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Influence of Bio-fertilizers and Inorganic Nutrient Levels on Growth and Yield of Garlic under Hill Agro-ecosystems of Uttarakhand

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Abstract

An experiment was conducted during *rabi* (October, 2022–February, 2023) in Chamoli district of Uttarakhand to study the combined effect of bio-fertilizers viz., phosphate solubilizing bacteria (PSB) and Azotobacter with different levels of NPK fertilizers (0, 50, 75 and 100 % NPK) on plant growth and bulb yield of garlic cv. 'Agrifound Parvati'. The application of bio-fertilizers either alone or in combination resulted in significant improvement in different growth parameters, yield parameters, bulb yield and benefit cost ratio. NPK fertilizers also significantly increased all the growth and yield parameters along with bulb yield with each incremental level of NPK. Significantly higher values were obtained with the application of 75% recommended dose of NPK with seed treatment with Azotobacter and PSB. Seed treatment with biofertilizers showed positive results for all the parameters. However, PSB and Azotobacter were more effective when applied along with 75% NPK. The interaction effects showed that bulb yield and benefit cost ratio increased in a linear manner with the application of bio-inoculants integrated with increasing levels of NPK fertilizers. The highest yield (128.13 q ha^{-1}) and benefit cost ratio (3.37) was recorded when the plots were supplemented with 75% NPK+clove treatment of both the inoculants. From this trial it can, therefore, be concluded that for sustainable production of garlic, application of 75% dose of inorganic fertilizer (NPK) coupled with inoculation of PSB and azotobacter can enhance yield and profitability of garlic.

Keywords: Garlic, inorganic fertilizers, bio-fertilizers, growth, yield, PSB, azotobacter, NPK

1. Introduction

Garlic (*Allium sativum* L.) belongs to the family Alliaceae is one of the most important spice crops. It has been originated in central Asia. It is a rich source of carbohydrates (29%), proteins (6.30%), minerals (0.30%), and essential oils (0.1–0.4%) and a fair source of fat, vitamin C and sulphur (Memane et al., 2008). It is an important and widely cultivated crop for food as well as medicinal purposes because of its thrombotic, lipid-lowering cardiovascular and anti-cancer effects. The ideal application of fertilizers in the cultivation of garlic is important to improve the growth, yield and marketable proportions of the bulbs, as well as the quality of the bulbs. Mineral fertilizers in adequate doses promote increases in leaf area and productivity (Kenea and Gedamu, 2019, Lana et al., 2022). The application of high input technologies such as chemical fertilizers, pesticides, herbicides have improved the production but there is growing concern over the adverse effects of the use of chemicals on soil productivity and environment quality (Ray et al., 2000, Sattar et al., 2018; Mounir et al., 2020). Thus, integrated nutrient management has become an accepted strategy to bring about improvement in soil fertility and protecting the environment. Indiscriminate use of synthetic fertilizers imparts reduced nutritive value and sensory parameters, whereas integration of organic amendments and bio-fertilizers reduces the NPK doses and improves the soil health and plant nutrient availability resulting in higher crop yields besides being environmentally safe (Sharma and Sharma, 2010, Badawy et al., 2019 and Barboza et al., 2020). Biofertilizer is a natural product carrying living microorganisms derived from the root or cultivated soil. Besides their role in atmospheric nitrogen fixation and phosphorous solubilisation, these also help in

stimulating the plant growth hormones providing better nutrient uptake and increased tolerance towards drought and moisture stress. *Azotobacter chroococcum*, represents the main group of heterotrophic free living nitrogen-fixing bacteria, a non-symbiotic bacteria is the potential bio-fertilizer and has the capability for contribution nitrogen to a number of non-legumes by tapping atmospheric nitrogen (Singh and Sinsinwar, 2006, Virgolino et al., 2017 and Boutasknit et al., 2020) and can meet up to 15–20 kg N requirement of crop. Azotobacter sp. can produce antifungal compounds to fight against many plant pathogens. It can also produce some growth promoting substances and vitamins that help in increasing the yield (Das et al., 2006). Microorganisms are also involved in the availability of phosphorus, the second most important nutrient required by crop plants. Phosphate Solubilizing Bacteria solubilizes phosphorus to increase soil fertility and biological activities (Ibrahim et al., 2019 and Mohsen et al., 2017). The PSB solubilize the insoluble phosphates and make them available for crop plants in the rhizosphere region through production of aliphatic and aromatic acids, phytase and phospholipase (Kumar and Ahlawat, 2006). Several soil bacteria and fungi notably species of Pseudomonas, Bacillus and Aspergillus etc. secrete organic acids and lower the pH in their vicinity to bring about solubilization of bound phosphates in soil. The full potential of a crop can only be judged when the nutrient supply system includes both organic sources and synthetic fertilizers. Therefore, integration of inorganic fertilizers, organic manures and biofertilizers is capable to maintain the good soil health, productivity and fertility status of soil (Nainwal et al., 2015, Chanchan et al., 2018, Priyanshu et al., 2020 and Gupta et al., 2024). However, a very little information is available on the response of bio-fertilizers in garlic, the important cash crop of hilly regions. Therefore, the onfarm trial was conducted to determine the effects of integrated use of biological amendments and synthetic sources of nutrients on the growth and yield of garlic.

2. Materials and Methods

Experiment was conducted during *rabi* (October, 2022–February, 2023) in Chamoli district. The soil of the experimental fields was sandy loam in texture with a pH of 6.8, medium in organic carbon (0.70), available N (420 kg ha^{-1}), available P (19.4 kg ha^{-1}) and K (223 kg ha^{-1}). Experiment consisted of 4 levels of bio-fertilizers (no inoculation, dipping of garlic cloves in the culture of Azotobacter (Indigenous strain), *PSB* (Indigenous strain) and their combination) for 15 min, and 4 level of N, P and K fertilizers (0, 50, 75 and 100% of the recommended dose of 125:75:60 kg N: P_2O_5 and K_2O). Thus, these 16 treatment combinations were evaluated in two factor RBD design, replicated thrice. The popular garlic variety 'Agrifound Parvati' was planted at a spacing of 20×10 cm^2. The recommended dose of farm yard manures at 20 t ha^{-1} was uniformly applied in all the treatment combinations except control. The entire P, K and half of N were applied through single super phosphate, muriate of potash and urea, respectively as per treatments at the time of planting. The remaining N was top dressed in two equal splits at an interval of 30 and 60 days after planting. The recommended package of practices was followed to raise a good crop. Observations on all growth and yield attributing traits were recorded on ten randomly selected plants at harvesting. Economics was worked out on the basis of prevailing market prices of inputs and outputs. Mean values of all observations were statistically analysed using the procedure given by Gomez and Gomez (1984).

3. Results and Discussion

3.1. Effect of bio-fertilizers

The analysis of data presented in Table 1 and 2 revealed significant difference among all the treatments for all the traits. The application of bio-fertilizers significantly influenced all the attributes of garlic viz., plant height, number of leaves $plant^{-1}$, bulb weight, cloves $bulb^{-1}$ and benefit cost ratio. The combined application of PSB and Azotobacter resulted in maximum growth for all the traits compared to control treatment or individual application of the bio-fertilizers. This increase in growth and yield attributes might be due to direct contribution of bio-fertilizers in improving the fertility of the soil because of bacterial activity. Nainwal et al., 2015, Singh et al., 2017, Chanchan et al., 2018, Talware et al., 2018 and Priyanshu et al., 2019 also reported the positive effects of bio-fertilizers on garlic. The application of both the bio-fertilizers either in sole or in combination significantly increased the bulb yield of garlic. However, *Azotobactor* in combination with *PSB* gave significantly highest marketable bulb yield (123.15 q ha^{-1}) which was followed by sole application of *PSB* (116.16 q ha^{-1}). The combination of bio-fertilizers (*Azotobacter+PSB*), *PSB* and *Azotobacter,* reported more yield, over un-inoculated control. This increase in yield may be ascribed to higher and continuous availability of atmospheric nitrogen by Azotobacter, phosphorus by the solubilising effect of PSB and the secretion of large number of plant growth hormones (Malik et al., 2005, El-Morsy et al., 2005, Das et al., 2006, Nainwal et al., 2015, Singh et al., 2017b, Chanchan et al., 2018, Talware et al., 2018 and Priyanshu et al., 2019).

3.2. Effect of NPK fertilizers

The application of NPK fertilizers significantly influenced all the growth and yield parameters of garlic (Table 1). The application of 75% NPK fertilizers recorded significantly the highest marketable bulb yield (119.71 q ha^{-1}) compared to control (109.16 q ha^{-1}), 50% NPK level (113.23 q ha^{-1}) and 100% NPK (115.74 q ha^{-1}). This increase could be due to increase in yield attributes and well developed root system that ultimately resulted in healthy plant system (Sridevi and Ramakrishnan, 2010). The economics revealed almost similar trend, the highest benefit cost ratio (3.27) was observed with the application of 75% NPK fertilizers. The effect of optimum

Table 1: Effect of bio-fertilizers and different levels of NPK on Growth and yield characters of bulbs in garlic "Agrifound Parvati"

Treatments	Plant height in garlic	No. of leaves plant^{-1}	Average weight of bulbs	No. of cloves bulb^{-1}	Yield ha^{-1}
B_0	50.09	11.22	30.73	8.15	107.07
B_1	49.27	13.08	34.97	12.65	111.45
B_2	49.28	13.13	34.15	12.87	116.16
B_3	49.85	13.39	36.71	14.19	123.15
Mean	49.62	12.71	34.14	11.97	114.46
CD (*p*=0.05)	0.39	0.33	0.61	0.37	0.97
N_0	49.18	12.35	33.75	11.43	109.16
N_1	49.45	12.61	33.84	12.07	113.23
N_2	50.11	12.81	34.59	12.45	119.71
N_3	49.77	13.06	34.37	11.92	115.74
Mean	49.63	12.71	34.14	11.97	114.46
CD (*p*=0.05)	0.39	0.33	0.61	0.37	0.97
$B_0 N_0$	49.02	11.08	30.37	7.65	99.88
$B_0 N_1$	49.99	11.21	30.38	8.00	106.72
$B_0 N_2$	51.09	11.26	31.12	8.70	113.00
$B_0 N_3$	50.27	11.34	31.04	8.25	108.67
$B_1 N_0$	49.12	12.64	34.25	12.08	107.00
$B_1 N_1$	49.14	13.09	35.07	13.09	110.71
$B_1 N_2$	49.58	13.13	35.33	13.25	115.38
$B_1 N_3$	49.25	13.45	35.24	12.17	112.72
$B_2 N_0$	49.00	12.68	34.03	12.30	111.33
$B_2 N_1$	49.05	13.00	33.67	12.97	114.08
$B_2 N_2$	49.56	13.23	34.64	13.20	122.33
$B_2 N_3$	49.50	13.61	34.24	13.00	116.90
$B_3 N_0$	49.56	13.00	36.37	13.67	118.42
$B_3 N_1$	49.60	13.12	36.25	14.21	121.38
$B_3 N_2$	50.18	13.61	37.29	14.64	128.13
$B_3 N_3$	50.07	13.83	36.94	14.25	124.67
Mean	49.62	12.70	34.14	11.96	114.46
CD (*p*=0.05)	0.39	NS	NS	NS	1.93

Level of biofertilizers- B_0: control, B_1: Azotobacter, B_2: PSB, B_3: Azotobacter+PSB, level of NPK- N_0: Control, N_1: NPK 50 %, N_2: NPK 75%, N_3: NPK 100%

levels of NPK to enhance the bulb yield and its attributing traits were also reported by (Nainwal et al., 2015, Singh and singh, 2017a, Chanchan et al., 2018, Talware et al., 2018, Priyanshu et.al., 2019 and Sharma and Sharma, 2010).

3.3. Interaction effects

The combined effect of bio-fertilizer and NPK application was found significant for bulb yield and benefit cost ratio (Table 1). The interaction effects showed that the bulb yield increased in a linear manner with the application of bio-inoculants integrated with optimum levels of NPK fertilizers. The application of 75% NPK in combination with *Azotobacter*+phosphorus solubilising bacteria (*PSB)* registered the highest bulb yield (128.13 q ha^{-1}) and highest benefit cost ratio (3.27) that was higher (114.46 q ha^{-1}) than the recommended dose of NPK fertilizers (100%). Furthermore, it was observed that the bulb yield (121.38 q ha^{-1}) obtained with the 50% NPK +*Azotobacter* +*PSB* (115.38 q ha^{-1}) and this treatment recorded the benefit cost ratio (3.21). Similar findings were also reported by Ahmed and

Table 2: Cost of cultivation (₹) of garlic "Agrifound Parvati" as affected by different treatments

Treatments (T)	Yield ha^{-1}	COC	GR	NR	B:C
$B_0 N_0$	99.88	160000	599280	439280.00	2.75
$B_0 N_1$	106.72	170000	640320	470320.00	2.77
$B_0 N_2$	113.00	172000	678000	506000.00	2.94
$B_0 N_3$	108.67	174000	652020	478020.00	2.75
$B_1 N_0$	107.00	165000	642000	477000.00	2.89
$B_1 N_1$	110.71	168000	664260	496260.00	2.95
$B_1 N_2$	115.38	171000	692280	521280.00	3.05
$B_1 N_3$	112.72	174000	676320	502320.00	2.89
$B_2 N_0$	111.33	165000	667980	502980.00	3.05
$B_2 N_1$	114.08	168000	684480	516480.00	3.07
$B_2 N_2$	122.33	171000	733980	562980.00	3.29
$B_2 N_3$	116.90	174000	701400	527400.00	3.03
$B_3 N_0$	118.42	170000	710520	540520.00	3.18
$B_3 N_1$	121.38	173000	728280	555280.00	3.21
$B_3 N_2$	128.13	176000	768780	592780.00	3.37
$B_3 N_3$	124.67	180000	748020	568020.00	3.16

COC: Cost of cultivation; GR: Gross return; NR: Net return

Sarah, 2024, Damse et al., 2014, Gupta et al., 2024, Sharma and Sharma, 2010, Nainwal et al., 2015, Singh et al., 2017b, Chanchan et.al.,2018, Talware et al., 2018; Singh et al., 2015 and Priyanshu et al., 2019 in different vegetable crops. The increase in bulb yield could be ascribed to optimum and continuous availability of nutrients from combined source at vital growth period that might have increased the plant height and mean bulb weight. This resulted in better photosynthetic activities of the carbohydrates to the storage organs and ultimately enhanced biomass production (Das et al., 2006).

4. Conclusion

Profitable yield (128.13 q ha^{-1}) of garlic cv. 'Agrifound Parvati' could be obtained when the garlic cloves were dipped for 15 min in *Azotobacter+PSB* along with the application of 75% levels of NPK with highest benefit cost ratio of 3.37. For sustainable production of garlic, application of optimum dose (75%) of inorganic fertilizer (NPK) coupled with inoculation of PSB and azotobacter can help to reduce the use of chemical fertilizers and enhance yield and profitability of garlic.

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