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Research Article

FIELD EVALUATION OF PLANT OIL FORMULATIONS AS POTENTIAL CONTROL MEASURES AGAINST THE COTTON MEALYBUG (*PHENACOCCUS SOLENOPSIS* TINSLEY)

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ABSTRACT

The cotton crop is heavily infested by various insect pests, including *Phenacoccus solenopsis*. Antagonistic plants offer an alternative source of insect biocontrol agents because they contain various bioactive materials, many of which are selective or have no adverse effects on non-target organisms or the environment, unlike synthetic insecticides. Therefore, three locally available plant oils were tested to evaluate their efficacy in reducing *P. solenopsis* in cotton fields. Statistical analysis showed a highly significant difference (DF = 3, 23; F = 194.42; P = 0.0000) for the reduction of the *P. solenopsis* population. After the first spray, the highest overall mean reduction of *P. solenopsis* (61.26±10.69%) was recorded in the cotton plot sprayed with neem oil, followed by castor oil (50.11±10.94%) and mustard oil (38.30±8.39%). After the second spray, the highest overall mean reduction of *P. solenopsis* (70.01±9.26%) was again observed with neem oil, followed by castor oil (50.51±8.90%) and mustard oil (40.06±8.74%). Furthermore, results concluded that neem oil achieved the highest reduction of *P. solenopsis* population (84.45%) on the third day, with an overall reduction of 65.64±9.94%. The second-highest reduction (68.96%) with an overall reduction of 50.31±9.9% was recorded in the plot sprayed with castor oil, followed by mustard oil, which reduced the population by 54.05% with an overall reduction of 39.18±8.55%. The results also indicate that the efficacy of neem oil remained effective until the third day after spraying, while on the seventh day, the *P. solenopsis* population began to increase gradually.

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INTRODUCTION

Cotton, *Gossypium hirsutum* L. (Malvales: Malvaceae), is a plant-based fiber crop of significant economic importance in cotton-producing nations globally (Hulsekemp et al., 2014). This crop is attacked by a wide variety of arthropod pests, causing severe losses to farmers (Uthamasamy, 1994; Sahito et al., 2017). Insect pests and diseases result in annual output losses of 15-20%, and in certain years, these losses can reach up to 50% (Masood et al., 2011; Raman, 2017; Lawrence et al., 2019). Notable pests include the whitefly, *Bemisia tabaci* (Hemiptera: Aleyrodidae), the jassid, *Amrasca biguttula biguttula* Ishida (Hemiptera: Cicadellidae), and the cotton mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) (Fuchs et al., 1991; Ellsworth et al., 2001; Dhawan et al., 2011). *P. solenopsis* is a polyphagous pest that consumes weeds as well as various cultivated crops (Patel et al., 2009; Iftikhar et al., 2018; Muhammad et al., 2022).

Synthetic pesticides play a crucial role in controlling insect pests and diseases in cotton and other field crops. However, the prolonged use of chemical pesticides often leads to a decrease in natural enemy populations, increasing insecticide resistance, and heightened environmental contamination (Wang et al., 2011). Moreover, the chemical management of cotton mealybug is challenging due to its broad host range, waxy body covering, and high reproductive capacity. The crawler stage is the most delicate and manageable phase in its life cycle.

Plant oils can significantly contribute to the protection of crops, fruits, and even stored grains, reducing the need for and risks associated with insecticides. Due to growing environmental concerns and increasing insecticide resistance among insect populations, there has been a surge in interest in botanicals over the past fifteen years. As naturally occurring insecticides derived from plants, plant oils are known as botanical insecticides (Isman, 2000). Several studies have identified numerous essential plant oils and extracts that effectively repel various insect pests (Sarac and Tunc, 1995; Shaaya et al., 1997; Tunc et al., 2000; Kim et al., 2003; Lee et al., 2003; Asian et al., 2005; Cetin and Yanikoglu, 2006; Negahban et al., 2007; Ayvaz et al., 2009). These natural alternatives have proven to be successful substitutes for synthetic insecticides.

Therefore, the present study aimed to evaluate the effectiveness of locally available plant oils against the cotton mealybug *P. solenopsis* under field conditions in Tandojam, Sindh, Pakistan.

MATERIALS AND METHODS

Trial site

A field trial was conducted at the Plant Protection Research Institute, Agriculture Research Centre Tandojam during the 2023 cotton growing season to evaluate the efficacy of different plant oils against the cotton mealybug, *Phenacoccus solenopsis* L. The trial utilized the "Mehran" cotton variety and incorporated standard agronomical practices.

Insect pest

The insect pest studied was the cotton mealybug, *Phenacoccus solenopsis* (Pseudococcidae, Hemiptera).

Treatments

The following treatments were applied:

T1 = Neem oil (*Azadirachta indica*)

T2 = Castor oil (*Ricinus communis*)

T3 = Mustard oil (*Brassica nigra*)

T4 = Control (no treatment)

Preparation of plant oils and mixtures

Neem, castor, and mustard oils were purchased from the local market in Tandojam, district Hyderabad. Each plant oil bottle contained 1000 ml of distilled water and 2 ml of the respective oil. Additionally, 2 spoons of detergent were added and thoroughly mixed in a spray bottle before application (Figure 1).

Experimental design and field observations

The experiment followed a randomized complete block design (RCBD) with plots measuring 100 ft × 50 ft (length × width), divided into 16 blocks. Each block measured 12 ft × 12 ft and consisted of four replications. Two sprays were applied at 15-day intervals. Observations were recorded at various time points: pre-treatment (1 day before spray) and 1, 2, 3, and 7 days after each spray.

For each treatment, observations were made on 5 whole plants per replication, with a total of 20 plants examined to record the *P. solenopsis* population. Reduction rates were calculated using the Henderson and Tilton (1955) algorithm.

$$\text{Reduction (\%)} = \frac{\text{No. in control before treatment} \times \text{No. in treatment after treatment}}{\text{No. in control after treatment} \times \text{No. in treatment before treatment}} \times 100$$

RESULTS

Population of *P. solenopsis* after the first spray

The results in Figure 2 show that the overall mean population of *P. solenopsis* ranged between 106.25 and 124.25 across all plots before spraying. However, after the first spray, the lowest population (26.50) was recorded on the third day, where neem oil was used. The highest population (133.00) of *P. solenopsis* was recorded in the control plot seven days after the first spray.

Population of *P. solenopsis* after the second spray

The results in Figure 3 show that the overall mean population of *P. solenopsis* ranged between 67.75 and 137.50 in all plots before the second spray. After the second spray, the lowest population (9.75) was recorded on the third day in the neem oil plot, and the highest population (155.75) was recorded in the control plot seven days after the second spray.

Figure 1. Field activities during internship period: A = Mehran cotton variety, B = *Phenacoccus solenopsis* infestation, C= Different plant oils and detergent, D+E+F = Spraying plant oils on cotton, G+H+I= Recording data.

Average reduction of *P. solenopsis* population after the first spray

The results in Figure 4 show that the highest mean reduction percentage of *P. solenopsis* (81.88%) was recorded in the neem oil plot on the third day after the first spray, followed by 71.67% in the castor oil plot and 54.05% in the mustard oil plot.

Average reduction of *P. solenopsis* population after the second spray

The results in Figure 5 show that the highest mean reduction percentage of *P. solenopsis* (87.01%) was recorded in the neem oil plot on the third day after the second spray, followed by 66.25% in the castor oil plot and 54.05% in the mustard oil plot.

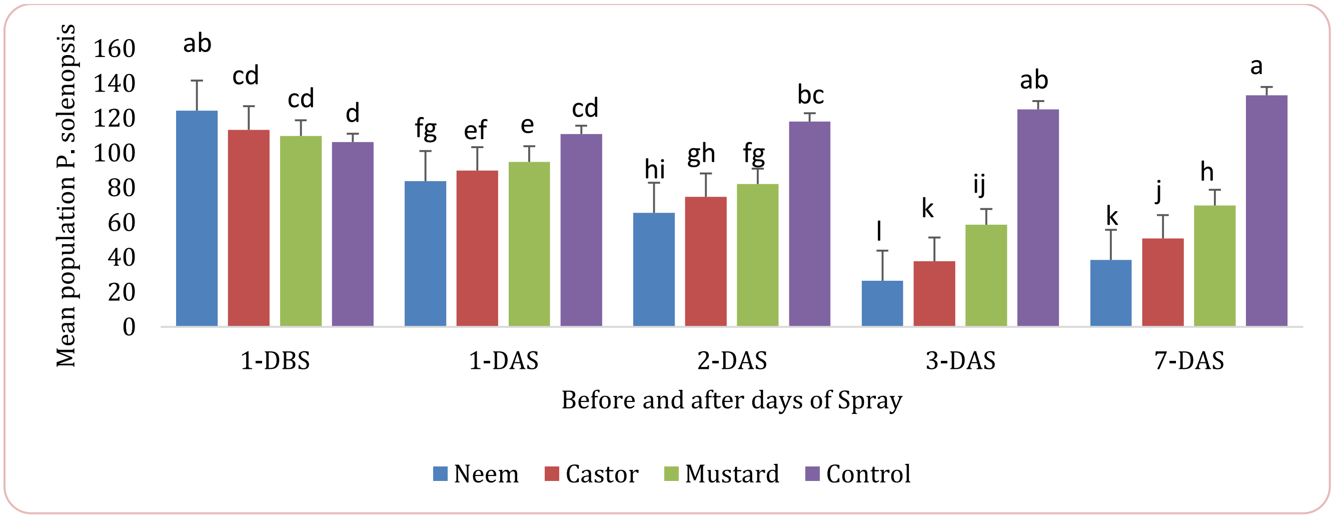

Figure 2. Overall mean population of *P. solenopsis* before and after the first spray of different plant oils.

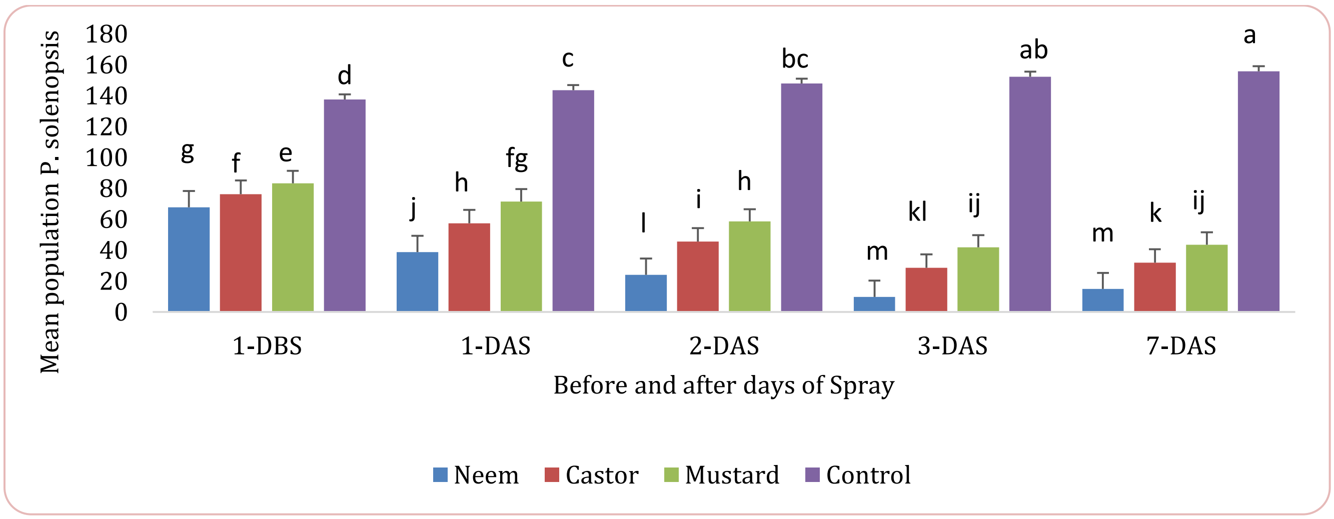

Figure 3. Overall mean population of *P. solenopsis* before and after the second spray of different plant oils.

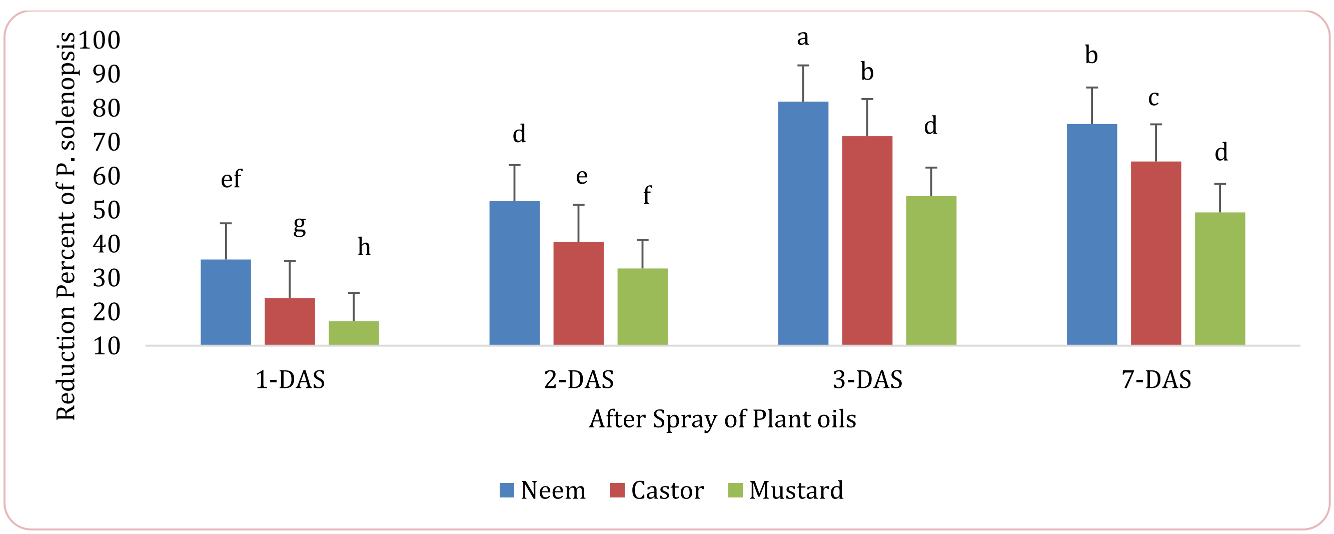

Figure 4. Overall mean reduction percent of *P. solenopsis* before and after the first spray of different plant oils.

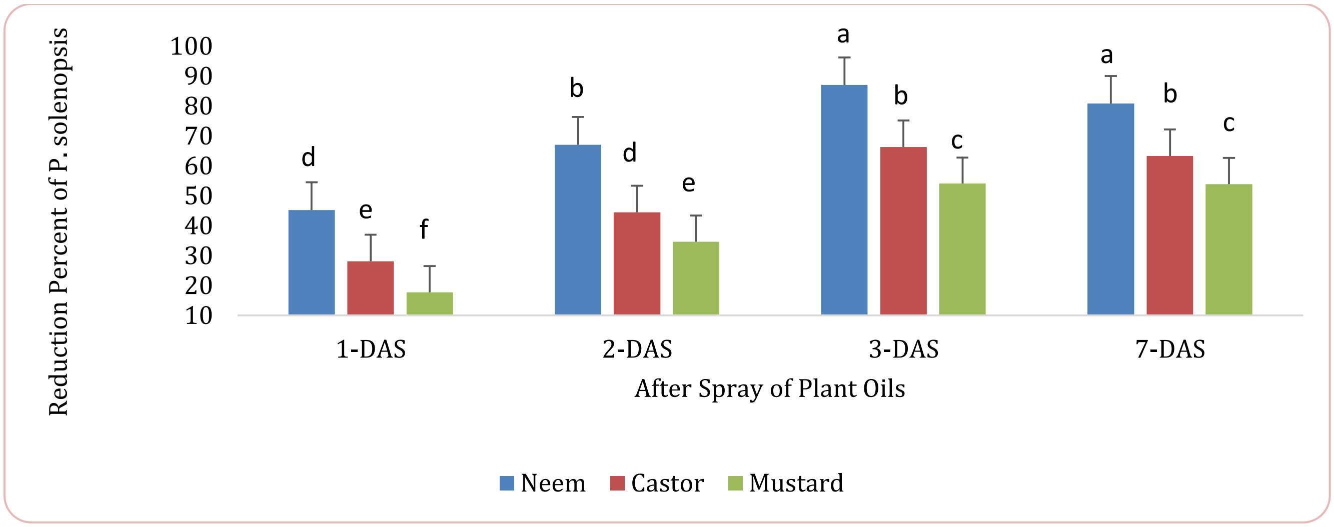

Figure 5. Overall mean reduction percent of *P. solenopsis* before and after the second spray of different plant oils.

Reduction percentage of *P. solenopsis* after the first spray

Statistical results show a highly significant reduction in the mealybug population after the application of various plant oils compared to the control after the first spray at different days (DF = 3, 47; F = 206.63; P = 0.0000) at (P < 0.05).

Table 1 shows that the *P. solenopsis* population ranged between 106.25 and 124.25 one day before applying plant oils. The highest overall mean reduction percentage (61.26 ± 10.69) was recorded in the cotton plot sprayed with neem oil, followed by 50.11 ± 10.94 in the castor oil plot and 38.30 ± 8.39 in the mustard oil plot. The lowest mean *P. solenopsis* population (53.56 ± 12.95) was recorded in the neem oil plot after spraying, followed by 63.25 ± 11.69 in the castor oil plot, and 76.31 ± 7.77 in the mustard oil plot. The control plot showed an increasing trend in *P. solenopsis* population (121.69 ± 14.76) (Table 1).

Table 1. Overall mean and reduction of *P. solenopsis* before and after the first spray of different plant oils in the cotton field.

Observations and Reduction%	Plant oils			
	Neem oil	Castor oil	Mustard oils	Untreated or Control
1-DBS	124.25	113.25	109.75	106.25
1-DAS	83.75	89.75	94.75	110.75
Reduction%	35.34	23.98	17.18	-
2-DAS	65.50	74.75	82.00	118.00
Reduction%	52.54	40.57	32.73	-
3-DAS	26.50	37.75	58.75	125.00
Reduction%	81.88	71.67	54.05	-
7-DAS	38.50	50.75	69.75	133.00
Reduction%	75.30	64.21	49.23	-
Mean±SE	53.56±12.95 c	63.25±11.69 c	76.31±7.77 b	121.69±14.76a
Reduction%±SE	61.26±10.69 a	50.11±10.94 b	38.30±8.39 c	-

Columns having the same letters are not statistically different (P≥0.05, ANOVA).

Reduction percentage of *P. solenopsis* after the second spray

Statistical results after the second spray showed a highly significant reduction in the mealybug population after applying different plant oils compared to the control at different days (DF = 3, 47; F = 144.49; P = 0.0000) at (P < 0.05).

Table 2 shows that the *P. solenopsis* population ranged between 67.75 and 137.50 one day before applying plant oils. The highest overall mean reduction percentage (70.01 ± 9.26) was recorded in the cotton plot sprayed with neem oil, followed by 50.51 ± 8.90 in the castor oil plot and 40.06 ± 8.74 in the mustard oil plot. The lowest mean *P. solenopsis* population

(21.81 ± 6.37) was recorded in the neem oil plot after spraying, followed by 40.75 ± 6.62 in the castor oil plot and 53.81 ± 6.99 in the mustard oil plot. The control plot showed an increasing trend in *P. solenopsis* population (149.81 ± 2.67) (Table 2).

Overall mean and reduction percentage of *P. solenopsis* after both sprays

Statistical results for the overall mean and reduction percentage showed a highly significant difference in *P. solenopsis* population reduction among various plant oils concerning their effect on different days compared to the control (DF = 3, 23; F = 194.42; P = 0.0000) at (P < 0.05).

The results for the overall mean and reduction percentage of *P. solenopsis* in both sprays of different plant oils showed that the overall mean population ranged between 94.75 and 121.88 in the pre-treatment data collection. After spraying, neem oil showed the highest reduction in *P. solenopsis* population (84.45%) on the third day with an overall reduction of 65.64 ± 9.94%. The second-highest reduction (68.96%) with an overall reduction of 50.31 ± 9.9% was recorded in the castor oil plot, followed by mustard oil with a reduction of 54.05% and an overall reduction of 39.18 ± 8.55% on the third day after spraying (Table 3).

The results further indicate that the efficacy of neem oil remained effective until the third day after spraying, while on the seventh day, the *P. solenopsis* population began to gradually increase.

Table 2. Overall mean and reduction of *P. solenopsis* before and after the second spray of different plant oils in cotton fields.

Observations and Reduction%	Plant oils			
	Neem oil	Castor oil	Mustard oils	Untreated or Control
1-DBS	67.75	76.25	83.25	137.5
1-DAS	38.75	57.25	71.50	143.50
Reduction%	45.20	28.06	17.71	-
2-DAS	24.00	45.50	58.50	147.75
Reduction%	67.04	44.47	34.61	-
3-DAS	9.75	28.50	41.75	152.25
Reduction%	87.01	66.25	54.05	-
7-DAS	14.75	31.75	43.50	155.75
Reduction%	80.80	63.24	53.88	-
Mean±SE	21.81±6.37 d	40.75±6.62 c	53.81±6.99 b	149.81±2.67a
Reduction%±SE	70.01±9.26 a	50.51±8.90 b	40.06±8.74 c	-

Columns having the same letters are not statistically different (P≥0.05, ANOVA).

Table 3. Overall mean and reduction at pre- and post-treatments of both sprays of different plant oils against *P. solenopsis* in cotton field.

Botanicals	Pre-treatment (1-DBS)	Post-treatment				
		1-DAS	2-DAS	3-DAS	7-DAS	Mean ± SE. and Reduction%±SE.
Neem oil	96.00	61.25	44.75	18.13	26.63	37.69±9.62c
	Reduction%	40.27	59.79	84.45	78.05	65.64±9.94a
Castor oil	94.75	73.50	60.13	33.13	41.25	52.00±9.13bc
	Reduction%	26.02	42.52	68.96	63.73	50.31±9.91b
Mustard oils	96.50	83.13	70.25	50.25	56.63	65.06±7.32b
	Reduction%	17.45	33.67	54.05	51.56	39.18±8.55c
Control	121.88	127.13	132.88	138.63	144.38	135.75±3.71a

Columns having the same letters are not statistically different (P≥0.05, ANOVA).

DISCUSSION

Cotton, *Gossypium hirsutum* (L.), is often referred to as "white gold" and belongs to the Malvaceae family. It is a primary source of fiber (Sahito et al., 2013), nutrition, and manufacturing material (Shah et al., 2017). This versatile plant can be cultivated in both tropical and subtropical regions and is susceptible to a wide array of pests, including *Phenacoccus solenopsis* (Tanwar et al., 2007). Several active components, such as monoterpenoids, contribute to the insecticidal properties found in many plant extracts and essential oils. Previous research suggests that plant oils may be effective alternatives to synthetic insecticides, with efficacy varying based on factors such as the insect's developmental stage, species, and the plant source (Tunc et al., 2000; Chiasson et al., 2001; Choi et al., 2003; Sedy and Koschier, 2003; Negahban et al., 2007).

The present study evaluated the effects of plant oils, such as neem, castor, and mustard oil, in reducing *P. solenopsis* infestations on cotton crops. Similarly, Bhosle et al. (2009) tested the efficacy of *Azadirachta indica* (neem) seed extracts for pest management and found them to be equally successful. They further determined that tobacco, datura, and meetha neem are nonhazardous, cost-effective, and safe options, showing high effectiveness against a wide range of pest insects without causing harmful effects.

Our results demonstrated that the mean number of *P. solenopsis* was significantly reduced on the third day after spraying different plant oils, although the numbers increased again by the seventh day. These findings are consistent with those of Prishanthini and Vinobaba (2014), who investigated the effectiveness of various locally available botanicals against the cotton mealybug *P. solenopsis* on shoe flower plants. They used plant extracts with varying concentrations (0.2%, 0.4%, 0.6%, 0.8%, 1.0%, 1.2%, 1.5%, 2.0%) of *A. indica*, *Ocimum sanctum*, *Calotropis gigantea*, *Nicotiana tabacum*, and *Allium sativum*, with the addition of soap solutions.

Moreover, our results suggest that the highest overall reduction in the *P. solenopsis* population was observed with neem oil, followed by castor oil and mustard oil, respectively, after both sprays compared to the control plot. These findings align with those reported by Sardar et al. (2018), who studied the effectiveness of neem extract solutions at concentrations of 1%, 2%, and 3% on the mortality rate of adult female and third-instar *P. solenopsis*. They reported a mortality rate of 40-44% in adult females and 20-45% in third-instar nymphs. The results of our study are also consistent with those of Mamoon-Ur-Rashid et al. (2011), who conducted experiments on cotton plants using neem oil at concentrations of 1.5% and 2%, resulting in a reduction in the *P. solenopsis* population by 43% and 52%, respectively.

CONCLUSIONS

To replace the excessive and indiscriminate use of chemical pesticides, three different plant oils viz. neem oil, castor oil, and mustard oil were tested for their efficacy in reducing *P. solenopsis* populations in cotton fields. The findings concluded that neem oil was the most effective, reducing *P. solenopsis* populations by 70 to 80%, followed by castor oil (60 to 70%) and mustard oil (50 to 60%). Furthermore, the results showed that the highest reduction in *P. solenopsis* was recorded on the third day after spraying. However, by the seventh day, the *P. solenopsis* population began to increase slightly.

Based on these results, it is recommended that neem oil, castor oil, and mustard oil be used to control the cotton mealybug, *P. solenopsis*. Moreover, these botanicals should be tested against other mealybug species and various insect pests on crops, fruits, and vegetables, as they have no environmental or health side effects and could serve as a viable alternative to synthetic insecticides.

AUTHORS' CONTRIBUTION

AL and SHR highlighted the problem and designed the field research activities; AL and KF conducted research trials, collected, and arranged data; AWS analyzed the data; AL and KHD wrote the manuscript; BKS supervised the study; MYR proofread the manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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