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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 x1.5 m plot at 20 x15 cm spacing in with three replications. Two nitrogen fixing biofertilizers (*Azospirillum lipoferum* and *Azotobacter chrococcum*), two phosphatic biofertilizers (Vesicular arbuscular mycorrhiza - *Glomus fasciculatum*) and phosphate solubilising bacteria (*Bacillus polymixa*) and one potassic solubilizer (*Fraturia 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 m^2) 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]. Biofertlizers can plays 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 indispensible 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 (*Azospirillium lipoferum* and *Azotobacter chroococcum*), a phosphate solubilizing bacterium (*Bacillus polymixa* thereby

PSB) and one potassium solubilizer (*Fraturia 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_2O_5 and 150 kg K_2O per hectare. In biofertilizer combinations the FYM, full dose of P_2O_5 and K_2O 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, 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.

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; plot yield (0.95 kg/m^2) 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	28.94	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 =Azospirillium, 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	165,043	2.52	2.58	2.55
NPK (75%) +Azot. + VAM + KS	95,369	111,584	103,477	191,520	222,800	207,160	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	170,800	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	81,584	107,018	94,301	1.85	1.95	1.91

Azot.=Azotobacter, Azos.=Azospirillium, VAM=Vesicular arbuscular mycorrhiza,
PSB = Phosphate solublising 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 application of biofertilizers. Chattoo et al. [15] observed better growth, yield and quality attributes when *Azotobacter* + phosphotbacteria 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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