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Effect of bio-fertilizers and bio-regulators on yield and net returns of garlic (*Allium sativum* L.)

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Abstract
A field experiment was conducted at Horticulture Farm, S.K.N. College of Agriculture, Jobner (Jaipur) during *Rabi* season 2016-17 and 2017-2018. The experiment consisted four bio-fertilizers (*Azotobacter*, PGPR (*Pseudomonas*) and *Azotobacter* + PGPR (*Pseudomonas*) and five bio-regulators (Thiourea @ 500ppm, Thiourea @ 1000ppm, salicylic acid @ 100 ppm and mepiquat chloride @ 100 ppm). The total 20 treatment combinations were tested in split-plot design with three replications. Further, it can be concluded that combined application of *Azotobacter* + PGPR (*Pseudomonas*) along with thiourea @ 1000 ppm proved to be most superior treatment combination as it fetched comparable bulb yield (223.58 q/ha), net returns (₹ 1,89,332 /ha) and B: C ratio (2.40) followed by *Azotobacter* + PGPR (*Pseudomonas*) along with thiourea @ 500 ppm and *Azotobacter* + PGPR (*Pseudomonas*) along with salicylic acid @ 100 ppm.

Keywords: *Azotobacter*, PGPR (*Pseudomonas*), thiourea, salicylic acid and mepiquat chloride

Introduction
Garlic is the second important bulb crop after onion. Botanically it is known as *Allium sativum* which belongs to the family Amaryllidaceae. It is a multiple or compound bulb consists of smaller bulblets called 'cloves' and is surrounded by a thin white or pinkish papery sheath. The economic yield is obtained from these cloves. As bio-fertilizers are the recent sources for fixation of atmospheric nitrogen in to the soil and making it readily available for the growth of plants. Among the bio-fertilizers, *Azotobacter* though having limited use in vegetables, yet has established its bio-activity in cereals, oilseeds and other crops for mobilizing the useful macro nutrients from unusable to usable state and increase the crop production by enhancing soil fertility. In addition, the bio-fertilizers not only supplement the nutrition but also improve the efficiency of applied nutrients (Somani *et al.*, 1990) [18].

Further, *Pseudomonas fluorescens*is common non-pathogenic saprophyte that colonizes in soil, water and on plant surfaces. It produces a soluble greenish fluorescent pigment. It suppress plant diseases by protecting the seeds and roots from fungal infections by production the number of secondary metabolites including antibiotics, siderophores and hydrogen cyanide. This microbe has the unique ability to enter the plant vascular system and reach to the various parts of the plant system and act as a systemic bio-control agent against various fungal and bacterial diseases. It is applied as Seed treatment @ 4-5 g per kg of seeds as per standard wet treatment (Yawalkar *et al*., 1996) [22].

Furthermore, thiourea plays a vital role in the physiology of plants both as a sulfhydryl compound and to some extent as an amino compound like urea. The stimulating action of thiourea in various physiological activities of plant is well known. Thiourea is mainly known for its dormancy breaking and germination stimulating effect (Mayer, 1956; Mayer and Poljak off-Mayber, 1958) [10, 11]. The dormancy breaking effect of thiourea was suggested to be related to its growth enhancing effect. Similarly salicylic acid is one of the important bio-regulator which positively affects growth of plants. It is classified as phenolic growth regulator, a non-enzymatic antioxidant, a signaling or messenger molecule in plants to induce responses of plants to environmental stressors. SA plays an important role in the regulation and development of ion uptake, transport and membrane permeability (Simaei *et al*., 2012) [16]. Salicylic acid (SA) or ortho-hydroxy benzoic acid is a common plant-produced phenolic compound. Which contributes in the regulation of physiological, biochemical and molecular processes and therefore, it affects the plant growth, development and productivity (Hayat *et al.*, 2010) [9].

Material and Methods

The experiment was laid out in Split Plot Design and replicated three times. The treatments were randomly allotted to different plots using random number table of Fisher and Yates (1963) [8]. The seeds of cv. G 282 procured from NHRDF, Karnal (Haryana). The seeds (cloves) of garlic were first treated with Carbendazim @ 2 g per kg seed to control seed borne diseases. The seeds were sown on 3rd November, 2016 and 8th November, 2017 manually with a seed rate of 500 kg /ha in row at 15 cm apart. It is also known as Yamuna Safed-3. The variety has done very well in Northern parts and also in Central parts of India. It was developed by mass selection technique from a local collection obtained from Dindigul (TN) in 1990. The leaves are wider than other varieties. Bulbs are creamy white and bigger sized (5-6 cm diameter), size index 27-29 cm^2, diameter of cloves 1.2-1.5 cm., 15-18 number of cloves per bulb, TSS 38-42%, dry matter 39-43% and medium storer. Average yield is 175-200 q/ha. The variety is suitable for export.

Application of bio-fertilizers was done as per treatment. For this 125 g of Jaggery was mixed in one litre of boiled water. Appropriate quantity of *Azotobacter* 50 g of culture was poured in Jaggery solution separately and stirred well. The seeds were allowed to air dry in shade. The cloves were sown on the same day after inoculation. The process of inoculation was preceded by clove treatment with fungicide then clove inoculation with *Azotobacter* and *Pseudomonas fluorescens* before the sowing by putting seeds in 20 per cent sucrose solution and then inoculated with respective culture @ 10 g/kg of seeds by putting the uniform coating of chalk powder on seeds and were allowed to air dry in shade. The seeds were sown on the same day after inoculation. The seeds of control plot were treated with sucrose solution only. The recommended dose of N and K for garlic was applied @ 120: 100 kg/ ha, respectively. Full dose of potassium and half dose of nitrogen were applied as basal dose just before sowing and rest half dose of nitrogen was applied as top dressing in two split doses. To protect the crop from blight and purple blotch the crop was sprayed twice with Diathane M-45 at the rate of 0.25 per cent while for the garlic thrips, the crop was also sprayed twice with Malathion @ 0.1%.

Results and Discussion

It is apparent from the data presented in table 1 that different bio-fertilizers significantly influenced the bulb yield of garlic during both the years. Combined application of *Azotobacter* + PGPR produced significantly maximum bulb yield of 3.73 kg/plot among all the treatment and registered 22.69 per cent higher bulb yield per plot of garlic over control. Spray of thiourea @1000 ppm recorded maximum bulb yield (3.71 kg/plot) and found significantly superior over rest of the treatments except P_1 and P_3 which, were statistically at par to it. The magnitude in increase of bulb yield per plot with the application of thiourea @1000 ppm / ha was 26.62 per cent over control. Different levels of bio-fertilizers had significant influenced on the bulb yield of garlic during course of study. Combined application of *Azotobacter* + PGPR represented significantly maximum bulb yield (207.37 q/ha) over all the treatments and this treatment represented the maximum increase of 22.63 per cent in bulb yield q/ha over control.

Examination of pooled data further revealed that spray of thiourea @1000 ppm recorded significantly maximum bulb yield (206.36 q/ha) over rest of the treatment except P_1 (thiourea @ 500 ppm) and P_3 (SA @ 100 ppm) which found statistically at par to each other, where as it was noted minimum (162.71 q/ha) under control. The magnitude in increase of bulb yield with the application of thiourea @1000 ppm / ha was 26.82 per cent over control.

Table 1: Effect of bio-fertilizers and bio-regulators on bulb and bulb yield

Treatments	Bulb yield kg/plot			Bulb yield q/ha		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Bio-fertilizers						
B_0 (Control No inoculation)	2.95	3.14	3.04	164.00	174.18	169.09
B_1 (*Azotobacter*)	3.37	3.42	3.40	187.20	190.17	188.68
B_2 (PGPR)	3.47	3.55	3.51	193.03	197.15	195.09
B_3 (*Azotobacter* + PGPR)	3.69	3.77	3.73	205.19	209.54	207.37
SEm±	0.07	0.06	0.06	2.96	3.60	2.28
CD (P=0.05)	0.22	0.18	0.18	9.31	10.34	7.03
Bio-regulators						
P_0 (Control water spray)	2.88	2.98	2.93	159.82	165.60	162.71
P_1 (Thiourea @ 500 ppm)	3.57	3.64	3.61	198.29	202.48	200.39
P_2 (Thiourea @ 1000 ppm)	3.67	3.76	3.71	203.76	208.97	206.36
P_3 (Salicylic acid @ 100 ppm)	3.51	3.64	3.58	195.25	202.49	198.87
P_4 (Mepiquat chloride @ 100 ppm)	3.23	3.32	3.28	179.65	184.25	181.95
SEm±	0.05	0.10	0.05	2.98	3.47	2.58
CD (P=0.05)	0.14	0.30	0.14	8.56	10.95	7.30

The increase in bulb yield owing to this treatment may be due to the fact that N and P play an important role in synthesis of chlorophyll and amino acid (Black, 1967) and *Azotobacter* and PGPR ensured the continuous supply of these nutrients, very limited work has been earned out on the use of bio-fertilizers in garlic, therefore, literature reviewed did not provide much relavation on garlic. However, Singh and Pandey (2006) [17], Anonymous (2007) [1], Balemi *et al*. (2007) [2], Bhandari *et al*. (2012) [4], Choudhary *et al*. (2014) [7], Banjare *et al*. (2015) [3] and Sachin *at al*. (2017) [14] in garlic. Maximum bulb yield of garlic was registered with treatment Azotobacter + PGPR both were found significantly inferior to rest of the treatments. Insufficient supply of nutrients along with reduced growth parameters and poor yield attributes might be the reason for lower bulb yield in these treatments.

Examination of pooled data indicated that combined application of *Azotobacter* + PGPR represented significantly maximum the net returns (₹170106) over other treatment. This bio-fertilizer (B_3) had better effect and represented the maximum increase of 36.65 per cent more net returns over control. Analysis of pooled data revealed that spray of thiourea @1000 ppm recorded maximum net returns (₹ 168825) whereas minimum net returns (₹116843) was recorded under control. This treatment (P_2) was found

significantly superior over rest of the treatments except P_1 and P_3 which were statistically at par to it. The magnitude in increase of the net returns with the application of thiourea @1000 ppm / ha was 44.48 per cent over control.

It is apparent from the data presented in table 2 that different levels of bio-fertilizers significantly influenced the B: C ratio of garlic during course of investigation. Analysis of pooled data indicated that combined application of *Azotobacter* + PGPR represented the significantly maximum B:C ratio of (2.16) over other treatment and registered an increase of 35.84 per cent higher B:C ratio over control. Examination of pooled data revealed that spray of thiourea @1000 ppm recorded maximum B:C ratio (2.14) as compared to other treatment. This treatment was found significantly superior over rest of the treatments except P_1 and P_3 which were statistically at par to it. An increase of the B:C ratio with the application of thiourea @1000 ppm / ha was noted 43.62 per cent over control.

Table 2: Effect of bio-fertilizers and bio-regulators on net returns and B: C ratio

Treatments	Net returns (₹/ha)			B:C ratio		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Bio-fertilizers						
B_0 (Control No inoculation)	118376	130586	124481	1.51	1.67	1.59
B_1 (*Azotobacter*)	146066	149626	147846	1.86	1.90	1.88
B_2 (PGPR)	153046	157996	155521	1.95	2.01	1.98
B_3 (*Azotobacter* + PGPR)	167496	172716	170106	2.13	2.19	2.16
SEm±	3663	4499	2734	0.06	0.06	0.04
CD (P=0.05)	11540	12929	8424	0.18	0.16	0.13
Bio-regulators						
P_0 (Control water spray)	113375	120312	116843	1.45	1.53	1.49
P_1 (Thiourea @ 500 ppm)	159337	164362	161850	2.03	2.09	2.06
P_2 (Thiourea @ 1000 ppm)	165700	171950	168825	2.10	2.18	2.14
P_3 (Salicylic acid @ 100 ppm)	155777	164465	160121	1.98	2.09	2.04
P_4 (Mepiquat chloride @ 100 ppm)	137042	142567	139805	1.74	1.82	1.78
SEm±	3819	4060	3234	0.04	0.06	0.04
CD (P=0.05)	10975	12793	9137	0.11	0.19	0.11

It is evident from (Table 2) that better monetary returns from garlic crop with maximum ₹ 189332/- as net returns per hectare and B: C ratio of 2.40 from treatment combination B_3P_2 (application of *Azotobacter* + PGPR with Thiourea @ 1000 ppm) was obtained which was followed by the treatment combination B_3P_1 and B_3P_3 *i.e. Azotobacter* + PGPR along with Thiourea @ 500 ppm and *Azotobacter* + PGPR along with salicylic acid @ 100, respectively. Similar results were found by Bose *et al*. (2008) [5], Pratap *et al*. (2011) [12], Puttaraju *et al*. (2011) [13], Verma and Gupta (2011) [20] and Talware *et al*. (2012) [19] in garlic.

Interaction of bio-fertilizers and bio-regulators on net returns and B: C ratio

The data revealed that application of *Azotobacter* + PGPR along with thiourea @1000 ppm/ha recorded significantly higher net returns (Rs. 189332/ha) of over other treatment combination except B_3P_1, B_3P_3, B_2P_2, B_1P_2 and B_3P_4 which were remained at par (Table 3).

Table 3: Interactive effect of bio-fertilizers and bio-regulators on net returns (/ha)

Treatments	B_0	B_1	B_2	B_3
2016-17				
P_0	109492	111592	114332	118082
P_1	122042	163692	166632	184982
P_2	129092	170342	176832	186532
P_3	116882	163232	163922	179072
P_4	114372	121472	143512	168812
For B at same level of P			SEm±	CD (P=0.05)
			7638	22003
For p at same or diff. level of B			12053	34719
2017-18				
P_0	123492	115342	119182	123232
P_1	127042	168492	171732	190182
P_2	139092	174592	181982	192132
P_3	136732	168132	168722	184272
P_4	126572	121572	148362	173762
For B at same level of P			SEm±	CD (P=0.05)
			8998	25920
For p at same or diff. level of B			13971	40246
Pooled				
P_0	116492	113467	116757	120657
P_1	124542	166092	169182	187582
P_2	134092	172467	179407	189332
P_3	126807	165682	166322	181672

P_4	120472	121522	145937	171287
For B at same level of P			SEm±	CD (P=0.05)
			6468	18273
For p at same or diff. level of B			9886	27929

Interactive effect of different levels of bio-fertilizers and bio-regulators on B:C ratio (Table 4). The data revealed that application of *Azotobacter* + PGPR along with thiourea @1000 ppm/ha recorded significantly higher B:C ratio of over other treatment combination except B_3P_1 (2.38), B_3P_3 (2.31), B_2P_2 (2.28), B_1P_2 (2.19) and B_3P_4 (2.18) which were found statistically at par to each other. Similar results were reported by Singh and Pandey, (2006) [17], Chattoo *et al.* (2007) [6] Bhandari *et al.* (2012) [4] and Sharma (2014) [15].

Table 4: Interactive effect of bio-fertilizers and bio-regulators on B:C ratio

Treatments	B_0	B_1	B_2	B_3
2016-17				
P_0	1.40	1.42	1.46	1.50
P_1	1.56	2.08	2.12	2.35
P_2	1.64	2.16	2.24	2.36
P_3	1.49	2.08	2.09	2.28
P_4	1.46	1.55	1.83	2.15
For B at same level of P			SEm±	CD (P=0.05)
			0.08	0.23
For p at same or diff. level of B			0.15	0.45
2017-18				
P_0	1.58	1.47	1.52	1.57
P_1	1.62	2.14	2.18	2.41
P_2	1.77	2.22	2.31	2.43
P_3	1.74	2.14	2.15	2.34
P_4	1.61	1.55	1.89	2.21
For B at same level of P			SEm±	CD (P=0.05)
			0.11	0.32
For p at same or diff. level of B			0.18	0.52
Pooled				
P_0	1.49	1.45	1.49	1.54
P_1	1.59	2.11	2.15	2.38
P_2	1.70	2.19	2.28	2.40
P_3	1.62	2.11	2.12	2.31
P_4	1.54	1.55	1.86	2.18
For B at same level of P			SEm±	CD (P=0.05)
			0.08	0.22
For p at same or diff. level of B			0.18	0.51

Summary

It may be concluded on the basis of results of two-year experiments that the combined application of *Azotobacter* + PGPR (*Pseudomonas*) along with thiourea @ 1000 was found significantly better in terms of yield, net returns and B: C ratio (223.58 q ha^{-1}, ₹ 189332 and 2.40), respectively. Although, application of (*Azotobacter* + PGPR (*Pseudomonas*) + thiourea @ 500 ppm) and (*Azotobacter* + PGPR (*Pseudomonas*) + salicylic acid @ 100 ppm were found statistically at par to it.

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