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Effect of biofertilizers on growth, yield and quality of chilli (*Capsicum annuum* L.)

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Abstract
A field study was carried out at Vegetable Research Farm of C. S. Azad University of Agri. & Tech., Kalyanpur, Kanpur during-2017-18. Experiment was conducted in randomized block design with nine treatments and three replications. The treatments comprised of four levels of inorganic fertilizers (25, 50, 75 and 100% recommended dose of fertilizers) along with *Azospirillum* and VAM individually and 100 per cent recommended dose of fertilizers only. The plant height (30, 60, 90, 120 and 150 DAT) was significantly increased by the application of biofertilizers in combination with inorganic fertilizers. The treatment with 100 per cent recommended dose of fertilizers with *Azospirillum* and VAM (T_8) recorded the highest plant height of 46.21, 79.54, 105.17, 122.45 and 128.38 cm at 30, 60, 90, 120 and 150 DAT, respectively and these treatment was at par with T_7 (75% RDF + *Azospirillum* + VAM). The number of primary, secondary and tertiary branches was significantly increased by the application of biofertilizers in combination with inorganic fertilizers. Hundred per cent recommended dose of fertilizers along with *Azospirillum* and VAM recorded the maximum number of primary (9.89), secondary (15.03) and tertiary (28.93), branches per plant at 150 DAT, which was at par with T_7 (75% RDF + *Azospirillum* + VAM). Maximum dry weight (68.77g) and chlorophyll content in the leaves (1.578 mg g^{-1}) were recorded in the treatment T_8 with 100 per cent RDF + *Azospirillum* + VAM and it was at par with T_7 (75% RDF + *Azospirillum* + VAM). The chilli crop registered earliness in commencement of flowering and 50 per cent flowering under the treatment T_8 (100% RDF + *Azospirillum* + VAM), T_7 (75% RDF + *Azospirillum* + VAM) and T_9 (100% RDF). Regarding the number of days taken for commencement of flowering registered by T_8, T_7 and T_9 were 33.30, 33.56 and 34.20 days, while number of days for 50 per cent flowering registered by T_8, T_7 and T_9 were 38.44, 38.76 and 39.00 days, respectively. Maximum number of fruits per plant (166.09), fresh fruit yield per plant (473.32g), dry fruit yield per plant (126.47 g) and dry fruit yield per hectare (49.20q) were recorded in the treatment T_8 (100% RDF + *Azospirillum* + VAM), which was at par with T_7 (75% RDF + *Azospirillum* + VAM). Application of biofertilizers along with 100 per cent RDF (T_8) recorded maximum fruit weight (2.84 g), driage per cent (26.72%) and 1000-seeds weight (4.56 g). The treatment T_8 (100% RDF + *Azospirillum* + VAM) was at par with T_7 (75% RDF + *Azospirillum* + VAM). Application of 100 per cent RDF along with biofertilizers significantly increased the quality interms of oleoresin content (9.87%) and capsaicin content (0.55%), followed by T_7 (75% RDF + *Azospirillum* + VAM) with 9.82 and 0.54 per cent, respectively. These two treatments were at par with each other. Among all the treatments highest net returns (Rs.1,01,596 ha^{-1}) and B:C ratio (2.24) were obtained with the application of 75 per cent RDF + *Azospirillum* + VAM.

Keywords: biofertilizer, *Azospirillum*, VAM, yield and economics

Introduction
Chilli (*Capsicum annuum* L.) is an important vegetable cum spice crop grown in almost all parts of tropical and subtropical regions of the world. It belongs to the family Solanaceae and originated from South and Central America where it was domesticated around 7000 BC. The genus Capsicum includes 30 species, five of which are cultivated: *Capsicum annuum* L., *C. frutescens* L., *C. chinense* Jacq, *C. pubescens* R. and P. and *C. baccatum* L. Chilli is cultivated either for pungent fruited genotypes called chilli (synonyms: Hot pepper, American pepper, Chile, Azi, Cayenne, etc.) or non-pungent fruited genotypes called sweet pepper (synonyms: Capsicum, Paprika, Bell pepper, Shimla mirch). Chilli has many culinary advantages. It comprises numerous chemicals including steam-volatile oils, fatty oils, capsaicinoids, carotenoids, vitamins, proteins, fibres and mineral elements. Capsicum fruits may serve as a source of natural bactericidal agents to be used in food and medicinal systems (Anonymous, 2020) [1].

Many chilli constituents are important for nutritional value, flavor, aroma, texture and colour. Chillies are low in sodium and cholesterol free, rich in vitamin A, vitamin C, vitamin E, a good source of potassium and folic acid. Fresh green chilli peppers contain more vitamin C than citrus fruits and fresh red chilli has more vitamin A than carrot. It is bright in colour and less pungency are preferred in Europe and in the West. Chilli is commercially important for two qualities, *i.e.,* its red colour is due to the pigment capsanthin and its biting pungency is due to capsaicin. Among these alkaloids, capsaicin and dihydrocapsaicin are the major alkaloids that contribute up to 80 per cent of the total capsaicinoids. In India, chilli (dried) occupies an area of 0.811 million hectares with annual production of 1.52 million tonnes (Anonymous, 2020) [1]. Andhra Pradesh, Telangana, Madhya Pradesh, Karnataka, West Bengal, Odisha, Nagaland and Maharashtra are major chilli growing states in India which together contributes about 80 per cent of the total cultivated area and production. Andhra Pradesh has been the largest chilli growing state followed by Telangana and Madhya Pradesh. In recent years, there has been a great demand for increasing the diversity in chilli for both culinary and ornamental purposes. Though India is the leading producer, but the average yield is very low 1.11 t ha^{-1} dry chilli as compared to developed countries like USA, China, South Korea, Taiwan, etc., where the average yield ranges from 3-4 t ha^{-1}. Low productivity in chilli is mainly attributed to lack of high yielding as well as pest and disease resistant varieties or hybrids. Only about 2.60 per cent chilli area is under hybrids in India, while in the countries like Korea and Taiwan more than 90 per cent area is covered by hybrids (Singh *et al*., 2016) [2].

Biofertilizers not only add nitrogen, they also increase native phosphorus availability to some extent. The chemical fertilizers are main suppliers of major plant nutrient (N, P & K). Therefore, the rational and practical means to maintain soil fertility and to supply plant nutrients in balanced proportion is to practice integrated plant nutrients supply through the combined use of chemical and biological sources of plant nutrients. Biofertilizers are microbial inoculants of selective micro-organism like bacteria, algae and fungi already existing in nature.

The indiscriminate use of chemical fertilizers has caused serious damage to the soil rendering them often saline and less suitable for cultivation. High cost of nitrogenous and phosphatic fertilizers is also another factor to be reckoned with for a developing country like ours. In view of this, use of biofertilizers particularly for seasonal crops is gaining popularity. Biofertilizers offer an economically attractive and ecologically sound means of reducing inputs and improving the quality and quantity of the crop. Biofertilizers are less expensive, ecofriendly and improve crop growth and quality of crops by producing plant harmones and phytoalexins.

Among biofertilizers, *Azospirillum* has gained much importance as they not only improve crop yields but also save 20.0 to 40.0 per cent of nitrogen requirement. *Vesicular Arbuscular Mycorrhizae* (VAM) are of prime importance in phosphorus mobilization in soil. This fungus can accumulate the available 'P' in the vesicles where the roots can not approach and increase the 'P' availability in the rhizosphere zones (Sajan *et al.,* 2020) [7].

Materials and Methods

A field experiment was conducted during *Rabi* seasons of 2017-18 at Vegetable Research Farm of C. S. Azad University of Agri. & Tech., Kalyanpur, Kanpur in alluvial soil. The soil of the experimental field was sandy loam in texture and slightly calcareous having organic carbon 0.33%, total nitrogen 0.03%, available P_2O_5 17.85 kg ha^{-1}, available K_2O 131.30 kg ha^{-1}, pH 7.9, electrical conductivity 0.36 dS m^{-1}, wilting point 6.3%, field capacity 18.6%, water holding capacity 29.2%, Bulk density 1.35 Mg m^{-1}, Particle density 2.60 Mg m^{-1} and porosity 48.07%. The field experiment was conducted in randomized block design with three replications. Keeping 9 treatment *viz.* T_1: Control, T_2: *Azospirillum* @ 2 Kg ha^{-1} as soil application, T_3: VAM @ 10 Kg ha^{-1} as soil application, T_4: *Azospirillum* + VAM, T_5: 25% RDF + *Azospirillum* @ 2 kg ha^{-1} + VAM @ 10 Kg ha^{-1} as soil application, T_6: 50% RDF + *Azospirillum* @ 2 kg ha^{-1} + VAM @ 10 Kg ha^{-1} as soil application, T_7: 75% RDF + *Azospirillum* @ 2 kg ha^{-1} + VAM @ 10 Kg ha^{-1} as soil application, T_8: 100% RDF + *Azospirillum* @ 2 kg ha^{-1} + VAM @ 10 Kg ha^{-1} as soil application, T_9: 100% RDF only (without biofertiliers).

Results and Discussion

The plant height (30, 60, 90, 120 and 150 DAT) was significantly increased by the application of biofertilizers in combination with inorganic fertilizers. The treatment with 100 per cent recommended dose of fertilizers with *Azospirillum* and VAM (T_8) recorded the highest plant height of 46.21, 79.54, 105.17, 122.45 and 128.38 cm at 30, 60, 90, 120 and 150 DAT, respectively and these treatment was at par with T_7 (75% RDF + *Azospirillum* + VAM). Similar results were reported by Singh *et al.,* (2016) [2].

The number of primary, secondary and tertiary branches was significantly increased by the application of biofertilizers in combination with inorganic fertilizers. Hundred per cent recommended dose of fertilizers along with *Azospirillum* and VAM recorded the maximum number of primary (9.89), secondary (15.03) and tertiary (28.93), branches per plant at 150 DAT, which was at par with T_7 (75% RDF + *Azospirillum* + VAM). Maximum dry weight (68.77g) and chlorophyll content in the leaves (1.578 mg g^{-1}) were recorded in the treatment T_8 with 100 per cent RDF + *Azospirillum* + VAM and it was at par with T_7 (75% RDF + *Azospirillum* + VAM). Similar results were reported by Kumar, (2008).

The chilli crop registered earliness in commencement of flowering and 50 per cent flowering under the treatment T_8 (100% RDF + *Azospirillum* + VAM), T_7 (75% RDF + *Azospirillum* + VAM) and T_9 (100% RDF). Regarding the number of days taken for commencement of flowering registered by T_8, T_7 and T_9 were 33.30, 33.56 and 34.20 days, while number of days for 50 per cent flowering registered by T_8, T_7 and T_9 were 38.44, 38.76 and 39.00 days, respectively. Maximum number of fruits per plant (166.09), fresh fruit yield per plant (473.32g), dry fruit yield per plant (126.47 g) and dry fruit yield per hectare (49.20q) were recorded in the treatment T_8 (100% RDF + *Azospirillum* + VAM), which was at par with T_7 (75% RDF + *Azospirillum* + VAM). Similar results were reported by Singh *et al.,* (2015) [3].

Application of biofertilizers along with 100 per cent RDF (T_8) recorded maximum fruit weight (2.84 g), driage per cent (26.72%) and 1000-seed weight (4.56 g). The treatment T_8 (100% RDF + *Azospirillum* + VAM) was at par with T_7 (75% RDF + *Azospirillum* + VAM). Application of 100 per cent RDF along with biofertilizers significantly increased the quality interms of oleoresin content (9.87%) and capsaicin content (0.55%), followed by T_7 (75% RDF + *Azospirillum* + VAM) with 9.82 and 0.54 per cent respectively. These two

treatments were at par with each other. Similar results were reported by Meena *et al.*, (2016) [4].

Among all the treatments highest net returns (Rs.1,01,596 ha^{-1}) and B:C ratio (1:2.24) were obtained with the application of 75 per cent RDF + *Azospirillum* + VAM. Similar results were reported by Mishra *et al.*, (2013) [5].

Table 1: Effect of biofertilizers on plant stand, primary, secondary and tertiary branches per plant in chilli.

Treatment	Plant Height (cm)					Primary branches per plant					Secondary branches per plant					Tertiary branches per plant				
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
T_1	35.40	53.34	70.00	80.87	84.41	2.85	3.75	5.00	6.00	6.37	5.00	6.50	7.20	8.25	8.79	2.21	11.00	13.98	15.47	17.52
T_2	38.05	58.07	76.66	88.09	92.00	3.00	4.20	5.18	6.41	6.85	5.63	7.98	8.55	9.37	9.86	2.60	12.35	15.63	18.12	19.37
T_3	38.97	59.20	78.12	90.37	93.25	3.20	4.38	5.30	6.63	7.10	5.92	8.20	8.84	9.42	10.00	2.85	12.92	15.98	18.50	19.78
T_4	40.10	63.68	81.96	94.45	100.02	3.62	5.22	6.16	7.06	7.57	6.54	8.69	9.60	10.14	10.88	3.87	14.00	17.50	19.38	21.09
T_5	41.23	67.71	86.50	97.00	103.00	4.06	5.38	6.57	7.48	7.98	7.00	9.00	9.99	10.77	11.20	3.93	15.21	19.12	21.00	22.46
T_6	43.37	70.52	92.00	103.35	110.21	4.48	5.91	7.20	8.23	8.67	7.85	9.83	11.00	11.82	12.50	4.98	16.45	20.64	23.09	24.56
T_7	45.96	78.35	102.86	119.00	124.56	5.45	7.29	8.43	9.54	9.67	9.20	10.41	13.17	14.00	14.90	6.63	18.97	24.66	26.54	28.10
T_8	46.21	79.54	105.17	122.45	128.38	5.49	7.36	8.52	9.78	9.89	9.32	10.83	13.65	14.32	15.03	6.84	19.23	25.09	27.00	28.93
T_9	44.53	74.40	97.51	109.97	117.18	5.30	6.98	7.79	8.88	9.35	8.80	10.34	12.20	12.97	13.70	6.18	17.80	22.45	24.85	26.32
SE (d)	1.23	1.81	2.42	2.88	2.89	0.14	0.21	0.27	0.31	0.32	0.32	0.37	0.45	0.47	0.53	0.32	0.54	0.68	0.77	0.80
CD (P=0.05)	2.61	3.85	5.14	6.10	6.14	0.30	0.45	0.57	0.65	0.68	0.69	0.79	1.00	1.00	1.14	0.69	1.15	1.64	1.64	1.70

Table 2: Effect of biofertilizers on Dry weight of the plant at first & second picking, Dry weight of the plant at first picking, Days to commencement of flowering, Days to 50% of Flowering, Number of fruits per plant, Fresh fruit yield per plant (g) and Individual Fresh fruit yield per plant (g) in chilli.

Treatment	Dry weight of the plant at first picking	Dry weight of the plant at second picking	Dry weight of the plant at first picking	Days to commencement of flowering	Days to 50% of Flowering	Number of fruits per plant	Fresh fruit yield per plant (g)	Individual Fresh fruit yield per plant (g)
T_1	28.56	31.00	0.905	38.45	45.54	106.88	213.77	1.98
T_2	33.42	36.16	1.012	37.55	43.00	115.94	251.93	2.14
T_3	35.90	39.57	1.026	36.47	42.41	119.15	273.61	2.25
T_4	40.20	45.26	1.093	36.00	41.00	127.56	309.50	2.40
T_5	45.66	49.88	1.185	35.52	40.04	136.82	353.41	2.59
T_6	49.45	55.82	1.298	34.68	39.16	148.00	399.90	2.67
T_7	57.48	66.58	1.523	33.56	38.76	164.62	468.02	2.83
T_8	60.00	68.77	1.578	33.30	38.44	166.09	473.32	2.84
T_9	53.50	61.70	1.406	34.20	39.00	157.70	433.50	2.72
SE (d)	1.80	2.24	0.049	1.18	1.19	2.27	15.72	0.02
CD (P=0.05)	3.82	4.76	0.105	1.93	2.52	4.82	33.34	0.04

Table 3: Effect of biofertilizers on Dry Fruit Yield per Plant, Dry Fruit Yield,% driage, 1000-seeds weight, Oleoresin content (%) and economics in chilli.

Treatment	Dry Fruit Yield per Plant (g)	Dry Fruit Yield (q ha^{-1})	Per cent driage	1000-seeds weight (g)	Oleoresin content (%)	Cost of cultivation	Gross income	Net income	B:C Ratio
T_1	45.75	17.51	21.42	3.70	8.79	33098	52530	19432	0.59
T_2	55.56	21.63	22.06	3.87	8.98	34013	65880	30967	0.89
T_3	62.29	24.04	22.87	3.91	9.04	36067	71000	35033	0.97
T_4	73.06	28.52	23.61	4.14	9.20	37204	85560	48356	1.30
T_5	86.38	34.55	24.45	4.37	9.32	41257	103650	62393	1.51
T_6	100.01	40.38	25.00	4.41	9.43	42264	121148	78884	1.86
T_7	124.47	48.98	26.65	4.53	9.82	45344	146940	101596	2.24
T_8	126.47	49.20	26.72	4.56	9.87	46447	147600	101153	2.18
T_9	113.33	45.24	26.14	4.51	9.60	43917	135600	91803	2.09
SE (d)	4.80	1.72	0.92	0.04	0.04	-	-	-	-
CD (P=0.05)	10.19	3.65	1.95	0.08	0.10	-	-	-	-

Conclusion

Application of 100 per cent RDF along with biofertilizers even though increases growth, yield and quality parameters simultaneously but it also increases cost of cultivation. The same growth, yield and quality levels can be realized from 75 per cent RDF + *Azospirillum* + VAM with less cost of cultivation and high B:C ratio. From the present study finally it is concluded that application of biofertilizers (*Azospirillum* + VAM) along with inorganic fertilizers (75% RDF) could be recommended for higher production of chilli.

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