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ECO-FRIENDLY APPROACHES AGAINST CHILI THRIPS *SCIRTOTHRIPS DORSALIS* HOOD (THYSANOPTERA: THRIPIDAE)

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ABSTRACT

Chili (*Capsicum annuum* L.) is a crucially economically viable vegetable and spice crop cultivated worldwide. Numerous issues impact chili production, both vertebrate and non-vertebrate, leading to significant reductions in both quantity and quality. The chili thrips, *Scirtothrips dorsalis*, poses a serious threat to chili, causing approximately 50-70% yield loss in every season. In Pakistan, farmers frequently resort to using synthetic pesticides to control the pest population. Unfortunately, the injudicious use of pesticides results in environmental, soil, and water pollution, leading to hazards for humans, animals, and wildlife. This study employed a combination of eco-friendly tactics to suppress the thrips population. The lowest thrips population was observed in plots where maize was planted as a barrier for chili, followed by marigold cultivated as a trap. Maize exhibited a remarkable disruptive effect against the thrips population, acting as a barrier to restrict their entrance into the main crop. The combined release of the biocontrol agents *Chrysoperla carnea* and *Coccinella septempunctata* proved to be more effective against the thrips population than plots with a single bio-control agent. Among the natural remedies, neem seed kernel powder was the most effective in reducing the thrips population, followed by neem leaves extract and neem oil. Notably, neem oil showed the lowest reduction percentage of thrips compared to neem seed kernel powder and neem leaves extract. The cost/benefit ratio of Integrated Pest Management (IPM) plots compared to conventional plots revealed that the IPM plot had a lower estimated production cost (Rs. 19,277) and yielded 547 kg more than the conventional plot. Similarly, a higher cost/benefit ratio (3:13) was recorded in the IPM plot than in the conventional plot (1:36). IPM, through eco-friendly measures, proves to be an efficient approach to suppress *S. dorsalis* in chili crop.

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INTRODUCTION

Chili, *Capsicum annuum* L., is considered one of the most essential spicy cash crops and is cultivated broadly all over the world (Venkateshalu et al., 2009). It possesses colossal profitable, nutritional, and medicinal values (Marin et al., 2004; Choudhary et al., 2009). Globally, Asian countries are the largest producers of chili (Truong et al., 2013). In Pakistan, the thriving production of chili is affected by several factors including adverse ecological conditions, diseases, insects, and arachnidan pests (Khan et al., 2012; Zhani et al., 2013; Shahbaz et al., 2015; Asghar et al., 2020; Tariq-

Khan et al., 2017, 2020; Saba et al., 2022; Aslam and Mukhtar, 2023a,b, 2024; Zeeshan et al., 2023). Among these, insects are the main constraints that significantly affect the quantity and quality of chili. Several studies have documented that chili crops are damaged by over 39 genera and 51 species of insects (Hosamani et al., 2005). Among them, *Scirtothrips dorsalis* is considered one of the most destructive pests, causing 30-50% yield loss in every season (Bhede et al., 2008).

For the management of this noxious pest, several control methods have been used (Ashfaq et al., 2014; Aslam et al., 2017). However, the majority of farmers rely on insecticides (Segnou et al., 2013). Insecticidal control is not always effective due to its small size and obscure feeding habits. Conversely, it leads to several problems such as insect outbreaks, resistant development, environmental hazards, and health issues (Halder et al., 2014).

Integrated pest management (IPM) is a promising control technique that utilizes all possible control measures to manage insect pest populations and balance the natural ecosystem (Boucher et al., 2003; Bibi et al., 2023; Mukhtar et al., 2023; Shahbaz et al., 2023). Nowadays, this technique is used worldwide because it is environmentally safe and sound (Devi and Roy, 2017). Determining the attraction of trap crops or the barrier of border crops against pests according to their characteristics may assist in developing new pest control strategies against this noxious pest (Finley and Ryan, 2018). Intercropping systems significantly reduce pest populations (Mercader et al., 2011). Maize and Marigold crops are considered the most effective strategies for integrated pest control and can enhance the population of natural enemies (Sujay and Giraddi, 2016). This ultimately affects the population of crop pests, improves crop quality, and helps conserve soil and the environment (Hossain et al., 2021).

Recent studies have investigated and confirmed the effects of plant-based products against various homopteran insect pests (Sruthi et al., 2018). Neem products, in particular, are useful against >350 species of arthropods (Singh and Raheja, 1996). This is because the *Azadirachta indica* plant contains alkaloid compounds that possess deterrent and antifeedant characteristics, adversely affecting insect pest populations (Girish and Bhat, 2008). On the other hand, bio-pesticides are less cost-effective, non-hazardous, and environmentally safe, addressing the current need (Sruthi et al., 2018).

The demand for native and ecologically protected agricultural products is increasing worldwide. In this regard, biological control methods are considered suitable alternatives to chemicals and play an important role in tackling pest problems. Different bio-control agents have been recommended against harmful soft-bodied insect pests for manipulating the behavior of insect populations and reducing the risk of products (Van Lenteren, 2012). Among them, the green lacewing *Chrysoperla carnea* and the seven-spotted beetle *Coccinella septempunctata* are mainly released into fields to enhance biological control of this noxious pest of chili i.e. thrips (Truong et al., 2013). This phenomenon is gaining importance for pest management in Pakistan.

The goal of biological control of pests is achieved by the release of predators such as *C. carnea* and *C. septempunctata*. In this context, several factors support and influence this approach, including water deficiency, saline soil, and higher humidity content, by cultivating highly resistant varieties to overcome thrips population densities (Truong et al., 2013). While various control methods have been used for the management of this noxious pest, most do not meet the requirements and, in addition, lead to several problems.

Addressing this point, the management of *S. dorsalis* should be based on suitable (Eco-friendly) integrated pest management (IPM) strategies. Thus, the present research was carried out to develop a potential eco-friendly IPM model for the management of *S. dorsalis* in chili crops.

MATERIALS AND METHODS

The current research was carried out in the vicinity of Tandoallahyar during the kharif season. Various eco-friendly tactics were employed to control *S. dorsalis* in the chili crop.

Impact of intercropping system on the population of chili thrips

To investigate the impact of trap crops on the population of *S. dorsalis*, two trap crops were tested: i) maize as a barrier (one row around the plots), and ii) marigold as a trap (one row of marigold planted after every five rows of chili crop). Additionally, a control treatment with no implementation was included. The local chili variety, Ghotki, was transplanted in a Randomized Complete Block Design (RCBD) with four replications, and a plot size of 15×10 meters.

Maize was cultivated two weeks before chili as a barrier crop, while marigold was cultivated two weeks later. All standard cultural practices, including fertilizers, inter-culturing, and irrigation, were adopted from germination to harvest. The treatment arrangements were Chili + Maize, Chili + Marigold, and Chili alone. Observations on the population of *S. dorsalis* were taken from fifteen randomly selected plants. Three leaves from the upper, middle, and bottom sections were examined one month after transplanting into the main field. The observations for *S. dorsalis* population were primarily recorded early in the morning at one-week intervals.

Field evaluation of bio-control agents

To determine the efficiency of different bio-control agents i.e. *Chrysoperla carnea* and *Coccinella septempunctata* against *S. dorsalis* in chilli crop following procedure was adopted.

Culture development of bio-control agents

Initially, the culture of *C. carnea* larvae was obtained from the Plant Protection Division, Nuclear Institute of Agriculture (NIA), Tandojam, and reared on natural hosts under laboratory conditions at an optimal temperature. Various species of aphids, such as *Aphis fabae* and *A. gossypii*, were collected from various fields on a daily basis and provided as food for *C. carnea*. Adults that emerged in glass vials were promptly transferred into cages for further multiplication. To ensure adult survival, an artificial diet was provided inside the cage, and optimal relative humidity and temperature were maintained within the insect rearing room. Subsequently, eggs laid by females were carefully collected and placed into glass vials, and cards were prepared.

Preparation of egg cards of *C. carnea* for field release

Cards were prepared by uniformly mixing 200 g of acacia gum in 1 L of boiling water to create a thick solution, ensuring the proper adherence of eggs on sheet cards (2 × 2.5 inches). Each card was loaded with 350 eggs of *C. carnea*, randomly spread along with frozen eggs of *S. cerealella* at a ratio of 1:3.

Collection of *Coccinella septempunctata*

On the other hand, the immature stages of *C. septempunctata* were initially collected from various fields, including cotton, akk (*Calotropis gigantea*), and okra. These stages were then placed into a petri dish (1.5 cm in height with a 9 cm diameter). The collected culture was reared on natural hosts under laboratory conditions, utilizing aphids, whiteflies, thrips, jassids, and other soft-bodied insects until the larvae transformed into the pupal stage. Subsequently, the pupal stages were released into the targeted fields.

Releases procedure of bio-control agents in the field

C. carnea cards were deployed in the chili field one month after chili transplantation. Five cards of *C. carnea* per plot were released three times for each plot (10 × 15 m). The experiment comprised four treatments: *C. carnea* alone, *C. septempunctata* alone, C. carnea + *C. septempunctata*, and a control (untreated) without any application of bio-control agents.

Evaluation of botanical extracts against *S. dorsalis*

To assess the impact of neem-based botanical ingredients against *S. dorsalis* under field conditions, four treatments were employed: T1 = Neem leaf extracts (solution obtained after boiling neem leaves), T2 = Neem seed kernel powder (NSKP) (solution obtained after soaking the powder), T3 = Neem oil (oil extracted from the seeds), and T4 = Control (Untreated).

Extraction and preparation of neem leaf extract (NLE)

The neem leaves were dried in an oven at 50°C for 30 minutes and then processed by blending 50 g of the dried leaves with 100 ml of methanol for 10 minutes. The crude extract was filtered through muslin cloth, followed by Whatman No. 1 filter paper, before autoclaving (121°C for 15 minutes). Subsequently, the extract was stored at -20°C. The following morning, it was sprayed onto the plants in the respective treatment plots. For the preparation of neem leaf extracts, 10 kg of fresh neem leaves were collected and boiled in 100 L of water until the final volume reached 20 L. After cooling, the extract was filtered through muslin cloth and sprayed onto the targeted plants the next morning.

Preparation of neem seed kernel powder (NSKP)

The fresh and mature neem fruits/seeds, totaling 5 kg, were collected, washed, and dried before being ground. Grinding was carried out using both a grinder machine and the traditional method (by hand with a homogenizer) until the neem seeds were completely converted into fine mesh powder. After grinding, the powder was stored in jars. The next day, a stock solution was prepared by dissolving 0.5 kg of neem seed kernel powder in 5 L of water. The solution was further diluted and sprayed.

Effect of neem oil on population of *S. dorsalis*

The effect of neem oil on the population of *S. dorsalis* was evaluated using a 1-liter bottle of neem oil obtained from the commercial market, with a purity of > 98%. One hundred milliliters of neem oil was diluted in 5 L of water and sprayed on chili plots. To count the population of *S. dorsalis* on chili crops, 15 plants were randomly selected from each plot, with three leaves, one from the bottom, one from the middle, and one from the top strata and examined. Four observations were made: one the day before the spray (pre-treatment observation) and three observations after the sprays (post-treatment) at intervals of one, three, seven, and ten days.

$$\% \text{ Population Change } \frac{Ta}{Tb} \times \frac{Cb}{Ca} \times 100$$

Where:

Tb = Number of pests in treated plots before treatment.

Ta = Number of pests in treated plots after treatment.

Cb = Pest population in the control plots before treatment.

Ca = Pest population in the control plots after treatment.

Data analysis

The percentage reduction was calculated using the standard formula proposed by Fleming and Ratnakaran (1985). Statistical analysis was performed using a one-way analysis of variance (ANOVA). To compare the effects of the predators, a post hoc Tukey's test was employed to identify significant differences within the treatments.

RESULTS

Assessment of trap cropping system on the population of *S. dorsalis*

The minimum thrips population (1.32 ± 0.53 per leaf) was recorded in the Chili + Maize field, followed by (3.99 ± 1.50 thrips per leaf) in the Chili + Marigold field. This trend was consistently observed in both years of the study, and statistical analysis revealed a significant difference between the treatments ($P < 0.001$) (Figure 1).

Bio-control agents

A comprehensive comparison of two different bio-control agents released singly and in combination over both years revealed a statistically significant difference in the mean thrips population across various experimental plots ($F = 15.65$; df = 2,73; $P < 0.001$). Notably, the plot where both bio-control agents were released (*C. septempunctata* + *C. carnea*) exhibited the highest reduction in the population of chili thrips compared to plots with single bio-control agents (Figure 2).

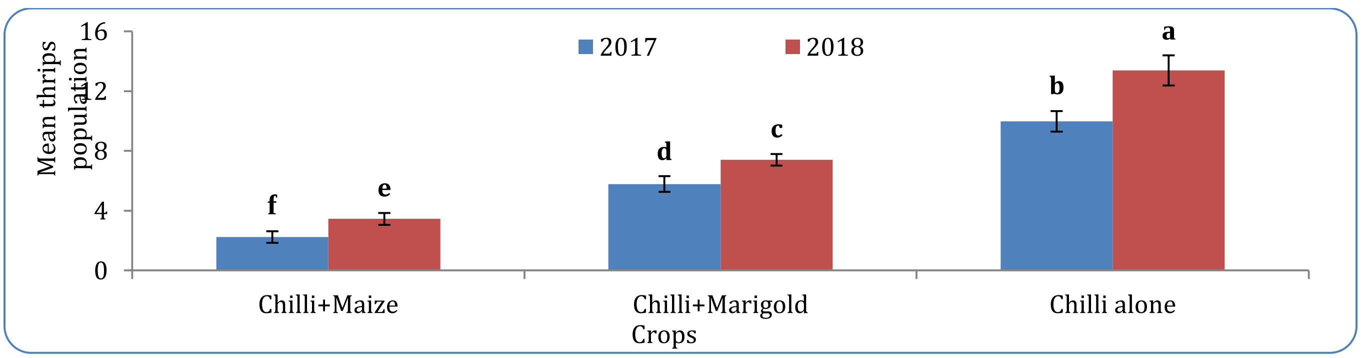

Figure 1: Overall (Mean + SE) chilli thrips population influenced by trap and border crop.

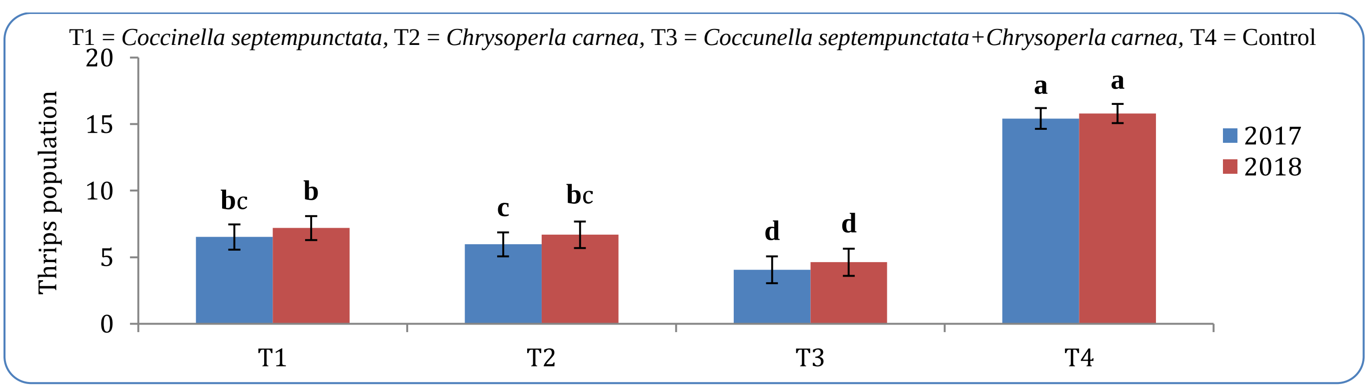

Figure 2: Influence of bio-control agents on population of chilli thrips.

A similar trend in thrips population was observed in the second year of the experiment, although the thrips population was higher in the *C. carnea* plot and the control plot in 2018 compared to 2017 (Figure 2).

Efficacy of different neem parts against chili thrips

The data recorded one day after the imposition of treatments indicated that neem seed kernel powder (NSKP) was the most effective and superior among all the treatments. The data showed a significant difference ($F = 18.58$; $df = 3, 58$; $P < 0.002$) in NSKP (73.08%) at ten days after the spray application, followed by neem leaf extract (NLE) (64.49%) and neem oil (26.67%), respectively. However, a similar trend of reduction percentage was observed in both NSKP and NLE in all the treatments after one, three, seven, and ten days after the spray, respectively. The trend was different in the case of neem oil. In all NSKP treatments, the maximum reduction percentage (83.29%) was observed at seven days, followed by (75.11%) at three days and (33.28%) at ten days, respectively. Furthermore, the data revealed that neem leaf extracts showed the highest reduction percentage (75.11%) at seven days after the spray, followed by (64.49%) at ten days, (46.85%) at three days, and (35.60%) at one day after the spray application (Figure 3).

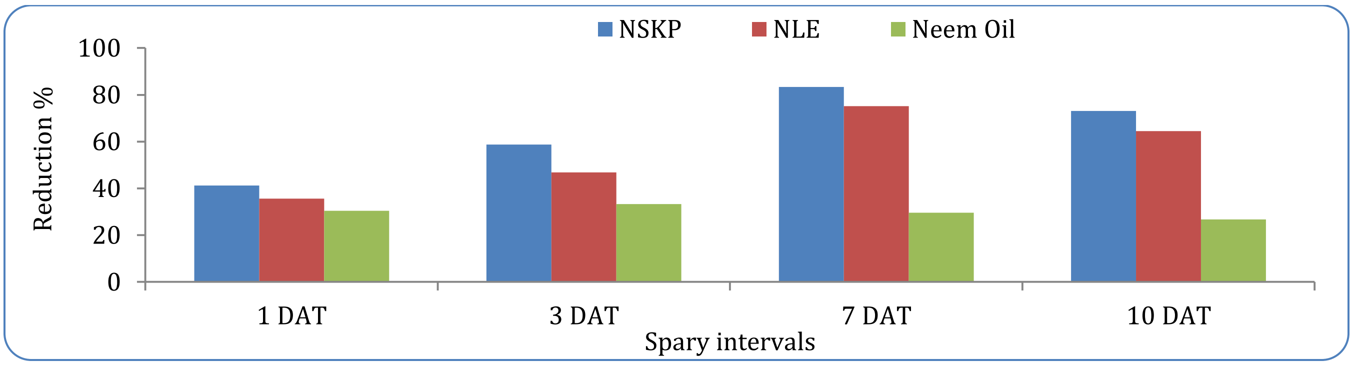

Figure 3: Mean reduction percentage after application of botanical insecticide spray in different treatments against chili thrips 2017.

The treatments were revised to assess the efficacy of various parts of the neem tree observed during the kharif season of 2018. The maximum reduction percentage (85.49%) was observed with neem seed kernel powder at seven days after sowing (DAS), followed by neem leaf extracts (77.89%) and neem oil (26.20%), respectively. Statistical analysis revealed a significant difference ($F = 33.05$; $df = 385$; $P < 0.001$), as indicated by different letters in Figure 4. Furthermore, the results indicated the highest reduction in the population of *S. dorsalis* on neem seed kernel powder (91.11%) at 10 DAS, followed by (85.49%) at seven DAS, (65.83%) at three DAS, and (43.72%) at one DAS, respectively. Additionally, the data demonstrated the highest reduction percentage (77.89%) on neem leaf extract at seven DAS, followed by (76.94%) at 10 DAS, (59.72%) at three DAS, and (28.39%) at one DAS in different treatments.

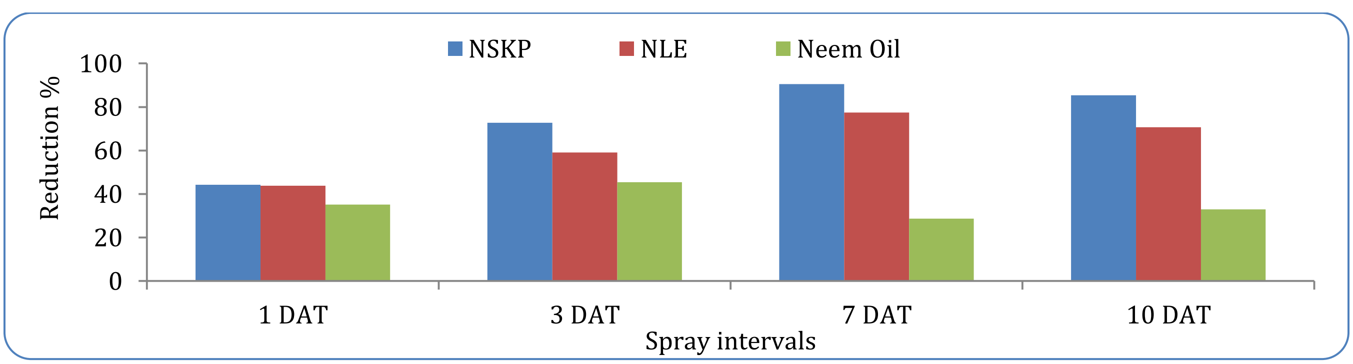

Figure 4: Efficacy of different treatments against chili thrips during kharif season 2018.

Impact of IPM strategies on the yield of chili crop

The impact of various eco-friendly tactics on the per-acre cost of production, yield difference, net income, and cost/benefit ratio of IPM and conventional plots was assessed. It was observed that the IPM plot had an estimated production cost Rs. 19,277 less than the conventional plot. Additionally, the IPM plots yielded 547 kg more than the conventional plot. Similarly, a higher cost/benefit ratio was recorded in the IPM plot compared to the conventional plots (Table 1).

Table 1: Impact of IPM strategies on the yield of chilli crop.

Treatments	Total cost of Production (Rs.)	Production kg/ acre	Gross income	Net income	Cost benefit ratio
IPM plot	70,773	2000	293,000	222,227	3:13
Conventional plot	90,050	1453	212,864	122,814	1:36

DISCUSSION

Chili is one of the most essential vegetable crops, and its production is highly affected by chili thrips, which are also difficult to control using only synthetic insecticides or any single practice. Therefore, the present research was conducted to carry out field trials and develop a potential Integrated Pest Management (IPM) model against this noxious pest. Various control measures were employed to manage the insect pest population below damaging levels in field crops. The impacts of trap and barrier crops were determined against the chili thrips, *S. dorsalis* population, with the barrier crop proving most effective in reducing the *S. dorsalis* population on chili crops.

Several studies have reported that intercropping systems are the most efficient method to reduce the infestation intensity and population incidence of various insect pests (Ganiger et al., 2009). The intercropping method is considered one of the common, traditional, and important tools of IPM (Boucher et al., 2003). The findings of the present work validate previous results (Ferers, 2000; Smitha and Giraddi, 2006). On the other hand, during the mid or later stages of the crop, the infestation and population trend were significantly lower compared to barrier crops. These outcomes are highly correlated with previous studies (Sujay and Giraddi, 2016).

Most studies have reported that trap and barrier crops not only attract insect pests but also attract predators that feed on noxious insect pests (Hooks and Ferers, 2006). The attraction of predators by trap and barrier crops could be crucial to controlling insect pest populations (Vaiyapuri et al., 2007; Maharjan et al., 2013). However, to protect the main crop (chili) from insect pest infestation, marigold and maize crops can be planted as intercrops in the chili agro-ecosystem. The intercropping system not only reduces the insect population and infestation intensity of the main crop but also reduces the use of synthetic chemicals. *S. dorsalis* is usually difficult to control using pesticides due to developed resistance. It may be suggested that barrier crops prohibit the migration of thrips, and marigold acts as a trap crop for *S. dorsalis*. Therefore, planting marigold as a trap and maize as barrier crops might help overcome thrips infestation in the chili agro-ecosystem.

Several techniques and methods have been introduced to destroy colonies of insect pests in outdoor cropping systems, with biological control being an important component of IPM in sustainable agriculture. Bio-control practices gain importance in IPM programs as they emphasize the need for managing agricultural or natural ecosystems enhanced by natural enemies for the benefits of biological control, managing insect pest populations below damaging levels (Naranjo and Ellsworth, 2009).

In the present findings, releasing a single bio-control agent, i.e., C. carnea or *C. septempunctata* separately, was not as effective as combining the release of these two different bio-control agents. Both predators depend not only on thrips but also get nourishment from other small, soft-bodied insects and mites (Sanda and Sunusi, 2014). Our current findings demonstrate that both bio-control agents can reduce the population density of chili thrips *S. dorsalis*, in contrast to releasing both bio-control agents combined in the same experimental plots.

Bio-pesticides have great importance in the field of agriculture pest management and environmental protection (Sruthi et al., 2018). We tested different neem products against chili thrips, and as a result, NSKP was the most efficient in minimizing the *S. dorsalis* population in chili crops compared to NLE and NO. The present findings are consistent with those of Power (2010) who reported that bio-pesticides are most effective against thrips and cause moderate mortality compared to synthetic pesticides. Similar results were obtained by Patel et al. (2009), supporting the present findings that a high reduction percentage of thrips was found in the NSKE-treated plot. Neem derivatives not only minimize the insect pest population but also protect natural enemies and reduce human and environmental exposure to hazardous chemicals (Varghese, 2003). Therefore, Power (2010) stated that people are encouraged to improve the agro-ecosystem by using neem derivatives as bio-pesticides. However, a recent study confirms that among all three different neem derivatives, NSKP proved to have high reduction capability against *S. dorsalis*.

CONCLUSIONS

Based on the two-year results, it is concluded that the intercropping system is considered an important tool of Integrated Pest Management (IPM). In the current study, the results indicate that using Maize as a border and Marigold as a trap crop significantly reduced the thrips population in the chili crop and could enhance the population of natural enemies. This, in turn, has an ultimate effect on the insect pest population (data not shown), although the presence of natural enemies was observed in the targeted field. Bio-control practices are environmentally safe and effective methods for pest control. In the present research, the released bio-control agents, i.e., *C. carnea* and *C. septempunctata*, in the chili crop, showed a significant reduction in the thrips population. Furthermore, the combined use of these agents revealed the maximum reduction in the thrips population compared to individual applications. The utilized neem-based products exhibited a significant reduction in the thrips population. Neem seed kernel powder showed the maximum reduction, followed by neem leaves extracts and neem oil.

RECOMMENDATIONS

After conducting a series of field experiments for managing chilli thrips, the following strategies are suggested to suppress the pest population. First, cultivating Maize as a border and Marigold as a trap crop may help overcome the population trend of thrips and, additionally, enhance the population of natural enemies. Second, a combination of two bio-agents, *Chrysoperla carnea* and *Coccinella septempunctata*, should be released in targeted fields during the manifestation of thrips. Lastly, the application of sprays containing neem-based products, such as neem seed kernel powder, could be initiated when other control methods are failing to decrease the thrips problem.

AUTHORS' CONTRIBUTIONS

SP conceived the idea, executed experiments, collected, and arranged the data; AWS analysed the data, wrote up the manuscript; JMM designed the experiments and guided the first author; AGL analysed and explained the bio-control agent's data; AB compiled the results and proofreads the manuscript.

CONFLICT OF INTEREST

The authors declared no conflict of interest.

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