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Effect of bio-regulators and bio-fertilizers on growth 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 consisting of four bio-fertilizers (Control, *Azotobacter*, PGPR (*Pseudomonas*) and *Azotobacter* + PGPR (*Pseudomonas*) and five bio-regulators (Control, Thiourea @ 500 ppm, Thiourea @ 1000 ppm, salicylic acid @ 100 ppm and piquet chloride @ 100 ppm). The total 20 treatment combinations were tested in split-plot design with three replications. It was observed that the application of bio-fertilizers *Azotobacter* + PGPR (*Pseudomonas*) significantly increased the plant height at 45 DAP and at harvest as compared to control. The results of the study clearly indicated that foliar application of thiourea @ 1000 ppm to the garlic crop significantly increased the plant height, fresh weight of leaves, leaf area, dry weight of leaves and crop growth rate, being statistically at par with application of thiourea @ 500 ppm and salicylic acid @ 100 ppm.

Keywords: Bio-regulators, bio-fertilizers, growth, garlic, *Allium sativum* L.

Introduction
Garlic is the second most important bulb crop after onion. Botanically it is known as *Allium sativum* which belongs to the family Amaryllidaceae. The economic yield is obtained from these cloves. It is especially rich in protein, carbohydrates and ascorbic acid. Garlic is used in flavoring foods, preparing chutneys, pickles, curry powder, tomato ketchup etc. It also contains phosphorus, potash, calcium, magnesium and a colorless as well as odorless water-soluble amino acid called 'Alin' after crushing of bulb cloves an enzyme alliinase acts upon all in and breaks down to produce Allicin. The principal ingredient of which is odoriferous diallyl-desulphated, which is the major flavoring component of garlic. Garlic extracts and oil have potential uses as an effective insecticide and fungicide in the present scenario of organic farming (Kumara *et al*., 2014) [10]. Allicin present in aqueous extract of garlic reduces blood cholesterol level (Shankaracharya, 1974) [21]. Garlic oil or its juice is recommended to inhale in cases of pulmonary tuberculosis, rheumatism, sterility, impotency, cough and redness of eyes (Pruthi, 1979) [17]. India ranks second in area and third in production of garlic in the world. In India, the major garlic producing states are Madhya Pradesh, Rajasthan, Uttar Pradesh and Gujarat however, In Rajasthan, it is grown extensively in Chittorgarh, Baran, Jodhpur, Jhalawar, Kota, Bondi, Jaipur and Sikar districts. The low productivity of the crop in India and Rajasthan may be due to its unscientific cultivation and lesser care of growers to its nutritional management (Anonymous, 2017) [2]. Bio-fertilizers are the recent sources for fixation of atmospheric nitrogen into 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 bioactivity 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, bio-fertilizers not only supplement the nutrition but also improve the efficiency of applied nutrients (Somani *et al.*, 1990) [25]. Further, *Pseudomonas fluorescence*'s is a common non-pathogenic saprophyte that colonizes in soil, water and on plant surfaces. It produces a soluble greenish fluorescent pigment. It suppresses 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 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) [30]. *Pseudomonas* spp. is ubiquitous bacteria in agricultural soil and has many traits that make them well suited as PGPR. The most effective strain of *pseudomonas* has been *fluorescent pseudomonas* spp. and considerable research is underway globally to exploit the potential of one group of bacteria that belong to *fluorescent pseudomonas* (FLPs). FLPs help in the maintenance of soil health and are metabolically and functionally most diverse (Lata *et al.*, 2002) [11].

Besides nutrients, thiourea also plays an important role in mechanizing yield potentials of the crop in arid and semi-arid regions as it may prove beneficial by inducing stress tolerance. 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 it in various physiological activities of plant is well known. Thiourea regulates the plant growth by maintaining higher photosynthetic rate up to the reproductive stage and increased the yield by improving carbon partitioning towards sink (Anonymous, 1999) [1]. Thiourea is mainly known for its dormancy breaking and germination stimulating effect (Mayer, 1956; Mayer and Poljak off-Mayber, 1958) [12, 13]. The dormancy breaking effect of thiourea was suggested to be related to its growth enhancing effect.

Similarly salicylic acid is positively affecting the growth of the 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) [23]. Salicylic acid is a common plant-produced phenolic compound. Which contributes in the regulation of physiological, biochemical and molecular processes and therefore affects plant growth, development and productivity (Hayat *et al.*, 2010) [6]. However, higher concentrations of salicylic acid had an inhibitory effect. Salicylic acid has been reported to induce flowering in a number of plants. Likewise, Moniqua enhances reproductive organs by allowing plants to direct more energy towards reproductive structures (Wang *et al*., 1995) [28]. Redistribution of assimilates between vegetative and reproductive growth may be one means by which yield can be increased foliar spray with piquet chloride (pix) compound, has interaction on garlic productivity and storability throughout the growth period. The present investigation is therefore an attempt to bridge this knowledge gap to obtain the higher productivity levels of the crop. Bio-fertilizers and bio-regulators were applied as treatments in the present experiment to study the growth of garlic.

Materials and Methods

The present study was carried out at the Department of Horticulture, S.K.N. College of Agriculture, Jobner during *Rabi*, 2016-17 and 2017-18. The experiment was comprised of twenty treatment combinations with four bio-fertilizers B_0 (Control-no inoculation), B_1 (*Azotobacter*) B_2 (PGPR-*Pseudomonas*) and B_3 (*Azotobacter* + PGPR) and inoculation with Bio-regulators P_0 (Control-water spray, P_1 (Thiourea 500 ppm), P_2 (Thiourea 1000 ppm), P_3 (Salicylic acid 100 ppm) and P_4 (Moniqua chloride 100 ppm). The experiment was laid out in Split Plot Design and replicated 3 times. The treatments were randomly allotted to different plots using random number table of Fisher and Yates (1963) [31]. Bio-regulators: thiourea, salicylic acid and Moniqua chloride were applied as foliar spray in the plots as per treatments. Thiourea was sprayed @ 500 ppm and 1000 ppm at 30 and 45 DAS. Similarly, salicylic acid @ 100 ppm and Moniqua chloride was also sprayed @ 100 ppm at 30 and 45 DAS in respective plots. Application of bio-fertilizers was done as per treatment. For this 125 g of Jaggery was mixed in one liter 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 percent 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.

Results and Discussion

Effect of Bio-fertilizers

Different levels of bio-fertilizers significantly influenced the plant height of garlic at 45 days after planting and at harvest on a pooled basis. Combined application of *Azotobacter* + PGPR represented the significantly maximum (33.94 cm) and (37.70 cm) plant height at 45 DAP and at harvest respectively over control. However, Kore *et al*. (2006) [9] revealed that *Azotobacter* + PGPR /ha significantly attained higher values of plant height and number of leaves per plant in garlic. The bio-fertilizers had better effect and registered the maximum increase the plant height 22.48 percent at 45 DAP and 23.60 percent at harvest over control. Number of leaves (46.01%) per plant registered more under treatment B_3 over control. Combined application of same treatment represented significantly maximum (22.37, 24.50 and 26.88 g) fresh weight of leaves at 30, 45 and 60 DAP over rest of the treatment and had better effect registered 28.41, 26.15 and 25.08 percent increase in fresh weight of leaves over control at 30, 45 and 60 DAP, respectively. Maximum leaf area (107.70 cm^2) at 45 DAP was observed under same treatment over rest of the treatments and percentage wise maximum increase of 46.05 percent higher over control. maximum dry weight of leaves (5.66, 5.82 and 5.98 g) at 30, 45 and 60 DAP over all the treatments. This treatment represented the maximum increase of 37.04, 36.61 and 39.06 percent over control. combined application of *Azotobacter* +PGPR represented the significantly maximum crop growth rate (5.36 and 5.39) at 30-45 and 45-60 DAP over rest of the treatment. This treatment registered an increase of 40.68 and 31.78 percent more crop growth rate over control. Balemi *et al*. (2007) [3], in other crops, Prabhu *et al*. (2002) [16] obtained tallest plant and maximum leaves in okra with the application of *Azotobacter* + PGPR /ha. Similarly, Singh and Pandey (2006) [24] concluded that combined use of FYM, chemical fertilizers and bio-

fertilizers would be a sound integrated nutrient management practice for production of onion.

Effect of Bio-regulators

Spray of thiourea @ 1000 ppm recorded maximum plant height of 33.39 cm and 37.05 cm at 45 DAP and at harvest, whereas minimum plant height of 26.98 cm, 28.26 cm were recorded under control. The magnitude in increase of plant height at 45 DAP and at harvest with the application of thiourea @ 1000 ppm / ha was 23.75 and 31.10 percent over control, respectively. The maximum fresh weight of leaves at 30, 45 and 60 DAP (22.02, 24.07 and 26.25 g) and dry weight of leaves (5.54 g, 5.71 g and 5.81 g) under same treatment whereas, minimum fresh weight of leaves (17.13, 18.99 and 21.25 g) and dry weight of leaves (4.06, 4.22 and 4.25) at 30, 45 and 60 DAP was recorded under control. Maximum leaf area at 45 DAP (103.03) recorded maximum under same treatment whereas minimum (73.53) was recorded under control and 40.11 h increment higher over control. The magnitude in increase of dry weight of leaves at 30, 45 and 60 DAP with the application of thiourea @1000 ppm / ha was noted 36.45, 35.30 and 36.70 percent over control, respectively. Application of bio-regulators had significant influence on the crop growth rate at 30-45 and 45-60 DAP of garlic during experimentation. Spray of thiourea @ 1000 ppm recorded maximum crop growth rate (5.26 and 5.29) at 30-45 and 45-60 DAP under treatment P_2, whereas minimum crop growth rate (3.84 and 3.81) at 30-45 and 45-60 DAP were recorded under control. The magnitude in increase of crop growth rate at 30-45 and 45-60 DAP with the application of same bio-regulator as 36.97 and 38.84 percent were noted over control, respectively significantly superior over rest of the treatments. Similar, results were obtained by Wani and Konde (1998) [29], Hossain *et al*. (1998) [7], Mengistu and Singh (1999) [14], Turk and Tawaha (2001) [27], Jayathilake *et al*. (2002) [8], Banafar *et al*. (2004) [4], Reddy and Reddy (2005) [18], Talware *et al*. (2012) [26], Mohd *et al*. (2011) [15], Sharma *et al*. (2013) [22] and Sachin *et al*. (2017) [20] in garlic. Reduced growth stature of garlic (plant height, length and width of leaf, fresh and dry weight/plant and leaf area index) was noticed with the *Azotobacter* + PGPR which might be due to supply of Insufficient quantity of nutrients, denying satisfactory level of growth due to retarded cell division and multiplication.

Conclusion

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 to be significantly better in terms of growth and yield. Although, application of (*Azotobacter* + PGPR (*Pseudomonas*) + thiourea @ 500 ppm) and (*Azotobacter* + PGPR (*Pseudomonas*) + salicylic acid @ 100 ppm were found statistically at par to it.

Hence, application of *Azotobacter* + piper (*Pseudomonas*) and thiourea @ 500 ppm (b_3p_1) to garlic crops in semi-arid region is recommended.

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