Quest Journals
Journal of Research in Agriculture and Animal Science
Volume 9 ~ Issue 8 (2022) pp: 01-07
ISSN(Online) : 2321-9459
www.questjournals.org

Research Paper

Compatibility ofacaropathogenic fungi, *Hirsutellathompsonii* Fisher with different insecticides and acaricides

Ishita M Hirapara[1*] and Lalit V Ghetiya[1]
[1]*Department of Agricultural Entomology, N. M. College of Agriculture,*
Navsari Agricultural University, Navsari-396450, Gujarat, India

---

ABSTRACT:
The red spider mite, Tetranychusurticae Koch is the major pest of the okra crop which causes severe damage and yield loss. Hirsutellathompsonii Fisher is widely used as an acaropathogen in biological control for mite pests. So, it needs to be checked their compatible nature insecticides and acaricideswhich are used in okra crop for the management of other insects.In compatibility studies, among all tested insecticides and acaricidesthiamethoxam 25 WG, fenpropathrin 30 EC, cypermethrin 25 EC, hexythiazox 5.45 EC, acetamiprid 20 SP, spiromesifen 240 SC, imidacloprid 17.8 SL, buprofezin 25 SC, fenpyroximate 5 EC and diafenthiuron 50 WPwere compatible with minimum growth inhibition of H. thompsonii. Emamectin benzoate 5 SG and fenazaquin 10 EC were found moderate compatible with H. thompsonii, while quinalphos 25 EC, lambda-cyhalothrin2.5 EC and propargite 57 ECexhibited the least compatible reaction with the H. thompsonii compared to untreated control. A chlorantraniliprole 18.5 SC was fully incompatible with H. thompsoniiand caused cent percent growth inhibition of H. thompsonii.The present finding revealed that those insecticides and acaricides caused lower growth inhibition of H. thompsoniiwhich was compatible and used with H. thompsoniiinthe okra crop.

Keywords: *Biological control, Compatibility, Hirsutellathompsonii Fisher, Insecticides*

R*eceived 23 July, 2022;* ***R****evised 04 August, 2022;* ***A****ccepted 06 August, 2022 © The author(s) 2022.*
P*ublished with open access at* ***www.questjournals.org***

I. INTRODUCTION

Numerous methods have been applied to control mite pests to improve the quality and quantity of crop production in agricultural systems. Of these, synthetic acaricides are the main method for mite control. Over-reliance on chemical acaricides with its indiscriminate use created many complications *viz*., food contamination through the accumulation of unwanted residues (Kumar *et al*. 2005 and Inobeme*et al*. 2020), development of resistance against acaricides(Edge *et al*. 1987; Grafton-Cardwell *et al*. 1987; Herron *et al*. 1993; Herron *et al*. 1997; Sato *et al*. 2005; Stavrinides and Hadjistylli2009 and Vassiliou and Kitsis2012), the resurgence of minor pests and outbreak of secondary pests (Hardin*et al*. 1995;Hajek 2004), ecological imbalance, destruction of natural enemies (Azod*et al*. 2016) and pollinators (Besard*et al*. 2010), the increasing cost of pest management, etc.Therefore, the above noted adverse effects have forced the scientific communities to focus on the development of mycoacaricide as an alternative eco-friendly measure.

The okra crop is susceptible to various insect and mite pests of which red spider mite, *Tetranychusurticae* Koch. is most predominant (Ghosh 2013).One of the limiting factors in the cultivation of okra is the incidence of *T. urticae*, especially during the summer season which causes severe damage. In modern agriculture, management of red spider mites by chemical acaricides is becoming ineffective and costly due to the development of resistance to most of the acaricides in a short time. Hence, there is a need to develop an effective and sustainable alternative control measure for red spider mites. Of late, the role played by parasitic acaropathogenic fungi in the mite population has received worldwide attention. In theory, acari make a good host for fungal pathogens because they have generally soft bodies and many inhabit environments with humid micro-climates that favour infection and disease transmission (Hajek and Leger 1994). In India, there are very rare reports about the natural incidences of fungal pathogens against tetranychid mites (Ramaseshiah 1971).

The genus *Hirsutella* includes many species that are pathogens of insects, mites and nematodes. There are about 50 entomopathogenic species under the genus *Hirsutella* (McCoy *et al*. 1988), whose potential to be developed as mite-controlling bioagents have been exploited.Of all the species, *H. thompsonii* is specific to the mite and is the most widely studied one. (McCoy 1981).

Management of entomopathogens that occur naturally, or are introduced for insect control (Oliveira *et al*. 2003) enforces an understanding of the compatibility of entomopathogenic fungi with other insecticides and acaricides which was used for the management of other insect pest in okra that might inhibit the development of pathogens. Pesticides can have negative effects on entomopathogenicfungi (Clark *et al*. 1982). The use of insecticides with beneficial fungi can improve control, allowing reductions in the volume of insecticides applied (Moino and Alves 1998; Quintela and McCoy 1998).

The application of different selective chemical insecticides and fungi when used in combination provides satisfactory control against many agricultural insect pests (Serebrov*et al.* 2005; Purwar and Sachen 2006). On the other hand, the use of nonselective or incompatible chemical pesticides may have the potential to hinder the vegetative growth and development of fungi adversely affecting the IPM (Anderson and Roberts 1983). For this reason, it is necessary to identify those insecticides or acaricideswhich put less effect on the germination of EPF (entomopathogenic fungi), mycelia growth and spore production to maintain their effectiveness. Therefore, in vitro compatibility of *H. thompsonii* with different insecticides and acaricidesespecially for conidial germination, mycelial radial growth and spore production are kept as an important part of the study. Based on the results of compatibility trials, growers can mix the insecticides and acaricideswith *H. thompsonii* to avoid antagonistic effects on the efficacy of each pesticide to be mixed up and unnecessary labour expenditure too.

II. MATERIALS AND METHODS

A study on the compatibility of *H. thompsonii* with different Insecticides and acaricidesis an essential part of pest management strategies. The compatibility trial was carried out at the Bio-control laboratory, Department of Entomology, Navsari Agricultural University, Navsariin 2021.

Fungal strains

The freeze-dried culture of *H. thompsonii*was purchased from CSIR- Institute of microbial technology, MTCC (Microbial Type Culture Collection & Gene Bank), Chandigarh, India.

Preparation of Media with Pesticides:

A totalof sixteendifferent insecticides and acaricideswere procured from the local market of Navsari. These all insecticides and acaricideswere evaluated for compatibility with *H. thompsonii.* Pesticides (insecticides and acaricides) were tested for their compatibility with *H. thompsonii*using the poisoned food technique (Grower and Moore 1962) under laboratory conditions.

In the poisoned food technique, the required quantity of PDA media was prepared in a one-liter flask then filled up in the 20 ml media in a 50 ml conical flask and plug it with sterilized non-absorbent cotton. All media containing flasks were kept in an autoclave at 15 lbs pressure and 121℃ temperatures for 30 minutes. The required quantity of insecticides and acaricides were incorporated into the melted sterile PDA aseptically, thoroughly mixedand poured into Hi-media disposable Petri dish (90 mm) and allowed to solidify under a laminar flow cabinet. After solidification of the medium, the plate was inoculated in the center by placing a five-millimeter diameter mycelial culture block with thehelp of a cork borer from a 10-day old pure culture of *H. thompsonii*. The inoculated plates were incubated at 25±2℃ temperatures in a BOD incubator.

Effect of insecticides and acaricides on vegetative radial growth

The colony growth of *H. thompsonii* has examined in two days intervals for 10 days of culturing to measure the colony diameter (in mm). Each treatment was performed in three replicates. The recorded values of each replications were averaged. The inhibition percentage of radial growth was estimated as follows:

$$Radial\ growth\ inhibition\ percentage = C - T/C \times 100$$

Where,

C= Colony diameter in control

T- Colony diameter in treatment

Statistical Analysis

The data obtained from various treatments were subjected to a square root transformation for radial growth and CFU count data and an angular transformation for inhibition percentage to stabilize the variance.The transformed data were carried out in complete randomized design (CRD) and submitted to analysis of variance

ANOVA by using online tools OPSTAT and GOASTAT. The means of inhibition and CFU were separated among the treatments by using the least significant difference (LSD) test ($P \leq 0.05$).

III. RESULTS AND DISCUSSION

The compatibility of *H. thompsonii* with differentinsecticides and acaricides used in okra for the management of other insects and mites was studied in *vitro*. The compatibility was measured by three parameters, Radial growth measurement (in mm), growth inhibition percentage based on mycelial growth and conidial germination (CFU).

Effect of insecticides or acaricides

A total sixteen insecticides and acaricides were evaluated for their effect on the growth of the *H. thompsonii***.** The results thus obtained are statistically analyzed and presented in Table no 1.

Two days after inoculation

At two days after inoculation, thiamethoxam 25 WG (28.00 mm diameter) and imidacloprid 17.8 SL (28.00 mm diameter) exhibited superior compatibility among sixteen different insecticides, which was remained at par with untreated control (30.00 mm diameter). The next order of merit was Fenpropathrin 30 EC (27.83 mm diameter), buprofezin 25 EC (27.00 mm diameter), spiromesifen (26.33 mm) and acetamiprid 20 SP (25.67 mm) which were found at par with cypermethrin 25 EC (25.33 mm). The next best treatment was hexythiazox 5.45 EC (22.00 mm). Emamectin benzoate 5 SG (20.67 mm) and fenpyroximate (19.67 mm) remained at par with hexythiazox 5.45 EC. The lowest growth was observed in propargite 57 EC (11.00 mm) and diafenthiuron 50 WP (13.67 mm) at two days after inoculation. There was no growth observed in chlorantraniliprole 18.5 SC two days after inoculation. The descending order of the radial growth of *H. thompsonii* with different insecticides at two days after inoculation was found as $T_{17} \geq T_{16} = T_{11} \geq T_8 \geq T_2 \geq T_{15} \geq T_1 > T_4 > T_{10} \geq T_6 \geq T_9 \geq T_{14} \geq T_{12} \geq T_7 > T_5 > T_{13} > T_{3.}$

The lowest growth inhibition after two days of inoculation was observed in thiamethoxam 25 WG (6.67%), imidacloprid 17.8 SL (6.67%) and fenpropathrin 30 EC (7.19%), which was significantly superior over rest of the treatments. The next merit of the order was buprofezin 25 SC (9.97%) and spiromesifen 240 SC (12.27%), which were found at par with thiamethoxam 25 WG, acetamiprid 20 SP (14.45%) and cypermethrin 25 EC (15.60%). Whereas, the highest inhibition was recorded in chlorantraniliprole 18.5 SC (100.00%) and propargite 57 EC (63.34%) followed by diafenthiuron 50 WP (54.63%) and fenazaquin 10 EC (50.04%) at two days after inoculation. The ascending order of per cent growth inhibition was $T_{16} = T_{11} \leq T_8 \leq T_2 \leq T_{15} \leq T_1 \leq T_4 < T_{10} \leq T_6 < T_9 \leq T_{14} < T_{12} < T_7 \leq T_5 < T_{13} < T_3$ two days after inoculation.

Four days after inoculation

Thiamethoxam 25 WG (40.00 mm diameter), fenpropathrin 30 EC (40.00 mm diameter) and buprofezin 25 SC (39.67 mm) were found superior amongst all tested insecticides and remained at par with imidacloprid 17.8 SL (38.00 mm diameter), acetamiprid 20 SP (37.33 mm) and cypermethrin 25 EC (37.00 mm). The next best treatment was spiromesifen 240 SC (36.33 mm) followed by diafenthiuron 50 WP (29.00 mm). Whereas, propargite 57 EC (21.00 mm) and fenazaquin 10 EC (22.67 mm diameter) showed the lowest radial growth following emamectin benzoate 5 SG (25.67 mm diameter), lambda-cyhalothrin 2.5 EC (26.00 mm) and quinalphose 25 EC (26.00 mm) at four days after inoculation. There was no growth observed in chlorantraniliprole 18.5 SC. The descending order of the radial growth of *H. thompsonii* with different insecticides was $T_{17} > T_{16} = T_8 \geq T_2 \geq T_{11} \geq T_1 \geq T_4 \geq T_{15} > T_5 \geq T_{10} \geq T_9 \geq T_{14} = T_{12} \geq T_6 > T_7 \geq T_{13} > T_3$ four days after inoculation.

The lowest growth inhibition was observed in thiamethoxam 25 WG (11.00%), fenpropathrin 30 EC (11.11%) and buprofezin 25 SC (11.91%), which were significantly superior to the rest of the treatments. Imidacloprid 17.8 SL showed 15.56 per cent growth inhibition and was found at par with acetamiprid 20 SP (17.11%), cypermethrin 25 EC (17.85%) and spiromesifen 240 SC (19.28%). The next merit of order was diafenthiuron 50 WP (35.60%), which remained at par with fenpyroximate (40.77%) and hexythiazox (37.79%). Hexythiazox was found at par with emamectin benzoate 5 SG (43.03%) that remained at par with quinalphos 25 EC (42.24%) and lambda-cyhalothrin 2.5 EC (42.19%). Whereas, the highest inhibition was recorded in chlorantraniliprole 18.5 SC (100.00%) following propargite 57 EC (53.33%) and fenazaquin 10 EC (49.70%). The ascending order of per cent growth inhibition was $T_{16} = T_8 \leq T_2 \leq T_{11} \leq T_1 \leq T_4 \leq T_{15} < T_5 \leq T_{10} \leq T_9 \leq T_{12} = T_{14} \leq T_6 < T_7 \leq T_{13} < T_3$ four days after inoculation.

Six days after inoculation

Significantly better growth was observed in thiamethoxam 25 WG (59 mm diameter) amongst tested insecticides, which was remained at par with untreated control (61.00 mm diameter) and followed by cypermethrin 25 EC (53.00 mm) and fenpropathrin 30 EC (53.00 mm) at six days after inoculation. Buprofezin

25 SC (52.00 mm), hexythiazox 5.45 EC (52.00 mm), spiromesifen 240 SC (51.00 mm) and imidacloprid 17.8 SL (50.67 mm) were found at par with cypermethrin 25 EC and fenpropathrin 30 EC. The treatment acetamiprid 20 SP (48.67%) was remained at par fenpyroximate 5 EC (48.33%) and followed by emamectin benzoate 5 SG (40.00%) and diafenthiuron 50 WP (39.67%). No growth was observed in chlorantraniliprole 18.5 SC. However, significantly the lowest (31.00 mm diameter) radial growth was observed in propargite 57 EC following lambda-cyhalothrin 2.5 EC (36.00 mm diameter). The descending order of the radial growth of *H. thompsonii*with different insecticides was $T_{17} \geq T_{16} > T_4 = T_8 \geq T_2 = T_{10} \geq T_{15} \geq T_{11} \geq T_1 \geq T_9 > T_6 \geq T_5 \geq T_7 \geq T_{14} \geq T_{12} > T_{13} > T_3$ at six days after inoculation.

Significantly lower growth inhibition of *H. thompsonii*was observed in thiamethoxam 25 WG (3.30%) followed by cypermethrin 25 EC (13.14%), fenpropathrin 30 EC (13.14%), buprofezin 25 SC (14.76%) and hexythiazox 5.45 EC (14.76%). Cypermethrin, fenpropathrin, buprofezin, hexythiazox, spiromesifen and imidacloprid were found equally compatible with *H. thompsonii* considering low growth inhibition at six days of inoculation. Spiromesifen 240 SC (16.41%), imidacloprid 17.8 SL (16.95%) and acetamiprid 20 SP (20.26%) were remained at par with hexythiazox 5.45 EC and fenpyroximate 5 EC (20.78%). Growth inhibition in fenpyroximate 5 EC (20.78%) was followed by emamectin benzoate 5 SG (34.49%), diafenthiuron 50 WP (35.02%) and fenazaquin 10 EC (37.73%). Quinalphos 25 EC (39.87%) was found at par with lambda-cyhalothrin 2.5 EC (40.98%). Whereas, significantly the highest inhibition was observed in chlorantraniliprole 18.5 SC (100.00%) following propargite 57 EC (49.21%) and lambda-cyhalothrin 2.5 EC (40.98%). The ascending order of per cent growth inhibition was $T_{16} < T_4 = T_8 \leq T_2 = T_{10} \leq T_{15} \leq T_{11} \leq T_1 \leq T_9 < T_6 \leq T_5 \leq T_7 \leq T_{14} \leq T_{12} < T_{13} < T_3$ at six days after inoculation.

Eight days after inoculation

The results at eight days after inoculation showed significantly highest redial growth in thiamethoxam 25 WG with 71.00 mm diameter, which was significantly differed from untreated control (75.00 mm diameter) and at par with fenpropathrin 30 EC (68.00 mm diameter). The Next merit of the order was cypermethrin 25 EC (66.00 mm) and found at par with fenpropathrin followed by buprofezin 25 SC (65.67 mm) and hexythiazox 5.45 EC (65.00 mm). Acetamiprid 20 SP and spiromesifen 240 SC showed 63.33 mm and 61.00 mm growth respectively, which were remained at par with imidacloprid 17.8 SL (60.00 mm) and fenpyroximate 5 EC (60.00 mm). The growth in diafenthiuron 50 WP was 51.33 mm followed by emamectin benzoate 5 SG (47.67 mm) and fenazaquin 10 EC (43.33). The mycelial growth of *H. thompsonii* did not appear in Chlorantraniliprole 18.5 SC. However, significantly lowest (34.17 mm diameter) radial growth was observed in propargite 57 EC following lambda-cyhalothrin 2.5 EC (38.67 mm) and quinalphos 25 EC (38.67 mm). The descending order of the radial growth of *H. thompsonii* with different insecticides was $T_{17} > T_{16} \geq T_8 \geq T_4 \geq T_2 \geq T_{10} \geq T_1 \geq T_{15} \geq T_9 = T_{11} > T_5 > T_6 > T_7 > T_{14} = T_{12} > T_{13} > T_3$ at eight days after inoculation.

Significantly lowest growth inhibition of *H. thompsonii* was recorded in thiamethoxam 25 WG with 5.33 per cent inhibition, which was significantly superior compared to the rest of the treatments. The next merit of order was fenpropathrin 30 EC (9.34%) followed by cypermethrin 25 EC (12.01%), buprofezin 25 SC (12.45%) and hexythiazox 5.45 EC (13.33%). In acetamiprid 20 SP, 15.59 per cent growth inhibition was observed. The next in order insecticides were spiromesifen 240 SC (18.67%), fenpyroximate 10 EC (20.00%) and imidacloprid 17.8 SL (20.01%). Diafenthiuron 50 WP showed 31.57 per cent growth inhibition followed by emamectin benzoate 5 SG (36.46%) and fenazaquin 10 EC (42.33%). The cent per cent inhibition was observed in chlorantraniliprole 18.5 SC. However, significantly higher inhibition was recorded in propargite 57 EC (54.42%) following lambda-cyhalothrin 2.5 EC and quinalphos 25 EC (48.43%). The ascending order of per cent growth inhibition was $T_{16} < T_8 < T_4 \leq T_2 \leq T_{10} \leq T_1 \leq T_{15} \leq T_9 = T_{11} < T_5 < T_6 < T_7 < T_{14} = T_{12} < T_{13} < T_3$ at eight days after inoculation.

Ten days after inoculation

The highest (74.00 mm) growth of *H. thompsonii*at ten days after inoculation was observed in thiamethoxam 25 WG, which was found at par with control treatment (77.00 mm) and followed by fenpropathrin 30 EC (71.33 mm). The next best treatment was cypermethrin 25 EC (68.67 mm), hexythiazox 5.45 EC (67.67 mm), acetamiprid 20 SP (67.00 mm), spiromesifen 240 SC (67.00 mm) and imidacloprid 17.8 SL (66.67 mm) which was at par with buprofezin 25 SC (66.00 mm) and fenpyroximate 5 EC (64.67 mm). Diafenthiuron 50 WP showed 58.57 mm growth followed by emamectin benzoate 5 SG (53.00 mm), fenazaquin 10 EC (52.67 mm) and quinalphose 25 EC (46.17 mm). The mycelial growth was not observed in chlorantraniliprole 18.5 SC. The lowest growth was obtained in propargite 57 EC (41.33 following lambda-cyhalothrin 2.5 EC (42.17 mm). The descending order of the radial growth of *H. thompsonii* with different insecticides was $T_{17} \geq T_{16} \geq T_8 \geq T_4 \geq T_{10} \geq T_1 = T_{15} \geq T_{11} \geq T_2 \geq T_9 > T_5 > T_6 \geq T_7 \geq T_{14} > T_{12} \geq T_{13} > T_3$ at ten days after inoculation.

The lowest growth inhibition was observed in thiamethoxam 25 WG (3.90%) followed by fenpropathrin 30 EC (7.38%), they were found as compatible with *H. thompsonii*. The cypermethrin 25 EC

(10.83%) and hexythiazox 5.45 EC (12.13%) were found compatible, which was found at par with acetamiprid 20 SP (13.00%), spiromesifen 240 SC (13.00%), imidacloprid 17.8 SL (13.43%) and buprofezin 25 SC (14.30%). The growth inhibition in fenpyroximate 10 EC was 16.04 per cent followed by diafenthiuron 50 WP (23.83%), emamectin benzoate 5 SG (31.19%) and fenazaquin 10 EC (31.64%). The highest inhibition (100.00%) was in chlorantraniliprole 18.5 SC which was following propargite 57 EC (46.29%), lambda-cyhalothrin 2.5 EC (45.20%) and quinalphos 25 EC (40.03%). The ascending order of per cent growth inhibition was $T_{16} < T_8 < T_4 \leq T_{10} \leq T_{15} = T_1 \leq T_{11} \leq T_2 \leq T_9 < T_5 < T_6 \leq T_7 < T_{14} \leq T_{12} \leq T_{13} < T_3$ at 10 days after inoculation.

Effect of various insecticides on sporulation of *H. thompsonii*

Significantly higher spore production was observed in untreated control (72.67×10^{6} cfu/ml) followed by thiamethoxam 25 WG (68.00×10^{6} cfu/ml) and fenpropathrin 30 EC (62.33×10^{6} cfu/ml). The next merit of order was cypermethrin 25 EC (46.67×10^{6} cfu/ml) followed by hexythiazox 5.45 EC (36.33×10^{6} cfu/ml) and spiromesifen 240 SC (35.33×10^{6} cfu/ml). These spiromesifen 240 SC was found at par with acetamiprid 20 SP (34.33×10^{6} cfu/ml) and imidacloprid 17.8 SL (32.00×10^{6} cfu/ml). The sporulation in buprofezin 25 EC, hexythiazox 5.45 EC and diafenthiuron 50 WP were observed 30.33, 26.00 and 22.00×10^{6} cfu/ml, respectively. The spore of *H. thompsonii* did not appear in chlorantraniliprole 18.5 SC. However, significantly lower spore production was observed in propargite 57 EC (8.67×10^{6} cfu/ml), lambda-cyhalothrin2.5 EC (9.00×10^{6} cfu/ml) andquinalphos 25 EC (10.33×10^{6} cfu/ml) following emamectin benzoate 5 SG (21.33×10^{6} cfu/ml) and fenazaquin 10 EC (18.67×10^{6} cfu/ml). The descending order of sporulation was $T_{17} \geq T_{16} \geq T_8 > T_4 > T_{10} \geq T_{15} = T_1 \geq T_{11} \geq T_2 \geq T_9 \geq T_5 \geq T_6 \geq T_7 > T_{14} \geq T_{12} \geq T_{13} > T_3$ at 10 days after inoculation (Table 1).

More than 750 species of fungi, mostly Deuteromycetes and Entomophthorales from about 100 genera are pathogenic to insects. Among these, the *H. thompsonii*relatively less known is gaining importance because of their target specificity and effectiveness in controlling many microscopic to sub-microscopic pests which are difficult to control by conventional management practices (Banik and Halder 2013).

Alone use of *H. thompsonii*doesnot give good control of mite pests, so needs to use of other chemical insecticides and acaricidesalong with *H.thompsonii*for better management of mites. The present investigation showed the compatibility of *H. thompsonii*with different insecticides and acaricides which been used in okra crops.

Results of the present study revealed that thiamethoxam 25 WG, fenpropathrin 30 EC, cypermethrin 25 EC, hexythiazox 5.45 EC, acetamiprid 20 SP, spiromesifen 240 SC, imidacloprid 17.8 SL, buprofezin 25 SC, fenpyroximate 5 EC and diafenthiuron 50 WP were found compatible with *H. thompsonii* considering its growth and development. While, quinalphos 25 EC, lambda-cyhalothrin2.5 EC and propargite 57 ECexhibited the least compatible reaction with the *H. thompsonii* compared to untreated control. A chlorantraniliprole 18.5 SC was incompatible with *H. thompsonii* and caused cent percent growth inhibition of *H. thompsonii.*

The present findings compared well with those of other scientists who conducted similar trials with *Hirsutella* spp. as well as another entomopathogen for compatibility test with other insecticides as well as acaricides. According to the findings of earlier workers; the thiamethoxam was compatible with *H.thompsonii*, *B. bassiana*, *M. anisopliae*, *V. lecanii* and *N. rileyi* approved by Filho*et al*. (2001) in Campinas, SP, Brazil. The hexythiazox 50 EC had the weakest inhibitory action on *H. nodulosa* was confirmed by Tkaczuk*et al*. (2004). Similarly, Smitha and Mathew (2011) reported that inhibition of *Hirsutella* sp. was exhibited by quinalphos. The present finding was closely matched to the result of Khan *et al.* (2012) who recorded acetamiprid (0.004%), thiomethoxam (0.005%), and imidacloprid (0.005%) to be compatible and comparatively safer to *B. bassiana* and *M. anisopliae*. The results of the present finding also confirm with Niassy*et al.* (2012) who reported that the imidacloprid was highly compatible with *M. anisopliae*; thiamethoxam was compatible, whereas lambda-cyhalothrin and spiromesifen were moderate to highly toxic to the fungus, adversely affecting vegetative growth and sporulation. As per Perez-Gonzalez and Sanchez-Pena (2017) imidacloprid dramatically increased conidial yield (624.0%) in three *Hirsutella* strains.

IV. CONCLUSIONS

Overall compatibility tests with insecticides and acaricidesindicate that thiamethoxam 25 WG, fenpropathrin 30 EC, cypermethrin 25 EC, hexythiazox 5.45 EC, acetamiprid 20 SP, spiromesifen 240 SC, imidacloprid 17.8 SL, buprofezin 25 SC, fenpyroximate 5 EC and diafenthiuron 50 WP were found compatible with *H. thompsonii*. Emamectin benzoate 5 SG and fenazaquin 10 EC were found moderate compatible with *H. thompsonii*, while quinalphos 25 EC, lambda-cyhalothrin2.5 EC and propargite 57 ECexhibited the least compatible reaction with *H. thompsonii*compared to untreated control. A chlorantraniliprole was found fully incompatible with *H. thompsonii*considering mycelial growth and development of acaropathogenic fungus (*H. thompsonii*) and cent percent growth inhibition of

H. thompsonii. Further experiments in field conditions are recommended for evaluating the efficacy of *H. thompsonii* in combination with insecticides and acaricidesagainst *T. urticae*.

REFERENCES

[1]. Anderson, T. E. and Roberts, D. W. 1983. Compatibility of *Beauveriabassiana*isolates with insecticide formulations used in Colorado potato beetle (Coleoptera: Chrysomelidae) control. *J Econ Entomol*, 76(6): p. 1437-1441. https://doi.org/10.1093/jee/76.6.1437 as on 02-01-2019

[2]. Azod, F., Shahidi-Noghabi, S., Mahdian, K. and Smagghe, G. 2016. Lethal and sublethal effects of spirotetramat and abamectin on predatory beetles (*Menochilussexmaculatus*) via prey (*Agonoscenapistaciae*) exposure, important for integrated pest management in pistachio orchards. *Belg J Zool*, 146(2): p. 113–122.https://doi.org/10.26496/bjz.2016.46

[3]. Banik, S. and Halder, J. 2013.Acaropathogenic and entomopathogenic fungus Hirsutella–A review. *Ann Entomol*, 31(1): p. 143-155.

[4]. Besard, L., Mommaerts, V., Vandeven, J., Cuvelier, X., Sterk, G. and Smagghe, G. 2010. Compatibility of traditional and novel acaricides with bumblebees (*Bombusterrestris*): A first laboratory assessment of toxicity and sublethal effects. *Pest ManagSci*, 66(7): p. 786-793.DOI: 10.1002/ps.1943

[5]. Clark, R. A., Casagrande, R. A. and Wallace, D. B. 1982. Influence of pesticides on *Beauveriabassiana* a pathogen of the Colorado potato beetle. *Environ Entomol*, 11(1): p. 67-70. doi:10.1093/ee/11.1.67

[6]. Edge, V. J., Rophail, J. and James, D. G. 1987.Acaricide resistance in two spotted mites, *Tetranychusurticae* in Australian horticultural crops. In: Thwaite WG (ed) Proceedings, Symposium on Mite Control in Horticultural Crops. Orange Agricultural College, Orange, NSW, Australia, p. 87.

[7]. Filho, A. B., Almeida, J. E. M. and Lamas, C. 2001. Effect of thiamethoxam on entomopathogenic microorganisms. *Neotropical Entomol*, 30(3): p. 437-447. https://doi.org/10.1590/S1519-566X2001000300017

[8]. Ghosh, S. 2013. Incidence of red spider mite (*Tetranychusurticae* Koch) on okra (*Abelmoschusesculentus* (L.) Moench) and their sustainable management. *Current Biotica*, 7(1&2): p. 40-50.

[9]. Grafton-Cardwell, Granett, E. E. and Leigh, T. F. 1987. Spider mite species (Acari: Tetranychidae) response to propargite: Basis for an acaricide resistance management program. *J Econ Entomol,* 80(3): p. 579–587. https://doi.org/10.1093/jee/80.3.579

[10]. Grower, K. K. and Moore, J. D. 1962.Taximetric studies of fungicides against brown rot organisms, *Sclerotiniafructicola* and *S. laxa*. *Phytopathol*52(9): p. 876-880.

[11]. Hajek, A. E. 2004. Natural enemies: an introduction to biological control. 15th Ed. Cambridge University Press. Cambridge UK. 396 p. (ISBN-13: 978-0521653855)

[12]. Hajek, A. E and Leger, R. J. 1994. Interactions between fungal pathogens and insects' hosts. *Annu Rev Entomol*, 39(3): p. 293-322. doi:10.1146/annurev.en.39.010194.001453

[13]. Hardin, M. R., Benrey, B., Coli, M., Lamp, W. O., Roderick, G. K. and Barbosa, P. 1995. Arthropod pest resurgence: An overview of potential mechanisms. *Crop Prot*, 14(1): p. 3-18.

[14]. Herron, G. A., Edge, V. E. and Rophail, J. 1993.Clofentezine and hexythiazox resistance in *Tetranychusurticae* Koch in Australia. *ExpApplAcarol*, 17: p. 433–440.

[15]. Herron, G. A., Learmonth, S. E, Rophail, J. andBarchia, I. 1997.Clofentezine and fenbutatin oxide resistance in the two-spotted spider mite, *Tetranychusurticae* Koch (Acari: Tetranychidae) from deciduous fruit tree orchards in Western Australia. *ExpApplAcarol*, 21: p.163–169. https://doi.org/10.1023/A:1018434618919

[16]. Inobeme, A., Mathew, J. T., Okonkwo, S., Ajai, A. I., Jacob, J. O. andOlori, E. 2020. Pesticide residues in food: distribution, route of exposure and toxicity: in review. *MOJ Food Process Technols*, 8(3): p. 121–124.doi:10.15406/mojfpt.2020.08.00251

[17]. Khan, S., Bagwan, N. B., Fatima, S. and Mohammed, A. I. 2012. *In vitro* compatibility of two entomopathogenic fungi with selected insecticides, fungicides and plant growth regulators. *Libyan Agric ResCen J Intl*, 3(1): p. 36-41.

[18]. Kumar, D., Singh, K. P. and Jaiswal, R. K. 2005. Screening of different media and substrates for cultural variability and mass culture of *Arthrobotrysdactyloides*Drechsler. *Mycobiol,* 33(4): p. 215-222. doi: 10.4489/MYCO.2005.33.4.215

[19]. McCoy, C. W. (1981) Fungi. Pest control by *Hirsutellathompsonii*. In: H.D. Burges (Editor), Microbial control of insects, mites and plant diseases. Academic Press, London, UK, pp. 499-512.

[20]. McCoy, C. W., Samson, R. A. and Boucias, D. G.1988.Entomogenous Fungi. In: Ignoffo, C. M. and Mandava, N. B., Eds., Handbook of Natural Pesticides, Vol. V, Microbial Insecticides, Part A, CRC Press, Boca Raton, 151-236.

[21]. Moino, A. J. and Alves, S. B. 1998. Effects of Imidacloprid and Fipronil on *Beauveriabassiana* (Bals.) Vuill. and *Metarhiziumanisopliae* (Metsch.) Sorok. and on the Grooming Behavior of *Heterotermes tenuis* (Hagen). *An SocEntomolBrasil*, 27(4): p. 611-619. doi:10.1590/S0301805911998000400014

[22]. Niassy, S., Maniania, N. K., Subramanian, S., Gitonga, M. L., Marangab, R., Obonyo, A. B. andEkesi, S. 2012.Compatibility of *Metarhiziumanisopliae* isolate ICIPE 69 with agrochemicals used in French bean production. *Int J Pest Manag,* 58(2): p. 131–137. doi:10.1080/09670874.2012.669078

[23]. Oliveira, C. N., Neves, P. M. O. J. and Kawazoe, L. S. 2003.Compatibility between the entomopathogenic fungus *Beauveriabassiana* and insecticides used in coffee plantations. *Scientia Agricola,* 60(4): p. 663-667. doi:10.1590/S0103-90162003000400009

[24]. Perez-Gonzalez, O. and Sanchez-Pera, S. R. 2017. Compatibility *in vitro* and *in vivo* of the entomopathogenic fungi *Beauveriabassiana* and *Hirsutellacitriformis* with selected insecticides. *Society of Southwestern Entomologists*, 42(3): p. 707-718. doi: 10.3958/059.042.0309

[25]. Purwar, J. P. and Sachan, G. C. 2006. Synergistic effect of entomogenous fungi on some insecticides against Bihar hairy caterpillar *Spilarctiaobliqua*(Lepidoptera: Arctiidae). *MicrobiolRes,* 161(1): p. 38-42. https://doi.org/10.1016/j.micres.2005.04.006

[26]. Quintela, E. D. and McCoy, C. W. 1998. Synergistic effect of imidacloprid and two entomopathogenic fungi on the behavior and survival of larvae of *Diaprepes abbreviates* (Coleoptera: Curculionidae) in soil. *J EconEntomol,* 91(1): p. 110-122. https://doi.org/10.1093/jee/91.1.110

[27]. Ramaseshiah, G. 1971. Occurrence of an Entomophthora on tetranychid mites in India. *J InvertebrPathol*, 18(3): p. 421-424. doi:10.1016/0022-2011(71)90049-8

[28]. Sato, M. E., DaSilva, M. Z., Raga, A. and DeSouzaFilho, M. F. 2005.Abamectin Resistance in *Tetranychusurticae* Koch (Acari: Tetranychidae): Selection, Cross-resistance and Stability of Resistance. *NeotropEntomol*, 34(6): p. 991-998. https://doi:10.1590/S1519-566X2005000600016

[29]. Serebrov, V. V., Khodyrev, V. P., Gerber, O. N. and Tsvetkova, V. P. 2005. Perspectives of combined use of entomopathogenic fungi and chemical insecticides against Colorado beetle (*Leptinotarsadecemlineata*). *MikolFitopatol*, 39(3): p. 89-98. (Fide: https://www.researchgate.net/publication/292870422 as accessed on 05-05-2022).

[30]. Smitha, M. S. and Mathew, M. P. 2011.*In vitro* assays on the influence of selected pesticides on the growth parameters of entomopathogen, *Hirsutella* sp. *Indian J Entomol*,73(4): p. 343-345.

[31]. Stavrinides, M. C. and Hadjistylli, M. 2009. Two-spotted spider mite in Cyprus: ineffective acaricides, causes and considerations. *Pest Sci*, 82(2): p. 123–128. doi:10.1007/s10340-008-0230-0

[32]. Tkaczuk, C., Labanowska, B. H. andMiętkiewski, R. (2004).The influence of pesticides on the growth of fungus *Hirsutellanodulosa* (Petch) – entomopathogen of Strawberry mite (*Phytonemuspallidus* ssp. *fragariae*ZIMM.). *J Fruit Ornam Plant Res*, 12: p. 119-126.

[33]. Vassiliou, V. A. andKitsis, P. 2012.Acaricide resistance in *Tetranychusurticae* (Acari: Tetranychidae) populations from Cyprus. *J Econ Entomol*, 106(4): p. 1848-1854. http://dx.doi.org/10.1603/EC12369

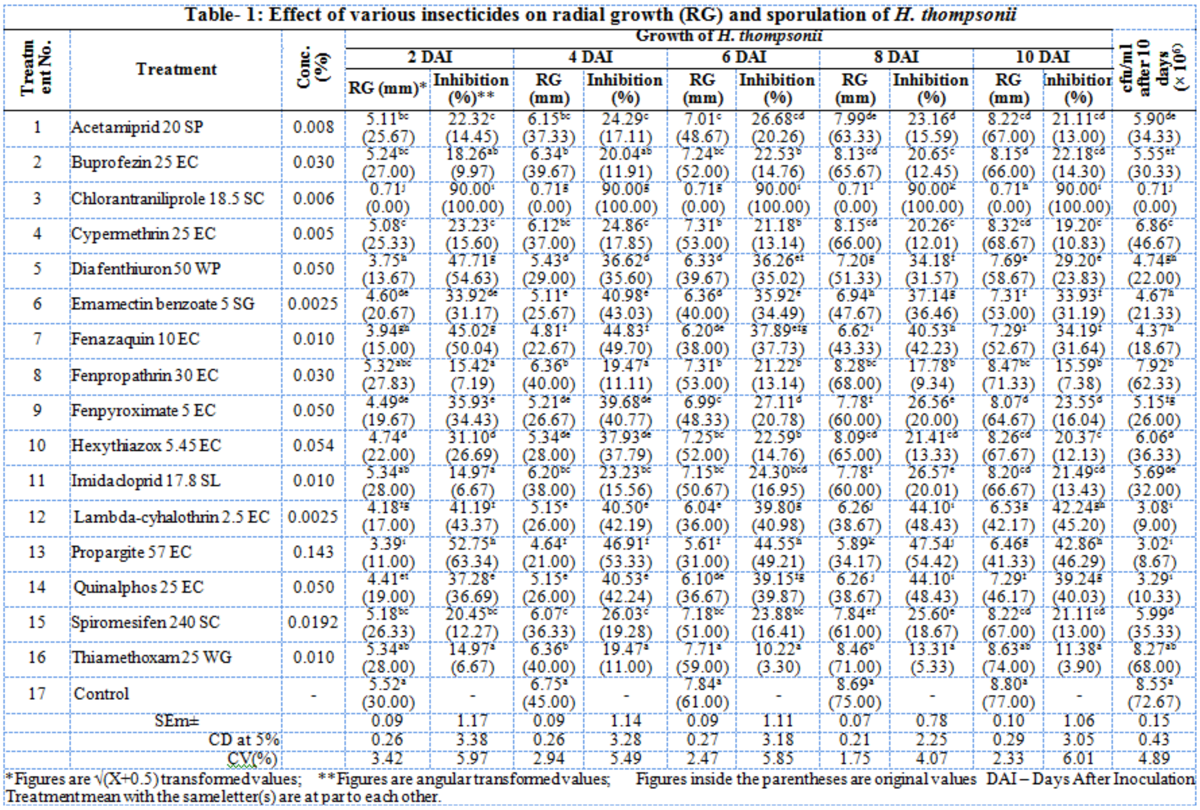

Table- 1: Effect of various insecticides on radial growth (RG) and sporulation of *H. thompsonii*

Treatment No.	Treatment	Conc. (%)	Growth of *H. thompsonii*										cfu/ml after 10 days (× 10^6)
			2 DAI		4 DAI		6 DAI		8 DAI		10 DAI		
			RG (mm)*	Inhibition (%)**	RG (mm)	Inhibition (%)	RG (mm)	Inhibition (%)	RG (mm)	Inhibition (%)	RG (mm)	Inhibition (%)	
1	Acetamiprid 20 SP	0.008	5.11^{bc} (25.67)	22.32^{c} (14.45)	6.15^{bc} (37.33)	24.29^{c} (17.11)	7.01^{c} (48.67)	26.68^{cd} (20.26)	7.99^{de} (63.33)	23.16^{d} (15.59)	8.22^{cd} (67.00)	21.11^{cd} (13.00)	5.90^{de} (34.33)
2	Buprofezin 25 EC	0.030	5.24^{bc} (27.00)	18.26^{ab} (9.97)	6.34^{b} (39.67)	20.04^{ab} (11.91)	7.24^{bc} (52.00)	22.53^{b} (14.76)	8.13^{cd} (65.67)	20.65^{c} (12.45)	8.15^{d} (66.00)	22.18^{cd} (14.30)	5.55^{ef} (30.33)
3	Chlorantraniliprole 18.5 SC	0.006	0.71^{j} (0.00)	90.00^{i} (100.00)	0.71^{g} (0.00)	90.00^{g} (100.00)	0.71^{g} (0.00)	90.00^{i} (100.00)	0.71^{l} (0.00)	90.00^{k} (100.00)	0.71^{h} (0.00)	90.00^{i} (100.00)	0.71^{j} (0.00)
4	Cypermethrin 25 EC	0.005	5.08^{c} (25.33)	23.23^{c} (15.60)	6.12^{bc} (37.00)	24.86^{c} (17.85)	7.31^{b} (53.00)	21.18^{b} (13.14)	8.15^{cd} (66.00)	20.26^{c} (12.01)	8.32^{cd} (68.67)	19.20^{c} (10.83)	6.86^{c} (46.67)
5	Diafenthiuron 50 WP	0.050	3.75^{h} (13.67)	47.71^{g} (54.63)	5.43^{d} (29.00)	36.62^{d} (35.60)	6.33^{d} (39.67)	36.26^{ef} (35.02)	7.20^{g} (51.33)	34.18^{f} (31.57)	7.69^{e} (58.67)	29.20^{e} (23.83)	4.74^{gh} (22.00)
6	Emamectin benzoate 5 SG	0.0025	4.60^{de} (20.67)	33.92^{de} (31.17)	5.11^{e} (25.67)	40.98^{e} (43.03)	6.36^{d} (40.00)	35.92^{e} (34.49)	6.94^{h} (47.67)	37.14^{g} (36.46)	7.31^{f} (53.00)	33.93^{f} (31.19)	4.67^{h} (21.33)
7	Fenazaquin 10 EC	0.010	3.94^{gh} (15.00)	45.02^{g} (50.04)	4.81^{f} (22.67)	44.83^{f} (49.70)	6.20^{de} (38.00)	37.89^{efg} (37.73)	6.62^{i} (43.33)	40.53^{h} (42.23)	7.29^{f} (52.67)	34.19^{f} (31.64)	4.37^{h} (18.67)
8	Fenpropathrin 30 EC	0.030	5.32^{abc} (27.83)	15.42^{a} (7.19)	6.36^{b} (40.00)	19.47^{a} (11.11)	7.31^{b} (53.00)	21.22^{b} (13.14)	8.28^{bc} (68.00)	17.78^{b} (9.34)	8.47^{bc} (71.33)	15.59^{b} (7.38)	7.92^{b} (62.33)
9	Fenpyroximate 5 EC	0.050	4.49^{de} (19.67)	35.93^{e} (34.43)	5.21^{de} (26.67)	39.68^{de} (40.77)	6.99^{c} (48.33)	27.11^{d} (20.78)	7.78^{f} (60.00)	26.56^{e} (20.00)	8.07^{d} (64.67)	23.55^{d} (16.04)	5.15^{fg} (26.00)
10	Hexythiazox 5.45 EC	0.054	4.74^{d} (22.00)	31.10^{d} (26.69)	5.34^{de} (28.00)	37.93^{de} (37.79)	7.25^{bc} (52.00)	22.59^{b} (14.76)	8.09^{cd} (65.00)	21.41^{cd} (13.33)	8.26^{cd} (67.67)	20.37^{c} (12.13)	6.06^{d} (36.33)
11	Imidacloprid 17.8 SL	0.010	5.34^{ab} (28.00)	14.97^{a} (6.67)	6.20^{bc} (38.00)	23.23^{bc} (15.56)	7.15^{bc} (50.67)	24.30^{bcd} (16.95)	7.78^{f} (60.00)	26.57^{e} (20.01)	8.20^{cd} (66.67)	21.49^{cd} (13.43)	5.69^{de} (32.00)
12	Lambda-cyhalothrin 2.5 EC	0.0025	4.18^{fg} (17.00)	41.19^{f} (43.37)	5.15^{e} (26.00)	40.50^{e} (42.19)	6.04^{e} (36.00)	39.80^{g} (40.98)	6.26^{j} (38.67)	44.10^{i} (48.43)	6.53^{g} (42.17)	42.24^{gh} (45.20)	3.08^{i} (9.00)
13	Propargite 57 EC	0.143	3.39^{i} (11.00)	52.75^{h} (63.34)	4.64^{f} (21.00)	46.91^{f} (53.33)	5.61^{f} (31.00)	44.55^{h} (49.21)	5.89^{k} (34.17)	47.54^{j} (54.42)	6.46^{g} (41.33)	42.86^{h} (46.29)	3.02^{i} (8.67)
14	Quinalphos 25 EC	0.050	4.41^{ef} (19.00)	37.28^{e} (36.69)	5.15^{e} (26.00)	40.53^{e} (42.24)	6.10^{de} (36.67)	39.15^{fg} (39.87)	6.26^{j} (38.67)	44.10^{i} (48.43)	7.29^{f} (46.17)	39.24^{g} (40.03)	3.29^{i} (10.33)
15	Spiromesifen 240 SC	0.0192	5.18^{bc} (26.33)	20.45^{bc} (12.27)	6.07^{c} (36.33)	26.03^{c} (19.28)	7.18^{bc} (51.00)	23.88^{bc} (16.41)	7.84^{ef} (61.00)	25.60^{e} (18.67)	8.22^{cd} (67.00)	21.11^{cd} (13.00)	5.99^{d} (35.33)
16	Thiamethoxam 25 WG	0.010	5.34^{ab} (28.00)	14.97^{a} (6.67)	6.36^{b} (40.00)	19.47^{a} (11.00)	7.71^{a} (59.00)	10.22^{a} (3.30)	8.46^{b} (71.00)	13.31^{a} (5.33)	8.63^{ab} (74.00)	11.38^{a} (3.90)	8.27^{ab} (68.00)
17	Control	-	5.52^{a} (30.00)	-	6.75^{a} (45.00)	-	7.84^{a} (61.00)	-	8.69^{a} (75.00)	-	8.80^{a} (77.00)	-	8.55^{a} (72.67)
	SEm±		0.09	1.17	0.09	1.14	0.09	1.11	0.07	0.78	0.10	1.06	0.15
	CD at 5%		0.26	3.38	0.26	3.28	0.27	3.18	0.21	2.25	0.29	3.05	0.43
	CV(%)		3.42	5.97	2.94	5.49	2.47	5.85	1.75	4.07	2.33	6.01	4.89

*Figures are √(X+0.5) transformed values; **Figures are angular transformed values; Figures inside the parentheses are original values DAI – Days After Inoculation
Treatment mean with the same letter(s) are at par to each other.