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EVALUATION OF INSECTICIDES AGAINST WOOLLY APPLE APHID *ERIOSOMA LANIGERUM* AND ITS PARASITOID *APHELINUS MALI*

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ABSTRACT

Evaluation of certain insecticides and biopesticides against the woolly apple aphid *Eriosoma lanigerum* (Hausmann) on apple revealed that spirotetramat (0.015%) is the most effective resulting in reduction of 68.48 and 61.04% in colony count and colony size, respectively followed by flonicamid (0.05%). Higher concentrations of biopesticides viz., *Beauveria bassiana* (2x10^{10}cfu/l), fish oil (1.0%), neem oil (2.0%) and azadirachtin (0.02%) remained at par with each other registering 29.17, 31.32, 28.95 and 29.83% reduction in colony count. Neem oil with 60 to 80% parasitoid (*Aphelinus mali*) emergence was the safest, whereas, chlorpyriphos (0.04%) with 15 to 20% parasitoid emergence was the most toxic. Spirotetramat and flonicamid were moderately safe to the parasitoid.

Key words: *Eriosoma lanigerum, Aphelinus mali,* azadirachtin, fish oil, neem oil, *Beauveria bassiana***,** chlorpyriphos, spirotetramat, flonicamid

Apple (*Malus domestica* Borkhhausen) is predominantly cultivated in the North-Western Himalayas comprising Jammu and Kashmir, Himachal Pradesh and Uttarakhand. It is a major source of income for the farmers of Himachal Pradesh (Anonymous, 2018). The crop suffers from a wide variety of insect pests and diseases, of which the woolly apple aphid *Eriosoma lanigerum* (Hausmann) is a major pest (Thakur and Dogra, 1980). Both aerial and subterranean plant parts are infested, and damage by piercing the bark (i.e. phloem tissue) and sucking the sap results in reduced tree vigour. It also causes hypertrophy and gall formation which develop splits in reaction to feeding in as little as eight weeks (Brown et al., 1991). This pest remains in colonies and from a distance a colony appears as mass of cotton on the tree.

An aphelinid endoparasitoid *Aphelinus mali* (Haldeman) introduced in Kullu valley during 1937 (Rahman and Khan, 1941) is well established. Use of insecticides is important for the management of woolly apple aphid and large number of insecticides *viz*., organophosphates and carbamates had been recommended (Thakur and Dogra, 1980; Thakur and Gupta, 1998; Singh and Gupta, 2006; Gupta et al., 2013). Most of these earlier recommended insecticides does not figure in the approved usage list of the Central Insecticide Board (CIB) and hence there is dire need to find some pesticides with other modes of action and also some biopesticides which are safe. Therefore, in the present study, some new insecticide molecules and bio-pesticides have been evaluated against the woolly apple aphid.

MATERIALS AND METHODS

The field experiments were carried out in the farmer's field at Matiana, District Shimla, Himachal Pradesh (2300 M asl). Against the aerial form of woolly apple aphid, an apple orchard (20 years old) having infestation was selected. Two concentrations of each of the treatments namely, spirotetramat (0.007 and 0.015%), flupyradifurone (0.017 and 0.03%), flonicamid (0.025 and 0.05%), buprofezin (0.025 and 0.05%), *Beauveria bassiana*, (1x10^{10} cfu/l, fish oil (0.5 and 0.1%), neem oil (1.0 and 2.0%) and azadirachtin (0.01 and 0.02%) were evaluated along with the earlier recommended insecticides *viz.,* namely chlorpyriphos (0.04%) and thiamethoxam (0.025%), and untreated control (only water spray). Emulsion of neem oil was prepared with 0.01% sticker (Indtron-AE) added in the spray solution. The spray application was done in autumn, 2016 with the high volume sprayer till the point of run off. The trial was laid out in a randomized block design having three replications with a tree as one replicate.

Observations were made on colony count and colony size. For colony count, pre-treatment aphid colony count on four marked branches/tree was taken before spray in all the trees, and thereafter the same branches were observed on 3, 7, 14, 21 and 28 days after spray (DAS). With these data, reduction in colony count over pre-treatment count was calculated. Likewise, colony size observed in four colonies/selected branch (16 colonies /tree) with a Vernier calliper before spray and 3, 7, 14, 21, and 28 DAS, and % reduction in colony size was calculated.

For evaluating safety of insecticides/biopesticides against aphelinid endoparasitoid *A. mali*, parasitized aphids (lacking woolly strands and showing mummification) were collected from the experimental trees 3, 7 and 14 DAS and were brought to the laboratory. The parasitized aphids without exit holes were separated by observing under stereozoom microscope using camel hair brush. Twenty parasitized aphids from each treatment collected after 3, 7 and 14 DAS were kept in clean glass vials (15 ml) for further observations. The emergence of parasitoid adults were observed upto three months and % emergence of parasitoid was calculated. Analysis of the data was done using SPSS 21.0 software.

RESULTS AND DISCUSSION

Field efficacy

The data on colony count given in Table 1recorded three days after treatment reveal that spirotetramat (0.015%) and flonicamid (0.05%) being at par proved effective and resulted in 38.33 and 35.37% reduction in colony count and 33.24 and 28.36% in colony size of woolly apple aphid, respectively. These were at par with thiamethoxam (0.025%) where 38.80% reduction in colony count and 29.70% reduction in colony size were observed. Buprofezin was the least effective. The recommended insecticide, chlorpyriphos (0.04%) with 51.80% reduction in colony count and 40.96% reduction in colony size was the most effective. Amongst biopesticides, 17.50, 19.03, 19.86 and 16.76% reduction in colony count and 22.46, 21.55, 20.33 and 25.43% reduction in colony size were obtained at higher concentrations of *B. bassiana*, fish oil, neem oil and azadirachtin, respectively, all of which were at par.

Similar trend was observed when the data was recorded after seven days of treatment where, spirotetramat (0.015%) and flonicamid (0.05%) with 62.16 and 60.06% reduction in colony count and 48.62 and 49.67% reduction in colony size, respectively, were the most effective treatments (Table 1). All the treatments proved to be significantly inferior to the earlier recommended insecticides thiamethoxam (0.025%), except spirotetramat which was at par. However, all the treatments including spirotetramat (0.015%) were statistically inferior to chlorpyriphos (0.04%) with 74.36% reduction in colony count and 61.50% reduction in colony size.

After 14 and 21 days of foliar application the trend remained the same, where spirotetramat with 71.80 and 81.63% reduction in colony count and 63.96 and 78.26% reduction in colony size after 14 and 21 days after spray application, respectively was the most effective treatments. The recommended insecticides namely, thiamethoxam (0.025%) and chlorpyriphos (0.04%) proved superior to all the other treatments, when the data were recorded after 14 and 21 days of spray application. After 28 days of treatment, a slight increase in per cent reduction in colony count and colony size were noticed and again spirotetramat (0.015%) proved to be the most effective treatment resulting in 88.46 and 86.00 % reduction in colony count and colony size, respectively, which was at par with thiamethoxam (0.025%) and chlorpyriphos (0.04%) resulting in 90.00 and 89.66 % reduction in colony count, respectively.

When the overall treatment means were compared, spirotetramat (0.015%) was found significantly superior over all others with a mean reduction of 68.48 and 61.04% in colony count and size, respectively. It was followed by flonicamid (0.05%) which resulted in 61.31 and 55.96 % mean reduction in colony count and size, respectively. The biopesticides were not so effective though were found superior over control. However, the conventional insecticides namely thiamethoxam (0.025%) and chlorpyriphos (0.04%) were found more efficacious. Chlorpyriphos (0.04%) resulted in 51.80 and 40.96 % reduction in colony count and colony size, respectively, just after 3 days of treatment which was comparatively higher than the other test products as well as thiamethoxam (0.025%) which probably is due to the fact that, chlorpyriphos is a contact insecticide which resulted in immediate mortality of the pest whereas most of the test insecticides and earlier recommended thiamethoxam are systemic in nature which become effective after entering into the plant sap, thereby taking more time in reducing the population. Our results are in line with the findings of Nauen et al. (2008), who found that when apple seedlings infested with woolly apple aphid were treated with spirotetramat (20-100 µg ai/ leaf) resulted in 70-90% reduction in woolly apple aphid population after 28 days of application.

Table 1. Field efficacy of insecticides and biopesticides against *E. lanigerum* in apple

Treatment	Concentration (%)	Colony count % reduction over pre-count (DAT) 3	7	14	21	28	Mean(%)	Colony size % reduction over pre-count (DAT) 3	7	14	21	28	Mean(%)
Spirotetramat	0.007	21.60 (27.64)	33.26 (35.19)	43.63 (41.31)	46.73 (43.10)	51.26 (45.70)	39.30 (38.59)	20.25 (26.72)	32.95 (35.00)	34.93 (36.20)	40.40 (39.44)	43.53 (41.26)	34.41 (35.72)
	0.015	38.33 (38.23)	62.16 (52.03)	71.80 (57.93)	81.63 (64.66)	88.46 (70.18)	68.48 (56.61)	28.36 (32.15)	48.62 (44.19)	63.96 (53.15)	78.26 (62.21)	86.00 (68.00)	61.04 (51.94)
Flupyradifurone	0.017	15.34 (23.01)	20.20 (26.63)	25.46 (30.26)	32.50 (34.73)	38.35 (38.23)	26.38 (30.57)	24.61 (29.70)	27.83 (31.80)	31.94 (34.39)	35.22 (36.38)	45.29 (42.27)	32.98 (34.91)
	0.03	20.53 (26.91)	28.30 (32.16)	35.07 (36.28)	48.60 (44.17)	56.20 (48.55)	37.75 (37.62)	26.42 (30.89)	32.87 (34.96)	38.31 (38.20)	40.70 (39.62)	48.34 (44.03)	37.33 (37.54)
Flonicamid	0.025	20.66 (27.01)	29.10 (32.59)	35.20 (36.37)	45.06 (42.15)	53.00 (46.70)	36.60 (36.96)	16.32 (23.75)	26.52 (30.95)	36.32 (37.03)	41.42 (40.03)	50.53 (45.28)	34.22 (35.41)
	0.05	35.37 (36.47)	60.06 (50.84)	67.40 (55.16)	70.00 (56.82)	73.73 (59.17)	61.31 (51.69)	33.24 (35.17)	49.67 (44.79)	59.54 (50.49)	66.75 (54.78)	70.60 (57.16)	55.96 (48.48)
Buprofezin	0.025	14.99 (22.73)	20.16 (26.52)	29.50 (32.84)	36.66 (37.24)	38.30 (38.18)	27.92 (31.50)	15.16 (22.90)	20.60 (26.97)	28.26 (32.09)	31.23 (33..90)	33.66 (35.44)	25.78 (30.26)
	0.05	16.30 (23.77)	25.50 (30.31)	36.80 (37.32)	44.20 (41.63)	58.50 (49.88)	36.26 (36.58)	19.50 (26.19)	26.43 (30.92)	30.50 (33.45)	34.00 (35.64)	40.60 (39.55)	30.20 (33.15)
B. bassiana	1x10[10] cfu/l	10.26 (18.62)	20.20 (26.62)	25.63 (30.37)	25.63 (30.37)	22.30 (28.12)	20.81 (26.82)	18.23 (25.21)	20.20 (26.62)	30.16 (33.28)	37.30 (37.62)	39.63 (38.99)	29.10 (32.35)
	2x10[10] cfu/l	17.50 (24.61)	22.80 (28.52)	28.60 (32.29)	36.40 (37.07)	40.50 (39.49)	29.17 (32.40)	22.46 (28.25)	25.60 (30.35)	35.46 (36.52)	41.20 (39.90)	44.81 (42.00)	33.91 (35.40)
Fish oil	0.5	13.95 (21.83)	18.80 (25.65)	24.18 (29.35)	26.50 (30.93)	26.50 (30.93)	21.99 (27.74)	15.40 (23.03)	20.50 (26.83)	25.26 (30.13)	25.26 (30.13)	25.26 (30.13)	22.34 (28.05)
	1.0	19.03 (25.80)	25.90 (30.53)	30.50 (33.47)	40.60 (39.55)	40.60 (39.55)	31.32 (33.78)	21.55 (27.60)	30.30 (33.36)	38.27 (38.19)	31.10 (33.85)	31.10 (33.85)	30.46 (33.37)
Neem oil	1.0	14.16 (22.06)	18.30 (25.27)	25.83 (30.50)	28.30 (32.07)	28.53 (32.25)	23.03 (28.43)	16.46 (23.90)	20.10 (26.55)	24.56 (29.68)	28.33 (32.12)	30.43 (33.45)	23.98 (29.14)
	2.0	19.86 (26.41)	25.20 (30.06)	30.23 (33.30)	35.50 (36.52)	34.00 (35.63)	28.95 (32.38)	20.33 (26.68)	25.23 (30.13)	28.13 (32.01)	32.40 (34.67)	35.46 (36.52)	28.31 (32.00)
Azadirachtin	0.01	15.60 (23.20)	20.50 (26.78)	25.60 (30.33)	29.58 (32.88)	33.80 (35.51)	25.01 (29.74)	20.58 (26.95)	24.36 (29.55)	30.49 (33.47)	35.50 (36.54)	37.43 (37.69)	29.67 (32.84)
	0.02	16.76 (24.11)	25.70 (30.37)	31.80 (34.22)	39.77 (39.05)	35.08 (36.28)	29.83 (32.81)	25.43 (30.23)	28.66 (32.33)	35.83 (36.74)	39.30 (38.79)	45.66 (42.49)	34.98 (36.12)
Thiamethoxam	0.025	38.80 (38.50)	68.36 (55.76)	83.13 (65.76)	89.66 (71.53)	90.00 (71.22)	73.99 (60.56)	29.70 (32.97)	54.14 (47.40)	74.63 (59.77)	81.40 (64.68)	86.06 (68.11)	65.18 (54.59)
Chlorpyriphos	0.04	51.80 (46.02)	74.36 (59.89)	79.20 (62.84)	87.53 (69.34)	89.66 (71.24)	76.51 (61.86)	40.96 (39.76)	61.50 (51.67)	71.86 (57.96)	81.20 (64.39)	86.33 (68.48)	68.37 (56.45)
Control	-	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Mean		22.47 (27.12)	32.25 (33.37)	42.06 (39.54)	48.02 (43.31)	50.40 (44.89)		21.84 (26.95)	30.32 (32.33)	37.81 (36.99)	42.15 (39.72)	46.35 (42.35)	

Colony count: $CD_{0.05}$
Treatment (T) : (1.75)
Days (D) : (0.89)
T x D : (3.91)
DAT (Days After Treatment)

Colony size: $CD_{0.05}$
Treatment (T) : (1.41)
Days (D) : (0.72)
T x D : (3.15)
DAT (Days After Treatment)

Reduction in colony count was observed till last day of observation in an increasing trend, which indicates that spirotetramat persisted till 28th day after spray and caused significant reduction in colony count. Long lasting effect of spirotetramat is reported by Kumar et al. (2009) and Pasqualini and Scannavini (2015) though against different pests. Misra (2009) reported flonicamid to be quite effective against sucking pests of rice. In the present study, flonicamid was next to spirotetramat. Present findings however differ from that of Patel et al. (2010) who observed up to 95% mortality of mealy bug *P. solenopsis* population with buprofezin. The present findings also differ from Chand et al. (2010) who observed 84.18% reduction in *L. erysimi* population with *B. bassiana*, when applied @ 3.0 g/l of water.

Both of the neem products viz., neem oil and azadirachtin were not able to provide desirable level of control against woolly apple aphid population. Findings are supported by Caldwell et al. (2013), who stated that effectiveness of insecticides with semi systemic activity, such as azadirachtin or neem oil based products is usually insufficient against woolly apple aphid.

It is thus concluded that spirotetramat (0.015%) and flonicamid (0.05%) were effective, while the earlierchlorpyriphos (0.04%) and thiamethoxam (0.025%) were slightly better.

Effect on *Aphelinus mali*

Moderate emergence of parasitoid was observed from the samples collected 3 days after treatment followed by low emergence from the mummified aphids collected after 7 days of treatment. Maximum emergence was in the parasitized aphids collected after 14 days of treatment. However, in case of fish oil, neem oil and chlorpyriphos, emergence increased from the mummified aphids collected after 7 days of treatment in comparison to 3 days after treatment, which further recorded slight increase in the samples of 14 days after treatment (Table 2). Emergence of adult parasitoids was noticed till last week of November and thereafter in December and January no adult emergence was recorded which again resumed in February. This is due to the fact that parasitoid overwintered during winter months and resumed its activity with the warming of the season as reported by Gupta et al. (2007).

Lower concentration (0.025%) of flonicamid proved to be the safest which resulted in 75.00, 60.00 and 80.00 % emergence of adult parasitoids, whereas, among biopesticides, neem oil (1.0%) was the safest

Table 2. Toxicity of insecticides and biopesticides to *A. mali*

Treatment	Concentration (%)	% emergence of parasitoids from parasitized aphids collected from field at different interval (DAT)		
		3	7	14
Spirotetramat	0.007	60.00 (50.83)	55.00 (47.86)	65.00 (53.74)
	0.015	55.00 (47.86)	50.00 (44.98)	60.00 (50.76)
Flupyradifurone	0.017	65.00 (53.74)	60.00 (50.83)	65.00 (53.84)
	0.03	55.00 (47.89)	55.00 (47.89)	60.00 (50.83)
Flonicamid	0.025	75.00 (60.29)	60.00 (50.83)	80.00 (63.90)
	0.05	60.00 (50.83)	55.00 (47.89)	65.00 (53.74)
Buprofezin	0.025	55.00 (47.89)	50.00 (44.98)	60.00 (50.76)
	0.05	45.00 (42.07)	40.00 (39.19)	50.00 (44.98)
B. bassiana	$1x10^{10}$ cfu/l.	60.00 (50.83)	55.00 (47.86)	65.00 (53.74)
	$2x10^{10}$ cfu/l.	55.00 (47.89)	50.00 (44.98)	65.00 (53.84)
Fish oil	0.5	60.00 (50.83)	70.00 (56.97)	75.00 (60.05)
	1.0	55.00 (47.89)	70.00 (56.81)	70.00 (56.81)
Neem oil	1.0	60.00 (50.83)	75.00 (60.05)	80.00 (63.90)
	2.0	55.00 (47.89)	70.00 (56.97)	75.00 (60.29)
Azadirachtin	0.01	60.00 (50.74)	55.00 (47.86)	60.00 (50.76)
	0.02	55.00 (47.89)	50.00 (44.98)	60.00 (50.76)
Thiamethoxam	0.025	55.00 (47.86)	50.00 (44.98)	60.00 (50.83)
Chlorpyriphos	0.04	15.00 (22.58)	20.00 (26.44)	20.00 (26.44)
Control	-	90.00 (71.92)	95.00 (77.04)	90.00 (71.92)
$CD_{0.05}$		(8.19)	(7.59)	(8.08)

*Figures in parentheses are arcsine transformed values
DAT (Days After Treatment)

and resulted in 60.00, 75.00 and 80.00% from the first, second and third collections of parasitized aphids, respectively. Azadirachtin (0.02%) proved to be most resulting in 55.00, 50.00 and 60.00% emergence from the three collections of parasitized aphids, respectively. This treatment was at par with higher concentration ($2x10^{10}$cfu/l) of *B. bassiana* which resulted in 56.66% emergence.

All the evaluated insecticides and biopesticides were safer in comparison to chlorpyriphos (0.04%) which resulted in 15.00, 20.00 and 20.00 % emergence only, of adult parasitoids, respectively, from first, second and third collection; thiamethoxam (0.025%) resulted in 55.00, 50.00 and 60.00 % emergence, respectively, from first, second and third collection and was comparatively safer than chlorpyriphos as well as higher concentration (0.05%) of buprofezin.

These results agree with those of Gupta et al. (2013), who observed 59.70% emergence of *A. mali* adults in thiamethoxam (0.025%) from the parasitized aphids collected 5 days after the spray. In chlorpyriphos (0.04%), only 12.5% emergence was observed corroborating the findings of the present study. Toxicity of chlorpyriphos to *A. mali* had been observed by Khajuria et al. (2010) from Kullu. Cohen et al. (1996) reported chlorpyriphos as highly toxic to adult*A. mali* and but safe to its immature stages, which is contrary to the present observations on its toxicity to immature stages.

Thus spirotetramat with a mean reduction of 68.48 % in colony count of woolly apple aphid is most effective followed by flonicamid (0.05%). Neem oil (1.0%) and flonicamid (0.025%) with 60-80 and 75-80 % parasitoid emergence, respectively, were the safest. Spirotetramat (0.015%) and flonicamid (0.05%) with 55-60% and 60-65% parasitoid emergence, respectively, were moderate in safety.

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