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Effect of inorganic nutrients and bio-fertilizers in combination with bio-control agents and botanical extracts on growth and yield attributes of garlic (*Allium sativum* L.) under semi-arid tropical zone of Telangana

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Abstract
Garlic (*Allium sativum* L.) most widely cultivated bulbous crop in the world after onion. The main aim of the study to provide better growth and yield attributes as well as output per hectare. The present investigation entitled "Effect of inorganic nutrients and bio-fertilizers in combination with bio-control agents and botanical extracts on growth and yield attributes of garlic (*Allium sativum* L)." under semi-arid tropical zone of Telangana." was carried out two consecutive years at Medicinal and Aromatic Plant Research Station, Rajendranagar, Hyderabad -SKLTGHU, during *Rabi*, 2022-23 and 2023-24 by applying methodology of contrast factorial randomized block design with ten treatments and three replications. In two years of study, it was found that, N_2B_1 (50%N + 100%P + 50%K + *Azotobactor* @ 5kg/ha + KSB@ 6Kg/ha + *Trichoderma viride* @ 10ml/l + Neem oil @ 0.5%) performed better in respect to growth parameters *viz.*, plant height (47.63 cm, 58.93 cm and 65.59 cm at 60, 90 and 120 DAS), leaf length (36.83 cm, 49.88 cm and 53.27 cm at 60, 90 and 120 DAS), Number of leaves (7.17 and 10.57 at 60 and 120 DAS), leaf width (1.59 cm, 1.83 cm and 2.06 cm 60, 90 and 120 DAS) and neck thickness (9.18 mm, 12.25 mm and 12.82 mm at 60, 90 and 120 DAS), and regarding yield parameters like polar diameter of bulb (3.90 cm), equatorial diameter of bulb (4.16 cm), length and width of cloves (2.70 cm and 1.06 cm), number of cloves per bulb (18.73), bulb yield (3.91 Kg/plot), bulb yield (6.52 t/ha), total biomass (4.68 kg/plot), harvest index (82.97%). Based on the present investigation results, it may be concluded that N_2B_1 (50%N + 100%P + 50%K + *Azotobactor* @ 5kg/ha + KSB@ 6Kg/ha + *Trichoderma viride* @ 10ml/l + Neem oil @ 0.5%) proved better as compared to other treatment combinations.

Keywords: Growth, yield, *Azotobactor*, *Bacillus subtilis*, sesame oil

Introduction
Garlic (*Allium sativum* L.,) called as different names at different places but most commonly known as "Lashun". It can be used as spice and condiment. It is one of the important cultivated allium species after onion belonging to family Alliaceae and originated in central Asia with chromosome number 2n=16. It is a frost hardy bulbous perennial; erect herb having white narrow flat leaves and bears small white flower and bulbils. In point of vegetative growth, the exposure of plant to lower temperature favors the growth of the plant subsequently, the day length plays an important role in bulbing. The bulb development take place during the longer days as well as at higher temperature conditions. The temperature and critical day length around 12 hours per day influence the bulb growth.

Economic part of garlic is clove. It contains 0.1% of volatile oil. The main constituent of oil is Diallyl disulphide (60%), Diallyl trisulphide (20%) and Allyl propyl trisulphide (6%) and it also contains potassium, phosphorus and magnesium. Aqueous extract of garlic contains allicin and it reduces cholesterol level in human blood. Garlic has more nutritive value than other bulbous crops. It is a rich source of carbohydrate (29%), protein (6.3%), minerals (0.3%) and essential oils (0.1-0.4%) and also has some amount of fat, vitamin- C and Sulphur (Memane *et al.*, 2008) [10] major content of green garlic is ascorbic acid.

Garlic has anti-bacterial, antiviral, antifungal, anti-oxidant, anti-cancer, and anti-protozoal properties (Harris *et al.*, 2001) [6].

Garlic has tremendous medicinal properties which protect against gastro-intestinal neoplasia, and act as gastric stimulant to help in digestion and absorption of food and used as co-adjuvant therapy in diabetes treatment. The person suffer with risk of vascular calcification with high blood cholesterol can be reduced by supplementation with garlic extract (Durak *et al.*, 2004) [4]. In addition, it reduces the nematode population in soil, garlic extract along with chilli and ginger most effective to kill nematodes. Besides, it also found effective against several fungi and bacteria thereby garlic used as good integral component of integrated pest management.

Nitrogen, phosphorus, and potassium play key roles in garlic's vegetative development and output (Mallangouda *et al.*, 1995) [9]. Garlic requires nitrogen supplementation to ensure good vegetative development (Kakara *et al.*, 2002) [7]. It is also responsible for bulb dry matter production and bulb yield, in addition to its beneficial effects on bulb growth and development. Phosphorus stimulates root growth and serves as a storage site for nucleic acid components.

Biofertilizers are products that contain living cells of various types of microorganisms that could convert nutritionally important elements. Bio-fertilizers are also known to play an important role in increasing nitrogen and phosphorus availability, as well as improving biological fixation of atmospheric nitrogen and producing hormones and anti-metabolites. Furthermore, given the negative impact of just using chemical fertilizers on soil health, integrating inorganic fertilizers with bio-fertilizers will be environmentally friendly. Azotobacter, PSB, and KSB fix atmospheric nitrogen and solubilize phosphorous and potassium, respectively increasing soil fertility and biological activity.

Biocontrol agents are essential for preventing illness and boosting crop output, plant content, and growth parameters. Numerous strategies, including mycoparasitism, antibiosis, competition, cell wall breakdown, induced resistance to plant growth stimulation, and rhizosphere colonization capabilities, can be used to reduce disease. *Trichoderma* is the most potent bioagent that has been researched to date and seems to combat infections through a variety of ways. It suppresses the disease-causing germs by inducing host resistance and employing antibiosis

Materials and Methods

The present investigation entitled “Effect of inorganic nutrients and bio-fertilizers in combination with bio-control agents and botanical extracts on growth and yield attributes of garlic (*Allium sativum* L).” under semi-arid tropical zone of Telangana.” was conducted at Medicinal and Aromatic Plant Research Station, Sri Konda Laxman Telangana Horticultural University, Rajendranagar, Hyderabad during *rabi*, 2022 to 2024. Geographically, it lies at latitude of 17°.19’ N, longitude of 79°.23’ E and an altitude of 542.6 m above mean sea level. The topography of the experimental site was falls under southern Telangana zone. The soil is sandy loam in nature, coarse in texture, poor in water holding capacity land was ploughed thoroughly and the beds were prepared as 3mx2m size. The application of treatments carried out at timely intervention. The present experiment aims to assess the growth and yield of garlic by applying inorganic nutrients along with biofertilizers (N1:100% N +50% P + 50% K + PSB @ 5Kg/ha +KSB@ 6Kg/ha; N2: 50%N +100%P+50%K+ *Azotobactor* @ 5kg/ha+ KSB@ 6Kg/ha; N3:50%N +50%P+ 100%K+ *Azotobactor* @ 5kg/ha+ PSB @ 5Kg/ha) and bioformulations (B1: *Trichoderma viride* @ 10ml/l + Neem oil @ 0.5%; B2: *Pseudomonas fluorescence* @ 10ml/l + Pongamia oil @ 0.5%; B3: *Bacillus subtilis* @ 10ml/l + Sesame oil @ 1%) by using methodology of contrast factorial randomized Block Design with ten treatments and three replications.

The growth parameters like plant height were measured with the help of measuring scale from the ground level to tip of the longest leaf by holding the plant vertically. The number of leaves plant^{-1} measured by counting all the normal and healthy leaves of ten randomly selected plants. The leaf length and leaf width computed from the randomly selected ten plants by a measuring scale and neck thickness measured just above the soil at collar region of randomly selected ten plants with digital vernier calliper. The yield parameters were recorded after harvesting of the crop. The bulb length and breadth were measured with digital vernier calliper from the polar and equatorial side of the bulb and the mean valve was calculated.

The clove length and breadth of outer two whorl of the cloves of randomly selected bulbs measured by digital vernier calliper and average was worked out in centimeters. The number of cloves per bulb measured by counting number of cloves present in the five randomly selected bulbs and average was calculated. The bulb yield was computed each plot harvested and cured for one week and the weight was recorded and mean value was worked out in Kilograms. Based on bulb yield plot^{-1}, bulb yield hectare^{-1} was calculated in t ha^{-1}. Total biomass is expressed in terms of yield kg/plot and quintals/ha. The total biomass is noted after harvesting of plants from individual plots. The harvested bulbs along with fresh leaves weighed treatment wise on electronic balance and weight has been recorded in terms of kg/plot and the harvest index calculated by using following formulae:

Harvest index = (Economic yield/ Biological yield) x100

Results and Discussion

Plant height

Significant difference was observed in plant height at 90 and 120 DAS. The maximum plant height (46.08 cm, 56.44 cm and 64.42 cm) (Table 1) was recorded at 60, 90 and 120 Days after sowing with N_2 (50%N +100%P+50%K+ *Azotobactor* 5kg/ha+ KSB 6Kg/ha). Among the application of bio-formulations, maximum plant height (43.17 cm, 54.45 cm and 63.04 cm) was noted at 60, 90 and 120 Days after sowing respectively with B_1 (*Trichoderma viride* 10ml/l + Neem oil 0.5%). The combination of N_2B_1 (50%N +100%P+50%K+ *Azotobactor* 5kg/ha+ KSB 6Kg/ha +*Trichoderma viride* 10ml/l + Neem oil 0.5%) performed best overall, with maximum pant height (47.63 cm, 58.93 cm and 65.59 cm) at 60, 90 and 120 Days after sowing

Table 1: Effect of inorganic nutrients and bio-formulations on Plant height of garlic

Treatments	Plant height								
	60 Days after sowing			90 Days after sowing			120 Days after sowing		
	2022-2023	2023-2024	pooled	2022-2023	2023-2024	pooled	2022-2023	2023-2024	pooled
Nutrients									
N_1	40.28	42.27	41.28	51.87	54.52	53.19	61.21	63.15	62.18
N_2	44.83	47.32	46.08	55.30	57.57	56.44	63.82	65.03	64.42
N_3	38.29	38.81	38.55	49.14	50.05	49.59	58.89	56.11	57.50
S.Em±	0.15	0.02	0.12	0.17	0.11	0.09	o.12	0.21	0.11
CD(5%)	0.45	0.60	0.36	0.42	0.33	0.29	0.36	0.57	0.33
Bio-agents									
B_1	42.33	44.01	43.17	53.07	55.82	54.45	62.86	63.22	63.04
B_2	39.85	41.67	40.76	50.67	52.09	51.38	59.33	59.63	59.48
B_3	41.22	42.73	41.97	52.57	54.22	53.40	61.73	61.43	61.58
S.Em±	0.15	0.02	0.12	0.17	0.11	0.09	o.12	0.21	0.11
CD(5%)	0.45	0.60	0.36	0.42	0.33	0.29	0.36	0.57	0.33
Interaction (NXB)									
N_1B_1	41.03	43.87	42.45	52.18	55.35	53.76	63.42	63.85	63.64
N_1B_2	39.47	40.76	40.11	51.54	53.63	52.59	59.94	63.12	61.53
N_1B_3	40.34	42.18	41.26	51.88	54.57	53.23	60.28	62.47	61.38
N_2B_1	46.52	48.74	47.63	58.16	59.70	58.93	65.48	65.70	65.59
N_2B_2	43.87	45.85	44.86	52.80	55.64	54.22	60.61	64.34	62.47
N_2B_3	44.11	47.37	45.74	54.95	57.37	56.16	65.36	65.04	65.20
N_3B_1	39.45	39.41	39.43	48.88	52.43	50.65	59.68	60.09	59.89
N_3B_2	36.22	38.40	37.31	47.65	47.00	47.33	57.44	51.45	54.45
N_3B_3	39.19	38.64	38.91	50.89	50.72	50.80	59.54	56.78	58.16
S.Em±	0.45	0.60	0.36	0.52	0.33	0.29	0.36	0.57	0.33
CD(5%)	NS	NS	NS	1.56	1.01	0.86	1.10	1.06	0.94
Control	45.63	47.84	46.60	56.30	58.67	57.48	59.66	63.74	61.70
S.Em±	0.45	0.60	0.36	0.52	0.33	0.29	0.36	0.57	0.33
CD(5%)	1.80	2.33	1.42	2.01	1.31	1.132	1.42	2.24	1.22

Leaf length: The pooled data related to leaf length revealed that**,** maximum leaf length (35.50 cm, 46.82cm and 50.02cm) (Table 2.) was recorded at 60, 90 and 120 Days after sowing with N_2 (50%N +100%P+50%K+ *Azotobactor* 5kg/ha+ KSB 6Kg/ha). Among the application of bio-formulations maximum leaf length (33.72cm, 45.01cm and 48.44cm) was noted at 60, 90 and 120 Days after sowing respectively with B_1 (*Trichoderma viride* 10ml/l + Neem oil 0.5%). The interaction between soil nutrients and bioformulation did not affect on length of leaves at 60 and 120 DAS

Table 2: Effect of inorganic nutrients and bio-formulations on leaf length of garlic

Treatments	Leaf length								
	60 Days after sowing			90 Days after sowing			120 Days after sowing		
	2022-2023	2023-2024	pooled	2022-2023	2023-2024	pooled	2022-2023	2023-2024	pooled
Nutrients									
N_1	31.56	33.18	32.37	42.31	54.52	42.86	46.88	48.09	46.79
N_2	34.32	36.68	35.50	46.26	57.57	46.82	49.65	51.55	50.02
N_3	28.38	31.50	29.94	39.99	50.05	40.83	45.63	43.71	44.67
S.Em±	0.14	0.11	0.08	0.12	0.15	0.07	0.10	0.16	0.08
CD(5%)	0.44	0.33	0.24	0.37	0.46	0.22	0.29	0.50	0.27
Bio-agents									
B_1	32.57	34.86	33.72	44.13	43.41	45.01	48.37	49.36	48.44
B_2	30.16	32.92	31.54	41.68	47.38	42.15	46.50	46.79	45.95
B_3	31.54	33.58	32.56	42.76	41.67	43.34	47.29	47.19	47.09
S.Em±	0.14	0.11	0.08	0.12	0.15	0.07	0.10	0.16	0.08
CD(5%)	0.44	0.33	0.24	0.37	0.46	0.22	0.29	0.50	0.27
Interaction (NXB)									
N_1B_1	33.34	34.18	33.76	43.38	44.14	43.76	47.04	48.32	47.68
N_1B_2	30.00	32.23	31.11	41.00	42.89	41.94	46.78	49.47	46.04
N_1B_3	31.35	33.14	32.24	42.56	43.20	42.88	46.82	46.48	46.65
N_2B_1	35.33	38.32	36.83	48.85	50.90	49.88	51.98	54.56	51.99
N_2B_2	33.04	35.55	34.29	44.24	44.33	44.29	47.72	48.78	48.25
N_2B_3	34.60	36.17	35.39	45.67	46.92	46.29	49.24	51.30	49.82
N_3B_1	29.04	32.08	30.56	40.16	42.66	41.41	46.10	45.21	45.65
N_3B_2	27.43	30.99	29.21	39.79	40.67	40.23	45.00	42.13	43.57
N_3B_3	28.68	31.44	30.06	40.04	41.67	40.86	45.80	43.78	44.79
S.Em±	0.44	0.33	0.24	0.37	0.46	0.22	0.29	0.50	0.24
CD(5%)	NS	NS	NS	1.11	1.30	0.65	NS	NS	NS
Control	34.66	36.39	35.53	46.56	48.21	47.39	48.63	50.04	49.37
S.Em±	0.44	0.33	0.24	0.37	0.46	0.22	0.29	0.50	0.24
CD(5%)	1.71	1.27	0.93	1.43	1.68	0.84	1.17	1.73	0.96

Number of leaves per plant

The pooled data related to number of leaves per plant revealed that, based on the results maximum number of leaves (6.92, 9.72 and 9.97) (Table 3.) was recorded at 60, 90 and 120 Days after sowing with N_2 (50%N +100%P+50%K+ *Azotobactor* 5kg/ha+ KSB 6Kg/ha). Among the application of bio-formulations highest number of leaves per plant (6.65, 9.10 and 9.57) was noted at 60, 90 and 120 Days after sowing respectively with B_1 (*Trichoderma viride* 10ml/l + Neem oil 0.5%). Statistically there was no significant difference was observed between the combination of soil nutrients and bioformulations at 60 and 90 days after sowing.

Table 3: Effect of inorganic nutrients and bio-formulations on number of leaves of garlic

Number of leaves per plant									
Treatments	60 Days after sowing			90 Days after sowing			120 Days after sowing		
	2022-2023	2023-2024	pooled	2022-2023	2023-2024	pooled	2022-2023	2023-2024	pooled
Nutrients									
N_1	6.31	6.61	6.46	8.32	8.59	8.46	9.03	9.25	9.14
N_2	6.89	6.94	6.92	9.48	9.96	9.72	9.96	9.98	9.97
N_3	5.91	6.14	6.03	7.76	8.07	7.91	8.50	8.55	8.52
S.Em+	0.02	0.02	0.01	0.06	0.02	0.03	0.02	0.02	0.01
CD(5%)	0.06	0.06	0.04	0.17	0.07	0.08	0.07	0.06	0.05
Bio-agents									
B_1	6.55	6.74	6.65	8.95	9.26	9.10	9.57	9.58	9.57
B_2	6.22	6.44	6.33	8.10	8.52	8.31	8.79	9.00	8.90
B_3	6.34	6.51	6.42	8.50	8.84	8.67	9.13	9.19	9.16
S.Em+	0.02	0.02	0.01	0.06	0.02	0.03	0.02	0.02	0.01
CD(5%)	0.06	0.06	0.04	0.17	0.07	0.08	0.07	0.06	0.05
Interaction (NXB)									
N_1B_1	6.42	6.79	6.60	8.76	8.95	8.86	9.33	9.54	9.44
N_1B_2	6.25	6.50	6.37	7.67	8.33	8.00	8.83	8.88	8.86
N_1B_3	6.25	6.55	6.40	8.54	8.50	8.52	8.92	9.32	9.12
N_2B_1	7.24	7.10	7.17	9.98	10.54	10.26	10.62	10.51	10.57
N_2B_2	6.58	6.84	6.71	9.07	9.49	9.28	9.42	9.68	9.55
N_2B_3	6.84	6.89	6.87	9.38	9.84	9.61	9.84	9.75	9.80
N_3B_1	6.00	6.34	6.17	8.13	8.28	8.20	8.75	8.69	8.72
N_3B_2	5.82	5.99	5.90	7.57	7.75	7.66	8.13	8.45	8.29
N_3B_3	5.92	6.10	6.01	7.58	8.18	7.88	8.62	8.50	8.56
S.Em+	0.06	0.06	0.04	0.17	0.07	0.08	0.07	0.06	0.05
CD(5%)	NS	NS	NS	NS	NS	NS	0.21	0.16	0.17
Control	6.80	6.88	6.84	9.31	9.81	9.56	9.63	9.71	9.67
S.Em+	0.06	0.06	0.04	0.17	0.07	0.08	0.07	0.06	0.05
CD(5%)	0.24	0.22	0.15	0.64	0.26	0.33	0.27	0.21	0.22

Leaf width

Data related to width of leaves revealed that among the application of soil nutrients found statistically significant difference was found, the highest width of leaves 1.46 cm, 1.77 cm and 2.01 at 60, 90 and 120 Days after sowing was noted in N_2 (50%N +100%P+50%K+ *Azotobactor* 5kg/ha+ KSB 6Kg/ha). The significant difference was observed with respect to bio formulation application. The maximum width of leaves noted in B_1 (*Trichoderma viride* 10ml/l + Neem oil 0.5%) 1.45 cm, 1.72 cm and 1.98 cm at 60, 90 and 120 DAS respectively. However, the interaction between soil nutrients and bioformulation application did not differ at 60, 90 and 120 Days after sowing

Table 4: Effect of inorganic nutrients and bio-formulations on leaf width of garlic

Leaf width									
Treatments	60 Days after sowing			90 Days after sowing			120 Days after sowing		
	2022-2023	2023-2024	pooled	2022-2023	2023-2024	pooled	2022-2023	2023-2024	pooled
Nutrients									
N_1	1.36	1.42	1.39	1.70	1.65	1.68	1.83	2.04	1.94
N_2	1.45	1.48	1.46	1.77	1.78	1.77	1.91	2.11	2.01
N_3	1.30	1.29	1.30	1.59	1.54	1.57	1.77	1.98	1.88
S.Em+	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CD(5%)	0.02	0.03	0.01	0.02	0.03	0.01	0.02	0.02	0.01
Bio-agents									
B_1	1.42	1.48	1.45	1.73	1.71	1.72	1.87	2.08	1.98
B_2	1.34	1.31	1.33	1.64	1.59	1.62	1.81	2.02	1.91
B_3	1.35	1.40	1.37	1.69	1.67	1.68	1.83	2.04	1.94
S.Em+	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CD(5%)	0.02	0.03	0.01	0.02	0.03	0.01	0.02	0.02	0.01
Interaction (NXB)									
N_1B_1	1.37	1.43	1.40	1.73	1.70	1.72	1.85	2.06	1.95
N_1B_2	1.34	1.39	1.37	1.68	1.58	1.63	1.82	2.03	1.93

N_1B_3	1.36	1.43	1.40	1.69	1.68	1.68	1.83	2.04	1.93
N_2B_1	1.55	1.63	1.59	1.84	1.85	1.84	1.97	2.15	2.06
N_2B_2	1.43	1.35	1.39	1.68	1.70	1.69	1.90	2.10	2.00
N_2B_3	1.38	1.45	1.41	1.78	1.78	1.78	1.87	2.09	1.98
N_3B_1	1.33	1.37	1.35	1.62	1.57	1.60	1.81	2.02	1.91
N_3B_2	1.24	1.20	1.22	1.56	1.51	1.53	1.71	1.92	1.82
N_3B_3	1.32	1.31	1.31	1.61	1.55	1.58	1.80	2.00	1.90
S.Em±	0.02	0.03	0.02	0.02	0.03	0.02	0.02	0.02	0.02
CD(5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Control	1.48	1.52	1.50	1.75	1.77	1.76	1.80	1.99	1.89
S.Em±	0.02	0.03	0.02	0.02	0.03	0.02	0.02	0.02	0.02
CD(5%)	0.07	0.13	0.06	0.06	0.10	0.06	0.08	0.07	0.06

Neck thickness

The pooled data related to neck thickness revealed that**,** significant difference was observed the highest neck thickness (8.79 mm, 11.57 mm and 12.02 mm) (Table 5) was recorded at 60, 90 and 120 Days after sowing with N_2 (50%N +100%P+50%K+ *Azotobactor* 5kg/ha+ KSB 6Kg/ha). Among the application of bio-formulations highest neck thick ness (8.62 mm, 11.21 mm and 11.74 mm) was noted at 60, 90 and 120 Days after sowing respectively with B_1 (*Trichoderma viride* 10ml/l + Neem oil 0.5%). The combination of N_2B_1 performed best overall, with maximum neck thickness (9.18 mm, 12.25 mm and 12.82 mm) at 60, 90 and 120 days after sowing

Table 5: Effect of inorganic nutrients and bio-formulations on neck thickness of garlic

Treatments	Neck thickness								
	60 Days after sowing			90 Days after sowing			120 Days after sowing		
	2022-2023	2023-2024	pooled	2022-2023	2023-2024	pooled	2022-2023	2023-2024	pooled
Nutrients									
N_1	8.38	8.36	8.37	10.49	11.05	10.77	10.85	11.56	11.21
N_2	8.74	8.85	8.79	11.33	11.81	11.57	11.55	12.49	12.02
N_3	8.02	7.89	7.95	10.03	10.44	10.23	10.54	10.97	10.75
S.Em±	0.02	0.03	0.01	0.03	0.02	0.01	0.03	0.04	0.02
CD(5%)	0.05	0.21	0.28	0.09	0.06	0.05	0.10	0.11	0.08
Bio-agents									
B_1	8.61	8.64	8.62	10.91	11.52	11.21	11.35	12.13	11.74
B_2	8.19	8.13	8.16	10.41	10.80	10.61	10.70	11.19	10.94
B_3	8.35	8.34	8.34	10.52	10.98	10.75	10.90	11.69	11.30
S.Em±	0.02	0.03	0.01	0.03	0.02	0.01	0.03	0.04	0.02
CD(5%)	0.05	0.21	0.28	0.09	0.06	0.05	0.10	0.11	0.08
Interaction (NXB)									
N_1B_1	8.47	8.47	8.47	10.55	11.36	10.96	11.00	11.80	11.40
N_1B_2	8.30	8.25	8.27	10.38	10.75	10.56	10.75	11.35	11.05
N_1B_3	8.39	8.38	8.38	10.54	11.04	10.79	10.80	11.54	11.17
N_2B_1	9.13	9.22	9.18	11.99	12.51	12.25	12.31	13.34	12.82
N_2B_2	8.50	8.65	8.57	10.94	11.37	11.16	11.09	11.82	11.46
N_2B_3	8.58	8.68	8.63	11.05	11.55	11.30	11.26	12.30	11.78
N_3B_1	8.22	8.23	8.22	10.18	10.69	10.43	10.73	11.26	10.99
N_3B_2	7.76	7.49	7.63	9.93	10.28	10.10	10.26	10.40	10.33
N_3B_3	8.09	7.95	8.02	9.97	10.36	10.16	10.64	11.24	10.94
S.Em±	0.05	0.07	0.04	0.09	0.06	0.05	0.10	0.11	0.08
CD(5%)	NS	NS	0.13	0.24	0.19	0.13	0.29	0.33	0.26
Control	8.61	8.91	8.76	11.03	12.05	11.54	11.52	12.64	12.08
S.Em±	0.05	0.07	0.04	0.09	0.06	0.05	0.10	0.11	0.08
CD(5%)	0.21	0.28	0.17	0.31	0.24	0.17	0.39	0.42	0.33

The morphological parameters like plant height, leaf length, number of leaves, leaf width and neck thickness were observed with N_2B_1 (50%N +100%P+50%K+ *Azotobactor* 5kg/ha+ KSB 6Kg/ha + *Trichoderma viride* 10ml/l + Neem oil 0.5%) (Table 1 to Table 5) during 2022-23, 2023-24 and pooled data. The combined application of inorganic nitrogen, phosphorus, and potassium along with the biofertilizers azotobacter and KSB may be the reason for the improved morphological traits under the respective treatments. This may increase plant height by increasing the plant's foliage, which turn in increases photosynthesis. It is believed that a sufficient supply of the three main nutrients—nitrogen, phosphorus, and potassium will favorably control the physiological processes and morphological responses of plants. Garlic plants will be able to achieve their full potential through the use of phosphorus fertilizer, which increases root development and resistance to root infections. Numerous studies have demonstrated comparable results. (Shaheen *et al*., 2007; Arif *et al*., 2016 and Mulatu *et al*., 2017) [16, 1, 11].

Azotobacter is a free-living nitrogen-fixing bacterium that can enhance plant growth by increasing the availability of nitrogen in the soil, which fixes the atmospheric nitrogen as well as soil nitrogen and made available to the plant. Research has shown that the application of Azotobacter can significantly improve plant height in garlic. A study by Sharma *et al*. (2019) [17] found that the combination of NPK with Azotobacter resulted in increased plant height compared to treatments with only NPK.

These findings are also conformity with the findings earlier

reported by Elshahawy *et al.* (2019) [5] who reported that the synergistic beneficial activity of bio formulations contain microbes was attained the plant height through the production of plant growth regulators such as analogues of auxins, gibberellins, and an extremely diverse range of metabolites that may have triggered the plant response rapidly and transiently through cell division, cell elongation, and cell differentiation.

Yield attributes

Among the application of soil nutrients highest Polar, equatorial diameter of bulb and highest number of cloves per bulb (3.71 cm, 3.95 cm and 17.21) respectively was recorded in N2 (50%N +100%P+50%K+ *Azotobactor* 5kg/ha+ KSB 6Kg/ha). Among the bio formulations application B1 (*Trichoderma viride* 10ml/l + Neem oil 0.5%) recorded highest Polar, equatorial diameter of bulb and highest number of cloves per bulb (3.50 cm, 3.79 cm and 16.28). The interaction between soil nutrients and bio formulation found significant difference between the treatments among the all combination the application of N_2B_1 (50%N +100%P+50%K+ *Azotobactor* 5kg/ha+ KSB 6Kg/ha + *Trichoderma viride* 10ml/l + Neem oil 0.5%) recorded the maximum polar, equatorial diameter of bulb and highest number of cloves per bulb 3.90 cm, 4.16 cm and 18.73 respectively

It appears that the significant effect on yield parameters such as bulb diameter as a consequence of organic fertilizers and chemical fertilization is due to the increased nutritional status of the soil resulting into increased growth of the crop. This may be attributed to favorable effect of organic sources on microbial activity and root proliferation in soil which caused solubilizing effect on native nitrogen, phosphorus, potassium and other nutrients. The application of 50 percent recommended dose of NPK favored the metabolic and auxin activities in plant and ultimately resulted in increased bulb weight and bulb diameter.

The highest bulb diameter might be due to the influence of inorganic, biofertilizer and biocontrol agents' enrichment, thus, increasing the vegetative growth, dry matter generation and photosynthate translocation which led to greater bulb development resulting in a larger bulb diameter.

Table 6: Effect of inorganic nutrients and bio-formulations on polar, equatorial and number of cloves per bulb of garlic

Treatments	Polar diameter			Equatorial diameter			Number of cloves		
	2022-2023	2023-2024	pooled	2022-2023	2023-2024	pooled	2022-2023	2023-2024	pooled
Nutrients									
N_1	3.32	3.43	3.37	3.41	3.82	3.62	15.00	15.39	15.20
N_2	3.69	3.72	3.71	3.83	4.07	3.95	17.72	16.70	17.21
N_3	2.74	3.27	3.00	3.34	3.58	3.46	14.48	14.25	14.37
S.Em±	0.02	0.01	0.01	0.01	0.01	0.01	0.10	0.04	0.04
CD(5%)	0.06	0.03	0.03	0.04	0.04	0.03	0.28	0.14	0.14
Bio-agents									
B_1	3.35	3.59	3.50	3.64	3.94	3.79	16.53	16.03	16.28
B_2	3.13	3.36	3.24	3.41	3.66	3.54	15.03	15.05	15.04
B_3	3.28	3.46	3.35	3.52	3.87	3.70	15.64	15.26	15.45
S.Em±	0.02	0.01	0.01	0.01	0.01	0.01	0.10	0.04	0.04
CD(5%)	0.06	0.03	0.03	0.04	0.04	0.03	0.28	0.14	0.14
Interaction (NXB)									
N_1B_1	3.40	3.47	3.43	3.43	3.86	3.64	14.82	15.95	15.39
N_1B_2	3.33	3.38	3.36	3.40	3.79	3.59	15.33	14.96	15.15
N_1B_3	3.24	3.43	3.33	3.41	3.81	3.61	14.83	15.27	15.05
N_2B_1	3.79	3.96	3.90	4.12	4.20	4.16	19.59	17.87	18.73
N_2B_2	3.63	3.54	3.58	3.56	3.99	3.77	16.45	15.99	16.22
N_2B_3	3.65	3.65	3.66	3.80	4.04	3.92	17.12	16.25	16.69
N_3B_1	3.00	3.34	3.17	3.37	3.76	3.57	15.17	14.28	14.72
N_3B_2	2.44	3.17	2.79	3.28	3.22	3.25	13.31	14.21	13.76
N_3B_3	2.80	3.30	3.05	3.36	3.76	3.56	14.97	14.25	14.61
S.Em±	0.05	0.03	0.03	0.04	0.04	0.03	0.02	0.01	0.01
CD(5%)	0.13	0.09	0.08	0.12	0.13	0.14	0.85	0.45	0.42
Control	3.64	3.59	3.62	3.76	4.03	3.90	16.89	16.03	16.46
S.Em±	0.05	0.03	0.03	0.04	0.04	0.03	0.02	0.01	0.01
CD(5%)	0.16	0.11	0.11	0.16	0.17	0.14	1.09	0.58	0.55

Date pertaining to clove length, clove breadth and yield per plot was found significant difference among the soil nutrients application. The highest clove length, clove breadth and yield per plot (2.36 cm, 1.00 cm and 3.71 kg/plot) respectively was recorded in N_2 (50%N +100%P+50%K+ *Azotobactor* 5kg/ha+ KSB 6Kg/ha). Among the bio formulations application B_1 (*Trichoderma viride* 10ml/l + Neem oil 0.5%) recorded statistically clove length, clove breadth and yield per plot (2.25 cm, 0.96 cm and 3.46 kg/plot). The interaction between soil nutrients and bio formulation found significant difference between the treatments among the all combinations the application of N_2B_1 (50%N +100%P+50%K+ *Azotobactor* 5kg/ha+ KSB 6Kg/ha + *Trichoderma viride* 10ml/l + Neem oil 0.5%) recorded the maximum clove length, and yield per plot 2.70 cm and 3.91 kg/plot respectively)

Table 7: Effect of inorganic nutrients and bio-formulations on clove length, breadth and yield per plot of garlic

Treatments	Clove length			Clove breadth			Yield per plot		
	2022-2023	2023-2024	pooled	2022-2023	2023-2024	pooled	2022-2023	2023-2024	pooled
Nutrients									
N_1	1.93	2.25	2.09	0.86	0.99	0.93	3.28	3.33	3.31
N_2	2.20	2.52	2.36	0.94	1.07	1.00	3.67	3.75	3.71
N_3	1.71	2.03	1.87	0.76	0.89	0.83	2.86	2.93	2.90
S.Em±	0.02	0.01	0.01	0.01	0.003	0.01	0.01	0.01	0.01
CD(5%)	0.05	0.03	0.02	0.02	0.01	0.01	0.04	0.05	0.03
Bio-agents									
B_1	2.09	2.41	2.25	0.90	1.03	0.96	3.45	3.48	3.46
B_2	1.84	2.16	2.00	0.81	0.94	0.88	3.04	3.10	3.07
B_3	1.91	2.23	2.07	0.85	0.98	0.91	3.32	3.43	3.38
S.Em±	0.02	0.01	0.01	0.01	0.003	0.01	0.01	0.01	0.01
CD(5%)	0.05	0.03	0.02	0.02	0.01	0.01	0.04	0.05	0.03
Interaction (NXB)									
N_1B_1	1.94	2.26	2.10	0.88	1.01	0.95	3.35	3.41	3.38
N_1B_2	1.91	2.23	2.07	0.84	0.97	0.91	3.21	3.28	3.24
N_1B_3	1.93	2.25	2.09	0.86	0.99	0.93	3.28	3.30	3.29
N_2B_1	2.54	2.86	2.70	0.99	1.12	1.06	3.84	3.98	3.91
N_2B_2	1.96	2.28	2.12	0.89	1.02	0.95	3.43	3.43	3.43
N_2B_3	2.11	2.43	2.27	0.93	1.06	1.00	3.74	3.83	3.79
N_3B_1	1.79	2.11	1.95	0.82	0.95	0.89	3.16	3.04	3.10
N_3B_2	1.64	1.96	1.80	0.71	0.84	0.78	2.49	2.60	2.55
N_3B_3	1.69	2.01	1.85	0.75	0.88	0.82	2.93	3.16	3.05
S.Em±	0.05	0.03	0.02	0.02	0.01	0.01	0.04	0.05	0.03
CD(5%)	0.10	0.10	0.10	NS	NS	NS	0.12	0.14	0.10
Control	2.09	2.41	2.25	0.91	1.04	0.98	3.45	3.59	3.52
S.Em±	0.05	0.03	0.02	0.02	0.01	0.01	0.04	0.05	0.03
CD(5%)	0.13	0.13	0.13	0.04	0.04	0.04	0.16	0.19	0.14

Table 8: Effect of inorganic nutrients and bio-formulations on yield t/ha, total biomass and harvest index of garlic

Infestation Treatments	Yield t/ha			Total biomass			Harvest index		
	2022-2023	2023-2024	pooled	2022-2023	2023-2024	pooled	2022-2023	2023-2024	pooled
Nutrients									
N_1	5.47	5.55	5.51	4.29	4.21	4.27	76.48	79.07	77.78
N_2	6.12	6.24	6.18	4.53	4.66	4.57	80.98	80.39	80.68
N_3	4.77	4.89	4.83	3.88	3.81	3.84	73.52	76.35	74.93
S.Em±	0.02	0.02	0.02	0.01	0.01	0.01	0.18	0.23	0.15
CD(5%)	0.07	0.08	0.06	0.04	0.04	0.03	0.50	0.70	0.63
Bio-agents									
B_1	5.75	5.80	5.77	4.40	4.28	4.35	78.35	81.08	79.71
B_2	5.07	5.17	5.12	4.05	4.05	4.04	74.79	75.82	75.31
B_3	5.53	5.72	5.63	4.26	4.34	4.29	77.84	78.90	78.37
S.Em±	0.02	0.02	0.02	0.01	0.01	0.01	0.18	0.23	0.15
CD(5%)	0.07	0.08	0.06	0.04	0.04	0.03	0.50	0.70	0.63
Interaction (NXB)									
N_1B_1	5.58	5.69	5.64	4.35	4.28	4.36	76.98	79.67	78.32
N_1B_2	5.34	5.46	5.40	4.24	4.15	4.22	75.69	78.87	77.28
N_1B_3	5.47	5.50	5.49	4.27	4.20	4.24	76.79	78.66	77.72
N_2B_1	6.41	6.63	6.52	4.65	4.78	4.68	82.59	83.36	82.97
N_2B_2	5.71	5.71	5.71	4.31	4.44	4.34	79.56	77.20	78.38
N_2B_3	6.24	6.39	6.31	4.63	4.76	4.69	80.78	80.61	80.69
N_3B_1	5.27	5.07	5.17	4.19	3.79	4.01	75.48	80.20	77.84
N_3B_2	4.14	4.34	4.24	3.60	3.56	3.57	69.11	71.40	70.26
N_3B_3	4.89	5.26	5.08	3.86	4.07	3.93	75.96	77.45	76.70
S.Em±	0.07	0.08	0.06	0.04	0.04	0.03	0.53	0.70	0.46
CD(5%)	0.22	0.24	0.21	0.13	0.13	0.09	1.60	2.07	1.40
Control	5.74	5.98	5.86	4.61	4.73	4.65	74.77	75.90	75.33
S.Em±	0.07	0.08	0.06	0.04	0.04	0.03	0.50	0.70	0.63
CD(5%)	0.30	0.31	0.22	0.16	0.17	0.14	2.07	2.60	0.55

Pooled data related to yield characters revealed that there was statistically significant difference was observed the highest yield, total biomass and harvest index (6.18 t/ha, 4.57 kg/plot and 80.68%) respectively was recorded in N_2 (50%N +100%P+50%K+ *Azotobactor* 5kg/ha+ KSB 6Kg/ha). The application bio formulations recorded statistically significant difference among B_1 (*Trichoderma viride* 10ml/l + Neem oil 0.5%) noted highest yield, total biomass and harvest index (5.77

t/ha, 4.35 kg/plot and 79.71%). The interaction between soil nutrients and bio formulation found significant difference between the treatments among the all combinations the application of N_2B_1 (50%N +100%P+50%K+ *Azotobactor* 5kg/ha+ KSB 6Kg/ha + *Trichoderma viride* 10ml/l + Neem oil 0.5%) recorded the maximum yield, total biomass and harvest index (6.52 t/ha, 4.68 kg/plot and 82.97%) respectively.

The main and important objective of any production programme is to have maximum crop yield for better returns. The substantial quantity of stored photosynthetic energy that has been translocated into different yield attributes may be the reason for the maximum yield. When inorganic, organic, and biofertilizers are used together, the economic significance of yield characteristics may increase due to persistent mineralization and the availability of nutrients as needed later in crop growth (Talware *et al.* 2012) [18]. Effective photosynthetic translocation to bulbs results in larger bulbs and a higher buildup of dry matter in the bulbs. Increased plant growth in terms of height and leaf count may be the cause of the yield improvement observed with the use of an integrated nutrient strategy. Healthy top growth may be the trigger of increased photosynthesis and accumulated carbohydrates, which lead to larger bulbs as measured by polar and equatorial bulb diameters. Additionally, a higher number of cloves may have an impact on the average bulb weight, length, and width of the cloves, all of which ultimately resulted in a higher yield. Therefore, the combined action of the nutrients as described under the growth parameter may have certainly contributed to the increased yield. These results are in close conformity with the finding of Bhandari *et al*. (2012), Kore *et al*. (2006), Ranjan *et al*. (2010) [14] Choudhary *et al.* (2013) [3], Sachin *et al.* (2017) [15], Rai *et al*. (2004) [13] in garlic and Banjare *et al*. (2015) [2] in onion.

Conclusion

The study conducted to evaluate the influence of crop management practices pertaining to growth and yield of the crop among various treatments the application of 50%N +100%P+50%K+ *Azotobactor* 5kg/ha+ KSB 6Kg/ha + *Trichoderma viride* 10ml/l + Neem oil 0.5%. performed in terms of growth and yield of crop.

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