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

Ganpat Lal Yadav, SP Singh and Mahendra Yadav

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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 ‘coves’ 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) [10]. 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 sulphhydryl 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) [10]. 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) [6]. 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 cm², 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 kg/ha of garlic thrips, the crop was also protected 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 P3 and P4 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 influence 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 P3 (thiourea @ 500 ppm) and P1 (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.

| Treatments                  | Bulb yield kg/plot | Bulb yield q/ha |
|-----------------------------|--------------------|-----------------|
|                            | 2016-17            | 2017-18         | Pooled    | 2016-17            | 2017-18         | Pooled    |
| **Bio-fertilizers**         |                    |                 |           |                    |                 |           |
| B0 (Control No inoculation) | 2.95               | 3.14            | 3.04      | 164.00             | 174.18          | 169.09    |
| B1 (Azotobacter)            | 3.37               | 3.42            | 3.40      | 187.20             | 190.17          | 188.68    |
| B2 (PGPR)                   | 3.47               | 3.55            | 3.51      | 193.03             | 197.15          | 195.09    |
| B3 (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-regulator**           |                    |                 |           |                    |                 |           |
| P0 (Control water spray)    | 2.88               | 2.98            | 2.93      | 159.82             | 165.60          | 162.71    |
| P1 (Thiourea @ 500 ppm)     | 3.57               | 3.64            | 3.61      | 198.29             | 202.48          | 200.39    |
| P2 (Thiourea @ 1000 ppm)    | 3.67               | 3.76            | 3.71      | 203.76             | 208.97          | 206.36    |
| P3 (Salicylic acid @ 100 ppm)| 3.51              | 3.64            | 3.58      | 195.25             | 202.49          | 198.87    |
| P4 (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) [8] and Sachin et 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 (B3) 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 (P2) was found to be the reason for lower bulb yield in these treatments.
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 P1 and P3, 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 |        |        |       |        |        |       |
| B0 (Control No inoculation) | 118376 | 130586 | 124481 | 1.51 | 1.67 | 1.59 |
| B1 (Azotobacter) | 146066 | 149626 | 147846 | 1.86 | 1.90 | 1.88 |
| B2 (PGPR) | 153046 | 157996 | 155521 | 1.95 | 2.01 | 1.98 |
| B3 (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 |        |        |       |        |        |       |
| P0 (Control water spray) | 113375 | 120312 | 116843 | 1.45 | 1.53 | 1.49 |
| P1 (Thiourea @ 500 ppm) | 159337 | 164362 | 161850 | 2.03 | 2.09 | 2.06 |
| P2 (Thiourea @ 1000 ppm) | 165700 | 171950 | 168825 | 2.10 | 2.18 | 2.14 |
| P3 (Salicylic acid @ 100 ppm) | 155777 | 164465 | 160121 | 1.98 | 2.09 | 2.04 |
| P4 (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 B1P2 (application of Azotobacter + PGPR with Thiourea @ 1000 ppm) was obtained which was followed by the treatment combination B1P1 and B2P1 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) [3], Pratap *et al.* (2011) [12], Puttaraju *et al.* (2011) [13], Verma and Gupta (2011) [20] and Talware *et al.* (2012) [19] in garlic.

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

| Treatments | B0 | B1 | B2 | B3 |
|------------|----|----|----|----|
|            | 2016-17 | | | |
| P0 | 109492 | 111592 | 114332 | 118082 |
| P1 | 122042 | 163692 | 166632 | 184982 |
| P2 | 129092 | 170342 | 176832 | 186532 |
| P3 | 116882 | 163232 | 163922 | 179072 |
| P4 | 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 | | | | |
| P0 | 123492 | 115342 | 119182 | 123232 |
| P1 | 127042 | 168492 | 171732 | 190182 |
| P2 | 139092 | 174592 | 181982 | 192132 |
| P3 | 136732 | 168132 | 168722 | 184272 |
| P4 | 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 | | | | |
| P0 | 116492 | 113467 | 116757 | 120657 |
| P1 | 124542 | 166092 | 169182 | 187582 |
| P2 | 134092 | 172467 | 179407 | 189332 |
| P3 | 126087 | 165682 | 166322 | 181672 |
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$_3$:P$_2$ (2.38), B$_1$:P$_1$ (2.31), B$_2$:P$_2$ (2.28), B$_1$:P$_2$ (2.19) and B$_3$:P$_3$ (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) [18] and Sharma (2014) [19].

| 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) |
| For p at same or diff. level of B | 0.08 | 0.23 |
| **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) |
| For p at same or diff. level of B | 0.11 | 0.32 |
| 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) |
| For p at same or diff. level of B | 0.08 | 0.22 |

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 ppm 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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