Response of Biofertilizers and Primary Nutrients on Growth and Yield of Garlic (*Allium sativum* L.) in New Alluvial Soil of West Bengal

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Authors’ contributions

This work was carried out in collaboration among all authors. Author SD designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author FHR managed the analyses of the study and interpreted the results. Authors SM and KN managed the literature searches and corrected the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The experiment was carried out at Horticulture Research Station, Mondouri, BCKV, Mohanpur, Nadia, West Bengal during the years 2014-15 and 2015-16. The cloves were planted during middle of the October in 2.0 x 1.5 m plot at 20 x 15 cm spacing in with three replications. Two nitrogen fixing biofertilizers (*Azospirillum lipoferum* and *Azotobacter chroococcum*), two phosphatic biofertilizers (Vesicular arbuscular mycorrhiza - *Glomus fasciculatum*) and phosphate solubilising bacteria (*Bacillus polymixa*) and one potassic solubilizer (*Fratulia aurantea*) were included. Biofertilizers were applied @ 6 g per plot with 250 g well rotten Farm yard manure. Three levels of recommended dose of NPK i.e., 100%, 75% and 50% were included. Two way combinations of both nitrogenous and phosphatic biofertilizers were followed in Total 12 treatments along with

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control. Quantitative attributes like plot yield (2.85 kg/3 m²) and projected yield (7.12 t/ha) were noticed in NPK (100%) + Azospirillium + PSB + K solubilizer. Looking to economics of various treatments, maximum net return (Rs 165,043) and B:C ratio (1.55) was obtained from NPK (100%) + Azospirillium + PSB + K solubilizer. Whereas, minimum B:C ratio (0.60) was recorded under NPK (50%) + Azotobacter + VAM + K solubilizer. These results suggested that the optimum production of garlic can be obtained with combined application of 100% NPK and biofertilizers (Azotobacter @ 5 kg/ha + PSB @ 5 kg/ha). The results also indicate the scope of reduction of 25% of inorganic fertilizer through inoculations of biofertilizers.

Keywords: Azotobacter; Azospirillium; PSB; potassium solubilizer; VAM; yield; garlic.

1. INTRODUCTION

Garlic (Allium sativum L.) is one of the most important bulb crop after onion in India and its belongs to family Alliaceae. The bulb of garlic is of a compound nature, consisting of numerous bulb lets, so-called cloves, of different size, the whole surrounded by layers of white scale leaves. Garlic is used as a seasoning in many foods worldwide; without garlic, many of our popular dishes would lack the flavor and character that make them favourites. Its volatile oil has many sulphur containing compounds that are responsible for the strong odour, its distinctive flavour and pungency as well as for its healthful benefits [1]. Garlic has some antifungal, antimicrobial, insecticidal and other medicinal properties. It has hypoglycaemic (capable of lowering blood sugar) properties. Garlic therapy has also been suggested in flatulence, constipation, faulty digestion, inadequate food intake, chronic coughs, leprosy and many other diseases [2].

High nitrogen fertilizer applications have also caused soil salinization and acidification [3,4]. Biofertilizers can play an important role in increasing availability of nitrogen and phosphorous, by improving biological fixation of atmospheric nitrogen or by solubilization of scarcely soluble phosphates [5,6]. Among the species mostly applied as biofertilizers can be listed Azotobacter, Azospirillum for N-fixing while several Pseudomonas strains are used to solubilise phosphorous and to increase soil fertility and its biological activities. Therefore, keeping in view the above facts in mind, an attempt has been made in the present investigation to study the effect of Biofertilizers and NPK on yield of garlic and nutrient availability of soil.

Availability of nitrogen is important for growing plants. It is a main constituent of protein and nucleic acid molecules. It is also a part of chlorophyll molecules. Phosphorus is indispensable constituent of nucleic acids, phospholipids and several enzymes. It is also needed for the transfer of energy within the plant system and is involved in its various metabolic activities. Phosphorus has its beneficial effect on early root development, plant growth, yield and quality [7]. Potassium plays a vital role in plant metabolism such as photosynthesis, translocation of photosynthates, regulation of plant pores, activation of plant catalyst and resistance against pests and diseases. Potassium improves colour, glossiness and dry matter accumulation besides improving keeping quality of the crop [8]. Plant nutrition is one of the key factors influencing the growth and yield of crop plants. Chemical fertilizers are jeopardizing the environment through nitrate poisoning and exterminating soil microflora by adversely altering the chemical and physical properties of soil. This has created huge problems and agriculture in India ceases to be sustainable. Thus, biofertilizers offer an economically attractive and ecologically sustainable means of reducing external inputs and improving the quality and quantity of natural land resources. Keeping in view the benefits of biofertilizer on nutrient management, the present investigation was undertaken to find out the effect of biofertilizers with graded levels of inorganic fertilizers on growth and yield of garlic.

2. MATERIALS AND METHODS

The present investigation was undertaken during the rabi (winter) season of two consecutive years i.e., 2014-15 and 2015-16 at HRS, Mondouri, B.C.K.V, Nadia, West Bengal. The soil of the experimental field was Gangetic alluvial. The medium to bigger cloves were planted during middle of October in 2.0 x 1.5 m plot at 20 x 15 cm spacing during both the years. The experiment was laid out in Randomised Block Design with three replications. Two nitrogen fixing bioinocula (Azospirillum lipoferum and Azotobacter chroococcum), a phosphate solubilizing bacterium (Bacillus polymixa) thereby
PSB) and one potassium solubilizer (Fratetria aurantea) with a concentration of CFU: 5 x 10^7 cells/g of powder, pH: 6.5-7.5 and two phosphatic biofertilizers based on arbuscular mycorrhizal fungi- (Glomus fasiculatum, there by VAM with a concentration of 100 g of finished product with minimum 60 spores per gram, pH: 6-7.5) were included. Biofertilizers were tested @ 6 g per plot with 250 g mature farmyard manure (FYM). Three levels of recommended dose of NPK i.e., 100%, 75% and 50% were included. Two way combination of both nitrogenous and phosphatic biofertilizers were followed with each level of inorganic fertilizers which results in 12 treatment combination having potassium mobilize common to all treatment. Full dose of recommended fertilizer applied alone was considered as control.

All experimental plots received a uniform dose of FYM at 20 tonnes per hectare. The recommended dose of fertilizer is 150 kg N, 125 kg P_{2}O_{5} and 150 kg K_{2}O per hectare. In biofertilizer combinations the FYM, full dose of P_{2}O_{5} and K_{2}O and ½ dose of nitrogen were applied three weeks after application of biofertilizers and remaining half dose of nitrogen were applied 65 days after planting (DAP) as top dressing. The observations were recorded on five randomly selected plants from each plot on different growth and yield parameters. The observation regarding the plant height and leaf number were recorded at 60 and 120 (DAP). The crop was harvested during end of March. Data recorded on different parameters of garlic for both the years were pooled together and analyzed statistically to express the result. The significance of different treatment of variation was tested by Fisher and Snedecor's latest at a probability of 0.05. For the determination of critical difference at 5% level of significance was considered.

While calculating the Gross cost, price of seed bulb; costs of chemical fertilizers, FYM, biofertilizers and labour charges were accounted, whereas, Gross return was calculated taking selling price of garlic as rate fixed by the University. Benefit:Cost (B:C) ratio has been calculated on the basis of following formula: Benefit:Cost ratio = Gross return/Gross cost.

3. RESULTS AND DISCUSSION

The results are presented in Table 1., The treatment with the best result for the different measured parameters is following listed: neck thickness (1.08 cm) was observed in NPK (100%) + Azotobacter + VAM + K solubilizer; number of cloves/bulb (32.86) under NPK (100%) + Azospirillium + VAM + K solubilizer; weight of cloves (Large) (1.12 g) in NPK (100%) + Azospirillium + PSB + K solubilizer; yield (0.95 kg/m²) and projected yield (7.12 t/ha) were observed in plants raised under NPK (100%) + Azospirillium + PSB + K solubilizer. The plants raised with NPK (100%) + Azotobacter + PSB + K solubilizer recorded maximum plant height (75.42 cm) and maximum number of leaves/plant (11.45) was observed in NPK (100%) + Azospirillium + PSB + K solubilizer. The maximum projected yield (7.12 t/ha) was recorded in NPK (100%) + Azospirillium + PSB + K solubilizer followed by NPK (100%) + Azotobacter + PSB + K solubilizer (6.64 t/ha) and NPK (50%) + Azospirillium + PSB + K solubilizer (6.28 t/ha) as compared to lowest yield under NPK (50%) + Azotobacter + VAM + K solubilizer (3.85 t/ha). The yield under full recommended dose of fertilizer was 5.20 t/ha. They also noted the beneficial effect of nitrogen and phosphatic biofertilizer with 100% recommended dose of fertilizer for enhancing growth and yield of garlic.

The increase in yield might be due to better root proliferation, more uptake of nutrients and water, more photosynthesis [5,6]. The increase in yield was largely the consequence of the cumulative effect of plant growth characters such plant height, number of leaves/plant and neck thickness. Similar growth and yield increases were recorded earlier also with combined inoculation of biofertilizers in garlic [9], in onion [10] and in turmeric [11].

The experimental results indicated that Azospirillium and PSB were superior as compared to others. Besides nitrogen fixing potential, the effect of Azospirillium might be due to the production of plant growth hormones. Phyto-hormones produced by Azospirillium also stimulated root growth and induced changes in root morphology which in turn improved the assimilation of nutrients and the yield [12,13]. In addition, PSB could also produce indole acetic acid (IAA), stimulating the roots growth and increasing the number of root hairs and root laterals [14,5] ultimately resulted in the observed better growth of plants.

The yield under treatment combination of NPK (75%) + biofertilizers were more or at par with NPK (100%) alone, indicating there is a chance of saving of 25% inorganic NPK through biofertilizers. These results are in conformity with the findings of Kore et al. [9] and
Table 1. Response of biofertilizers with graded levels inorganic NPK on growth and yield of garlic (pooled of two years)

| Treatments                         | Plant height (cm) | Number of leaves/plant | Neck thickness (cm) | Number of cloves/bulb | Weight of cloves (g) (Large) | Plot yield (kg/3m^2) | Projected yield (t/ha) |
|------------------------------------|-------------------|-------------------------|---------------------|-----------------------|-----------------------------|-----------------------|------------------------|
|                                    | 60 DAP 120 DAP 60 DAP 120 DAP |                         |                     |                       |                             |                       |                        |
| NPK (100%) + Azot. + VAM + KS     | 42.83 72.61 6.12 10.28 1.08 29.94 | 0.98                  | 2.32               | 5.80                  |                             |                       |                        |
| NPK (100%) + Azot. + PSB + KS     | 44.65 75.42 6.72 11.27 1.02 31.18 | 1.08                  | 2.65               | 6.64                  |                             |                       |                        |
| NPK (100%) + Azos. + VAM + KS     | 41.36 69.30 6.43 10.53 0.96 32.86 | 1.02                  | 2.43               | 6.08                  |                             |                       |                        |
| NPK (100%) + Azos. + PSB + KS     | 42.96 71.13 6.84 11.45 1.04 32.12 | 1.12                  | 2.85               | 7.12                  |                             |                       |                        |
| NPK (75%) + Azot. + VAM + KS      | 39.62 65.34 5.84 9.75 0.95 27.84 | 0.94                  | 2.18               | 5.44                  |                             |                       |                        |
| NPK (75%) + Azot. + PSB + KS      | 42.93 69.83 6.26 10.86 0.88 28.53 | 0.96                  | 2.36               | 5.90                  |                             |                       |                        |
| NPK (75%) + Azos. + VAM + KS      | 40.36 66.25 5.42 8.96 0.82 29.62 | 0.88                  | 2.25               | 5.62                  |                             |                       |                        |
| NPK (75%) + Azos. + PSB + KS      | 42.08 70.18 6.08 10.28 0.91 28.49 | 1.04                  | 2.51               | 6.28                  |                             |                       |                        |
| NPK (50%) + Azot. + VAM + KS      | 37.84 61.14 5.12 8.63 0.78 21.73 | 0.83                  | 1.69               | 4.23                  |                             |                       |                        |
| NPK (50%) + Azot. + PSB + KS      | 39.06 67.28 5.47 9.24 0.72 23.45 | 0.84                  | 1.76               | 4.40                  |                             |                       |                        |
| NPK (50%) + Azos. + VAM + KS      | 36.53 59.25 5.23 8.45 0.76 25.84 | 0.82                  | 1.72               | 4.32                  |                             |                       |                        |
| NPK (50%) + Azos. + PSB + KS      | 40.15 64.14 5.92 9.58 0.84 25.32 | 0.92                  | 1.94               | 4.85                  |                             |                       |                        |
| NPK (100%) - Control              | 39.26 67.46 5.58 9.12 0.86 25.72 | 0.89                  | 2.08               | 5.20                  |                             |                       |                        |
| S. Em (±)                          | 1.085 1.085 0.172 0.418 0.052 0.675 | 0.047                | 0.048              | 0.124                  |                             |                       |                        |
| C.D. (P = 0.05)                    | 3.086 3.086 0.490 1.188 0.149 1.921 | 0.138                | 0.137              | 0.353                  |                             |                       |                        |

Azot. = Azotobacter, Azos = Azospirillum, VAM = Vesicular arbuscular mycorrhiza, PSB = Phosphate solublising bacteria, KS = Potassium solubilizer
Table 2. Response of biofertilizers with graded levels inorganic NPK on economics of garlic production

| Treatments                  | Gross cost (Rs./ha) | Gross return (Rs./ha) | Net return (Rs./ha) | B:C ratio |
|-----------------------------|---------------------|-----------------------|--------------------|-----------|
|                             | 2014-15  | 2015-16  | Mean  | 2014-15  | 2015-16  | Mean  | 2014-15  | 2015-16  | Mean  | 2014-15  | 2015-16  | Mean  |
| NPK (100%) +Azot. +VAM +KS | 97,998    | 114,816  | 106,407| 200,520  | 241,200  | 220,860| 102,522| 126,384  | 114,453  | 2.05  | 2.10  | 2.08  |
| NPK (100%) +Azot. +PSB +KS | 97,848    | 114,666  | 106,257| 229,680  | 276,000  | 252,840| 131,832| 161,334  | 146,583  | 2.35  | 2.41  | 2.38  |
| NPK (100%) +Azos. +VAM +KS | 97,998    | 114,816  | 106,407| 214,200  | 248,000  | 231,100| 116,202| 133,184  | 124,693  | 2.19  | 0.00  | 2.17  |
| NPK (100%) +Azos. +PSB +KS | 97,848    | 114,666  | 106,257| 246,600  | 296,000  | 271,300| 148,752| 181,334  | 146,583  | 2.52  | 2.58  | 2.55  |
| NPK (75%) +Azot. +VAM +KS  | 95,369    | 111,584  | 103,477| 222,800  | 207,160  | 191,520| 96,151 | 111,216  | 103,684  | 2.01  | 2.00  | 2.00  |
| NPK (75%) +Azot. +PSB +KS  | 95,219    | 111,434  | 103,327| 213,840  | 234,400  | 224,120| 118,621| 122,966  | 120,794  | 2.25  | 2.10  | 2.17  |
| NPK (75%) +Azos. +VAM +KS  | 95,369    | 111,584  | 103,477| 203,400  | 223,600  | 213,500| 108,031| 112,016  | 110,024  | 2.13  | 2.00  | 2.06  |
| NPK (75%) +Azos. +PSB +KS  | 95,219    | 111,434  | 103,327| 231,480  | 245,200  | 238,340| 136,261| 133,766  | 135,014  | 2.43  | 2.20  | 2.31  |
| NPK (50%) +Azot. +VAM +KS  | 92,742    | 108,352  | 100,547| 159,480  | 161,200  | 160,340| 66,738 | 52,848   | 59,793   | 1.72  | 1.49  | 1.59  |
| NPK (50%) +Azot. +PSB +KS  | 92,592    | 108,202  | 100,397| 163,080  | 170,000  | 166,940| 70,488 | 62,598   | 66,543   | 1.76  | 1.58  | 1.66  |
| NPK (50%) +Azos. +VAM +KS  | 92,742    | 108,352  | 100,547| 158,040  | 170,000  | 164,020| 65,298 | 61,648   | 63,473   | 1.70  | 1.57  | 1.63  |
| NPK (50%) +Azos. +PSB +KS  | 92,592    | 108,202  | 100,397| 163,440  | 206,400  | 184,920| 70,848 | 98,198   | 84,523   | 1.77  | 1.91  | 1.84  |
| NPK (100%) -Control        | 95,536    | 112,182  | 103,859| 177,120  | 219,200  | 198,160| 81,358 | 107,018  | 94,301   | 1.85  | 1.95  | 1.91  |

Azot.=Azotobacter, Azos.=Azospirillium, VAM = Vesicular arbuscular mycorrhiza, PSB = Phosphate solubilising bacteria, KS = Potassium solubilizer.
Chattoo et al. [15] in garlic, Kumar et al. [16] in onion and Roy and Hore [17,18] in turmeric. They also recorded the saving of 25% inorganic fertilization through the application of biofertilizers. Chattoo et al. [15] observed better growth, yield and quality attributes when Azotobacter + phosphobacteria was applied in conjugation with 75% NP resulting in a fertilizer saving of 25% without affecting the crop yield. Jayathilake et al. [19], Sevak et al. [20]; Choudhary et al. [21], Sharma et al. [22], Das et al. [23], Kumara et al. [24] and Nainwal et al. [25] also reported the 50% saving of nitrogenous fertilizer in onion through inoculation of Azospirillium on the contrary obtained significantly increased different yield attributes and seed yield per hectare with the application of 150% RDF + FYM + biofertilizer.

3.1 Economics

Data on economics of various treatments were presented in Table 2 revealed that the plot treated with NPK (100%) + Azospirillium + PSB + K solubilizer gave maximum net returns of Rs 165,043 per hectare. Maximum benefit: cost ratio (2.55) was also observed in NPK (100%) + Azospirillium + PSB + K solubilizer while minimum (1.59) was recorded under NPK (50%) + Azotobacter + VAM + K solubilizer. Roy and Hore [18] also recorded higher growth, yield and B:C ratio in turmeric with NPK (75%) + Azospirillium + VAM followed by NPK (75%) with Azotobacter + VAM, indicating the scope of saving of 25% of inorganic fertilizer. While calculating the Gross cost, price of seed bulb; costs of chemical fertilizers, FYM, bio-fertilizers and labour charges were accounted, whereas, Gross return was calculated taking selling price of garlic as rate fixed by the University. Benefit : Cost (B:C) ratio has been calculated on the basis of following formula: Benefit : Cost ratio = Gross return / Gross cost.

4. CONCLUSION

From the finding of present investigation, it is evident that treatments, NPK (100%) + Azospirillium + PSB + K solubilizer followed by NPK (100%) + Azotobacter + PSB + K solubilizer and NPK (75%) + Azospirillium + PSB + K solubilizer are found to be effective for maximum yield as well as treatment NPK (100%) + Azospirillium + PSB + K solubilizer for maximum net return and B:C under alluvial plains of West Bengal.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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