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Effect of *Azotobacter* on growth, yield and quality of pearl millet

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Abstract
A field experiment was conducted at Agronomy farm, of S.K.N. College of Agriculture, Jobner (Rajasthan) during *kharif* 2015 on loamy sand soil, which consisted eight treatments of fertilizers/manures (Control, RDF (60:30:0), FYM @ 12 t/ha, FYM @ 6 t/ha + ½ RDF, vermicompost @ 5 t/ha, Vermicompost @ 2.5 t/ha + ½ RDF, Poultry Manure @ 4 t/ha, Poultry Manure @ 2 t/ha + ½ RDF) and two treatments of microbial inoculation (without inoculation and with *Azotobacter*) thereby making sixteen treatment combinations were tested in randomized block design with three replications. Recommended dose of fertilizer for pearl millet was 60 kg N and 30 kg P_2O_5/ha. Results indicated that seed inoculation with *Azotobacter* significantly increased plant height, dry matter accumulation, total number of tillers, chlorophyll content effective tillers, ear length, grains/ear, test weight, grain, stover and biological yield, protein content, total uptake of N, P and K and their concentration in grain and stover. The seed inoculation with *Azotobacter* was found economical fetching highest returns (`29615/ha).

Keywords: Azotobacter, plant height, tillers, grains

Introduction
Pearl millet [*Pennisetum glaucum* (L.) R. Br. emend Stuntz] is one of the important millet crop of hot and dry areas of arid and semi-arid climatic condition particularly of Rajasthan. It has been estimated that pearl millet embodies a tremendous productivity potential particularly in areas having extreme environmental stress condition on account of drought. It is nutritionally better than many cereals as it is a good source of protein having higher digestibility (12.1%), fats (5%), carbohydrates (69.4%) and minerals (2.3%).

Increased use of fertilizers without organic recycling has not only aggravated multinutrient deficiencies in soil-plant-system but also detrimental to soil health and has created environmental pollution. Moreover, chemical fertilizers are becoming costlier in agriculture. Therefore, it is the right time to evaluate the feasibility and efficiency of organic sources not only for improving and building up soil fertility but also to increase the fertilizer use efficiency. Integration of chemical fertilizer with organic manures has been found quite promising not only in sustaining the soil health and productivity but also in stabilizing the crop production in comparison to the use of each component, separately (Nambiar and Abrol, 1989) [1].

Materials and methods
The field experiment was conducted at Agronomy farm of S.K.N. College of Agriculture, Jobner during *Kharif* season of the year 2015 with pearl millet variety "Raj-171" which is a medium statured variety attaining a height of about 200 cm with good tillering capacity and suitable for normal as well as late sown conditions. The climate of this region in typically semi- arid, with extremes of temperatures during both the seasons. During summers, the temperature may go as high as 48^0C while in winter, it may fall as low as -1.0^0C. The soil of the experimental field was loamy sand in texture and alkaline in reaction. It was poor in organic carbon, low in available nitrogen and phosphorus and medium in available potash.

The experiment consisted 16 treatment combinations involving eight treatments of fertilizers and manures [Control, RDF (60:30:0), FYM @ 12T/ha, FYM @ 6 t/ha + ½ RDF, Vermicompost @ 5 t/ha, Vermicompost @ 2.5 t/ha + ½ RDF, Poultry Manure @ 4 t/ha, Poultry Manure @ 2 t/ha + ½ RDF] and two treatments of microbial inoculation (Without inoculation, With *Azotobacter*,).

The experiment was basically planned as rainfed but due to long dry spell at reproductive stage, one life saving irrigation was given on 09.09.2015. The experimental area (net plot) was harvested separately from each plot on October 2, 2015 leaving two border rows on each side along the length of the plot and 0.5 m along the width on both sides.

The harvested produce of each net plot was tield up in the bundles separately and tagged.

Results and discussion

Growth attributes

The significantly higher plant height, dry matter accumulation and total tillers per metre row length at different growth stages of pearl millet were observed due to seed inoculation with *Azotobacter* over without inoculation (table 1). The maximum values of the above parameters were recorded with inoculation with *Azotobacter*. Increased growth under the influence of *Azotobacter* inoculation might be due to the increased number of efficient and healthy strain of *Azotobacter* in the rhizosphere, which in turn resulted in better utilization of atmospheric nitrogen. *Azotobacter* is a free living nitrogen fixing bacteria which has been reported to fix about 20 kg N/ha in nonlegumes (Subba Rao, 1982) [2]. It fixes elemental nitrogen into ammonical form (NH_4^+) which is being utilized by the crop. In addition to this, the ability of *Azotobacter* to synthesize auxins, vitamins, growth substances and antifungal antibiotics confer it with supplementary advantage. The nitrogen which is being fixed by the *Azotobacter* in soil near root zone (rhizosphere) was absorbed by the roots that might have improved the growth parameters of the crop. These results are in close conformity with the findings of Singh (2000) [3] in barley, Rathore and Gautam (2003) [4] in pearl millet and Kumar *et al*., (2012) [5] in pearl millet.

Yield attributes and yield

It is revealed from the data in table no. 1 that Seed inoculation with *Azotobacter* significantly increased the number of effective tillers per metre row length, number of grains per ear, ear head length, test weight as well as grain and stover yields over without inoculation. This could mainly be ascribed to the increased availability of the nitrogen to the plants through biological nitrogen fixation in rhizosphere by *Azotobacter* that caused better root development. Thus, the greater availability of nitrogen might have helped in better root proliferation and vigorous plant growth, resulting in more dry matter and ultimately better flowering and ear head development. The increase in yield might be due to the cumulative effect of increased growth and yield attributes noted under this treatment. The results obtained are in close agreement with the findings of Sushila and Giri (2000) [6], Husain *et al.,* (2013) [7] in and Patel *et al.,* (2014) [8] in pearl millet.

Table 1: Effect of *Azotobacter* on growth, yield attributes, yield and economics of pearl millet

Treatments	Plant stand per m row	Growth characters				Yield attributes					Yield (kg/ha)			Economics
		Plant height (cm)	Dry matter accumulation	Total tillers per metre row length	Chloro phyll content	No. Of effective tillers per metre row length	Grain per ear head	Ear length	Test weight (gm)	Harvest Index (%)	Grain yield	Stover yield	Biological yield	Net return (Rs./ha)
Azotobacter														
Without inoculation	7.7	178.3	275.6	20.5	2.66	20.6	1244	24.8	6.43	25.71	1534	4426	5960	25588
With inoculation	7.8	192.4	302.3	26.8	2.92	23.3	1300	30.5	7.18	26.05	1685	4776	6461	29615
SEm ±	0.14	3.8	5.5	0.4	0.04	0.4	20.23	0.5	0.12	0.47	32	117	160	601
CD (P=0.05)	NS	11.0	15.9	1.2	0.12	1.2	NS	1.5	0.35	NS	92	339	462	1735
CV (%)	7.40	8.2	7.6	7.0	6.15	7.5	6.36	7.3	6.85	7.22	7.94	10.20	10.30	8.71

Table 2: Effect of *Azotobacter* on contents and uptake of nutrients and quality parameters of pearl millet

Treatments	Nutrient content						Nutrient uptake whole crop			Kernels Quality
	N (%)		P (%)		K (%)		N	P	K	Protein
	Grain	Stover	Grain	Stover	Grain	Stover	(kg/ha)	(kg/ha)	(kg/ha)	(%)
Azotobacter										
Without inoculation	1.65	0.47	0.264	0.128	0.543	1.868	46.49	9.74	91.32	10.30
With inoculation	1.76	0.51	0.279	0.135	0.592	1.955	54.43	11.25	103.70	11.03
SEm ±	0.03	0.01	0.004	0.003	0.010	0.032	1.38	0.33	2.21	0.24
CD (P=0.05)	0.08	0.03	0.012	NS	0.028	0.094	3.99	0.94	6.37	0.70
CV (%)	6.26	7.94	6.22	8.67	6.88	6.80	10.95	12.45	9.05	9.07

Economics

Net returns

It is further evident from data presented in table 1 revealed that seed inoculation with *Azotobacter* gave significantly higher net returns over without inoculated. The treatment recorded a net return of Rs. 29615 / ha which indicated an increase of 17.9 per cent over control.

B : C ratio

Data presented in table 1 revealed that seed inoculation with *Azotobacter* recorded the significantly highest benefit: cost ratio (2.65) over without inoculation (2.44).

Nutrient concentration, uptake and quality

It is evident from the data in table no. 2 that seed inoculation with *Azotobacter* significantly enhanced nitrogen and phosphorus concentration in grain and stover, protein content in grain and nitrogen, phosphorus and potassium uptake over without inoculation. The concentration and uptake of any nutrient in the plant is directly related to its availability in the root zone and growth of the plant. Use of *Azotobacter* significantly increased the nitrogen, phosphorus, potassium concentration in grain and stover that might mainly be attributed to their availability in soil in appreciable amount and in the available form due to this microbial inoculant. It also promotes secretion of growth promoting substances

which also resulted in better utilization of other nutrients like phosphorus by plants. The greater uptake of nitrogen, phosphorus and potassium are directly related with the increased concentration of these nutrients in seed and stover and significantly higher seed and stover yields observed under inoculation of seed with *Azotobacter* treatment than without inoculation. These results also corroborate with the findings of Raj and Sangwan (2003) [9] in pearl millet, Sharma *et al.* (2006) [10] in wheat and Kumar *et al.,* (2006) [11] in wheat and pearl millet.

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