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Effect of Novel Insecticide Molecules in Mulberry on Cocoon Parameters of Silkworm *Bombyx mori* L

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A B S T R A C T

Efficacy of novel insecticides on the cocoon parameters of mulberry silkworm *Bombyx mori* resulted in the maximum single cocoon weight of 1.81 g (10 DAS), 1.83 g (20 DAS), 1.90 g (30 DAS) and1.87 g (40 DAS) in the untreated control. Pupal weight was recorded was recorded maximum in untreated control along with other insecticides *viz*., azadirachtin 1 % @ 1 ml, dinotefuran 20 SG @ 0.25 & 0.12 g/l, pymetrozine 50 WG @ 0.6 g/l and buprofezin 25 SC @ 1ml/l at 10 and 20 Days After Spraying. Among the treatments untreated control exhibited maximum shell weight of 0.34 (20, 30 and 40 DAS) and 0.33 g at 10 DAS of insecticides which was on par with dichlorvos 76 EC @ 2.63 ml/l (0.31g), dinotefuron 20SG @ 0.25 g/l and pymetrozine 50 WG @ 0. 6g/l. Hence proving, these green labelled insecticides as an effective alternate for dichlorovos in sericulture.

Introduction

India is the second largest silk producing country next only to China and sericulture is an integral part of the rural economy in an agrarian country like India. Mulberry is the sole food of silkworm *Bombyx mori* L. and is infested by several pests. These pests affect the growth of mulberry and cause considerable economic damage to the farmers. The insecticides applied for the management of mulberry pests have greater impact on silkworm. Pesticides leave residues on mulberry leaves which in turn affect the sensitive silkworm.

To overcome this problem, safe waiting period is very essential for leaf harvesting (Yokoyama, 1962). Sik *et al.*, (1976) reported that more than 1.4 per cent of yield reduction in sericulture was due to side effect of pesticide application. 49.4 per cent was due to

the application of different pesticides in rice fields, 21.2 per cent in fruit gardens and 12.3 per cent in olericulture. It was observed that there was loss of cocoon yield from silkworms which fed on mulberry leaves sprayed with insecticides (Narasimhanna, 1988).

Exposure to the residue of pesticides in the mulberry leaves could affect growth and quality of economic characteristics of cocoons. Pest management in mulberry sericulture is highly selective because silkworm cannot tolerate even sub lethal doses of toxic compounds.

Dichlorvos (DDVP) is the common insecticide used for management of sucking pests in mulberry. Newer chemicals with novel and specific mode of action have been introduced for management of sucking pests in other crops *viz.,* cotton, grapes, chilli, sunflower etc.

However, the choices of newer insecticides require information against sucking insects in mulberry ecosystem, waiting period and residual toxicity.

Consequent to this, a study was initiated using different novel insecticides, corresponding waiting periods and residual toxicity to silkworm, especially on the cocoon parameters of silkworm *B. mori* L.

Materials and Methods

Experimental layout

The experiment was conducted at the Department of Sericulture, UAS, GKVK, Bengaluru with well-established mulberry garden of V_1 variety fed to Kolar Gold which is a commercial cross breed (PM × CSR_2). The experiment was laid out in Completely Randomized Design with 13 treatments, each replicated three times.

Treatment details

Insecticides like buprofezin 25 SC @ (1 ml/l and 2 ml/l), pymetrozine 50 WG @ (0.3 g/l and 0.6 g/l), flonicamid 50 WG @ (0.15 g/l and 0.3 g/l), dinotefuron 20 SG @ (0.12 g/l and 0.25 g/l), azadirachtin 1% @ (1 ml/l and 2 ml/l), dichlorvos 76 EC @ (1.32 ml/l and 2.63 ml/l) and untreated control were sprayed on the mulberry plants and care was taken by holding a polythene cover along the treated plants while spraying to ensure that there was no drifting of chemicals due to wind and the treated leaves were fed to the silkworms.

Before the commencement of silkworm rearing the appliances were sun dried and rearing room, appliances were thoroughly cleaned and the floor was washed using 2 per cent bleaching powder solution. Then the entire rearing room was later disinfected by following standard procedure (Dandin *et al.,* 2003).

The rearing room was kept air tight for 24 hours and then the room was kept open and used for rearing. The third instar larvae were provided with chopped mulberry leaves of required quantity and quality.

After 30 minutes of initial feeding, 90 larvae were transferred to each experimental tray in thee replications along with the mulberry leaves.

Later, in order to assess extent of toxicity in insecticides to silkworm and to determine the safety period for effective molecules, the silkworm rearing was carried out.

Observations such as single cocoon weight (g), pupal weight (g), cocoon shell weight (g) and cocoon shell ratio (%) were recorded during rearing.

Table.1 Effect of insecticides on single cocoon weight (g)

Treatments		Single cocoon weight (g)			
		10 DAS	**20 DAS**	**30 DAS**	**40 DAS**
T_1	Buprofezin 25 SC @ 1ml/l	1.70^{cd}	1.70^{cd}	1.67^{cde}	1.69^{cde}
T_2	Buprofezin 25 SC @ 2 ml/l	1.65^{de}	1.59^{f}	1.64^{e}	1.69^{cde}
T_3	Pymetrozine 50 WG @ 0.3 g/l	1.58f	1.60^{f}	1.66^{cde}	1.66^{e}
T_4	Pymetrozine 50 WG @ 0.6 g/l	1.73^{bc}	1.73^{bc}	1.71^{cde}	1.73^{bcde}
T_5	Flonicamid 50 WG @ 0.15 g/l	1.69^{cd}	1.67^{de}	1.65^{de}	1.67^{de}
T_6	Flonicamid 50 WG @ 0.3 g/l	0.00^{g}	1.03^{g}	1.05^{f}	1.05^{f}
T_7	Dinotefuron 20 SG @ 0.12 g/l	1.72^{bc}	1.72^{cd}	1.75^{bc}	1.74^{bcd}
T_8	Dinotefuron 20 SG @ 0.25 g/l	1.77^{ab}	1.78^{b}	1.85^{a}	1.79^{ab}
T_9	Azadirachtin 1 % @ 1 ml/l.	1.62^{ef}	1.61^{ef}	1.70^{cde}	1.72^{bcde}
T_{10}	Azadirachtin 1 % @ 2 ml/l	1.72^{bc}	1.73^{bc}	1.74^{bcd}	1.75^{bcd}
T_{11}	Dichlorvos 76 EC @ 1.32 ml/l	1.63^{ef}	1.67^{d}	1.64^{e}	1.77^{bc}
T_{12}	Dichlorvos 76 EC @ 2.63 ml/l (std. check)	1.80^{a}	1.71^{cd}	1.82^{ab}	1.75^{bcd}
T_{13}	Untreated control	1.81^{a}	1.83^{a}	1.90^{a}	1.87^{a}
F-test		*	*	*	*
SE.m ±		0.019	0.019	0.032	0.026
CD at 5 %		0.056	0.055	0.092	0.077

*Significant at 5 %, DAS - Days after spraying.

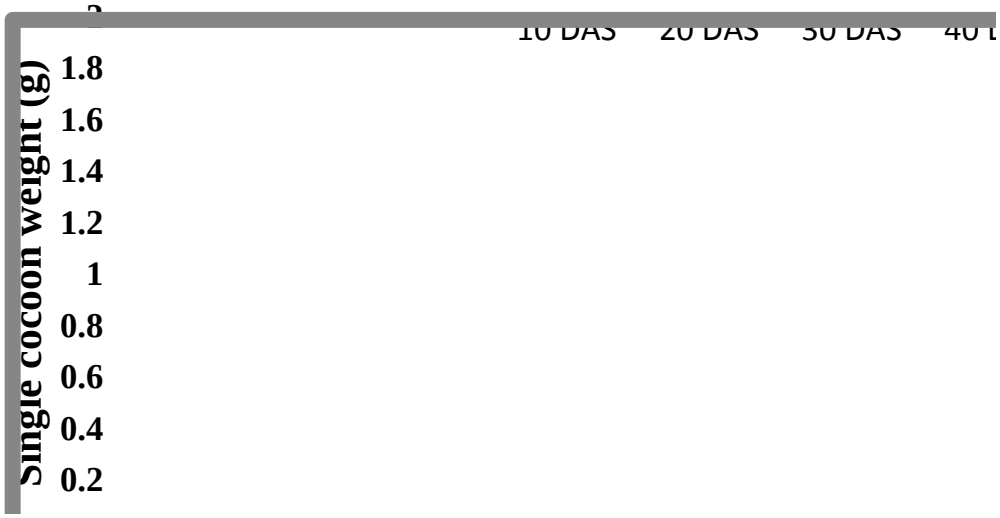

Fig.1 Effect of insecticides on Single cocoon weight (g)

T_1- Buprofezin 25 SC @ 1ml/l
T_2- Buprofezin 25 SC @ 2 ml/l
T_3- Pymetrozine 50 WG @ 0.3 g/l
T_4- Pymetrozine 50 WG @ 0.6 g/l
T_5- Flonicamid 50 WG @ 0.15 g/l
T_6- Flonicamid 50 WG @ 0.3 g/l
T_7- Dinotefuron 20 SG @ 0.12 g/l
T_8- Dinotefuron 20 SG @ 0.25 g/l
T_9- Azadirachtin 1 % @ 1 ml/l
T_{10}- Azadirachtin 1 % @ 2 ml/l
T_{11}- Dichlorovas 76 EC @ 1.32 ml/l
T_{12}- Dichlorovas 76 EC @ 2.63 ml/l
T_{13} - Untreated control
DAS- Days after spraying

Results and Discussion

Single cocoon weight (g)

The parameter Single cocoon weight (g) was found significant in all the four sets of DAS. The maximum cocoon weight was recorded in the treatment of untreated control (1.81 g) followed by dichlorvos 76 EC @ 2.63 ml/l (1.80 g) and dinotefuron 20 SG @ 0.25 g/l (1.77 g) which were significantly on par with each other.

The minimum cocoon weight was recorded in the treatment pymetrozine 50 WG @ 0.3 g/l (1.58 g) which were significantly on par with azadiractin 1 % @ 1 ml (1.62 g) and dichlorvos 76 EC @ 2.63 ml/l (1.63 g).

In the silkworm batches reared on 20 DAS minimum cocoon weight was recorded from the treatment flonicamid 50 WG @ 0.3 g/l (1.03 g) and untreated control exhibited maximum cocoon weight of 1.83 g. Buprofezin 25 SC @ 1 ml/l, pymetrozine 50 WG @ 0.6 g/l, dinotefuron 20 SG @ 0.12 g/l, azadirachtin 1% @ 2 ml/l and dichlorvos 76 EC @ 2.63 ml/l exhibited on par results like 1.70 g, 1.73 g, 1.72 g, 1.73 g and 1.71 g respectively. The treatments pymetrozine 50 WG @ 0.3 g/l, azadirachtin 1% @ 1 ml/l and buprofezin 25 SC @ 2 ml/l also recorded on par cocoon weight like 1.60 g, 1.61 g and 1.59 g respectively

Untreated control (1.90 g) yielded highest cocoon weight among the treatments in the silkworm batches of 30 DAS this was statistically on par with dinotefuron 20 SG @ 0.25 g/l exhibiting cocoon weight of 1.85 g and dichlorvos 76 EC @ 2.63 ml/l which exhibited statistically on par values with it of 1.82 g .

Cocoon weight of 1.75 g was recorded in dinotefuron 20 SG @ 0.12 g/l, followed by pymetrozine 50 WG @ 0.6 g/l (1.71 g), azadirachtin 1 % @ 2 ml/l (1.74 g), azadirachtin 1 % @ 1 ml/l (1.70 g) the treatments like buprofezin 25 SC @ 1 ml/l (1.67 g), buprofezin 25 SC @ 2 ml/l (1.64 g), dichlorvos 76 EC @ 1.32 ml/l (1.64 g), pymetrozine 50 WG @ 0.3 g/l (1.66 g) and flonicamid 50 WG @ 0.15 g/l (1.65 g) exhibited on par values. The minimum cocoon weight obtained was in the treatment flonicamid 50 WG @ 0.3 g/l (1.05 g) (Table 1; Fig. 1).

On the 40 DAS of insecticides, the silkworm exhibited significant values for cocoon weight where the highest cocoon weight was recorded in the treatment untreated control (1.87 g) which was on par with and dinotefuron 20 SG @ 0.25 g/l (1.79 g) and the least cocoon weight was recorded in the treatment flonicamid 50 WG @ 0.3 g/l (1.05 g) (Table 1; Fig 1).

During the evaluation on efficacy of insecticides on the cocoon weight parameters the untreated control exhibited the highest cocoon weight of 1.81 g (10 DAS), 1.83 g (20 DAS), 1.90 g (30 DAS) and1.87 g (40 DAS).

Cocoon weight recorded in the treatment, dinotefuran 20 SG @ 0.25 g/l was on par with untreated control at 10, 20, 30 and 40 DAS. This was followed by azadirachtin 1 % @ 2 ml/l at all the time intervals. Lowest cocoon weight was recorded in flonicamid 50WG @ 0.3 g/l at 20 DAS, 30 DAS and 40 DAS.

Except dinotefuron, the decline in cocoon weight in general was noticed with all other insecticides assessed. Similarly, Bandyopadhyay *et al.*, (2005) reported significant decline in the commercial characters like cocoon weight when silkworm larvae were fed with monocrotophos, acephate and dichlorvos and azadirachtin 1500 ppm & 300 ppm which is in conformity with present results.

Table.2 Effect of insecticides on single pupal weight (g)

Treatments		Single pupal weight (g)			
		10	20	30	40 DAS
T_1	Buprofezin 25 SC @ 1ml/l	1.44^{abc}	1.43^{abc}	1.39^{c}	1.41^{def}
T_2	Buprofezin 25 SC @ 2 ml/l	1.45^{abc}	1.39^{cd}	1.43^{bc}	1.49^{bcd}
T_3	Pymetrozine 50 WG @ 0.3 g/l	1.33^{e}	1.33^{d}	1.41^{bc}	1.39^{ef}
T_4	Pymetrozine 50 WG @ 0.6 g/l	1.42^{cd}	1.48^{ab}	1.42^{bc}	1.47^{bcde}
T_5	Flonicamid 50 WG @ 0.15 g/l	1.44^{bc}	1.39^{cd}	1.40^{c}	1.39^{f}
T_6	Flonicamid 50 WG @ 0.3 g/l	0.00^{f}	0.86^{e}	0.95^{d}	0.96^{g}
T_7	Dinotefuron 20 SG @ 0.12 g/l	1.43^{bc}	1.44^{abc}	1.48^{ab}	1.48^{bcd}
T_8	Dinotefuron 20 SG @ 0.25 g/l	1.43^{bc}	1.47^{ab}	1.52^{a}	1.49^{bc}
T_9	Azadirachtin 1 % @ 1 ml/l	1.43^{bc}	1.43^{abc}	1.52^{a}	1.61^{a}
T_{10}	Azadirachtin 1 % @ 2 ml/l	1.43^{bc}	1.44^{abc}	1.44^{bc}	1.44^{cdef}
T_{11}	Dichlorvos 76 EC @ 1.32 ml/l	1.37^{de}	1.41^{bc}	1.39^{c}	1.49^{bcd}
T_{12}	Dichlorvos 76 EC @ 2.63 ml/l (std.	1.49^{a}	1.39^{cd}	1.51^{a}	1.44^{cdef}
T_{13}	Untreated control	1.48^{ab}	1.50^{a}	1.56^{a}	1.52^{b}
F-test		*	*	*	*
SE.m ±		0.019	0.024	0.027	0.026
CD at 5 %		0.054	0.069	0.078	0.077

*Significant at 5 %, DAS - Days after spraying.

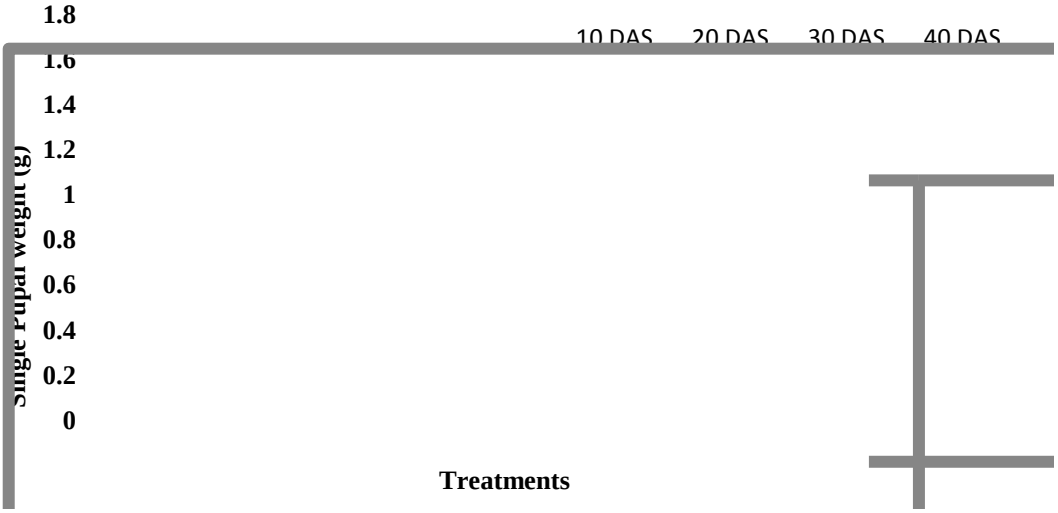

Fig.2 Effect of insecticides on pupal weight (g)

T_1- Buprofezin 25 SC @ 1ml/l
T_2- Buprofezin 25 SC @ 2 ml/l
T_3- Pymetrozine 50 WG @ 0.3 g/l
T_4- Pymetrozine 50 WG @ 0.6 g/l
T_5- Flonicamid 50 WG @ 0.15 g/l
T_6- Flonicamid 50 WG @ 0.3 g/l
T_7- Dinotefuron 20 SG @ 0.12 g/l
T_8- Dinotefuron 20 SG @ 0.25 g/l
T_9- Azadirachtin 1 % @ 1 ml/l
T_{10}- Azadirachtin 1 % @ 2 ml/l
T_{11}- Dichlorovas 76 EC @ 1.32 ml/l
T_{12}- Dichlorovas 76 EC @ 2.63 ml/l
T_{13}- Untreated control
DAS- Days after spraying

Single pupal weight (g)

Among the silkworm batches reared on 10 DAS, the pupal weight of each treatment differed significantly from each other, as the treatment dichlorvos 76 EC @ 2.63 ml/l exhibited maximum weight (1.49 g) which was statistically on par with untreated control (1.48 g) , buprofezin 25 SC @ 2 ml/l (1.45 g), buprofezin 25 SC @ 1 ml/l (1.44 g), flonicamid 50 WG @ 0.15 g/l (1.44 g). Dichlorvos 76 EC @ 1.32 ml/l yeilded 1.37 g pupal weight followed by pymetrozine 50 WG @ 0.3 g/l which exhibited the lowest pupal weight (1.33 g) (Table 2; Fig. 2).

On 20 DAS the silkworm batches reared expressed significant difference in the values for pupal weight, where the maximum pupal weight was recorded in the untreated control (1.50 g) and flonicamid 50 WG @ 0.3 g/l recorded the lowest pupal weight (0.86 g).

Dichlorvos 76 EC @ 1.32 ml/l recorded pupal weight of 1.41 g which exhibited on par values with the treatments buprofezin 25 SC @ 2 ml/l (1.39 g), flonicamid 50 WG @ 0.15 g/l (1.39 g) and dichlorvos 76 EC @ 2.63 ml/l (1.39 g). Pymetrozine 50 WG @ 0.3 g/l recorded lowest pupal weight of 1.33 g.

There was significant difference among the treatments in the silkworm batches reared on 30 DAS. Untreated control (1.56 g) recorded the maximum weight of pupa which was statistically on par with the treatments dinotefuron 20 SG @ 0.25 g/l (1.52 g), azadirachtin 1 % @ 1 ml/l (1.52 g), dichlorvos 76 EC @ 2.63 ml/l (1.51 g) and dinotefuron 20 SG @ 0.12 g/l (1.48 g). The minimum pupal weight was recorded in flonicamid 50 WG @ 0.3 g/l (0.95 g) (Table 2; Fig. 2).

Pupal weight recorded was highest in untreated control along with other insecticides *viz*., azadirachtin 1 % @ 1 ml, dinotefuran 20 SG @ 0.25 & 0.12 g/l, pymetrozine 50 WG @ 0.6 g/l and buprofezin 25 SC @ 1ml/l at 10 DAS and 20 DAS. At 40 DAS, highest pupal weight was recorded in azadirachtin 1 % @ 1ml/l (1.61 g) which was on par with untreated control (1.52 g).

The lowest pupal weight was observed in flonicamid 50WG @ 0.3 g/l at 20, 30 and 40 days after spraying. Similar to these findings, Maria *et al.,* (2000) studied the effects of buprofezin on the growth of silkworm and concluded that among the different insecticides treated buprofezin gave higher pupal weight of 1.5 g / cocoon.

However, studies by Gayathri (2007) exhibited that application of methy demeton, dimethoate, DDVP and azadirchtin did not differ significantly among them in respect of pupal weight.

Contrarily, when the larvae were fed with 4th instar onwards, there was a significant increase in pupal weight with increase in days after the spray.

Single cocoon Shell weight (g)

The result obtained from the treated batches of worms from 10 DAS exhibited significant difference among the treatments where the maximum cocoon shell weight was observed in the treatment dinotefuron 20 SG @ 0.25 g/l (0.34 g), it was followed by untreated control (0.33 g), pymetrozine 50 WG @ 0.6 g/l and dichlorvos 76 EC @ 2.63 ml/l (standard Check) which exhibited similar results of shell weight (0.31 g) and were also on par with each other.

The least shell weight was obtained from the treatment azadirachtin 1% @ 1 ml/l (0.19 g) which was statistically on par with buprofezin 25 SC @ 1 ml/l (0.21 g).

Table.3 Effect of insecticides on single cocoon shell weight (g)

Treatments		Single cocoon shell weight (g)			
		10 DAS	20	30	40
T_1	Buprofezin 25 SC @ 1ml/l	0.25^{e}	0.27^{d}	0.28^{de}	0.28^{cd}
T_2	Buprofezin 25 SC @ 2 ml/l	0.21^{f}	0.21^{e}	0.20^{g}	0.20^{e}
T_3	Pymetrozine 50 WG @ 0.3 g/l	0.25^{e}	0.27^{cd}	0.25^{f}	0.27^{cd}
T_4	Pymetrozine 50 WG @ 0.6 g/l	0.31b^{c}	0.26^{d}	0.29^{cd}	0.26^{d}
T_5	Flonicamid 50 WG @ 0.15 g/l	0.26^{e}	0.28^{cd}	0.24^{f}	0.29^{bc}
T_6	Flonicamid 50 WG @ 0.3 g/l	0.00^{g}	0.17^{e}	0.10^{h}	0.09^{f}
T_7	Dinotefuron 20 SG @ 0.12 g/l	0.28^{d}	0.28^{cd}	0.26^{ef}	0.26^{d}
T_8	Dinotefuron 20 SG @ 0.25 g/l	0.34^{a}	0.31^{abc}	0.32^{ab}	0.30^{b}
T_9	Azadirachtin 1 % @ 1 ml/l	0.19f	0.18^{e}	0.18^{g}	0.11^{f}
T_{10}	Azadirachtin 1 % @ 2 ml/l	0.29^{cd}	0.29^{bcd}	0.30^{bed}	0.31^{b}
T_{11}	Dichlorvos 76 EC @ 1.32 ml/l	0.26^{e}	0.26^{d}	0.25^{f}	0.28^{cd}
T_{12}	Dichlorvos 76 EC @ 2.63 ml/l (std. check)	0.31^{bc}	0.33^{ab}	0.31^{bc}	0.31^{b}
T_{13}	Untreated control	0.33^{ab}	0.34^{a}	0.34^{a}	0.34^{a}
F-test		*	*	*	*
SE.m ±		0.009	0.015	0.010	0.007
CD at 5 %		0.026	0.042	0.028	0.021

*Significant at 5 %, DAS - Days after spraying.

Fig.3 Effect of insecticides on Shell weight (g)

T_1- Buprofezin 25 SC @ 1ml/l
T_2- Buprofezin 25 SC @ 2 ml/l
T_3- Pymetrozine 50 WG @ 0.3 g/l
T_4- Pymetrozine 50 WG @ 0.6 g/l
T_5- Flonicamid 50 WG @ 0.15 g/l
T_6- Flonicamid 50 WG @ 0.3 g/l
T_7- Dinotefuron 20 SG @ 0.12 g/l
T_8- Dinotefuron 20 SG @ 0.25 g/l
T_9- Azadirachtin 1 % @ 1 ml/l
T_{10}- Azadirachtin 1 % @ 2 ml/l
T_{11}- Dichlorovas 76 EC @ 1.32 ml/l
T_{12}- Dichlorovas 76 EC @ 2.63 ml/l
T_{13}- Untreated control
DAS- Days after spraying

The silkworms reared by feeding mulberry leaves 20 DAS of insecticides have recorded significant difference among treatments, where the untreated control yielded maximum single cocoon shell weight (0.34 g), which was statistically on par with insecticide treated batches *viz*., dichlorvos 76 EC @ 2.63 ml/l (Standard Check) (0.33 g), dinotefuron 20 SG @ 0.25 g/l (0.31 g) and azadirachtin 1 % @ 2 ml/l (0.29 g). The minimum cocoon shell weight was recorded in the treatment flonicamid 50 WG @ 0.3 g/l (0.17 g) which was on par with azadirachtin 1 % @ 1 ml/l (0.18 g). Whereas buprofezin 25 SC @ 1 ml/l, pymetrozine 50 WG @ 0.3 g/l, pymetrozine 50 WG @ 0.6 g/l, flonicamid 50 WG @ 0.15 g/l, dinotefuron 20 SG @ 0.12 g/l and dichlorvos 76 EC @ 1.32 ml/l were found on par with each other. Significant values were recorded in the batches of silkworms fed with mulberry leaves 30 DAS of insecticides. Here also untreated control (0.34 g) has yielded maximum cocoon shell weight which was on par with dinotefuron 20 SG @ 0.25 g/l (0.32 g), dichlorvos 76 EC @ 2.63 ml/l (standard Check) (0.31 g) and azadirachtin 1 % @ 2 ml/l (0.30 g). Flonicamid 50 WG @ 0.3 g/l has yielded very less cocoon shell weight (0.10 g). The rest of the treatments possess the single cocoon shell weight varying from 0.18 g to 0.3 g (Table 3; Fig. 3).

The significant higher single cocoon shell weight was recorded in untreated control (0.34 g) in the batches reared on 40 DAS which was on par with treatments of insecticides azadirachtin 1 % @ 2 ml/l and dichlorvos 76 EC @ 2.63 ml/l (standard Check) which exhibited the similar values (0.31 g).

Flonicamid 50 WG @ 0.3 g/l has yielded very less cocoon shell weight (0.09 g). The rest of the treatments possess the single cocoon shell weight varying from 0.20 g to 0.3 g. Among the treatments untreated control exhibited highest shell weight of 0.34 (20, 30 and 40 DAS) and 0.33 g at 10 DAS of insecticides. This was on par with dichlorvos 76 EC @ 2.63 ml/l (0.31g), dinotefuron 20SG @ 0.25 g/l and pymetrozine 50 WG @ 0. 6g/l.

At 20, 30 and 40 DAS, shell weight was highest in untreated control and the values were on par with the shell weight recorded in dichlorvos 76 EC @ 2.63 ml/l and dinotefuron 20SG @ 0.25 g/l.

Azadirachtin 1 % (1ml/l) recoded significantly lower shell weight at 10, 20, 30 and 40 DAS as compared to untreated control. Similarly, Narayanaswamy *et al.*, (2017) reported significantly lower shell weight when worms were fed with NSKE 4 % treated leaves harvested after 16th, 17th, 18th, 19th day after spray.

In another study, similar to the current findings, buprofezin 25SC @ 1 ml/l exhibited decline in the shell weight when larvae of silkworm *Bombyx mori* were fed with treated leaves harvested at 20, 30 and 40 DAS (Maria *et al.*, 2000).

Cocoon Shell ratio (%)

Dinotefuron 20 SG @ 0.25 g/l (19.24 %) has recorded maximum cocoon shell ratio, was found statistically on par with untreated control (18.38 %) and pymetrozine 50 WG @ 0.6 g/l (17.92 %). The lowest cocoon shell ratio was found in azadirachtin 1 % @ 1 ml/l (11.55 %) which was on par with buprofezin 25 SC @ 2 ml/l (12.50 %). The other treatments possess cocoon shell ratio from 14.94 to 17.18 per cent (Table 4; Fig. 4).

Dichlorvos 76 EC @ 2.63 ml/l (standard Check) resulted in maximum cocoon shell ratio (19.08 %). This was statistically on par with untreated control (18.37 %), dinotefuron 20 SG @ 0.25 g/l (17.44 %), flonicamid 50

WG @ 0.15 g/l (16.97 %), azadirachtin 1% @ 2 ml/l (16.92 %), pymetrozine 50 WG @ 0.3 g/l (16.85 %) and flonicamid 50 WG @ 0.3 g/l (16.62 %). The lowest cocoon shell ratio was exhibited by azadirachtin 1 % @ 1 ml/l (11.15 %) which is on par with buprofezin 25 SC @ 2 ml/l (12.97 %).

When the silkworms were fed with mulberry leaves 30 DAS of insecticides, the maximum cocoon shell ratio was recorded in dinotefuron 20 SG @ 0.25 g/l (17.49 %), which is on par with the highest cocoon shell ratio possessed by untreated control (17.92 %). Whereas dinotefuron 20 SG @ 0.25 g/l was on par with azadirachtin 1 % @ 2 ml/l (17.27 %), pymetrozine 50 WG @ 0.6 g/l (17.17 %), dichlorvos 76 EC @ 2.63 ml/l (standard Check) (16.99 %) and buprofezin 25 SC @ 1 ml/l (16.80 %). The lowest value among the treatments was recorded in flonicamid 50 WG @ 0.3 g/l (9.54 %) which was statistically on par with azadirachtin 1 % @ 1 ml/l (10.41 %).

The cocoon shell ratio varied from 6.20 to 17.83 per cent, when the silkworms were reared with the mulberry leaves fed with 40 DAS of insecticides. The untreated control has yielded highest cocoon shell ratio (18.40 %). Among the treated batches dichlorvos 76 EC @ 1.32 ml/l (17.83 %) has resulted in maximum cocoon shell ratio, which was found on par with dichlorvos 76 EC @ 2.63 ml/l (standard Check) (17.59 %), azadirachtin 1 % @ 2 ml/l (17.53 %) and flonicamid 50 WG @ 0.15 g/l (17.13 %). The lowest value among the treatments was recorded in azadirachtin 1 % @ 1 ml/l (06.20 %) (Table 4; Fig. 4).

The silkworm batch reared by feeding mulberry leaves 10 days after spraying of insecticides recorded highest cocoon shell ratio in the treatment dinotefuron 20SG @ 0.25 g/l (19.24 %) and the lowest shell ratio was recorded in the treatment azadirachtin 1% @ 2 ml/l (11.55 %).

Similar finding were reported by Manoja *et al.,* (2011) wherein, thiamethexam (0.015%) treated mulberry leaves fed to silkworms exhibited an increased shell ratio of 17.35 % over control.

Dinotefuran belongs to the same group of insecticides (neonicotinods) as that of thiamethaxam and the current findings are in conformity with this report. On 20 days after spraying, highest cocoon shell ratio was recorded in the treatment dichlorvos 76 EC @ 2.63 ml/l (19.08 %).

Lowest cocoon shell ratio was observed in azadirachtin 1% @ 1 ml/l at 20 (11.15 %). At 30 days after spraying, highest cocoon shell ratio of 17.92 % was recorded in the untreated control and the lowest shell ratio was recorded in the treatment flonicamid 50 WG @ 0.3 g / l (9.54 %).

When silkworms were fed with leaves harvested at 40 days after spraying, the highest cocoon shell ratio was recorded in untreated control (18.40 %) and the lowest cocoon shell weight was recorded in azadirachtin 1% @ 1 ml/l (6.20 %).

Contrary to the current findings, Bandyopadhyay *et al.,* (2013) observed 19 % shell ratio when silkworms were fed with 1% neem oil treated mulberry leaves. Shell ratio recorded here was on par with the ratio observed in untreated control.

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

Table.4 Effect of insecticides on cocoon shell ratio (%)

Treatments		Cocoon shell ratio (%)			
		10 DAS	20 DAS	30 DAS	40 DAS
T_1	Buprofezin 25 SC @ 1ml/l	14.94^{f}	15.73^{bc}	16.80^{a}	16.56^{bc}
T_2	Buprofezin 25 SC @ 2 ml/l	12.50^{g}	12.97^{de}	12.43^{c}	12.05^{e}
T_3	Pymetrozine 50 WG @ 0.3 g/l	15.81^{def}	16.85^{abc}	15.02^{b}	16.08^{cd}
T_4	Pymetrozine 50 WG @ 0.6 g/l	17.92^{abc}	14.85^{cd}	17.17^{a}	15.07^{d}
T_5	Flonicamid 50 WG @ 0.15 g/l	15.17^{ef}	16.97^{abc}	14.79^{b}	17.13^{abcf}
T_6	Flonicamid 50 WG @ 0.3 g/l	0.00^{h}	16.62^{abc}	9.54^{d}	8.57^{d}
T_7	Dinotefuron 20 SG @ 0.12 g/l	16.51^{cde}	16.31^{bc}	15.09^{b}	14.91^{bc}
T_8	Dinotefuron 20 SG @ 0.25 g/l	19.24^{a}	17.44^{abc}	17.49^{a}	16.90^{g}
T_9	Azadirachtin 1 % @ 1 ml/l	11.55^{g}	11.15^{e}	10.41^{d}	6.20^{ab}
T_{10}	Azadirachtin 1 % @ 2 ml/l	$16.^{88cd}$	16.92^{abc}	17.27^{a}	17.53^{cd}
T_{11}	Dichlorvos 76 EC @ 1.32 ml/l	15.73^{def}	15.54^{cd}	15.01^{b}	17.83^{cd}
T_{12}	Dichlorvos 76 EC @ 2.63 ml/l (std. check)	17.18^{bcd}	19.08^{a}	16.99^{a}	17.59^{ab}
T_{13}	Untreated control	18.38^{ab}	18.37^{ab}	17.92^{a}	18.40^{a}
F-test		*	*	*	*
SE.m ±		0.507	0.935	0.457	0.464
CD at 5 %		1.474	2.718	1.330	1.349

*Significant at 5 %, DAS - Days after spraying.

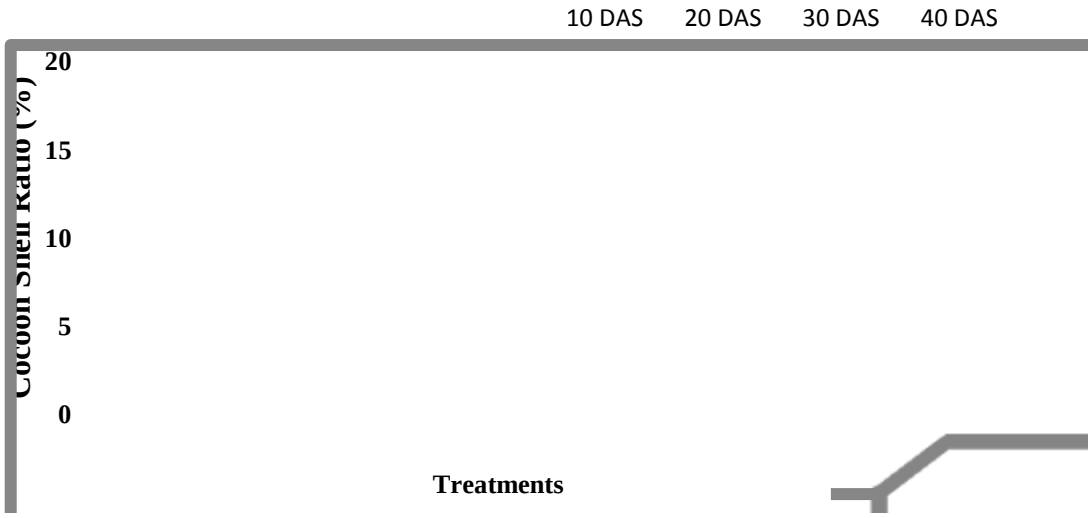

Fig.4 Effect of insecticides on shell ratio (%)

T_1- Buprofezin 25 SC @ 1ml/l
T_2- Buprofezin 25 SC @ 2 ml/l
T_3- Pymetrozine 50 WG @ 0.3 g/l
T_4- Pymetrozine 50 WG @ 0.6 g/l
T_5- Flonicamid 50 WG @ 0.15 g/l
T_6- Flonicamid 50 WG @ 0.3 g/l
T_7- Dinotefuron 20 SG @ 0.12 g/l
T_8- Dinotefuron 20 SG @ 0.25 g/l
T_9- Azadirachtin 1 % @ 1 ml/l
T_{10}- Azadirachtin 1 % @ 2 ml/l
T_{11}- Dichlorovas 76 EC @ 1.32 ml/l
T_{12}- Dichlorovas 76 EC @ 2.63 ml/l
T_{13}- Untreated control
DAS- Days after spraying

Plate.11 Cocoon formation among the silkworm batches treated with insecticides

Cocoons got in the treatment dinotefuron 25 SG @ 0.25 g/l

Cocoons got in the treatment flonicamid 50 WG @ 0.3 g/l

The evaluation on efficacy of insecticides on the cocoon weight parameters the untreated control exhibited the highest cocoon weight in every batch reared by feeding the silkworms with mulberry at 10, 20, 30 and 40 DAS. Dinotefuran 20 SG @ 0.25 g/l and azadirachtin 1 % @ 2 ml/l also exhibited higher cocoon weight along with control and the lowest cocoon weight was recorded in flonicamid 50WG @ 0.3 g/l at 20 DAS, 30 DAS and 40 DAS this may be due to the residual action of flonicamid in mulberry and even though flonicamid is a selective feeding blocker specific to sucking insects with repellent action, it appears that silkworms have lower tolerance limits for this molecule and the weight of the cocoon is altered. Pupal weight recorded was highest in untreated control along with other insecticides *viz*., azadirachtin 1 % @ 1 ml, dinotefuran 20 SG

@ 0.25 & 0.12 g/l, pymetrozine 50 WG @ 0.6 g/l and buprofezin 25 SC @ 1ml/l at 10 DAS and 20 DAS. At 40 DAS, highest pupal weight was recorded in azadirachtin 1 % @ 1ml/l (1.61 g) which was on par with untreated control (1.52 g).

The lowest pupal weight was observed in flonicamid 50WG @ 0.3 g/l at 20, 30 and 40 days after spraying. The untreated control exhibited highest shell weight of 0.34 (20, 30 and 40 DAS) and 0.33 g at 10 DAS of insecticides which was on par with the shell weight recorded in dichlorvos 76 EC @ 2.63 ml/l and dinotefuron 20SG @ 0.25 g/l whereas azadirachtin 1 % (1ml/l) recoded lower shell weight at 10, 20, 30 and 40 DAS as compared to untreated control.

The silkworm batch reared by feeding mulberry leaves 10 days after spraying of insecticides recorded highest cocoon shell ratio in the treatment dinotefuron 20SG @ 0.25 g/l (19.24 %) and the lowest shell ratio was recorded in the treatment azadirachtin 1% @ 2 ml/l (11.55 %). On 20 days after spraying, highest cocoon shell ratio was recorded in the treatment dichlorvos 76 EC @ 2.63 ml/l (19.08 %).

Lowest shell ratio was observed in azadirachtin 1% @ 1 ml/l at 20 (shell ratio of 11.15 %). At 30 days after spraying, highest cocoon shell ratio of 17.92 % was recorded in the untreated control and the lowest shell ratio was recorded in the treatment flonicamid 50 WG @ 0.3 g / l (9.54 %). When silkworms were fed with leaves harvested at 40 days after spraying, the highest cocoon shell ratio was recorded in untreated control (18.40 %) and the lowest cocoon shell weight was recorded in azadirachtin 1% @ 1 ml/l (6.20 %). By considering these facts dinotefuron 20SG along with azadiractin and pymetrozine can be used as an effective substitute for DDVP in Sericulture.

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