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Effect of *Azotobacter* and phosphate solubilizing fungi on growth and yield of Chilli (*Capsicum annuum* L.)

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Abstract
Chilli (*Capsicum annuum* L.) is a popular vegetable and spice crop. It is an essential and indispensible item in every kitchen because of its pungency and spicy taste, also green Chilli is rich source of vitamin A and C. After green revolution modern agriculture is mostly relied on utilization of high yielding seeds combined with high doses of chemical fertilizers. Continuous indiscriminate and imbalance use of chemical fertilizers results in environmental pollution by damaging soil and water resources. In the present study, fifteen *Azotobacter* and five phosphate solubilizing fungal (PSF) isolates were isolated from Chilli rhizosphere of Kolhapur District. All isolates were identified on the basis of morphological, cultural, microscopic features and different biochemical tests. The results of yield parameters revealed that the treatment T9, 100% RDF + commercial *Azotobacter* + commercial PSF, showed the highest number of flowers (55.29 / plant), number of fruits (41.30 / plant), length of fruit (7.13 cm) and green Chilli yield (24.50 t/ ha) was on par with treatment T5, 100% RDF + Efficient *Azotobacter* + Efficient PSF i.e. number of flowers (53.85 / plant), number of fruits (40.02 / plant), length of fruit (6.53 cm) and green Chilli yield (22.02 t/ ha). Whereas, highest dry matter weight (104.04 g), available N (178.75 Kg/ha), P (22.03 Kg/ha) and K (187.22 Kg/ha) was showed by treatment T9, 100% RDF + commercial *Azotobacter* + commercial PSF which was on par with treatment T5, 100% RDF + Efficient *Azotobacter* + Efficient PSF i.e. dry matter weight (99.73 g), available N (176.66 Kg/ha), P (21.59 Kg/ha) and K (186.40 Kg/ha) in soil after harvest.

Keywords: *Azotobacter*, phosphate, solubilizing, Chilli, *Capsicum annuum* L.

Introduction
Chilli (*Capsicum annuum* L.) is a popular vegetable and universal spice crop, widely cultivated throughout temperate, tropical and sub-tropical countries. It is an essential and indispensible item in every kitchen because of its pungency, spice taste, appealing odour and flavor. Green Chillis are high in rutin, which is used extensively in pharmaceuticals (Purseglove, 1977) [14]. Nutrient management is one of the most important factors to improve the productivity of chilli.

Continuous indiscriminate and imbalance use of chemical fertilizers results in environmental pollution by damaging soil and water resources as well as less nutrient uptake efficiency of plants, resulting in decreasing yield consequently. In the last decades many micro organisms have been used in the form of biofertilizers.

Biofertilizers are micro-organisms that originated either from root nodule or rhizospheric soil and enrich the soil by enhancing the availability of nutrients to crop also reduce the application of chemical fertilizers, ensuring environmental safety. *Azotobacter* is a free living, aerobic, nitrogen fixing, non-symbiotic heterotrophic bacteria found in soil which can fix an average 20 kg N/ha/year. Some species of *Azotobacter* are associated with some plants (Kass *et al.*, 1971) [7]. *Azotobacter* also produces biologically active copounds such as phytohormones like auxins (Ahmad *et al.*, 2005) [1] thereby stimulating plant growth (Oblisami *et al.*, 2005) [12], (Rajaee *et al.*, 2007) [15]. Phosphorus is abundant in soils in both organic and inorganic form but it is unavailable to plants. Under in vitro conditions, the dissolution of inorganic phosphorus by microbial communities such as fungi, bacteria and other is common. Mineral solubilization, biological control, and production of secondary metabolites are the characteristics of fungi. It has also been observed that the available P and aggregate stability levels, higher soil carbon levels, enzyme activities, and lower soil pH were reported due to inoculation of phosphate solubilising fungi. (Malviya *et al.*, 2011) [9]. The heavy use of inorganic fertilizers in chilli pollutes environment, whereas biofertilizers alone cannot meet the crop's nutrient requirement. As a result, an appropriate ratio of biofertilizer and chemical source of the inputs is required to

achieve quantity and quality of chilli and also improving soil quality. Keeping in this view the present investigation was undertaken to find out effect of *Azotobacter* and phosphate solubilizing fungi on growth and yield of Chilli.

Material and Methods

The experiment was undertaken during the summer season at Department of Plant Pathology and Agricultural Microbiology, Rajarshee Chhatrapati Shahu Maharaj College of Agriculture Kolhapur during the year 2020-2021. Fifteen *Azotobacter* and five phosphate solubilizing fungal (PSF) isolates were isolated from chilli rhizosphere of Kolhapur District. All isolates were identified and selected efficient strains on the basis of morphological (gram staining, cell shape, cell arrangement, stain colour, motility test, KOH test), cultural (colony colour, shape, structure, margin, elevation, size), microscopic observations and different biochemical test *viz.* methyl red test, catalase test, starch hydrolysis, geletine hydrolyase, gas production, H2S production, oxidase test, N fixing and P solubilizing ability respectively. The efficient strain of Azotobacter (Azoto-1) and phosphate solubilizing fungus (PSF-1) were selected for field studies. The expt. was laid out in Randomized Block Design with three replications and eleven treatments (Table 1). Seeds of Phule Jyoti were sown on raised beds and seedlings were grown.

Roots of healthy seedlings of chilli were treated in the talcum based fungal inoculums for a half an hour by using seedling root dip method. After that seedlings were treated with lignite based Azotobacter inoculums of isolate for a half an hour as per treatment.The seedlings were grown in field on raised beds and transferred to field treated with culture by root dip method as per treatments**.** As per the plan of layout treated seedlings transplanted in respective plots. Data are recorded and analysed statistically to express the yield.

Results and Discussion

The experimental results (Table 1) revealed a number of features on growth, yield attributing parameters and yield of chilli. The data represented in Table 1 specified that the seed germination, plant height, leaf area, number of branches and plant spread were significantly increased when seedlings were treated with *Azotobacter* and phosphate solubilizing fungi as compared to single inoculation and uninoculated control. The treatment T_9, 100% RDF + commercial *Azotobacter* + commercial PSF showed highest (90%) germination however, T_{10} (88.33%); treatment T_5 (88%) and treatment T_6 (87.67%) were at par with treatment T_9. while the lowest seed germination 66% was observed in treatment control with RDF. The results are in conformity with Sandeep *et al.*, (2011) [16], and Nagaraj *et al.*, (2016) [11].

The treatment T_9, 100% RDF + commercial *Azotobacter* + commercial PSF, showed the highest plant height (59.83 cm), leaf area (25.28 cm2), number of branches (17.21 / plant) and plant spread (33.57 cm) at 60 DAT which was on par with treatment T_5, 100% RDF + Efficient *Azotobacter* + Efficient PSF i.e. plant height (58.26 cm), leaf area (23.75 cm2), number of branches (16.70 / plant) and plant spread (32.46 cm). Whereas, highest dry matter weight (104.04 g) was showed by treatment T_9. The results are in agreement with Din *et al.*, (2019) observed that use of nitrogen fixing Azotobacter and phosphate solubilizing fungi showed maximum plant height as compared to single inoculation in Lagenaria siceraria and Abelmoschus esculentus, Islam *et al*., (2018) found that leaf area increases with increase in availability of nitrogen and phosphorus in chilli. Khan and Pariari (2012) reported that number of branches per plant increase significantly in 100% RDF with Azotobacter treatment (25.06 per plant) as compared to other Azotobacter treatments and control with RDF (21.17 per plant), and Yadav *et al.*, (2018).

The results concern yield parameters revealed that the treatment T_9, 100% RDF + commercial *Azotobacter* + commercial PSF, showed the highest number of fruits (41.30 / plant), and green chilli yield (24.50 t/ ha) was on par with treatment T_5, 100% RDF + Efficient *Azotobacter* + Efficient PSF i.e. number of fruits (40.02 / plant), and green chilli yield (22.02 t/ ha). The results are in conformity with following researchers. Din *et al*., (2019) [3], observed that the inoculation of Azotobacter and Aspergillus niger increased number of fruit significantly (15) in Lagenaria siceraria as compared to single inoculation i.e. Azotobacter (9), Aspergillus niger (11) and uninoculated control (7)., Jadhav *et al*.,(2014) [6] treatment, 80% N + 100% PK with *Azotobacter* showed highest (77.75) number of fruits per plant and yield (10 t/ha)as compared to other *Azotobacter* treatments and control with RDF (72.50) in Chilli crop.

Table 1: Effect of efficient *Azotobacter* and phosphate solubilizing fungi on growth parameters of Chilli

Tr. No.	Germination %	Plant Height (cm)	Leaf Area (cm^2)	Number of Branches (per plant)	Plant Spread (cm)	Dry matter Weight (g)	Number of Fruits / Plant	Yield of Chilli (t/ha)
		60 DAT	60 DAT	60 DAT	60 DAT			
T_1	80.33	53.42	22.76	15.21	29.15	95.37	36.10	20.05
T_2	79.33	42.44	20.30	11.69	20.79	82.23	26.50	14.22
T_3	75.33	49.46	22.06	13.95	26.42	90.39	32.88	18.31
T_4	73.67	40.83	20.02	11.21	19.77	80.22	25.20	13.89
T_5	88.00	58.26	23.75	16.70	32.46	99.73	40.02	22.02
T_6	87.67	44.26	21.19	12.45	22.79	84.85	28.70	16.28
T_7	82.33	56.57	22.88	15.70	30.74	96.32	37.40	20.63
T_8	77.33	51.09	22.27	14.45	27.47	92.09	34.21	19.15
T_9	90.00	59.83	25.28	17.21	33.57	104.04	41.30	24.50
T_{10}	88.33	46.65	21.57	13.20	24.41	87.42	30.60	17.16
T_{11}	66.00	48.21	21.95	13.70	25.52	89.15	31.91	18.15
S.E.±	1.48	1.48	0.79	0.48	1.24	1.46	1.15	1.31
C.D. at 5%	4.38	4.37	2.33	1.43	3.68	4.32	3.42	3.87

The analysis of results from Table 2 stated that, the use of Azotobacter and PSF significantly increases available N, P and K in some amount as compared to control. The highest available N (178.75 Kg/ha), P (22.03 Kg/ha) and K (187.22

Kg/ha) was showed by treatment $T_{9,}$ 100% RDF + commercial *Azotobacter* + commercial PSF which was on par with treatment $T_{5,}$ 100% RDF + Efficient *Azotobacter* + Efficient PSF i.e. available N (176.66 Kg/ha), P (21.59 Kg/ha) and K (186.40 Kg/ha) in soil after harvest. It is in agreement with the obtained results by Mehana and Wahid (2002) [10] and El-Azouni and Iman (2008) [4].

The maximum (22.50×10^6 cfu/g) population of *Azotobacter* was observed in treatment T_7, 100% RDF + Commercial strain of *Azotobacter* and treatment T_1, 100% RDF + Efficient *Azotobacter* (21.83×10^6 cfu/g) was found statistically at par with treatment T_7. The highest (3.37×10^6 cfu/g) PSF population was observed in treatment T_8, 100% RDF + Commercial strain of PSF and treatment T_3, 100% RDF + Efficient PSF (3.23×10^6 cfu/g) was found statistically at par with treatment T_7. It is in agreement with the obtained results by Patil *et al*., (2017) [13] and Barge (2021) [2].

Table 2: Effect of efficient *Azotobacter* and phosphate solubilizing fungi on available NPK in soil after harvest and population count of *Azotobacter* and phosphate solubilizing fungi at 50% flowering

Tr. No.	Available N (Kg/ha)	Available P (Kg/ha)	Available K (Kg/ha)	Microbial Population	
				Azotobacter (10^6 cfu/g)	PSF (10^6 cfu/g)
T_1	173.41	19.08	185.62	21.83	1.63
T_2	162.71	17.51	176.02	18.73	1.53
T_3	168.24	20.62	183.69	16.33	3.23
T_4	158.87	18.40	175.71	15.73	2.53
T_5	176.66	21.59	186.40	19.60	2.70
T_6	164.29	18.63	178.13	17.33	2.03
T_7	174.63	19.38	186.12	22.50	1.60
T_8	170.27	20.93	184.56	16.50	3.37
T_9	178.75	22.03	187.22	20.10	2.93
T_{10}	163.13	18.81	180.49	17.80	2.33
T_{11}	166.39	19.04	185.07	16.80	1.73
S.E.±	2.01	0.48	2.32	0.35	0.05
C.D. at 5%	5.93	1.44	6.85	1.06	0.17

Conclusion

Results indicates that, the treatment T9, 100% RDF + commercial *Azotobacter* + commercial PSF showed highest yield parameters and available N, P, K in soil after harvest followed by treatment T5, 100% RDF + Efficient *Azotobacter* + Efficient PSF. Also it was observed that dual inoculation of *Azotobacter* and phosphate solubilizing fungus has harmonious effect as compared to single inoculation on the growth and yield of Chilli.

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