***Original Research Article***

**Response of biofertilizers and micronutrients on growth and yield of garlic**

**ABSTRACT**

A field experiment was conducted during winter season *(Rabi*) in the year 2023-24 at the Vegetable research farm of Bihar Agricultural University, Sabour, Bhagalpur, Bihar. The experiment was laid out in factorial RBD having three replications. The treatment factors consisted of two biofertilizers *viz.,* PSB, Azotobacter and their combination and two micronutrients *viz.,*0.2 % and 0.4 % zinc sulphate and 0.2% and 0.4% borax. Biofertilizers were applied via seed treatment and micronutrients by way of foliar application. The application of biofertilizers and micronutrients had a significant effect on growth and yield of garlic over control. The treatment B3M2 (PSB+Azotobacter+0.4% zinc sulphate) recorded maximum plant height (68.47 cm), number of leaves (11.23), leaf length (49.58 cm), leaf width (1.61 cm), fresh weight of bulb (35.59g), number of cloves per bulb (48.77), fresh weight of 50 cloves (40.12 g), bulb yield (2.62 kg/plot) while minimum were recorded in control.

**Keywords:-Biofertilizer, Micronutrient, Garlic,** **chemical fertilizers**

## Introduction

“Garlic (*Allium sativum* L.), belonging to the family Amaryllidaceae, is the second most widely cultivated bulb crop after onion. It has long been recognized as a valuable spice and condiments throughout India. Garlic possesses highly nutritive value and it is considered as a rich source of carbohydrate, proteins and phosphorus.The present day modern agriculture depends heavily on use of chemical fertilizers for boosting crop yield. The continuous use of higher doses of chemical fertilizer deteriorates the soil health and microorganisms’ activity. So, to maintain the soil fertility status, soil health and microorganism activity of soil for longer duration use of biofertilizers is necessary. A biofertilizer is a substance which contain microorganism when applied to seed, plant surface, or soil, colonizes the rhizosphere or the interior of the plant and promote growth by increasing the supply or availability of primary nutrients to the host plant” (Vessey et al. 2003). “Biofertilizers add nutrients through the natural processes of nitrogen fixation, solubilizing phosphorus and stimulating plant growth through the synthesis of growth promoting substances, Micronutrients are just as important in plant nutrition as the major nutrients. Micronutrients are more beneficial and play important role in plants such as Zn is involved in many enzymatic activities of plants. It helps in synthesis of tryptophan, a compound in some proteins needed for the production of growth hormones such as IAA and GA, which is essential for normal cell division and helps in the formation of chlorophyll. Boron is absorbed by plant in the form of boric acid (H3BO3). It plays an important role in the development and growth of new cells in plant meristem. It also acts as regulator of K/Ca ratio in plants and is necessary for the translocation of sugar, starch, phosphorus and synthesis of amino acid and proteins. Boric acid increases bulb size and bulb yield as well as the TSS content” (Srivastava et al., 2005).

## Materials and Methods

The field experiment was conducted during winter (*Rabi*) season of 2023-24 at the research farm of Bihar Agricultural University, Sabour, Bhagalpur, Bihar, located at a longitude of 87º 2’ 42” East and latitude of 25º15’40 North. It is situated at an altitude of 45.57 meter above mean sea level in the heart of the vast Indo-Gangetic plains of North-eastern India. The experimental plot had well drained sandy loam soil of pH 7.2 with good fertility and levelled surface. The climate of this place is tropical to sub-tropical with slight semi-arid nature and is characterized by very dry summer, moderate rainfall and very cold winter. Plots of 1.5 × 1.0 m size were prepared for cultivation of garlic. The distance between plant to plant as well as row to row was kept at 15 × 10 cm. Thus, 100 plants were accommodated in each plot. The experiment was laid out in factorial RBD having three replications. The treatment factors consisted of 2 biofertilizers viz., PSB, Azotobacter and their combination and 2 micronutrient viz., 0.2 % and 0.4 % zinc sulphate and 0.2% and 0.4% borax with the total 20 treatments. Biofertilizers were applied *via* seed treatment and micronutrients via foliar application. Treatment combination were as followed (B0MO)Control,(B0M1),Control + 0.2% Zinc sulphate, (B0M2)Control + 0.4% Zinc sulphate, (B0M3)Control + 0.2% Borax, (B0M4)Control + 0.4% Borax, (B1M0)PSB + Control, (B1M1)PSB + 0.2% Zinc sulphate, (B1M2 )PSB + 0.4% Zinc sulphate, (B1M3)PSB + 0.2% Borax, (B1M4)PSB + 0.4% Borax, (B2M0) Azotobacter + Control, (B2M1)Azotobacter + 0.2% Zinc sulphate, (B2M2)Azotobacter + 0.4% Zinc sulphate, (B2M3)Azotobacter + 0.2% Borax, (B2M4) Azotobacter + 0.4% Borax,(B3M0)PSB + Azotobacter + Control, (B3M1)PSB + Azotobacter + 0.2% Zinc sulphate, (B3M2)PSB + Azotobacter + 0.4% Zinc sulphate, (B3M3)PSB + Azotobacter + 0.2% Borax, (B3M4)PSB + Azotobacter + 0.4% Borax. All the growth and yield attributes data were collected with proper instruments or methods.

## Result and Discussion

**Growth attributes**

According to the present study, foliar application of micronutrients and biofertilizer inoculation showed a significant increase in growth attributes in comparison to control. The maximum value of growth attributes *i.e* plant height (68.470 cm),(**Table1),**number of leaves per plant (11.230),(**Table 2),**length of leaf (49.577 cm),(**Table 3),** width of leaf (1.610 cm), (**Table 4),**were recorded with the application of PSB+ Azotobacter+ 0.4% ZnSo4 (B3M2) and minimum was recorded under control (B0M0). These results are in conformity with the findings of Ramakrishnan and Selvakumar (2012), Mahfouz and Sharaf-Eldin. (2007), Bareth. (1998). The inoculation of biofertilizers and foliar spraying of micronutrients may be the cause of the rise in plant growth indices. Azotobacter plays important role in growth attributes by making nitrogen in available form for plants which is required in large amount. It improves root development and produces phytohormones required by plants for their growth, PSB may have improved the quantity of phosphorus that was accessible in the root zone for plant growth and development. These bacteria have the ability to mineralise organic phosphorus into a soluble state in addition to solubilising phosphate. The rhizosphere is where these reactions occur, and the microorganisms release more phosphorus into the soil, which is necessary for their healthy growth and metabolism.It also produces growth promoting substances, like auxins, gibberellins, cytokinin etc. which influence the plant growth parameters by enhancing cell division, cell elongation and thus increasing the metabolic activity. The micronutrients (Zn) produced the highest value of vegetative growth in addition to biofertilizers since they are essential for numerous physiological processes and plant cellular development. Additionally, it plays a crucial function in enhancing plant growth by facilitating the biosynthesis of endogenous hormones, which strengthen plant cell walls, encourage plant growth, and facilitate the movement of glucose from leaves to other plant components (Battal, 2004). Numerous scientists have also noted similar patterns: El-Tohamy et al. (2009), Sliman et al. (1999), and El-Gamelli (2000) in onion.**Yield and Yield attributes**

The fresh weight of bulb, number of cloves per bulb, fresh weight of 50 cloves, and bulb yield per plot increased significantly with application of biofertilizers and micronutrients over control. The maximum values of yield and yield attributes *i.e.* fresh weight of bulb (35.590 g),(**Table 5),**number of cloves per bulb (48.773 cloves),(**Table 6)**, fresh weight of 50 cloves (40.117 g), (**Table 7)**and bulb yield per plot (2.623 kg)(**Table 8),**was recorded with the inoculation of PSB+ Azotobacter+ 0.4% ZnSo4 (B3M2)and minimum was recorded under control (B0M0).The increase in yield and yield attributes by the application of biofertilizer and micronutrient might be due to sufficient availability of nitrogen and phosphorus by solubilisation which increased uptake of nutrients and its effective utilization for efficient metabolism. It also helps in synthesis of carbohydrates, greater vegetative growth and subsequent partitioning and translocation from leaf (source) to the head (sink). It also facilitates release of energy rich organic compounds by the biofertilizers which ultimately increased auxin activities, growth and activity of microbial saprophytes and phosphates activity which ultimately influenced the yield and yield attributes. Furthermore, the micronutrient zinc (Zn) may have affected the production of certain growth hormones in plants due to its association with water relations, involvement in auxin metabolism (such as tryptophane synthetase and tryptomine metabolism), influence on the activity of dehydrogenase enzymes (such as pyridine nucleotide, glucose-6 phosphate, and triose phosphate), and synthesis of tryptophane, a protein compound required for the synthesis of growth hormones like IAA and GA. Similar findings were recorded by Noggle and Fritz. (1980), Vimla and Natarajan (2000) in pea, Raghav and Sharma (2003) in tomato, Abd-El-Moneem et al. (2005) in garlic Mahfouz and Sharaf-Eldin (2007) in fennel, Upadhyay et al. (2012) in cabbage.

 **Conclusion**

On the basis of results and discussion made, it may be concluded that application of PSB + Azotobacter + Zn 0.4 % (B3M2) was found to be outstanding, being superior to rest of the treatment in respect to all growth and most of the yield parameters having highest yield of 174.87 q/ha followed by the treatment PSB + Azotobacter + Borax 0.4 % (B3M4). Therefore the treatment, PSB + Azotobacter + Zn 0.4 % (B3M2) may be recommended for higher yield performance of garlic crop. Moreover, the inputs being organic, the soil health is also not adversely affected.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatment** | **Control****(M0)** | **Zinc (0.2%)****(M1)** | **Zinc (0.4%)****(M2)** | **Boron (0.2%)****(M2)** | **Boron (0.4%)****(M4)** | **MEAN** |
| **Control (B0)** | 50.850 | 51.180 | 53.260 | 51.077 | 52.640 | 51.801 |
| **PSB (B1)** | 53.240 | 54.760 | 58.850 | 56.120 | 55.650 | 55.724 |
| **Azotobacter (B2)** | 53.363 | 57.650 | 58.600 | 57.660 | 57.820 | 57.019 |
| **PSB+Azoto (B3)** | 52.047 | 58.420 | 68.470 | 59.280 | 66.750 | 60.993 |
| **MEAN** | 52.375 | 55.503 | 59.795 | 56.034 | 58.215 |  |
|  | **Biofertilizer** | **Micronutrient** | **Biofertilizer×Micronutrient** |  |  |
| **SEM (±)** | 0.764 | 0.854 | 1.709 |  |  |
| **C.D at 5%** | 2.196 | 2.455 | 4.910 |  |  |
| **C.V** | 5.25 |

**Table 1: Effect of biofertilizers and micronutrients on plant height (cm)**

**Table 2: Effect of biofertilizers and micronutrients on number of leaves**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatment** | **Control****(M0)** | **Zinc (0.2%)****(M1)** | **Zinc (0.4%)****(M2)** | **Boron (0.2%)****(M2)** | **Boron (0.4%)****(M4)** | **MEAN** |
| **Control (B0)** | 8.493 | 8.543 | 8.877 | 8.530 | 8.777 | 8.644 |
| **PSB (B1)** | 8.870 | 9.100 | 9.643 | 9.287 | 9.223 | 9.225 |
| **Azotobacter (B2)** | 8.890 | 9.490 | 9.613 | 9.493 | 9.517 | 9.401 |
| **PSB+Azoto (B3)** | 8.687 | 9.590 | 11.230 | 9.697 | 10.910 | 10.023 |
| **MEAN** | 8.735 | 9.181 | 9.841 | 9.252 | 9.607 |  |
|  | **Biofertilizer** | **Micronutrient** | **Biofertilizer×Micronutrient** |  |  |
| **SEM (±)** | 0.128 | 0.143 | 0.286 |  |  |
| **C.D at 5%** | 0.368 | 0.411 | 0.823 |  |  |
| **C.V** | 5.32 |

**Table 3: Effect of biofertilizers and micronutrients on length of leaf (cm)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatment** | **Control****(M0)** | **Zinc (0.2%)****(M1)** | **Zinc (0.4%)****(M2)** | **Boron (0.2%)****(M2)** | **Boron (0.4%)****(M4)** | **MEAN** |
| **Control (B0)** | 36.253 | 36.483 | 37.890 | 36.413 | 37.483 | 36.905 |
| **PSB (B1)** | 37.877 | 38.840 | 41.180 | 39.653 | 39.373 | 39.385 |
| **Azotobacter (B2)** | 37.957 | 40.527 | 41.043 | 40.533 | 40.617 | 40.135 |
| **PSB+Azoto (B3)** | 37.083 | 40.947 | 49.577 | 41.403 | 47.887 | 43.379 |
| **MEAN** | 37.293 | 39.199 | 42.423 | 39.501 | 41.340 |  |
|  | **Biofertilizer** | **Micronutrient** | **Biofertilizer×Micronutrient** |  |  |
| **SEM (±)** | 0.675 | 0.755 | 1.509 |  |  |
| **C.D at 5%** | 2.180 | 2.437 | 4.874 |  |  |
| **C.V** | 6.54 |

**Table 4: Effect of biofertilizers and micronutrients on width of leaf (cm)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatment** | **Control****(M0)** | **Zinc (0.2%)****(M1)** | **Zinc (0.4%)****(M2)** | **Boron (0.2%)****(M2)** | **Boron (0.4%)****(M4)** | **MEAN** |
| **Control (B0)** | 1.230 | 1.237 | 1.287 | 1.237 | 1.273 | 1.253 |
| **PSB (B1)** | 1.287 | 1.317 | 1.397 | 1.347 | 1.337 | 1.337 |
| **Azotobacter (B2)** | 1.287 | 1.373 | 1.393 | 1.373 | 1.380 | 1.361 |
| **PSB+Azoto (B3)** | 1.257 | 1.390 | 1.610 | 1.407 | 1.580 | 1.449 |
| **MEAN** | 1.265 | 1.329 | 1.422 | 1.341 | 1.393 |  |
|  | **Biofertilizer** | **Micronutrient** | **Biofertilizer×Micronutrient** |  |  |
| **SEM (±)** | 0.018 | 0.020 | 0.041 |  |  |
| **C.D at 5%** | 0.052 | 0.058 | 0.117 |  |  |
| **C.V** | 6.95 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatment** | **Control****(M0)** | **Zinc (0.2%)****(M1)** | **Zinc (0.4%)****(M2)** | **Boron (0.2%)****(M2)** | **Boron (0.4%)****(M4)** | **MEAN** |
| **Control (B0)** | 26.280 | 26.487 | 27.740 | 26.430 | 27.377 | 26.863 |
| **PSB (B1)** | 27.730 | 28.580 | 30.670 | 29.310 | 29.060 | 29.070 |
| **Azotobacter (B2)** | 27.803 | 30.090 | 30.550 | 30.090 | 30.170 | 29.741 |
| **PSB+Azoto (B3)** | 27.017 | 30.460 | 35.590 | 30.870 | 34.970 | 31.781 |
| **MEAN** | 27.208 | 28.904 | 31.138 | 29.175 | 30.394 |  |
|  | **Biofertilizer** | **Micronutrient** | **Biofertilizer×Micronutrient** |  |  |
| **SEM (±)** | 0.444 | 0.497 | 0.994 |  |  |
| **C.D at 5%** | 1.274 | 1.424 | 2.847 |  |  |
| **C.V** | 5.87 |

 **Table 5: Effect of biofertilizers and micronutrients on fresh weight of bulb (g)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatment** | **Control****(M0)** | **Zinc (0.2%)****(M1)** | **Zinc (0.4%)****(M2)** | **Boron (0.2%)****(M2)** | **Boron (0.4%)****(M4)** | **MEAN** |
| **Control (B0)** | 35.610 | 35.837 | 37.223 | 35.770 | 36.820 | 36.252 |
| **PSB (B1)** | 37.210 | 38.150 | 40.453 | 38.953 | 38.680 | 38.689 |
| **Azotobacter (B2)** | 37.283 | 39.810 | 40.320 | 39.813 | 39.903 | 39.426 |
| **PSB+Azoto (B3)** | 36.433 | 40.223 | 48.773 | 40.673 | 46.090 | 42.439 |
| **MEAN** | 36.634 | 38.505 | 41.693 | 38.803 | 40.373 |  |
|  | **Biofertilizer** | **Micronutrient** | **Biofertilizer×Micronutrient** |  |  |
| **SEM (±)** | 0.569 | 0.636 | 1.273 |  |  |
| **C.D at 5%** | 1.630 | 1.823 | 3.645 |  |  |
| **C.V** | 5.63 |

**Table 6: Effect of biofertilizers and micronutrients on number of cloves per bulb**

**Table 7: Effect of biofertilizers and micronutrients on fresh weight of 50 cloves**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatment** | **Control****(M0)** | **Zinc (0.2%)****(M1)** | **Zinc (0.4%)****(M2)** | **Boron (0.2%)****(M2)** | **Boron (0.4%)****(M4)** | **MEAN** |
| **Control (B0)** | 29.510 | 29.713 | 30.857 | 29.653 | 30.527 | 30.052 |
| **PSB (B1)** | 30.843 | 31.630 | 33.533 | 32.293 | 32.067 | 32.073 |
| **Azotobacter (B2)** | 30.910 | 33.000 | 33.423 | 33.007 | 33.077 | 32.683 |
| **PSB+Azoto (B3)** | 30.200 | 33.343 | 40.117 | 33.717 | 39.553 | 35.386 |
| **MEAN** | 30.366 | 31.922 | 34.483 | 32.168 | 33.806 |  |
|  | **Biofertilizer** | **Micronutrient** | **Biofertilizer×Micronutrient** |  |  |
| **SEM (±)** | 0.435 | 0.487 | 0.974 |  |  |
| **C.D at 5%** | 1.248 | 1.395 | 2.790 |  |  |
| **C.V** | 5.19 |

**Table 8: Effect of biofertilizers and micronutrients on bulb yield per plot**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatment** | **Control****(M0)** | **Zinc (0.2%)****(M1)** | **Zinc (0.4%)****(M2)** | **Boron (0.2%)****(M2)** | **Boron (0.4%)****(M4)** | **MEAN** |
| **Control (B0)** | 1.600 | 1.620 | 1.743 | 1.617 | 1.707 | 1.657 |
| **PSB (B1)** | 1.743 | 1.827 | 2.037 | 1.900 | 1.877 | 1.877 |
| **Azotobacter (B2)** | 1.750 | 1.977 | 2.023 | 1.980 | 1.983 | 1.943 |
| **PSB+Azoto (B3)** | 1.677 | 2.017 | 2.623 | 2.057 | 2.463 | 2.167 |
| **MEAN** | 1.693 | 1.860 | 2.107 | 1.888 | 2.008 |  |
|  | **Biofertilizer** | **Micronutrient** | **Biofertilizer×Micronutrient** |  |  |
| **SEM (±)** | 0.0261 | 0.0291 | 0.0583 |  |  |
| **C.D at 5%** | 0.075 | 0.083 | 0.167 |  |  |
| **C.V** | 5.28 |

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.

2.

3.

**References**

Abd-El-Moneem KMH, Fawaz SBM, Saeed FA, El-Shehaby AI (2005) Effect of clove size and certain micronutrients on Fusarium basal rot of garlic. *Assiut Journal of Agricultural Sciences*; 36(4): 163-175.

Bareth V (1998) Effect of phosphorus, molybdenum and PSB on growth and yield of cowpea, M.Sc. Thesis, Submitted to Rajasthan Agricultural University, Bikaner, Campus- Jobner.

Battal P(2004) Effect of some mineral nutrients on gibbrellic acid levels in maize plants.*Econ. Bot.*, 58(2):195-203.

El-Gamelli and El-Hadi H(2000) Effect of some foliarfertilizers application on growth, bulb yield, quality and storage ability of Giza 20 onion cultivar (*Allium cepa* L.).*Ann. Agric. Sci., Moshtohor*, 38(3): 1727-1737.

El-Tohamy WA, Khalid AK, El-Abagy HM, Abou-Hussein SD (2009) Essential Oil, Growth and Yield of Onion (*Allium cepa* L.) In Response to Foliar Application of Some Micronutrients. *Aust. j. basic appl. sci*., 3(1): 201-205.

Mahfouz SA and Sharaf-Eldin MA (2007) Effect of Mineral vs. Biofertilizer on Growth, Yield and Essential Oil Content of Fennel (*Foeniculum vulgare* Mill.).*Int. Agrophys* , 21, 361-366.

Mahfouz SA and Sharaf-Eldin MA (2007) Effect of Mineral vs. Biofertilizer on Growth, Yield and Essential Oil Content of Fennel (*Foeniculum vulgare* Mill.).*Int. Agrophys* , 21, 361-366.

Noggle GR and Fritz GT (1980) Introductory Plant Physiology, *Prentice Hall of India Pvt. Ltd. Publication*, New Delhi.

Raghav M and Sharma RD (2003) Growth and yield in tomato, okra, vegetable pea cropping sequence as affected by level and method of zinc application.*Progress. Hortic*., 35(1): 96-99.

Ramakrishnan K and Selvakumar G(2012) Effect of biofertilizers on enhancement of growth and yield on tomato (*Lycopersicum esculantum* Mill.).*Int. j. botany res.,* 2(4): 20-23.

Sliman ZT, Abdelhakim MA, Omran AA (1999) Response of onion to foliar application of some micronutrients.*Egypt. J. Agric. Res.,* 77(3): 983-993.

Srivastava R, Agarwal A, Tiwari RS, Kumar S (2005) Effect of micronutrients, zinc and boron on yield, quality and storability of garlic (*Allium sativum* L). *Indian J. Agric. Sci.,*75(3): 157-159.

Upadhyay AK, Bahadur A, Singh J (2012) Effect of organic manures and biofertilizers on yield, dry matter partitioning and quality traits of cabbage (*Brassica oleracea var.capitata*). *Indian J. Agric. Sci.*, 82 (1): 31-34.

Vessey JK (2003) Plant Growth Promoting Rhizobacteria as Biofertilizers. *Plant and Soil*, 255, 571-586.

Vimala B and Natarajan S (2000) Effect of nitrogen, phosphorus and biofertilizers on pod characters, yield and quality in pea (*Pisum sativum* L. spp. *hortense*) *South Indian Horticulture*, 48: 60-63.