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Efficacy of Pesticides Against Yellow Mite in Mulberry and its Residual Toxicity on Silkworm

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Abstract

Evaluation of efficacy of pesticides against the *Polyphagotarsonemus latus* in mulberry revealed that propargite 57 EC @ 1.5ml/l caused maximum mortality of eggs and active stages, thus proving as the best pesticide followed by dicofol @ 2.5 ml/l, wettable sulphur 80WP @ 3g/l and wettable sulphur 80WP @ 2g/l in the decreasing order of their efficacy. There was a continued efficacy up to 7 DAS and most of the pesticides lost their efficacy by 14 DAS. Regarding the safety of the pesticides to the silkworm, wettable sulphur 80WP @ 3g/l was the most safer which was on par with propargite 57 EC @ 1.5ml/l and dicofol 18.5EC @ 2.5ml/l for both larval and cocoon parameters. Though Wettable Sulphur 80WP @ 2g/l showed better silkworm safety parameters, it was less effective in inflicting significant mortality of *P. latus* in mulberry. Propargite 57 EC @ 1.5ml/l was found effective against *P. latus* and safer to silkworm with better economic traits *viz.,* grown up larval weight (2.85g), fifth instar larval duration (184.20 h), cocoon weight (1.31g), pupal weight (1.1g), shell weight (0.22g), shell ratio (16.58%) and ERR (96.66%) at 16 days after spray.

Keywords : Mulberry, *Polyphagotarsonemus latus*, Efficacy, Pesticides, Waiting period

Chemical acaricides are the only remedy that have been suggested for combating mites. However, problems like persistence of chemical residues and environmental contamination are the result of injudicious use of the chemical acaricides. To control these dreaded pests, farmers are spraying pesticides indiscriminately with short intervals between two sprays. Botanical pesticides in general and neem-based pesticides in particular could be of immense value in eco-friendly management of mites. Wettable sulphur acts as both acaricide and fungicide and propargite is an acaricide which targets respiration and inhibits mitochondrial ATP synthase. Azadirachtin and dicofol are the compounds of unknown or uncertain mode of action (www.irac.online.org) but still found effective against mites. Pest management in mulberry poses a great problem because of sensitivity of silkworm to most of the pesticides. The pesticide applied for the control of the mulberry pests affects silkworm since they leave residues on mulberry leaves. Field observations indicated loss of cocoon yield when silkworms were fed on mulberry leaves sprayed with pesticides. To overcome this problem safe waiting period should be followed to harvest leaves for silkworm rearing. Therefore, the safety of pesticides used to control the pests in mulberry to silkworm is of greater importance. The pesticides with minimum waiting period but which are more effective in the management of mulberry pest are more important (Chandrashekaran *et al*., 2007).

Material and Methods

The pesticides such as wettable sulphur, propargite, dicofol and azadirachtin were sprayed on mulberry, using a battery-operated knapsack sprayer. Treatments were imposed on 35th day after pruning (DAP) of mulberry. Pre-treatment observations were recorded one day before treatment imposition and post treatment observations were recorded at 1, 3, 5, 7 and 14 days after spray. The spray was done for two crops, first crop during September-October 2019 and second crop during December 2019-January 2020 and observations were recorded on number of eggs, active stages and total population/

cm^2 leaf area. Five plants were selected randomly in each replication and from each plant three growing leaves were selected and observations were recorded for the presence of eggs and active stages. The average data from two crops was subjected to statistical analysis.

$$\text{Per cent reduction over control} = \{ [1 - \left(\frac{Ta}{Tb}\right) \times \left(\frac{Cb}{Ca}\right)] \times 100 \}$$

Where,

Ta = mites count in Treatment after treatment imposition.

Tb = mites count in Treatment before treatment imposition.

Ca = mites count in control after treatment imposition.

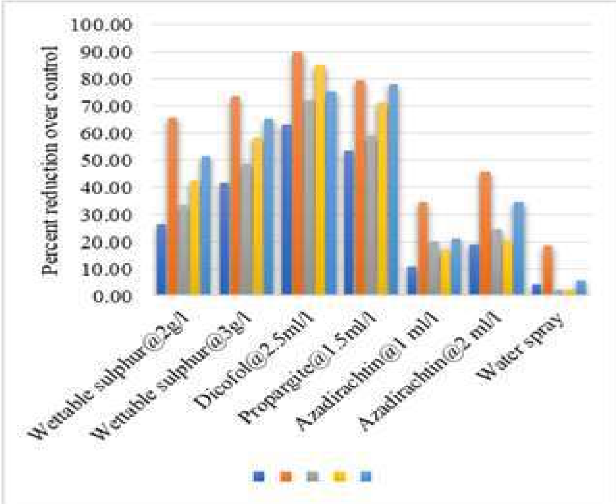
Cb = mites count in control before treatment imposition.

Studies to determine the efficacy of safe/waiting period of different pesticides on *P. latus* was done in the Department of Sericulture, College of Agriculture, UAS, GKVK, Bengaluru during September 2019-January 2020. To determine safe / waiting period of pesticides, to silkworm they were sprayed on mulberry by tagging five randomly selected plants in each row treatment-wise, date-wise and replication-wise separately. The spray was so scheduled to obtain treated leaves for feeding on the first day of the fifth instar at 0, 2, 4, 6, 8, 10, 12, 14, 16 days after spray imposition. The rearing experiment was laid out in completely randomised block design (CRD). The cross breed (PM x CSR$_2$) silkworm was used with 50 worms per replication in all the treatments. The treated leaves were fed to silkworms once on the first day of fifth instar (morning feed) and after which they were fed with healthy leaves.

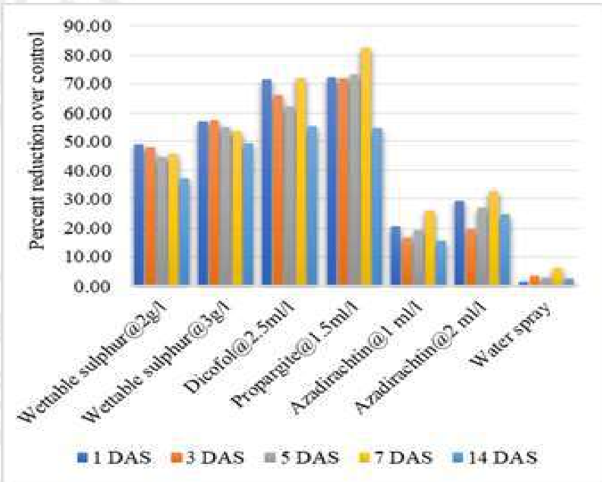
RESULTS AND DISCUSSION

Efficacy of Pesticides against Yellow Mite

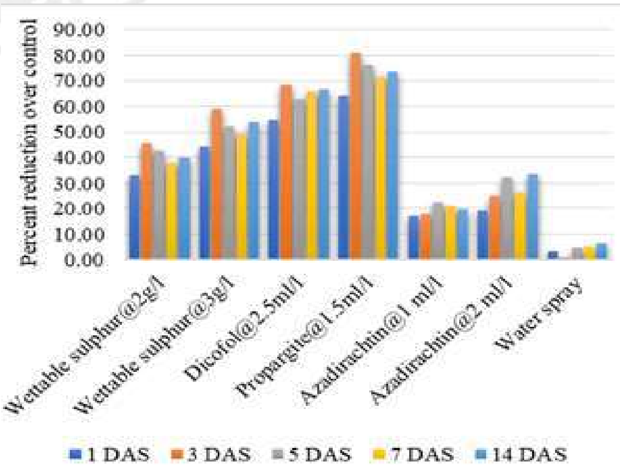
Efficacy of pesticides were tested against eggs and active stages of *P. latus*. Data both in terms of mean number/cm^2 and per cent reduction over control on pooled values of two sprayings are presented in the Table 1 and fig.1, respectively.



a) Eggs



b) Active stages



c) Total Population

Fig. 1 : Effect of pesticide spray on mulberry at 35 DAP on population reduction of *P. latus*

TABLE 1

Efficacy of pesticides sprayed to mulberry at 35th DAP on managing *P. latus*

	Mean number of eggs/cm^2 leaf area						Mean number of active stages/cm^2 leaf area						Mean number of eggs+active stages /cm^2 leaf area					
	1 DBS	1 DAS	3 DAS	5 DAS	7 DAS	14 DAS	1 DBS	1 DAS	3 DAS	5 DAS	7 DAS	14 DAS	1 DBS	1 DAS	3 DAS	5 DAS	7 DAS	14 DAS
Wettable sulphur 80WP @ 2g/l	59.20 (7.73)	20.17 (4.55)^{d}	15.64 (4.02)^{d}	15.63 (4.02)^{d}	20.83 (4.62)^{d}	13.57 (6.12)^{c}	60.03 (7.78)	10.05 (3.25)^{b}	14.13 (3.83)^{c}	13.07 (3.68)^{c}	15.53 (4.04)^{d}	21.34 (4.67)^{b}	61.46 (7.87)	18.17 (4.32)^{d}	12.33 (3.58)^{c}	14.98 (3.93)^{d}	18.83 (4.40)^{d}	16.33 (4.10)^{c}
Wettable sulphur 80WP @ 3g/l	61.34 (7.86)	16.65 (4.14)^{c}	12.41 (3.59)^{c}	12.61 (3.62)^{c}	15.46 (3.99)^{c}	10.05 (5.54)^{b}	57.37 (7.61)	8.22 (2.95)^{b}	10.96 (3.39)^{b}	10.23 (3.28)^{b}	13.00 (3.67)^{c}	16.57 (4.13)^{a}	59.58 (7.75)	14.57 (3.88)^{c}	9.00 (3.08)^{b}	12.03 (3.54)^{c}	14.98 (3.93)^{c}	12.16 (3.56)^{cb}
Dicofol 18.5EC @2.5ml/l	61.11 (7.85)	10.47 (3.31)^{a}	4.71 (2.28)^{a}	6.78 (2.70)^{a}	5.47 (2.44)^{a}	7.10 (5.01)^{a}	57.34 (7.61)	5.35 (2.42)^{a}	8.81 (3.05)^{a}	8.59 (3.01)^{a}	7.82 (2.88)^{a}	14.59 (3.89)^{a}	61.43 (7.87)	12.21 (3.57)^{a}	7.13 (2.76)^{b}	9.65 (3.19)^{a}	10.40 (3.30)^{a}	9.12 (3.10)^{a}
Propargite 57 EC @1.5ml/l	62.87 (7.96)	13.67 (3.76)^{b}	9.94 (3.23)^{b}	10.22 (3.27)^{b}	10.99 (3.39)^{b}	6.49 (5.16)^{a}	59.53 (7.75)	5.47 (2.44)^{a}	7.59 (2.84)^{a}	6.39 (2.62)^{ab}	4.95 (2.33)^{b}	15.41 (3.99)^{a}	62.00 (7.91)	9.78 (3.21)^{b}	4.30 (2.19)^{a}	6.22 (2.59)^{b}	8.82 (3.05)^{b}	7.40 (2.81)^{ab}
Azadirachtin 10000ppm @ 1 ml/l	62.47 (7.94)	26.00 (5.15)^{def}	31.53 (5.66)^{f}	19.83 (4.51)^{e}	31.50 (5.66)^{e}	23.17 (7.54)^{d}	58.39 (7.67)	15.33 (3.98)^{c}	21.94 (4.74)^{d}	18.67 (4.38)^{d}	21.00 (4.64)^{e}	28.00 (5.34)^{c}	61.55 (7.88)	22.50 (4.80)^{e}	18.63 (4.37)^{d}	20.17 (4.55)^{f}	24.17 (4.97)^{e}	22.00 (4.74)^{de}
Azadirachtin 10000ppm @ 2 ml/l	60.37 (7.85)	22.83 (4.83)^{de}	25.29 (5.08)^{e}	18.17 (4.32)^{e}	29.17 (5.45)^{e}	18.59 (7.40)^{c}	58.03 (7.65)	13.67 (3.76)^{c}	21.07 (4.64)^{d}	16.79 (4.16)^{d}	27.00 (4.42)^{de}	24.78 (5.03)^{bc}	60.46 (7.81)	21.57 (4.70)^{e}	16.67 (4.14)^{d}	17.33 (4.22)^{e}	22.17 (4.76)^{e}	17.83 (4.28)^{cd}
Water spray	61.17 (7.93)	27.33 (5.28)^{f}	38.36 (6.23)^{g}	23.83 (4.93)^{f}	36.33 (6.07)^{f}	27.33 (7.60)^{f}	59.39 (7.74)	19.33 (4.45)^{d}	25.92 (5.14)^{e}	22.83 (4.83)^{e}	29.00 (5.24)^{f}	32.83 (5.77)^{d}	62.10 (7.91)	26.50 (5.20)^{f}	22.95 (4.84)^{e}	25.17 (5.07)^{g}	29.33 (5.46)^{f}	25.83 (5.13)^{ef}
Absolute control	62.45 (8.57)	29.17 (5.45)^{f}	48.17 (6.98)^{h}	25.00 (5.05)^{f}	38.17 (6.22)^{f}	29.67 (8.24)^{f}	59.78 (7.76)	20.00 (4.53)^{d}	27.05 (5.25)^{e}	23.67 (4.92)^{e}	63.33 (5.43)^{f}	34.00 (5.87)^{d}	62.70 (7.95)	27.67 (5.31)^{f}	23.11 (4.86)^{e}	26.67 (5.21)^{g}	31.17 (5.63)^{f}	27.83 (5.32)^{f}
F test	NS	*	*	*	*	*	NS	*	*	*	*	*	NS	*	*	*	*	*
S.Em.±	-	0.08	0.12	0.07	0.08	0.10	-	0.14	0.09	0.14	0.12	0.12	-	0.08	0.12	0.08	0.09	0.17
C.D at p=0.05	-	0.23	0.36	0.21	0.25	0.30	-	0.43	0.27	0.42	0.36	0.36	-	0.25	0.36	0.25	0.26	0.51
C.V (%)	1.78	2.89	4.47	3.00	3.00	4.17	1.02	7.12	3.71	6.19	5.09	4.26	1.41	3.29	5.53	3.49	3.39	7.04

Note: Each observation is a mean of two crops

Figures in the parenthesis are $\sqrt{x + 0.5}$ transformed values for post spray count

NS-Non-significant; (*)- Significant at 5%; DAS- days after spraying; DBS- days before spraying; DAP- Days after pruning; Figures with same superscript are statistically on par

There was no significant difference in the pre-spray count observations among all treatments. On the day after spray least number of eggs (10.47) and maximum per cent reduction over control (63.24%) wasseen in dicofol 18.5EC @ 2.5ml/l followed by propargite 57EC @ 1.5ml/l (13.67 & 53.61%) whereas, least number and maximum per cent reduction over control for active stages was observed in propargite 57EC @1.5ml/l (9.78 & 64.19 per cent, respectively) followed by dicofol 18.5EC @ 2.5ml/l (12.21 & 54.84 per cent, respectively) similarly for total population propargite 57 EC @1.5ml/l (9.78 & 64.19 per cent, respectively) followed by dicofol 18.5EC @ 2.5ml/l (12.21 & 54.84%, respectively) showed the reduction. On 14 DAS propargite 57EC @ 1.5ml/l showed the least number of eggs (6.49) and maximum per cent reduction over control (77.96%) followed by dicofol 18.5EC @ 2.5ml/l (7.10 & 75.46%, respectively), whereas least number of active stages (14.59) and maximum per cent reduction over control (55.28%) was observed in dicofol 18.5EC @ 2.5ml/l followed by propargite 57EC @ 1.5ml/l (15.41 & 54.56 per cent, respectively) and least total population (7.40) and maximum per cent reduction over control (73.43%) was recorded in propargite 57EC @ 1.5ml/l. This is followed by dicofol 18.5 EC @ 2.5ml/l (9.12 & 66.57 %, respectively). The overall decreasing order of efficacy of the pesticides was found to be propargite 57 EC @ 1.5ml/l > dicofol 18.5 EC @ 2.5ml/l > wettable sulphur 80WP @ 3g/l > wettable sulphur 80WP @ 2g/l > azadirachtin 10000ppm @ 2 ml/l > azadirachtin 10000ppm @ 1 ml/l > water spray (Table 1 & Fig. 1).

The results obtained with respect to dicofol in the present investagation are in concurrence with findings of Rajalakshmi *et al.* (2009) (dicofol 18.5 EC @0.2%) in mulberry. Similar observation have been reported in Capsicum by Singh and Singh (2013) (dicofol 18.5 EC @ 2.70 ml/l), Sarkar *et al.* (2014) (dicofol 18.5 EC @ 200g a.i. ha^{-1}), Samantha *et al.* (2017) (dicofol 18.5 EC @ 277.50 g a.i. ha^{-1}), Pal and Karmakar (2017) (dicofol 18.5EC @ 1.5 ml/l) and Sharanappa *et al.* (2020) (dicofol 18.5EC @ 500 ml/acre). Pree *et al.* (1992) reported the persistence of toxic effects of the contact acaricides dicofol and propargite, to the European red mite, *Panonychus ulmi* (Koch) on peach where mortality on dicofol-treated foliage was > 50 per cent for more than 15 days. Kavya *et al*. (2015) reported that propargite @ 570 g. a.i/ ha and spiromesifen @ 100 g. a.i/ha were found effective against *T. urticae* on brinjal under polyhouse conditions.

Safety of Pesticides to Silkworm

Grown up Larval Weight

Grown up larval weight in treatment water spray (31.30 g/10 larvae) was found to be on par with absolute control (32.13 g/10 larvae) whereas dicofol 18.5EC @ 2.5ml/l (15.75 g/10 larvae) showed the lowest larval weight followed by propargite 57 EC @ 1.5ml/l (18.74 g/10 larvae) among all the treatments on 0 DAS. Larval weight on 16 DAS in water spray, wettable sulphur 80WP @ 2g/l, wettable sulphur 80WP @ 3g/l, propargite 57 EC @ 1.5ml/l, dicofol 18.5EC @ 2.5ml/l, azadirachtin 10000ppm @ 1 ml/l and azadirachtin 10000ppm @ 2 ml/l was found to be 31.17, 29.21, 28.59, 28.48, 27.98, 27.36 and 27.77 g/10 larvae, respectively. The larval weight of silkworms fed with mulberry leaves sprayed with pesticides on different days interval was found to be in the order water spray > wettable sulphur 80WP @2g/l > wettable sulphur 80WP @ 3g/l > propargite 57 EC @ 1.5ml/l > dicofol 18.5EC @ 2.5ml/l > azadirachtin 10000ppm @ 1 ml/l > azadirachtin 10000ppm @ 2 ml/l (Table 2).

Significant decrease in the fifth instar larval weight (3.35, 3.34 and 3.16 g/larva) in buprofezin 25 per cent WP (0.5, 1 and 2 g/l) compared to control for was reported by Vassarmidaki *et al*. (2000). Similarly, decreased larval weight (2.49, 2.51 g/larva on 14 and 21 DAS, respectively) of silkworm fed with thiamethoxam (0.015%) sprayed mulberry leaves was reported by Patnaik *et al*. (2011). The possible reason for decrease in larval weight may be due to decreased uptake of nutrients from leaf, enhanced metabolic activity of treated worms to overcome the effects of pesticide, reduced enzymatic activity

TABLE 2

Effect of feeding mulberry leaves sprayed with pesticides on 35th DAP on silkworm (PM×CSR2)

Treatments	Grown up larval weight(g/10 larvae)		Larval duration (h)		Per cent larval mortality		ERR(%)		Pupal weight (g/10 pupae)		Cocoon weight (g/10 cocoon)		Shell weight (g/10 shells)		Shell ratio (%)	
	0 DAS	16 DAS	0 DAS	16 DAS	0 DAS	16 DAS	0 DAS	16 DAS	0 DAS	16 DAS	0 DAS	16 DAS	0 DAS	16 DAS	0 DAS	16 DAS
Wettable sulphur 80WP @ 2g/l	24.45 ^{c}	29.21 ^{c}	191.40 ^{c}	182.68 ^{c}	13.34 (21.41) ^{e}	0.66 (4.66) ^{e}	84.66 (66.92) ^{b}	96.66 (79.44) ^{b}	9.29 ^{d}	11.25 ^{c}	11.04 ^{c}	13.69 ^{c}	1.68 ^{b}	2.30 ^{c}	15.20 (22.94) ^{c}	16.80 (24.19) ^{c}
Wettable sulphur 80WP @ 3g/l	23.71 ^{c}	28.59 ^{bc}	193.08 ^{b}	183.50 ^{b}	14.66 (22.50) ^{e}	1.34 (6.64) ^{d}	83.34 (65.80) ^{b}	96.00 (78.43) ^{b}	9.14 ^{d}	11.03 ^{c}	10.97 ^{bc}	13.58 ^{c}	1.60 ^{b}	2.22 ^{bc}	14.62 (22.47) ^{bc}	16.35 (23.84) ^{c}
Dicofol 18.5EC @2.5ml/l	15.75 ^{a}	27.98 ^{ab}	194.52 ^{a}	185.00 ^{a}	24.00 (29.32) ^{c}	9.34 (17.79) ^{a}	74.00 (59.32) ^{a}	88.66 (70.29) ^{a}	8.50 ^{a}	10.48 ^{a}	9.96 ^{a}	13.23 ^{b}	1.26 ^{a}	1.95 ^{a}	12.65 (20.83) ^{a}	14.74 (22.57) ^{a}
Propargite 57 EC @1.5ml/l	18.74 ^{b}	28.48 ^{bc}	193.24 ^{b}	184.20 ^{b}	15.34 (23.05) ^{d}	1.34 (6.64) ^{d}	82.66 (65.37) ^{b}	96.66 (79.44) ^{b}	8.99 ^{c}	10.97 ^{c}	10.83 ^{b}	13.15 ^{ab}	1.57 ^{b}	2.18 ^{b}	14.50 (22.37) ^{b}	16.58 (24.02) ^{c}
Azadirachtin 10000ppm @ 1 ml/l	22.97 ^{cd}	27.36 ^{a}	194.52 ^{a}	185.72 ^{a}	44.66 (41.92) ^{b}	2.00 (8.13) ^{cd}	53.34 (46.90) ^{c}	97.34 (80.58) ^{c}	8.82 ^{bc}	10.62 ^{a}	10.60 ^{d}	12.95 ^{a}	1.41 ^{c}	2.03 ^{a}	13.63 (21.66) ^{d}	15.68 (23.31) ^{b}
Azadirachtin 10000ppm @ 2 ml/l	21.63 ^{d}	27.77 ^{ab}	196.20 ^{d}	187.00 ^{d}	56.00 (48.43) ^{a}	3.34 (10.53) ^{b}	42.00 (40.38) ^{d}	94.66 (76.61) ^{d}	8.67 ^{b}	10.57 ^{a}	10.27 ^{e}	12.67 ^{d}	1.40 ^{c}	1.99 ^{a}	13.30 (21.38) ^{d}	15.71 (23.34) ^{b}
Water spray	31.30 ^{e}	31.17 ^{d}	182.72 ^{e}	181.12 ^{e}	10.66 (19.05) ^{f}	0.66 (4.66) ^{e}	87.34 (69.13) ^{e}	97.34 (80.58) ^{c}	11.40 ^{e}	11.78 ^{d}	13.50 ^{f}	14.35 ^{e}	2.10 ^{d}	2.57 ^{d}	15.56 (23.22) ^{e}	17.91 (25.03) ^{d}
Absolute control	32.13 ^{e}	32.48 ^{d}	181.96 ^{e}	180.72 ^{f}	4.00 (11.53) ^{g}	0.00 (0.00) ^{f}	94.00 (75.79) ^{f}	98.00 (81.84) ^{c}	12.55 ^{f}	11.90 ^{d}	15.37 ^{g}	14.53 ^{e}	2.76 ^{e}	2.77 ^{e}	17.95 (25.06) ^{f}	17.70 (24.87) ^{d}
F test	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
S.Em.±	0.50	0.45	0.28	0.26	0.50	0.53	0.53	0.51	0.05	0.10	0.05	0.07	0.04	0.04	0.17	0.13
C.D at p=0.05	1.50	1.37	0.85	0.77	1.50	1.58	1.60	1.52	0.15	0.30	0.15	0.21	0.12	0.13	0.50	0.40
C.V (%)	5.20	4.03	2.92	6.19	6.50	5.90	5.04	3.82	5.60	4.14	6.60	3.71	5.09	5.96	7.01	5.25

(*) - Significant at 5%; DAS- days after spraying; DAP- days after pruning; Figures with same superscript are statistically on par Figures in the parenthesis are arc sin transformed values of digestive juice, loss of digestive fluid during vomiting, diarrhoea and starvation. The decrease in larval weight in the azadirachitn treated batches may be due to its antifeedant property.

Larval Duration

The larval duration was found to be highest in azadirachtin @ 2ml/l (196.20 h), followed by azadirachtin @ 1ml/l (194.52 h) and lowest in water spray (182.72 h) which was on par with absolute control (181.96 h) followed by wettable sulphur @ 2g/l (191.40 h) on 0 DAS. However, in all interval of spraying from 0 to 16 DAS, the larval duration was found to be more in the azadirachtin @ 2ml/l and lowest in water spray followed by wettable sulphur @ 2g/l. The larval duration on 16 DAS in azadirachtin 10000ppm @ 2 ml/l, azadirachtin 10000ppm @ 1 ml/l, dicofol 18.5EC @ 2.5ml/l, propargite 57 EC @ 1.5ml/l, wettable sulphur 80WP @ 3g/l and wettable sulphur 80WP @ 2g/l was found to be 187.00, 185.72, 185.00, 184.20, 183.50 and 182.68 h, respectively. The larval duration of silkworms fed on mulberry leaves sprayed with pesticides on different days interval was found to be in the order of azadirachtin 10000ppm @ 2 ml/l> azadirachtin 10000ppm @ 1 ml/l > dicofol 18.5EC @ 2.5ml/l > propargite 57 EC @ 1.5ml/l > wettable sulphur 80WP @ 3g/l > wettable sulphur 80WP @ 2g/l (Table 2).

Kumar *et al.* (2019) reported an increased larval duration when silkworms were fed on mulberry leaves treated with azadirachtin 0.03 per cent EC @ 2ml/l on 15 DAS (215.33 h), 20 DAS (205.56 h), 25 DAS (190.00 h) and 30 DAS (184.00 h). Yeshika *et al.* (2019) reported that azadirachtin one per cent @ 1 ml/l caused longest 5th instar larval duration at 10 DAS (221.83 h) followed by 20 DAS (220 h) and 40 DAS (217 h). Kumutha *et al.,* (2009) also noticed increased larval duration with increase in insecticide concentration of dichlorvos 76 per cent EC, azadirachtin, neem oil and methyl parathion. Narayanawamy *et al.,* (2017) also reported increasing silkworm larval duration in fifth instar after the application of NSKE 4 per cent on mulberry. The increased fifth instar larval duration (196.20 h) of the current findings might be due to residual toxicity which may be higher in initial days of spray and its effect decreased as the number of day's after spray increased. The pesticides sprayed on mulberry leaves are also known to interfere with the release of the hormones in silkworm, resulting in increased instar duration (Nath, 2002)

Larval Mortality

The per cent larval mortality was found to be more in 0 DAS and decreased over the different days of spray. Though there was significant difference among the different pesticides treated per cent mortality was found to be significantly maximum in azadirachtin 10000 ppm @ 2 ml/l (56 %) followed by azadirachtin 10000ppm @ 1 ml/l (44.66 %) and wettable sulphur @ 2g/l (13.34 %) on 0 DAS and lowest in water spray (10.66 %). At 16 DAS mortality in azadirachtin 10000ppm @ 2 ml/l, azadirachtin 10000ppm @ 1 ml/l, dicofol 18.5EC @ 2.5ml/l, propargite 57 EC @ 1.5ml/l, wettable sulphur 80WP @ 3g/l and wettable sulphur 80WP @ 2g/l was found to be 3.34, 2.00, 9.34, 1.34, 1.34 and 0.66 per cent, respectively (Table 2).

Kumar *et al.* (2019) reported that silkworms fed on mulberry leaves sprayed with azadirachtin 0.03 EC @ 2. 0 ml/l caused 100.00, 75.00, 50.33, 10.00 and 12.00 per cent mortality on 10, 15, 20, 25 and 30 DAS, respectively. Bandyopadhyay *et al.* (2013) reported that neem oil @1500 ppm and azadirachtin 1 per cent recorded silkworm mortality of 10.80 per cent and 11.60 per cent, respectively at 7 DAS and 6.3 per cent and 8.3 per cent at 14 DAS, respectively. Yeshika *et al.* (2019) reported zero per cent mortality of silkworms fed on mulberry leaves sprayed with azadirachitin @ 1ml/l and 2 ml/l on 10, 20, 30 and 40 DAS which contradicts the present findings, where the mortality never reached zero from 0 to 16 DAS. Patnaik *et al.* (2011) reported that 0.015 per cent thiamethoxam treated silkworms recorded 100 per cent and

12 per cent mortality on 7th and 14th DAS. Increased mortality of silkworm indicates its susceptibility to azadirachtin while wettable sulphur is found to be relatively safe.

Effective Rate of Rearing

The effective rate of rearing (ERR) on the day of spray in propargite 57 EC @ 1.5ml/l, dicofol 18.5 EC @ 2.5ml/l, wettable sulphur 80WP @ 3g/l, wettable sulphur 80WP @ 2g/l, azadirachtin 10000ppm @ 2 ml/l, azadirachtin 10000ppm @ 1 ml/l and water spray was found to be 82.66, 74.00, 83.34, 84.66, 42.00, 53.34 and 87.34 per cent, respectively. On 16 DAS ERR was found to be highest in water spray (97.34%) followed by wettable sulphur @ 2g/l (96.66%) which was found to be on par with propargite 57 EC @ 1.5ml/l (96.66%) and lowest in azadhiractin @ 2ml/l (94.66%) (Table 2).

Patnaik *et al*. (2011) reported that silkworms fed with mulberry leaves sprayed with 0.015 per cent thiamethoxam recorded ERR of 94.35 per cent. When silkworms were fed with pesticide sprayed mulberry leaves from fourth and fifth instar onwards at different days after spraying recorded minimum ERR of 39.07 per cent with methyl demeton (0.05 %) and maximum ERR of 47.59 with nimbicidin (6 ppm) (Gayathri, 2007). One per cent neem oil treated mulberry leaves when fed to silkworm at 15 days after spray resulted in 93 per cent ERR (Bandyopadhyay *et al*., 2013). ERR recorded for azadirachtin during present investigation is in line with the findings of Patnaik *et al*. (2011) and Gayathri (2007).

Cocoon Weight

On the day of spray lowest cocoon weight (g/10 cocoons) was found in dicofol 18.5EC @ 2.5ml/l (9.96 g/10 cocoons) whereas water spray (13.50 g/10 cocoons) followed by the wettable sulphur 80WP @ 2g/l (11.04 g/10 cocoons) was found to be near to control (15.37 g/10 cocoons). On the 16 DAS cocoon weight in water spray, wettable sulphur 80WP @ 2g/l, wettable sulphur 80WP @ 3g/l, propargite 57 EC @ 1.5ml/l, dicofol 18.5EC @ 2.5ml/l, azadirachtin 10000ppm @ 1 ml/l and azadirachtin 10000ppm @ 2 ml/l was found to be 14.35, 13.69, 13.58, 13.15, 13.23, 12.95 and 12.67 g/10 cocoons, respectively. The cocoon weight of silkworms fed with mulberry leaves sprayed with pesticides on different days interval was found to be in the order of water spray > wettable sulphur 80WP @ 2g/l > wettable sulphur 80WP @ 3g/l > propargite 57 EC @ 1.5ml/l > dicofol 18.5EC @ 2.5ml/l > azadirachtin 10000ppm @ 1 ml/l > azadirachtin 10000ppm @ 2 ml/l (Table 2).

Silkworms when fed with 0.015 per cent thiame thoxam treated mulberry leaves on 14 and 7 DAS, recorded cocoon weight of 1.15 and 1.21g, respectively (Patnaik *et al*., 2011). Kumar *et al.* (2019) reported 1.59 g single cocoon weight in silkworms fed on mulberry leaves sprayed with azadirachtin @ 2ml/l. Manjunatha *et al.* (2017) reported 11.37g/10 cocoons when silkworms were fed on leaves treated with carbendazim 50WP at 0.1 per cent, followed by wettable sulphur 80WP at 0.1 per cent (11.22g/10 cocoons) and with hexaconazole 5EC at 0.3 per cent (6.69g/10 cocoons). The progressive increase in the cocoon weight over a period of time is due to reduction in insecticidal residue. The decrease in silk gland weight causes the decreased cocoon weight. Azadiractin is known to have both antifeedant property and growth regulating activities such as carbohydrate, protein and fat body metabolism, thereby affecting the cocoon weight (Thangaraj *et al*., 2018).

Pupal Weight

The lowest pupal weight was observed in dicofol 18.5EC @2.5ml/l (8.50 g/10 pupae) followed by azadirachtin 10000ppm @ 1 ml/l (8.82 g/10 pupae) and highest with wettable sulphur 80WP @ 2g/l (9.29 g/10 pupae) on 0 DAS. The pupal weight on the 16 DAS in wettable sulphur 80WP @ 2g/l, wettable sulphur 80WP @ 3g/l, propargite 57 EC @ 1.5ml/l, dicofol 18.5EC @ 2.5ml/l, azadirachtin 10000ppm @ 1 ml/l, azadirachtin 10000ppm @ 2 ml/l and water spray was found to be 11.25, 11.03, 10.97, 10.48, 10.62, 10.57 and 11.78 g/10 pupae, respectively. The pupal weight of silkworms fed with mulberry leaves sprayed with pesticides on different days interval was in the order water spray > wettable sulphur 80WP @ 2g/l > wettable sulphur 80WP @ 3g/l > propargite 57 EC @ 1.5ml/l > dicofol 18.5EC @ 2.5ml/l > azadirachtin 10000ppm @ 1 ml/l > azadirachtin 10000ppm @ 2 ml/l (Table 2).

Manjunatha *et al*. (2017) reported 8.29g/10 pupae in silkworms fed on mulberry leaves sprayed with wettable sulphur 80 WP at 0.1 per cent. The decrease in pupal weight may be due to decreased larva weight.

Shell Weight

The shell weight was found to be minimum in dicofol 18.5EC @ 2.5ml/l (1.26 g/10 shells) and highest in water spray (2.76 g/10 shells) followed by the wettable sulphur 80WP @ 2g/l (1.68 g/10 shells) on the day of spray. The shell weight increased with the advancement in the days after spray and on 16 DAS, the shell weight in water spray, wettable sulphur 80WP @ 2g/l, wettable sulphur 80WP @ 3g/l, propargite 57 EC @ 1.5ml/l, dicofol 18.5EC @ 2.5ml/l, azadirachtin 10000ppm @ 1 ml/l and azadirachtin 10000ppm @ 2 ml/l was found to be 2.57, 2.30, 2.22, 2.18, 1.95, 2.03 and 1.99 g/10 shells, respectively. The shell weight of silkworms fed with mulberry leaves sprayed with pesticides on different days interval was found to be in the order of water spray > wettable sulphur 80WP @ 2g/l > wettable sulphur 80WP @ 3g/l > propargite 57 EC @ 1.5ml/l > dicofol 18.5EC @ 2.5ml/l > azadirachtin 10000ppm @ 1 ml/l > azadirachtin 10000ppm @ 2 ml/l (Table 2).

Patnaik *et al*. (2011) reported that 0.015 per cent thiamethoxam treated mulberry leaves when fed to silkworms recorded shell weight of 0.19 to 0.21 g. Vassarmidaki *et al.* (2000) reported that silkworms fed on buprofezin 25 WP treated mulberry leaves produced shell weight of 0.37 to 0.47 g. The decrease in grown up larval weight, weight of the silk gland and also reduced spinning duration may contribute to reduced shell weight.

Shell Ratio

The shell ratio (%) was found to be highest in silk worms fed with mulberry leaves sprayed with water (15.56 %) followed by wettable sulphur @ 2g/l (15.20 %) and lowest in treatment dicofol 18.5EC @ 2.5ml/l (12.65 %) on 0 DAS. The shell ratio increased over the different days interval. On the 16 DAS the shell ratio in wettable sulphur 80WP @ 2g/l, wettable sulphur 80WP @ 3g/l, propargite 57 EC @ 1.5ml/l, dicofol 18.5EC @ 2.5ml/l, azadirachtin 10000ppm @ 1 ml/l, azadirachtin 10000ppm @ 2 ml/l and water spray was found to be 16.80, 16.35, 16.58, 14.74, 15.68 and 15.71 per cent, respectively. The shell weight of silkworms fed with mulberry leaves sprayed with pesticides on different days interval was found to be in the order of water spray > wettable sulphur 80WP @ 2g/l > wettable sulphur 80WP @ 3g/l > propargite 57 EC @ 1.5ml/l > dicofol 18.5EC @ 2.5ml/l > azadirachtin 10000ppm @ 1 ml/l > azadirachtin 10000ppm @ 2 ml/l (Table 2).

Manjunatha *et al.* (2017) recorded the shell ratio of 26.10 per cent and 26.11 per cent from silkworms fed on mulberry leaves sprayed with 0.1 per cent and 0.2 per cent wettable sulphur 80WP, respectively on 3 DAS. Patnaik *et al*. (2011) reported that 0.015 per cent thiamethoxam treated mulberry leaves when fed to silkworms gave shell ratio of 16.8 to 17.35 per cent. However, shell ratio of 23.79 to 25.79 per cent with buprofezin 25WP was reported by Vassarmidaki *et al.* (2000). The amount of organic compounds accumulated by silkworm is an obligatory part manage in its non-feeding stages, where the biomass proportionately gets distributed for silk production and pupa formation. The decreased accumulation of metabolites in larval stage contributes to reduced shell ratio.

The pesticides used against *P. latus* in mulberry is found to cause the increased larval duration and reduced grown up larval weight, pupal weight, cocoon weight, shell weight, shell ratio and ERR on

16 DAS. The waiting period of propargite is found to be 16 DAS. Bandyopadhyay *et al*. (2000) reported that residual toxicity of monocrotophos (36% SL), acephate (75% SP), dichlorovo (76% EC) and neem based pesticides (Azadirachtin 1500 ppm) continues atleast upto 14 days resulting in decline of larval weight, ERR, cocoon weight, shell weight, filament length and denier. Higher concentration of dichlorovos 20 ppm and 40 ppm showed a significant effect on the larval mortality and other economic traits analysed in both pure mysore bivoltine NB_4D_2 breeds (Raghuvee *et al*., 2006).

The order of safer pesticides for silkworm with minimum reduction in the growth and economic parameters *viz*., grown up larval weight, larval duration, larval mortality, ERR, cocoon weight, pupal weight, shell weight and shell ratio was found to be in the order of water spray > wettable sulphur 80WP @ 2g/l > wettable sulphur 80WP @ 3g/l > propargite 57 EC @ 1.5ml/l > dicofol 18.5EC @ 2.5ml/l > azadirachtin 10000ppm @ 1 ml/l > azadirachtin 10000ppm @ 2 ml/l. Propargite 57 EC @ 1.5ml/l was found to be effective in management of yellow mite with waiting period of 16 days with negligible effect on silkworm growth and cocoon yield.

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