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Efficacy of a parasitoid and synthetic insecticide against Woolly apple aphid, *Eriosoma lanigerum* (Hausmann) (Homoptera: Pemphigidae) on apple at Skardu-Baltistan

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Abstract
Eriosoma lanigerum (Hausmann) (Homoptera: Pemphigidae) causes heavy losses to apple yield in Skardu-Baltistan. Synthetic insecticides have been routinely used for the control of *E. lanigerum* in apple orchards. The efficacy of *Aphelinus mali* and Malathion against *E. lanigerum* was evaluated in apple orchards at three locations of Skardu-Baltistan during 2009. The results showed that *E. lanigerum* density was significantly lower in malathion treatment in apple orchards at Skurdu, Ashopee Shigar and Wazir Inayat Orchard at Skardu-Baltistan, 24h (58.66 aphids/leaf, 72.00 aphids/leaf, 75.00 aphids/leaf), 15 days (43.00 aphids/leaf, 48.67 aphids/leaf, 49.00 aphids/leaf) and 30 days (31.33 aphids/leaf, 32.00 aphids/leaf, 28.67 aphids/leaf), respectively after treatment. Overall mean density of the pest was significantly lower in malathion treatment (44.33 aphids/leaf, 51.00 aphids/leaf, 51.00 aphids/leaf), and higher in control (95.00 aphids/leaf, 126.67 aphids/leaf, 129.67 aphids/leaf) in apple orchards at Skardu, Ashopee Shigar and Wazir Inayat Orchard at Skardu-Baltistan, respectively.

Keywords: *Aphelinus mali*, *Eriosoma lanigerum*, apple, malathion

1. Introduction
Apple (*Malus sylvestris*) family Rosaceae is one of the most widely cultivated tree fruits throughout the world. In Pakistan apple is mostly grown in uplands of Quetta and Kallat divisions, and Muzaffarabad and Ponch districts of Azad Kashmir. The area under cultivation is 113.8 thousand hectares with a total production of 441.6 thousand tones [1].

The Wooly apple aphid, *Eriosoma lanigerum* (Hausmann) (Homoptera: Pemphigidae), is native to North America but distributed throughout the temperate regions of the world. In Pakistan this pest was initially detected in apple orchards of Murree hills, Muzaffarabad and Malakand division of KPK. In Northern Areas the pest was first time noticed on apple trees in Gilgit during 1994-95 from where it had spread to Hunza, Astore, Skardu, Khaplu and lower parts of the District Ghizer [2].

E. lanigerum is one of the several species of aphids that can infest apple trees in Northern areas. Other aphid species found on apple trees are rosy apple aphid (*Dysaphis plantaginea* Passerini) and green apple aphids (*Aphis pomi* (DeGeer)). *E. lanigerum* occurs sporadically in commercial orchards as well as in home plantings. It feeds mainly on apple but is a pest of pear and quince also. It usually lives on apple throughout the year [3].

E. lanigerum is an indirect pest that weakens the host by feeding on bark and roots, which reduces tree health, prevents wounds from healing and transmit perennial apple canker disease. It is also a direct pest when it infests fruit cores of some cultivars. It can also be nuisance pest during harvest when their waxy covering brushes off the tree and onto clothing of the pickers. The pest also contributed to the development of black sooty mold [4].

The natural enemies of *E. lanigerum* recorded in Pakistan are *Aphelinus mali*, *Syrphus sp*., *Menochilus sexmaculatus* and *Chrysoperla carnea*. *A. mali* was first introduced into Pakistan from Switzerland. It is native to eastern North America and has been used successfully against *E. lanigerum* in many regions around the world. The release of *A. mali* from artificial rearing for the control of *E. lanigerum* proved to be more suitable than the release of cards with parasitized mummies [5].

E. lanigerum is chemically controlled by using organophosphates and carbamates, such as azinphosmethyl, dimethoate, diazinon and endosulfan, with the systemic compounds oxamyl and dimethoate active against root colonies. Many of these chemicals are still used today in many parts of the world. The pest infestations were found to be extremely low in IPM programs utilizing mating disruption and fenoxycarb for codling moth *Cydia pomonella* L. control. Imidacloprid is known to provide excellent control of *E. lanigerum* on trees up to 7-years-old when applied as a root soil drench [6].

Keeping in the importance of the apple fruit and the damages caused by *E. lanigerum* to it the present study aimed to test efficacy of a natural enemy and an insecticide against *E. lanigerum* in apple orchards in Skardu-Baltistan.

2. Materials and Methods

2.1 Experimental field

For the study, three apple orchards highly infested with *E. lanigerum* were selected for the experiments. The experiment was laid out in Randomized Complete Block Design replicated three times and each having three treatments.

2.2 Collection of *E. lanigerum* for Parasitization

E. lanigerum were collected using fine camel hair brush from apple orchards and placed in Petri dishes (ten pairs each). The Petri dishes having *E. lanigerum* were brought to the Biological Based Organic Pest Management (OPM) field unit laboratory of Eco-Conservation Initiatives (ECI) Skardu, Baltistan for parasitization by *A. mali* (5 pairs per Petri dish). The Petri dishes (20 in no.) were then kept into the parasitization chambers under 30±2 ºC temperature and 65±5% RH and ten adult pairs of *A. mali* were released inside the chamber. After successful parasitization, the aphid mummies were put into the jam size bottles (30 each) covered through muslin cloth and tightened with the rubber band and stored at 30±2 ºC temperature and 65±5% RH.

2.3 Release of *A. mali*

Twenty plants were selected randomly in each apple orchard for releases of *E. lanigerum* mummies (30 per plant). The bottles (one per plant) were installed horizontally in the selected plants and tightened it with thread and cloth from the head. The bottles was removed in morning.

2.4 Insecticide Application

The insecticide used in the experiment was Malathion using Knapsack sprayer. The insecticide was used at the rate of 500ml/100 L of water/acre at all the three locations when the pest reached to economic threshold level.

2.5 Data Collection

E. lanigerum mummies installed plants were daily observed in each orchard for adult *A. mali* emergence and further *E. lanigerum* parasitization. Data of the population density of *E. lanigerum* were recorded by selecting of 6 inch linear shoot tips from 20 randomly selected plants from each apple orchard. The selected branches were divided into three portions: Top, Middle and Bottom (TMB). *E. lanigerum* were collected in the Petri dishes with the help of fine camel hair brush and counted. Pre-treatment data were recorded 24h before application of *A. mali* and Malathion. Post-treatment data were recorded after 24h and then at 15 days intervals.

2.6 Data analysis

The data recorded was individually subjected to the ANOVA technique by using STATISTIX (8.1) and means were separated by using LSD test [7].

3.1 Results and Discussion

A. mali was the only natural enemy of *E. lanigerum* recorded in the apple orchards at the three locations at Skurdu-Baltistan. The results of application of the natural enemy and synthetic chemical are presented below:

3.1 Effect of *A. mali* and Malathion on population density of *E. lanigerum* at Model Orchard Skardu

The results showed that 24h after biological and chemical application *E. lanigerum* density was significantly lower in malathion treatment (58.66 aphids leaf^{-1}) and higher in control (99.00 aphids leaf^{-1}) (Table 1). Fifteen days after treatment the pest density was significantly lower in chemical treatment (43.00 aphids leaf^{-1}) and higher in control (94.33 aphids leaf^{-1}). Thirty days after treatment the pest density was significantly lower in chemical treatment (31.33 aphids leaf^{-1}) and highest in control (91.00 aphids leaf^{-1}). The overall mean of the pest was significantly lower in chemical treatment (44.33 aphids leaf^{-1}) and higher in control (95.00 aphids leaf^{-1}).

Table 1: Mean density of *E. lanigerum* leaf^{-1} of apple at Model Orchard at Skardu Baltistan during 2009.

Treatment	Pre-treatment	After treatment			Overall mean
		24 hours	15 days	30 days	
A. mali	102.00 a	82.66 b	71.33 b	57.00 b	70.33 b
Malathion	100.00 a	58.66 c	43.00 c	31.33 c	44.33 c
Control	100.67 a	99.00 a	94.33 a	91.00 a	95.00 a
LSD Value	10.53	7.38	7.44	9.00	3.42

Means within columns followed by the different letters are significantly different at p = 0.05 (LSD test).

3.2 Effect of *A. mali* and Malathion on population density of *E. lanigerum* at Model Orchard Ashopee Shigar:

Table 2 shows the results of *E. lanigerum* density before and after treatment at Model Orchard Ashopee Shigar. Twenty four hours after treatment the pest density was significantly lower in chemical treatment (72.00 aphids leaf^{-1}) and higher in control (128.00 aphids leaf^{-1}). The pest density 15 days after treatment was significantly lower in malathion treatment (48.67 aphids leaf^{-1}) and higher in control (129.67 aphids leaf^{-1}). Thirty days after treatment the pest density was significantly lower in malathion treatment with 32.00 aphids/leaf and highest in control with 122.00 aphids leaf^{-1}. The overall mean of the pest was significantly lower in malathion treatment (51.00 aphids leaf^{-1}) and higher in control (126.67 aphids leaf^{-1}).

Table 2: Mean density of *E. lanigerum* leaf^{-1} of apple at Model Orchard at Ashopee Shigar during 2009.

Treatment	Pre-treatment	Post-treatment			Over all mean
		24 hours	15 days	30 days	
A. mali	134.00 a	87.00 b	72.00 b	58.33 b	72.33 b
Malathion	130.00 a	72.00 c	48.67 c	32.00 c	51.00 c
Control	135.00 a	128.00 a	129.67 a	122.00 a	126.67 a
LSD Value	12.84	7.16	7.38	6.77	4.13

Means with in columns followed by the different letters are significantly different at p = 0.05 (LSD test).

3.3 Effect of *A. mali* and Malathion on population density of *E. lanigerum* at Wazir Inayat Orchard Skardu Baltistan

The results of experiment at Wazir Inayat Orchard showed that 24h after treatment the pest density was significantly lower in malathion treatment (75.00 aphids leaf^{-1}) and higher in control (133.00 aphids leaf^{-1}). *E. lanigerum* density 15 days after treatment was significantly lower in malathion treatment (49.00 aphids leaf^{-1}) and higher in control (129.33 aphids leaf^{-1}). Thirty days after treatment the pest density was significantly lower in malathion treatment with 28.67 aphids leaf^{-1} and higher in control with 127.00 aphids leaf^{-1}. The overall mean density of the pest was significantly lower in chemical treatment (51.00 aphids leaf^{-1}) and higher in control (129.67 aphids leaf^{-1}).

Table 3: Mean density of *E. lanigerum* leaf^{-1} of apple at Wazir Inayat Orchard at Skardu Baltistan during 2009.

Treatment	Pre-treatment	Post-treatment			Overall mean
		24 hours	15 days	30 days	
A. mali	127.67 a	91.67 b	68.33 b	51.00 b	70.00 b
Malathion	140.33 a	75.00 c	49.00 c	28.67 c	51.00 c
Control	133.00 a	133.00 a	129.33 a	127.00 a	129.67 a
LSD Value	16.60	16.62	13.17	5.68	7.77

Means within columns followed by the different letters are significantly different at p = 0.05 (LSD test).

3.4 Effect of *A. mali* on population density of *E. lanigerum*

The results showed that *A. mali* significantly reduced the *E. lanigerum* population. The pest population was higher before but lowered after the release of *A. mali* as compared to the control in all the three locations. The results are similar to the findings of some earlier researchers. For example, *E. lanigerum* populations were monitored at the apple orchard in two apple cultivars as part of an experimental Integrated Fruit Production program which included the insect growth regulator insecticide tebufenozide. The aphid population increased during the first season in one cultivar ('Sturmer Pippin') from mid-February and reached 90% shoots infestation by late summer. Parasitism of the aphid by the specific end parasitoid, *Aphelinus mali* (Haldeman), was first recorded in late March 1995 and peaked at 13% by the end of April 1995 when monitoring ceased. In the second season the parasitoid was present from early summer and >80% parasitism was recorded by late April 1996. Aphid control was achieved without the need for specific aphicide sprays. The results indicate the potential for biological control of *E. lanigerum* by *A. mali* within a selective insecticide program [8]. *A. mali* was found to parasitize more than 50% of *E. lanigrum* in apple orchards where no other control method was necessary against it [9]. The release of adult's *A. mali* proved to be more suitable than the release of cards with parasitized mummies as practiced in the first trial. The release of adult *A. mali* at the beginning of season reduced the aphid population, though its efficiency was not high enough to prevent damage of the trees totally. The practical applications of *A. mali* in early spring (after blossom) were not effective because climatic conditions were not suitable enough. The fertility of *A. mali* depends on temperature and light intensity [5].

In a study on *E. lanigerum* and its natural enemy *A. Mali*, it was found that crawlers of *E. lanigerum* migrated from the roots into the apple trees during spring to initiate above-ground colonies. Its population peaked at the end of summer. *A. mali* became active from February until June. Population of *E. lanigerum* declined with the onset of winter but a few colonies remained on apple trees during winter [10].

3.5 Effect of Malathion on population density of *E. lanigerum*

The synthetic insecticide Malathion had significantly reduced the pest population. The pest density was higher before treatment but was significantly lowered with the malathion treatment. Reduction of the pest was significantly higher with malathion treatment than biological agent as well as in control. The present results are similar to the findings of some earlier researchers [11]. Higher mortality of *E. lanigerum* was recorded after the application of Thiodan and Diazinon as compared to Actara, Dimethoate, Provado and Aza-Direct and control [11]. Effects of a single application of chlorpyrifos, imidacloprid, pirimicarb or vamidothion, applied as a root drench over four growing seasons was compared. Imidacloprid provided excellent control of *E. lanigerum* on the trees and continued to do so for four seasons. Pirimicarb appeared to offer some suppression of *E. lanigerum* during the first season but not in subsequent seasons, while chlorpyrifos and vamidothion failed to control the aphid in any season [12].

The use of *A. mali* and Malathion significantly reduced the *E. lanigerum* population as compared to the control in all the three locations of Skardu Baltistan. The results are in comparison with the findings of some earlier researchers. Insecticide methyl-demeton (0·078% and 0·052% a.i.), dimethoate (0·0625% and 0·0417% a.i.), diazinon (0·0625% a.i.) and malathion (0·1041% a.i.) gave good control of infestations above ground, but methyl-demeton and diazinon gave the best control. Biological control of *E. lanigerum* by the hymenopterous parasite *A. mali* showed great promise [13].

Four insecticides, imidacloprid, pirimicarb, cartap and petroleum oil, were tested for their suitability to an integrated pest management program of woolly apple aphid (WAA). WAA index used to measure the efficacy of the insecticides against the WAA and showed that imidacloprid was the most efficient in suppressing WAA. Parasitoid index indicated that pirimicarb was the safest insecticide to WAA parasitoid *Aphelinus mali*, while imidacloprid caused drastic effect on mummified aphids. Selectivity index indicated that pirimicarb was the most suitable insecticide for controlling WAA as its application resulted in valuable suppression of WAA and very low negative impact to its parasitoid [14].

A. mali reared and released into apple orchards in Jordan provided a valuable suppression of WAA during the year of its release but its effectiveness was reduced in the next year due to the routine spraying of non-selective insecticides in neighbouring orchards that led to the movement of aphids to orchards where no insecticides were sprayed [15].

4. Conclusion and recommendations

E. lanigerum is a serious pest of apple orchards in northern areas of Pakistan. The use of *A. mali* and malathion effectively reduced *E. lanigerum* population in apple orchards. The use of *A. mali* should be encouraged for sustainable and long term control of *E. lanigerum* in apple orchards. The use of malathion though highly effective against *E. lanigerum* but its intensive use should be discouraged and reduced with time due to environmental and ecological concerns.

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