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Effect of biofertilizers on growth and yield of Spinach (*Beta vulgaris* L.)

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Abstract
An investigation on "Effect of biofertilizers on growth and yield of Spinach (*Beta vulgaris* L.)" was conducted at the experimental farm, College of Horticulture, V.N.M.K.V Parbhani, during kharif season 2016-2017. The experiment was laid out in Randomized Block Design (RBD) with ten treatments replicated thrice by using the variety Pusa All Green. The treatment comprises of control (T1), *Azotobacter@10kg*/ha (T2), PSB@10kg/ha (T3), *Azotobacter*+PSBeach@10kg/ha (T4), *Azotobacter* +PSB as seed treatment (T5), *Azotobacter* @ 2lit/ha (T6) PSB @2lit/ha (T7), *Azotobacter* +PSB each @ 2lit /ha (T8), *Azotobacter* @ 10kg and PSB @2lit/ha (T9), and *Azotobacter* @2lit +PSB @10kg/ha (T10). Regarding the growth attributes it is observed that, the maximum values of growth parameters like plant height (26.66 cm), number of leaves per plant (19.33), number of branches per plant (1.32) and minimum days required for maturity (28.12 days) were recorded with the application of *Azotobacter* + PSB each @2lit/ha (T8).The yield attributes like maximum fresh weight of whole plant (98.11 g) was recorded in treatment of *Azotobacter* + PSB each @2lit/ha (T8) weight of shoot (69.11 g) and shoot root ratio (2.47) was recorded in treatment PSB @ 10kg/ha (T3). However, the minimum values for all other characters and maximum root weight (44.33 g) was recorded in control (T1) treatment. Significantly maximum yield (3.8 kg/ plot) and yield (63.34 q) per hectare was recorded in the treatment (T8) i.e. application of *Azotobacter* +PSB each @ 2lit /ha and it was at par with treatment of *Azotobacter* + PSB each @ 10kg/ha(T4) and the application of *Azotobacter* @ 10kg+ @ 2lit/ha (T9).

Keywords: Spinach, biofertilizers, RBD, *Azotobacter*, PSB, Pusa All Green

Introduction
The spinach (*Beta vulgaris* L.) commonly called as palak belonging to family Chenopodiceae is one of the most popular vegetable crop grown in India and other parts of the world as leafy vegetable. It is used fresh, canned or as frozen products. It is low in calories and with a high biological value, extremely rich in antioxidants especially when fresh steam or quickly boiled. Spinach is a rich source of vitamin A, iron and calcium and also contains appreciable quantity of ascorbic acid, riboflavin and small quantity of thiamine. The leaves are bright green in colour, lustrous, fleshy and accepted by the varied groups of populations. The crop can be harvested 6 to 7 times, with application of nitrogen after each harvest. (Thompson and Kelly, 1957) [6]. In India, during last decade the area under vegetable crops is increasing steadily. The total area under vegetable during 2006-07 was 75.8 lakh hectares and production of 1149.9 lakh MT with productivity of 15.17 MT. The area under vegetables was increased to 101.06 lakh hectares and production 1690.64 MT with productivity of 16.73 MT in the year 2015-16. In Maharashtra During the year 2001- 02 the area under vegetable crops was 4.02 lakh hectares with production of 51.28 lakh MT with productivity of 12.75 MT, this area was gone up to 6.93 lakh hectares and production 103.60 lakh MT 14.95 MT productivity in the year 2015-16 (Annon, 2016) [2]. Biofertilizers are less expressive, eco-friendly and sustainable likely to assume greater significance complement or supplement to inorganic fertilizers. The recent trend in vegetables production is to produce chemical free, organic produce with high nutritive value, among different inputs in organic production of vegetables is biofertilizers. Biofertilizers besides increasing yield, improving quality also helps in improving the nutrient status of soil. *Azotobacter* is an aerobic, free living gram negative bacterium which fixes nitrogen from the atmosphere application of phosphate solubilizing bacteria can help in reducing the input of chemical fertilizer as well as in maintaining better soil health. Bacteria belonging to pseudomonas, bacillus, rhizobium, agro bacterium and micrococcus, burkholdearia, flavobactrium and ermine are reported as efficient phosphate solubilizing

microbial strains with multiple plant growth promoting properties are always beneficial as compared to strains with plant growth promoting trait mineral malnutrition also known as hidden hunger present a significant global challenge several strains of phosphate solubilizing bacteria (PSB) and fungi have been isolated have shown to possess the ability to solubilize soluble phosphate growth promotion and uptake of phosphate plant. PSB increases the availability of phosphorus in the soil through secretion of phosphates enzyme which leads to transfer of organic phosphorus and accumulation in plant tissue. Biofertilizers is an importance group of biological software containing some phosphorus from insoluble sources by the production of organic acid. There are very limited studies available on use of *Azotobacter* and PSB in vegetable crops. In brinjal (Doifode and Nandkar, 2014) [3] in cluster bean in coriander (Tripathi, *et al*., 2013 and Sahu *et al.*, 2014) [7, 4].

Materials and methods

The present investigation entitled "Effect of biofertilizers on growth and yield of spinach (*Beta vulgaris* L.)" was carried out at instructional cum research farm, College of Horticulture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, (Maharashtra) during 2016-2017. The details of Treatments Given below in table no. 1

Table 1: Number of treatments and treatment details:-

Treat No.	Treatments
T1	Control
T2	*Azotobacter* @ 10 kg/ha
T3	PSB @ 10 kg/ha
T4	*Azotobacter* + PSB each @ 10 kg/ha
T5	*Azotobacter* + PSB as seed treatment
T6	*Azotobacter* @ 2lit/ha
T7	PSB @ 2 lit/ha
T8	T8 *Azotobacter* + PSB each @ 2 lit/ha
T9	T9 *Azotobacter* @ 10 kg and PSB @ 2 lit/ha
T10	T10 *Azotobacter* @ 2 lit + PSB @ 10 kg/ha

Result and discussion

Growth characters

The observations on growth characters like plant height (cm), number of leaves per plant, number of branches per plant and days required for maturity were recorded and presented in Tables and illustrated graphically in figures.

Plant height (cm)

The data regarding plant height in presented in Table 2 indicated that, there were significant differences in the plant height among the different treatments recorded at 15 days and 30 days after sowing during course of experimentation. At 15 DAS, significantly maximum (20.55 cm) plant height was recorded in treatment (T8) where, *Azotobacter* + PSB is each @ 2lit/ha was applied over rest of the treatments under study and it was followed by the treatment T9 and T4. The minimum plant height (11.96 cm) was observed in treatment (T1) control. i.e. where only RDF was given. At 30 DAS, significantly maximum (26.66 cm) plant height was recorded in treatment (T8) where, *Azotobacter* + PSB is each @ 2lit/ha was applied over remaining treatments under present study. The next best treatments were T9, T4, T3 and T10 which showed intermediate results and were at par with each other. However, the minimum plant height (19.66 cm) was observed in treatment (T1) control. i.e. application of RDF.

Table 2: Influence of biofertilizers on height (cm) of spinach at various growth stages.

Treat No.	Treatments	15 Das	30 Das
T1	Control	11.96	16.55
T2	*Azotobacter* @ 10 kg/ha	15.33	19.66
T3	PSB @ 10 kg/ha	14.67	18.22
T4	*Azotobacter* + PSB each @ 10 kg/ha	16.33	21.44
T5	*Azotobacter* + PSB as seed treatment	14.78	20.89
T6	*Azotobacter* @ 2lit/ha	13.89	17.33
T7	PSB @ 2 lit/ha	13.11	17.11
T8	T8 *Azotobacter* + PSB each @ 2 lit/ha	20.55	26.66
T9	T9 *Azotobacter* @ 10 kg and PSB @ 2 lit/ha	17.00	22.00
T10	T10 *Azotobacter* @ 2 lit + PSB @ 10 kg/ha	15.88	20.33
S.E. ±		0.82	0.62
C.D. at 5%		2.43	1.86

Number of leaves per plant

The data regarding number of leaves per plant are presented in Table 3 indicated that, there were significant differences in the number of leaves per plant among the different treatments at 15 DAS, and 30 DAS of spinach. At 15 DAS, significantly maximum (9.88) number of leaves per plant was recorded in treatment (T8) where, *Azotobacter* + PSB each @ 2 lit/ha was applied over rest of the treatments under present investigation. It was followed by the treatment T9 (8.22). The minimum number of leaves per plant (6.33) was observed in treatment (T1) control. i.e. treatment applied with RDF. At 30 DAS, significantly maximum (19.33) number of leaves per plant was recorded in treatment (T8) applied with *Azotobacter* + PSB is each @ 2lit/ha over rest of the treatments under present investigation. The minimum number of leaves per plant (8.66) was observed in treatment applied with RDF.

Table 3: Number of leaves per plant of spinach as influenced by various treatments of biofertilizers.

Treat No.	Treatments	15 Das	30 Das
T1	Control	6.33	8.66
T2	*Azotobacter* @ 10 kg/ha	7.22	10.89
T3	PSB @ 10 kg/ha	8.22	10.77
T4	*Azotobacter* + PSB each @ 10 kg/ha	6.78	16.55
T5	*Azotobacter* + PSB as seed treatment	7.89	10.22
T6	*Azotobacter* @ 2lit/ha	7.44	10.00
T7	PSB @ 2 lit/ha	6.44	8.89
T8	T8 *Azotobacter* + PSB each @ 2 lit/ha	9.88	19.33
T9	T9 *Azotobacter* @ 10 kg and PSB @ 2 lit/ha	8.22	10.44
T10	T10 *Azotobacter* @ 2 lit + PSB @ 10 kg/ha	6.66	10.22
S.E. ±		0.37	0.51
C.D. at 5%		1.09	1.52

Number of branches per plant

The data regarding number of branches per plant is presented in Table 4 indicated that, there were significant differences recorded in the number of branches per plant among the different treatments at 15 DAS and 30 DAS during course of investigation in spinach. At 15 DAS, the study revealed that the maximum number of branches per plant (1.32) were recorded in the treatment (T8) where *Azotobacter* + PSB each @ 2lit/ha was applied and was found statistically at par with treatments T9, T10, T6 and T3. However, the lowest numbers of branches per plant (0.33) recorded in the treatments T2, T4, T5 and T7. At 30 DAS, the study revealed that the maximum number of branches per plant (1.32) were recorded in the treatment (T8) where *Azotobacter* + PSB each @ 2lit/ha. was applied and was found statistically at par with treatments T3, T9, T10, T6, T2, and T5. However, the lowest numbers of branches per plant (0.33) were recorded in the treatments T1.

Table 4: Number of branches per plant of spinach as influenced by various treatments of biofertilizers.

Treat No.	Treatments	15 Das	30 Das
T1	Control	0.33	0.33
T2	*Azotobacter* @ 10 kg/ha	0.33	0.66
T3	PSB @ 10 kg/ha	0.66	1.32
T4	*Azotobacter* + PSB each @ 10 kg/ha	0.33	0.66
T5	*Azotobacter* + PSB as seed treatment	0.33	0.36
T6	*Azotobacter* @ 2lit/ha	0.66	0.66
T7	PSB @ 2 lit/ha	0.33	0.66
T8	T8 *Azotobacter* + PSB each @ 2 lit/ha	1.32	1.32
T9	T9 *Azotobacter* @ 10 kg and PSB @ 2 lit/ha	0.99	0.99
T10	T10 *Azotobacter* @ 2 lit + PSB @ 10 kg/ha	0.66	0.66
S.E. ±		0.23	0.31
C.D. at 5%		0.70	0.93

Days required for maturity

The perusal data regarding days required for maturity of spinach are presented in Table 5 depicted in Fig- 4 indicated that there were significant differences in the days required for maturity of spinach among the different treatments of biofertilizers were recorded. The data revealed that, the minimum days required for maturity (28.12 days) was recorded in the treatment (T8) where *Azotobacter* + PSB each @ 2lit/ha. Was applied and it was statically at par with the treatment, T9 and T5. However, more days required for maturity (31.0 days) was found in the treatment T6 i.e. treatment applied with *Azotobacter* @ 2 lit/ha.

Table 5: Days required for maturity of spinach as influenced by various treatments of biofertilizers.

Treat No.	Treatments	Days required for maturity
T1	Control	29.67
T2	*Azotobacter* @ 10 kg/ha	29.67
T3	PSB @ 10 kg/ha	28.60
T4	*Azotobacter* + PSB each @ 10 kg/ha	30.67
T5	*Azotobacter* + PSB as seed treatment	29.33
T6	*Azotobacter* @ 2lit/ha	31.00
T7	PSB @ 2 lit/ha	30.33
T8	T8 *Azotobacter* + PSB each @ 2 lit/ha	28.12
T9	T9 *Azotobacter* @ 10 kg and PSB @ 2 lit/ha	28.32
T10	T10 *Azotobacter* @ 2 lit + PSB @ 10 kg/ha	29.67
S.E. ±		0.65
C.D. at 5 %		1.93

Yield Characteristics

The perusal of data presented in Table 6 and Fig.5 regarding yield character like fresh weight of whole plant (g), weigh of shoot (g), weight of root (g) and shoot root ratio revealed significant differences due to application of various treatments of biofertilizers in spinach.

Fresh weight of whole plant (g)

The data revealed that significantly maximum (98.11g) fresh weight of whole plant was recorded in the treatment application of *Azotobacter* + PSB each @ 2lit/ha (T8) over rest of the treatments under study and was statistically at par with treatments T3 and T9. However, the minimum fresh weight of whole plant (70.00 g) was found in treatment control (T1) where only RDF was applied.

Weight of shoot (g)

The data indicated that, there were significant differences in the weight of shoot among the different treatments studied in present investigation of spinach. The data revealed that significantly maximum (69.11 g) weight of shoot was recorded in the treatment application of PSB @ 10kg/ha (T3) over rest of the treatments under study. It was followed by the treatment T2 and T10. However, the minimum weight of shoot (25.67 g) was found in treatment control (T1) where only RDF was applied.

Weight of root (g)

The data indicated that there were significant differences in the weight of root produced as a result of application of different treatments of biofertilizers in spinach. The data revealed that significantly maximum (44.33 g) weight of root was recorded in the treatment control i.e. application of RDF (T1) over rest of the treatments under study and was statistically at par with treatments T8, T9, T10 and T4. However, the minimum weight of root (26.33 g) was recorded in treatment (T2) where *Azotobacter* was applied.

Shoot: root Ratio

The data regarding fresh weight of marketable produce indicated that, there were differences in the shoot: root ratio as a result of application of different treatments of biofertilizers in spinach. The data revealed that more shoot: root (2.47) was recorded in the treatment (T3) i.e. application of PSB @ 10kg/ha over rest of the treatments under study. The next best treatment was T2. However, minimum shoot: root (0.58) was recorded in treatment (T1) where RDF was applied.

Table 6

Treat No.	Treatments	Fresh weight of whole plant (g)	Weight of shoot (g)	Weight of root (g)	Shoot root ratio
T1	Control	70.00	25.67	44.33	0.58
T2	*Azotobacter* @ 10 kg/ha	88.22	61.89	26.33	2.35
T3	PSB @ 10 kg/ha	97.11	69.11	28.00	2.47
T4	*Azotobacter* + PSB each @ 10 kg/ha	89.77	55.11	34.67	1.59
T5	*Azotobacter* + PSB as seed treatment	75.33	43.00	33.33	1.33
T6	*Azotobacter* @ 2lit/ha	83.22	54.89	28.33	1.93
T7	PSB @ 2 lit/ha	91.44	57.77	33.67	1.71
T8	T8 *Azotobacter* + PSB each @ 2 lit/ha	98.11	59.78	39.33	1.56
T9	T9 *Azotobacter* @ 10 kg and PSB @ 2 lit/ha	95.44	58.44	37.00	1.58
T10	T10 *Azotobacter* @ 2 lit + PSB @ 10 kg/ha	93.89	59.22	34.67	1.70
S.E. ±		0.97	0.81	3.26	
C.D. at 5%		2.88	2.41	9.68	

Yield per plot (kg)

The data regarding yield per plot (kg) is presented in Table 7 indicated that, there were significant differences in the yield per plot among the different treatments. It is evident from the data that significantly maximum yield kg/plot (3.8) was recorded in the treatment (T8) i.e. application of *Azotobacter* + PSB each @ 2 lit/ha and it was statistically at par treatment T9. However, the minimum yield kg/plot (2.17) was recorded in treatment (T1) control where RDF was applied.

Table 7: Influence of biofertilizers treatments on yield of spinach.

Treat No.	Treatments	Yield per plot (kg)	Yield per hectare(q)	Percent increase over the control
T1	Control	2.17	36.22	-
T2	*Azotobacter* @ 10 kg/ha	2.90	48.34	33.46
T3	PSB @ 10 kg/ha	3.1 1	51.78	42.96
T4	*Azotobacter* + PSB each @ 10 kg/ha	3.50	58.33	61.07
T5	*Azotobacter* + PSB as seed treatment	2.9 5	49.17	35.75
T6	*Azotobacter* @ 2lit/ha	2.95	49.17	35.75
T7	PSB @ 2 lit/ha	2.93	48.78	34.68
T8	T8 *Azotobacter* + PSB each @ 2 lit/ha	3.80	63.34	74.87
T9	T9 *Azotobacter* @ 10 kg and PSB @ 2 lit/ha	3.50	58.33	61.07
T10	T10 *Azotobacter* @ 2 lit + PSB @ 10 kg/ha	3.12	52.00	43.57
S.E. ±		0.17	3.29	
C.D. at 5 %		0.50	9.77	

Yield per hectare (q)

The data regarding yield per hectare (q) table no. 7 indicated that, there were significant differences in the yield per hectare (q) among the different treatments The study revealed that the maximum (63.34 q) yield per hectare was recorded in treatment *Azotobacter* + PSB each 2lit/ha (T8) was applied which was statistically at par with treatments T4 and T9. However, the lowest (36.22q) yield per hectare (q) was obtained in control (T1) treatment.

Percent increase over the control

The data regarding percent increase in yield over control indicated that, there were significant differences in percent increase in yield due to application of different treatments of biofertilizers. The data regarding percent increase the yield over control indicated that the increase in yield ranging from 33.46% to 74.87% was observed due to application of different treatments of biofertilizers. The highest increase in yield (74.87%) was observed with the application the treatment (T8) i.e. *Azotobacter* +PSB each @ 2lit/ha. It was followed by the treatment application (T4) i.e. application of *Azotobacter* +PSB each @ 10kg/ha in solid form. The remaining treatments showed intermediate effects. The lowest increase in yield (33.46%) was observed with the application of *Azotobacter* @ 10kg/ha.

Conclusion

The critical evaluation of the results of the present investigation clearly indicated that application of biofertilizers influenced the growth, yield and quality of spinach in general. The application of biofertilizers in liquid from produced significantly superior results. As the treatments of application of *Azotobacter* + PSB each @ 2 lit/ha produced significantly maximum yield, better. Hence it will be beneficial to apply the liquid form of *Azotobacter* + PSB each @ 2 lit/ha for spinach crop under Marathwada conditions.

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