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The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; SP-10(12): 656-663

www.thepharmajournal.com
Received: 28-10-2021
Accepted: 30-11-2021

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Efficacy of different botanical and biopesticide against onion thrips (*Thrips tabaci* L.)

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Abstract
The field experiment was conducted to evaluate efficacy of botanical and biopesticide against thrips on onion and was carried out at experimental farm of Entomology section, College of Agriculture, Pune during *Rabi* season 2020-21. The most successful treatment was fipronil 80% WDG @ 0.15 g/ litre, which had the lowest average thrips population per plant (4.24/plant), followed by *Metarhizium anisoplae* @ 10^8 conidia/g @ 5 g/litre (8.87/plant). Azadirachtin 3000 ppm @ 4 ml/litre (9.93/plant) and Neem seed extract 5% (10.62/plant) were the next two successful treatments. In comparison to the untreated control, *Lecanicillium lecanii* @ 5 g/litre (12.18/plant), *Beauveria bassiana* @ 5 g/litre (12.56/plant) and pongamia oil 5% @ 5 ml/litre (12.60/plant) were shown to be better. The average thrips population was much higher (34.47/plant) in the untreated control condition.

Fipronil 80% WDG @ 0.15 g/litre yielded the most onion bulbs (22.55 t/ha), followed by *M. anisopliae* @ 5 g/litre (19.55 t/ha), Azadirachtin 3000 ppm @ 4 ml/litre (18.71 t/ha), Neem seed extract 5% (18.61 t/ha), Pongamia oil 5% @ 5 ml/litre (17.71 t/ha), *L. lecanii* @ 5 g/litre (16.75 t/ha), *B. bassiana* @ 5 g/litre (16.26 t/ha).

The Fipronil 80% WDG @ 0.15 g/litre treatment had the highest incremental cost benefit ratio (ICBR) (1:8.17). The next treatments with highest ICBR ratio are *M. anisopliae* @ 5 g/litre (1: 7.72), Neem seed extract 5% (1: 6.03), and Azadirachtin 3000 ppm @ 4 ml/litre (1: 4.15). The ICBR ratio was lower in the Pongamia oil 5% @ 5 ml/litre (1: 2.85), *L. lecanii* @ 5 g/litre (1: 2.68) and *B. bassiana* @ 5 g/litre (1: 1.79) as compare to above treatment.

Keywords: onion, thrips, efficacy, botanical, biopesticide, yield

Introduction
The most extensively farmed member of the genus Allium is the onion, *Allium cepa* L., often known as bulb onion or common onion, which belongs to the Amaryllidaceae family. It is one of the most popular and commercialized bulbous vegetables grown in India and around the world. The commercial importance lies not only in the considerable shelf life, but also in its ability to withstand the hazards of rough handling and long-distance transport. It is categorized as a vegetable which has unique properties that enhances the taste and flavour of meals as well as provide therapeutic benefits. It is used in salads, sauces, soups and pickles to season food in the kitchen. Onion may be used to make wide range of items. Minimally processed ready to use or ready to cook fresh onions, onion paste, dehydrated onion flakes, onion powder, onion oil, onion vinegar, onion sauce, pickled onion, onion wine and beverage etc. As a result, the Germans have named it the "Queen of Kitchen." Because of its great export potential, onions have become more important as a cash crop in recent years. Its cultivation is highly technical and is dependent on environmental variables like photoperiod, temperature and so on. It is also subjected to a number of biotic and abiotic factors that reduce crop output, with insect infestation being one of the most critical factors (Choudhary and Gora, 2015). Red spider mite (*Tetranychus cinnabarinus*), eriophyid mite (*Aceria tulipae*), bulb mite (*Rhizoglyphus robini*), cutworm (*Agrotis ipsilon*) and leaf minor (*Liriomyza sativa*) are the most common insect pests observed in onion. Among them, onion thrips (*Thrips tabaci* Lindeman) is the most common pest, causing 35 to 45 per cent production loss (Soumia *et al.*, 2017). Onion thrips, *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) is key pest in the world. Pest has reported development of insecticide resistance, ability to transmit plant pathogens, and frequency of producing more generations at high temperatures, onion thrips, has become a global pest of increasing concern in commercial onion over the past two decades (Diaz-Montana *et al.*, 2011) [6]. A female thrip lays an average of 15.6 eggs in clusters in the epidermal layer of the leaves. The average life span of adult female is 19.67 days.

In the laboratory, onion thrips complete its life cycle in 21 days during December/January and 14 days in April.

Onion thrips cause both direct and indirect damage to onions by feeding and ovipositing on onion leaves. Both adults and nymphs are the damaging stages and frequently consume plant sap that leads to develop silver grey patches on leaves. These are common side effects of feeding which render green onions (scallions) unmarketable and reduce the size of dry bulb onions. Thrips are present on a variety of host plants throughout the year, being most active on onions from October to May (Lall and Singh, 1968). *T. tabaci* can also spread a number of plant pathogens that causes disease like purple blotch and stemphylium leaf blight. The yellow spot virus is one of the most economically destructive onion pathogens spread by onion thrips (Gill *et al*., 2015).

Considering the heavy losses caused by thrips, the farmers are mostly depends upon chemical control for management of this pest. However, indiscriminate use of insecticides creates the problem of resistance, residue and reoccurrence of the pest and also become major threat to the environment and humanity. Most of new generation pesticides have a systemic mode of action, which might also result in a certain level of toxicity in the plant system, posing a health risk (Mishra *et al*., 2014) [17]. Therefore, eco friendly management of onion thrips with botanicals and biopesticides is the need of the era in the Maharashtra state.

Materials and Methods

Experimental details

The research work was carried out in *Rabi* season 2020 at the experimental farm of Agril. Entomology section, College of Agriculture, Pune-05. The experiment site was chosen had medium deep black soil with medium fertility, and good drainage. In the experiment used onion variety "N-2-4-1" for transplanting. The experiment was laid out in a Randomized Block Design with eight treatments that were replicated three times. To raise the onion crop, the other recommended agronomical package of practises was followed during the crop duration.

Method of observations

Evaluate efficacy of botanical and biopesticide

In each plot 5 plants were randomly selected and number of nymphs and adults thrips were recorded in central leaf axis one day before spraying and 5,7,10 and 14 days after each spray. Three sprays were given at an interval of fifteen days starting from thrips incidence at ETL i.e 15 nymphs and adults/plant. The population of adult and nymph were counted by naked eyes and with the help of 10x magnification hand lense. The yield data was recorded at harvest and then converted into tonnes per hectare.

Preparation of spray solution

A known dosage of botanicals/biopesticides was measured and dissolved in a small amount of water, then mixed thoroughly before adding the appropriate amount of clean water to make the desired strength of spray solution. Before spraying each insecticide, the sticker sandovit (1ml/l) was applied to the spray fluid. A hand-operated high-volume knapsack sprayer was used to apply the treatment sprays. The entire plot was treated in each of the three replications at the same time to avoid spray fluid drifting into adjoining plots. Before utilising other insecticides, the spray pump was thoroughly cleaned with water.

Harvesting

Harvesting was done 115 days after transplanting. Onion bulbs were harvested when the bulbs were fully matured. At maturity of bulb the neck became thin, leaves became yellow and drooped down. The bulbs from each treatment were harvested separately, weighed and recorded yield in kg/plot.

Statistical Analysis

The data on average survival population of thrips was transformed into square root transformation ($\sqrt{x+5}$) was subjected to statistical analysis as suggested by Panse and Sukhatme (1985). The standard error (S.E.) and critical difference (C.D.) at 5% level of probability were calculated. The yield data was subjected to statistical analysis.

Results and Discussion

First Spray

5 days after spray

The average thrips survival population per plant ranging from 4.13 to 15.33, compared to 22.40 in the untreated control. In chemical check treatment, fipronil 80% WDG @ 0.15 g/litre recorded the lowest thrips (4.13 thrips/plant) and was shown to be substantially superior to all other treatments. Azadirachtin 3000 ppm @ 4 ml/litre (12.53 thrips/plant) was the second best treatment, followed by Neem seed extract 5% (13.20 thrips/plant) and *M. anisopliae* @ 5 g/litre (13.27 thrips/plant) which were at par with each other. Pongamia oil 5% @ 5 ml/litre (14.13 thrips/plant), *B. bassiana* @ 5 g/litre (14.93 thrips/plant), and *L. lecanii* @ 5 g/ litre (15.33 thrips/plant) treatments were effective in lowering thrips population and substantially superior to the untreated control (22.40 thrips/plant).

7 days after spray

Thrips populations ranging from 3.00 to 13.07 thrips per plant as against 24.93 thrips per plant in the untreated control. The treatment with fipronil 80% WDG @ 0.15 g/litre recorded the lowest thrips population (3.00 thrips/plant) and was significantly superior over all other treatments. *M. anisopliae* @ 5 g/litre (10.87 thrips/plant) was the second best treatment, which was at par with Azadirachtin 3000 ppm @ 4 ml/litre (11.13 thrips/plant). Treatments with Neem seed extract 5% (11.60 thrips/plant), pongamia oil 5% @ 5 ml/litre (12.40 thrips/plant), *B. bassiana* 5% @ 5 g /litre (12.93 thrips/plant), and *L. lecanii* 5% @ 5 g/litre (13.07 thrips/plant) were shown to be superior over untreated controls.

10 days after spray

The average - population of thrips at ten days after spray was 4.33 to 14.80 thrips per plant, compared to 26.93 thrips in the untreated control. The treatment with fipronil 80% WDG @ 0.15 g/litre recorded lowest thrips population (4.33 thrips/plant) which was significantly superior over all the treatments. *M. anisopliae* @ 5 g/litre (9.40 thrips/plant) was the second most effective treatment which was significantly superior over remaining treatments. Treatments with *L. lecanii* @ 5 g /litre (10.87 thrips/plant), *B. bassiana* @ 5 g/litre (11.53 thrips/plant), Azadirachtin 3000 ppm @ 4 ml/litre (12.80 thrips/plant), Neem seed extract 5% (13.13 thrips/plant), and pongamia oil 5% @ 5 ml/litre (14.80 thrips/plant) were found effective over untreated control.

14 days after spray

The average thrips survival population after fourteen days of spray was 6.40 to 17.80 thrips per plant, compared to 29.00 thrips in the untreated control. The treatment with fipronil 80% WDG @ 0.15 g/litre (6.40 thrips/plant) has recorded the lowest thrips population and which was significantly superior over all the treatments. The second best treatment was *M. anisopliae* @ 5 g/litre (12.87 thrips/plant) was also significantly best over rest of the treatments. Azadirachtin 3000 ppm @ 4 ml/litre (15.27 thrips/plant), Neem seed extract 5% (15.73 thrips/plant), *L. lecanii* @ 5 g/litre (17.00 thrips/plant), pongamia oil 5% @ 5 ml/litre (17.73 thrips/plant), and *B. bassiana* @ 5 g/litre (17.80 thrips/plant) were shown to be superior over untreated control.

Second spray

5 days after spray

The average survival thrips population per plant ranged from 1.13 to 13.93 as compared to 31.33 in untreated control. In Chemical check treatment with fipronil 80% WDG @ 0.15 g/litre recorded the lowest thrips population (1.13 thrips/plant) and was shown to be considerably superior to all other treatments. Azadirachtin 3000 ppm @ 4 ml/litre (7.60 thrips/plant) was the second best treatment, which was at par with Neem seed extract 5% (8.13 thrips/plant). *M. anisopliae* @ 5 g/litre (9.07 thrips/plant), pongamia oil 5% @ 5 ml/litre (9.40 thrips/plant), *L. lecanii* @ 5 g/litre (13.53 thrips/plant), and *B. bassiana* @ 5 g/litre (13.93 thrips/plant) were shown to be effective in decreasing thrips population and substantially superior to the untreated control (31.33 thrips/plant).

7 days after spray

Thrips populations ranging from 1.60 to 12.67 per plant compared to 33.67 per plant in the untreated control. The lowest thrips population (1.60 thrips/plant) was recorded in fipronil 80% WDG @ 0.15 g/litre and which was significantly superior over all other treatments. Azadirachtin 3000 ppm @ 4 ml/litre (7.27 thrips/plant) was the second best treatment, which was at par with *M. anisopliae* @ 5 g/litre (7.53 thrips/plant) and Neem seed extract 5% (7.80 thrips/plant). The treatment pongamia oil 5% @ 5 ml/litre (8.27 thrips/plant), *L. lecanii* @ 5 g/litre (12.00 thrips/plant), and *B. bassiana* @ 5 g/litre (12.67 thrips/plant) treatments were shown to be more effectual than the untreated control.

10 days after spray

The average survival population of thrips ten days after spray was 2.80 to 11.13 thrips per plant, compared to 36.60 thrips in the untreated control. The treatment with fipronil 80% WDG @ 0.15 g/litre recorded lowest thrips population (2.80 thrips/plant), which was clearly superior to all of the other treatments. The next best treatment was *M. anisopliae* @ 5 g/litre (7.87 thrips/plant) which was at par with Azadirachtin 3000 ppm @ 4 ml/litre (7.93 thrips/plant) and Neem seed extract 5% (8.13 thrips/plant). Treatments with *L. lecanii* @ 5 g/litre (10.07 thrips/plant), *B. bassiana* @ 5 g/litre (11.07 thrips/plant), and pongamia oil 5% @ 5 ml/litre (11.13 thrips/plant) were shown to be more effective than the untreated control.

14 days after spray

At fourteen days after spraying, the average thrips survival population was 4.27 to 13.00 thrips per plant, as against 39.93 thrips in the untreated control. The similar trend of 10th day after spray was observed on fourteen day also. The treatment with fipronil 80% WDG @ 0.15 g/litre recorded lowest thrips population (4.27 thrips/plant) which was significantly efficacious over all the treatments. Azadirachtin 3000 ppm @ 4 ml/litre (9.07 thrips/plant), which was at par with *M. anisopliae* @ 5 g/litre (9.13 thrips/plant) and Neem seed extract 5% (9.33 thrips/plant). Chronologically treatments *viz*., pongamia oil 5% @ 5 ml/litre (12.40 thrips/plant), *L. lecanii* @ 5 g/litre (12.93 thrips/plant), and *B. bassiana* @ 5 g/litre (13.00 thrips/plant) treatments were shown to be more effective than the untreated control.

Third Spray

5 days after spray

The average thrips survival population per plant ranging from 0.80 to 9.60, compared to 38.80 in the untreated control. The treatment with fipronil 80% WDG @ 0.15 g/litre recorded least (0.80 thrips/ plant) thrips and emerged as significantly superior over all other treatment. The next best treatment were Azadirachtin 3000 ppm @ 4 ml/litre (5.33 thrips/plant) which was at par with Neem seed extract 5% (5.66 thrips/plant). The treatment with *M. anisopliae* @ 5 g/litre (6.13 thrips/plant), pongamia oil 5% @ 5 ml/litre (6.87 thrips/plant), *L. lecanii* @ 5 g/litre (9.40 thrips/plant) and *B. bassiana* @ 5 g/litre (9.60 thrips /plant) were found effective in reducing thrips population and significantly superior over untreated control (38.80 thrips/plant).

7 days after spray

Thrips populations varies from 0.67 to 7.07 thrips per plant compared to 37.00 thrips per plant in the untreated control. The treatment with fipronil 80 percent WDG @ 0.15 g/litre had the lowest thrips population (0.67 thrips/plant), which was significantly superior to all other treatments. The second best treatment, Azadirachtin 3000 ppm @ 4 ml /litre (4.47 thrips/plant) which was significantly superior over rest of all the treatments. *M. anisopliae* @ 5 g/litre (5.00 thrips/plant), Neem seed extract 5% (5.07 thrips/plant), pongamia oil 5% @ 5 ml/litre (5.93 thrips/plant), *L. lecanii* @ 5 g/litre (7.00 thrips/plant), and *B. bassiana* @ 5 g/litre (7.07 thrips/plant) were chronologically best treatments and found effective over untreated control.

10 days after spray

The average thrips survival population ten days after spray was 1.33 to 6.60 thrips per plant, compared to 36.07 thrips in the untreated control. The treatment with fipronil 80% WDG @ 0.15 g/litre recorded lowest thrips population (1.33 thrips/plant) which was significantly superior to the all the treatments. *M. anisopliae* @ 5 g/litre (4.53 thrips/plant) which was at par with Azadirachtin 3000 ppm @ 4 ml/litre (5.00 thrips/plant). Treatments with *L. lecanii* @ 5 g/litre (5.13 thrips/plant), *B. bassiana* @ 5 g/litre (5.67 thrips/plant), Neem seed extract 5% (5.67 thrips/plant), and pongamia oil 5% @ 5 ml/litre (6.60 thrips/plant) were shown to be more effective than the untreated control.

14 days after spray

At fourteen days, the average thrips survival population was 2.07 to 7.67 thrips per plant, as against 34.47 thrips/plant in the untreated control. The treatment with fipronil 80% WDG @ 0.15 g/litre recorded lowest thrips population (2.07 thrips/plant), which was significantly superior over all the treatments. The second best treatment *M. anisopliae* @ 5 g/litre recorded (4.60 thrips/plant) which was also significantly efficacious over rest of the treatments. Azadirachtin 3000 ppm @ 4 ml/litre (5.47 thrips/plant), *L. lecanii* @ 5 g/litre (6.60 thrips/plant), Neem seed extract 5% (6.80 thrips/plant), *B. bassiana* @ 5 g/litre (6.87 thrips/plant), and pongamia oil 5% @ 5 ml/litre (7.67 thrips/plant) were shown to be more effective over untreated control (34.47 thrips/plant).

Overall bioefficacy

5 days after spray

The average thrips survival population per plant varies from 2.02 to 12.82, compared to 30.84 in the untreated control. The lowest (2.02 thrips/plant) was recorded in fipronil 80% WDG @ 0.15 g/litre which was significantly superior over all other treatments. Azadirachtin 3000 ppm @ 4 ml (8.49 thrips/plant) which was at par with Neem seed extract 5% (9.00 thrips/plant). *M. anisopliae* @ 5 g/litre (9.49 thrips/plant), pongamia oil 5% @ 5 ml (10.13 thrips/plant), *L. lecanii* @ 5 g/litre (12.75 thrips/plant), and *B. bassiana* @ 5 g/litre (12.82 thrips/plant) were found equally effective in reducing thrips population and significantly superior over untreated control (30.84 thrips/plant).

7 days after spray

Thrips populations ranging from 1.76 to 10.89 thrips / plant as against 31.87 thrips/ plant in the untreated control. The treatment with fipronil 80% WDG @ 0.15 g/litre recorded lowest thrips population (1.76 thrips/plant) and which was significantly superior over all other treatments. The next effective treatments was Azadirachtin 3000 ppm @ 4 ml/litre (7.62 thrips/plant) which is superior from all other treatments except *M. anisopliae* @ 5 g/litre (7.80 thrips/plant). Neem seed extract 5 percent (8.16 thrips/plant), pongamia oil 5 per cent @ 5 ml/litre (8.87 thrips/plant), *L. lecanii* @ 5 g/litre (10.69 thrips/plant) and *B. bassiana* @ 5 g/litre (10.89 thrips/plant) were found equally effective treatment over untreated control.

10 days after spray

The average thrips survival population ten days after spray was 2.82 to 10.84 thrips per plant, compared to 33.20 thrips in the untreated control. The lowest thrips population was recorded in the treatment with fipronil 80% WDG @ 0.15 g/litre which was significantly efficacious over all the treatments. The next most successful treatments were *M. anisopliae* @ 5 g/litre (7.27 thrips/plant), Azadirachtin 3000 ppm @ 4 ml/litre (8.58 thrips/plant), *L. lecanii* @ 5 g/litre (8.69 thrips/plant), Neem seed extract 5% (8.98 thrips/plant), *B. bassiana* @ 5 g/litre (9.42 thrips/plant), and pongamia oil 5% @ 5 ml/litre (10.84 thrips/plant) were found equally effective over untreated control. There were no significant differences amongst all the treatment except untreated control.

14 days after spray

The average survival population of thrips recorded at fourteen days after spray was in the range of 4.24 to 12.60 thrips per plant as against 34.47 thrips in untreated control. The lowest thrips population (4.24 thrips/plant) was found in the fipronil 80% WDG @ 0.15 g/litre treated plot which was superior over all other treatment. The next better treatment were *M. anisopliae* @ 5 g/litre (8.87 thrips/plant), which significantly successful over rest of the treatments. Azadirachtin 3000 ppm @ 4 ml/litre (9.94 thrips/plant), Neem seed extract 5 per cent (10.62 thrips /plant), *L. lecanii* @ 5 g/litre (12.18 thrips/plant), *B. bassiana* @ 5 g/litre (12.56 thrips/plant) and pongamia oil 5% @ 5 ml/litre (12.60 thrips/plant), which were superior over untreated control.

During the present investigation, fipronil 80% WDG was the most effective treatment in reducing the survival population of onion thrips and it is superior than all other treatments. Amongst, biopesticide and botanical treatments *M. anisopliae* @ 5 g/litre is the second best treatment which also effectual over rest of the treatments. The next better treatment is Azadirachtin 3000 ppm @ 4 ml/litre managing thrips population in onion crop.

The present findings are confirmative with earlier research workers. Hosamani *et al.* (2012) [11] reported that fipronil 80% WG was effective in reducing the thrips population with increased yield of onion. Similarly results were also obtained by Visalakshy and Krishnamoorthy (2012) [32] who reported that *M. anisopliae* recorded the lowest onion thrips population contributing to 58% reduction. Patil *et al.* (2016) [21], they reported that *M. anisopliae* 7.5 g recorded significantly lowest thrips population in onion. The present findings are in conformity with Fathy and Saad (2017) [10] reported that *M. anisopliae* caused the highest mortality rates in life stages of onion thrips, at $1x10^8$ conidia/ml concentration. Similar results were also obtained by Balikai (2018) [2] who reported that fipronil 80% WG was most effective in reducing grape thrips population than other insecticides in grape. Likewise Reddy and Sreehari (2009) [24] revealed that fipronil 80% WG recorded lowest number of chilli thrips population. Ramalakshmi *et al*. (2020) reported that among the different tested insecticides, fipronil 5% SC has shown 76.7 per cent reduction in cotton thrips population followed by fipronil 80% WG showing 74.5 per cent reduction. Kumar *et al.* (2013) [14] revealed that population of cotton thrips per 3 leaves was significantly lower in fipronil.

The present finding are confirmative with Vestergaard *et al.* (1995) [31] reported that treatment using *M. anisopliae* resulted in at least 94% mortality in Western flower thrips at 7 days post inoculation as compared to *V. lecanii* which shows 20-70% mortality under laboratory conditions. The present finding is corroborative with Bhojane *et al.* (2019) [3] they reported that *L. lecanii* and *M. anisopliae* were found effective with 62.36 and 60.38% reduction in cucumber thrips population.

Kordy and Barakat (2014) [13] revealed Azadirachtin 0.03% showed 94.64% reduction in onion thrips population seven days after application. Elango *et al.* (2019) [8] reported that Azadirachtin 10000 ppm showed 40.83% mortality after 48 hrs of treatment while NSKE 5% showed 43.33% mortality against pomogrante thrips. Shinde *et al*. (2014) [28] concluded that Azadirachtin showed 73.23% reduction in chilli thrips population. Shruthi *et al*. (2021) found Azadirachtin and *L. lecanii* effective against thrips in tomato. Prema *et al.* (2018) [23] observed that NSKE 5% most effective against both nymph and adult with more than 40% mortality after 48 hrs of treatment in cotton. Saljoqi *et al*. (2021) [25] reported effectiveness of NSE 5% with reduced garlic thrips population up to 3.26 nymph and 2.69 adult/plant.

Effect of different biopesticide and botanical treatment on bulb yield of onion

All the treatment were significantly superior and produced greater yield over untreated control. Amongst the various treatment, the treated plot with fipronil 80% WGD @ 0.15 g/litre recorded highest (22.55 t/ha) onion bulb yield and which was significantly superior over all the treatments. Second best treatment *M. anisopliae* @ 5 g/litre recorded yield of onion bulbs (19.55 t/ha) which was significantly superior over rest of the treatments except Azadirachtin 3000 ppm @ 5 g/litre (18.71 t/ha), Neem seed extract 5% (18.61 t/ha) and pongamia oil 5% @ 5 ml/litre (17.71 t/ha). The next treatments were *L. lecanii* @ 5 g/litre (16.75 t/ha), *B. bassiana* @ 5 g/litre (16.26 t/ha) which was at par with each other.

Economics of different botanical and biopesticide treatment

Additional returns on different treatments

The treatment with fipronil 80% WDG @ 0.15 g/litre resulted in a maximum additional income of Rs. 69,850 per hectare. *M. anisopliae* @ 5 g/litre, Neem seed extract 5%, and Azadirachtin 3000 ppm @ 4 ml/litre were the next best treatments, with increased revenue of Rs. 42,850, Rs. 33,450, and Rs. 32,230 per hectare, respectively. Treatments with pongamia oil 5% @ 5 ml/litre (Rs. 22,200), *L. lecanii* @ 5 g/litre (Rs. 14,850), and *B. bassiana* @ 5 g/litre (Rs. 9,950), on the other hand, yielded significantly lower additional returns over control.

Incremental cost benefit ratio (ICBR)

The treatment with fipronil 80% WDG @ 0.15 g/litre had the highest incremental cost benefit ratio (ICBR) (1:8.17). As per the ICBR chronological order *M. anisopliae* @ 5 g /litre (1: 7.72), Neem seed extract 5 per cent (1: 6.03), and Azadirachtin 3000 ppm @ 4 ml (1: 4.15) were the best biopesticide and botanical treatments. Pongamia oil 5% @ 5 ml/litre (1: 2.85), *L. lecanii* @ 5 g/litre (1: 2.68) and *B. bassiana* @ 5 g/litre (1: 1.79) had lower ICBR than the other treatments.

Table 1: Effect of different biopesticide and botanical treatments on onion thrips (*Thrips tabaci* L.) after first spray

Sr. No.	Treatment	Pre count	Survival population of thrips/plant			
			5 DAS	7 DAS	10 DAS	14 DAS
T_1	*Metarhizium anisopliae* @ 5 g/litre	21.13 (4.65)	13.27 (3.71)	10.87 (3.37)	9.40 (3.15)	12.87 (3.66)
T_2	*Beauveria bassiana* @ 5 g/litre	20.67 (4.60)	14.93 (3.93)	12.93 (3.66)	11.53 (3.47)	17.80 (4.28)
T_3	*Lecanicillium lecanii* @ 5 g/litre	21.13 (4.65)	15.33 (3.98)	13.07 (3.68)	10.87 (3.37)	17.00 (4.18)
T_4	Azadirachtin 3000 ppm @ 4 ml/litre	20.47 (4.57)	12.53 (3.61)	11.13 (3.41)	12.80 (3.65)	15.27 (3.97)
T_5	Neem seed extract 5%	21.13 (4.65)	13.20 (3.70)	11.60 (3.48)	13.13 (3.69)	15.73 (4.03)
T_6	Pongamia oil 5% @ 5 ml/litre	21.47 (4.69)	14.13 (3.83)	12.40 (3.59)	14.80 (3.91)	17.73 (4.27)
T_7	Fipronil 80% WDG @ 0.15 g/litre (S.C)	20.93 (4.63)	4.13 (2.15)	3.00 (1.87)	4.33 (2.20)	6.40 (2.63)
T_8	Untreated control	20.67 (4.60)	22.40 (4.79)	24.93 (5.04)	26.93 (5.24)	29.00 (5.43)
	S.E. (±)	0.03	0.04	0.03	0.02	0.02
	CD at 5%	NS	0.11	0.10	0.05	0.06

*Figures in parenthesis denote √x+0.5 transformed value NS- Non-Significant

Table 2: Effect of different biopesticide and botanical treatments on onion thrips (*Thrips tabaci* L.) after second spray

Sr. No.	Treatment	Survival population of thrips/plant			
		5 DAS	7 DAS	10 DAS	14 DAS
T_1	*Metarhizium anisopliae* @ 5 g/litre	9.07 (3.09)	7.53 (2.83)	7.87 (2.89)	9.13 (3.10)
T_2	*Beauveria bassiana* @ 5 g/litre	13.93 (3.80)	12.67 (3.63)	11.07 (3.40)	13.00 (3.67)
T_3	*Lecanicillium lecanii* @ 5 g/litre	13.53 (3.75)	12.00 (3.54)	10.07 (3.25)	12.93 (3.66)
T_4	Azadirachtin 3000 ppm @ 4 ml/litre	7.60 (2.85)	7.27 (2.79)	7.93 (2.90)	9.07 (3.09)
T_5	Neem seed extract 5%	8.13 (2.94)	7.80 (2.88)	8.13 (2.94)	9.33 (3.14)
T_6	Pongamia oil 5% @ 5 ml/litre	9.40 (3.15)	8.27 (2.96)	11.13 (3.41)	12.40 (3.59)
T_7	Fipronil 80% WDG @ 0.15 g/litre (S.C)	1.13 (1.27)	1.60 (1.44)	2.80 (1.81)	4.27 (2.18)
T_8	Untreated control	31.33 (5.64)	33.67 (5.85)	36.60 (6.09)	39.93 (6.36)
	S.E. (±)	0.03	0.03	0.03	0.04
	CD at 5%	0.10	0.10	0.09	0.12

*Figures in parenthesis denote √x+0.5 transformed value NS- Non-Significant

Table 3: Effect of different biopesticide and botanical treatments on onion thrips population (*Thrips tabaci* L.) after third spray

Sr. No.	Treatment	Survival population of thrips/plant			
		5 DAS	7 DAS	10 DAS	14 DAS
T_1	*Metarhizium anisopliae* @ 5 g/litre	6.13 (2.58)	5.00 (2.34)	4.53 (2.24)	4.60 (2.26)
T_2	*Beauveria bassiana* @ 5 g/litre	9.60 (3.18)	7.07 (2.75)	5.67 (2.48)	6.87 (2.71)
T_3	*Lecanicillium lecanii* @ 5 g/litre	9.40 (3.15)	7.00 (2.74)	5.13 (2.37)	6.60 (2.66)
T_4	Azadirachtin 3000 ppm @ 4 ml/ litre	5.33 (2.42)	4.47 (2.23)	5.00 (2.34)	5.47 (2.44)
T_5	Neem seed extract 5%	5.66 (2.48)	5.07 (2.36)	5.67 (2.48)	6.80 (2.70)
T_6	Pongamia oil 5% @ 5 ml/litre	6.87 (2.71)	5.93 (2.54)	6.60 (2.66)	7.67 (2.86)
T_7	Fipronil 80% WDG @ 0.15 g/ litre (S.C)	0.80 (1.14)	0.67 (1.08)	1.33 (1.35)	2.07 (1.60)
T_8	Untreated control	38.80 (6.27)	37.00 (6.12)	36.07 (6.05)	34.47 (5.91)
	S.E.(±)	0.03	0.03	0.03	0.03
	CD at 5%	0.09	0.08	0.10	0.10

*Figures in parenthesis denote √x+0.5 transformed value NS- Non-Significant

Table 4: Effect of different biopesticide and botanical treatments on onion thrips, *Thrips tabaci* L. (Average of three sprays)

Sr. No.	Treatment	Survival population of thrips/plant			
		5 DAS	7 DAS	10 DAS	14 DAS
T_1	*Metarhizium anisopliae* @ 5 g/litre	9.49 (3.13)	7.80 (2.85)	7.27 (2.76)	8.87 (3.01)
T_2	*Beauveria bassiana* @ 5 g/litre	12.82 (3.64)	10.89 (3.35)	9.42 (3.12)	12.56 (3.56)
T_3	*Lecanicillium lecanii* @ 5 g/litre	12.76 (3.62)	10.69 (3.32)	8.69 (3.00)	12.18 (3.50)
T_4	Azadirachtin 3000 ppm @ 4 ml/litre	8.49 (2.96)	7.62 (2.81)	8.58 (2.97)	9.93 (3.17)
T_5	Neem seed extract 5%	9.00 (3.04)	8.16 (2.91)	8.98 (3.04)	10.62 (3.29)
T_6	Pongamia oil 5% @ 5 ml/litre	10.13 (3.23)	8.87 (3.03)	10.84 (3.33)	12.60 (3.57)
T_7	Fipronil 80% WDG @ 0.15 g/ litre (S.C)	2.02 (1.52)	1.76 (1.46)	2.82 (1.79)	4.24 (2.14)
T_8	Untreated control	30.84 (5.57)	31.87 (5.67)	33.20 (5.79)	34.47 (5.90)
	S.E.(±)	0.03	0.03	0.21	0.03
	CD at 5%	0.10	0.08	0.64	0.09

*Figures in parenthesis denote √x+0.5 transformed value

Table 5: Effect of different biopesticide and botanical treatments on onion yield

Sr. No.	Treatment	Avg. yield (kg/plot)	Yield t/ha	% increase in yield over control
T_1	*Metarhizium anisopliae* @ 5 g/litre	11.73	19.55	32.81
T_2	*Beauveria bassiana* @ 5 g/litre	9.76	16.26	10.46
T_3	*Lecanicillium lecanii* @ 5 g/litre	10.05	16.75	13.79
T_4	Azadirachtin 3000 ppm @ 4 ml/litre	11.23	18.71	27.10
T_5	Neem seed extract 5%	11.17	18.61	26.43
T_6	Pongamia oil 5% @ 5 ml/litre	10.63	17.71	20.31
T_7	Fipronil 80% WDG @ 0.15 g/ litre (S.C)	13.53	22.55	53.19
T_8	Untreated control	8.83	14.72	-
	S.E.(±)	0.55	0.91	-
	CD at 5%	1.65	2.76	-

Table 6: Treatment's impact on yield of onion and Incremental Cost Benefit Ratio (ICBR)

Tr. No	Treatments	Dose ml/g/ ha	Yield (T/ha)	Cost of treatments +Spraying (Rs./ha)	Cost of cultivation + Cost of insecticides (Rs./ha)	Gross monetary return (Rs.)	Net monetary return (Rs.)	Additional income over control (Rs.)	B: C ratio	I.C.B.R.
T_1	*Metarhizium anisopliae* @ 5 g/litre	2500	19.55	5550	93112	195500	102388	42850	1:2.10	1:7.72
T_2	*Beauveria bassiana* @ 5 g/litre	2500	16.26	5550	93112	162600	69488	9950	1:1.75	1:1.79
T_3	*Lecanicillium lecanii* @ 5 g/litre	2500	16.75	5550	93112	167500	74388	14850	1:1.80	1:2.68
T_4	Azadirachtin 3000 ppm @ 4 ml/ litre	2000	18.71	7770	95332	187100	91768	32230	1:1.96	1:4.15
T_5	Neem seed extract 5%	25000	18.61	5550	93112	186100	92988	33450	1:2.00	1:6.03
T_6	Pongamia oil 5% @ 5 ml/litre	2500	17.71	7800	95362	177100	81738	22200	1:1.86	1:2.85
T_7	Fipronil 80% WDG @ 0.15 g/litre (S.C)	75	22.55	8550	96112	225500	129388	69850	1:2.35	1:8.17
T_8	Untreated control	-	14.71	-	87562	147100	59538	-	1:1.68	
	S.E.(±)		0.91							
	CD at 5%		2.77							

Market price- Rs. 10/kg Labour charges- Rs.450/person

Table 7: Insecticides and spraying costs

Tr. No	Treatments	Quantity need for 3 sprays (ml or g/ha)	Cost of insecticide/ kg or L	Cost (Rs/ha)	Application fare for spray (Rs/ha)	Total cost (insecticide and spraying)
T_1	*Metarhizium anisopliae* @ 5 g/litre	7500	200	1500	4050	5550
T_2	*Beauveria bassiana* @ 5 g/litre	7500	200	1500	4050	5550
T_3	*Lecanicillium lecanii* @ 5 g/litre	7500	200	1500	4050	5550
T_4	Azadirachtin 3000 ppm @ 4 ml/ litre	6000	620	3720	4050	7770
T_5	Neem seed extract 5%	75000	20	1500	4050	5550
T_6	Pongamia oil 5% @ 5 ml/litre	7500	500	3750	4050	7800
T_7	Fipronil 80% WDG @ 0.15 g/ litre (S.C)	225	20000	4500	4050	8550
T_8	Untreated control	-	-	-	-	-

Conclusion

Three sprays of Fipronil 80% WDG @ 0.15 g/litre at an interval of 15 days starting at ETL was found most effective for control of onion thrips (*T. tabaci* L) while *M. anisopliae* @ 5 g/litre found next best treatment. The treatment with Azadirachtin 3000 ppm @ 4 ml/litre and Neem seed extract 5% was found equally effective for control of onion thrips.

The treatment with pongamia oil 5% @ 5 ml/lit found least effective for control of onion thrips. The treatment with Fipronil 80% WDG @ 0.15 g/litre recorded highest yield (22.55 t/ha) and highest ICBR ratio (1: 8.17).

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