Plant Archives Vol. 24, No. 1, 2024 pp. 1441-1452 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2024.v24.no.1.202

ECO-FRIENDLY APPROACHES FOR CONTROLLING SUCKING PESTS IN CHILI (*CAPSICUM ANNUUM* L.)

N.R. Ingale[1], S.L. Borkar[1], S.V. Dhonde[2], A.N. Humane[1]*, D.B. Undirwade[1] and S.B. Nakade[3]

[1]Department of Entomology, Post Graduate Institute, Dr. P.D.K.V., Akola - 444 104, India.

[2]Entomology Section, College of Agriculture, Nagpur - 440 012, India.

[3]Taluka Agriculture Officer, Mauda, District Nagpur - 441 104, India.

*Corresponding author E-mail : akankshahumane5@gmail.com

(Date of Receiving-13-01-2024; Date of Acceptance-19-03-2024)

ABSTRACT

The research, titled "Eco-Friendly Approaches for Controlling Sucking Pests in Chili (*Capsicum annuum* L.)", was conducted during the *kharif* season of 2019-20 on chili crops (Variety PKV Hirkani) at the Department of Entomology, Dr. P.D.K.V. Akola, Maharashtra , India. The primary objectives were to evaluate the efficacy of various botanicals and bio-pesticides against major chili pests and the incidence of leaf curl disease. Eight treatments, including botanicals (NSE 5%, Neem oil 2%, Azadirachtin 300 ppm, Azadirachtin 1500 ppm) and bio-pesticides (*Beauveria bassiana*, *Metarhizium anisopliae*, *Verticillium lecanii* at 1×10^9 CFU/ml), along with an untreated control, were applied at 10-day intervals. Observations on pest populations were recorded at 3, 7, and 10 days of post-spray, considering three leaves from the top, middle and bottom canopy of five randomly selected plants. The results indicated specific treatments that were effective against different pests, with Neem oil 2%, *M. anisopliae*, and NSE 5% showing promising results against aphids, whiteflies, thrips, and mites. The Treatment NSE 5% emerged as the most effective in minimizing Leaf Curl Index (LCI), followed by Neem oil 2% and Azadirachtin 1500 ppm. Neem oil 2% resulted in the highest green chili yield, and Azadirachtin 1500 ppm also performed well. NSE 5% demonstrated the highest Incremental Cost-Benefit Ratio (ICBR), indicating economic viability. The study underscores the significance of employing eco-friendly approaches, particularly the use of NSE 5%, in effectively managing sucking pests and mitigating leaf curl disease in chili crops. The notable success of Neem oil 2% and Azadirachtin 1500 ppm in enhancing chili yields further emphasizes the practicality of bio-intensive methods. The highest Incremental Cost-Benefit Ratio (ICBR) associated with NSE 5% not only showcases its effectiveness in pest control, but also establishes its economic viability.

Key words : Biopesticides, Botanicals, Eco-Friendly, Leaf Curl Index, Sucking pests.

Introduction

Chilli (*Capsicum annuum* L.), known as "Mirch" in Hindi, is a tropical and subtropical crop extensively cultivated across India and belonging to the Solanaceae family. Beyond its traditional use in vegetables, spices, sauces and pickles, green chillies are a rich source of vitamins A, C and E (Mondal and Mondal, 2012). Among the two main chilli species, *Capsicum annum* L. and *Capsicum frutescence*, Indian chilli (*C. annum*) stands out as a crucial vegetable crop, adaptable to diverse climatic conditions. The majority of hot chili are categorized under *Capsicum annuum* L., which are part of the *Capsicum annuum* group are commonly utilized in numerous cuisines as a spice to introduce heat to the food (Abd-Elgawad, 2020). The medicinal value of chilli, attributed to its vitamin 'C' and capsaicin content, contributes to its pungency, stemming from the crystalline volatile alkaloid "Capsaicin", while the red colour is due to the presence of pigment "Capsanthin" (Choudhary and Fageria, 2009; Abd-Elgawad, 2020).

Though chilli cultivation is widespread in India, it is concentrated mostly in southern states, including Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu, covering about 75% of the total area. Despite its potential for export and a substantial domestic market, the crop faces productivity challenges due to significant occurrences of diseases and insect pests (Gundannavar et al., 2007).

The pest spectrum in chilli is intricate, involving over 293 insect and mite species affecting the crop in both fields and storage (Dey *et al.*, 2001). Notable pests include aphids (*Myzus persicae* Sulzer, *Aphis gossypii* Glover), thrips (*Scirtothrips dorsalis* Hood), yellow mites (*Polyphagotarsonemus latus* Banks) and the fruit borer (*Helicoverpa armigera* Hubner). Severe infestations result in visible damage, such as upward leaf curling caused by thrips and downward curling by mites (Kandasamy *et al.*, 1990; Kethran *et al.*, 2014).

The study of thrips dates back to 1916, with observations on castor and chilli. Thrips, known as "chilli thrips", inflicts damage known as leaf curl disease or "Mudatha" or "Korivi" during distinct seasons. Mites, recognized since 1890, cause "Murada" disease in chilli, impacting flowering and fruiting stages (Amin *et al.*, 1981 and Ayyar *et al.*, 1935). Green peach aphid, reported in 1938, has become a serious pest on various hosts, including chilli (Deshpande, 1938).

Whiteflies, being polyphagous pests, cause direct damage to chillies, impacting plant nutrient absorption and photosynthetic processes (Oliveira *et al.*, 2001; Cruz-Estrada *et al.*, 2013). Despite the application of pesticides for viral disease control, their use poses environmental and health threats. Yield losses due to these pests are estimated at 50% (Hosmani, 2007; Lee *et al.*, 2018). Chilli leaf curl complex, caused by thrips and mites, leads to significant crop losses.

The increasing pest build-up due to chilli monoculture necessitates frequent chemical sprays, with a minimum of 5 to 6 applications, resulting in high cultivation costs and risks. Pesticidal sprays threaten the chilli ecosystem, causing pest resurgence and harm to natural enemies (Devi *et al.*, 2017). Pesticide residues in chillies raise concerns for both domestic consumption and exports (Nandahalli, 1979; Joia *et al.*, 2001). Using hazardous pesticides not only costs a lot but also harms the environment, negatively affecting soil fertility and microorganisms in the soil (Mishra *et al.*, 2018). Using harmful chemicals to control pests has caused a lot of problems. The biggest issue is that these chemicals leave behind residues and pests are becoming resistant to them. To successfully deal with these challenges in farming, it's important to keep coming up with new and better ways (Reddy and Chowdary, 2021). And the biological method is a great option for keeping insect populations in check without harming other organisms and helpful entities in the ecosystem (Lv *et al.*, 2011).

Effective non-chemical pest management strategies against sucking pests, such as thrips, aphids, whiteflies, mites and leaf curl disease are crucial for sustained crop management and healthy food production. Therefore, exploring non-chemical pest management strategies, including organic amendments, botanical pesticides and bio-agents, becomes imperative. Extracts of neem (*Azadirachta indica*) and Entomopathogenic fungi (EPF) like *Beauveria bassiana*, *Verticillium lecanii*, *Metarhizium anisopliae* and *Paecilomyces fumosoroseus* (Wize) have been recognized as potential agents to control *B. tabaci* and *Aphis gossypii* (Saito and Sugiyama, 2005; Ali *et al.*, 2018; Ghongade *et al.*, 2021). These fungi are important tools for managing various agricultural insect pests, such as whiteflies, mealy bugs, aphids, thrips, psyllids, mites and weevils, in both outdoor and greenhouse crops (Torrado-Leon *et al.*, 2006; Akmal *et al.*, 2013).

Therefore, the current study focuses on botanicals and bio-pesticides as common and popular methods for pest management. By employing botanicals with novel modes of action and higher bio-efficacy, the study aims to save the environment and mammals. The efficacy of bio-pesticides needs thorough examination for formulating effective and economical strategies against chilli thrips.

Materials and Methods

This study, titled "Eco-Friendly Approaches for Controlling Sucking Pests in Chili" aimed to assess the effectiveness of various treatments using neem products (Azadirachtin, Neem oil, NSE) and microbial preparations (*Beauveria bassiana*, *Metarhizium anisopliae*, *Verticillium lecanii*) on the yield performance of chilli crops (Variety – PDKV Hirkani). The field experiment took place at the Department of Entomology, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, during the *kharif* season of 2019-20. The experimental field followed a Randomized Block Design with eight treatments and three replications. Each gross plot measured 4.00 m × 3.00 m, with a distance of 1.20 m between two replications and 0.60 m between two treatments. The total experimental area covered 406 sq. m. List and details of the treatments are given in the Tables 1 and 2.

Spray Solution preparation

The preparation of spray solutions was conducted on-site as part of the pre-application procedure. The necessary amount of solution was measured with

Table 1 : List of treatments used during experiment.

Treatment No.	Treatment details		Concentration ml/l
T_1	NSE	5%	50 ml/l
T_2	Neem oil	2%	20 ml/l
T_3	Azadirachtin	300 ppm	5 ml/l
T_4	Azadirachtin	1500 ppm	3 ml/l
T_5	*Beauveria bassiana*	1×10^9 CFU/ml	4 g/l
T_6	*Metarhizium anisopliae*	1×10^9 CFU/ml	4 g/l
T_7	*Verticillium lecanii*	1×10^9 CFU/ml	4 g/l
T_8	Untreated control	-	-

Table 2 : Details of the treatments used in the experiment.

S. no.	Common name	Trade name	Formulation	Chemical name	Source of supply
1.	Neem Seed Extract (NSE)	NSE	5%	In crude form (*Azadirachta indica* A. Juss)	Jay Bajrang Krushi Sewa Kendra, Akola
2.	Neem oil	NeemAzal	2%	Azadirachtin	MIDC, Khamgaon
3.	Azadirachtin	MULTINEEM	300 ppm (0.03%)	Azadirachtin	Aradhana Krushi Sewa Kendra, Deulgaon Raja
4.	Azadirachtin	NEEM FIGHTER	1500 ppm (0.15%)	Azadirachtin	Aradhana Krushi Sewa Kendra, Deulgaon Raja
5.	*Beauveria bassiana*	PDKV	1×10^9 CFU/ml	*Beauveria bassiana*	Deptt. of Plant Pathology PGI, Akola
6.	*Metarhizium anisopliae*	PDKV	1×10^9 CFU/ml	*Metarhizium anisopliae*	Deptt. of Plant Pathology PGI, Akola
7.	*Verticillium lecanii*	PDKV	1×10^9 CFU/ml	*Verticillium lecanii*	Deptt. of Plant Pathology PGI, Akola

Table 3 : Scoring of Leaf Curl based on per cent infestation.

S. no.	Score	Observation
1.	0	No symptom.
2.	1	1 to 25% leaves/plant showing curling.
3.	2	26 to 50% leaves/plant showing curling, moderately damaged.
4.	3	51 to 75% leaves/plant showing curling, heavily damaged malformation of growing points, reduction in plant height.
5.	4	> 75% leaves/plant showing curling, severe and complete destruction of growing points, drastic reduction in plant height, defoliation and severe malformation.

precision using a plastic bucket. Subsequently, the measured components were thoroughly mixed to achieve a homogeneous solution. This meticulous mixing process is crucial for ensuring that the concentration of active ingredients remains consistent throughout the spray solution. Once the solution was well-mixed, it was then transferred to the spray pump, which was the apparatus used for the actual application of the treatments.

This step-by-step approach to solution preparation was implemented to guarantee accuracy and uniformity in the concentration of botanicals, bio-pesticides and their respective formulations. Consistency in the preparation process is essential to obtaining reliable results, as any variation in the solution's composition could impact the effectiveness of the treatments.

The application of sprays was carried out using a knapsack sprayer, and meticulous care was taken to ensure proper cleaning of the sprayer after the administration of each treatment. A total of six sprays were administered throughout the course of the study. This standardized procedure was followed to maintain consistency and prevent any potential cross-contamination between different treatments. The careful washing of the sprayer after each application aimed to eliminate any residue that could interfere with the accurate assessment of the treatments' efficacy. This meticulous approach to application and equipment maintenance contributes to the reliability and validity of the study's results, ensuring that the observed effects can be confidently attributed to the specific botanicals, bio-pesticides and their concentrations under investigation.

Neem seed extracts (NSE 5%) preparation

For the Neem seed extract at a 5% concentration, took 5 kg of dried neem seeds for every 100 liters of water needed. Crushed the seeds and soaked them overnight in a vessel with enough water one day before spraying. The next morning, filtered the extract through muslin cloth, repeating the process with water washing until complete extraction was ensured. Then adjusted the obtained suspension by adding the remaining water. To improve coverage on the crop, then added 0.2% soap powder (200 g per 100 liters of water) to the extract.

Method of recording observations

To manage the major sucking pests of chili, treatments were applied at 10-day intervals after infestation was observed in the experimental plot, continuing until the last picking of chili fruit. Population observations were made at 3, 7 and 10 days after each treatment spray. Five plants were randomly selected from each net plot, and three leaves per plant (top, middle and bottom canopy) were observed. Five random plants were labelled from 1 to 5 for each treatment. Thrips population was recorded on the terminal six leaves, while other sucking pests were assessed based on three sample leaves randomly selected from the top, middle, and bottom leaves of the observation plants. For aphids, thrips, whiteflies, nymphs and adults were recorded on three leaves (top, middle and bottom canopy) of chili plants. Mites were observed on three sample leaves randomly selected from the top, middle, and bottom leaves of observation plants, using a magnifying lens in the early morning. Leaf curl symptoms were recorded weekly from ten randomly selected and tagged plants in each plot. Scoring was done visually following the provided Table 3.

Scoring for leaf curl was conducted seven days after each spraying. The Leaf Curl Index (LCI) was determined by summing the product of the number of plants and the corresponding category score, then dividing this sum by the total number of scored plants, as per Niles (1980). The leaf curl rating data were converted into a percentage Leaf Curl Index using the formula provided by McKinney (1923).

$$\text{Per cent Leaf Curl Index} = \frac{\text{Sum of numerical ratings}}{\text{Total number of plant observed}} \times \frac{100}{\text{Maximum Disease grade in the score table}}$$

Observation on Chilli yield parameters

The impact of organic products on chilli yield parameters was observed at different crop stages, specifically the number of fruits per plant at 60, 90 and 120 days after transplanting (DAT). Green chilli yield was documented during each harvest, recorded in kilograms per plot and then converted to quintals per hectare. Based on the total yield achieved in each treatment involving organic products and the untreated control, the increase in fruit yield for each treatment over the untreated control was calculated. Subsequently, the Incremental Cost Benefit Ratio (ICBR) for each treatment was determined.

Statistical analysis

The collected data were roughly transformed and subjected to statistical analysis to assess the significance of treatments, following the method outlined by Gomez and Gomez (1984).

Results

Effect of different botanicals and bio-pesticides against major sucking pests of chilli

a. Cumulative efficacy of botanicals and bio-pesticides on the population of aphids (*Aphis gossypii*) at 3, 7 and 10 DAS (Days After Spraying)

At 3 Days After Spraying (DAS) : The results indicate that all treatments were significantly ($P < 0.05$) more effective than the untreated control. The Neem oil 2% treatment exhibited the lowest aphid population at 0.84/leaf, surpassing all other treatments. Following closely were NSE 5%, *Metarhizium anisopliae*, *Beauveria bassiana*, *Verticillium lecanii* and Azadirachtin 300 ppm, with aphid counts of 1.49, 1.49, 1.70, 1.80 and 1.87 per leaf, respectively. However, these five treatments showed no significant difference among themselves. The next moderately effective treatment was Azadirachtin 1500 ppm, recording 1.98 aphids/leaf, while the untreated control had the highest count at 2.84 aphids/leaf (Table 4).

At 7 DAS : The data from 3 reveal that all treatments were significantly ($P < 0.05$) more effective than the untreated control. Neem oil 2% treatment again showed the lowest aphid population at 0.66/leaf, followed by *M. anisopliae* (1.30), NSE 5% (1.35), *B. bassiana* (1.55), *V. lecanii* (1.67), Azadirachtin 300 ppm (1.74) and Azadirachtin 1500 ppm (1.85) aphids/leaf. However, these six treatments demonstrated no statistically significant differences. The untreated control had the highest aphid population at 2.76 aphids/leaf.

At 10 DAS : The data presented in Table 3 show that all treatments were significantly (P <0.05) more effective than the untreated control. Neem oil 2% treatment resulted in the lowest aphid population on leaves at 0.93, followed by *M. anisopliae* at 1.50/leaf. These two treatments were statistically similar. The next effective treatments were NSE 5% (1.59), *B. bassiana* (1.87), Azadirachtin 300 ppm (1.93), *V. lecanii* (1.94), and Azadirachtin 1500 ppm (2.09) aphid population per leaves, all observed to be statistically similar. The untreated control exhibited the highest aphid population at 3.05 per leaf.

b. Cumulative efficacy of botanicals and bio-pesticides on the population of whitefly (*Bemisia tabaci*) at 3, 7 and 10 DAS (Days After Spraying)

At 3 DAS : All treatments were significantly (P <0.05) better than the untreated control. *V. lecanii* and Neem oil 2% were the most effective treatments, recording minimum whitefly population of 1.23 and 1.74 per leaf, respectively, at par with each other. *M. anisopliae, B. bassiana*, NSE 5% and Azadirachtin 1500 ppm demonstrated statistically equal effects with populations of 1.74, 1.75, 2.05 and 2.10 per leaf. Azadirachtin 300 ppm recorded 2.58 whitefly/leaf, while the untreated control had 4.01 per leaf (Table 5).

Table 4 : Cumulative efficacy of botanicals and bio-pesticides on the population of aphids (*Aphis gossypii*) at 3, 7 and 10 DAS (Days After Spraying).

Tr. no.	Treatment details	Cumulative population of aphids/leaf			
		3 DAS	7 DAS	10 DAS	Mean
T_1	NSE 5%	1.49(1.22)	1.35(1.16)	1.59(1.26)	1.48(1.21)
T_2	Neem oil 2%	0.84(0.91)	0.66(0.81)	0.93(0.96)	0.81(0.89)
T_3	Azadirachtin 300 ppm	1.87(1.36)	1.74(1.28)	1.93(1.38)	1.85(1.34)
T_4	Azadirachtin 1500 ppm	1.98(1.40)	1.85(1.36)	2.09(1.40)	1.97(1.39)
T_5	*Beauveria bassiana* $1x10^9$ CFU/ml	1.70(1.30)	1.55(1.24)	1.87(1.37)	1.71(1.30)
T_6	*Metarhizium anisopliae* $1x10^9$ CFU/ml	1.49(1.22)	1.30(1.14)	1.50(1.22)	1.43(1.19)
T_7	*Verticillium lecanii* $1x10^9$ CFU/ml	1.80(1.34)	1.67(1.29)	1.94(1.39)	1.80(1.34)
T_8	Untreated control	2.84(1.68)	2.76(1.65)	3.05(1.75)	2.88(1.69)
	F 'test'	Sig	Sig	Sig	Sig
	SE(m)±	0.06	0.08	0.09	0.08
	CD at 5%	0.17	0.24	0.26	0.22
	CV %	7.43	11.02	11.09	9.85

(Figures in parentheses are square root transformed values) DAS – Days After Spraying.

Table 5 : Cumulative efficacy of botanicals and bio-pesticides on the population of whitefly (*Bemisia tabaci*) at 3, 7 and 10 DAS (Days After Spraying)

Tr. no.	Treatment details	Cumulative population of whitefly/leaf			
		3 DAS	7 DAS	10 DAS	Mean
T_1	NSE 5%	2.05(1.43)	1.82(1.34)	2.41(1.55)	2.09(1.44)
T_2	Neem oil 2%	1.74(1.31)	1.51(1.22)	2.03(1.42)	1.76(1.32)
T_3	Azadirachtin 300 ppm	2.58(1.61)	2.35(1.53)	2.89(1.70)	2.61(1.61)
T_4	Azadirachtin 1500 ppm	2.10(1.45)	1.85(1.36)	2.46(1.57)	2.14(1.46)
T_5	*Beauveria bassiana* $1x10^9$ CFU/ml	1.75(1.32)	1.57(1.25)	2.11(1.45)	1.81(1.34)
T_6	*Metarhizium anisopliae* $1x10^9$ CFU/ml	1.74(1.32)	1.55(1.24)	2.18(1.47)	1.82(1.34)
T_7	*Verticillium lecanii* $1x10^9$ CFU/ml	1.23(1.11)	1.02(1.01)	1.57(1.25)	1.27(1.12)
T_8	Untreated control	4.01(1.99)	4.14(2.03)	4.42(2.09)	4.19(2.04)
	F 'test'	Sig	Sig	Sig	Sig
	SE(m) ±	0.07	0.07	0.07	0.07
	CD at 5%	0.20	0.20	0.21	0.20
	CV %	8.04	8.38	7.82	8.08

(Figures in parentheses are square root transformed values) DAS – Days After Spraying.

At 7 DAS : All treatments significantly (P <0.05) outperformed the untreated control. *V. lecanii* had the lowest whitefly population (1.02/leaf), followed by Neem oil 2% (1.51), *M. anisopliae* (1.55), *B. bassiana* (1.57), NSE 5% (1.82) and Azadirachtin 1500 ppm (1.85) per leaf, with similar effects. Azadirachtin 300 ppm recorded 2.35 whitefly/leaf, while the untreated control had highest white fly count *i.e* 4.14 per leaf.

At 10 DAS : All treatments were significantly (P <0.05) better than the untreated control. *V. lecanii* recorded the minimum whitefly population (1.57/leaf), followed by Neem oil 2% (2.03) and *B. bassiana* (2.11), with equal effectiveness. *M. anisopliae*, NSE 5% and Azadirachtin 1500 ppm showed next effectiveness with populations of 2.18, 2.41 and 2.46 whitefly/leaf, respectively, statistically at par with each other. Azadirachtin 300 ppm recorded 2.89 whitefly/leaf which was moderately effective, while the untreated control had the maximum population of 4.42 per leaf.

c. Cumulative efficacy of botanicals and bio-pesticides on the population of thrips (*Scirtothrips dorsalis*) at 3, 7 and 10 DAS (Days After Spraying)

At 3 DAS : The data presented in Table 6 are statistically significant (P <0.05). NSE 5% recorded the least thrips population (1.95/leaf), followed by Azadirachtin 300 ppm (2.63) and *M. anisopliae* (2.65), significantly superior to other treatments. Azadirachtin 1500 ppm (2.85), *B. bassiana* (3.01), and *V. lecanii* (3.14) showed next effectiveness, statistically at par with each other. Neem oil 2% recorded 3.77 thrips/leaf found moderately effective, while the untreated control had the highest population of 5.44/leaf.

At 7 DAS : Results presented in Table 5 are statistically significant (P <0.05). NSE 5% was the most effective treatment, recording the lowest thrips population (1.66/leaf), followed by *M. anisopliae* (2.31), statistically at par with each other. Azadirachtin 300 ppm (2.33), Azadirachtin 1500 ppm (2.49*)*, *B. bassiana* (2.73), and *M. anisopliae* (2.85) showed similar effectiveness, statistically equal. Neem oil 2% recorded 3.51 thrips per leaf, while the untreated control had the highest population of 5.49 thrips/leaf.

At 10 DAS : Results in Table 5 are statistically significant (P <0.05). NSE 5% recorded the lowest thrips population (1.94/leaf), followed by Azadirachtin 300 ppm (2.56) and *M. anisopliae* (2.73), significantly superior to other treatments. *B. bassiana* (2.95), Azadirachtin 1500 ppm (3.20), *V. lecanii* (3.32) and Neem oil 2% (4.02) showed similar thrips population, statistically at par with each other. The untreated control recorded the highest thrips population of 5.60/leaf.

d. Cumulative efficacy of botanicals and bio-pesticides on the population of mites (*Polyphagotarsonemus latus*) at 3, 7 and 10 DAS (Days After Spraying)

Mite Population Control at 3, 7 and 10 Days After Spraying (DAS)

At 3 DAS : Results in Table 7 show statistically significant (P <0.05) differences in mite populations. NSE 5% demonstrated the lowest mite population (1.35/leaf), followed by Azadirachtin 1500 ppm (1.53) and Neem oil 2% (1.81), significantly outperforming other treatments. Azadirachtin 300 ppm, *M. anisopliae*, *V. lecanii* and *B. bassiana* were next effective, recording 1.96, 2.14, 2.27 and 2.33 mites per leaf, respectively, with no statistical difference. The untreated control had the highest mite population at 4.72 per leaf.

At 7 DAS : Data in Table 6 are statistically significant (P <0.05), with all treatments surpassing the untreated control. NSE 5% recorded the lowest mite population (1.03/leaf), followed by Azadirachtin 1500 ppm (1.32), both significantly superior to other treatments. Neem oil 2%, Azadirachtin 300 ppm, *M. anisopliae*, *V. lecanii* and *B. bassiana* recorded 1.63, 1.77, 2.01, 2.14 and 2.21 mites per leaf, respectively, statistically similar. The untreated control had the maximum mite population at 4.91 per leaf.

At 10 DAS : Results in Table 6 are statistically significant. NSE 5% and Azadirachtin 1500 ppm both showed the minimum mite population (1.35/leaf), statistically (P <0.05) similar. Neem oil 2%, Azadirachtin 300 ppm, *M. anisopliae*, *V. lecanii* and *B. bassiana* recorded 1.91, 2.06, 2.30, 2.41 and 2.49 mites per leaf, respectively, statistically at par. The untreated control had the highest mite population at 4.90 per leaf.

Effect of different botanicals and bio-pesticides on the incidence of leaf curl disease in chilli

Efficacy of botanicals and bio-pesticides on the incidence of leaf curl disease index in chilli at 7 days after first, second, third, fourth, fifth and sixth spray illustrated in Table 8.

7 DAS (First Spray)

All treatments significantly (P <0.05) outperformed the untreated control. NSE 5% had the lowest Leaf Curl Index (LCI) at 3.33%, followed by Neem oil 2% and Azadirachtin 1500 ppm with 5.83% and 7.50% LCI, respectively. Azadirachtin 300 ppm, *M. anisopliae*, *V. lecanii* and *B. bassiana* showed equal effectiveness with

Table 6 : Cumulative efficacy of botanicals and bio-pesticides on the population of thrips (*Scirtothrips dorsalis*) at 3, 7 and 10 DAS (Days After Spraying).

Tr. no.	Treatment details	Cumulative population of thrips/leaf			
		3 DAS	7 DAS	10 DAS	Mean
T_1	NSE 5%	1.95(1.40)	1.66(1.28)	1.94(1.39)	1.85(1.36)
T_2	Neem oil 2%	3.77(1.94)	3.51(1.87)	4.02(2.01)	3.77(1.94)
T_3	Azadirachtin 300 ppm	2.63(1.62)	2.33(1.53)	2.56(1.60)	2.51(1.58)
T_4	Azadirachtin 1500 ppm	2.85(1.69)	2.49(1.58)	3.20(1.77)	2.85(1.68)
T_5	*Beauveria bassiana* $1x10^9$ CFU/ml	3.01(1.73)	2.73(1.64)	2.95(1.72)	2.90(1.70)
T_6	*Metarhizium anisopliae* $1x10^9$CFU/ml	2.65(1.60)	2.31(1.52)	2.73(1.64)	2.56(1.59)
T_7	*Verticillium lecanii* $1x10^9$ CFU/ml	3.14(1.75)	2.85(1.69)	3.32(1.82)	3.10(1.75)
T_8	Untreated control	5.44(2.33)	5.49(2.32)	5.60(2.36)	5.51(2.34)
	F 'test'	Sig	Sig	Sig	Sig
	SE(m) ±	0.08	0.08	0.10	0.09
	CD at 5%	0.25	0.24	0.29	0.26
	CV %	7.97	8.19	9.26	8.47

(Figures in parentheses are square root transformed values) DAS – Days After Spraying.

Table 7 : Cumulative efficacy of botanicals and bio-pesticides on the population of mites (*Polyphagotarsonemus latus*) at 3, 7 and 10 DAS (Days After Spraying)

Tr. no.	Treatment details	Cumulative population of mites/leaf			
		3 DAS	7 DAS	10 DAS	Mean
T_1	NSE 5%	1.35(1.16)	1.03(1.01)	1.35(1.15)	1.24(1.11)
T_2	Neem oil 2%	1.81(1.34)	1.63(1.27)	1.91(1.38)	1.78(1.33)
T_3	Azadirachtin 300 ppm	1.96(1.40)	1.77(1.33)	2.06(1.43)	1.93(1.39)
T_4	Azadirachtin 1500 ppm	1.53(1.22)	1.32(1.15)	1.62(1.27)	1.49(1.21)
T_5	*Beauveria bassiana* $1x10^9$ CFU/ml	2.33(1.52)	2.21(1.46)	2.49(1.57)	2.34(1.52)
T_6	*Metarhizium anisopliae* $1x10^9$CFU/ml	2.14(1.46)	2.01(1.41)	2.30(1.52)	2.15(1.46)
T_7	*Verticillium lecanii* $1x10^9$ CFU/ml	2.27(1.50)	2.14(1.46)	2.41(1.55)	2.27(1.50)
T_8	Untreated control	4.72(2.17)	4.91(2.21)	4.90(2.21)	4.84(2.20)
	F 'test'	Sig	Sig	Sig	Sig
	SE(m) ±	0.07	0.07	0.07	0.07
	CD at 5%	0.22	0.20	0.20	0.21
	CV %	8.48	8.14	7.65	8.09

(Figures in parentheses are square root transformed values) DAS – Days After Spraying.

10.00% LCI. Untreated control had the highest LCI at 15.00%.

7 DAS (Second Spray)

All treatments were significantly (P <0.05) superior to the untreated control. NSE 5% demonstrated the lowest LCI at 7.50%, followed by Neem oil 2% (10.83%), with similar effects. Azadirachtin 1500 ppm, Azadirachtin 300 ppm and *M. anisopliae* showed statistically similar effects. *V. lecanii*, *B. bassiana* and untreated control had similar LCIs at 17.50%, 20.00% and 22.50%, respectively.

7 DAS (Third Spray)

All treatments significantly (P <0.05) surpassed the untreated control. NSE 5% had the lowest LCI at 10.83%. Neem oil 2%, Azadirachtin 1500 ppm, Azadirachtin 300 ppm, *M. anisopliae* and *V. lecanii* showed similar effects. B. bassiana was next effective with 18.33% LCI. Untreated control recorded the highest LCI at 34.17%.

7 DAS (Fourth Spray)

All treatments significantly (P <0.05) outperformed the untreated control. NSE 5% was the most effective with 15.83% LCI, followed by Neem oil 2% and

Table 8 : Efficacy of botanicals and bio-pesticides on the incidence of leaf curl disease index in chilli at 7 days after first, second, third, fourth, fifth and sixth spray.

Tr. no.	Treatment details	Leaf curl disease index score (%)					
		7 DAS (1st)	7 DAS (2nd)	7 DAS (3rd)	7 DAS (4th)	7 DAS (5th)	7 DAS (6th)
T_1	NSE 5%	3.33(10.37)	7.50(15.75)	10.83(19.19)	15.83(23.35)	9.17(17.59)	6.67(14.90)
T_2	Neem oil 2%	5.83(13.63)	10.83(19.10)	11.67(19.95)	18.33(25.00)	10.00(18.34)	10.00(18.34)
T_3	Azadirachtin 300 ppm	10.00(18.11)	14.17(22.05)	14.17(22.09)	23.33(28.68)	12.50(20.64)	13.33(21.40)
T_4	Azadirachtin 1500 ppm	7.50(15.32)	12.50(20.64)	13.33(21.40)	21.67(27.58)	11.67(19.95)	11.67(19.89)
T_5	*Beauveria bassiana* 1×10^9 CFU/ml	12.50(20.49)	20.00(26.57)	18.33(25.31)	28.33(32.13)	16.67(24.08)	19.17(25.95)
T_6	*Metarhizium anisopliae* 1×10^9 CFU/ml	10.00(18.11)	16.67(24.05)	15.00(22.74)	25.83(30.51)	13.33(21.29)	15.83(23.35)
T_7	*Verticillium lecanii* 1×10^9 CFU/ml	11.67(19.80)	17.50(24.69)	16.67(24.08)	27.50(31.57)	15.00(22.74)	16.67(24.05)
T_8	Untreated control	15.00(22.63)	22.50(28.29)	34.17(35.54)	33.33(35.25)	29.17(32.52)	28.33(31.73)
	F 'test'	Sig	Sig	Sig	Sig	Sig	Sig
	SE(m) ±	0.86	1.17	1.91	1.74	1.35	1.81
	CD at 5%	2.62	3.56	5.79	5.26	4.09	5.47
	CV %	8.64	8.98	14.22	10.27	10.55	13.92

(Figures in parentheses are arc sine transformed values) DAS – Days After Spraying.

Azadirachtin 1500 ppm. Azadirachtin 300 ppm, *M. anisopliae, V. lecanii* and *B. bassiana* showed statistically equal effects. Untreated control had the highest LCI at 33.33%.

7 DAS (Fifth Spray)

All treatments were significantly ($P < 0.05$) superior to the untreated control. NSE 5% had the lowest LCI at 9.17%, followed by Neem oil 2%, Azadirachtin 1500 ppm, and Azadirachtin 300 ppm. *V. lecanii* and *B. bassiana* had similar effects. Untreated control recorded the highest LCI at 29.17%.

7 DAS (Sixth Spray)

All treatments were significantly ($P < 0.05$) superior to the untreated control. NSE 5% recorded the minimum LCI at 6.67%, followed by Neem oil 2% and Azadirachtin 1500 ppm with equal effectiveness. Azadirachtin 300 ppm, *M. anisopliae, V. lecanii* and *B. bassiana* showed similar effects. Untreated control had the highest LCI at 28.33% due to thrips and mites.

Note: LCI represents Leaf Curl Index, and DAS represents Days After Spraying.

Effects of Botanicals and Bio-pesticides on Green Chilli yield

The data depicted in Fig. 1 are statistically significant ($P < 0.05$), revealing insights into the yield of green chilli. The highest green chilli yield was observed in the Neem oil 2% treatment, reaching 111.77 q/ha. Azadirachtin 1500 ppm, Azadirachtin 300 ppm, and NSE 5% treatments followed closely, with yields of 80.02 q/ha, 75.39 q/ha, and 74.07 q/ha, respectively. These three treatments showed no significant difference in yield. *M. anisopliae* and *V. lecanii* treatments demonstrated yields of 65.47 q/ha and 63.49 q/ha, respectively and were statistically similar to each other. *B. bassiana* treatment resulted in a yield of 59.52 q/ha. The untreated control exhibited the lowest yield, recording only 29.09 q/ha and the highest

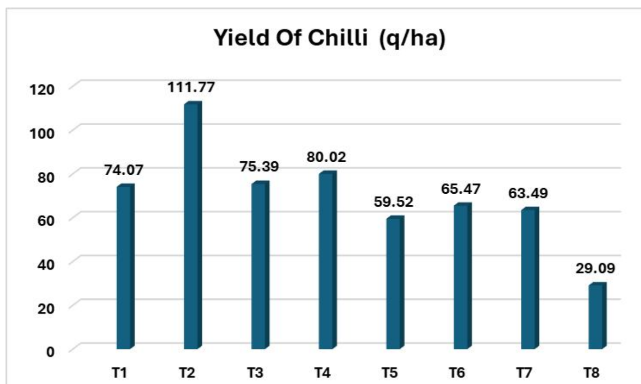

Fig. 1 : Effects of different botanicals and bio-pesticides on the yield of green chilli.

Table 9 : Incremental Cost Benefit Ratio (ICBR) of different botanicals and bio-pesticides.

Tr. no.	Treatments	No. of sprays	Qty. per ha.	Rate per kg or lit.	Cost of treatments: Cost of insecticides (Rs./ha)	Labour cost and machinery charges (Rs./ha)	Total cost (Rs./ha) A	Yield (q/ha)	Yield increased over control (q/ha)	Value of increased yield (Rs.) B	Incremental benefit (Rs.) B-A	ICBR (B-A)/A	Rank
1.	NSE 5%	6	150 kg	Rs.30	4750	4260	9000	74.07	44.98	80964	71964	1:8.00	1
2.	Neem oil 2%	6	60 lit	Rs.250	15240	4260	19500	111.77	82.68	148824	129324	1:6.63	3
3.	Azadirachtin 300 ppm	6	15 lit	Rs.450	6750	4260	11010	75.39	46.30	83340	72330	1:6.57	4
4.	Azadirachtin 1500 ppm	6	09 lit	Rs.860	7740	4260	12000	80.02	50.93	91674	79674	1:6.64	2
5.	*Beauveria bassiana* 1×10^{9}CFU/ml	6	12 kg	Rs.400	4800	4260	9060	59.52	30.43	54774	45714	1:5.05	6
6.	*Metarhizium anisopliae* 1×10^{9}CFU/ml	6	12 kg	Rs.730	8760	4260	13020	65.47	36.38	65484	52464	1:4.03	7
7.	*Verticillium lecanii* 1×10^{9}CFU/ml	6	12 kg	Rs.350	4200	4260	8460	63.49	34.40	61902	53442	1:6.32	5
8.	Untreated control	-	-	-	-	-	-	29.09	-	-	-	-	-

Note: 1) Neem Seed Extract : Rs.30/kg 2) Neem oil : Rs 250/ lit 3) Azadirachtin 300 ppm : Rs.450/lit 4) Azadirachtin 1500 ppm : Rs.860/lit 5) *Beauveria bassiana* : Rs 400/kg 6) *Metarhizium anisopliae* : Rs.730/kg 7) *Verticillium lecanii* Rs.350/Kg. 8) Detergent powder : Rs.40/kg. 9) Spray pump charges : Rs.50/day. 10) Labour charges : Rs.220/day 11) Sale price chilli fruit : Rs.1800/q 12) Labour/ha : 03 labour/spray.

incremental cost benefit ratio (ICBR) of (1:8.00) was obtained in the treatment of NSE 5% (Table 9) and observed as the economically most viable treatment. The next treatment in order of incremental cost benefit ratio were, application of Azadirachtin 1500 ppm (1:6.64), Neem oil 2% (1:6.63) and Azadirachtin 300 ppm (1:6.57), respectively.

Discussion

The extensive investigation into the efficacy of different botanicals and bio-pesticides in the cultivation of green chilli has yielded significant findings that hold substantial implications for pest and disease management practices. The study addressed the impact of various treatments on aphids, whiteflies, thrips, mites, leaf curl disease and overall green chilli yield. The collective results offer valuable insights into the potential of sustainable and eco-friendly alternatives, laying the groundwork for enhanced agricultural practices. Such effectiveness of botanicals like Neem oil 2% and NSE 5% against aphids has been reported by earlier workers like Anitha and Nandihali (2008), Sujay *et al*. (2010, 2011), Naik *et al*. (2012), Halder *et al*. (2016), Boda *et al*. (2017), Kumar *et al*. (2017) and Dehariya *et al*. (2018) in minimizing the population of aphids thus supports the present findings. These studies collectively reinforce the reliability and consistency of Neem oil and NSE 5% in aphid control across different regions and conditions.

The treatments of bio-pesticides like *V. lecanii*, *M. anisopliae* and botanical Neem oil 2% have also shown good performance in registering the minimum population of whitefly on chilli leaves. Similar observations were reported by Sharma *et al*. (2015), Halder *et al*. (2016), Noonari *et al*. (2016), Saini *et al*. (2016), Sarkar *et al*. (2016), Kumar *et al*. (2017), Naik *et al*. (2017) and Sharma and Summarwar (2017). These studies collectively affirm the effectiveness of *V. lecanii*, *M. anisopliae* and Neem oil against whitefly, endorsing the current study's outcomes.

The similar kind of effectiveness of

botanicals like NSE 5%, Azadirachtin 1500 ppm and bio-pesticide *M. anisopliae* against thrips on chilli leaves has been reported by earlier workers like Hadiya *et al*. (2016), Noonari *et al*. (2016), Saini *et al*. (2016), Boda *et al*. (2017), Kumar *et al*. (2017), Meena *et al*. (2017) and Samota *et al*. (2017). These studies collectively reinforce the efficacy of NSE 5%, Azadirachtin 1500 ppm and *M. anisopliae* in controlling thrips populations on chilli plants.

The performance of botanicals like NSE 5%, Azadirachtin 1500 ppm and Neem oil 2% against chilli mites is authenticated with the reports of several workers like Sujay *et al*. (2011, 2015), Chinniah *et al*. (2016), Halder *et al*. (2016) and Kumar *et al*. (2017). These findings consistently support the efficacy of these botanicals in minimizing mite populations on chilli leaves, highlighting their potential in integrated pest management strategies.

Such effectiveness of botanicals like NSE 5%, Neem oil 2% and Azadirachtin 1500 ppm in minimizing the incidence of Leaf Curl Index (LCI) on chilli leaves has been demonstrated by several workers like Pandey *et al*. (2010), Mondal and Mondal (2012), Chakraborty and Nath (2015), Chaubey *et al*. (2017), Zeeshan and Kudada (2019). These studies collectively affirm the efficacy of NSE 5%, Neem oil 2% and Azadirachtin 1500 ppm in reducing leaf curl disease in chilli plants, supporting, and confirming the present findings.

The consistent alignment of the current study's results with established research provides robust evidence supporting the effectiveness of Neem oil 2%, NSE 5%, Azadirachtin 1500 ppm, *M. anisopliae* and *V. lecanii* in pest and disease management, yield as well as ICBR in chilli cultivation. Meena *et al*. (2017) reported the maximum yield of chilli in the treatment of Neem oil when compared amongst different botanicals and bio-pesticides, in close agreement with the present findings. Dehariya *et al*. (2018) obtained the maximum yield of brinjal by using Neem oil 1% and Selvam (2018) recorded the highest yield after the treatment of neem formulation having 0.03% of Azadirachtin over untreated control, further confirming the positive impact of Neem-based formulations on crop yield. The effectiveness of botanicals, including NSE 5%, Azadirachtin 1500 ppm, Neem oil 2% and Azadirachtin 300 ppm, has been consistently reported by various researchers. Sujay *et al*. (2011) demonstrated comparable results in terms of Incremental Cost Benefit Ratio (ICBR) in Neem oil-treated plots in chili crops, aligning with our present findings. In the evaluation of bio-efficacy against sucking pests of brinjal, Karkar *et al*. (2014) identified NSKE 5% and Neem oil 0.03% as the treatments with the highest ICBR, further supporting our current results. Hadiya *et al*. (2016) explored bio-pesticides, including *B. bassiana*, *M. anisopliae* and *V. lecanii*, against sucking pests of chili. Their study revealed that M. anisopliae exhibited the highest ICBR, followed by *V. lecanii* and *B. bassiana*, endorsing our findings. Similarly, Dehariya *et al*. (2018) achieved economically superior ICBR values with Neem oil 1%, emphasizing its effectiveness against sucking pests of brinjal at various intervals after spraying. These results collectively strengthen and confirm our present findings, highlighting the economic benefits associated with the application of these botanicals and bio-pesticides in pest management strategies.

In summary, the present study not only contributes valuable insights into the efficacy of botanicals and bio-pesticides in pest and disease management but also reinforces their positive impact on chilli yield. These findings can inform sustainable and environmentally friendly practices for chilli cultivation, promoting reduced reliance on synthetic chemicals and fostering the adoption of integrated pest management strategies by farmers.

Conclusion

In conclusion, the findings collectively underscore the significance of integrating botanicals and bio-pesticides into pest and disease management strategies for green chilli cultivation. The results not only contribute to the existing body of knowledge but also provide practical solutions for farmers seeking sustainable alternatives. The demonstrated efficacy of Neem oil 2%, NSE 5%, *V. lecanii*, *M. anisopliae* and Azadirachtin formulations positions these treatments as viable options for environmentally conscious and economically sustainable agricultural practices. As the agricultural landscape evolves, adopting such integrated pest management approaches becomes crucial for ensuring food security, environmental sustainability and the economic well-being of farmers. The study's findings hold practical implications for farmers, offering actionable strategies for sustainable chilli cultivation. emphasizing the role of bio-based solutions, the study contributes to the broader goal of sustainable agriculture. Continued research in this direction can further refine and expand the repertoire of effective botanicals and bio-pesticides. The overall study emphasizes the significance of eco-friendly alternatives in securing crop health, ensuring food security, and promoting sustainable agricultural practices.

Acknowledgements

The authors express their gratitude to the Dr. D. B. Undirwade, Head, Department of Entomology, Dr. PDKV, Akola, for providing the facilities to conduct the

current experiment.

References

Abd-Elgawad, M.M. (2020). Biological control agents in the integrated nematode management of potato in Egypt. *Egypt J Biol Pest Cont.*, **30**, 1-13.

Akmal, M., Freed S., Malik M.N. and Gul H.T. (2013). Efficacy of *Beauveria bassiana* (Deuteromycotina: Hypomycetes) against different aphid species under laboratory conditions. *Pak. J Zool.*, 45, 71–78.

Ali, S., Farooqi M.A., Sajjad A., Ullah M.I., Qureshi A.K., Siddique B., Waheed W., Sarfraz M. and Asghar A. (2018). Compatibility of entomopathogenic fungi and botanical extracts against the wheat aphid, *Sitobion avenae* (Fab.) (Hemiptera: Aphididae). *Egypt J Biol Pest Control*, **28**, 97.

Amin, P.W., Reddy D.V.R., Ghaneker A.W. and Reddy M.S. (1981). Transmission of tomato spotted wilt virus, causal agent of bud necrosis of peanut by *Scirtothrips dorsalis* and *Frankliniella schultzei*. *Pl Disease*, **63**, 663-665.

Anitha, K.R. and Nandihalli B.S. (2008). Utilization of Botanicals and Mycopathogens in the Management of Sucking Pests of Okra. *Karnataka J. Agric. Sci.*, **21(2)**, 231-233.

Ayyar, T.V.R., Subbaih M.S. and Krishnamoorthy P.S. (1935). The leaf curl disease of chillies caused by thrips in the Guntur and Madurai Tracts, Madras. *Agric J.*, **23**, 403-410.

Boda, V. and Ilyas M. (2017). Evaluation of new insecticides against sucking pests of *Bt* cotton. *Int J Pl Ani Env Sci.*, **7(2)**, 2231-4490.

Chakraborty, A. and Nath D. (2015). Impact of certain bio-pesticides to manage leaf curl disease and its vectors in chilli. *Int J Plant Prod.*, **8(1)**, 208-210.

Chaubey, A.N., Mishra R.S. and Singh V. (2017). Eco-friendly management of leaf curl disease of chilli through botanical bio-pesticides. *Plant Archives*, **17(1)**, 285-291.

Chinniah, C., Ravikumar A., Kalyanasundaram M. and Parthiban P. (2016). Management of sucking pests, by integration of organic sources of amendments and foliar application of entomopathogenic fungi on chilli. *J Biopest.*, **9(1)**, 34-40.

Choudhary, B. R. and Fageria S. (2009). *A textbook on production technology of vegetables* (Kalyani publishers) 2:66–67.

Cruz-Estrada, A., Gamboa-Angulo M., Borges-Argáez R. and Ruiz-Sánchez E. (2013). Insecticidal effects of plant extracts on immature whitefly *Bemisia tabaci* Genn. (Hemiptera: Aleyroideae). *Electron J Biotechnol.*, **16**, 6.

Dehariya, S.K., Shukla A., Barde S.K. and Ahirwar K. (2018). Efficacy of Botanical Pesticides against Sucking Insects Pests in Brinjal. *Int J Curr Microbiol App Sci.*, **7(1)**, 1930-1935.

Deshpande, V.G. (1938). A preliminary account of the aphididae of poona. *J Bombay Nat His. Soc.*, **30**, 740-744.

Devi, M., Niranjana R.F. and Indirakumar K. (2017). Management of chilli (*Capsicum annuum* L.) thrips and mites using organics. *Int J Curr Microbio Appl Sci.*, **6(4)**, 1541-1546.

Dey, P.K., Sarkar P.K. and Somchoudhury A.K. (2001). Efficacy of different treatment schedule of profenofos against major pests of Chilli. *Pestology*, **25(11)**, 26-29. Willy, Singapore

Ghongade, D.S. and Sangha K.S. (2021). Efficacy of biopesticides against the whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae), on parthenocarpic cucumber grown under protected environment in India. *Egypt J Biol Pest Cont.*, **31(1)**, 1-11.

Gomez, K.A. and Gomez A.A. (1984). *Statistical procedures for agricultural research*.

Gundannavar, K.P., Giraddi R.S., Kulkarni K.A. and Awaknavar J.S. (2007). Development of integrated pest management modules for chilli pests. *Karnataka J. Agrl. Sci.*, **20**, 757-760.

Hadiya, G.D., Kalariya G.B. and Kalola N.A. (2016). Efficacy of different Entomopathogenic Fungus on Chilli Thrips. *Adv Life Sci.*, **5(5)**, 1658-1660.

Halder, J., Kodandaram M.H., Rai A.B. and Kumar R. (2016). Impact of different pest management modules against the major sucking pests complex of chilli (*Capsicum annuum*). *Ind J Agril Sci.*, **86(6)**, 792–795.

Hosamani, A. (2007). Management of chilli murda complex in irrigated ecosystem. *Ph. D thesis*, Uni. Agril. Sci., Dharwad.

Joia, B.S., Kaur J. and Udean A.S. (2001). Persistence of Ethion residues on chilli. In: National Symposium on Integrated Pest Management (IPM) in horticultural crops, Bangalore, 17-19 October 2001.

Kandasamy, C., Mohanasundaram M. and Karuppachamy P. (1990). Evaluation of insecticides for the control of thrips. *Scirtothrips dorsalis* Hood in chillies (*Capsicum annuum* L.). *The Madras Agric J.*, **77**, 169-172.

Karkar, D.B., Korat D.M. and Dabhi M.R. (2014). Evaluation of botanicals for their bio-efficacy against insect pests of brinjal. *Karnataka J Agric Sci.*, **27(2)**, 145-147.

Kethran, M.R., Sun Y.Y., Khan S., Baloch S.U., Wu L.L., Lu T.T. and Yang Y. (2014). Effect of different sowing dates on insect pest population of chillies (*Capsicum annuam* L). *J Bio Agri Hlth.*, **4(25)**, 196-214.

Kumar, Y.A., Sanp R.K. and Acharya V.S. (2017). Bio-Efficacy of Newer Insecticide and Botanicals against Sucking Insect- Pests of Chilli. *Int J Agri Sci.*, **9(24)**, 4288-4291.

Lee, M.H., Lee H.K., Lee H.G., Lee S.G., Kim J.S., Kim S.E., Kim Y.S., Suh J.K. and Youn Y.N. (2018). Effect of cyantraniliprole against of *Bemisia tabaci* and prevention of tomato yellow leaf curl virus (TYLCV). *Korean J. Pestic Sci.*, **18**, 33–40

Lv, J., Wilson L.T., Beuzelin J.M., White W.H., Reagan T.E. and Way M.O. (2011). Impact of *Cotesia flavipes* (Hymenoptera: Braconidae) as an augmentative biocontrol agent for the sugarcane borer (Lepidoptera: Crambidae) on rice. *Biol Control,* **56(2)**, 159–169.

Mckinney, H.H. (1923). A New System of Grading of Plant Diseases. *J Agril Res*., **26**, 195-218.

Meena, R.K. and Tayde A.R. (2017). Field efficacy of certain bio-pesticides against Chilli thrips *Scirtothrips dorsalis* (HOOD) on Chilli (*Capsicum annum* L.). *Int J Curr Microbiol App Sci.,* **6(6)**, 2188-2192.

Mishra, R.K., Bohra A., Kamaal N., Kumar K., Gandhi K., Sujayanand G.K. and Saabale P.R. (2018). Utilization of biopesticides as sustainable solutions for management of pests in legume crops: Achievements and prospects. *Egypt J Biol Pest Control*, **28**, 3.

Mondal, B. and Mondal P. (2012). Eco-friendly pest management practices for leaf curl complex of chilli (*Capsicum annuum* L.). *J. Biopest.*, **5**, 115-118.

Mondal, D. and Mondal T. (2012). A review on efficacy of *Azadirachta indica* A. Juss based bio-pesticides: An Indian perspective. *Res J Rec. Sci.,* **1(3)**, 94-99.

Naik, R.H., Devakumar N., Rao G.E., Vijaya N., Khan H.S. and Subha S. (2012). Performance of botanical and fungal formulation for pest management in organic okra production system. *J Biopest.*, **5**, 12-16.

Naik, V.C., Kranthi S. and Viswakarma R. (2017). Impact of newer pesticides and botanicals on sucking pest management in cotton under high density planting system (HDPS) in India. *J Ento Zoo Stud.*, **5(6)**, 1083-1087.

Nandahalli, B.S. (1979). Efficacy of different insecticides in the control of chilli leaf curl and their residues. *MSc (Ag) thesis*, University of Agricultural Sciences, Bangalore, India.

Niles, G.A. (1980). Breeding cotton for resistance to insect pests. In : *Breeding Plant Resistance to Insects*, Macwell, F.G. and Jennings P.R. (Eds). John Wiley and Sons, New York, pp. 337-369.

Noonari, A.M., Abro G.H., Khuhro R.D. and Buriro A.S. (2016). Efficacy of bio-pesticides for management of sucking insect pests of cotton, *Gossypium hirsutum* (L.). *J Basic Appl Sci.*, **12**, 306-313.

Oliveira, M.R.V., Henneberry T.J. and Anderson P. (2001). History current status, and collaborative research projects for *Bemisia tabaci*. *Crop Prot.*, **20**, 709–723.

Pandey, S.K., Mathur A.C. and Srivastava M. (2010). Management of leaf curl disease of chilli (*Capsicum annum* L.). *Int J Vir*, **6(4)**, 246-250.

Reddy, D.S. and Chowdary N.M. (2021). Botanical biopesticide combination concept—A viable option for pest management in organic farming. *Egypt J Biol Pest Cont.*, **31(1)**, 1-10.

Saini, A., Ahir K.C., Rana B.S. and Kumar R. (2016). Management of major sucking insect pests infesting chilli (*Capsicum annum* L.). *Sav nat to sur*, **11(3)**, 1725-1728.

Saito, T. and Sugiyama K. (2005). Pathogenicity of three Japanese strains of entomopathogenic fungi against the silver leaf whitefly, *Bemisia argentifolii*. *Appl Entomol Zool.*, **40(1)**, 169–172.

Samota, R.G., Jat B.L. and Choudhary M.D. (2017). Efficacy of newer insecticides and bio-pesticides against thrips, *Scirtothrips dorsalis* Hood in chilli. *J Pharmco Phytoch.*, **6(4)**, 1458-1462.

Sarkar, S., Patra S. and Samanta A. (2016). Efficacy of different bio-pesticides against sucking pests of okra (*Abelmoschus esculentus* L. Moench). *J Appl Nat Sci.*, **8(1)**, 333–339.

Selvam, K. (2018). Efficacy of botanicals and entomogenous fungi against major pod borers of black gram. *Biopestic. Int.*, **14(2)**, 109-122.

Sharma, M., Budha P.B. and Pradhan S.B. (2015). Efficacy test of bio-pesticides against tobacco whitefly *Bemisia tabaci* (Gennadius, 1889) on tomato plants in Nepal. *J Inst Sci Tech.*, **20(2)**, 11-17.

Sharma, R. and Summarwar S. (2017). Efficacy of bio agents against Jassid (*Amrasca biguttula biguttula* Ishida) Population on RCH-134 *Bt* (BG-II). *Int J Fa Bio Stud.*, **4(4)**, 26-28.

Sujay, Y.H., Dhandapani N., Kumar B.H.P. and Pushpa V. (2011). Effect of plant growth promoting rhizobacteria (*Pseudomonas fluorescens*), naphthalene acetic acid and neem oil application on the incidence of sucking pests of chilli (*Capsicum annuum* L.). *Int J Pl Protec.*, **4(1)**, 120-126.

Sujay, Y.H., Dhandapani N., Kumar P., Sanjaya B.H., Topagi C. and Pushpa V. (2010). Evaluation of eco-friendly management module in comparison with farmers practices against chilli sucking pests. *Int J Pl Prot.*, **3(2)**, 319-324.

Sujay, Y.H., Dhandapani N., Pushpa V. and Giraddi R.S. (2009). Evaluation of eco-friendly approaches for the management of sucking pests in chilli. *Karnataka J Agri. Sc.*, **22(3)**, 720-721.

Sujay, Y.H., Giraddi R.S. and Udikeri S.S. (2015). Efficacy of New Molecules and botanicals against Chilli (*Capsicum annuum* L.) Pests. *Madras Agric J.*, **102(10-12)**, 348-352.

Torrado-Leon, E., Montoya-Lerma J. and Valencia-Pizo E. (2006). Sub lethal effects of *Beauveria bassiana* (Balsamo) *Vuillemin* (Deuteromycotina: Hyphomycetes) on the whitefly *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae) under laboratory conditions. *Mycopathologia*, **162**, 411–419.

Zeeshan, N. and Kudada N. (2019). Eco-friendly management of chilli leaf curl disease complex through plant products. *J Pharma Phyto*., **8(1)**, 1045-1049.