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Influence of *Azotobacter* and Phosphate Solubilizing Fungi on Growth and Yield of *Capsicum annuum*

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A B S T R A C T

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. Nitrogen and phosphorus are the major plant nutrients, which are referred to as the master key element in crop production. Some of the beneficial microbes used in biofertilizers are N2 –fixing bacteria, phosphate-solubilizing microbes which are able to fix atmospheric nitrogen or solubilize phosphorus in the soil. 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, 100% RDF + commercial *Azotobacter* + commercial PSF, showed the highest number of flowers (55.67 / plant), number of fruits (41.67 / plant), length of fruit (9.60 cm) and green Chilli yield (25.23 t/ ha) was on par with treatment, 100% RDF + Efficient *Azotobacter* + Efficient PSF i.e. number of flowers (52.87 / plant), number of fruits (39.00 / plant), length of fruit (8.80 cm) and green chilli yield (21.69 t/ ha). Whereas, highest dry matter weight (102.21 g), available N (178.75 Kg/ha), P (22.03 Kg/ha) and K (187.22 Kg/ha) was showed by treatment, 100% RDF + commercial *Azotobacter* + commercial PSF which was on par with treatment, 100% RDF + Efficient *Azotobacter* + Efficient PSF i.e. dry matter weight (98.00 g), available N (176.66 Kg/ha), P (21.59 Kg/ha) and K (186.40 Kg/ha) in soil after harvest.

Introduction

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. Biofertilizer contains living microorganisms and promotes growth by increasing the availability of primary nutrient (nitrogen and phosphorus) to the host plant. Biofertilizer also provides nutrients required by the plants and helps to increase the soil quality with natural microorganism (Vessey, 2003). Some of the beneficial microbes used in biofertilizers are N2–fixing bacteria, phosphate-solubilizing microbes and mycorrhizae which are able to fix atmospheric nitrogen or solubilize phosphorus in the soil (Subba, 1999). Microorganisms are extensively used as biofertilizers in agricultural practices. The biofertilizers are the live or contain latent cell of beneficial microorganisms, which augment the availability of nutrients to the plants. The beneficial micro organisms are *Rhizobium, Azotobacters, azospirillum, cyanobacteria, phosphobacteria, Aspergillus, Penicillium and mycorrhiza.* Among these Azotobacters and phosphate fungi play major role in the supply of nutrients and in the plant growth promoting activities. The multiplied artificially and incorporated into the agricultural lands in the form of biofertilizers. A lot of research work is available on the biofertilizers in agriculture practices. Nitrogen and phosphorus are the major plant nutrients, which are referred to as the master key element in crop production.

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). 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. *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). *Azotobacter* also produces biologically active copounds such as phytohormones like auxins (Ahmad *et al.*, 2005) thereby stimulating plant growth (Oblisami *et al.*, 2005), (Rajaee *et al.*, 2007). Phosphorus is abundant in soils in both organic and inorganic form but it is unavailable to plants. It is a greater part of soil phosphorus (approximately 95-99%) is present in the form of insoluble form; dominant in alkaline soil and unable to utilize by the plants (Lee *et al.*, 2005). Under in vitro conditions, the dissolution of inorganic phosphorus by microbial communities such as fungi, bacteria and other is common. 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 influence of *Azotobacter* and phosphate solubilizing fungi on growth and yield of chilli.

Materials and Methods

The experiment was undertaken during the summer season at Department of Agronomy, 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 two efficient strains of *Azotobacter* and phosphate solubilizing fungus resp. were identified, Azoto 1 & PSF-1 used by PG student. The effect of strains was at par so I have done research on Azoto 2 & PSF 2. 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.

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 100% RDF + commercial *Azotobacter* + commercial PSF showed highest (91%) germination was at par with treatment 75% RDF + Commercial strain of *Azotobacter* + Commercial strain of PSF (87.33%). while the lowest seed germination 68.33% was observed in treatment control with RDF. The results are in conformity with Sandeep *et al.,* (2011), observed increase in seed germination in *Amaranthus gangaticus* with maximum length of plumule and radicle when inoculated with *Azotobacter chroococcum* as compared to uninoculated control. Nagaraj *et al.,* (2016) observed that the seeds treated with Penicillum sp. for 6 hr. showed maximum seed germination i.e. 85.75%, 85.75% and 83% as compared to control 72.75%, 70% and 77% in pearl millet, brinjal and tomato, respectively. The treatment, 100% RDF + commercial *Azotobacter* + commercial PSF, showed the highest plant height (61.38 cm), leaf area (24.82 cm2), number of branches (17.70 / plant) and plant spread (33.97 cm) at 60 DAT which was on par with treatment, 100% RDF + Efficient *Azotobacter* + Efficient PSF i.e. plant height (56.64 cm), leaf area (23.50 cm2), number of branches (16.30 / plant) and plant spread (31.25 cm). Whereas, highest dry matter weight (102.21 g) was showed by treatment 100% RDF + commercial *Azotobacter* + commercial PSF. The results are in agreement with Jadhav *et al.,* (2014), Khan and Pariari (2012) observed that plant height increase significantly in all inoculated treatments as compared to control with RDF. The plant height was increased significantly in treatment having Azotobacter with 100% RDF as compared to treatment having *Azotobacter* with 80% RDF. El-Azouni and Iman (2008), reported that plant height was increased significantly when coinoculated with Aspergillus and Penicillium as compaired to single inoculation. The similar results are obtained by Yasari and Patwardhan (2007) observed that use of *Azotobacter* biofertilizer increases leaf area index at rosette stage by 3.5 % in Canola. Islam *et al.,* (2018) found that leaf area increases with increase in availability of nitrogen and phosphorus in chilli. Sandeep *et al.,* (2011), observed that the number of branches was highest in treatment having *Azotobacter chroococcum* isolate from zone 5 (6.3 per plant) as compared to other isolates and uninoculated control. Jadhav *et al.,* (2014) who observed that that number of branches per plant increase significantly in 100% RDF with Azotobacter treatment (25 per plant) as compared to other Azotobacter treatments and control with RDF (21.25 per plant). Yadav *et al.,* (2018) reported that the treatment, Azotobacter + PSB along with 75%N and RDFYM recorded highest plant spread (39.14 cm) in Marigold. Rathi *et al.,* (2005) observed that the highest plant spread (31.47 E-W and 37.47 N-S) was recorded in 75 % N + Full dose of PK with Azotobacter and Phosphobacteria. Islam *et al.,* (2018), observed that plant canopy was increased with increase in nitrogen and phosphorus level.

Sandeep *et al.,* (2011) and Malviya *et al.,*(2011), observed that the dry matter weight increases significantly in Groundnut when co-inoculation with phosphate solubilizing fungi i. e. *Aspergillus* and *Penicillium* (22 g) as compared to single inoculation i.e. *Aspergillus* (19 g), *Penicillium (*16.7 g) uninoculated control (11.2 g).

Table.1 Effect of efficient *Azotobacter* and phosphate solubilizing fungi on growth parameters of chilli

Tr. No.	Treatment detail	Germination %	Plant Height (cm) 60 DAT	Leaf Area (cm^2) 60 DAT	Number of Branches (per plant) 60 DAT	Plant Spread (cm) 60 DAT	Dry matter Weight (g)	Number of Fruits / Plant	Yield of Chilli (t/ha)
T_1	100% RDF + Efficient strain of *Azotobacter*	78.33	52.58	22.60	14.90	28.71	93.50	35.53	19.70
T_2	75% RDF + Efficient strain of *Azotobacter*	75.00	41.13	20.10	11.40	20.57	81.50	26.00	14.59
T_3	100% RDF + Efficient strain of PSF	72.33	49.78	21.95	13.90	26.10	89.90	32.53	18.29
T_4	75% RDF + Efficient strain of PSF	70.67	39.61	19.70	10.70	19.46	80.08	24.67	14.31
T_5	100% RDF + Efficient strain of *Azotobacter* + Efficient strain of PSF	83.00	56.64	23.50	16.30	31.25	98.00	39.00	21.69
T_6	75% RDF + Efficient strain of *Azotobacter*+ Efficient strain of PSF	83.00	43.08	20.70	12.20	22.11	84.00	28.33	15.60
T_7	100% RDF + Commercial strain of *Azotobacter*	82.33	55.83	23.30	16.00	30.92	97.00	37.27	20.97
T_8	100% RDF + Commercial strain of PSF	77.33	53.64	22.40	14.70	27.80	92.80	34.50	19.45
T_9	100% RDF + Commercial strain of *Azotobacter* + Commercial strain of PSF	91.00	61.38	24.82	17.70	33.97	102.21	41.67	25.23
T_{10}	75% RDF + Commercial strain of *Azotobacter* + Commercial strain of PSF	87.33	47.80	21.70	13.50	24.80	88.00	31.00	17.62
T_{11}	Control (RDF)	68.33	48.42	21.90	13.70	25.87	89.51	32.03	18.29
	S.E.±	**1.55**	**1.69**	**0.68**	**0.58**	**1.20**	**1.59**	**1.39**	**1.23**
	C.D. at 5%	**4.59**	**5.01**	**2.02**	**1.73**	**3.54**	**4.71**	**4.11**	**3.66**

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	100% RDF + Efficient strain of *Azotobacter*	173.41	19.08	185.62	21.83	1.63
T_2	75% RDF + Efficient strain of *Azotobacter*	162.71	17.51	176.02	18.73	1.53
T_3	100% RDF + Efficient strain of PSF	168.24	20.62	183.69	16.33	3.23
T_4	75% RDF + Efficient strain of PSF	158.87	18.40	175.71	15.73	2.53
T_5	100% RDF + Efficient strain of *Azotobacter* + Efficient strain of PSF	176.66	21.59	186.40	19.60	2.70
T_6	75% RDF + Efficient strain of *Azotobacter*+ Efficient strain of PSF	164.29	18.63	178.13	17.33	2.03
T_7	100% RDF + Commercial strain of *Azotobacter*	174.63	19.38	186.12	22.50	1.60
T_8	100% RDF + Commercial strain of PSF	170.27	20.93	184.56	16.50	3.37
T_9	100% RDF + Commercial strain of *Azotobacter* + Commercial strain of PSF	178.75	22.03	187.22	20.10	2.93
T_{10}	75% RDF + Commercial strain of *Azotobacter* + Commercial strain of PSF	163.13	18.81	180.49	17.80	2.33
T_{11}	Control (RDF)	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**

The results concern yield parameters revealed that the treatment, 100% RDF + commercial *Azotobacter* + commercial PSF, showed the highest number of fruits (41.67 / plant), and green chilli yield (25.23 t/ ha) was on par with treatment, 100% RDF + Efficient *Azotobacter* + Efficient PSF i.e. number of fruits (39.00 / plant), and green chilli yield (21.69 t/ ha). The results are in conformity with following researchers. Khan and Pariari (2012) reported that treatment having 75% N + Full PK with Azotobacter showed significantly increased (79) in number of fruits per plant as compared to other Azotobacter treatments and control with RDF (71.85) in chilli.

Jadhav *et al.*, (2014) treatment, 80% N + 100% PK with Azotobacter showed highest (77.75) number of fruits per plant as compared to other Azotobacter treatments and control with RDF (72.50) in chilli crop.

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, 100% RDF + commercial *Azotobacter* + commercial PSF which was on par with treatment, 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. The results are in agreement with the following researchers. Mehana and Wahid (2002) reported that the highest total N (219 mg/Kg soil) was observed in treatment *Rhizobium leguminosarum* + 15.5 Kg P2O5 per fed + *Aspergillus niger* followed by treatment *Rhizobium leguminosarum* + 15.5 Kg P2O5 per fed + *Penicillium pinophilum* (196 mg/Kg soil) and the highest level of available P (26 mg/Kg soil) was observed in treatment *Rhizobium leguminosarum* + 31 Kg P2O5 per fed + *Penicillium pinophilum*. El-Azouni (2008) revealed that the inoculation of Phosphate solubilizing fungi increases the available P in soil as compared to uninoculated treatments. The highest available P (7.1 ppm) was observed in treatment soil + TCP + *Aspergillus niger* + *Penicillium italicum.*

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