1}
T_7 Azotobacter -10 g/kg seeds +PSB -10 g/kg seeds+Zinc 5 kg.ha^{1}
T_8 Azotobacter -10 g/kg seeds +PSB -10 g/kg seeds+Zinc 10 kg.ha^{1}
T_9 Azotobacter -10 g/kg seeds +PSB -10 g/kg seeds+Zinc 15 kg.ha^{1}

3. RESULTS AND DISSCUSION

3.1 Growth Parameters

3.1.1 Plant height

At harvest significantly higher plant height (191.33cm) was recorded in T9 (Azotobacter 10g/kg seeds + PSB 10 g/kg seeds + zinc 15 kg.ha^{1}). However, T8 (Azotobacter 10g/kg seeds+ PSB 10g/kg seeds + zinc 10 kg.ha^{1}) and T_7 (Azotobacter 10g/kg seeds + PSB 10g/kg seeds + zinc 5 kg.ha^{1}) statistically at par to T9 (Azotobacter 10g/kg seeds + PSB 10g/kg seeds + zinc 15 kg.ha^{1}). Plant height of mustard was influenced by the application of biofertilizers and zinc. The observed improvement in plant height due to zinc might be due to biosynthesis of IAA growth hormones, cell enlargement, cell division and multiplication which ultimately led to better plant height of mustard and boosted plant growth. Similar findings were also reported by Sharma and Jain [9].

3.1.2 Number of branches per plant

Successive increase in the No,of branches of mustard was observed from 20 DAS to at harvest showing a significant impact of Azotobacter, PSB and Zinc, and N:P:K as basal application respectively. At harvest significantly the maximum number of branches (10.40) was recorded in T9 (Azotobacter 10g/kg seeds + PSB 10g/kg seeds + zinc 15 kg.ha^{1}). However, T7(Azotobacter 10 g/kg seeds+ PSB 10g/kg seeds + zinc 5 kg/ha) and T8(Azotobacter 10g/kg seeds + PSB 10g/kg seeds + zinc 10 kg.ha^{1}) are statistically at par to T9 (Azotobacter 10g/kg seeds + PSB 10g kg/seeds + zinc 15 kg.ha^{1}).

Application of Azotobacter, PSB and Zinc along with NPK increased the number of branches per plant. Addition of biofertilizers in relation to N and P fertilization is instrumental in increasing the attributes in every level of plant growth. Seed inoculation of Azotobacter and PSB significantly increase the growth viz., number of primary and secondary branches of plant. The favorable effect of bacterial inoculation could be attributed to increase in N supply in inoculated plots due to N-fixation ability of these bacteria. This explanation was given by Singh and Sinsinwar [10].

3.1.3 Dry weight

At harvest significantly highest plant dry weight (34.99g) was recorded in T9 (Azotobacter 10g/kg seeds + PSB 10g/kg seeds + zinc 15 kg.ha^{1}) However, T7 (Azotobacter 10 g/kg seeds + PSB 10g/kg seeds + zinc 5 kg.ha^{1}) and T8 (Azotobacter 10 g/kg seeds + PSB 10g/kg seeds + zinc 10 kg.ha^{1}) are statistically at par to T9 (Azotobacter 10 g/kg seeds + PSB 10g/kg seeds + zinc 15 kg.ha^{1}.

3.2 Yield Attributes

3.2.1 Number of siliqua/plant

Successive increase in the Number of siliqua/plant of mustard was observed at harvest showing significant impact of biofertilizers and Zinc management respectively. At Harvest significantly higher Number of siliqua/plant of mustard (283.93) was recorded in T9

(Azotobacter 10g/kg seeds +PSB 10g/kg seeds + Zinc 15 kg.ha^{1}), however, T8 (Azotobacter 10g/kg seeds +PSB 10g/kg seeds + Zinc 10 kg.ha^{1})and T7 (Azotobacter 10g/kg seeds +PSB 10g/kg seeds + Zinc 5 kg.ha^{1}) is statistically at par to T9 (Azotobacter 10g/kg seeds+PSB 10g/kg seeds + Zinc 15 kg.ha^{1}).

3.2.2 Number of seeds/siliqua

At Harvest significantly higher Number of seeds/siliqua of mustard (14.99) was recorded in T9 (Azotobacter 10g/kg seeds +PSB 10 g/kg seeds +Zinc 15 kg.ha^{1}), however, T8 (Azotobacter 10 g/kg seeds+PSB 10 g/kg seeds + Zinc 10 kg.ha^{1}) and T7 (Azotobacter 10 g/kg seeds +PSB 10 g/kg seeds + Zinc 5 kg.ha^{1}) is statistically at par to T9 (Azotobacter 10 g/kg seeds +PSB 10 g/kg seeds +Zinc 15 kg.ha^{1}).

3.3 Test Weight

At Harvest significantly higher test weight (3.80 g) was recorded in T9 (Azotobacter 10g/kg seeds +PSB 10g/kg seeds + Zinc 15 kg.ha^{1}), however, T8 (Azotobacter 10g/kg seeds+PSB 10g/kg seeds+ Zinc 10 kg.ha^{1}), T7 (Azotobacter 10g/kg seeds +PSB 10g/kg seeds + Zinc 5 kg.ha^{1}), are statistically par to T9 (Azotobacter 10g/kg seeds +PSB 10g/kg seeds + Zinc15 kg.ha^{1}.

Application of Azotobacter, PSB and Zinc increased the yield attributes. The yield attributes viz., number of siliquae/plant, siliquae length, and number of seeds/siliquae, seed weight plant^{-1} and 1000 seed weight increased due to increasing levels of zinc. The findings confirm the results of Yadav et al. [11] and Zizala et al. [12]. Seed inoculation with Azotobacter and PSB significantly increased yield attributes. This favorable effect of bacterial inoculation could be attributed to increase in N supply in inoculated plot due to N-fixation ability of these bacteria. This confirms the finding of Singh and Sinsinwar [10].

3.4 Seed Yield

At harvest significantly higher number of Seed yield (2.23 t/ha) was recorded in T9 (Azotobacter 10g/kg seeds +PSB 10g/kg seeds + Zinc 15 kg.ha^{1}). However, T8 (Azotobacter 10g/kg seeds +PSB 10g/kg seeds + Zinc 10kg.ha^{1}) is statistically par with T9 (Azotobacter 10g/kg seeds +PSB 10 g/kg seeds + Zinc15 kg.ha^{1}).

The application of biofertilizers and zinc has increased the yield of mustard. The increase in yield might be due to the role of zinc in the biosynthesis of indole acetic acid (IAA) and especially due to its role in initiation of primordial for reproductive parts and partitioning of photosynthates towards them, which resulted in better flowering and fruiting. The findings of present investigation are supported by Jat and Mehra [13]. Bio-fertilizers have been identified as a good supplement to chemical fertilizers to increase soil fertility and crop production in sustainable farming [14]. The use of biofertilizers results in the highest biomass and increased in the nutrient uptake by plants. Similar results were reported by Chandan et al. [15]. The plant emerging from biofertilizer inoculated seeds recorded significantly higher seed yield than plant emerging from biofertilizer uninoculated seeds. Similar finding was reported by Yadav et al. [3].

3.5 Stover Yield

At harvest significantly higher number of stover yield (4.90 t/ha) was recorded in T9 (Azotobacter 10 g/kg seeds +PSB 10 g/kg seeds + Zinc 15 kg.ha^{1}). However, T8 (Azotobacter 10 g/kg seeds+PSB 10 g/kg seeds + Zinc 10 kg.ha^{1}) is statistically par with T9 (Azotobacter 10 g/kg seeds +PSB 10 g/kg seeds + Zinc 15 kg.ha^{1}).

3.6 Harvest Index

At harvest significantly higher Harvest index (31.34) was recorded in T6 (PSB 20g/kg seeds + Zinc 15 kg.ha^{1}). However, T4 (PSB 20g/kg seeds + Zinc 5 kg/ha), T5 (PSB 20g/kg seeds + Zinc 10 kg.ha^{1}), T7 (*Azotobacter* 10g/kg seeds +PSB 10 g/kg seeds + Zinc 5 kg.ha^{1}),T8 (Azotobacter 10 g/kg seeds +PSB 10g/kg seeds + Zinc 10 kg.ha^{1}) and T9 (Azotobacter 10g/kg seeds + PSB 10 g/kg seeds + Zinc 15 kg.ha^{1}) is statistically par with T6 (PSB 20g/kg seeds + Zinc 15 kg.ha^{1}).

Table 1. Effect of Spacing and Foliar application of Zinc on yield and yield attributing characters of Sesame

At harvest				60-80DAS	
Treatment combinations	**Plant height (cm)**	**No. of branches (No.)**	**Plant dry weight (g/plant)**	**CGR (g/m^2/day)**	**RGR (g/g/day)**
Azotobacter 20g/kg seeds + Zinc 5 kg/ha	166.23	9.40	32.32	12.30	0.0106
Azotobacter 20g/kg seeds + Zinc 10 kg/ha	165.67	9.60	33.25	12.72	0.0106
Azotobacter 20g/kg seeds + Zinc 15 kg/ha	179.90	9.87	34.13	13.86	0.0112
PSB 20g/kg seeds+ Zinc 5 kg/ha	160.07	9.20	31.99	12.77	0.0110
PSB 20g/kg seeds+ Zinc 10 kg/ha	171.00	9.47	32.71	12.66	0.0107
PSB 20g/kg seeds+ Zinc 15 kg/ha	176.63	9.73	33.75	13.24	0.0109
Azotobacter 10g/kg seeds +PSB 10g/kg seeds+ Zinc 5 kg/ha	183.30	10.00	34.29	14.28	0.0114
Azotobacter 10g/kg seeds +PSB 10g/kg seeds+ Zinc 10 kg/ha	185.60	10.13	34.79	14.43	0.0114
Azotobacter 10g/kg seeds +PSB 10g/kg seeds+ Zinc 15 kg/ha	191.33	10.40	34.99	14.72	0.0115
F test	**S**	**S**	**S**	**S**	**NS**
Sem(±)	3.77	0.15	0.34	0.29	0.0003
CD (P=0.05)	11.31	0.45	1.02	0.86	-

Table 2. Effect of biofertilizers and zinc on yield attributes and yield of mustard

Treatment combinations	**No. of siliquae /plant (No.)**	**No. of seeds/ sili qua(No.)**	**Test weight (g)**	**Seed yield (t/ha)**	**Stover yield (t/ha)**	**Harvest index (%)**
Azotobacter 20g/kg seeds + Zinc 5 kg/ha	267.53	12.63	3.43	1.95	4.36	30.88
Azotobacter 20g/kg seeds + Zinc 10 kg/ha	271.13	13.07	3.50	2.02	4.51	30.95
Azotobacter 20g/kg seeds + Zinc 15 kg/ha	274.80	13.57	3.53	2.08	4.6	31.10
PSB 20g/kg seeds+ Zinc 5 kg/ha	266.80	12.50	3.40	1.91	4.22	31.21
PSB 20g/kg seeds+ Zinc 10 kg/ha	269.93	12.87	3.46	1.99	4.36	31.32
PSB 20g/kg seeds+ Zinc 15 kg/ha	272.93	13.52	3.50	2.05	4.48	31.34
Azotobacter 10g/kg seeds +PSB 10g/kg seeds + Zinc 5 kg/ha	277.60	14.10	3.63	2.12	4.68	31.24
Azotobacter 10g/kg seeds +PSB 10g/kgseeds + Zinc 10 kg/ha	281.60	14.47	3.73	2.17	4.77	31.25
Azotobacter 10g/kg seeds +PSB 10g/kg seeds +Zinc15 kg/ha	283.93	14.99	3.80	2.23	4.90	31.28
F test	**S**	**S**	**NS**	**S**	**S**	**S**
Sem(±)	3.39	0.46	0.08	0.02	0.05	0.07
CD (P=0.05)	10.17	1.37	-	0.07	0.16	0.20

4. CONCLUSION

It is concluded that the application of Azotobacter 10 g/kg seeds along with PSB 10 g/kg seeds and Zinc 15 kg.ha[1] in Treatment 9 recorded higher growth and yield parameters. It also recorded maximum gross return, net return and benefit cost ratio. Since it is economically more profitable, it, can be recommended to the farmers after further trails.

ACKNOWLEDGEMENTS

I am highly indebted to my advisor Dr. Vikram Singh as well as to Dr. Biswarup mehra my co-advisor for their consistent guidance and support. Their invaluable suggestions played pivotal role for betterment in this research work. My heartfelt appreciation to the faculty members of Department of Agronomy, SHUATS, Prayagraj, Uttar Pradesh, India for their assistance, moral support and co-operation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/87391