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Entomocidal Efficacy of Different Botanical Extracts against Cotton Mealybug, *Phenacoccus solenopsis* Tinsley (Sternorrhyncha: Pseudococcidae)

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Abstract
Use of botanicals is an age-old practice where people used to utilize the extracts from the plant parts to control the insects. In the present study entomocidal effect of different plant extracts was studied against cotton mealybug, *Phenacoccus solenopsis* (Tinsley), Hemiptera, Pseudococcidae. Two experiments were carried out in the laboratory of Entomology Department, Gomal University, Dera Ismail Khan, Pakistan. Five treatments, viz. Neem (*Azadirachta indica*), Ak (*Calotropis procera*), Bitter Cress (*Cardamine hirsuta*), Ajwain (*Trachyspermum ammi*), Hareer (*Terminalia chebula*) and Garlic (*Allium sativum*) were evaluated at three different concentrations of 1, 2 and 3% and replicated three times. The adults or 3rd instar nymphs of mealybugs were exposed to botanical extracts on *Hibiscus rosasinensis* leaves in glass petri dishes at constant conditions of 27±2^{0}C, 65± 5% R.H. In both experiments, *A. indica* extracts showed a higher mortality of both adult and 3rd instar of cotton mealybug at all the tested concentrations as compared to other treatments. The efficacy of the evaluated plant extracts increased by increasing the exposure period. From the overall mean results, *A. indica* (Neem) seed extract at 2% registered highest (51.37%) mortality of the adult cotton mealybug. Similarly, *A. indica* seed extract at 3% registered highest (45.00%) mortality of 3rd instar of cotton mealybug, whereas, lowest mortality was recorded in *C. procera* extracts at all the tested concentrations. The present results might help in getting better and safer control of cotton mealybug.

Keywords: Neem, Botanical extracts, Mortality, Cotton mealybug, *Phenacoccus solenopsis*.

1. Introduction
The mealybug (Hemiptera, Pseudococcidae) species are widespread throughout the world [6]. Mealybug is a soft-bodied, small, plant sucking insects belonging to the second largest family of scale insects (Pseudococcidae). It comprises approximately 300 genera and about 2000 species worldwide [19, 22].

In Pakistan, cotton mealybug, *P. solenopsis* first appeared during 2005 and got pest status in cotton crop mostly in the cotton growing areas of Punjab and Sindh provinces [1].

Cotton Mealybug *P. solenopsis* attack on different plants including woody plants to herbaceous weeds. It has been reported to attack 154 plant species including 20 field crops, 64 weeds, 45 ornamental plants and 25 shrubs and trees [12]. In ornamentals plants, *P. solenopsis* attack on shoe flower (*Hibiscus rosasinensis*), sonkadi (*Vicoa indica*) and fire cracker plant (*Crossandra infundibuliformis*) [26].

Their name mealybug is due to the waxy material covering the bodies of adult females. They are sexually dimorphic, the female does not experience complete metamorphosis and is wingless.

Males possess two pairs of long white waxy tails having nonfunctional mouth parts and live for only 2-4 days. Male passes through egg, nymphal, pupal and adult stages while female passes through egg, nymphal and adult stage. The adult female is covered with white waxy powder with some black dorsal spots on the body [24].

They feed on plant sap and phloem tissues of plants. Leaves become twisted, turn yellow in color and ultimately drop down [10]. *P. solenopsis* produces heavy amount of honeydew similar to other sucking insect pests of cotton such as aphid and whiteflies. Due to heavy secretion of honey dew, plants become dead and leaves dropped down from the stalks such condition is

called sooty mould. Honeydew interferes with the process of photosynthesis [3, 17].

Major symptoms of cotton mealybug infestation are distorted shoots, wrinkled leaves, white powder like substances on leaves, bushy branches, deformation of flowers, minimum number of bolls, stunting of plants and chlorosis [16].

In central America it has a wide geographical distribution [7] and is also documented by information of the Chile [8], Ecuador [6], Brazil and Argentina.

In Pakistan, India and Nigeria *P. solenopsis* is a serious pest of shoe flower, *Hibiscus rosasinensis* [2, 17]. From Pakistan, in Punjab and Sindh it has been recorded as a serious pest since 2005 on cotton, *Gossypium hirsutum.* It is also a serious pest in India and a serious threat in china [12, 15]. The synthetic insecticides used against mealybugs are very toxic to natural enemies of mealybugs [18, 25]. The researchers are working all over the world on plant based pesticides, called as Phyto pesticides or botanical pesticides. About 2,400 plant species carrying insecticidal properties have been tested for the management of different insect pests [8]. These plant derivatives are environmental safe for bio control agents, cost effective and are easily available. *A. indica* based pesticides are well known carrying toxicity against more than 400 pest insects [20, 23]. Neem based pesticides have slight toxicity against non-target insects such as predators, pollinators and parasitoids [3, 1, 30].

In developed countries, biological control is a very effective method to control insect pests but very less attention is given to such IPM techniques in developing countries like Pakistan.

Alternative strategies i.e. use of plant derivatives is the most appropriate method to control this pest. Plant derivatives are readily biodegradable. In Pakistan, neem, *Azadirachta indica* tree is mostly found in Sindh and Punjab provinces. Neem tree contains bioactive ingredients and other chemical compounds among which azadirachtin is the most effective bio-active compound having great insecticidal properties. Compounds derived from *Azadirachta indica* and numerous other botanicals have great insecticidal and lethal properties for killing pest insects.

The present study was carried out to investigate the insecticidal potential of different locally available plant materials for the management of mealybug.

2. Materials and Methods

Efficacy of different plant extracts against Adult and 3rd instar of Cotton Mealybug

Plant Materials

Leaves of *Cardamine hirsuta* (Bitter cress), *Calotropis procera* (Ak) and *Azadirachta indica* (Neem) were collected from the local farmers, whereas, *Trachyspermum ammi* (Ajwain), *Terminalia chebula* (Hareer) and *Allium sativum* (Garlic cloves) were bought from local market.

Table 1: List of Plant Materials used against 3rd instar and Adults of cotton mealybug, *P. solenopsis*

S. No.	Common Name	Scientific Name	Family
1	Neem	*Azadirachta indica*	Meliaceae
2	Hareer	*Terminalia chebula*	Terminalia
3	Ajwain	*Trachyspermum ammi*	Apiaceae
4	Bitter cress	*Caralluma tuberculata*	Cardamine
5	Ak	*Calotropis procera*	Asclepiadaceae
6	Garlic	*Allium sativum*	Amaryllidaceae

Preparation of plant extracts

The collected plant parts were washed with distilled water to remove dirt and allowed to dry for one month under shade conditions. After that, dried materials were crushed and grinded with the help of grinder until the whole material turned into fine powder. The powdered material was stored in refrigerator until used for experimentation.

Laboratory Studies

The Mealy bugs were collected from unsprayed *Hibiscus* plants from the garden. Un-infested tender Leaves and twigs of *H. rosasinensis* plant infested with *P. solenopsis* were brought to the laboratory. For the evaluation of bio-efficacy of selected botanicals against 3rd instar and Adult cotton mealybug, fresh leaves of *H. rosasinensis* were washed thoroughly with distilled water and were completely dried.

The evaluated concentrations were prepared in distilled water (w/v) by adding 1g, 2g and 3g powder of plant extracts in distilled water to obtain 100ml of solution. For a good suspension warm water was used, whereas; in control treatments only distilled water was used. For the treatment of leaves, the leaves of *H. rosasinensis* were submersed in each botanical solution for 5 minutes and then allowed to dry for 30 minutes.

The 3rd instar and adults of *P. solenopsis* were released separately in individual petri dishes (having 9 cm diameter) containing treated leaves of *H. rosasinensis*. In each petri dish 10 adults or 10 3rd instar nymphs of mealybugs were released. Six treatments at three different concentrations of 1, 2 and 3% were used and replicated thrice. Mortality of the 3rd instar and adult mealybugs in petri dishes was noted after 24, 48, 72 hours and one week of exposure period. The mortality of the mealybugs was noted and converted to percent mortality with the help of following formula:

$$\text{Corrected percent mortality} = \frac{\text{Percent mortality in treatment} - \text{Percent mortality in control}}{100 \text{ percent mortality in control}} \times 100$$

2.2 Statistical analysis

The collected data were subjected to statistical analysis using analysis of variance (ANOVA) technique and means were separated by LSD test at 5% P-value using computer software STATISTIX 8.1 package.

3. Results

3.1 Efficacy of Botanical extracts against Adult Cotton Mealybug

Mortality due to 1% concentration

After an exposure period of 24 hours, the *A. indica* extracts gave maximum mortality of 21.66%. It was followed by *C. procera* (18.33%). The *T. ammi*, *C. tuberculata* and *A. sativum* extracts were found statistically similar having 13.33% mortality. Minimum mortality of 3.33% was found on *H. rosasinensis* leaves treated with aqueous extracts of *T. chebula* (Table-2).

After 48 hours, the maximum mortality of 33.33% was recorded on *H. rosasinensis* leaves treated with *A. indica* aqueous extracts which differed non-significantly from 23.33% mortality recorded in *T. chebula*, *T. ammi* and *C. procera* respectively. The minimum mortality of 13.33% was recorded in *C. tuberculata* and *A. sativum* extracts.

At 72 hours after exposure, maximum mortality of 36.67% was observed in *A. indica* extracts which was found at par with 30.00% mortality in *A. sativum* aqueous extracts. Minimum mortality of 16.67% was recorded in *C. tuberculata* extracts treated leaves.

At 1-week exposure period, maximum mortality of 70.00% was registered in *A. indica* extracts which was statistically similar with 63.33% mortality in *A. sativum* extracts. The *T. chebula*, *T. ammi* and *C. tuberculata* extracts were found statistically similar with each other showing 53.33, 53.33 and 56.67% mortality, respectively, while *C. procera* extracts recorded minimum mortality of 43.33% compared to other botanical extracts.

It is evident from overall mean results, that maximum mortality of adult cotton mealybug was noted on *H. rosasinensis* leaves treated with *A. indica* extracts having 40.41% mortality.

The *A. sativum* extracts registered 29.99% mortality which was found at par with 29.17% mortality in *T. ammi* extracts. Comparable results were also found in *T. chebula* and *C. tuberculata* extracts having 26.66 and 24.11% mortality. The minimum mortality of 17.91% was found in *C. procera* extracts (Table-2).

Mortality due to 2% concentration

Results from the (Table-3) revealed that, *A. indica* aqueous extracts recorded maximum mortality of 30.00% after 24 hours exposure period which showed non-significant difference with 23.33% mortality in aqueous extracts of *T. chebula*. Data recorded after 24 hours exposure period showed non-significant difference among *C. tuberculata*, *C. procera* and *A. sativum* with 6.67, 3.33 and 6.67% mortality, respectively.

At 48 hours exposure period, maximum mortality of 36.67% was recorded on leaves treated with *A. indica* extracts whereas; minimum mortality of 6.67% was observed in *C. procera* extracts treated *H. rosasinensis* leaves (Table-3).

After 72 hours of exposure, results revealed that maximum mortality of 56.67% was recorded in *A. indica* aqueous extracts which differed non-significantly from 46.67% mortality found in *A. sativum* extracts. The *T. ammi* and *C. tuberculata* extracts were found statistically similar having 26.67% mortality. Minimum mortality of 13.33% was recorded in *C. procera* aqueous extracts (Table-3).

Results showed that after 1-week of exposure period, maximum mortality of 83.33% was recorded in *A. indica* extracts which differed non-significantly from 53.67% mortality in *A. sativum* extracts. Non-significant results were found in the *T. chebula*, *T. ammi* and *C. hirsute* extracts treated leaves with percentage mortality of 33.33, 33.33 and 36.33% respectively, while minimum mortality of 23.33% was recorded in *C. procera* extracts (Table-3).

The overall results from Table-3 revealed that, maximum mortality of 51.40% was registered in leaves treated with *A. indica* extracts which differed significantly from the rest of the treatments. Non-significant difference was found in *T. chebula* and *A. sativum* extracts having 31.03 and 32.13% mortality, respectively. The *T. ammi*, *C. tuberculata* and *C. procera* extracts were found statistically similar with 27.48, 28.70 and 26.22% mortality, respectively.

Mortality due to 3% concentration

Results from the (Table-4) show that after 24 hours of exposure, *A. indica* extracts recorded maximum mortality of 16.33% which differed non-significantly from *T. chebula*, *C. tuberculata*, *C. procera* and *A. sativum* extracts. Minimum mortality of 6.67% was found in *T. ammi* extracts.

Results showed that after 72 hours of exposure, maximum mortality of 33.33% was recorded on leaves treated with *A. indica* extracts which didn't differ significantly from 30.00% mortality in *A. sativum* extracts. Non-significant difference was also found in *T. chebula*, *T. ammi* and *C. tuberculata* extracts with percentage mortality of 13.33% (Table-4).

After 1 Week of exposure, the maximum mortality of 63.33% was documented in *A. indica* aqueous extracts which was non-significantly different from 53.33% mortality in *A. sativum* extracts. The aqueous extracts of *T. chebula*, *T. ammi* and *C. procera* were found not-significantly different from each other showing percentage mortality of 23.33, 20.00 and 23.33%, respectively. The minimum mortality of 16.67% was recorded in *C. tuberculata* aqueous extracts (Table-4).

Overall, maximum mean mortality of 44.72% was recorded on leaves treated with *A. indica* extracts which was non-significantly different from 34.17% mortality in *C. procera* extracts. The *T. chebula*, *T. ammi* and *C. procera* extracts were found statistically similar having 2.78, 28.89 and 28.56% mortality, respectively.

Table 2: Mean percent corrected mortality of adult *P. solenopsis* due to different plant aqueous extracts at 1% concentration

Treatments	24 hours	48 hours	72 hours	1 week	Mean
Azadirachta indica	21.66 a	33.33 a	36.67 a	70.00 a	40.41 a
Terminalia chebula	3.33 c	23.33 ab	26.67 b	53.33 b	26.66 bc
Trachyspermum ammi	13.33 b	23.33 ab	26.67 b	53.33 b	29.17 b
Caralluma tuberculata	13.33 b	13.33 b	16.67 bc	56.66 b	24.11 bc
Calotropis procera	18.33 ab	23.33 ab	26.66 b	43.33 c	17.91 c
Allium sativum	13.33 b	13.33 b	30.00 ab	63.33 ab	29.99 b
LSD Value 9.60		10.27	13.90	11.86	20.46

Means followed by common letters are not significantly different from each other by LSD test at α = 0.05.

Table 3: Mean percent corrected mortality of adult *P. solenopsis* due to different plant aqueous extracts at 2% concentration

Treatments	24 hours	48 hours	72 hours	1 week	Mean
Azadirachta indica	30.00 a	36.67 a	56.67 a	83.33 a	51.37 a
Terminalia chebula	23.33 ab	23.67 bc	23.33 bc	33.33 b	31.03 b
Trachyspermum ammi	10.00 bc	19.67 b	26.67 b	33.33 b	27.47 c
Caralluma tuberculata	6.67 c	19.67 b	26.67 b	36.33 b	28.69 c
Calotropis procera	3.33 c	6.67 c	13.33 c	23.33 bc	26.22 c
Allium sativum	6.67 c	19.67 b	46.67 ab	53.67 ab	32.13 b
LSD Value	13.26	7.29	10.27	12.57	2.55

Means followed by common letters are not significantly different from each other by LSD test at α = 0.05.

Table 4: Mean percent corrected mortality of adult *P. solenopsis* due to different plant aqueous extracts at 3% concentration

Treatments	24 hours	48 hours	72 hours	1 week	Mean
Azadirachta indica	16.33 a	26.67 a	33.33 a	63.33 a	44.72 a
Terminalia chebula	13.33 ab	13.33 bc	13.33 bc	23.33 b	27.78 b
Trachyspermum ammi	6.67 b	13.67 bc	13.33 bc	20.00 b	28.89 b
Caralluma tuberculata	13.67 ab	13.00 bc	13.33 bc	16.67 bc	21.39 bc
Calotropis procera	13.67 ab	16.67 b	18.67 b	23.33 b	28.56 b
Allium sativum	13.67 ab	23.67 ab	30.00 a	53.33 ab	34.17 ab
LSD Value	10.27	7.81	10.27	13.90	21.51

Means followed by common letters are not significantly different from each other by LSD test at $\alpha = 0.05$.

3.2 Efficacy of botanical extracts against 3rd instar of Cotton Mealybug

Mortality due to 1% concentration

It is evident from the results that after 24 hours of exposure, maximum mortality of 6.00% was recorded on leaves treated with *A. indica* extracts which was non-significantly different from all other treatments (Table-5).

After 48 hours of exposure, maximum mortality of 13.00% was recorded on leaves treated with *A. indica* extracts which was found at par with 7.53% mortality in *A. sativum* aqueous extracts. Non-significant differences were found between *T. chebula*, *T. ammi*, *C. tuberculata* and *C. procera* extracts registering 5.00, 5.00, 4.00 and 4.33 with percent mortality, respectively (Table-5).

At 72 hours after exposure period, maximum mortality of 16.67% was recorded on *H. rosasinensis* leaves treated with *A. indica* extracts which was found statistically similar with 14.00% mortality in *A. sativum* extracts.

At 1-week exposure period, maximum mortality of 50.33% was found in *A. indica* extracts treated which showed non-significant difference with 45.33% mortality in *A. sativum* extracts. The *T. chebula*, *T. ammi*, *C. tuberculata* and *C. procera* aqueous extracts were found statistically similar with 30.00, 36.67, 36.67 and 33.33% mortality respectively (Table-5).

The overall mean showed that maximum mortality of 20.75% was found on leaves treated with *A. indica* extracts which didn't differ significantly from 17.50% mortality found in *A. sativum* extracts. Non-significant differences were found between *T. ammi* and *C. tuberculata* aqueous extracts registering 14.00 and 13.50% mortality. Minimum mortality of 12.17 and 12.67% was found in *T. chebula* and *C. procera* aqueous extracts treated *H. rosasinensis* leaves (Table-5).

Mortality due to 2% concentration

The *A. indica* extracts resulted in highest reduction of 16.67% after 24 hours of exposure which didn't differ significantly from *A. sativum* extracts with 10.00% mortality.

After 48 hours of exposure, the maximum mortality of 26.67% was recorded on *H. rosasinensis* leaves leaves treated with *A. indica* aqueous extracts which differ significantly from all the other treatments.

At 72 hours of exposure, maximum mortality of 46.67% was recorded on leaves treated with *A. indica* extracts, which differed significantly from all the other evaluated botanical extracts. The *T. chebula* extracts registered 28.33% mortality of 3rd instar mealybug. The extracts of *T. ammi* and *C. tuberculata* were found statistically similar registering 20.00% mortality. Similarly, no-significant difference was found between *C. procera* and *A. sativum* extracts showing 26.33 and 26.00% mortality, respectively (Table-6).

After 1 week of exposure period, the maximum mortality of 56.33% was recorded on leaves treated with *A. indica* aqueous extracts which differed significantly from all the other treatments. Non-significant difference was noted between *T. chebula* and *T. ammi* extracts registering 36.67% mortality. Similarly, non-significant difference was found in *C. tuberculata*, *C. procera* and *A. sativum* aqueous extracts with percentage mortality of 30.00, 32.33 and 30.00, respectively (Table-6).

Overall, *A. indica* extracts were found most effective which registered 36.60% mortality of 3rd instar cotton mealybug. The *T. chebula* aqueous extracts were also found effective causing 22.09% mortality. The aqueous extracts of *T. ammi*, *C. procera* and *A. sativum* showed non-significant difference with 17.83, 19.66 and 19.83% mortality, respectively. The minimum mortality of 16.16% was found in *C. tuberculata* extracts (Table-6).

Mortality due to 3% concentration

Results from the (Table-7) showed that after 24 hours of exposure, maximum mortality of 23.33% was recorded on leaves treated with *A. indica* aqueous extracts which was statistically at par with 16.67% mortality in *A. sativum* extracts. The aqueous extracts of *T. chebula*, *T. ammi* and *C. procera* showed non-significant difference registering 13.33, 13.33 and 10.00% mortality, respectively. The minimum mortality of 3.33% was recorded in *C. tuberculata* extracts.

At 48 hours after exposure, maximum mortality of 33.33% was recorded on leaves treated with *A. indica* extracts which was found statistically similar with 26.67% mortality in *A. sativum* extracts. Non-significant difference was observed among the aqueous extracts of *T. chebula* and *T. ammi* with 20.00% mortality. Similarly, aqueous extracts of *C. tuberculata* and *C. procera* were found statistically similar with 13.33 and 16.67% mortality (Table-7).

Data after 72 hours of exposure period showed that maximum mortality of 43.33% was registered in aqueous extracts of *A. indica* which showed non-significant difference from 30.00% mortality in *A. sativum* extracts. Non-significant results were also found in aqueous extracts of *T. chebula*, *T. ammi*, *C. tuberculata* and *C. procera* with percentage mortality of 23.33, 23.00, 20.67 and 26.67, respectively.

After 1 week of exposure period, maximum mortality of 80.00% was recorded on leaves treated with *A. indica* extracts which was found at par with 73.33% mortality in *A. sativum* extracts.

The *T. chebula*, *T. ammi*, *C. tuberculata* and *C. procera* extracts showed non-significant results with each other, showing percentage mortality of 33.33, 30.00, 33.33 and 30.00 respectively (Table-7).

Results from the overall mean showed that maximum mortality of 45.00% was registered in *A. indica* extracts which was found statistically similar with 34.17% mortality in *A. sativum* extracts. Statistically comparable results were found in extracts of *T. chebula*, *T. ammi*, *C. tuberculata* and *C. procera* with 20.00, 20.83, 19.17 and 20.83% mortality respectively (Table-7).

Table 5: Mean percent corrected mortality of 3rd instar *P. solenopsis* due to different plant aqueous extracts at 1% concentration

Treatments	24 hours	48 hours	72 hours	1 week	Mean
Azadirachta indica	6.00 a	13.00 a	16.66 a	50.33 a	20.75 a
Terminalia chebula	3.00 ab	5.00 b	10.66 b	30.00 b	12.17 c
Trachyspermum ammi	3.00 ab	5.00 b	11.33 b	36.66 b	14.00 bc
Caralluma tuberculata	3.33 ab	4.00 b	10.00 b	36.66 b	13.50 bc
Calotropis procera	2.00 b	4.33 b	10.00 b	33.33 b	12.67 c
Allium sativum	3.33 ab	7.53 a	14.00 a	45.33 ab	17.50 ab
LSD Value	5.93	5.93	10.27	15.68	5.02

Means followed by common letters are not significantly different from each other by LSD test at α = 0.05

Table 6: Mean percent corrected mortality of 3rd instar *P. solenopsis* due to different plant aqueous extracts at 2% concentration

Treatments	24 hours	48 hours	72 hours	1 week	Mean
Azadirachta indica	16.67 a	26.67 a	46.67 a	56.33 a	36.60 a
Terminalia chebula	6.67 b	16.67 b	28.33 b	36.67 b	22.09 b
Trachyspermum ammi	3.33 bc	11.33 bc	20.00 c	36.67 b	17.83 bc
Caralluma tuberculata	3.33 bc	11.33 bc	20.00 c	30.00 bc	16.16 c
Calotropis procera	6.67 b	15.33 b	26.33 bc	32.33 bc	19.66 bc
Allium sativum	10.00 ab	15.33 b	26.00 bc	30.00 bc	19.83 bc
LSD Value	9.37	11.09	10.27	14.52	5.83

Means followed by common letters are not significantly different from each other by LSD test at α = 0.05

Table 7: Mean percent corrected mortality of 3rd instar *P. solenopsis* due to different plant aqueous extracts at 3% concentration

Treatments	24 hours	48 hours	72 hours	1 week	Mean
Azadirachta indica	23.33 a	33.33 a	43.33 a	80.00 a	45.00 a
Terminalia chebula	13.33 b	20.00 b	23.33 b	33.33 b	20.00 b
Trachyspermum ammi	13.33 b	20.00 b	23.00 b	30.00 b	20.83 b
Caralluma tuberculata	3.33 c	13.33 bc	20.67 b	33.33 b	19.17 b
Calotropis procera	10.00 b	16.67 bc	26.67 b	30.00 b	20.83 b
Allium sativum	16.67 ab	26.67 ab	30.00 ab	73.33 ab	34.17 ab
LSD Value	11.86	16.77	16.77	16.24	12.08

Means followed by common letters are not significantly different from each other by LSD test at α = 0.05

4. Discussion

A variety of plant species carry chemical substances including alkaloids, phenolics and terpenoids etc. which may contribute to the control of insect pests [5]. *A. indica* extracts carrying a variety of biological activities including anti-feedant, insect repellent, growth regulating and anti-ovipositional properties against insect pests and mites [9]. In the current investigations, *A. indica* seed extracts at all the evaluated concentrations showed higher mortality rate of cotton mealybug compared to other treatments. These results are in concordance with the findings of other scientists where *A. indica* extracts showed better control of different insect pests. [1, 28].

Results showed that mortality of the mealybug with *A. indica* extracts increased with increase in the exposure time. Comparable results were also documented by other researchers [27, 21]. The *A. indica* extracts provided better control of *P. solenopsis* under laboratory conditions. *A. indica* seed extract at 2.0% registered 51.38% mortality of adult *P. solenopsis* in one Week. These results are in agreement with the findings of Banu *et al*., (2010) they exposed both nymphs and adults of *P. solenopsis* to *A. indica* oil at 2.5 l/ha + Norma powder at 0.1%, which provided more than 50% mortality of *P. solenopsis* on Bt cotton [22].

The *A. sativum* extracts were also found effective against adult cotton mealybug with greater mortality effects. Percentage mortality of adult cotton mealy increased after 72 hours to 1 week in *A. sativum* extracts 1% concentration whereas in *A. sativum* 2% concentration, the percentage mortality of adult cotton mealybug increased after 48 hours up to 1 week. Okolle *et al*. (2017) also found highest mortality rate of 88.1% in *A. sativum* extracts against mealybug *Pseudococcus longispinus* [31].

A. indica seed extract at 3% concentration recorded highest (45.00%) mortality of 3rd instar cotton mealybug. Similarly, *A. sativum* showed maximum (34.17%) mortality of 3rd instar mealybug with 3% concentration compared to other tested concentrations. Similar results were also documented by other researchers [28, 29].

The results showed that *A. indica* extracts at all the tested concentrations remained highly effective against both adults and 3rd instar of cotton mealybug. The results are in agreement with Ramzi *et al*. (2017) and Rashid *et al*. (2011) [28, 11]. The present research also showed that *A. sativum* extracts were also found effective as compared to other tested botanical extracts.

A. indica and other botanical extracts have been used by various researchers under both laboratory and field conditions against various insect pests. Our results showed that *A. indica* seed extracts have insecticidal properties against *P. solenopsis* which is also stated by Mostafa *et al*. (2018) and Maheswari and Govindaiah (2017) [30, 29].

5. Conclusion

In conclusion *A. indica* and *A. sativum* extracts at 3% concentration provided good control of *P. solenopsis* and can be used in swapping to synthetic chemicals for the management of *P. solenopsis.*

6. References

1. Mamoon-ur-Rashid M, Khattak MK, Abdullah K. Evaluation of botanical and synthetic insecticides for the management of cotton pest insects. Pakistan Journal of Zoology. 2012; 44(5):1317-1324.

2. Akintola AJ, Ande AT. First record of *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) on Hibiscus rosa-sinensis in Nigeria. Agricultural Journal. 2008; 3(1):1-3.
3. Ascher KS. Nonconventional insecticidal effects of pesticides available from the neem tree, *Azadirachta indica*. Archives of insect Biochemistry and Physiology. 1993; 22(3, 4):433-449.
4. Nisbet AJ. Azadirachtin from the neem tree *Azadirachta indica*: its action against insects. Anais da Sociedade Entomológica do Brasil. 2000; 29(4):615-632.
5. Banu JG, Surulivelu T, Amutha M, Gopalakrishnan N. Laboratory evaluation of insecticides and biopesticides against *Phenococcus solenopsis* and *Paracoccus marginatus* infesting cotton. Journal of Biopesticides. 2010; 3(1):343-346.
6. Ben-Dov Y. A systematic catalogue of the mealybugs of the world (Insecta: Homoptera: Coccoidea: Pseudococcidae and Putoidae) with data on geographical distribution, host plants, biology and economic importance. Intercept Limited, 1994.
7. Fuchs TW, Stewart JW, Minzenmayer R, Rose M. First record of *Phenacoccus solenopsis* Tinsley in cultivated cotton in the United States. Southwestern Entomologist. 1991; 16(3):215-221.
8. Larraín PS. Insect and mite pest incidence on sweet pepinos (Solanum muricatum Ait.) cultivated in the IV Region, Chile. Agricultura-Tecnica. 2002; 62(1):15-26.
9. Mordue AJ, Blackwell A. Azadirachtin: an update. Journal of Insect Physiology. 1993; 39(11):903-924.
10. Nathan SS, Choi MY, Paik CH, Seo HY, Kim JD, Kang SM *et al*. The toxic effects of neem extract and azadirachtin on the brown planthopper, Nilaparvata lugens (Stål)(BPH) (Homoptera: Delphacidae). Chemosphere. 2007; 67(1):80-88.
11. Mamoon-ur-Rashid M, Abdullah K, Hussain S. Toxic and residual activities of selected insecticides and neem oil against cotton mealybug, *Phenacoccus solenopsis* Tinsley (Sternorrhyncha: Pseudococcidae) under laboratory and field conditions. Pakistan Entomologist. 2011; 33(2):151-155.
12. Wang Y, Wu S, Zhang R. Pest risk analysis of a new invasive pest, *Phenacoccus solenopsis*, to China. Chinese Bulletin of Entomology. 2009; 46(1):101-106.
13. Edwards CA, Arancon NQ, Vasko-Bennett M, Askar A, Keeney G, Little B *et al*. Suppression of green peach aphid (Myzus persicae) (Sulz.), citrus mealybug (Planococcus citri) (Risso), and two spotted spider mite (Tetranychus urticae) (Koch.) attacks on tomatoes and cucumbers by aqueous extracts from vermicomposts. Crop Protection. 2010; 29(1):80-93.
14. Ahmad F, Akram W, Sajjad A, Imran AU. Management Practices against Cotton Mealybug, *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae). International Journal of Agriculture & Biology. 2011; 13(4):547-552.
15. Saeed S, Ahmad M, Ahmad M, KWON YJ. Insecticidal control of the mealybug Phenacoccus gossypiphilous (Hemiptera: Pseudococcidae), a new pest of cotton in Pakistan. Entomological Research. 2007; 37(2):76-80.
16. Mansour R, Suma P, Mazzeo G, Lebdi KG, Russo A. Evaluating side effects of newer insecticides on the vine mealybug parasitoid *Anagyrus sp*. near *pseudococci*, with implications for integrated pest management in vineyards. Phytoparasitica. 2011; 39(4):369-376.
17. Abbas G, Arif MJ, Muhammad A, Muhammad A, Shafqat S. Host plants distribution and overwintering of cotton mealybug (*Phenacoccus solenopsis*; Hemiptera: Pseudococcidae). International Journal of Agriculture and Biology. 2010; 12(3):421-425.
18. Ram P, Saini RK. Biological control of *P. solenopsis* mealybug, *Phenacoccus solenopsis* Tinsley on cotton: a typical example of fortuitous biological control. Journal of Biological Control. 2010; 24(2):104-109.
19. Noureen N, Hussain M, Fatima S, Ghazanfar M. Cotton mealybug management: A Review. Journal of Entomology and Zoology Studies. 2016; 4(4):657-663.
20. Prishanthini M, Vinobaba M. Efficacy of some selected botanical extracts against the Cotton mealybug *Phenacoccus solenopsis*(Tinsley) (Hemiptera: Pseudococcidae). International Journal of Scientific and Research Publications. 2014; 4(3):1-6.
21. Rizvi SA, Jaffar S. Efficacy of some selected chemical insecticides and bio-pesticides against tomato fruit worm, (*Helicoverpa armigera*) under the agro climatic condition of Gilgit Baltistan, Pakistan. Journal of Entomology and Zoology Studies. 2015; 3(4):50-52.
22. Ahmadi M, Amiri-Besheli B, Hosieni SZ. Evaluating the effect of some botanical insecticides on the citrus mealybug *Planococcus citri* (Risso) (Hemiptera: Pseudococcidae). African Journal of Biotechnology. 2012; 11(53):11620-11624.
23. Sathyaseelan V, Bhaskaran V. Efficacy of some native botanical extracts on the repellency property against the pink mealy bug, *Maconellicoccus hirsutus* (green) in mulberry crop. Recent Research in Science and Technology. 2010; 2(10):35-38.
24. Arain MI. Effect of Botanical pesticides against mealy bug on cotton, 2009.
25. Hussain MA, Viraktamath CA. Management of citrus mealybug, *Planococcus citri* (Risso) on guava using botanical oils. Insect Environment. 1996; 2(3):73-74.
26. Santos TM, Costa NP, Torres AL, Boiça Júnior AL. Effect of neem extract on the cotton aphid. Pesquisa Agropecuária Brasileira. 2004; 39(11):1071-1076.
27. Badshah H, Ullah F, Farid A, Calatayud PA, Crickmore N. Toxicity of Neem seed *Azadirachta indica* Juss (Meliaceae) different solvents extracts against cotton mealybug *Phenacoccus solenopsis* Tinsley (Sternorrhyncha: Pseudococcidae) under Laboratory conditions. Journal of Entomology and Zoological Studies. 2015; 3(4):45-49.
28. Ramzi S, Seraji A, Azadi Gonbad R, Mirhaghparast SK, Mojib Haghghadam Z, Haghighat S, *et al*. Toxicity of *Artemisia annua* (Asteraceae) essential oil on the tea mealy bug, *Pseudococcus viburni* (Sigornet) (Hemiptera: Pseudococcidae). Archives of Phytopathology and Plant Protection. 2017; 50(19, 20):941-956.
29. Maheswari M, Govindaiah G. Evaluation of different plant extracts for management of mealy bugs and leaf rollers in the mulberry field. Entomol Journal. 2017; 5(6):2081-2085.

30. Mostafa ME, Youssef NM, Abaza M. Insecticidal activity and chemical composition of plant essential oils against cotton mealybug, *Phenacoccus solenopsis* (Tinsley) (Hemiptera: Pseudococcidae). Entomol Journal. 2018; 6(2):539-543.
31. Okolle JN, Lum NM, Ngosong C, Nanganoa LT, Clovis T, Peter N *et al*. Efficacy of four plant emulsions for managing long tail mealybugs (*Pseudococcus longispinus*) infesting banana plantations in Cameroon. Journal of Entomology and Zoology Studies. 2018; 6(3):837-843.