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Impact of chemical insecticides used for management of mulberry thrips on silkworm rearing performance

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Abstract

A field experiment was conducted during 2021, at Gandhi Krishi Vigyan Kendra, UAS Bengaluru, to know the Effect of chemical insecticides used for management of mulberry thrips on silkworm rearing performance. The experiment was planned in Randomized Complete Block Design (RCBD) with 7 treatments T₁: Acephate 75 SP, T₂: Acetamiprid 20 SP, T₃: Dimethoate 30 EC, T₄: Fipronil 5 SC, T₅: Imidacloprid 17.8 SC, T₆: Dichlorvos 76 EC (std check) and T₇: Control (water spray). It was recorded that Fipronil 5 SC @ 2 ml/l and Imidacloprid 17.8 SC @ 0.3 ml/l were found safer to silkworms 15 DAS and exhibited better rearing and reeling parameters. On contrary though Acetamiprid 20 SP @ 0.2 g/l and Acephate 75 SP @ 1 g/l were effective against thrips but had negative impact on silkworm rearing.

Keywords: Chemical insecticides used, mulberry thrips, silkworm rearing performance

Introduction

Sericulture is an integral part of the rural economy in India. It is remunerative and rural welfare oriented agro-based industry, which is highly labour intensive. In the global context, China is the largest silk producing country which is followed by India. India has the uniqueness of being the only country in the world to produce all four types of commercial silks. Mulberry is the only source of food for the silkworm, *Bombyx mori* L. The production of quality mulberry leaves is based on several factors such as cultivation practices, variety, biotic and abiotic factors (Krishnaswami *et al.* 1970) [1].

The production of good quality leaves in required quantity is influenced by pests (18%), diseases (24%), weeds (7%) and others (51%) (Govindaiah *et al.* 2005) [8].

Amongst the sap suckers infesting mulberry, infestation by thrips is highest (42.55%) which results in 40-50 percent loss (Etebari *et al.* 1998) [5], which is followed by mealy bug, (20.80%), leaf hopper, 20.28 percent and scale insects, (1.65%) (Anonymous, 1993) [1]. Infestation of mulberry by thrips is at its peak during the months of February-May and lowers during June-July season as reported by Radha and Muthukrishnan (1980) [18]. In the traditional areas, since the silkworm rearing is practiced 4-5 times in a year, leaf production must be made at a faster rate maintaining both the qualitative as well as quantitative characters. To match the synchronized rearing schedules, farmers must maintain pest-free mulberry garden for which the methods suggested above are tedious, time consuming and unrealistic. So, the only alternative is to go for insecticidal spray as a measure of plant protection to control thrips and production of good quality as well as quantity of mulberry leaves. The selection of older chemicals in controlling the thrips is limited because of their long safety period to silkworms. The efficacy of new chemical insecticides with novel mode of action have dominated the scenario for controlling of sucking pests in other cultivated crops.

Dichlorvos 76 EC is the most commonly recommended insecticide against insect pests in mulberry. As per Government of India notification, dated 28th December 2016 dichlorvos 76 EC usage is to be completely banned from 31st December, 2020 (Anon., 2016) [2]. Therefore, it is need of the hour to explore the efficacy of new molecules of insecticides that are introduced during the recent past for management of thrips and to select the best insecticide among them as substitute for Dichlorvos 76 EC with minimum effect on silkworm rearing performance.

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Materials and Methods

The investigation on “Management of mulberry thrips through chemical insecticides and their effect on mulberry leaf yield” was conducted during 2020-21, at the Department of Sericulture, University of Agricultural Sciences, GKVK, Bengaluru. The experimental site is located in the Eastern Dry Zone (zone-5) of Karnataka at 12°58' N latitude and 77°35' E longitude and at an altitude of 930 m above mean sea level. The material used and methods adopted during the study are detailed below.

Table 1: Experiment details

Crop	Mulberry
Variety	Victory-1(V1)
Spacing	(90+150) *60 cm (paired row)
No. of treatments	7
No. of replications	3
Season	Summer 2021
Crop period	February-April 2021
Design	RCBD
Gross plot size	200.7m ²
Net plot size	116.4m ²

Table 2: Treatment details

Treatment No.	Treatment	Dosage
T ₁	Acephate 75 SP	1.00 g/l
T ₂	Acetamiprid 20 SP	0.20 g/l
T ₃	Dimethoate 30 EC	2.00 ml/l
T ₄	Fipronil 5 SC	2.00 ml/l
T ₅	Imidacloprid 17.8 SC	0.30 ml/l
T ₆	Dichlorvos 76 EC (std check)	2.63 ml/l
T ₇	Control (water spray)	-

3. Observations Recorded

a) **Larval duration (days/instar):** The interval between two moults is known as larval duration. The duration between previous moult to next moult was recorded in each instar in days.

b) **Larval mortality (%):** The larval mortality was calculated for all three replications in each treatment by using the formula

$$\text{Larval mortality (\%)} = \frac{\text{Number of dead larvae}}{\text{Total number of worms per treatment}} \times 100$$

c) **Larval weight (g):** Weight of ten randomly picked silkworms of third, fourth and fifth instar prior to moult was taken per replication and the average of the same was calculated.

d) **Larval mortality (in each instar):** Mortality of the larvae due to toxic effect of insecticides and mortality due to diseases in each replication were observed and recorded.

e) **Effective rate of rearing (%):** The total number of cocoons harvested from each replication at the end of rearing were recorded and the ERR was calculated by using the formula.

$$\text{ERR (\%)} = \frac{\text{Number of cocoons harvested}}{\text{Number of larvae brushed}} \times 100$$

f) **Cocooning percent**

$$\text{CP (\%)} = \frac{\text{Number of cocoons formed}}{\text{Total number of larvae kept for cocooning}} \times 100$$

g) **Cocoon weight (g):** Randomly selected ten cocoons from each replication were weighed and recorded on the fifth day of spinning.

h) **Pupal weight (g):** Weighed cocoons were cut and pupae were weighed and average was calculated to obtain the mean pupal weight.

i) **Shell weight (g):** After taking cocoon weight and pupal weight, the same cocoon shells were weighed and the average was calculated to get the mean shell weight.

j) **Cocoon shell ratio (%):** Total quantity of silk available from a single cocoon indicates the cocoon shell ratio and is expressed as a percentage. It was calculated by using the following formula:

$$\text{Cocoon shell ratio} = \frac{\text{Single shell weight (g)}}{\text{Single cocoon weight (m)}} \times 100$$

k) **Silk filament length (m):** Three cocoons were randomly drawn from each treatment and were cooked in boiling water for two to three minutes to soften the sericin layer and were reeled on an epprouvette. Length of the silk filament was calculated by using the formula:

$$L = R \times 1.125 \text{ m}$$

Where,

L = Length of the silk filament (m)

R = Number of revolutions 1.125

m = Circumference of the Eupprovette

l) **Non-breakable filament length (cm):** It represents the average length of the filament from a cocoon that can be unwound without any breaks. It is calculated by the formula

$$\text{NBFL} = \frac{\text{filament length}}{1 + \text{Number of breaks}} \times 100$$

m) **Filament weight (g):** It can be obtained by weighing the reeled silk filament of each replication of each treatment. Six cocoons are reeled from each treatment and average is calculated to obtain average filament weight.

n) **Filament denier:** Denier was calculated by using the formula,

$$\text{Denier} = \frac{\text{Weight of silk filament (g)}}{\text{Length of silk filament (m)}} \times 9000$$

Results and Discussions

Effect of insecticide treated mulberry on silkworm rearing parameters

After the application of insecticides on mulberry, their effect on silkworms was studied. The mulberry leaves were harvested at 15 DAS and silkworms were fed on these harvested leaves from third instar till ripening. Rearing parameters viz., larval mortality (%), larval duration (hr), larval weight (g), ERR (%), cocooning (%), cocoon weight (g), pupal weight (g), cocoon shell weight (g) and cocoon shell ratio (%) was recorded. The findings of this study are discussed here under.

Effect of insecticides on silkworm larval mortality (%)

The larval mortality was recorded after feeding silkworms with mulberry leaves harvested 15 days after spraying. Mortality rates showed variation in each instar (3rd, 4th and

5th) among the treatments. In the 3rd instar T₂ (acetamiprid 20 SP @ 0.2 g/l) recorded highest mortality of 23.33 percent followed by T₁ (acephate 75 SP @ 1 g/l) (10%). However, in all other treatments viz., T₃ (dimethoate 30 EC @ 2 ml/l), T₄ (fipronil 5 SC @ 2 ml/l), T₅ (imidacloprid 17.8 SC @ 0.3 ml/l), T₆ (dichlorvos 76 EC @ 2.63 ml/l) and T₇ (control) (water spray) no larval mortality was recorded (Table 3).

In the 4th instar T₂ (acetamiprid 20 SP @ 0.2 g/l) recorded highest mortality of 13.33 percent followed by T₁ (acephate 75 SP @ 1 g/l) (7.78%). However, in all other treatments larval mortality was not observed (Table 3).

In the 5th instar T₂ (acetamiprid 20 SP @ 0.2 g/l) recorded highest mortality of 13.33 percent followed by T₁ (acephate 75 SP @ 1 g/l) (4.44%). However, in all other treatments larval mortality was not observed (Table 3). Though acetamiprid 20 SP @ 0.2 g/l and acephate 75 SP @ 1 g/l are selective feeding blocker specific to sucking insects with repellent action, it shows that silkworms have lower tolerance limit for these molecules.

In the present investigation, barring acetamiprid 20 SP @ 0.2 g/l and acephate 75 SP @ 1 g/l, all the new insecticide molecules were observed to be safe to silkworms, as toxicity was not noticed even as early as 15 DAS. This clearly suggests that silkworms were not affected adversely by these insecticide molecules. The new molecules that were tried in this study possess unique modes of action on different insects. They are more effective on homopteran insects including thrips and have limited action on biting & chewing type of insects. Probably, this is the reason for their safety to silkworm.

Similarly, Subramanian *et al.* (2010) [21] conducted a bio-assay with insecticide and botanical- treated leaves on silkworm (PM × CSR₂) and did not observe any mortality on 7th day for neem oil and pungam oil and on 10th day for dichlorvos. Triazophos and thiomethoxam were safe to silkworm after 15 days, whereas the safe period was on 20 days after spraying for acetamiprid. Mathiranjani and Raguraman (2013) [14] reported that, when silkworm larvae fed with spinosad 48 SC dipped mulberry leaves at 100g a.i., per hectare caused maximum (45%) mortality of silkworm larvae while other doses were found less toxic causing mortality (26.6% to 38.3%) at 72 hrs after treatment. Singh *et al.* (2008) [19] found that higher larval mortality was assessed when the silkworm *Bombyx mori* L. larvae fed with insecticide treated mulberry leaves. Avramova *et al.* (2012) [3] observed that the larvae fed with imidacloprid and thiamethoxam sprayed leaves showed symptoms like shortening of the body, swelling, down shaking of the head and vomiting of dark brown liquid. Maria *et al.* (2000) [13] studied the effect of buprofezin on the growth of silkworm and the results revealed that, the larvae fed on buprofezin leaves treated with three different concentrations (0.5, 1, 2 g/l) on the first day of each instar did not show any mortality. Yokoyama (1962) [22] reported that the application of insecticides on mulberry pests caused residual problems on leaves for a long time which in turn affected the silkworms.

Effect of chemical insecticides on larval duration (days) from 15 days after spraying

With most of the insecticides, the prolongation of larval period was noticed at third, fourth and fifth instars when they were fed with insecticide treated leaves and harvested at 15 (DAS) days after spray.

The silkworm larval duration (days) 15 (DAS) days after spraying showed significant difference among the treatments in 3rd, 4th and 5th instar. The longest larval

duration of third instar was recorded in the treatment T₂ (acetamiprid 20 SP @ 0.2 g/l) (3.52 days). The shortest larval duration was recorded in T₆ (dichlorvos 76 EC @ 2.63 ml/l) (2.94 days).

The treatment T₁ (acephate 75 SP @ 1g/l) recorded larval duration of 3.43 days which was followed by T₅ (imidacloprid 17.8 SC @ 0.3 ml/l) (3.21 days), T₄ (fipronil 5 SC @ 2 ml/l) (3.17 days), T₃ (dimethoate 30 EC @ 2 ml/l) (3.03 days) and control (3.01 days) (Table 4).

T₂ (acetamiprid 20 SP @ 0.2 g/l) exhibited longest fourth instar larval duration of 4.90 days which was followed by T₁ (acephate 75 SP @ 1g/l) (4.78 days). Next longest duration was recorded in T₅ (imidacloprid 17.8 SC @ 0.3 ml/l) (4.26 days) followed by T₄ (fipronil 5 SC @ 2 ml/l) (4.23 days), T₃ (dimethoate 30 EC @ 2 ml/l) (4.11 days) and control (4.07 days) and the shortest larval duration was recorded in T₆ (dichlorvos 76 EC @ 2.63 ml/l) (3.86 days) (Table 4).

Table 3: Effect of chemical insecticides treated mulberry harvested from 15 days after spraying on silkworm mortality (%)

Treatments	Silkworm larval mortality (%)		
	3 rd instar	4 th instar	5 th instar
T ₁ (Acephate 75 SP)	10.00	7.78	4.44
T ₂ (Acetamiprid 20 SP)	23.33	13.33	13.33
T ₃ (Dimethoate 30 EC)	0.00	0.00	0.00
T ₄ (Fipronil 5 SC)	0.00	0.00	0.00
T ₅ (Imidacloprid 17.8 SC)	0.00	0.00	0.00
T ₆ (Dichlorvos 76 EC)	0.00	0.00	0.00
T ₇ (Control)	0.00	0.00	0.00
F- test	*	*	*
S. Em. ±	0.985	0.891	0.840
CD @ 5%	3.035	2.745	2.588

*Significant at 5%

T₂ (acetamiprid 20 SP @ 0.2 g/l) exhibited longest fifth instar larval duration of 8.48 days which was followed by T₁ (acephate 75 SP @ 1 g/l) (7.99 days). Next longest duration was recorded in T₅ (imidacloprid 17.8 SC @ 0.3 ml/l) (7.64 days) followed by T₄ (fipronil 5 SC @ 2 ml/l) (7.58 days), T₃ (dimethoate 30 EC @ 2 ml/l) (7.27 days) and control (7.26 days) and the shortest larval duration was recorded in T₆ (dichlorvos 76 EC @ 2.63 ml/l) (7.22 days) (Table 4).

In comparison to present study, the cumulative infestation of thrips would lead to the prolonged developmental period of silkworm larvae (Hongyi *et al.* 1997) [9]. An increase in second and third instar larval duration of *B. mori* (PM × NB₄D₂) was observed when silkworms fed with thrips-damaged mulberry leaves. (Naik *et al.* 2000) [16]. Mallinath (2019) [12] opined that the silkworm *Bombyx mori* when fed with dichlorvos 76% EC sprayed mulberry leaves on first day of third instar resulted in increased larval duration corresponding to increased insecticide concentration.

Effect of chemical insecticides on larval weight (g/10 larva)

The silkworms reared on mulberry leaves treated with chemical insecticides harvested after 15 days of spraying exhibited significant difference in larval weight in 3rd, 4th and 5th instar.

In third instar highest larval weight was recorded in control (0.94 g/10 larvae) followed by T₆ (dichlorvos 76 EC @ 2.63 ml/l) (0.93 g/10 larvae), T₃ (dimethoate 30 EC @ 2 ml/l) (0.89 g/10 larvae), T₄ (fipronil 5 SC @ 2 ml/l) (0.86 g/10 larvae), T₅ (imidacloprid 17.8 SC @ 0.3 ml/l) (0.85 g/10 larvae), T₁ (acephate 75 SP @ 1 g/l) (0.85 g/10 larvae) and

the lowest value for larval weight was recorded in T₂ (acetamiprid 20 SP @ 0.2 g/l) (0.83 g/10 larvae) (Table 5). The percent reduction in larval weight over control was recorded highest in T₂ (acetamiprid 20 SP @ 0.2 g/l) (11.35%) followed by T₁ (acephate 75 SP @ 1 g/l) (9.92%), T₅ (imidacloprid 17.8 SC @ 0.3 ml/l) (9.59%), T₄ (fipronil 2 ml/l) (8.52%), T₃ (dimethoate 30 EC) (5.66%) and it was found least in T₆ (dichlorvos 76 EC) (0.71%).

Table 4: Effect of chemical insecticides on larval duration (days) from 15 DAS

Treatments	Larval duration (days)		
	3 rd instar	4 th instar	5 th instar
T ₁ (Acephate 75 SP)	3.43	4.78	7.99
T ₂ (Acetamiprid 20 SP)	3.52	4.90	8.48
T ₃ (Dimethoate 30 EC)	3.03	4.11	7.27
T ₄ (Fipronil 5 SC)	3.17	4.23	7.58
T ₅ (Imidacloprid 17.8 SC)	3.21	4.26	7.64
T ₆ (Dichlorvos 76 EC)	2.94	3.86	7.22
T ₇ (Control)	3.01	4.07	7.26
F- test	*	*	*
S. Em. ±	0.044	0.036	0.020
CD @ 5%	0.134	0.110	0.063

*Significant at 5%, DAS - Days after spraying

In fourth instar highest larval weight was recorded in control (5.39 g/10 larvae) followed by T₆ (dichlorvos 76 EC @ 2.63 ml/l) (5.34 g/larvae), T₃ (dimethoate 30 EC @ 2 ml/l) (5.32 g/10 larvae), T₅ (imidacloprid 17.8 SC @ 0.3 ml/l) (5.27 g/10 larvae), T₄ (fipronil 5 SC @ 2 ml/l) (5.02 g/10 larvae), T₁ (acephate 75 SP @ 1 g/l) (3.50 g/10 larvae) and the lowest value for larval weight was recorded in T₂ (acetamiprid 20 SP @ 0.2 g/l) (3.13 g/10 larvae) (Table 5). The percent reduction in larval weight over control was recorded highest in T₂ (acetamiprid 20 SP @ 0.2 g/l) (41.80%) followed by T₁ (acephate 75 SP @ 1 g/l) (34.99%), T₄ (fipronil 5 SC @ 2 ml/l) (6.58%), T₅ (imidacloprid 17.8 SC @ 0.3 ml/l) (1.74%), T₃ (dimethoate 30 EC @ 2 ml/l) (1.07%) and it was found least in T₆ (dichlorvos 76 EC @ 2.63 ml/l) (0.60%).

In fifth instar highest larval weight was recorded in control (32.06 g/10 larvae) followed by T₆ (dichlorvos 76 EC @ 2.63 ml/l) (29.89 g/10 larvae), T₃ (dimethoate 30 EC @ 2 ml/l) (29.20/10 larvae), T₅ (imidacloprid 17.8 SC @ 0.3 ml/l) (28.25 g/10 larvae), T₄ (fipronil 5 SC @ 2 ml/l) (26.95 g/10 larvae), T₁ (acephate 75 SP @ 1 g/l) (25.52 g/10 larvae) and the lowest value for larval weight was recorded in T₂ (acetamiprid 20 SP @ 0.2 g/l) (24.52 g/10 larvae) (Table 5). The percent reduction in larval weight over control was recorded highest in T₂ (acetamiprid 20 SP @ 0.2 g/l) (23.50%) followed by T₁ (acephate 75 SP @ 1 g/l) (20.39%), T₄ (fipronil 5 SC @ 2 ml/l) (15.92%), T₅ (imidacloprid 17.8 SC @ 0.3 ml/l) (11.88%), T₃ (dimethoate 30 EC @ 2 ml/l) (8.91%) and it was found least in T₆ (dichlorvos 76 EC @ 2.63 ml/l) (6.77%).

Silkworm growth and cocoon traits influenced by feeding mulberry leaves sprayed with insecticides and biorationals recorded shorter larval duration in buprofezin sprayed mulberry leaves. The mature larval weight was high in vermiwash @ 5% and buprofezin. The effective rate of rearing was high in fipronil, vermiwash @ 5% and

diafenthiuron. The highest pupal weight was recorded in diafenthiuron, vermiwash @ 5%, DDVP and buprofezin sprayed mulberry leaves. Maximum cocoon weight was recorded in diafenthiuron, while the cocoon shell weight was more in vermiwash @ 5% followed by diafenthiuron. The cocoon yield was highest in fipronil sprayed mulberry leaves. (Poornima, 2015) [17].

Present study similar with Maria *et al.* (2000) [13], who reported that some insecticides are known to decrease the larval weight of silkworms fed with insecticide sprayed mulberry leaves. When mulberry leaves were soaked in buprofezin and fed to silkworms, it resulted in significant decrease in the fifth instar larval weight in comparison to control.

Effect of chemical insecticides effective rate of rearing (ERR) (%) and cocooning (%)

The silkworms reared on feeding mulberry leaves treated with insecticides harvested after 15 days of spraying exhibited significant difference in ERR percentage. The maximum ERR was observed in the control (97.78%) followed by T₆ (dichlorvos 76 EC @ 2.63 ml/l) (96.67%) and T₃ (dimethoate 30 EC @ 2 ml/l) (96.67%). T₄ (fipronil 5 SC @ 2 ml/l) recorded ERR of 95.56 percent followed by T₅ (imidacloprid 17.8 SC @ 0.3 ml/l) (94.44%), T₁ (acephate 75 SP @ 1 g/l) (74.44%) and the least was recorded in T₂ (acetamiprid 20 SP @ 0.2 g/l) (46.67%) (Table 6).

Cocooning percent did not show any significant difference between treatments, however, among the treatments highest cocooning percent was recorded in control (97.78%), followed by T₆ (dichlorvos 76 EC @ 2.63 ml/l) (96.67%) and T₃ (dimethoate 30 EC @ 2 ml/l) (96.67%). T₁ (acephate 75 SP @ 1 g/l) recorded 95.71 percent cocooning followed by T₄ (fipronil 5 SC @ 2 ml/l) (95.56%), T₅ (imidacloprid 17.8 SC @ 0.3 ml/l) (94.44%) and the least was recorded in T₂ (acetamiprid 20 SP @ 0.2 g/l) (93.31%) (Table 6).

Similarly, Soliman and Sherif (2019) [20] reported that in silkworms fed with mulberry leaves sprayed with 1 ml/l of cypermethrin and 0.1 ml/l of spinosad, the cocooning percentage, cocoon shell ratio and silk productivity also decreased when compared to control.

In contrary, when silkworms were fed with thrips infested leaves, there was a significant decrease in larval weight, ERR, total cocoon production, cocoon weight, pupal weight, shell weight, silk filament length and silk filament weight (Geetha *et al.* 2015) [7].

Effect of chemical insecticides on cocoon weight (g), shell weight (g), pupal weight (g) and cocoon shell ratio (%)

Cocoon weight (g) has found significant difference among the different treatments. The highest cocoon weight was recorded in the control of about 18.31 g for 10 cocoons followed by T₆ (dichlorvos 76 EC @ 2.63 ml/l) (17.53 g/10 cocoons), T₃ (dimethoate 30 EC @ 2 ml/l) (17.45 g/10 cocoons), T₅ (imidacloprid 17.8 SC @ 0.3 ml/l) (16.47 g/10 cocoons) T₄ (fipronil 5 SC @ 2 ml/l) (16.38 g/10 cocoons) and T₁ (acephate 75 SP @ 1 g/l) (14.55 g/10 cocoons). The lowest cocoon weight was recorded in the treatment T₂ (acetamiprid 20 SP @ 0.2 g/l) (13.22 g/10 cocoons) (Table 7).

Table 5: Effect of chemical insecticides on larval weight from 15 DAS

Treatments	Silkworm larval weight (g/10 larvae)			Percent reduction in silkworm larval weight over control		
	3 rd instar	4 th instar	5 th instar	3 rd instar	4 th instar	5 th instar
T ₁ (Acephate 75 SP)	0.85	3.50	25.52	9.92	34.99	20.39
T ₂ (Acetamidrid 20 SP)	0.83	3.13	24.52	11.35	41.80	23.50
T ₃ (Dimethoate 30 EC)	0.89	5.32	29.20	5.66	1.07	8.91
T ₄ (Fipronil 5 SC)	0.86	5.02	26.95	8.52	6.58	15.92
T ₅ (Imidacloprid 17.8 SC)	0.85	5.27	28.25	9.59	1.74	11.88
T ₆ (Dichlorvos 76 EC)	0.93	5.34	29.89	0.71	0.60	6.77
T ₇ (Control)	0.94	5.39	32.06	-	-	-
F- test	*	*	*	*	*	*
S. Em. ±	0.010	0.133	0.151	1.207	2.387	0.465
CD @ 5%	0.032	0.409	0.465	3.804	7.521	1.466

*Significant at 5%, DAS - Days after spraying

Shell weight (g) showed significant difference among the treatments. Maximum cocoon shell weight was observed in the control (3.24 g/10 shell), followed by T₆ (dichlorvos 76 EC @ 2.63 ml/l) (3.14 g/10 shell), T₃ (dimethoate 30 EC @ 2 ml/l) (3.07 g/10 shell), T₅ (imidacloprid 17.8 SC @ 0.3 ml/l) (2.94 g/10 shell), T₄ (fipronil 5 SC @ 2 ml/l) (2.86 g/10 shell) and T₁ (acephate 75 SP @ 1 g/l) (2.33 g/10 shell). The lowest shell weight was recorded in T₂ (acetamidrid 20 SP @ 0.2 g/l) (2.05 g/10 shell) (Table 7). Similarly, Zhou *et al.* (2016) [23] worked on the residual toxicity test for buprofezin on mulberry silkworm, *Bombyx mori*. The results revealed that the growth and development, pupation rate, cocoon weight, cocoon shell weight and cocoon shell ratio were not different from those of the control after 21 days when the third instar worms were fed with mulberry leaves treated with 1000, 500 and 250 mg per litre buprofezin. Thus, they concluded that the safe period for buprofezin was 21 days. In contrary Muthuswami *et al.* (2010) [15] reported that cocoon parameters in botanicals sprayed plots showed relatively better performance over untreated control but they were lower than that of chemical insecticide treatments.

Table 6: Effect of chemical insecticides on Effective Rate of Rearing (%) and cocooning (%)

Treatments	ERR (%)	Cocooning (%)
T ₁ (Acephate 75 SP)	74.44	95.71
T ₂ (Acetamidrid 20 SP)	46.67	93.31
T ₃ (Dimethoate 30 EC)	96.67	96.67
T ₄ (Fipronil 5 SC)	95.56	95.56
T ₅ (Imidacloprid 17.8 SC)	94.44	94.44
T ₆ (Dichlorvos 76 EC)	96.67	96.67
T ₇ (Control)	97.78	97.78
F- test	*	NS
S. Em. ±	1.260	1.049
CD @ 5%	3.882	3.231

*Significant at 5%, NS- Non-significant, ERR- Effective Rate of Rearing

The pupal weight showed significant difference among the different treatments, the highest weight of 15.03 g per 10 pupae was recorded in control followed by T₆ (dichlorvos 76 EC @ 2.63 ml/l) (14.39/10 pupae), T₃ (dimethoate 30 EC @ 2 ml/l) (14.34 g/10 pupae), T₅ (imidacloprid 17.8 SC @ 0.3 ml/l) (13.44 g/10 pupae), T₄ (fipronil 5 SC @ 2 ml/l) (13.42 g/10 pupae) and T₁ (acephate 75 SP @ 1g/l) (12.12 g/10 pupae). The lowest pupal weight was recorded in T₂ (acetamidrid 20 SP @ 0.2 g/l) (11.17 g/10 pupae) (Table 7).

However, studies by Gayathri (2007) [6] showed that application of methyl demeton, dimethoate, DDVP and azadirachtin did not differ in respect of pupal weight. In contrary, when the larvae were fed from 4th instar onwards, there was a significant increase in pupal weight with increase in duration after the spray.

The cocoon shell ratio did not show any significant difference among the different treatments. Among the different treatments the highest cocoon shell ratio was recorded in T₆ (dichlorvos 76 EC @ 2.63 ml/l) (17.89%) followed by T₅ (imidacloprid 17.8 SC @ 0.3 ml/l) (17.82%), T₇ (control) (17.69%), T₃ (dimethoate 30 EC @ 2 ml/l) (17.57%), T₄ (fipronil 5 SC @ 2 ml/l) (17.44%), T₁ (acephate 75 SP @ 1 g/l) (15.98%) and it was found least in T₂ (acetamidrid 20 SP @ 0.2 g/l) (15.49%) (Table 7).

Gayathri (2007) [6] reported adverse effects of insecticides on shell ratio. When the fourth instar silkworms were fed with organophosphate insecticide (methyl demeton 0.05%), cocoon shell ratio was lower than that of untreated control.

Effect of chemical insecticides on cocoon filament length (m), non-breakable filament length (m), filament weight (g) and denier

Cocoon filament length recorded significant difference among the different treatments (Table 8). The treatment T₇ (control) recorded longest filament length (724.67 m) followed by T₅ (imidacloprid 17.8 SC @ 0.3 ml/l) (714 m), dichlorvos 76 EC @ 2.63 ml/l (680.67 m), T₄ (fipronil 5 SC @ 2 ml/l) (679 m), T₃ (dimethoate 30 EC @ 2 ml/l) (675 m), and T₁ (acephate 75 SP @ 1 g/l) (590 m). The lowest filament length was recorded in the treatment T₂ (acetamidrid 20 SP @ 0.2 g/l) (572 m).

Non-breakable filament length was highest in control (678.75 m) followed by T₅ (imidacloprid 17.8 SC @ 0.3 ml/l) (671.25 m), dichlorvos 76 EC @ 2.63 ml/l (638.81 m), T₄ (fipronil 5 SC @ 2 ml/l) (636.75 m), T₃ (dimethoate 30 EC @ 2 ml/l) (633.94 m), and T₁ (acephate 75 SP @ 1 g/l) (555.38 m). The shortest non-breakable filament length was recorded in T₂ (acetamidrid 20 SP @ 0.2 g/l) (535.38 m) (Table 8).

Cocoon filament weight recorded significant difference among the different treatments (Table 8). The highest filament weight was recorded in the treatment T₇ (control) (0.27 g) followed by dichlorvos 76 EC @ 2.63 ml/l (0.25 g), T₅ (imidacloprid 17.8 SC @ 0.3 ml/l) (0.23 g), T₃ (dimethoate 30 EC @ 2 ml/l) (0.22 g), T₄ (fipronil 5 SC @ 2 ml/l) (0.18 g) and T₁ (acephate 75 SP @ 1 g/l) (0.17 g). The lowest filament weight was recorded in T₂ (acetamidrid 20 SP @ 0.2 g/l) (0.15).

Table 7: Effect of chemical insecticides on cocoon weight (g), shell weight (g), pupal weight (g) and cocoon shell ratio (%)

Treatments	Cocoon weight (g)	Shell weight (g)	Pupal weight (g)	Cocoon shell ratio (%)
T ₁ (Acephate 75 SP)	14.55	2.33	12.12	15.98
T ₂ (Acetamiprid 20 SP)	13.22	2.05	11.17	15.49
T ₃ (Dimethoate 30 EC)	17.45	3.07	14.34	17.57
T ₄ (Fipronil 5 SC)	16.38	2.86	13.42	17.44
T ₅ (Imidacloprid 17.8 SC)	16.47	2.94	13.44	17.82
T ₆ (Dichlorvos 76 EC)	17.53	3.14	14.39	17.89
T ₇ (Control)	18.31	3.24	15.03	17.69
F- test	*	*	*	NS
S. Em. ±	0.076	0.182	0.169	1.268
CD @ 5%	0.233	0.560	0.522	3.907

*Significant at 5%

With regard to the denier, the effect of different chemical insecticide was found significant among the different treatments (Table 8). Denier was high in control (2.98) followed by dichlorvos 76 EC @ 2.63 ml/l (2.94), T₃ (dimethoate 30 EC @ 2 ml/l) (2.61), T₅ (imidacloprid 17.8

SC @ 0.3 ml/l) (2.57), T₁ (acephate 75 SP @ 1 g/l) (2.28), T₄ (fipronil 5 SC @ 2 ml/l) (2.12). The finest denier was recorded in T₂ (acetamiprid 20 SP @ 0.2 g/l) (2.06).

Similar to these results, Bandyopadhyay *et al.* (2005) [4] also noticed higher filament length with dichlorvos 0.1% and azadirachtin at 1% compared to other insecticides assessed. Similar trend was noticed in another study where azadirachtin 0.15% EC showed higher cocoon filament length in comparison with other insecticides viz., emamectin benzoate, flubendiamide, abamectin and *Bacillus thuringiensis* (Kordy, 2014) [10]. Feeding of buprofezin 25% WP treated mulberry leaves to silkworms, resulted in reduced in denier as compared to control, (Maria *et al.* 2000) [13]. In contrary, the longest cocoon filament was recorded with mulberry leaves sprayed with diafenthiuron. (Poornima 2015) [17]. When silkworms were fed with thrips infested mulberry leaves and insecticide treated mulberry leaves, no significant difference was noticed in shell ratio, denier and renditta, but there was significant difference in case of silk filament length and silk filament weight (Geetha *et al.*, 2015) [7].

Table 8: Effect of chemical insecticides on cocoon filament length (m), non-breakable filament length (m), filament weight (g) and denier

Treatments	Filament length (m)	Non-breakable filament length (m)	Filament weight (g)	Denier
T ₁ (Acephate 75 SP)	590.00	555.38	0.17	2.28
T ₂ (Acetamiprid 20 SP)	572.00	535.38	0.15	2.06
T ₃ (Dimethoate 30 EC)	675.00	633.94	0.22	2.61
T ₄ (Fipronil 5 SC)	679.00	636.75	0.18	2.12
T ₅ (Imidacloprid 17.8 SC)	714.67	671.25	0.23	2.57
T ₆ (Dichlorvos 76 EC)	680.67	638.81	0.25	2.94
T ₇ (Control)	724.67	678.75	0.27	2.98
F- test	*	*	*	*
S. Em. ±	0.005	137.434	0.005	0.080
CD @ 5%	0.016	423.475	0.016	0.246

*Significant at 5%

Conclusion

Feeding insecticide sprayed mulberry leaves resulted in larval mortality in 3rd, 4th and 5th instar silkworms in acetamiprid 20 SP @ 0.2 g/l and acephate 75 SP @ 1g/l and no larval mortality was observed in any of the other treatments. Even though acetamiprid 20 SP @ 0.2 g/l and acephate 75 SP @ 1g/l are selective feeding blocker specific to sucking insects with repellent action, silkworms seem to have lower tolerance limit for these molecules.

With most of the insecticides, larval period was prolonged at 3rd, 4th and 5th instars on feeding them with insecticide treated leaves. The 3rd instar larval duration of silkworm was prolonged to 3.52 days when the worms were fed on mulberry leaves sprayed with acetamiprid 20 SP @ 0.2 g/l. The larval duration was found shortest in dichlorvos 76 EC @ 2.63 ml/l (2.94 days). This may be due to the later effects of trace amount of insecticides in the leaves. The longest 4th and 5th instar larval duration was also noticed in acetamiprid 20 SP @ 0.2 g/l 4.90 and 8.48 days respectively, followed by acephate 75 SP @ 1 g/l (4.78 and 7.99 days). The shortest larval duration of 3.86 and 7.22 days in 4th and 5th instars was recorded with dichlorvos 76 EC @ 2.63 ml/l.

Larval weight was highest in control in 3rd (0.94 g/10 larva), 4th (5.39 g/10 larva), and 5th instar (32.06 g/10 larva). Where as lowest larval weight was recorded in acetamiprid 20 SP @ 0.2 g/l in 3rd (0.83 g/10 larvae), 4th (3.13 g/10 larvae) and 5th (24.52 g/10 larvae) instar. The highest percent reduction in larval weight over control was recorded in acetamiprid 20

SP @ 0.2 g/l in 3rd (11.35), 4th (41.80) and 5th instar (23.50). where as it was lowest in dichlorvos 76 EC @ 2.63 ml/l in 3rd (0.71), 4th (0.60) and 5th instar (6.77).

The maximum ERR was observed in the control (97.78%) where in it was noticed least in the treatment acetamiprid 20 SP @ 0.2 g/l (46.67%). Cocooning (%) did not show significant difference among the treatments, however among the treatments highest cocooning (%) was recorded in control (97.78%) and it was found least in acetamiprid 20 SP @ 0.2 g/l (93.31%).

The evaluation on efficacy of insecticides on the cocoon weight parameters revealed that the control exhibited the highest cocoon of 18.31g per 10 cocoons. Whereas lowest cocoon weight was recorded in acetamiprid 20 SP @ 0.2 g/l (13.22 g/10 cocoons).

Maximum cocoon shell weight was observed in the control (3.24 g/10 shell), followed by dichlorvos 76 EC @ 2.63 ml/l (3.14g/10 shell), dimethoate 30 EC @ 2 ml/l (3.07 g/10 shell), imidacloprid 17.8 SC @ 0.3 ml/l (2.94 g/10 shell), fipronil 5 SC @ 2 ml/l (2.86 g/10 shell) and acephate 75 SP @ 1g/l (2.33 g/10 shell). The lowest shell weight was recorded with acetamiprid 20 SP @ 0.2 g/l (2.05 g/10 shell). The highest weight of 15.03 g for 10 pupae was recorded in control. Among the chemical insecticides, dichlorvos 76 EC @ 2.63 ml/l recorded highest pupal weight of 14.39/10 pupae and the lowest pupal weight was recorded with acetamiprid 20 SP @ 0.2 g/l (11.17 g/10 pupae).

There was no significant difference among the treatments with respect to cocoon shell ratio however, highest cocoon shell ratio was recorded with dichlorvos 76 EC @ 2.63 ml/l (17.89%) and lowest cocoon shell ratio was recorded with acetamiprid 20 SP @ 0.2 g/l (15.49%).

Longest filament length was recorded in control (724.67 m) and shortest filament length was observed with acetamiprid 20 SP @ 0.2 g/l (572 m). Non-breakable filament length was highest in the control (678.75 m). The shortest non-breakable filament length was recorded in the treatment acetamiprid 20 SP @ 0.2 g/l (535.38 m).

The filament weight was highest in control (0.27 g), followed by dichlorvos 76 EC @ 2.63 ml/l (0.25 g), imidacloprid 17.8 SC @ 0.3 ml/l (0.23 g). The lowest filament weight was recorded with acetamiprid 20 SP @ 0.2 g/l (0.15).

The coarser denier was found in control (2.98) followed by dichlorvos 76 EC @ 2.63 ml/l (2.94) and the finest denier was recorded with acetamiprid 20 SP @ 0.2 g/l (2.06).

Among the chemical insecticides evaluated, imidacloprid 17.8 SC @ 0.3 ml/l and fipronil 5 SC @ 2 ml/l exhibited higher efficiency in management of mulberry thrips in the field. These two chemicals were also found safer on natural enemies and recorded higher mulberry yield and were safer to silkworms. Further, these chemicals recorded good larval weight, cocoon weight, shell weight, filament length and denier. Hence fipronil and imidacloprid can be used as an alternative to DDVP in management of mulberry thrips without adversely affecting the performance of silkworm.

On the other hand, acetamiprid 20 SP @ 0.2 g/l and acephate 75 SP @ 1 g/l were found most effective against mulberry thrips in the field but are phytotoxic to mulberry plant. In addition, these insecticides also adversely affected the rearing performance of silkworm.

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