Research Article

Impact of Bio-Fertilizers and Zinc on Growth and Yield of Sprouting Broccoli (*Brassica Oleracea* Var. *Italica* L. Plenck) Under Lucknow Conditions

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Abstract

The field experiment was conducted at Horticultural Research Farm of the Department of Applied Plant Science (Horticulture), Babasaheb Bhimrao Ambedkar University (A Central University), Vidya-Vihar, Rai-Bareli Road, Lucknow - 226025 (U.P.), India during Rabi season of 2016-17. The experiment comprised of 16 treatment combinations with four levels of each bio-fertilizers (Control, *Azotobacter*, PSB and *Azotobacter*+ PSB) and Zinc (Control, 10, 20 and 30 kg/ha) in randomized block design with three replications. The application of *Azotobacter* +PSB resulted in the maximum and significantly more values of growth and yield attributes viz., plant height (28.70 cm and 52.21 cm at 30 and 60 DAT), number of leaves (7.91 and 16.71 at 30 and 60 DAT), diameter of stem (1.36 cm and 2.57 cm at 30 and 60 DAT), plant spread (22.92 cm and 33.97 cm at 30 and 60 DAT), weight of curd (398.21 g), diameter of curd (12.28 cm), total number of secondary curd (10.50), volume of curd (109.16 cc), yield per plot (4.90 kg) and yield ha-1 (226.85 q ha-1) as compared to control. Similarly, the application of 30 kg zinc ha-1 resulted in the maximum and significantly more values of growth and yield attributes viz., plant height (29.75 cm and 55.16 cm at 30 and 60 DAT) and number of leaves per plant (7.91 and 16.90 at 30 and 60 DAT), stem diameter (1.38 cm and 2.62 cm at 30 and 60 DAT), plant spread (22.41 cm and 35.60 cm at 30 and 60 DAT) weight of curd (420.07 g), diameter of curd (12.72 cm), total number of secondary curd (10.14), volume of curd (113.42 cc), yield per plot (4.34 kg) and yield ha-1 (215.05 q ha-1). It is recommended for higher production of sprouting broccoli under Lucknow conditions.

Keywords: Broccoli, Zinc, *Azotobacter*, PSB and Yield.

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Introduction

Sprouting broccoli (*Brassica oleracea var. italica* L. Plenck) is one of the most nutritious vegetable amongst the cole crops grown for its tender curds. It belongs to the family *Cruciferae (Brassicaceae).* It is a winter season rare vegetable in India, commonly known as Harigobhi. The name '*broccoli'* refers to the young shoots which develop in spring on same species of the genus *Brassica* ('brocco' is Italian world for a shoot. It is a source of valuable nutrients Vitamin A (130 times more Vitamin A contents than cauliflower and 22 times more than cabbage), thiamin, riboflavin, niacin, vitamin C and minerals like Ca, P, K and Fe. *Brassica* vegetables possess both antioxidant and anticarcinogenic properties [1]. Sprouting broccoli contains indole-3-carbinol, which helps to fight breast and lung cancer. Its sprouts are rich source of glucosinolate, particularly glucoraphanin, the substance associated with reducing of cancer [2]. Bio-fertilizers include a range of nitrogen fixers, viz., Rhizobium, *Azotobacter*, *Azospirillium*, Blue Green Algae and Azolla. Out of these the importance of *Azotobacter* and *Azospirillium* has been well recognized for vegetable crops and there are several reports that showed the role of nitrogen fixing through *Azotobacter* and *Azospirillium.* These bio-fertilizers are organic in origin and thus are absolutely safe, therefore, it is essential to adopt a strategy of integrated nutrient management using combination of chemical fertilizers, organic manures and bio-fertilizers so as to minimize the cost of production and to maintain biological productivity of soils, particularly because the farmers are reluctant to adopt recommended fertilizer doses due to the high cost and risk of crop failure on account of aberrant weather condition. Phosphate solubilizing bio-fertilizer native in soil and applied in inorganic fertilizers becomes mostly unavailable to crops because of it is low levels of mobility and solubility and its tendency to become fixed in the soil. The PSB are life forms that can help in improving the phosphate uptake of plants in various ways. PSB also has the potential to enable the utilization of India's abundant rock phosphate deposits, much

of which is not enriched a significant role in solubilizing insoluble phosphate [3]. The beneficial role of bio-fertilizers in improving soil physical, chemical, and biological role is well known, which in turn helps in better nutrient absorption by plants and resulting high yield [4]. Hence, the present investigation have been planned to study of "Impact of bio-fertilizers and zinc on growth and yield of sprouting broccoli (*Brassica oleracea var. italica* L. Plenck) under Lucknow conditions.

Materials and Methods

The present investigation entitled "Impact of bio-fertilizers and zinc on growth and yield of sprouting broccoli (*Brassica oleracea var. italica* L. *Plenck*) under Lucknow conditions was carried out at the Horticulture Research Farm- I of the Department of Applied Plant Sciences (Horticulture), Babasaheb Bhimrao Ambedkar University, (A central university), Vidya-Vihar Rae Bareli Road, Lucknow- 226025 (U.P.) India. The field experiment was conducted at Horticulture Research Farm-I of the Babasaheb Bhimrao Ambedkar University during Rabi season of 2016-17. The seed of broccoli collected from Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan (H.P.). Broccoli seeds Palam Samridhi were sown in the nursery beds of Horticulture Research Farm-I, BBAU, Lucknow, by sowing in row method on 7 October 2016. Raised bed about 5-6 meter long, one meter width and 15 cm above ground level, was prepared. The experiment was laid out in Randomized Block Design (RBD) with three replication and experiment comprised of 16 treatment combinations with four levels of each bio-fertilizers (Control, *Azotobacter*, PSB, *Azotobacter*+ PSB) and Zinc (Control, 10, 20 and 30 kg/ha). Zinc Sulphate ($ZnSo_4$) was applied at the time of transplanting. Before sowing the seed were treated with Azotobactor and PSB inoculums, which was added with 5 g jiggery in 50 ml of boiled water and made in to a sticky paste. The seed were treats for half an hour and then dried in shade for 30 minutes and then sown the experimental plot immediately. These healthy seedling uniform shape and size were selected and transplanting in well prepared field. Five plants were randomly selected and tagged before flowering from each line to record the data on the following attributes. The observations were recorded on plant height, number of leaves per plant, Width of leaves (cm), Length of leaves (cm), Stem diameter (cm) Days taken to curd initiation, Plant spread (cm), Weight of curd (g), Diameter of curd (cm), Total number of secondary curd, Volume of curd (cc), Yield per plant (g), Yield per plot (kg), Yield per hectare (q). Least significant difference at 5% level was used for finding the significant differences among the treatment means. The data obtained from selected plants were subjected to analysis of variance [5].

Figure 1 A general view of experimental field of broccoli

Result and Discussion

Effect of bio-fertilizers

Growth attributes

The results of present investigation on inoculation of various bio-fertilizers increased the plant height, number of leaves, leaf length, leaf width, stem diameter, and plant spread at different growth stages of the crop over control. The data regarding the effect of different bio-fertilizers on the plant height of broccoli has been presented in the **Table 1**.

Table 1 Impact of bio-fertilizers and zinc on vegetative growth parameters of broccoli

Treatment	Plant Height		Number of leaves		Width of leaves (cm)		Length of leaves (cm)		Stem diameter(cm)		Days taken to curd initiation	Plant spread (cm)	
	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT		30 DAT	60 DAT
Bio fertilizers													
Control	21.47	41.15	6.04	12.41	7.26	29.05	18.29	29.25	1.01	2.00	47.71	16.11	28.30
Azotobactor	25.19	45.1	6.67	14.18	8.47	31.83	20.13	31.83	1.18	2.21	48.11	18.37	31.37
PSB	26.00	48.29	7.06	15.36	9.59	32.19	20.77	34.01	1.24	2.34	49.12	20.25	30.05
Azotobacter+PSB	28.7	52.21	7.91	16.71	11.08	35.64	22.88	36.64	1.36	2.57	52.22	22.92	33.97
SEm±	0.68	1.26	0.19	0.41	0.26	0.91	0.53	0.86	0.03	0.06	1.37	0.54	0.82
CD(P=0.05	1.97	3.63	0.54	1.17	0.76	2.61	1.54	2.49	0.10	0.18	NS	1.55	2.38
Zinc Sulphate ($ZnSo_4$)													
Control	20.42	37.84	5.87	12.44	7.38	26.17	16.68	26.75	1.02	1.93	47.93	16.46	26.24
10Kg/ha	23.46	43.45	6.57	13.94	8.45	30.00	19.12	30.67	1.14	2.17	47.54	18.42	29.42
20Kg/ha	27.10	50.21	7.33	15.39	9.79	34.62	22.08	35.44	1.26	2.40	52.62	20.36	32.42
30Kg/ha	29.75	55.16	7.91	16.90	10.78	37.91	24.19	38.87	1.38	2.62	49.07	0.54	35.60
SEm±	0.63	1.26	0.19	0.41	0.26	0.91	0.53	0.86	0.03	0.06	1.37	0.54	0.82
CD(P=0.05)	1.97	3.63	0.54	1.17	0.76	2.61	1.24	2.49	0.10	0.18	NS	1.55	2.38

The perusal of data revealed that the plant height at 30 and 60 DAT was also significantly affected by various bio-fertilizers. The maximum Plant height (28.07 and 52.21cm respectively) was recorded with *Azotobacter* + PSB, while minimum plant height was under control (21.47 and 41.15 cm, respectively). The inoculation with (*Azotobacter + PSB*) was found superior over control, *Azotobacter* and PSB respectively. The mean increase in plant height under PSB (B_2) was recorded 21.01 and 17.35 % at 30 and 60 DAT as compared to control. The numbers of leaves at 30 and 60 DAT were also significantly influenced by inoculation with different bio-fertilizers. The maximum number of leaves at 30 and 60 DAT 7.91 and 16.71 was found with *Azotobacter* + PSB (B_3) which were significantly higher over control, *Azotobacter* and PSB. The mean increase in number of leaves under the treatment B_2 was found to be higher by 16.89 and 23.77 % compared to B_0 *i.e.* control. The inoculation of broccoli seedlings with bio-fertilizers significantly increased the width of leaves over control. Seedling inoculation with *Azotobacter* +PSB produced significantly higher width of leaves over control, by 11.08 and 7.26t at 30 DAT and 35.64 and 29.05 % 60 DAT, respectively. Either inoculation with PSB also recorded significantly higher width of leaves over control in the tune of 32.09 and 10.81 %, respectively. The inoculation of broccoli seedlings with bio-fertilizers significantly increased the length of leaves over control. The maximum length of leaves recorded with *Azotobacter* +PSB 22.88 and 36.64 at 30 and 60 DAT, respectively. Either inoculation with PSB also recorded significantly higher length of leaves over control in the tune of 13.56 and 16.27 % respectively. The diameter of stem at 30 and 60 DAT were also significantly influenced by inoculation with different bio-fertilizers. The maximum diameter of stem at 30 and 60 DAT 1.36 and 2.57 was found with Azotobacter + PSB (B_3) which were significantly higher over control, *Azotobacter* and PSB. The mean increase in diameter of stem under the treatment B_2 was found to be higher by 22.77 and 17.00 % compared to B_0 *i.e.* control. The plant spread at 30 and 60 DAT were also significantly influenced by inoculation with different bio-fertilizers. The plant spread at 30 and 60 DAT 22.92 and 33.97 was found with *Azotobacter* + PSB (B_3) which was significantly higher over control, *Azotobacter* and PSB. The mean increase in plant spread under the treatment B_2 was found to be higher by 25.69 and 6.18 % compared to B_0 *i.e.* control. The significant increase in a plant height, number of leaves, leaf length and leaf width was observed due to inoculation of *Azotobacter* over control. Thus, efficient and healthy strains of *Azotobacter* in the rhizosphere, which in turn have resulted in greater fixation of atmospheric nitrogen and consequently for use of by the plant resulting in vigorous growth of plant. Inoculation of PSB

significantly increased the plant height and number of leaves and leaf area over control. Since phosphorus is one of the essential nutrient and it's availability in an adequate amount leads to better growth and reproduction in the plants. Inoculation with PSB enhances its availability through solubilization of insoluble phosphorus through excretion of organic acids like succinic, lactic, oxalic, glioxalic malic, formalic, α-ketobutyric, propenic, formic, 2-ketogluconic acid etc. Out of these latic and 2-ketogluconic acids acts as chelaters of calcium [6]. These results are enclosing conformity with the findings of [7] in tomato. The combined inoculation of *Azotobacter* + PSB proved significantly superior to *Azotobacter*, PSB in terms of growth parameters *viz.*, plant height, leaf length, leaf width, number of leaves, stem diameter, plant spreading. *Azotobacter* + PSB might have improved both nitrogen and available phosphorus in rhizosphere as they are free nitrogen fixers and phosphate solubilizers, respectively. The combined inoculation of nitrogen fixer and PSB benefits the plant more than either group of organisms alone [8].

Effect of zinc

Data given in Table 1 further revealed that application of different levels of zinc also increased the plant height significantly at both the growth stages. The application of 30 kg Zn/ha recorded the maximum plant height. Application of 20 kg Zn/ha registered a significant increase of 32.71 and 15.52% at 30 DAT and 32.69 and 16.36% at 60 DAT over control and 10 kg Zn/ha respectively. Application of different levels of zinc also significantly influenced the number of leaves per plant. The maximum number of leaves 7.91 and 16.90 at 30 and 6 0 DAT respectively, was recorded with 30 kg Zn/ha. Application of 20 kg Zn/ha significantly increased the number of leaves per plant by 24.87 and 11.56 at 30 DAT and 23.71 and 10.40% at 60 DAT respectively over control and 10 kg Zn ha^{-1}. The data in further revealed that the application of Zn up to 30 kg/ha was found superior 10.78 and 37.91 to lower level at 30 and 60 DAT, respectively. Application of 20 kg Zn/ha registered an increase of 32.66 and 15.86 % at 30 DAT and 32.29 and 15.4% at 60 DAT over control and 10 kg Zn/ha, respectively. The data in further revealed that the application of Zn up to 30 kg/ha was found superior 24.19 and 38.87 to lower level at 30 and 60 DAT. Application of 20 kg Zn/ha registered an increase of 32.37 and 15.48% at 30 DAT and 32.48 and 15.55% at 60 DAT over control and 10 kg Zn/ha, respectively. Application of different levels of zinc also significantly influenced the diameter of stem. The maximum diameter of stem 1.38 and 2.62 at 30 and 60 DAT respectively were recorded with 30 kg Zn/ha. Application of 20 kg Zn/ha significantly increased the diameter of stem by 23.53 and 10.53 at 30 DAT and 24.35 and 10.60% at 60 DAT respectively over control and 10 kg Zn/ha. Data presented in showed that days taken to curd initiation were affected non-significantly due to different bio-fertilizers and level of zinc. Application of different levels of zinc also significantly influenced the plant spread. The maximum plant spread 22.41 and 35.60 at 30 and 60 DAT respectively, were recorded with 30 kg Zn/ha. Application of 20 kg Zn/ha significantly increased the plant spread by 23.69 and 10.53 at 30 DAT and 23.55 and 10.20% at 60 DAT respectively over control and 10 kg Zn/ha. The application of increasing level of zinc up to 30 kg/ha significantly increased the plant height and number of leaves per plant [9]. The micronutrient is helpful in improving the growth of cauliflower by playing a role in cellular oxidation, the fundamental process involved in the cell metabolism and respiration [10]. Also this micro element acted as a catalytic agent in oxidation-reduction processes and the auxin content of plant was improved in its presence [11]. Increased in growth attributes might be due to the fact that besides the role of zinc in chlorophyll formation, it also influenced cell division, meristematic activity of tissues, and expansion of cell and formation of cell wall. These results were also reported by [12].

Yield and yield attributing traits

Effect of bio-fertilizers

The results of present investigation on inoculation of various bio-fertilizers increased the weight of central curd, diameter of curd, volume of curd, total curd yield per plant, yield per plot, yield per hectare and total number of secondary curd content at different growth stages of the crop over control. The data regarding the effect of different bio-fertilizers on the plant height of broccoli has been presented in the **Table 2**. The perusal of data revealed that the inoculation of seedling with of various bio-fertilizers also significantly affected the total yield per hectare over control. Maximum total yield (226.85q) was recorded with the treatment B_3, while minimum was in B_0 (150q). The mean increase in total yield per hectare under the treatment B_2 was recorded to be 32.11% higher over control showed that effect of the inoculation with different bio-fertilizers on total curd yield per plot was found significant. The maximum yield per plot (4.90 kg) obtained with *Azotobacter* + PSB treatment (B_3) while minimum (3.10 kg) was observed in control. The yield per plot increased under B_2 (PSB) treatment was 38.70% over control (B_0) treatment. The inoculation of broccoli seedling with different bio-fertilizers also

significantly affected the biological yield per plant. The maximum yield (398.21 g) per plant was recorded with *Azotobacter* + PSB application (B_3). The % increase in yield under (B_2) application was found to be 10.1 compared to control (Table 2). Data given in various bio-fertilizers also affected significantly over control. The maximum volume of central curd (109.16 cc) was observed under B_3 (i.e. *Azotobacter* + PSB). The % increase in volume of central curd under (B_2) application was found to be 15.96 compared to control. The inoculation of broccoli seedlings with bio-fertilizers significantly increased the number of secondary curd over control per plant. Seedling inoculation with PSB (B_2) produced significantly higher number of secondary curd 26.76 % compared to control. The diameter of curd at 30 and 60 DAT were also significantly influenced by inoculation with different bio-fertilizers. The maximum diameter of curd at harvest 12.28 cm with *Azotobacter* + PSB (B_3) which was significantly higher over control, *Azotobacter* and PSB. The mean increase in diameter of curd under the treatment B_2 was found to be higher by 8.57 % compared to B_0 *i.e.* control. The inoculation of seedlings with various bio-fertilizers also affected significantly the average weight of curd significantly. The maximum weight of curd (398.21 g) was recorded with B_3 *i.e. Azotobacter* + PSB. The % increase in average weight of curd was found with B_2 treatment in the tune 10.01 over control The reason is due to the fact that *Azotobacter* is known to produce antibiotic and antifungal substances which inhibit varieties of soil fungi. It can also synthesize and secrete thiamine, riboflavin, pyridoxin, cynocobalamine, nicotinic acid, pentathonic acid, indole acetic acid and gibberellins or gibberellins like substances resulting in vigorous plant growth and dry matter which in turn resulted in better fertilization, curd formation and ultimately the higher yield. Phosphorus solubilizing bacteria (PSB) nourishes the crops and soil by liberating the growth promoting substances and vitamins. The improvement in yield characters in cabbage with inoculation of PSB is due to solubilization and increased availability of phosphorus from insoluble or otherwise fixed phosphorus for its plant availability [13]**.** The beneficial effects of PSB along with other nutrients increased yield of crop might have resulted due to higher rate in partitioning of different reproductive structure and yield attributes which might have ultimately in turned to higher yield of the crop. These findings corroborate the results of [14], [15] and [16]. The combined inoculation of *Azotobacter* + PSB significantly enhanced the yield attributes and yield of broccoli over control, *Azotobacter* and PSB.

Table 2 Impact of bio-fertilizers and zinc on yield and yield attributing traits of broccoli

Treatment	Weight of curd (g)	Diameter of curd (cm)	Total number of secondary curd	Volume of curd (cc)	Yield per plant (g)	Yield per plot (kg)	Yield per hectare (q)
Bio-fertilizers							
Control	332.77	9.56	7.10	86.43	332.77	3.10	150.40
Azotobactor	368.00	11.00	8.90	98.33	368.00	3.50	168.4
PSB	366.09	10.38	9.00	100.23	366.09	4.30	198.96
Azotobacter+PSB	398.21	12.28	10.50	109.16	398.21	4.90	226.85
SEm±	9.99	0.27	0.24	2.69	9.99	0.11	5.21
CD(P=0.05	28.87	0.79	0.70	7.77	28.87	0.33	15.05
Zinc Sulphate ($ZnSo_4$)							
Control	310.80	8.79	7.53	83.59	310.80	3.49	157.68
10Kg/ha	348.67	10.08	8.42	93.74	348.67	3.99	176.30
20Kg/ha	385.53	11.62	9.41	103.39	385.53	3.98	195.21
30Kg/ha	420.07	12.72	10.14	113.42	420.07	4.34	215.05
SEm±	9.99	0.27	0.24	2.69	9.99	0.11	5.21
CD(P=0.05)	28.87	0.79	0.70	7.77	28.87	0.33	15.05

Effect of zinc

The data indicated that the increasing levels of zinc up to 30 kg/ha brought increase in average weight of curd. Zinc application @30 kg/ha gave the highest average curd weight (420.07 g). The significant increase in average curd weight due to application of 20 kg Zn/ ha and 10 kg Zn/ ha, over control were 24.04 and 10.57 %, respectively. Application of different levels of zinc also significantly influenced the diameter of curd. The maximum diameter of curd 12.72 was recorded with 30 kg Zn/ ha Application of 20 kg Zn/ha significantly increased the diameter of curd by 32.1 and 15.28 % respectively over control and 10 kg Zn/ha. Similarly, the application of zinc up to 20 kg /ha significantly enhanced the number of secondary curd over its preceding doses. However, the maximum number of secondary curd (10.14) was registered with 30 kg Zn/ ha. The % increase in number of secondary curd with application of 20 kg Zn/ ha were found to be over control and 10 kg Zn/ha was 24.97 and 11.76 respectively. The data indicated that the increasing levels of zinc up to 30 kg /ha

brought significant increase in volume of central curd. Zinc application @30 kg/ha gave the highest volume of central curd (113.42 cc). The significant increase in volume of central curd due to application of 20 kg Zn/ ha over control and 10 kg Zn/ ha was 23.69 and 10.29 % respectively. Similarly, the increasing levels of zinc significantly increased the biological yield over its preceding level up to 10 kg Zn/ha. However, the maximum biological yield (420.07 g) was recorded with 30 kg Zn/ha. The % increase in biological yield under Zn 20 kg/ha over control and 10kg Zn ha^{-1} was 24.04 and 10.57 respectively. Application of different levels of zinc also significantly increased the total curd yield per plot up to 10 kg/ha. The maximum yield per plot (4.34 kg) was recorded with 30 kg Zn/ ha the % increase in total curd yields per plot to control and 20 kg/ha was 14.32 and 0.25 respectively. Similarly, the application of zinc @20 kg/ha enhanced the total yield per hectare over its preceding does. However, the maximum total yield per hectare (215.05q) was registered with 30 kg Zn/ ha. The % increase in total yield per hectare with application of 20 kg Zn/ ha over control and 10 kg Zn ha^{-1} was 23.80 and 10.73 respectively. The results presented in the preceding chapter indicate that application of increasing levels of zinc up to 30 kg/ha significantly increased the average weight of central curd and secondary curd per plant, volume of central curd. Whereas, biological per plant, total curd yield per plot and per hectare and total number of secondary curd increased significantly with the increased level of zinc upto 20 kg/ha. This might be possible due to increased supply of zinc through soil application that improved the availability of zinc in the plant together with other plant food elements. Zinc has been suggested to play an important role in regulating the auxin concentration in plants. Besides this, zinc also enhances the absorption of essential element via increasing the cation exchange capacity (C.E.C.) of roots. Thus, the application of zinc in a soil deficient in its content improved overall growth and development of plant and ultimately the curd and total biomass yield. The application of different levels of zinc increased the total yield of broccoli. These results are in close conformity with the finding of [17].

Conclusion

On the basis of the results obtained in the present investigation, it may be concluded that application of different bio-fertilizers and zinc levels enhanced the growth and yield of sprouting broccoli except day take to curd initiation in comparison to control. Application of 30 kg Zn SO_4 and inoculation with *Azotobacter* +PSB may be considered as best treatment in terms of broccoli curd (215.05q/ha and 226.85q/ha). It is recommended for higher production of sprouting broccoli under Lucknow conditions.

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