

Journal of Biological Control, 39(3): 356–364, 2025, DOI: 10.18311/jbc/2025/50794

Research Article

Efficacy of inorganic nutrients, biostimulants along with bioagents and botanical extracts against thrips and purple blotch of garlic (*Allium sativum* L.)

SEELOTHU RAKESH[1*], J. CHEENA[2], P. PRASANTH[3], M. SRINIVAS[4], B. NAVEEN KUMAR[5] and V. SURESH[6]

[1]*Department of Plantation, Spices, Medicinal and Aromatic Crops, Sri Konda Laxman Telangana State Horticultural University, Hyderabad – 500030, Telangana, India*

[2] *Sri Konda Laxman Telangana State Horticultural University, Mulugu, Siddipet – 502279, Telangana, India*

[3]*College of Horticulture, Sri Konda Laxman Telangana State Horticultural University, Hyderabad – 500030, Telangana, India*

[4]*Sri Konda Laxman Telangana State Horticultural University, Hyderabad – 500030, Telangana, India*

[5]*Horticulture Polytechnic (HPT) College, Sri Konda Laxman Telangana State Horticultural University, Ramagirikhilla, Peddapalli – 505212, Telangana, India*

[6]*Vegetable Research Station – Rajendranagar, Sri Konda Laxman Telangana State Horticultural University, Hyderabad – 500030, Telangana, India*

**Corresponding author E-mail:* seelothrakesh97@gmail.com

ABSTRACT: Garlic (*Allium sativum* L.), a member of the Alliaceae family, is one of the most extensively grown *Allium* species. The field experiments were conducted for two consecutive years at Medicinal and Aromatic Plant Research Station, Rajendranagar, Hyderabad - SKLTGHU, during *Rabi*, 2022-23 and 2023-24, to assess the efficacy of biorational and chemical treatments against thrips and blotch in garlic using contrast factorial randomized block design consisting of ten treatments with three replications. The results of the current study clearly demonstrate that, apart from chemical insecticides, the application of plant-based botanical extracts plays a key role in controlling thrips population dynamics. In a similar line, in the case of disease control, the liquid spraying of biological control agents plays a crucial role in controlling disease incidence. In the present study, the control plot, which received chemical insecticide Imidacloprid @ 0.3 ml/l, recorded the lowest population of thrips (3.10/plant) as well as thrips infestation (3.55%). However, the scenario was different in case of disease control, *i.e.*, the chemical treatment proved least effective in controlling the disease infestation and incidence and the combine treatments of 50% NPK+ Humic acid at5ml/ l with *Trichoderma viride* 10 ml/l along with neem oil @ 0.5% showed highest efficacy in controlling the disease infestation (1.88/plot) and incidence (2.34%). Complementary assessments of bioformulation treatments showed that neem oil spray is most effective in reducing the incidence of thrips, while other combinations showed modest performance. By reducing reliance on chemicals, *Trichoderma* and neem oil's excellent performance demonstrates the possibility of environmentally benign and sustainable garlic farming.

KEYWORDS: Blotch, imidacloprid, neem oil, oil extracts, *Trichoderma*

(Article chronicle: Received: 27-07-2025; Revised:10-09-2025; Accepted: 14-09-2025)

INTRODUCTION

Garlic (*A. sativum* L.) is a hardy, bulbous monocotyledonous plant that belongs to the family Alliaceae. It is the second most extensively grown vegetable after onions. In addition to being produced for its nutritional and therapeutic properties, it is valued for its culinary properties in every culture. Garlic has long been used medicinally for its antibacterial, antifungal, antiviral, anticancer, and antiseptic properties. The various minerals and vitamins obtained from garlic are suitable for good health (Deresse, 2010).

In the medical field, garlic is highly valued for its therapeutic properties and is thought by specialists to be able to treat a variety of conditions, such as tumours, food poisoning, cholera, fever, headaches, and gastrointestinal issues (Rathod *et al.*, 2023; Zugaro *et al.*, 2023). It is a crucial component of many culinary procedures because of its distinct flavour profile and aromatic properties. Garlic is widely prized in the medical world for its medicinal properties, and experts believe it may cure numerous illnesses, including tumours, food poisoning, cholera, fever, headaches, and gastrointestinal issues (Varade *et al.*, 2024). A study conducted by Alali *et al.* (2017) showed that garlic can effectively decrease blood

pressure in people with hypertension, lower cholesterol in people with hyperlipidemia, and improve blood sugar management in people with diabetes. The two main bioactive components of garlic are diallyl thiosulphate and allicin (Rakshit *et al.*, 2023).

According to Hauxwell (2008), thrips are positively thigmotactic, indicating that they prefer to be close to plant surfaces and enclosed within plant parts, such as tightly closed leaves, curled leaves, or petals. It is challenging to locate and manage them because of their behaviour. Depending on the temperature, *T. tabaci*'s life cycle lasts between 10 to 30 days, with higher temperatures accelerating it. When they hatch, nymphs eagerly consume the upper portions of plants, such as leaves and flowers, but adults thrive on the fruits. Usually, the pre-pupal stage found in soil or leaf litter, the pre-pupa and pupal instars are inactive and non-feeding in habit.

Purple blotch of garlic caused by *Alternaria porri,* which is a common saprophyte on plant debris and plant tissue. It leads to considerable loss in yield and quality of garlic. Among *Allium* sp. (onions, garlic, shallots, leeks, scallions, and chives), it is the most damaging disease. Alternaria species are harmful because they produce toxins that can cause illness, either specific or general in nature. The secondary metabolites of these toxins cause leaf necrosis, which kills unprotected cultivars (Mamgain *et al.*, 2013). Usually affecting a plant's leaves and bulbs, the disease can reduce productivity by up to 97% (Kareem *et al.*, 2012).

Nitrogen, phosphorus, and potassium play key roles in garlic's vegetative development and output (Mallangouda *et al.*, 1995). Garlic requires nitrogen supplementation to ensure good vegetative development (Kakara *et al.*, 2002). 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. Bio-stimulants also enhance plant growth, besides inorganic and biofertilizers, which are also known as metabolic enhancers, compounds other than fertilizers that increase plant growth when administered in tiny amounts. They minimize fertilizer requirements while improving nutrient absorption by growing deeper roots. They will boost the plant's immune system while also improving natural plant toxins and microbial root defence against insects and soil infections. Hence, they can also be included in the integrated schedule programme to reduce the load of inorganic fertilizers on the environment.

Because of its cost-efficiency, eco-friendliness, safety for the environment and public health, and effectiveness in managing pests, botanicals are now becoming an economically feasible component of Integrated Pest Management (IPM) methods for all crops. With the abundance of these plants, subtropical regions have a unique opportunity to use botanicals in pest management. Insecticide resistance has emerged in pest populations due to the frequent use of synthetic pesticides. Certain plant-based products have the ability to kill sucking insects. Despite this, an effort was conducted to ascertain the relative toxicity of plant extracts that were readily available locally against garlic thrips (Singh *et al.*, 2014). Since garlic is one of the most important Alliaceous crops (Alliaceae family) and is used as a vegetable and spice crop, organic and less hazardous production of garlic (*A. sativum* L.) is becoming more and more popular (Govind *et al.*, 2015).

In order to manage plant diseases, recent efforts have focused on creating bio-control techniques that are long-lasting, safe, and efficient. It has been demonstrated that using biocontrol agents to combat a variety of plant diseases is both environmentally beneficial and efficient. *Trichoderma* is regarded as the most significant fungal antagonist as it regulates a variety of soil-borne and seed infections brought on by a broad spectrum of fungal pathogens (Mathivanan *et al.*, 2000). When incorporated into the soil, *Trichoderma* multiplies quickly because it is inherently resistant to a variety of harmful substances, including phenolic chemicals, herbicides, fungicides, and insecticides like DDT. The *Trichoderma* strain's ABC transport systems may be the cause of its tolerance to harmful substances. Trichoderma's biocontrol strategies may be explained by mycoparasitism, nutritional competition, the release of toxic metabolites, and extracellular hydrolytic enzymes (Harman *et al.*, 2004).

To address this challenge, integrated pest and disease management strategies are crucial for sustainable management. These strategies combine chemical practices, biological control measures, and judicious insecticide application to achieve effective pest and disease suppression while minimizing economic losses and environmental impacts.

MATERIALS AND METHODS

The field experiment was conducted at Medicinal and Aromatic Plant Research Station, Sri Konda Laxman Telangana Horticultural University, Rajendranagar, Hyderabad. Geographically, it lies at a latitude of 17°.19' N, longitude of 79°.23' E and an altitude of 542.6 m above mean sea level. The site of the experiment is situated in a semi-arid tropical zone. The average maximum temperatures during the crop period, *i.e.*, 2022-23 and 2023-24, were 33.5°C and 36.3 and the minimum average temperatures were 13.7°C and 16°C, respectively. The average maximum relative humidity during the crop period, *i.e.*, 2022-23 and 2023-24, was 92.0%

and 92.0% and the average minimum relative humidity was 35.0% and 29.0%, respectively.

The experimental area 410 m^2 used in this study was further, the area was divided into three blocks, each of which was further divided into ten plots. The spacing between plants and rows was maintained at around 15 and 30 cm, respectively. In accordance with crop requirements, the same agronomic techniques were used. There were nine treatment combinations, and one control plot was grown, and each treatment was repeated thrice by using the methodology of Contrast Factorial Randomized Block Design according to the experiment's design. The raised beds of 3.0 × 2.0 m^2 were prepared, and each plot was divided from the others by a 50 cm-wide canal on four sides.

The design consist of factor-1 include chemical fertilizers combination with biostimulants and in factor - 2 include bioformulations and botanical extracts as follows (S_1 - 50% NPK+ Humic acid at 5 ml/l : S_2 - 50% NPK+ Fulvic acid at 5 ml/l; S_3 - 50% NPK+ Seaweed Extract at 5 ml/l, N_1:100% N +50 % P + 50% K + PSB @ 5 kg/ha +KSB @ 6 kg/ha; and bioformulations (B1: *Trichoderma viride* @ 10 ml/l + Neem oil @ 0.5%; B_2: *Pseudomonas fluorescens* @ 10 ml/l + *Pongamia* oil @ 0.5%; B_3: *Bacillus subtilis* @ 10 ml/l + Sesame oil @ 1%) including control (100% RDF + Imidacloprid 17.8 SL @ 0.3 ml/l).

Treatment combinations

T_1-50% NPK+ Humic acid @5 ml/l+ *Trichoderma viride* @10 ml/l + Neem oil @ 0.5%

T_2-50% NPK+ Humic acid @5 ml/l+ *Pseudomonas fluorescens* @ 10 ml/l + *Pongamia* oil @ 0.5%

T_3-50% NPK+ Humic acid @5 ml/l+ *Bacillus subtilis* @ 10 ml/l + Sesame oil @ 1%

T_4-50% NPK+ Fulvic acid @5 ml/l + *Trichoderma viride* @ 10 ml/l + Neem oil @ 0.5%

T_5-50% NPK+ Fulvic acid @5 ml/l + *Pseudomonas fluorescens* @ 10 ml/l + *Pongamia* oil @ 0.5%

T_6-50% NPK+ Fulvic acid @5 ml/l + *Bacillus subtilis* @ 10 ml/l + Sesame oil @ 1%

T_7-50% NPK+ Seaweed Extract @5 ml/l + *Trichoderma viride*@10 ml/l + Neem oil @ 0.5%

T_8-50% NPK+ Seaweed Extract @5 ml/l + *Pseudomonas fluorescens* @ 10 ml/l + *Pongamia* oil @ 0.5%

T_9-50% NPK+ Seaweed Extract @5 ml/l + *Bacillus subtilis* @ 10 ml/l + Sesame oil @ 1%

T_{10} – Control 100% RDF+ Imidacloprid @ 0.3 ml/lit

The bioformulation was applied as soil drenching as well as foliar application to the plants. From the first week of January until the crop was harvested, the experimental plots were regularly monitored for the *T. tabaci* population. Once the pest reached a specific economic threshold level, the treatments were administered at the rates indicated above. Post-treatment applications, *T. tabaci* (nymphs and adults) population data were recorded after every 15-day interval before and after every spraying from randomly selected ten plants in each treatment as well as the control plot. The control plot was grown separately to compare the data with treatment combinations. The percentage of infestation is calculated using the following formula:

Per cent infestation = No. of adults or larvae per plant/ Total no. of plants per plot. Eqn-1

The percentage of disease infestation was determined using the formula given below.:

Disease incidence (%) = (No. of plants diseased/No. of plants under observation) X 100. Eqn-2

Data analysis

The data about all characters studied were subjected to statistical analysis using variance techniques as described by Panse and Sukhatme (1967), Gomez and Gomez (1983) and Rangaswamy (2010). The significant difference of treatments was tested by the F-test at a 5 per cent level of significance. The Critical Difference (CD) was calculated when the difference among the treatments was found to be significant by the F-test.

RESULTS AND DISCUSSION

Incidence of thrips and percent infestation per plant

The two-year data related to the average number of thrips per plant revealed that the population of thrips was not noticed up to 60 days after sowing. However, the thrips population was observed after the 4th spray, *i.e.*, in the month of January, the population of thrips was increasing continuously up to the 8th spray, and after the 8th spray there is reduction in the thrips population per plant was observed. Table 1 and fig 1 showed that statistically, there is no significant difference between the soil nutrients and bioformulation. However, is significant difference was observed between the control and combined treatments. The population of thrips per plant ranged from 3.63 to 7.11 per plant. The population dynamics observed that there was gradual increase in of thrips population at every successive interval of 15 days, *i.e.*, 2.4, 3.18, 3.46, 3.63, 5.4 and 3.65 at 45, 60, 75,90,105 and 120 days after sowing respectively followed by S_1B_1 (50% NPK+ Humic acid @ 5 ml/l + *Trichoderma viride* @ 10 ml/l + Neem oil @ 0.5%) 3.28, 3.52, 3.93, 4.04, 4.10 and 3.94 at 45, 60, 75, 90, 105 and 120 days after sowing respectively Notably, the thrips population under spraying of chemical insecticide

Table 1. Efficacy of inorganic nutrients, bio-stimulants in combination with bio-control agents and botanical extracts on thrips population

									Number of adults/plants
Treatments	**After 4th spray**			**After 5th spray**			**After 6th spray**		
	2022-2023	**2023-2024**	**Pooled**	**2022-2023**	**2023-2024**	**pooled**	**2022-2023**	**2023-2024**	**Pooled**
Nutrients									
S_1	4.39	4.55	4.47	4.64	4.74	4.69	5.09	5.25	5.17
S_2	4.79	5.18	4.98	5.04	5.43	5.23	5.37	5.62	5.50
S_3	4.58	4.71	4.65	4.91	5.02	4.97	5.15	5.30	5.23
S. Em (+)	0.03	0.01	0.02	0.04	0.01	0.02	0.05	0.04	0.04
L.S.D (p≤0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Bio-agents									
B_1	3.52	3.62	3.57	3.84	3.99	3.91	4.19	4.30	4.24
B_2	5.49	5.97	5.73	5.83	6.14	5.98	6.28	6.55	6.42
B_3	4.75	4.85	4.80	4.92	5.06	4.99	5.15	5.32	5.24
S. Em (+)	0.03	0.01	0.02	0.04	0.01	0.02	0.05	0.04	0.04
L.S.D (p≤0.05)	0.11	0.03	0.06	0.13	0.03	0.07	0.15	0.12	0.13
Interaction									
S_1B_1	3.23	3.33	3.28	3.48	3.56	3.52	3.87	3.99	3.93
S_1B_2	5.69	5.99	5.84	5.99	6.09	6.04	6.65	6.78	6.72
S_1B_3	4.24	4.32	4.28	4.45	4.56	4.51	4.76	4.98	4.87
S_2B_1	3.87	4.03	3.95	4.06	4.28	4.17	4.46	4.58	4.52
S_2B2	5.36	6.24	5.80	5.61	6.36	5.99	5.97	6.53	6.25
S_2B3	5.13	5.28	5.21	5.45	5.64	5.55	5.69	5.76	5.73
S_3B1	3.45	3.49	3.47	3.98	4.12	4.05	4.23	4.33	4.28
S_3B2	5.43	5.67	5.55	5.89	5.96	5.93	6.23	6.35	6.29
S_3B3	4.87	4.96	4.92	4.87	4.98	4.93	4.99	5.23	5.11
S. Em (+)	0.11	0.03	0.06	0.13	0.03	0.07	0.15	0.12	0.13
L.S.D (p≤0.05)	NS	0.10	NS	NS	0.10	NS	NS	NS	NS
Control	2.48	2.31	2.40	3.14	3.22	3.18	3.29	3.63	3.46
S. Em (+)	0.11	0.03	0.06	0.13	0.03	0.07	0.15	0.12	0.13
L.S.D (≤0.05)	0.45	0.13	0.21	0.53	0.12	0.27	0.59	0.46	0.49

NS = non-significant

						Number of adults/plants			
Treatments	**After 7th spray**			**After 8th spray**			**After 9th spray**		
	2022-2023	**2023-2024**	**Pooled**	**2022-2023**	**2023-2024**	**pooled**	**2022-2023**	**2023-2024**	**pooled**
Nutrients									
S_1	5.28	5.42	5.35	5.28	5.39	5.43	5.41	5.16	5.31
S_2	5.65	5.84	5.74	5.65	5.78	5.83	5.81	5.76	5.64
S_3	5.30	5.42	5.36	5.30	5.41	5.47	5.44	5.15	5.22
S. Em (+)	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.01	0.02
L.S.D(p≤0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Bio-agents									
B_1	4.34	4.45	4.39	4.34	4.42	4.48	4.45	4.21	4.34
B_2	6.65	6.91	6.78	6.65	6.79	6.82	6.81	6.71	6.63
B_3	5.24	5.33	5.29	5.24	5.37	5.44	5.41	5.16	5.20
S. Em (+)	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.01	0.02
L.S.D(p≤0.05)	0.13	0.12	0.12	0.13	0.12	0.12	0.12	0.04	0.06

Table 1. (Continued)

Interaction									
S_1B_1	3.99	4.09	4.04	3.99	4.08	4.12	4.10	3.87	4.01
S_1B_2	6.99	7.23	7.11	6.99	7.09	7.10	7.08	6.88	6.95
S_1B_3	4.87	4.95	4.91	4.87	4.99	5.06	5.03	4.73	4.96
S_2B_1	4.65	4.76	4.71	4.65	4.75	4.82	4.79	4.62	4.65
S_2B2	6.52	6.95	6.73	6.52	6.72	6.72	6.72	7.01	6.70
S_2B3	5.78	5.81	5.80	5.78	5.87	5.96	5.92	5.66	5.56
S_3B1	4.38	4.49	4.44	4.38	4.43	4.49	4.46	4.14	4.36
S_3B2	6.45	6.55	6.50	6.45	6.57	6.62	6.60	6.23	6.23
S_3B3	5.08	5.23	5.16	5.08	5.24	5.31	5.28	5.09	5.08
S. Em (+)	0.13	0.12	0.12	0.13	0.12	0.12	0.12	0.04	0.06
L.S.D($p \leq 0.05$)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Control	3.48	3.77	3.63	3.48	3.61	3.59	5.40	3.74	3.55
S. Em (+)	0.13	0.12	0.12	0.13	0.12	0.12	0.12	0.04	0.06
L.S.D($p \leq 0.05$)	0.53	0.45	0.47	0.53	0.49	0.47	0.47	0.18	0.22

NS = non-significant
S_1 - 50% NPK+ Humic acid at 5 ml/l
S_2 - 50% NPK+ Fulvic acid at 5 ml/l
S_3 - 50% NPK+ Seaweed extract at 5 ml/l
B_1 - *Trichoderma viride* at 10 ml/l + Neem oil at 0.5%
B_2 - *Pseudomonas fluorescens* at 10 ml/l + *Pongamia* oil at 0.5%
B_3 - *Bacillus subtilis* at 10 ml/l + Sesame oil at 1%
Control - 100% RDF + Imidacloprid 17.8 SL @ 0.3 ml/l

Imidacloprid @ 0.3 ml/l increased across all three levels after 60 DAS, reflecting the pest's life cycle dynamics. Based on this observation was noticed that the increase in thrips population was not rapid in all treatments, and it decreased the population of thrips at the crop reaches harvesting.

Thrips infestation

Data regarding the thrips Infestation per plant from Table 2 and Fig 1 revealed that statistically, there is no significant difference between the soil nutrients and bioformulation. However, is significant difference was observed between the control and combined treatments. The control recorded the lowest thrips infestation per plant, *i.e.*, 2.99, 3.98, 4.33, 4.54, 4.56 and 4.46 across 45, 60, 75, 90, 105, and 120 days after each spray followed by (50% NPK+ Humic acid @ 5 ml/l + *Trichoderma viride* @ 10 ml/l + Neem oil @ 0.5%) recorded 4.10, 4.40, 4.91, 5.05, 5.13 and 4.93, respectively at 45, 60, 75, 90, 105, and 120 days after sowing. The reduction of thrips infestation under Imidacloprid might be due to the Imidacloprid 17.8 SL @ 0.3 ml/l effective towards the suppression of pest population. Based on the above findings, it was concluded that spraying of Imidacloprid 17.8 SL @ 0.3 ml/l. At a 15-day interval, proven to be the best in controlling thrips population and infestation percentage of thrips per plant, the reason might be due to its systemic action and neurotoxic effects on insect pests. It is a neonicotinoid insecticide that mimics nicotine, binding to nicotinic acetylcholine receptors in the insect nervous system. This binding disrupts nerve signal transmission, leading to paralysis and death of the pest. Its systemic nature allows it to be absorbed by plants and translocated to various tissues, providing protection even in areas where thrips feed. These results were similar to those of Pandey *et al.* (2013) evaluated the effectiveness of chemical pesticides and botanicals based on neem against onion thrips. The outcome showed that neem-based formulations were less successful in controlling onion thrips than chemical pesticides.

Incidence of Purple blotch

Number of infected plants

The two-year data showed that there were no statistically significant results obtained between inorganic nutrients and bioagents. However, the application of biocontrol agents along with botanical extract reduces the disease-affected plants and disease incidence in all treatments. From Table 3 and Figure 2, it resulted that the foliar application of *Trichoderma* along with neem oil plays an effective role in reducing in number of infected plants. Based on two years of pooled data clear that the combined application of 50% NPK+ Humic acid @ 5 ml/l+ *Trichoderma viride* @ 10 ml/l + Neem oil @ 0.5% (1.88/plot) followed by 50% NPK+ Humic acid @ 5 ml/l+ *Bacillus subtilis* @ 10 ml/l + Sesame oil @

Table 2. Efficacy of inorganic nutrients, bio-stimulants in combination with bio-control agents and botanical extracts on the infestation of thrips per plant

Per cent of thrips infestation									
Treatments	After 4th spray			After 5th spray			After 6th spray		
	2022-2023	2023-2024	Pooled	2022-2023	2023-2024	pooled	2022-2023	2023-2024	Pooled
Nutrients									
S_1	5.48	5.68	5.58	5.80	5.92	5.86	6.37	6.56	6.46
S_2	5.98	6.48	6.23	6.30	6.78	6.54	6.72	7.03	6.87
S_3	5.73	5.88	5.81	6.14	6.28	6.21	6.44	6.63	6.53
S. Em (+)	0.04	0.01	0.02	0.05	0.05	0.02	0.06	0.05	0.05
L.S.D(p≤0.05)	NS	0.13	NS	NS	NS	NS	NS	NS	NS
Bio-agents									
B_1	4.40	4.52	4.46	4.80	4.98	4.89	5.23	5.38	5.30
B_2	6.87	7.46	7.16	7.29	7.67	7.48	7.86	8.19	8.02
B_3	5.93	6.07	6.00	6.15	6.33	6.24	6.43	6.65	6.54
S. Em (+)	0.04	0.01	0.02	0.05	0.05	0.02	0.06	0.05	0.05
L.S.D(p≤0.05)	0.14	0.04	0.08	0.17	0.15	0.08	0.19	0.15	0.16
Interaction									
S_1B_1	4.04	4.16	4.10	4.35	4.45	4.40	4.84	4.99	4.91
S_1B_2	7.11	7.49	7.30	7.49	7.61	7.55	8.31	8.48	8.39
S_1B_3	5.30	5.40	5.35	5.56	5.70	5.63	5.95	6.23	6.09
S_2B_1	4.84	5.04	4.94	5.08	5.35	5.21	5.58	5.73	5.65
S_2B2	6.70	7.80	7.25	7.02	7.95	7.48	7.47	8.16	7.81
S_2B3	6.41	6.60	6.51	6.81	7.05	6.93	7.11	7.20	7.16
S_3B1	4.31	4.36	4.34	4.98	5.15	5.06	5.29	5.41	5.35
S_3B2	6.79	7.09	6.94	7.36	7.45	7.41	7.79	7.94	7.86
S_3B3	6.09	6.20	6.14	6.09	6.23	6.16	6.24	6.54	6.39
S. Em (+)	0.14	0.04	0.08	0.17	0.15	0.08	0.19	0.15	0.16
L.S.D(≤0.05)	NS	NS	0.072	NS	NS	0.093	NS	NS	NS
Control	2.89	3.10	2.99	4.03	3.93	3.98	4.54	4.12	4.33
S. Em (+)	0.14	0.04	0.08	0.17	0.15	0.08	0.19	0.15	0.16
L.S.D(p≤0.05)	0.56	0.17	0.30	0.65	0.57	0.33	0.73	0.58	0.62

NS = non-significant

Per cent of thrips infestation									
Treatments	After 7th spray			After 8th spray			After 9th spray		
	2022-2023	2023-2024	Pooled	2022-2023	2023-2024	pooled	2022-2023	2023-2024	Pooled
Nutrients									
S_1	6.60	6.78	6.69	6.73	6.79	6.76	6.45	6.63	6.54
S_2	7.06	7.30	7.18	7.22	7.29	7.26	7.20	7.04	7.12
S_3	6.63	6.78	6.70	6.77	6.84	6.80	6.44	6.53	6.49
S. Em (+)	0.05	0.05	0.05	0.05	0.01	0.05	0.02	0.02	0.01
L.S.D(p≤0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Bio-agents									
B_1	5.43	5.56	5.49	5.53	5.60	5.56	5.26	5.43	5.34
B_2	8.32	8.64	8.48	8.49	8.52	8.51	8.38	8.28	8.33
B_3	6.55	6.66	6.61	6.71	6.80	6.76	6.45	6.50	6.48
S. Em (+)	0.05	0.05	0.05	0.05	0.01	0.05	0.02	0.02	0.01
L.S.D(p≤0.05)	0.17	0.15	0.15	0.16	0.04	0.15	0.05	0.07	0.05

Table 2. (Continued)

Interaction									
S_1B_1	4.99	5.11	5.05	5.10	5.15	5.13	4.84	5.01	4.93
S_1B_2	8.74	9.04	8.89	8.66	8.70	8.68	8.60	8.69	8.64
S_1B_3	6.09	6.19	6.14	6.24	6.33	6.28	5.91	6.20	6.06
S_2B_1	5.81	5.95	5.88	5.94	6.03	5.98	5.78	5.81	5.79
S_2B2	8.15	8.69	8.42	8.40	8.40	8.40	8.76	8.37	8.57
S_2B3	7.23	7.26	7.24	7.34	7.45	7.39	7.08	6.95	7.01
S_3B1	5.48	5.61	5.54	5.54	5.61	5.58	5.18	5.45	5.31
S_3B2	8.06	8.19	8.13	8.21	8.28	8.24	7.79	7.79	7.79
S_3B3	6.35	6.54	6.44	6.55	6.64	6.59	6.36	6.35	6.36
S. Em (+)	0.17	0.15	0.15	0.16	0.04	0.15	0.05	0.07	0.05
L.S.D(p≤0.05)	0.017	NS	NS	NS	0.12	NS	0.17	NS	NS
Control	**4.72**	**4.35**	4.54	4.48	4.63	4.56	4.34	4.58	4.46
S. Em (+)	0.17	0.15	0.15	0.16	0.04	0.15	0.05	0.07	0.05
L.S.D(P≤0.05)	0.66	0.59	0.60	0.62	0.16	0.58	0.22	0.28	0.20

NS = non-significant
S_1 - 50% NPK+ Humic acid at 5 ml/l
S_2 - 50% NPK+ Fulvic acid at 5 ml/l
S_3 - 50% NPK+ Seaweed extract at 5 ml/l
B_1 - *Trichoderma viride* at 10 ml/l + Neem oil at 0.5%
B_2 - *Pseudomonas fluorescence* at 10 ml/l + *Pongamia* oil at 0.5%
B_3 - *Bacillus subtilis* at 10 ml/l + Sesame oil at 1%
Control - 100% RDF + Imidacloprid 17.8 SL @ 0.3 ml/l

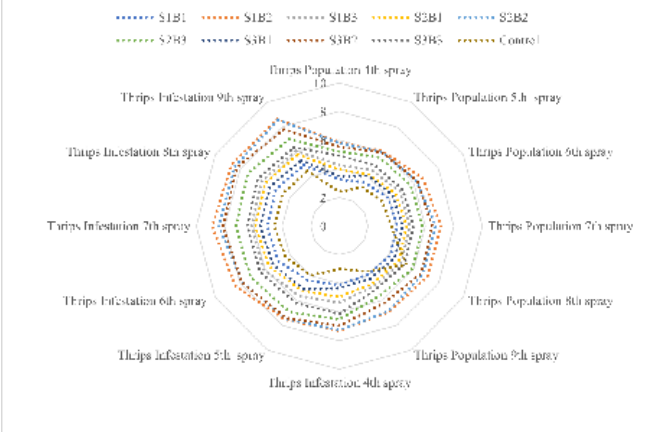


Figure 1. Effect of inorganic nutrients, bio-stimulants in combination with bio-control agents and botanical extracts on thrips population and infestation per plant.

1% (2.1/plot). However, control recorded the highest disease-infected plants, 3.77/plot, which indicates that the biological agents reduced the infected plants by almost 50% over the chemical application. The obtained results revealed that the combined application was better than individual applications.

Disease incidence

The data indicated that all bio-formulation treatments and botanical products displayed notably superior efficacy compared to the control throughout all observation intervals. However, there were significant variances in efficacy among them. From Table 3 and Figure 2, it was observed that the incidence of disease ranged from 2.34 to 4.71, even though the interaction between soil nutrients and bio-formulations did not differ significantly. However, there was a significant difference between the control and the rest of the treatments. The lowest per cent of disease incidence recorded under the combined treatment of 50% NPK + Humic acid @5 ml/l + *Trichoderma viride*@10 ml/l + Neem oil @ 0.5% (2.35%), followed by 50% NPK + Humic acid @ 5 ml/l + *Bacillus subtilis* @ 10 ml/l + Sesame oil @ 1% (2.65%). However, control recorded the highest disease incidence (4.72%). The efficacy of disease-controlling capacity among the biocontrol agents, in descending order of *Trichoderma viride, Bacillus subtilis, and Pseudomonas fluorescens,* consistently demonstrated that all treatments exhibited superior efficacy compared to the untreated control.

According to the findings, neem oil has been successfully used to reduce the incidence of disease when combined with biocontrol agents such as *Trichoderma viride* and *Pseudomonas fluorescens*. Neem oil and these agents significantly reduced the severity of disease and improved growth parameters in bulb crops (Tiwari *et al.*, 2022). The foliar application of biocontrol agents like *Trichoderma* plays an important role in the reduction of disease-infected plants, and the percentage of disease incidence that it

Table 3. Effect of inorganic nutrients, bio-stimulants in combination with bio-control agents and botanical extracts on the number of infected plants and the percentage of disease incidence of garlic

Treatments	Number of infected plants			Per cent of disease incidence		
	2022-2023	2023-2024	Pooled	2022-2023	2023-2024	Pooled
Nutrients						
S_1	2.01	2.18	2.10	2.51	2.73	2.62
S_2	2.89	3.06	2.98	3.61	3.83	3.72
S_3	2.46	2.58	2.52	3.08	3.22	3.15
S. Em (+)	0.007	0.007	0.005	0.009	0.009	0.006
L.S.D(p≤0.05)	0.02	0.02	0.02	0.02	0.02	0.01
Bio-agents						
B_1	2.29	2.41	2.35	2.86	3.01	2.94
B_2	2.62	2.81	2.72	3.27	3.51	3.39
B_3	2.45	2.6	2.53	3.06	3.25	3.16
S. Em (+)	0.007	0.007	0.005	0.009	0.009	0.006
L.S.D(p≤0.05)	0.02	0.02	0.02	0.02	0.02	0.01
Interaction						
S_1B_1	1.82	1.93	1.88	2.28	2.41	2.35
S_1B_2	2.15	2.42	2.29	2.69	3.03	2.86
S_1B_3	2.05	2.19	2.12	2.56	2.74	2.65
S_2B_1	2.72	2.85	2.79	3.4	3.56	3.48
S_2B2	3.05	3.28	3.17	3.81	4.09	3.95
S_2B3	2.89	3.06	2.98	3.61	3.83	3.72
S_3B1	2.32	2.45	2.39	2.9	3.06	2.98
S_3B2	2.65	2.72	2.69	3.31	3.4	3.36
S_3B3	2.41	2.56	2.49	3.01	3.2	3.11
S. Em (+)	0.02	0.02	0.02	0.02	0.02	0.01
L.S.D(p≤0.05)	NS	NS	NS	NS	NS	NS
Control	3.56	3.98	3.77	4.45	4.98	4.72
S. Em (+)	0.02	0.02	0.02	0.02	0.02	0.01
L.S.D(P≤0.05)	0.08	0.08	0.05	0.10	0.10	0.07

NS = non-significant
S_1 - 50% NPK+ Humic acid at 5 ml/l
S_2 - 50% NPK+ Fulvic acid at 5 ml/l
S_3 - 50% NPK+ Seaweed extract at 5 ml/l
B_1 - *Trichoderma viride* at 10 ml/l + Neem oil at 0.5%
B_2 - *Pseudomonas fluorescence* at 10 ml/l + *Pongamia* oil at 0.5%
B_3 - *Bacillus subtilis* at 10 ml/l + Sesame oil at 1%
Control - 100% RDF + Imidacloprid 17.8 SL @ 0.3 ml/l

might be due to *Trichoderma* can stimulate the plant's own defence mechanisms, leading to enhanced resistance against *A. porri*. This ISR (Induced Systemic Resistance) involves the activation of defence-related genes and accumulation of phytoalexins, besides these *Trichoderma* antagonistic fungi that suppress the growth of *A. porri* by competing for space

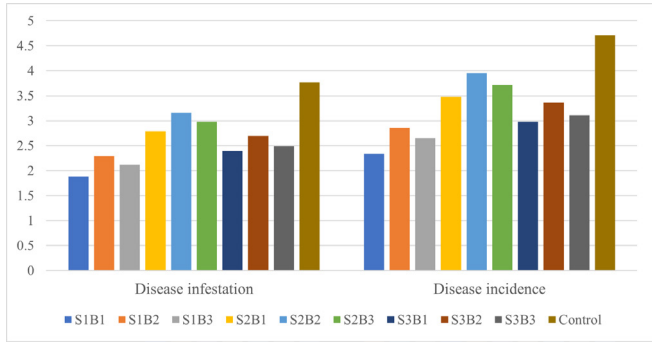


Figure 2. Effect of inorganic nutrients, bio-stimulants in combination with bio-control agents and botanical extracts on disease infestation and incidence of garlic.

and nutrients, parasitizing the pathogen, and producing antifungal metabolites.

CONCLUSION

In order to effectively manage thrips and blotch in garlic, it is important to integrate different components of control measures in a cohesive manner. The superior performance of *Trichoderma* and neem oil, environmentally friendly bioregulators highlights the potential of integrating into targeted chemical applications and cultural practices. This integrated approach not only reduces chemical reliance but also supports sustainable and eco-friendly cultivation.

ACKNOWLEDGEMENTS

We gratefully acknowledge the Sri Konda Laxman Telangana Horticultural University, Hyderabad, for giving us research facilities, laboratory, and technical support, and also to MoTA for financial support to carry out the current research.

REFERENCES

Alali, F. Q., El-Elimat, T., Khalid, L., Hudaib, R., Al-Shehabi, T. S., and Eid, A. H. 2017. Garlic for cardiovascular disease: Prevention or treatment. *Curr Pharm Des*, **23**(7): 1028-1041. https://doi.org/10.2174/1381612822666161010124530 PMid:27748188

Deresse, D. 2010. Antibacterial effect of garlic (*Allium sativum* L) on *Staphylococcus aureus*: An *in vitro* study. *Asian J Med Sci,* **10**: 62-65.

Gomez, K. A. and Gomez, A. A. 1983. Statistical Procedures for Agricultural Research. John Wiley and Sons series, 2nd ed.

Govind, S. M., Kumawat, R., Pal, A., Kumar, S., and Saha, S. 2015. Improvement of growth, yield and quality of garlic Cv. G-282 through a novel approach. *The Bioscan,* **10**(1): 23-27.

Harman, G. E., Howell, C. R., Viterbo, A., Chet, I., and Lorito, M. 2004. *Trichoderma species* opportunistic, avirulent plant symbionts. *Nat Rev Microbiol,* **2**: 43-56. https://doi.org/10.1038/nrmicro797 PMid:15035008

Hauxwell, C., 2008. Biology and management of pest thrips (Thysanoptera: Thripidae) with reference to Australia. Contribution to the report VG 06094: A scoping study of IPM compatible options for the management of key vegetable sucking pests.

Kakara, A. A., Abdullahzai, M. K., Saleem, M., and Shah, S. A. Q. 2002. Effect of nitrogenous fertilizer growth and yield of garlic. *Asian J Plant Sci*, **5**:544-545. https://doi.org/10.3923/ajps.2002.544.545

Kareem, M. A., Murthy, K. V. M. K., Nadaf, H. A., and Waseem, M. A. 2012. Effect of temperature, relative humidity and light on lesion length due to *Alternaria porri* in onion. *Asian J Environ Sci,* **7**: 47-49.

Mallangouda, B., Sulikeri G. S., Hulamari, W. S., Murthy, B. G., and Madalgeri, B. B. 1995. Effect of NPK and FYM on growth parameters of onion, garlic and coriander. *Curr Res,* **24**(11): 212-213.

Mamgain, A., Roychowdhury, R., and Tah, J. 2013. Alternaria pathogenicity and its strategic controls. *Res J Biol,* **1**: 1-9.

Mathivanan, N., Srinivasan, K., and Chellaiah, S. 2000. Field evaluation of *Trichoderma viride* pers. Ex. SF. Gray and *Pseudomonas fluorescens* Migula against foliar diseases of groundnut and sunflower. *J Biol Cont*, **14**: 31-34.

Pandey, S., Singh, B. K., and Gupta, R. P. 2013. Effect of neem-based botanicals, chemicals and bio- insecticides for the management of thrips in onion. *Indian J Agric Res,* **47**(6): 545-548.

Panse, V. G. and Sukhatme P. V. 1985. Statistical Methods for Agricultural Workers. ICAR, New Delhi.

Rakshit, D., Nayak, S., Kundu, S., Angelopoulou, E., Pyrgelis, E. S., Piperi, C., and Mishra, A. 2023. The pharmacological activity of garlic (*Allium sativum*) in Parkinson's disease: From molecular mechanisms to the therapeutic potential. *ACS Chem Neurosci*, **14**(6): 1033-1044. https://doi.org/10.1021/acschemneuro.2c00789 PMid:36861262

Rangaswamy, R. 1995. A Text Book of Agricultural Statistics. New Age International Publisher, New Delhi.

Rathod, N. V., Atla, J. S., and Rahane, J. 2023. Economics of production of garlic in Buldhana district. *Pharm Innov*, **12**(3): 1621-1627.

Singh, D. K., Verma, T. C., Aswal, S., and Aswani, G. 2014. Effect of different botanical pesticides against *Thrips tabaci* on garlic crop. *Asian Agri-Hist*, **18**(1): 57-61.

Tiwari, S., Tiwari, J. K., and Kumar, A. 2022. Eco-friendly management of purple blotch (*Alternaria Porri* (Ellis) disease of onion (*Allium Cepa* L.). *Bangladesh J Bot*, **51**(3): 541-546. https://doi.org/10.3329/bjb.v51i3.62000

Varade, S., Nadella, M., Hirake, A., Mungase, S. B., Ali, A., and Adela, R., 2024. Effect of garlic on the components of metabolic syndrome: A systematic review and meta-analysis of randomized controlled trials. *J Ethnopharmacol*, **318**(Pt B): Article 116960 https://doi.org/10.1016/j.jep.2023.116960 PMid:37517570

Zugaro, S., Benedetti, E., and Caioni, G. 2023. Garlic (*Allium sativum* L.) as an ally in the treatment of inflammatory bowel diseases. *Curr Issues Mol Biol*, **45**(1): 685-698. https://doi.org/10.3390/cimb45010046 PMid:36661532 PMCid:PMC9858111