The Pharma Innovation Journal 2023; 12(1): 2285-2290

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(1): 2285-2290

www.thepharmajournal.com
Received: 09-10-2022
Accepted: 12-11-2022

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# Management of Citrus blackfly through different insecticides and their effect on natural enemies

**KP Jivrag, BV Patil, NB Wadhekar, SG Pavhane and JL Savalkar**

**Abstract**
The field experiment was conducted to evaluate the efficacy of different treatments against Citrus blackfly (*Aleurocanthus woglumi*) and their impact on natural enemies at Sweet orange orchard of Nimkheda village district Aurangabad under the guidance of Research Guide, Department of Agricultural Entomology, College of Agriculture, Badnapur during *Mrig bahar*, 2020. The results indicated that the treatment of Flonicamid 50% WG was found to be most effective treatment in minimizing the blackfly population followed by Spinosad 45% SC and Spinetoram 11.7% SC. The treatments of Clothianidin 50% WDG, Imidacloprid 17.8% SL and Novaluron 10% EC found less effective. In case of natural enemies, all insecticides were found to be safe to relatively safe, with the exception of Novaluron 10% EC**.** The highest sweet orange yield (12.8 t/ ha) was obtained from trees treated with Flonicamid 50 WG @ 2.5 g/ 10 L. The maximum ICBR ratio was acquired from Clothianidin 50% WDG @ 0.8 g/10 L and recorded 1:27.61, while the lowest ICBR ratio was obtained from Novaluron 10% EC at 10 ml/10 L and recorded (1:2.20).

**Keywords:** Management, blackfly, sweet orange, flonicamid 50% WG, treatment

## 1. Introduction
Sweet orange (*Citrus sinesis* L. Osbeck) is the second most popular and lucrative crop in the Citrus group and it is cultivated all over the world. It is grown mainly in Brazil, China, Japan, Turkey and India. In India, the primary Sweet Orange growing states are Andhra Pradesh, Maharashtra, Karnataka, Punjab, Rajasthan and Haryana. In India, the area under Sweet Orange cultivation is 184.6 thousand ha with a production of 3265.8 thousand MT and a productivity of 6.1 MT/ha. (Anonymous, 2018) [1].

Citrus blackfly (*Aleurocanthus woglumi*) a whitefly species have native of Southeast Asia. Citrus blackfly is considered as a significant pest of citrus crop and called as blackfly because of its slate-blue colour. Citrus blackfly is considered an important agricultural insect in numerous nations because of the economic losses it causes (Batista *et al*., 2007) [2]. It has around 300 host plants (Oliveira *et al*., 1999) [9], with citrus being the most preferred host for population development (Nguyen and Hamon, 1993) [8]. Citrus blackfly causes damage by sucking cell sap from the phloem, depleting nutrients and perhaps disabling the plant by injecting toxic saliva (Silva *et al*., 2011) [13]. It excretes sugary honeydew, which coats the leaf and fruit surface and promotes the growth of saprophytic fungus such as sooty mould (*Capnodium citri* Berk and Desm) (Oliveira *et al*., 1999) [9]. Because this fungus grows thick and dark on the leaves, it hinders respiration and photosynthesis. A heavy infestation can cause rapid plant degradation and yield reduction (Fasulo and Brooks, 1993) [5]. Fruit set is substantially diminished, with *A. woglumi* causing losses of up to 80% or more (Eberling, 1954, Yamamoto *et al*., 2008) [4, 16]. *Aleurocanthus woglumi* causes Orange Kolshi disease (Rajak and Diwakar, 1987). 5 to 10 nymphs per square centimeter are sufficient to lower nitrogen levels below the 2.2% required for orange fruit growth (Bhut and Jethva, 2017) [3].

To address this problem of fruit quality deterioration caused by Citrus blackfly, it is necessary to develop eco-friendly management of this pest with the conservation their natural enemies. The use of insecticide is the most popular method of pest control among other methods for a farmer. Hence it is decided that to study the bio efficiency of different insecticide against blackfly and their effect on natural enemies.

## 2. Material and Methods
The field trial was carried out to study the efficacy of different treatments against Citrus blackfly and their impact on natural enemies during Mrig bahar, 2020 on sweet orange orchard

of Nimkheda village under the guidance of Research guide, Department of Agricultural Entomology, College of agriculture, Badnapur. Six year old severely infested orchard of sweet orange with the variety of Nucellar was selected. The spacing between trees was 6 x 6 m. Randomized block design (RBD) was made for study. In this experiment, 7 treatments including untreated control were imposed in three replications. Three rows of 7 plants were selected from an already established orchard of sweet orange. Observations on Citrus blackfly (nymph & adult) and population of their predators e.g. lady bird beetle, *Chrysopa* etc. (grubs & adults) was recorded from five randomly selected tender terminal twigs of 15cm length of each plant at one day before and 3, 7, 10 and 14 days after each spraying to study the efficacy of different insecticides against Citrus blackfly and safety of their predators. The first spray was imposed observing the ETL level of the pests and need based sprayings were imposed till the final harvest of the crop (at 15 days interval) (Bhut and Jethva, 2017) [3]. The data generated was transformed in to square root values which were subjected to the applicable statistical analysis suggested by Gomez & Gomez (1984) [6]. The treatments details are as below.

**Table 1:** Treatments details

| Sr. No. | Name of Insecticide | Dose for 10 lit of water |
|---|---|---|
| 1. | Spinetoram 11.7% SC | 3 ml |
| 2. | Spinosad 45% SC | 2.5 ml |
| 3. | Novaluron 10% EC | 10 ml |
| 4. | Clothianidin 50% WDG | 0.8 g |
| 5. | Flonicamid 50% WG | 2.5 g |
| 6. | Imidacloprid 17.8% SL | 2.5 ml |
| 7. | Untreated control | - |

## 3. Results and discussion

The observation on citrus blackfly and their predators were recorded one day before spraying and 3, 7, 10 and 14 days after each spraying and their mean were calculated. The total four spraying were taken to observe the efficacy of different treatment against blackfly and safety of their predators. The results of the experiment are discussed as follows.

### 3.1 Efficacy of different insecticide against blackfly after first spraying

#### 3.1.1 One day before first spraying

The data presented in Table 2 showed that the population of citrus blackfly one day before the first spray was evenly distributed throughout all treatment plots.

#### 3.1.2 After first spraying

The data on mean of 3, 7, 10 and 14 days of blackfly population recorded after first spraying presented in Table 2 indicated that all the treatments were significantly superior over the untreated control. The lowest population of blackfly was recorded with the treatment of Flonicamid 50% WG ($T_5$) @ 2.5 g/10 L (9.48 blackfly/twig) and proved as a superior treatment. The treatment of Spinosad 45% SC ($T_2$) @ 2.5 ml/10 L (10.18 blackfly/twig), Spinetoram 11.7% SC ($T_1$) @ 3 ml/10 L (12.06 blackfly/twig) and Clothianidin 50% WDG ($T_4$) @ 0.8 g/10 L (14.15 blackfly/twig) was at par with superior treatment ($T_5$). The treatment with Imidacloprid 17.8% SL ($T_6$) @ 2.5 ml/10 L (14.55 blackfly/twig) was second-best treatment and significantly superior over control followed by Novaluron 10% EC ($T_3$) @ 10 ml/10 L (16.62 blackfly/twig). The maximum population recorded by untreated check (27.67 blackfly/twig).

#### 3.1.3 After second spraying

It can been seen from mean data presented in Table 2 showed that the treatment with Flonicamid 50% WG ($T_5$) @ 2.5 g/10 L was superior after second spray (7.56 blackfly/twig) over control followed by Spinosad 45% SC ($T_2$) @ 2.5 ml/10 L (9.37 blackfly/twig) and Spinetoram 11.7% SC ($T_1$) @ 3 ml/10 L (10.41 blackfly/twig) and remain at par with $T_5$. The next best effective treatment were Imidacloprid 17.8% SL ($T_6$) @ 2.5 ml/10 L (12.48 blackfly/twig) followed by Clothianidin 50% WDG ($T_4$) @ 0.8 g/10 L (12.51 blackfly/twig) and Novaluron 10% EC ($T_3$) @ 10% ml/10 L (13.07 blackfly/twig). Control plant population was highest (23.35 blackfly/twig) among all the treatment.

#### 3.1.4 After third spraying

Observation recorded on citrus blackfly after third spray presented in Table 3 mean showed all the treatment were significantly superior over untreated control. The treatment of Flonicamid 50% WG ($T_5$) @ 2.5 g/10 L was emerged as superior treatment (6.95 blackfly/twig) over other treatments followed by Spinosad 45% SC ($T_2$) @ 2.5 ml/10 L (8.58 blackfly/twig) and Spinetoram 11.7% SC ($T_1$) @ 3 ml/10 L (9.70 blackfly/twig) were also significantly superior over control and at par with $T_5$. The treatment of Clothianidin 50% WDG ($T_4$) @ 0.8 g/10 L (11.37 blackfly/twig) was found next effective treatment and significantly superior over control followed by Imidacloprid 17.8% SL ($T_6$) @ 2.5 ml/10 L (12.12 blackfly/twig) and Novaluron 10% EC ($T_3$) @ 10 ml/10 L (12.57 blackfly/twig). Untreated control check recorded maximum population of blackfly (20.55 blackfly/twig).

#### 3.1.5 After fourth spraying

The mean data recorded after fourth spray presented in Table 3 showed that all treatments played significant role in minimizing the blackfly population. The treatment of Flonicamid 50% WG (T5) @ 2.5 g/10 L once again proved to be significantly superior (7.40 blackfly/twig) over control followed by Spinosad 45% SC (T2) @ 2.5 ml/10 L (7.77 blackfly/twig), Spinetoram 11.7% SC (T1) @ 3 ml/10 L (10.10 blackfly/twig) and Clothianidin 50% WDG (T4) @ 0.8 g/10 L (11.42 blackfly/twig) were also registered their efficacy over control and at par with T5. The treatment of Imidacloprid 17.8% SL (T6) @ 2.5 ml/10 L (12.27 blackfly/twig) was second best treatment and significantly superior over control followed by Novaluron 10% EC (T3) @ 10 ml/10 L (12.55 blackfly/twig). Control check population was highest (18.96 blackfly/twig) among all the treatments.

The present study supported by findings of earlier workers Karabhantanal (2018) [7] who reported that Flonicamid 50% WG @ 0.25 ml/l was found to be superior in reducing the blackfly population followed by imidacloprid 17.8% SL @ 0.30ml/l. Bhut and Jethva (2017) [3] indicated that the lowest number of blackfly per leaves was observed in the treatment of spinosad 45% SC 0.0072% and Imidacloprid 17.8% SL 0.0072% whereas, Novaluron 10% EC@ 0.01% found least effective.

### 3.2 Effect of different insecticides on ladybird beetle (LBB)

#### 3.2.1 After first spray

Effect of insecticides on ladybird beetle population presented in Table 4 after first spray. The mean data indicated that the highest population of ladybird was noted in control check ($T_7$), (1.60 LBB/twig) followed by Spinetoram 11.7% SC ($T_1$) @ 3 ml /10 L (1.20 LBB/ twig), Spinosad 45% SC ($T_2$) @ 2.5 ml / 10 L (1.10 LBB/twig), Flonicamid 50% WG ($T_5$) @ 2.5gm/ 10 L (1.08 LBB/twig) and Imidacloprid 17.8% SL ($T_6$) @ 2.5 ml/ 10 L (0.93 LBB/ twig). The treatment Clothianidin 50% WDG ($T_4$) @ 2.5 ml/ 10 of water was proved to be second best treatment as it recorded 0.81 LBB/twig. The minimum population of the ladybird beetle was observed in Novaluron 10% EC ($T_3$) @ 10 ml / 10L which recorded (0.70 LBB/ twig).

#### 3.2.2 After second spray

The mean data presented in Table 4 revealed that population of ladybird beetle was showed significant differences among all treatment. The lowest population of Ladybird beetle noticed in Novaluron 10% EC ($T_3$) @ 10 ml / 10L (0.52 LBB/ twig). Whereas, control plot ($T_7$) recorded maximum no. of ladybird beetle (1.35 LBB/twig) and which were at par with Spinetoram 11.7% SC ($T_1$) @ 3 ml /10 L (1.10 LBB/twig), Spinosad 45% SC ($T_2$) @ 2.5 ml / 10 L (1.05 LBB/twig), Flonicamid 50% WG ($T_5$) @ 2.5gm / 10 L (1.02 LBB/twig), Imidacloprid 17.8% SL ($T_6$) @ 2.5 ml / 10 L (0.80 LBB/ twig) and Clothianidin 50% WDG ($T_4$) @ 2.5 ml / 10 (0.72 LBB/ twig).

#### 3.2.3 After third spray

The same trend of efficacy followed after third spray. The mean data presented in Table 4 revealed the lowest population of Ladybird beetle noticed in Novaluron 10% EC ($T_3$) @ 10 ml / 10L (0.60 LBB/ twig). Whereas, control plot ($T_7$) recorded maximum number of ladybird beetle (1.33 LBB/twig) and which were at par with Spinetoram 11.7% SC ($T_1$) @ 3 ml /10 L (1.13 LBB/twig), Spinosad 45% SC ($T_2$) @ 2.5 ml / 10 L (1.10 LBB/twig), Flonicamid 50% WG ($T_5$) @ 2.5gm / 10 L (1.01 LBB/twig), Imidacloprid 17.8% SL ($T_6$) @ 2.5 ml / 10 L (0.80 LBB/ twig) and Clothianidin 50% WDG ($T_4$) @ 2.5 ml / 10 (0.75 LBB/ twig).

#### 3.2.4 After fourth spray

Data collected after fourth spray showed that there were no statistically significant changes between the treatments. The average number of ladybird beetles per twig ranged between 0.60 to 1.18.

The present findings are in conformity with earlier work carried out by Wagh *et al.* (2017) who reported that the effect of spinosad 45% SC @ 125 g a.i. /ha and Novaluron 10% EC @ 75 g a.i. /ha (1.51) on the natural enemy, were found safer to the predatory *Coccinellids*. Sumalatha *et al.* (2017) reported that the treatment of flonicamid 50% SG @ 75 g a.i. ha-1 and Spinosad 45% SC @ 73 g a.i. ha-1 were found promising regarding its safety to predators. Patil (2017) [10] reported that treatment with Spinetoram 12% SC @ 36 g a.i./ha recorded maximum population of predators of *Coccinellids*. The next better treatments were spinosad 45% SC @ 112.5 g a.i./ha.

### 3.3 Effect of different insecticides on Green lacewing (*Chrysopa*)

#### 3.3.1 After first spray

The mean data recorded after first spray presented in Table 4 revealed that, untreated control ($T_7$) (0.82 Chrysopa /twig) was significantly superior and at par with following treatments Spinetoram 11.7% SC ($T_1$) @ 3 ml /10 L (0.55 Chrysopa/twig), Spinosad 45% SC ($T_2$) @ 2.5 ml/ 10 L (0.52 Chrysopa/twig), Flonicamid 50% WG ($T_5$) @ 2.5gm/ 10 L (0.48 Chrysopa/twig) and Imidacloprid 17.8% SL ($T_6$) @ 2.5 ml/ 10 L (0.45 Chrysopa/twig) and proved safer to moderately safer. Among rest of treatment Clothianidin 50% WDG ($T_4$) @ 2.5 ml/10 was proved to be second best treatment as it recorded (0.93 Chrysopa/twig). The treatment of Novaluron 10% EC ($T_3$) @ 10 ml/ 10 L recorded lowest population (0.90 Chrysopa/twig) of Chrysopa.

#### 3.3.2 After second spray

After second insecticidal application, the higher population of Chrysopa was noted in control tree ($T_7$), (0.83 Chrysopa/twig) followed by Spinetoram 11.7% SC ($T_1$) @ 3 ml/10 L (0.60 Chrysopa/twig), Spinosad 45% SC ($T_2$) @ 2.5 ml/ 10 L (0.57 Chrysopa/twig), Flonicamid 50% WG ($T_5$) @ 2.5gm/ 10 L (0.51 Chrysopa/twig), Imidacloprid 17.8% SL ($T_6$) @ 2.5 ml/ 10 L (0.47 Chrysopa/twig) and Clothianidin 50% WDG ($T_4$) @ 2.5 ml/ 10 L (0.42 Chrysopa/twig). The minimum population of the Chrysopa was observed in Novaluron 10% EC ($T_3$) @ 10 ml/ 10 L which recorded (0.33 Chrysopa/twig).

#### 3.3.3 After third Spray

Data recorded after third spray presented in Table 4 revealed that control plot ($T_7$) (0.75 Chrysopa/twig) proved to be significantly superior over other treatments and at par with following treatments Spinetoram 11.7% SC ($T_1$) @ 3 ml /10 L (0.56 Chrysopa/twig), Flonicamid 50% WG ($T_5$) @ 2.5gm/ 10 L (0.51 Chrysopa/twig), Spinosad 45% SC ($T_2$) @ 2.5 ml/ 10 L (0.48 Chrysopa/twig), Imidacloprid 17.8% SL ($T_6$) @ 2.5 ml / 10 L (0.38 Chrysopa/twig) and Clothianidin 50% WDG ($T_4$) @ 2.5 ml/ 10 (0.32 Chrysopa/twig). Whereas lowest population of Chrysopa was observed in Novaluron 10% EC ($T_3$) @ 10 ml/ 10L (0.28 Chrysopa/twig)

#### 3.3.4 After fourth spray

Data reported after fourth spray presented in Table 4 revealed that there was non-significant variation among all insecticides on Chrysopa. The average no. of Chrysopa varies from 0.26 to 0.66 Chrysopa/twig.

Present findings were agreement with the findings of Patil (2017) [10] who revealed that maximum population of predators of Mallada recorded with the treatment of Spinetoram 12% SC @ 36 g a.i./ha followed by Spinosad 45% SC @ 112.5 g a.i./ha. Seal *et al.* (2006) [12] who reported that Spinosad 45% SC @ 200ml/ha were proved to be safe to *Chrysoperla carnea* eggs showing 93.3% hatchability.

### 3.4 Yield

The data concerning with yield of Sweet orange which has been displayed in the following Table 5 revealed that all insecticide treatments recorded significantly higher yield over untreated control. The yield of sweet orange in the differently treated plants was observed in the range of 9.11 to 12.80 t/ha. Among all the treatments, Flonicamid 50% WG ($T_5$) @ 2.5 g/10 L recorded maximum yield as compare to the rest of the

treatments. The treatment with Spinosad 45% SC ($T_2$) @ 3 ml/10 L, Spinetoram 11.7% SC ($T_1$) @ 3 ml/10 L, Clothianidin 50% WDG ($T_4$) @ 0.8 g/10 L, Imidacloprid 17.8% SL ($T_6$) @ 2.5 ml/10 L and Novaluron 10% EC ($T_3$) @ 10 ml/10 L were also recorded at par with $T_5$. The lowest yield recorded by control (9.11 t/ha).

In the present studies, the application of Flonicamid was found to be promising over control in getting highest yields. This finding was closely related with the finding of Karabhantanal (2018) [7] recorded highest Acid lime yield and net profit (240.05 q/ha and Rs. 468485/ha) in two year (2015-16 and 2016- 17 with Flonicamid 50% SG @ 0.25ml/l.

**Table 2:** Population of blackfly in Citrus after first and second spraying

| Tr. No. | Treatments | Dose / 10 L | Average no. of blackfly/twig after 1st spray | | | | | | Average no. of blackfly/twig after 2nd spray | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 DBS | 3 DAS | 7 DAS | 10 DAS | 14 DAS | Mean | 3 DAS | 7 DAS | 10 DAS | 14 DAS | Mean |
| $T_1$ | Spinetoram 11.7% SC | 3ml | 27.47 (5.26) | 13.73 (3.77) | 10.60 (3.32) | 11.33 (3.44) | 12.60 (3.60) | 12.06 (3.53) | 9.00 (3.07) | 8.93 (3.06) | 11.53 (3.46) | 12.20 ( 3.55) | 10.41 (3.28) |
| $T_2$ | Spinosad 45% SC | 2.5ml | 30.13 (5.53) | 9.60 (3.13) | 8.67 (3.00) | 9.40 (3.13) | 13.07 (3.68) | 10.18 (3.23) | 10.47 (3.30) | 8.40 (2.97) | 7.73 (2.83) | 10.87 (3.36) | 9.37 (3.11) |
| $T_3$ | Novaluron 10% EC | 10ml | 27.33 (5.26) | 19.13 (4.42) | 14.27 (3.84) | 15.40 (3.93) | 17.67 (4.24) | 16.62 (4.11) | 12.20 (3.55) | 11.60 (3.47) | 13.27 (3.68) | 15.20 (3.93) | 13.07 (3.66) |
| $T_4$ | Clothianidin 50% WDG | 0.8g | 23.73 (4.90) | 13.80 (3.78) | 12.53 (3.60) | 14.20 (3.83) | 16.07 (4.07) | 14.15 (3.82) | 11.13 (3.40) | 11.73 (3.48) | 11.93 (3.52) | 15.27 (3.97) | 12.51 (3.59) |
| $T_5$ | Flonicamid 50% WG | 2.5g | 23.80 (4.91) | 10.20 (3.25) | 8.27 (2.91) | 8.93 (3.07) | 10.53 (3.31) | 9.48 (3.13) | 6.53 (2.65) | 6.40 (2.62) | 8.00 (2.91) | 9.33 (3.13) | 7.56 (2.83) |
| $T_6$ | Imidacloprid 17.8% SL | 2.5ml | 26.67 (5.19) | 14.27 (3.83) | 13.20 (3.70) | 14.47 (3.87) | 16.27 (4.09) | 14.55 (3.87) | 12.00 (3.51) | 11.07 (3.39) | 12.80 (3.64) | 14.07 (3.81) | 12.48 (3.58) |
| $T_7$ | Untreated check | — | 26.53 (5.19) | 28.67 (5.39) | 28.73 (5.40) | 29.40 (5.45) | 23.87 (4.91) | 27.67 (5.29) | 24.27 (4.96) | 23.80 (4.91) | 22.60 (4.80) | 22.73 (4.79) | 23.35 (4.86) |
| | SE (m) ± | | 0.30 | 0.20 | 0.22 | 0.24 | 0.24 | 0.22 | 0.20 | 0.22 | 0.22 | 0.25 | 0.22 |
| | CD at 5% | | NS | 0.63 | 0.70 | 0.75 | 0.74 | 0.70 | 0.64 | 0.68 | 0.70 | 0.79 | 0.70 |
| | CV (%) | | 10.27 | 9.12 | 10.78 | 11.06 | 10.47 | 10.36 | 10.31 | 11.22 | 11.10 | 11.79 | 11.10 |

*Figures in parenthesis are $\sqrt{x+0.5}$ transformed values. (DBS- day before spraying, DAS- days after spraying).

**Table 3:** Population of blackfly in Citrus after third and fourth spraying

| Tr. No. | Treatments | Dose / 10 L | Average no. of blackfly/twig after 3rd spray | | | | | Average no. of blackfly/twig after 4th spray | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 3 DAS | 7 DAS | 10 DAS | 14 DAS | Mean | 3 DAS | 7 DAS | 10 DAS | 14 DAS | Mean |
| $T_1$ | Spinetoram 11.7% SC | 3ml | 7.67 (2.84) | 10.07 (3.24) | 10.47 (3.29) | 10.60 (3.33) | 9.70 (3.17) | 9.60 (3.18) | 9.53 (3.16) | 10.53 (3.30) | 10.73 (3.35) | 10.10 (3.25) |
| $T_2$ | Spinosad 45% SC | 2.5ml | 8.47 (2.97) | 8.40 (2.97) | 8.67 (3.02) | 8.80 (3.02) | 8.58 (2.99) | 6.80 (2.70) | 6.73 (2.68) | 8.67 (3.02) | 8.87 (3.03) | 7.77 (2.86) |
| $T_3$ | Novaluron 10% EC | 10ml | 12.47 (3.59) | 12.07 (3.53) | 12.40 (3.58) | 13.33 (3.70) | 12.57 (3.60) | 12.40 (3.58) | 12.33 (3.57) | 12.47 (3.59) | 13.00 (3.66) | 12.55 (3.60) |
| $T_4$ | Clothianidin 50% WDG | 0.8g | 11.47 (3.45) | 9.07 (3.07) | 12.27 (3.56) | 12.67 (3.62) | 11.37 (3.42) | 9.73 (3.19) | 11.20 (3.41) | 12.27 (3.56) | 12.47 (3.58) | 11.42 (3.43) |
| $T_5$ | Flonicamid 50% WG | 2.5g | 6.73 (2.68) | 6.47 (2.63) | 6.73 (2.68) | 7.87 (2.89) | 6.95 (2.72) | 8.47 (2.98) | 6.67 (2.68) | 6.80 (2.69) | 7.67 (2.85) | 7.40 (2.80) |
| $T_6$ | Imidacloprid 17.8% SL | 2.5ml | 12.20 (3.54) | 11.80 (3.50) | 12.07 (3.52) | 12.40 (3.58) | 12.12 (3.53) | 12.27 (3.57) | 12.00 (3.52) | 12.20 (3.55) | 12.60 (3.61) | 12.27 (3.56) |
| $T_7$ | Untreated check | — | 21.40 (4.67) | 19.40 (4.44) | 21.00 (4.61) | 20.40 (4.55) | 20.55 (4.57) | 19.73 (4.47) | 19.73 (4.47) | 18.40 (4.33) | 18.00 (4.27) | 18.96 (4.38) |
| | SE(m) ± | | 0.21 | 0.22 | 0.24 | 0.22 | 0.22 | 0.20 | 0.23 | 0.22 | 0.26 | 0.23 |
| | CD at 5% | | 0.65 | 0.68 | 0.74 | 0.69 | 0.69 | 0.62 | 0.72 | 0.70 | 0.80 | 0.71 |
| | CV (%) | | 10.82 | 11.48 | 12.10 | 11.14 | 11.38 | 10.31 | 12.06 | 11.57 | 13.00 | 11.73 |

*Figures in parenthesis are $\sqrt{x+0.5}$ transformed values. (DBS- day before spraying, DAS- days after spraying)

**Table 4:** Population of ladybird beetle and Chrysoperla in Citrus after spraying

| Tr. No. | Treatments | Dose / 10 L | Average no. of Ladybird beetle/twig after | | | | | Average no. of *Chrysoperla*/twig after | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Pre count | 1st Spray | 2nd Spray | 3rd Spray | 4th Spray | Pre count | 1st Spray | 2nd Spray | 3rd Spray | 4th Spray |
| $T_1$ | Spinetoram 11.7% SC | 3ml | 1.47 (1.38) | 1.20 (1.30) | 1.10 (1.26) | 1.13 (1.27) | 1.11 (1.26) | 0.80 (1.14) | 0.55 (1.02) | 0.60 (1.04) | 0.56 (1.03) | 0.53 (1.01) |
| $T_2$ | Spinosad 45% SC | 2.5ml | 1.27 (1.22) | 1.10 (1.26) | 1.05 (1.23) | 1.10 (1.25) | 1.03 (1.23) | 0.80 (1.14) | 0.52 (1.00) | 0.57 (1.03) | 0.48 (0.98) | 0.51 (1.00) |
| $T_3$ | Novaluron 10% EC | 10ml | 1.00 (1.10) | 0.70 (1.09) | 0.52 (1.00) | 0.60 (1.05) | 0.60 (1.05) | 0.53 (1.01) | 0.32 (0.90) | 0.33 (0.91) | 0.28 (0.88) | 0.26 (0.87) |
| $T_4$ | Clothianidin 50% WDG | 0.8g | 1.20 (1.30) | 0.82 (1.14) | 0.72 (1.09) | 0.75 (1.11) | 0.78 (1.13) | 0.60 (1.05) | 0.38 (0.93) | 0.42 (0.95) | 0.32 (0.90) | 0.38 (0.94) |
| $T_5$ | Flonicamid 50% WG | 2.5g | 1.33 (1.35) | 1.08 (1.25) | 1.02 (1.22) | 1.07 (1.24) | 0.98 (1.21) | 0.87 (1.16) | 0.48 (0.98) | 0.51 (1.00) | 0.51 (1.00) | 0.47 (0.98) |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $T_6$ | Imidacloprid 17.8% SL | 2.5ml | 1.33 (1.35) | 0.93 (1.19) | 0.80 (1.13) | 0.80 (1.13) | 0.70 (1.09) | 0.87 (1.16) | 0.45 (0.97) | 0.47 (0.98) | 0.38 (0.93) | 0.37 (0.92) |
| $T_7$ | Untreated check | — | 1.47 (1.40) | 1.60 (1.44) | 1.35 (1.35) | 1.33 (1.35) | 1.18 (1.29) | 0.80 (1.14) | 0.82 (1.14) | 0.83 (1.14) | 0.75 (1.11) | 0.66 (1.06) |
| | SE (m) ± | | 0.08 | 0.08 | 0.08 | 0.08 | 0.09 | 0.07 | 0.06 | 0.06 | 0.06 | 0.07 |
| | CD at 5% | | NS | 0.26 | 0.27 | 0.27 | NS | NS | 0.20 | 0.22 | 0.22 | NS |
| | CV (%) | | 11.51 | 11.94 | 13.01 | 12.76 | 13.60 | 11.87 | 11.61 | 12.20 | 12.86 | 13.13 |

*Figures in parenthesis are $\sqrt{x+0.5}$ transformed values.

**Table 5:** Enhancement of yield in Sweet Orange with various insecticides

| Tr. No. | Treatments | Dose/ 10 L | Avg. 1tree yield Kg/ treatment | Yield Tonne/ ha |
|---|---|---|---|---|
| $T_1$ | Spinetoram 11.7% SC | 3ml | 44.63 | 12.30 |
| $T_2$ | Spinosad 45% SC | 2.5ml | 45.29 | 12.50 |
| $T_3$ | Novaluron 10% EC | 10ml | 38.13 | 10.60 |
| $T_4$ | Clothianidin 50% WDG | 0.8g | 42.74 | 11.80 |
| $T_5$ | Flonicamid 50% WG | 2.5g | 46.25 | 12.80 |
| $T_6$ | Imidacloprid 17.8% SL | 2.5ml | 41.48 | 11.50 |
| $T_7$ | Untreated check | — | 33.05 | 9.11 |
| | SE (m) ± | | 2.72 | 0.75 |
| | CD at 5% | | 8.40 | 2.32 |
| | CV (%) | | 11.34 | 11.35 |

### 3.5 Incremental cost benefit ratio (ICBR) of Sweet orange with different insecticidal application.

According to the data presented in Table 6 in respect of (ICBR) revealed that the all the treatments recorded satisfactory incremental cost-benefit ratio. The highest incremental cost benefit ratio (ICBR) (1:27.61) recorded in Clothianidin 50% WDG ($T_4$) @ 0.8 g/10 L Whereas, the next treatments in order of ICBR were Imidacloprid 17.8% SL ($T_6$) @ 2.5 ml/10 L (1: 18.28), Flonicamid 50% WG ($T_5$) @ 2.5 g/10L (1:11.72), Spinetoram 11.7% SC ($T_1$) @ 3 ml/10 L (1: 8.05) and spinosad 45% SC ($T_2$) @ 3 ml/10L (1:4.06). Novaluron 10% EC ($T_3$) @ 10 ml/10 L of water (1: 2.20) recorded comparatively less ICBR as the insecticides was more costly as compare to other insecticides.

## 4. Conclusion

It was concluded that Flonicamid 50% WG ($T_5$) @ 2.5 g/10 L, Spinosad 45% SC ($T_2$) @ 3 ml/10 L & Spinetoram 11.7% SC ($T_1$) @ 2.5 ml/10 L was found effective against major sucking pests of Citrus. Spinetoram 11.7% SC ($T_1$), Spinosad 45% SC ($T_2$) @ 3 ml/10 L & Flonicamid 50% WG ($T_5$) @ 2.5 g/10L was found to be safe and remaining insecticides moderately safe to natural enemies. Among the newer insecticides used maximum net profit was obtained from Flonicamid 50% WG ($T_5$) @ 2.5 g/10 L followed by Spinetoram 11.7% SC @ 3 ml/10 L, Clothianidin 50% WDG ($T_4$) @ 0.8 g/10 L whereas the most economical treatment was Clothianidin 50% WDG ($T_4$) @ 0.8 g/10 L followed by Imidacloprid 17.8% SL ($T_6$) @ 2.5 ml/10L.

**Table 6:** ICBR (Incremental Cost Benefit Ratio of Sweet orange with different insecticide application) Avg. Market price of Sweet Orange: 23 Rs/kg.

| Tr. No. | Treatments | Dose/10 L. Water | Total Fruit Yield Tonne/ha. | Increase in Yield Over Control Tonne/ha. | Qty. of chemical required for four spray | Insecticide cost for four spray (Cost - A) (Rs./Ha) | Labour charge (Cost-B) | Total Cost | Value of additional yield over untreated control (Rs./ha) | Net Profit (Rs./ha) | ICBR | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $T_1$ | Spinetoram 11.7% SC | 3 ml | 12.30 | 3.19 | 1108 ml | 8310 | 800 | 9110 | 73370 | 64260 | 8.05 | IV |
| $T_2$ | Spinosad 45% SC | 2.5 ml | 12.50 | 3.39 | 919.64 ml | 18392.8 | 800 | 19192.8 | 77970 | 58777.2 | 4.06 | V |
| $T_3$ | Novaluron 10% EC | 10 ml | 10.60 | 1.49 | 3692.4 ml | 14769.6 | 800 | 15569.6 | 34270 | 18700.4 | 2.20 | VI |
| $T_4$ | Clothianidin 50% WDG | 0.8 g | 11.80 | 2.69 | 288.08 g | 1440.4 | 800 | 2240.4 | 61870 | 59629.6 | 27.61 | I |
| $T_5$ | Flonicamid 50% WG | 2.5 g | 12.80 | 3.69 | 919.64 g | 6437.48 | 800 | 7237.48 | 84870 | 77632.52 | 11.72 | III |
| $T_6$ | Imidacloprid 17.8% SL | 2.5 ml | 11.50 | 2.39 | 919.64 ml | 2207.1 | 800 | 3007.1 | 54970 | 51962.9 | 18.28 | II |
| $T_7$ | Untreated control | – | 9.11 | – | – | – | – | – | – | – | – | – |

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