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RESEARCH ARTICLE

Integrated crop management strategies for sustainable management of thrips and purple blotch in garlic (*Allium sativum* L.)

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Abstract

Garlic (*Allium sativum* L.) commonly known as *lashun* is the most widely cultivated *Allium* species after onion. However, the increasing prevalence of purple blotch disease and thrips incidence is a serious hazard that results in large losses in both qualitative and quantitative traits. This study aimed to evaluate the potential of combining cultural, biorational and chemical strategies for sustainable pest and disease management. Field experiments were conducted at Medicinal and Aromatic Plant Research Station, Rajendranagar, Hyderabad - SKLTGHU, during *Rabi*, 2022-23 and 2023-24 to assess efficacy of biorational and chemical against thrips and blotch. The experimental design consists of two factors (N_1:100 % N + 50 % P + 50 % K + PSB @ 5 kg/ha + KSB @ 6 kg/ha; N_2: 50 % N + 100 % P + 50 % K + *Azotobacter* @ 5 kg/ha + KSB @ 6 kg/ha; N_3:50 % N + 50 % P + 100 % K + *Azotobacter* @ 5 kg/ha + PSB @ 5 kg/ha) and bioformulations (B_1: *Trichoderma viride* @ 10 mL/L + neem oil @ 0.5 % ; B_2: *Pseudomonas fluorescence* @ 10 mL/L + pongamia oil @ 0.5 % ; B_3: *Bacillus subtilis* @ 10 mL/L + sesame oil @ 1 %) with ten treatments including control (100 % RDF + Imidacloprid 17.8 SL @ 0.3 mL/L). Among all treatments the least mean population of thrips (1.94 per plant) and percentage of thrips infestation (1.64 %) was recorded under control (Imidacloprid 17.8 SL @ 0.3 mL/L) and number of disease infected plants (1.57 plants per plot) and disease incidence (1.96 % per plot) and the highest yield of 6.52 t/ha recorded in combined application of 50 % N +100 % P + 50 % K + *Azotobacter* 5 kg/ha + KSB 6 kg/ha along with *Trichoderma viride* 10mL/L + neem oil 0.5 %.

Keywords: blotch; neem oil; pest and disease management; thrips; *Trichoderma*

Introduction

Allium sativum L., is an important vegetable crop and is being used in Pakistan, China, Russia, United States, Egypt and India for more than 5000 years (1). Garlic is usually grown as spice cum vegetable crop. In point of vegetative growth, the exposure subsequently over temperature favours the growth of the plant subsequently, the day length plays an important role in bulbing. Economic part of garlic is clove which 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, 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 has some amount of fat, vitamin C and sulphur (2), major content of green garlic is ascorbic acid. Garlic has anti-bacterial, antiviral, antifungal and anti-protozol properties and it has antioxidant and anti-cancer properties (3).

Different types of insect pests attack on garlic crop, among them the onion thrips, *Thrips tabaci* Linderman. (Thysanoptera: Thripidae) is considered as major insect pest of garlic. Damage is done by both nymph and adult stages by their sucking and rasping type mouthparts (4). Thrips are positively thigmotactic, preferring to be in close contact with plant surfaces and confined plant parts such as in tightly closed leaves, curled leaves or petals (5). This behaviour makes it difficult to find and control them. The life cycle of *T. tabaci* is between 10 and 30 days depending on the temperature and is faster at higher temperature. Adults have soft and sensitive fringed wings and are highly mobile. A female may lay eggs by inserting into the plant tissue making a small blister often visible along the leaf veins. Oviposition is done in batches of 50-200 eggs. Nymphs after hatching feed actively on the upper parts of the plants such as leaves, flowers and while the adults feed well on the fruits. The pre-pupa and pupal instars are typically found in leaf litter or in soil and are non-feeding and inactive. Apart from direct damage, thrips are also vector of important plant pathogenic viruses, especially Tospo-viruses (Bunyaviridae) such as Capsicum Chlorosis Virus (CaCv), Tomato Spotted Wilt Virus (TSWV) and others. They also hinder the photosynthesis process that results in reduction in bulb size and yield of garlic (6).

One possible non-chemical method of managing plant disease is biological control, which lowers pathogen inoculum levels by using hostile microorganisms. Such management would assist in preventing health risks and pollution (7). Several researchers have reported biological control and effective antagonistic potential of both fungal and bacterial antagonistic microorganisms for controlling onion purple blotch (8-9). *Trichoderma* isolates showed mycoparasitic activity and competitive capability against the mycelial growth of *A. porri* and caused 79.5 % disease reduction (10). *T. harzianum* was found to be effective and recorded least mean disease intensity. Among the diseases, purple blotch caused by *Alternaria porri* (Ellis) Neerg. is one of the destructive diseases, hence it causes frequent epidemic in most of the garlic and onion growing region of the country. Initial symptoms appear on leaves and inflorescence as small (2-3 mm in diameter) water-soaked lesions that quickly develop purple centre with yellow margin under favourable conditions. This disease has become a great menace to garlic growers in India, which was confirmed by 70 % of yield losses in Maharashtra by this pathogen. One of the factors contributing to the year-round spread of pathogens and epidemics is the lack of resistant varieties, which forces farmers to apply excessive amounts of pesticides on crops. It is deemed suitable to reduce the use of chemical fungicides in plant disease control due to the health risks and pollution dangers they provide. Apart from being the greatest substitute for fungicides, biological treatment of plant diseases by hostile microorganisms is sustainable and environmentally beneficial. The aim of study asses the efficacy of a synthetic insecticide along with botanical extracts and biocontrol agent in garlic was tested against *T. tabaci* and purple blotch.

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

Materials and Methods

Experimental site

Field study was conducted two consecutive years at Medicinal and Aromatic Plant Research Station, Rajendranagar, Hyderabad-SKLTGHU, during *Rabi*, 2022-23 and 2023-24. 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 average maximum temperatures during crop period i.e., 2022-2023 and 2023-2024 were 33.5 °C and 36.3 °C and the minimum average temperature were 13.7 °C and 16 °C, respectively. The average maximum relative humidity during crop period i.e., 2022-2023 and 2023-2024 was 92 % for both years and the average minimum relative humidity were 35 % and 29 % respectively. The soil is sandy loam in nature, coarse in texture, good in water holding capacity with low pH (acidic, 5.25). In both years, the composite soil samples from the entire experimental plots were collected randomly and analysed before planting.

Experimental setup

The total experimental area in this study was 410 m^2 which was divided into 3 blocks; each block was then subdivided into ten plots. The plant to plant and row to row distances were kept about 10 and 20 cm respectively. Same agronomic practices were applied as per crop requirement. There were 10 treatments, each treatment was repeated thrice by using methodology of contrast factorial randomized block design according to the experiment's design. Raised beds of 3 × 2 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 biofertilizers and in factor- 2 include bioformulations and botanical extracts as follows (N_1:100 % N + 50 % P + 50 % K + PSB @ 5 kg/ha + KSB @ 6 kg/ha; N_2: 50 % N + 100 % P + 50 % K+ *Azotobacter* @ 5 kg/ha+ KSB @ 6 kg/ha; N_3: 50 % N + 50 % P+ 100 % K + *Azotobacter* @ 5 kg/ha + PSB @ 5 kg/ha) and bioformulations (B_1: *Trichoderma viride* @ 10 mL/L + neem oil @ 0.5 % ; B_2: *Pseudomonas fluorescence* @ 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

N_1B_1- 100 % N +50 % P + 50 % K + PSB @ 5 kg/ha + KSB @ 6 kg/ha + *Trichoderma viride* @ 10 mL/L + neem oil @ 0.5 %

N_1B_2- 100 % N +50 % P + 50 % K + PSB @ 5 kg/ha + KSB @ 6 kg/ha + *Pseudomonas fluorescence* @ 10 mL/L + pongamia oil @ 0.5 %

N_1B_3- 100 % N + 50 % P + 50 % K + PSB @ 5 kg/ha + KSB @ 6 kg/ha+ *Bacillus subtilis* @ 10 mL/L + sesame oil @ 1 %

N_2B_1- 50 % N + 100 % P + 50 % K + *Azotobacter* @ 5 kg/ha + KSB @ 6 kg/ha + *Trichoderma viride* @ 10 mL/L + neem oil @ 0.5 %

N_2B_2- 50 % N + 100 % P + 50 % K + *Azotobacter* @ 5 kg/ha + KSB @ 6 kg/ha + *Pseudomonas fluorescence* @ 10 mL/L + pongamia oil @ 0.5 %

N_2B_3- 50 % N + 100 % P + 50 % K + *Azotobacter* @ 5 kg/ha + KSB @ 6 kg/ha + *Bacillus subtilis* @ 10 mL/L + sesame oil @ 1 %

N_3B_1- 50 % N + 50 % P + 100 % K + *Azotobacter* @ 5 kg/ha+ PSB @ 5 kg/ha + *Trichoderma viride* @ 10 mL/L + neem oil @ 0.5 %

N_3B_2- 50 % N + 50 % P + 100 % K+ *Azotobacter* @ 5 kg/ha + PSB @ 5 kg/ha + *Pseudomonas fluorescence* @ 10 mL/L + pongamia oil @ 0.5 %

N_3B_3- 50 % N + 50 % P + 100 % K+ *Azotobacter* @ 5 kg/ha+ PSB @ 5 kg/ha + *Bacillus subtilis* @ 10 mL/L + sesame oil @ 1 %

Control- 100 % RDF + Imidacloprid @ 0.3 mL/L

The required quantity of bioformulation applied as soil drenching as well as foliar application to the plants. The experimental plots were observed on regular basis for *T. tabaci* population from first week of January till the harvesting of crop. The treatments were applied as per above mentioned doses for every fifteen days interval. Pre and Post treatments applications, *T. tabaci* (nymphs and adults) population data were recorded after every 15 days intervals before and after every spraying from randomly ten selected plants in each treatment as well as control plot. the population of thrips assessed by naked eyes on both lower and upper side of leaves during early morning hours of day. The blotch infected plants were recorded based on colour symptoms of plant. The percent of thrips infestation calculated using the below formula:

Percent of infestation =

$$\frac{\text{Number of adults or larvae per plant}}{\text{Total number of plants per plot}} \quad \text{Eqn. 1}$$

The percentage of disease incidence was calculated using the formula given below:

Percent of disease incidence (%) =

$$\frac{\text{Number of plants diseased}}{\text{Number of plants under observation}} \times 100 \quad \text{Eqn. 2}$$

Data analysis

The thrips population data were transformed into a square root (angular) transformation and the modified data were subsequently analysed using ANOVA. The Least Significant Difference (LSD) test was employed to distinguish between the means of treatment. The significance level was fixed at $\alpha = 0.05$.

Results and Discussion

Thrips

Average number of thrips and percent of infestation per plant

The two years data related to average number of thrips per plant revealed that no population of thrips was noticed up to 60 days after sowing. However, the thrips population was observed after the 4th spray i.e., in month of January it is observed that the population of thrips was increasing continuously up to the 8th spray and after the 8th spray there is reduction in thrips population per plant was observed. Based on the pooled data of all sprays, the mean thrips population ranged from 1.94 to 3.43 per plant (Table 1). Notably, the thrips population increased across all the sprays reflecting the pest's life cycle dynamics. Based on this observation was noticed that the increasing of thrips population was not rapid in all treatments due to the application of particular treatments to the plants supressed the pest population and prevent the pest to reach at economic threshold level.

Data regarding the average number of thrips per plant resulted that statistically there is no significant difference between the soil nutrients and bioformulation (Fig. 1). However, there is significant difference was observed between the control and combined treatments. The control recorded the lowest thrips population per plant i.e., 2.02, 2.20, 2.35, 2.25, 2.17 and 2.58 across 45, 60, 75, 90, 105 and 120 days after each spray. The reduction of thrips population under Imidacloprid 17.8 SL @ 0.3 mL/L effective towards the suppression of pest population due to its systemic action followed by 50 % N +100 % P +50 % K+ *Azotobacter* 5 kg/ha + KSB 6 kg/ha along with *Trichoderma viride* 10 mL/L + neem oil 0.5 % effective in reduction of thrips populations i.e., 2.74, 2.79, 3.01, 3.12, 3.11 and 2.90 across 45, 60, 75, 90, 105 and 120 days after each spray. Among the botanical extracts tested against the thrips population application of neem oil (0.5 %) effective compared to pongamia and sesame oils. Based on overall means of all interval sprays against thrips population resulted that Imidacloprid 17.8 SL @ 0.3 mL/L recorded lowest thrips population (1.94 thrips per plant) which was followed by N_2B_1 which includes 50 % N + 100 % P + 50 % K+ *Azotobacter* 5 kg/ha + KSB 6 k g/ha and *Trichoderma viride* @ 10 mL/L + neem oil @ 0.5 % (2.52 thrips per plant) the highest thrips population 3.42 thrips per plant was noted under the application of 50 % N + 100 % P + 50 % K + *Azotobacter* 5 kg/ha + KSB 6 kg/ha along with *Pseudomonas fluorescence* @ 10 mL/L + pongamia oil @ 0.5 %.

Thrips infestation

Data regarding the thrips infestation per plant revealed that statistically there is no significant difference between the soil nutrients and bioformulation (Table 2). However, there is significant difference was observed between the control and combined treatments (Fig. 2). Pooled data showed that thrips infestation started to build up in 2nd week of January and continued till the 2nd week of March. Based on all sprays pooled data of both years the infestation ranged from 1.64 % to 4.29 % per plant. Control recorded the lowest thrips infestation per plant i.e., 1.60, 1.76, 1.88, 1.94, 2.06 and 2.23 across 45, 60, 75, 90, 105 and 120 days after each spray the reason behind the reduced infestation of thrips due to the adult thrips population was low because it works by disrupting the insect's nervous system, leading to paralysis and death which simulate the percentage of infestation as well. Fig. 3 shows that the highest thrips infestation i.e., 3.81, 4.17, 4.46, 4.22 and 4.01 across 60, 75, 90, 105 and 120 days after each spray was

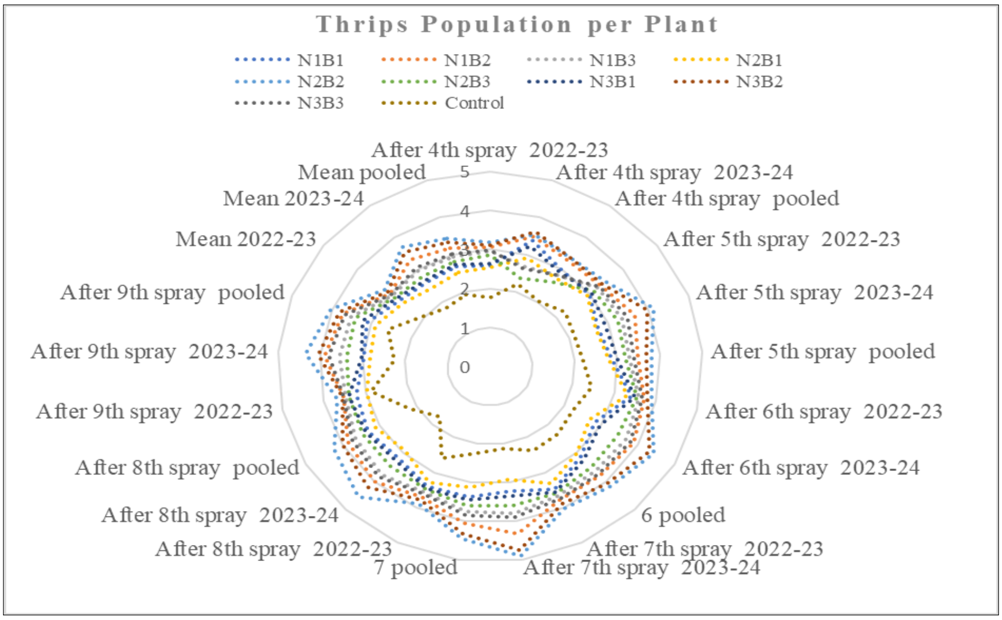

Fig. 1. Effect of integrated strategies on number of adults thrips per plant of garlic.

Table 1. Effect integrated strategies on number of adults thrips per plant of garlic

Number of adults/ plants	After 4th spray			After 5th spray			After 6th spray			After 7th spray			After 8th spray			After 9th spray			Mean		
Treatments	**2022-23**	**2023-24**	**pooled**	**2022-23**	**2023-24**	**pooled**	**2022-23**	**2023-24**	**pooled**	**2022-23**	**2023-24**	**pooled**	**2022-23**	**2023-24**	**pooled**	**2022-23**	**2023-24**	**pooled**	**2022-23**	**2023-24**	**pooled**
Nutrients																					
N_1	2.87	3.19	**3.03**	3.18	3.24	**3.21**	3.57	3.47	**3.52**	3.65	3.79	**3.72**	3.55	3.62	**3.61**	3.41	3.47	**3.43**	**2.89**	**2.97**	**2.94**
N_2	2.87	2.95	**2.91**	3.18	3.34	**3.26**	3.58	3.54	**3.56**	3.65	3.80	**3.72**	3.55	3.65	**3.60**	3.35	3.52	**3.44**	**2.88**	**2.97**	**2.93**
N_3	2.91	3.16	**3.04**	3.24	3.46	**3.35**	3.65	3.71	**3.68**	3.74	4.00	**3.87**	3.62	3.77	**3.70**	3.49	3.62	**3.56**	**2.95**	**3.10**	**3.03**
S.Em+	0.012	0.007	0.045	0.011	0.002	0.031	0.010	0.025	0.025	0.01	0.039	0.01	0.009	0.032	0.028	0.017	0.035	0.022	**0.01**	**0.02**	**0.02**
L.S.D(P≤0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.05	NS	**NS**	**0.02**	**NS**
Bio-agents																					
B_1	2.58	3.18	**2.88**	3.08	2.77	**3.03**	3.41	2.84	**3.13**	3.45	3.16	**3.31**	3.38	3.13	3.26	3.20	2.95	3.07	**2.73**	**2.58**	**2.67**
B_2	3.12	3.55	**3.33**	3.4	3.92	**3.66**	3.8	4.22	**4.01**	3.9	4.66	**4.28**	3.78	4.26	4.02	3.59	4.09	3.84	**3.08**	**3.53**	**3.31**
B_3	2.94	2.57	**2.76**	3.21	3.35	**3.28**	3.60	3.66	**3.63**	3.67	3.77	**3.72**	3.55	3.69	3.62	3.47	3.58	3.52	**2.92**	**2.95**	**2.93**
S.Em+	0.012	0.007	0.045	0.011	0.002	0.031	0.010	0.025	0.025	0.01	0.039	0.025	0.009	0.032	0.028	0.017	0.035	0.022	**0.01**	**0.02**	**0.02**
L.S.D(P≤0.05)	0.035	0.02	0.133	0.033	0.065	0.092	0.030	0.075	0.076	0.029	0.117	0.074	0.027	0.097	0.084	0.051	0.105	0.064	**0.02**	**0.01**	**0.02**
Interaction																					
N_1B_1	2.58	3.38	**2.98**	2.98	2.73	**2.86**	3.42	2.83	**3.13**	3.48	3.23	**3.36**	3.41	3.18	**3.3**	3.22	2.97	**3.1**	**2.73**	**2.62**	**2.68**
N_1B_2	3.05	3.49	**3.27**	3.32	3.65	**3.49**	3.71	3.89	**3.8**	3.79	4.32	**4.06**	3.69	4.01	**3.85**	3.52	3.89	**3.71**	**3.01**	**3.32**	**3.17**
N_1B_3	2.97	2.69	**2.83**	3.23	3.33	**3.28**	3.59	3.69	**3.64**	3.67	3.81	**3.74**	3.56	3.76	**3.66**	3.48	3.56	**3.52**	**2.93**	**2.98**	**2.95**
N_2B_1	2.55	2.93	**2.74**	2.92	2.66	**2.79**	3.31	2.71	**3.01**	3.32	2.92	**3.12**	3.28	2.93	**3.11**	2.97	2.84	**2.9**	**2.62**	**2.43**	**2.52**
N_2B_2	3.19	3.54	**3.36**	3.49	4.12	**3.81**	3.89	4.44	**4.17**	4.03	4.89	**4.46**	3.88	4.56	**4.22**	3.68	4.34	**4.01**	**3.17**	**3.70**	**3.43**
N_2B_3	2.86	2.38	**2.62**	3.12	3.23	**3.18**	3.53	3.48	**3.51**	3.59	3.59	**3.59**	3.48	3.46	**3.47**	3.41	3.38	**3.4**	**2.86**	**2.79**	**2.82**
N_3B_1	2.63	3.23	**2.93**	3.06	2.91	**2.99**	3.49	2.99	**3.24**	3.56	3.34	**3.45**	3.46	3.27	**3.37**	3.4	3.03	**3.22**	**2.80**	**2.68**	**2.74**
N_3B_2	3.12	3.62	**3.37**	3.38	3.98	**3.68**	3.79	4.32	**4.06**	3.89	4.76	**4.33**	3.78	4.21	**4.00**	3.56	4.05	**3.81**	**3.07**	**3.56**	**3.32**
N_3B_3	2.99	2.64	**2.82**	3.29	3.48	**3.39**	3.67	3.82	**3.75**	3.76	3.91	**3.84**	3.61	3.84	**3.73**	3.52	3.79	**3.66**	**2.98**	**3.07**	**3.03**
S.Em+	0.035	0.021	0.134	0.033	0.006	0.092	0.030	0.076	0.076	0.029	0.118	0.074	0.027	0.096	0.084	0.051	0.106	0.064	**0.02**	**0.01**	**0.02**
L.S.D(P≤0.05)	NS	NS	NS	NS	NS	0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.17	NS	**NS**	**0.09**	**NS**
Control	1.77	2.22	2.02	2.26	2.14	2.20	2.44	2.25	2.35	2.38	2.12	2.25	2.60	1.75	2.17	2.88	2.25	2.58	**2.05**	**1.82**	**1.94**
S.Em+	0.035	0.021	0.134	0.033	0.006	0.092	0.030	0.076	0.076	0.029	0.118	0.074	0.027	0.096	0.084	0.051	0.106	0.064	0.02	0.01	0.02
L.S.D(P≤0.05)	0.26	0.18	0.16	0.17	0.22	0.07	0.116	0.297	0.14	0.166	0.377	0.128	0.152	0.390	0.12	0.194	0.23	0.11	0.03	0.12	0.06

Table 2. Effect of integrated strategies on thrips infestation of garlic

Infestation	After 4th spray			After 5th spray			After 6th spray			After 7th spray			After 8th spray			After 9th spray			Mean		
Treatments	2022-23	2023-24	pooled	2022-23	2023-24	pooled	2022-23	2023-24	pooled	2022-23	2023-24	pooled	2022-23	2023-24	pooled	2022-23	2023-24	pooled	2022-23	2023-24	pooled
Nutrients																					
N_1	3.64	3.98	**3.81**	3.97	4.05	**4.01**	4.47	4.34	**4.40**	4.56	4.73	**4.65**	4.44	4.56	**4.50**	4.26	4.34	**4.31**	**3.62**	**3.71**	**3.67**
N_2	3.58	3.69	**3.63**	3.97	4.17	**4.07**	4.47	4.43	**4.45**	4.56	4.75	**4.65**	4.43	4.56	**4.50**	4.19	4.40	**4.30**	**3.60**	**3.71**	**3.66**
N_3	3.64	3.95	**3.80**	4.05	4.32	**4.19**	4.56	4.64	**4.60**	4.67	5.00	**4.84**	4.52	4.72	**4.62**	4.37	4.53	**4.45**	**3.69**	**3.88**	**3.79**
S.Em±	0.017	0.009	**0.018**	0.014	0.028	**0.010**	0.013	0.032	**0.014**	0.012	0.049	**0.027**	0011	0.040	**0.021**	0.021	0.044	**0.027**	**0.012**	**0.01**	**0.02**
L.S.D(P≤0.05)	NS	0.026	**NS**	NS	NS	**NS**	NS	NS	**0.041**	NS	NS	**NS**	NS	NS	**0.03**	NS	NS	**0.03**	**NS**	**0.03**	**NS**
Bio-agents																					
B_1	3.29	3.98	**3.63**	3.73	3.46	**3.60**	4.26	3.55	**3.91**	4.32	3.95	**4.14**	4.23	3.91	**4.07**	4.00	3.68	**3.84**	**3.40**	**3.22**	**3.31**
B_2	3.90	4.44	**4.17**	4.25	4.90	**4.57**	4.75	5.27	**5.01**	4.88	5.82	**5.35**	4.73	5.33	**5.03**	4.48	5.12	**4.80**	**3.86**	**4.41**	**4.13**
B_3	3.68	3.21	**3.44**	4.02	4.18	**4.1**	4.5	4.58	**4.54**	4.59	4.71	**4.65**	4.44	4.61	**4.52**	4.34	4.47	**4.4**	**3.65**	**3.68**	**3.66**
S.Em±	0.017	0.009	**0.018**	0.014	0.028	**0.010**	0.013	0.032	**0.014**	0.012	0.049	**0.027**	0.011	0.040	**0.021**	0.021	0.044	**0.027**	**0.012**	**0.01**	**0.02**
L.S.D(P≤0.05)	0.049	0.026	**0.024**	0.040	0.082	**0.031**	0.037	0.094	**0.043**	0.036	0.146	**0.079**	0.033	0.120	**0.062**	0.063	0.131	**0.081**	**0.03**	**0.03**	**0.02**
Interaction (NXB)																					
N_1B_1	3.40	4.23	**3.81**	3.73	3.41	**3.57**	4.28	3.54	**3.91**	4.35	4.04	**4.19**	4.26	3.98	**4.12**	4.03	3.71	**3.87**	**3.44**	**3.27**	**3.35**
N_1B_2	3.81	4.36	**4.09**	4.15	4.56	**4.36**	4.64	4.86	**4.75**	4.74	5.4	**5.07**	4.61	5.01	**4.81**	4.4	4.86	**4.63**	**3.76**	**4.15**	**3.96**
N_1B_3	3.71	3.36	**3.54**	4.04	4.16	**4.1**	4.49	4.61	**4.55**	4.59	4.76	**4.68**	4.45	4.7	**4.58**	4.35	4.45	**4.4**	**3.66**	**3.72**	**3.69**
N_2B_1	3.18	3.66	**3.42**	3.65	3.33	**3.49**	4.14	3.39	**3.76**	4.15	3.65	**3.9**	4.1	3.66	**3.88**	3.71	3.55	**3.63**	**3.28**	**3.03**	**3.15**
N_2B_2	3.99	4.43	**4.21**	4.36	5.15	**4.76**	4.86	5.55	**5.21**	5.04	6.11	**5.58**	4.85	5.7	**5.28**	4.6	5.43	**5.01**	**3.96**	**4.62**	**4.29**
N_2B_3	3.58	2.98	**3.28**	3.9	4.04	**3.97**	4.41	4.35	**4.38**	4.49	4.49	**4.49**	4.35	4.33	**4.34**	4.26	4.23	**4.24**	**3.57**	**3.49**	**3.53**
N_3B_1	3.29	4.04	**3.66**	3.83	3.64	**3.73**	4.36	3.74	**4.05**	4.45	4.18	**4.31**	4.33	4.09	**4.21**	4.25	3.79	**4.02**	**3.5**	**3.35**	**3.43**
N_3B_2	3.9	4.53	**4.20**	4.23	4.98	**4.6**	4.74	5.4	**5.07**	4.86	5.95	**5.41**	4.73	5.26	**4.99**	4.45	5.06	**4.76**	**3.84**	**4.45**	**4.15**
N_3B_3	3.74	3.3	**3.52**	4.11	4.35	**4.23**	4.59	4.78	**4.68**	4.7	4.89	**4.79**	4.51	4.8	**4.66**	4.4	4.74	**4.57**	**3.72**	**3.84**	**3.78**
S.Em±	0.049	0.026	**0.024**	0.040	0.082	**0.031**	0.037	0.094	**0.043**	0.036	0.146	**0.079**	0.033	0.120	**0.062**	0.063	0.131	**0.081**	**0.012**	**0.03**	**0.02**
L.S.D(P≤0.05)	NS	0.12	**NS**	NS	0.16	**NS**	NS	NS	**NS**	0.017	0.25	**NS**	0.11	0.24	**NS**	0.17	0.15	**NS**	**NS**	**0.09**	**NS**
Control	1.42	1.77	**1.60**	1.81	1.71	**1.76**	1.95	1.80	**1.88**	2.02	1.86	**1.94**	2.40	1.72	**2.06**	2.50	1.96	**2.23**	**1.73**	**1.55**	**1.64**
S.Em±	0.049	0.026	**0.024**	0.040	0.082	**0.031**	0.037	0.094	**0.043**	0.036	0.146	**0.079**	0.033	0.120	**0.062**	0.063	0.131	**0.081**	0.03	0.03	0.02
L.S.D(P≤0.05)	0.25	0.16	**0.168**	0.156	0.20	**0.08**	0.129	0.256	**0.159**	0.168	0.32	**0.145**	0.150	0.31	**0.133**	0.22	0.20	**0.14**	0.13	0.11	0.08

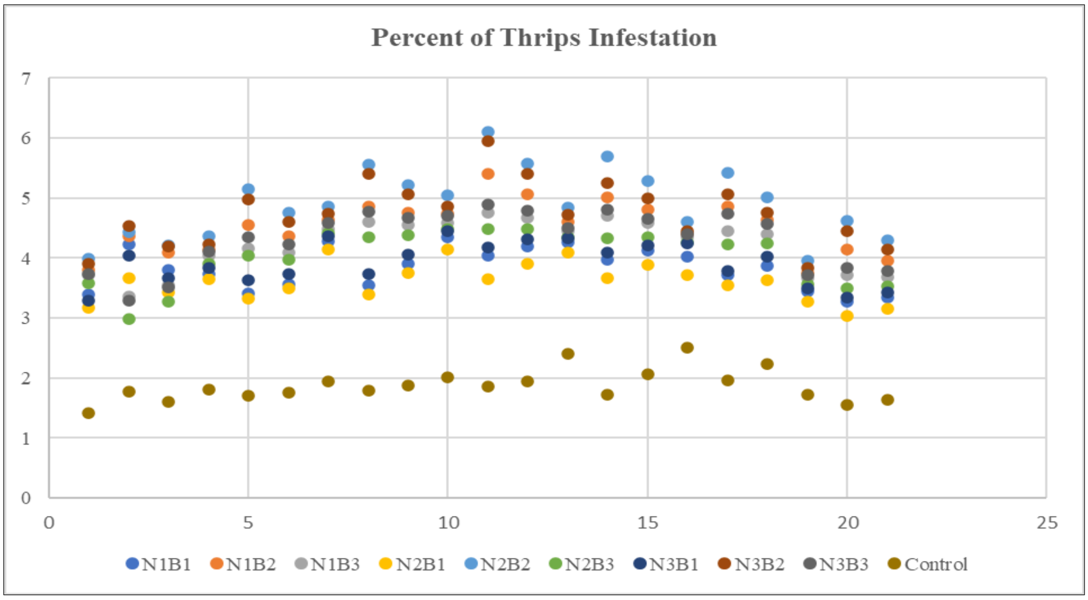

Fig. 2. Effect of integrated strategies on thrips infestation of garlic.

Fig. 3. Thrips infestation and its effect on development of bulbs.

recorded under 50 % N + 100 % P + 50 % K + *Azotobacter* 5 kg/ha + KSB 6 kg/ha along with *Pseudomonas fluorescence* @ 10 mL/L + pongamia oil @ 0.5 %. However, the overall mean of all sprays the control recorded the lowest thrips infestation i.e., 1.64 % followed by 50 % N + 100 % P + 50 % K + *Azotobacter* 5 kg/ha + KSB 6 kg/ha and *Trichoderma viride* @ 10 mL/L + neem oil @ 0.5 % (3.15 %). 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 above findings, it was concluded that spraying of Imidacloprid 17.8 SL @ 0.3 mL/L at 15 days interval proven the best in controlling thrips population and infestation percentage of thrips per plant the reason might be due to 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.

Present findings are in close conformity with previous studies which have shown that fipronil chemical pesticide is the most effective for suppression of thrips population (11), another study reported that botanicals, especially neem, can be used as a frontline management tool for controlling thrips at an early stage (12). These results matched with other reports showing that three sprays of fipronil at 0.15 g/L at an interval of 15 days starting at ETL was found most effective for control of onion thrips (*T. tabaci* L) (13). The treatment with pongamia oil 5 % at 5 mL/L found least effective for control of onion thrips. Lowest thrips population and highest seed yield was recorded with application of fipronil insecticides (14). Some research studies reported that spray of synthetic pesticide at 15 days interval recorded lowest thrips population. Spray of chemical pesticide @ 0.3 mL/L at 10 days interval effective for management of thrips in onion during *Rabi* season (15). The synthetic insecticide and all the botanical extracts significantly reduced thrips population (16).

Purple blotch

Number of infected plants

The two years data resulted that there were no statistically significant results obtained between soil nutrients and bioformulations. However, the application of bio control agents along with botanical extract reduces the disease affected plants and disease incident in all treatments. From the Table 3, it was observed that the foliar application of *Trichoderma* along with neem oil play effective role in reduction in number of infected plants. Based on two years pooled data (Fig. 4), combined application of 50 % N + 100 % P + 50 % K + *Azotobacter* @ 5 kg/ha + KSB @ 6 kg/ha and *Trichoderma viride* @ 10 mL/L + neem oil @ 0.5 % recorded lowest number of infected plants (1.57). Since *Trichoderma* produces various compounds, including Volatile Organic Compounds (VOCs) and other bioactive substances, that inhibit the growth and development of *A. porri* (17) which was followed by 50 % N + 100 % P + 50 % K + *Azotobacter* @ 5 kg/ha + KSB @ 6 kg/ha and *Trichoderma viride* @ 10 mL/L + neem oil @ 0.5 % (1.83). Fig. 5 depicts that highest number of infected plants (3.64 per plot) was observed under control treatment. From the obtained results it revealed that combined application was better than individual applications.

Disease incidence

Based on the pooled data from Table 3, the interaction between soil nutrients and bio formulations did not differ significantly. However, there was significant difference between control and rest of the treatments. Fig. 6 illustrate that the lowest percent of disease incidence recorded under the combined treatment of 50 % N + 100 % P + 50 % K + *Azotobacter* @ 5 kg/ha + KSB @ 6 kg/ha and *Trichoderma viride* @ 10 mL/L + neem oil @ 0.5 % (1.96 %) followed by 50 % N + 100 % P + 50 % K + *Azotobacter* @ 5 kg/ha + KSB @ 6 kg/ha and *Trichoderma viride* @ 10 mL/L + neem oil @ 0.5 % (2.32 %). The lowest disease incidence under *Trichoderma* consisting treatment is due to *Trichoderma* competes with *A. porri* for space and nutrients on the plant surface, reducing the pathogen's ability to establish and cause disease (18). However, control recorded the highest disease incidence (4.55 %).

From the results it revealed that Integrating neem oil with biocontrol agents like *Trichoderma viride* and *Pseudomonas fluorescens* has proven effective. For instance, a combination of neem oil with these agents resulted in significant reductions in disease intensity and improved growth parameters in bulb crops (19). The foliar application of biocontrol agents like *Trichoderma* plays important role in reduction of disease infected plants and percent of disease incidence it might be due to *Trichoderma* can stimulate the plant's own defense mechanisms, leading to enhanced resistance against *A. porri*. This Induced Systemic Resistance (ISR) involves the activation of defense-related genes and accumulation of phytoalexins besides these *Trichoderma* antagonistic fungi that suppress the growth of *A. porri* by competing for space and nutrients, parasitizing the pathogen and producing antifungal metabolites.

Table 3. Effect of integrated strategies on number of infected plants and disease incidence of garlic

Number of adults /plants	Number of infected plants			Disease incidence		
Treatments	**2022-23**	**2023-24**	**pooled**	**2022-23**	**2023-24**	**pooled**
Nutrients						
N_1	2.17	2.38	**2.28**	2.98	2.72	**2.85**
N_2	1.76	1.82	**1.79**	2.27	2.21	**2.24**
N_3	2.95	3.13	**3.04**	3.91	3.69	**3.8**
S.Em±	0.01	0.009	**0.009**	0.01	0.01	**0.01**
L.S.D(P≤0.05)	0.03	0.02	**0.02**	0.04	0.03	**0.03**
Bio-agents						
B_1	2.06	2.19	**2.13**	2.74	2.58	**2.66**
B_2	2.49	2.63	**2.56**	3.28	3.12	**3.2**
B_3	2.34	2.5	**2.42**	3.13	2.92	**3.03**
S.Em±	0.01	0.009	**0.009**	0.01	0.01	**0.01**
L.S.D(P≤0.05)	0.03	0.02	**0.02**	0.04	0.03	**0.03**
Interaction (NXB)						
N_1B_1	1.99	2.21	**2.10**	2.76	2.49	**2.63**
N_1B_2	2.32	2.52	**2.42**	3.15	2.9	**3.03**
N_1B_3	2.21	2.41	**2.31**	3.01	2.76	**2.89**
N_2B_1	1.54	1.59	**1.57**	1.99	1.93	**1.96**
N_2B_2	1.93	1.97	**1.95**	2.46	2.41	**2.44**
N_2B_3	1.82	1.89	**1.86**	2.36	2.28	**2.32**
N_3B_1	2.65	2.78	**2.72**	3.48	3.31	**3.40**
N_3B_2	3.23	3.39	**3.31**	4.24	4.04	**4.14**
N_3B_3	2.98	3.21	**3.10**	4.01	3.73	**3.87**
S.Em±	0.027	0.096	**0.084**	0.051	0.106	**0.064**
L.S.D(P≤0.05)	NS	NS	**NS**	NS	0.17	**NS**
Control	3.52	3.76	**3.64**	4.70	4.40	**4.55**
S.Em±	0.03	0.02	**0.02**	0.04	0.03	**0.03**
L.S.D(P≤0.05)	0.12	0.1	**0.1**	0.15	0.12	**0.12**

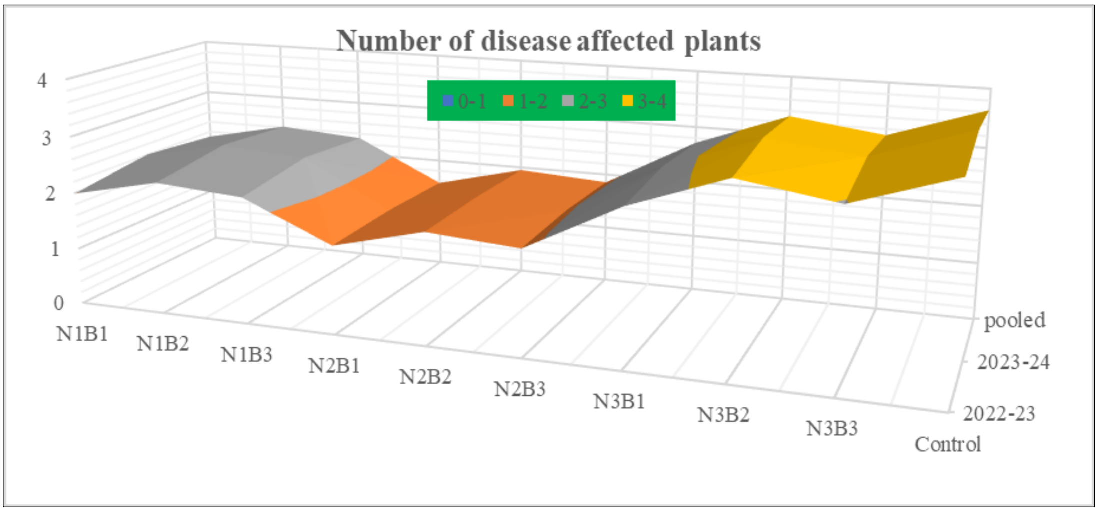

Fig. 4. Effect of integrated strategies on number of infected plants of garlic.

Fig. 5. Purple blotch infestation on garlic leaves.

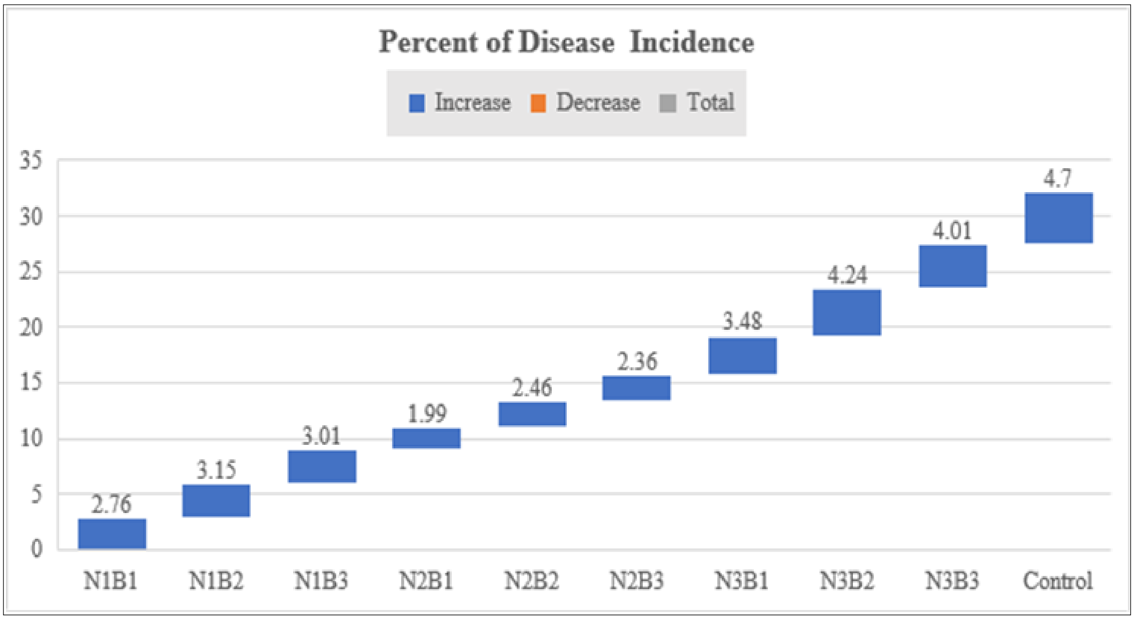

Fig. 6. Effect of integrated strategies on percent of disease incidence of garlic.

Conclusion

It is concluded from the above data that *T. tabaci* is serious pest of onion and its activity remained throughout the cropping season. The synthetic insecticide Imidacloprid 17.8 SL @ 0.3 mL/L and all the botanical extracts significantly reduced thrips population. The combined application of 50 % N + 100 % P + 50 % K + *Azotobacter* @ 5 kg/ha + KSB @ 6 kg/ha and *Trichoderma viride* @ 10 mL/L + neem oil @ 0.5 % worked out well in reducing the incidence of blotch disease. The results highlight the importance of integrating various pest and control measures into a cohesive strategy. The superior performance of *Trichoderma* and neem oil underscores the potential of combining environmentally friendly biorationals with targeted chemical applications and cultural practices for the effective management of thrips and blotch. This integrated approach not only reduces chemical reliance but also supports sustainable and eco-friendly cultivation.

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Authors' contributions

SR carried out the field experiment, collection, noting, recorded data, wrote drafts for research work. JC participated in the design of the study, supervised the whole research and helped in compiling the manuscript. PP contributed to analysis of samples data, technical manuscript writing and MS contributed to editing the manuscript. BNK helped to analyse soil and plant samples. VS performed the statistical analysis of data and supervision of pest dynamics in field. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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