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Field evaluation of botanicals extracts for suppressing the mango scale insect, *Aulacaspis tubercularis* (Newstead) (Hemiptera: Diaspididae)

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Abstract

Insecticidal property of aloe, ginger, garlic, and hot pepper extracts were evaluated in the form of alone spray or in combination of two plant sources or as a mixture of all plant extracts in comparison to the insecticide Lambda on the mango scale insect, *Aulacaspis tubercularis* (Newstead) (Hemiptera: Diaspididae). Field experiments were carried out at Fayoum Governorate, Egypt, in February 2017 and March 2018. Results revealed that Lambda insecticide decreased the population of treated *A. tubercularis*, and the total reduction rates reached to 62.0 and 72.52% in seasons 2017 and 2018, respectively. Meanwhile, the used botanical mixture caused 83.60 and 72.52% reduction of the scale insects in the respective seasons. Also, results revealed that the combination of garlic and aloe was the most effective one in reducing *A. tubercularis* in the two successive seasons by 58.71 and 59.93%, respectively. The hot pepper was the least effective one in reducing population with the rates of 19.48% in season 2017 and 21.51% in season 2018.

Keywords: Botanicals extract, Scale insect, *Aulacaspis tubercularis*, Control, Yield

Background

Mango is one of the most economic fruit trees, because its fruits are rich in carbohydrates, natural fibers, vitamins, and minerals (Hassan et al. 2012). Mango yield has been drastically decreased by the attack of certain diseases and pests. One of those is the scale insect, *Aulacaspis tubercularis* (Newstead) (Hemiptera: Diaspididae), which causes severe problems represented by removal of plant sap, turning of trees to pale green or yellow, and excretion of honey dew the suitable medium for the growth of sooty mold fungi, which cover mango leaves (Tandon and Verghese 1985). Due to this, photosynthesis is reduced resulting in great reduction of the yield and the income of the farmers. Scale insects are covered with waxy layer, which protect them from contact pesticides (Morsi et al. 2002; Radwan 2003; Abo-Shanab 2012). A broad spectrum of insecticides used to control the pest has led to environmental pollution, mammalian toxicity, and increased resistance of the insects to the insecticides (Delobel and Malonga 1987). Keeping in view facts about severity caused by chemical insecticides, natural alternatives as certain plant products have been taken into account as natural pesticides (El Sayed 1982). Mainly, certain botanicals that comprise compounds that possess insecticidal properties are commonly used in traditional control (Golob et al. 1982). Aloe, *Aloe vera* (Family: Aloaceae), is one of the most useful plants exhibiting repellent and insecticidal properties by its bitter taste (Gayathri 2016). Ginger, *Zingiber officinale* Roscoe (Family: Zingiberaceae) used worldwide as a traditional medicine, has recently been found possessing an insecticidal effect on many insects (Okonkwo and Ohaeri

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2013). Garlic, *Allium sativum* L. (Family: Alliaceae), has a strong odor, which helps in disturbing insects searching potential plant hosts. Besides, it contains salphone hydroxyl ion, which acts as a poison and repellent for insects including ants, moths, beetles, ticks, and termites in their developmental stages (Teklay et al. 2012). Hot pepper, *Capsicum annum* (Family: Capsaicidae), contains capsaicin compound and has many uses as spice and public medicine, as well as its ability to kill certain insects (Nesel et al. 2016). The present work dealt with the evaluation of spraying plant extracts either alone or as a mixture on mango trees to suppress the populations of scale insects on mango trees.

Materials and methods

Preparation of the plant extracts

The plant extracts were prepared at the rearing laboratory of Fayoum Governorate, Plant Protection Institute, Agricultural Research Center, Egypt. Fresh ginger rhizomes, garlic bulbs, and dry full grown hot pepper fruits were purchased, and aloe was collected from surrounding gardens of the laboratory. About 1 kg of ginger and garlic bulbs were cleaned, ground well, added to 1 kg of hot pepper in the form of well-developed fruits, dried well in electric oven, and then grinded by an electric grinder. All the plant sources were soaked in 10 l water for 72 h. Then, that mixture was refined by a piece of cotton cloth, squeezed well. One kilogram of aloe leaves was washed and cut into small pieces then blinded to collect the transparent gel, which was added to the resultant filtrate and diluted to 100 l water for spraying mango trees.

Field experiments

Field experiments were carried out on the 25th of February 2017 and the 3rd of March 2018, at a private orchard of mango trees (15 years old), at Naqalifah Village. Fayoum Governorate, Egypt. The tested botanical extracts and the insecticide Lambda (Chema Industries Company, Alexandria, Egypt) were evaluated and compared to the controls. In the two seasons, the experimental area used was one Feddan (4200 m^2), divided into plots in a complete randomized block design with three replicates/treatment and five trees/replicate. Each plot was separated from the adjacent plot by a row of mango trees as a barrier. The treatments were sprayed by a knapsack motor sprayer of 600 l at a mean rate of 20 l/tree to assure full covering of the tree. The treatments were sprayed in the early morning. The treatments were as follows:

- Each of the aloe, ginger, garlic, and hot pepper extracts were prepared by grinding 1 kg of each plant source and soaked in 10 l of water for 72 h, then filtered by means of a piece of cotton cloth, then the resultant was diluted to 100 l water and sprayed separately.
- Two botanical sources were combined together and sprayed as follows: ginger + garlic; ginger + hot pepper; ginger + aloe; garlic + hot pepper; garlic + aloe; and hot pepper + aloe.
- Mixture of ginger, garlic, and hot pepper with aloe.
- Lambda cyhalothrin 5 EC with the rate of 0.5 ml/l.
- Untreated control.

Data collection

Inspection was conducted by picking out 30 treated mango leaves (as there were no fruits at the time of the experiment) randomly per each replicate, placed in paper bags and transferred to the laboratory for examination, which was done by means of binocular microscope for counting live and dead individuals on both surfaces of the leaves. Inspection was accomplished pretreatment and post-treatment after 1, 3, and 7 days.

Statistical analysis

Reduction percentage of scale insect population was the base of the evaluation of the tested materials. It was calculated according to Henderson and Tilton (1955) equation:

$$\text{Reduction percentage} = \left[1 - \frac{\text{No.in Control before Treatment} \times \text{No.in Treatment after Treatment}}{\text{No.in Control after Treatment} \times \text{No.in Treatment before Treatment}}\right] \times 100$$

Obtained data of botanical sources was compared to those of Lambda and control plots. Analysis of variance was used on all data (ANOVA), and means were separated by Duncan's multiple range tests (Snedecor and Cochran 1980).

Results and discussion

Population number of scale insects on mango trees

Data in Table 1 revealed that the pre-count of *A. tubercularis* in all treatments ranged between 16.0 and 16.70 individuals/30 leaves. Controls recorded the highest number of scale insects after 1, 3, and 7 days of the treatments, respectively, with the means of 16.43, 16.33, and 16.6 individuals/30 leaves in season 2017 and 14.27, 14.43, and 13.93 scale insects/30 leaves in season 2018. The botanical extracts differed significantly in the counts of scale insects on mango leaves recorded 7.33, 1.17, and 0 scale insects/30 leaves in season 2017 and 7.0, 0.88, and 0 individuals/30 leaves in season 2018 after 1, 3, and 7 days, respectively. Also, in plots treated with Lambda insecticide the scale insects reduced to 10.0, 4.67, and 3.67 individuals/30 leaves in season 2017 and 7.33, 2.0,

Table 1 Population of scales pre- and post-treatments in seasons 2017 and 2018 at Fayoum Governorate

Treatment	Scale insects population/ 30 leaves in seasons									
	2017					2018				
	Pretreatment count	After 24 h	After 72 h	After 168 h.	Total mean no.	Pretreatment count	After 24 h	After 72 h	After 168 h.	Total mean no.
Aloe	16.67 ± 2.04^{ab}	10.73 ± 3.54^{bc}	8.67 ± 3.76^{e}	5.33 ± 3.78^{c}	8.24 ± 3.8^{d}	16 ± 2.49^{cd}	10.4 ± 3.44^{c}	4.47 ± 4.05^{c}	5 ± 3.9^{e}	6.62 ± 3.45^{c}
Ginger	16.7 ± 2.03^{a}	12 ± 2.56^{d}	9.83 ± 3.43^{f}	6.67 ± 3.55^{d}	9.5 ± 3.42^{de}	15.67 ± 2.61^{c}	10.97 ± 3.6^{c}	8.8 ± 3.7^{e}	5.63 ± 3.6^{e}	8.47 ± 3.78^{d}
Garlic	16.5 ± 2.10^{b}	11.1 ± 2.9^{c}	8.7 ± 3.66^{e}	6.67 ± 3.55^{d}	8.82 ± 3.79^{d}	16.17 ± 2.33^{d}	10.33 ± 3.8^{c}	8.37 ± 3.9^{e}	5.33 ± 3.7^{e}	8.01 ± 3.99^{d}
Hot Pepper	16.3 ± 2.21^{d}	13.57 ± 2.1^{e}	13.17 ± 2.01^{g}	11.67 ± 2.9^{g}	12.8 ± 1.99^{e}	16.27 ± 2.12^{d}	13.53 ± 4.11^{e}	13.13 ± 4.77^{g}	11.63 ± 4.5^{h}	12.76 ± 3.9^{f}
Ginger× garlic	16.33 ± 2.19^{d}	10.93 ± 3.6^{bc}	8.8 ± 3.55^{e}	5.67 ± 3.7^{c}	8.47 ± 3.78^{d}	16 ± 2.5^{cd}	10.6 ± 4.09^{c}	8.43 ± 3.67^{e}	5.33 ± 3.7^{e}	8.12 ± 3.8^{d}
Ginger × hot Pepper	16.63 ± 2.05^{ab}	11.33 ± 2.7^{6c}	9.67 ± 3.44^{f}	8.0 ± 3.87^{e}	9.67 ± 3.3^{de}	15.83 ± 2.11^{c}	10.53 ± 3.34^{c}	8.87 ± 3.7^{e}	7.2 ± 2.99^{g}	8.87 ± 3.7^{d}
Ginger × Aloe	16.43 ± 2.11^{c}	10.57 ± 2.11^{bc}	7.67 ± 4.43^{d}	4.17 ± 3.9^{bc}	7.47 ± 2.7^{c}	16.33 ± 2.09^{d}	10.47 ± 3.52^{c}	7.57 ± 2.5^{de}	4.07 ± 4.23^{d}	7.37 ± 2.9^{cd}
Garlic × hot Pepper	16.0 ± 2.55^{f}	11.03 ± 1.89^{c}	9.0 ± 2.33^{f}	9.4 ± 3.44^{f}	9.81 ± 3.9^{de}	16.3 ± 2.1^{d}	11.33 ± 2.7^{d}	9.3 ± 3.6^{f}	6.57 ± 3.7^{f}	9.07 ± 3.9^{e}
Garlic × Aloe	16.33 ± 2.09^{d}	11.23 ± 2.55^{c}	6.67 ± 3.99^{c}	3.33 ± 5.45^{b}	7.08 ± 2.91^{c}	16 ± 2.4^{cd}	9.9 ± 3.7^{b}	6.33 ± 3.33^{d}	3.0 ± 3.87^{c}	6.41 ± 3.8^{c}
Hot Pepper × Aloe	16.5 ± 2.10^{b}	10.67 ± 3.4b^{c}	8.67 ± 3.87^{e}	6.67 ± 3.55^{d}	8.67 ± 2, 88^{d}	16 ± 2.4^{cd}	10.33 ± 3.6^{c}	8.33 ± 3.9^{e}	6.17 ± 3.99^{f}	8.27 ± 3.8^{d}
Botanical's Mix	16.67 ± 2.01^{ab}	7.33 ± 4.6^{a}	1.17 ± 5.80^{a}	0 ± 0^{a}	2.83 ± 5.7^{a}	16.33 ± 2.09^{d}	7 ± 2.99^{a}	0.83 ± 5.44^{a}	0 ± 0^{a}	2.61 ± 4.11^{a}
Lambda	16.33 ± 2.21^{d}	10 ± 3.45^{b}	4.67 ± 4.33^{b}	3.67 ± 4.9^{b}	6.11 ± 3.33^{b}	13.67 ± 4.01^{a}	7.33 ± 2.5^{a}	2 ± 4.58^{b}	1.93 ± 4.9^{b}	3.75 ± 3.11^{b}
Control	16.27 ± 2.09^{e}	16.43 ± 2.93^{f}	16.33 ± 2.89^{h}	16.6 ± 2.5^{h}	16.45 ± 2.44^{f}	14 ± 4.12^{b}	14.27 ± 4.09^{f}	14.43 ± 4.02^{h}	13.93 ± 4.55^{i}	14.21 ± 4.91^{g}

Means followed by the same letter, in the same column, are not significantly different. (Duncan's multiple range tests) (Duncan 1955)

and 1.93 individuals/30 leaves in season 2018 at 1, 3, and 7 days post-treatment, respectively. Aloe extract decreased the population to 10.73, 8.67, and 5.33 scale insects/30 leaves in season 2017 and 10.4, 4.47, and 5.0 scale insects/30 leaves in season 2018, respectively, at the above mentioned intervals followed by the garlic extract, which recorded 11.1, 8.7, and 6.67 scale insects/30 leaves in season 2017 and 10.33, 8.37, and 5.33 scale insects/30 leaves in season 2018 at different tested intervals. Results revealed that the combination of garlic + aloe extracts decreased the population to 11.23, 6.67, and 3.33 scale insects/30 leaves in season 2017 and 9.9, 6.33, and 3.0 scale insects/30 leaves in 2018 season after 1, 3, and 7 days, respectively.

Reduction percentages of the scale insect, *A. tubercularis*

The percentages of the scale insect reduction on mango leaves varied among the tested materials where it varied with the inspection intervals in season 2017. The most obvious reduction was calculated after the treatment with the botanical extracts as they indicated 56.45, 93.03 and 100% followed by that treated with Lambda insecticide, which recorded 39.4, 71.54, and 78.002% post the intervals of 1, 3, and 7 days, respectively. In season 2018, the same trend was noticed for the reduction of scale insects, *A. tubercularis*, on mango leaves treated with the botanical extracts, as they indicated percentages of 57.94, 95.05, and 100% at 1, 3, and 7 days, respectively, after treatments. Also, the plots treated with Lambda showed reduction in scale insects that reached to 47.34, 85.81, and 85.79% at the previous intervals, respectively. Results showed that aloe extract alone decreased the percentages of scale insects to 36.25, 48.21, and 68.64% in season 2017 and 37.52, 43.47, and 69.24% in season 2018 at the intervals of 1, 3, and 7 days, respectively, followed by the garlic extract, which were 33.41, 47.49, and 60.41% in 2017 and 37.27, 49.8, and 66.85% in 2018. Also, the combination of garlic + aloe extracts was superior in its lethal effect than the other combinations in seasons 2017 and 2018 as it

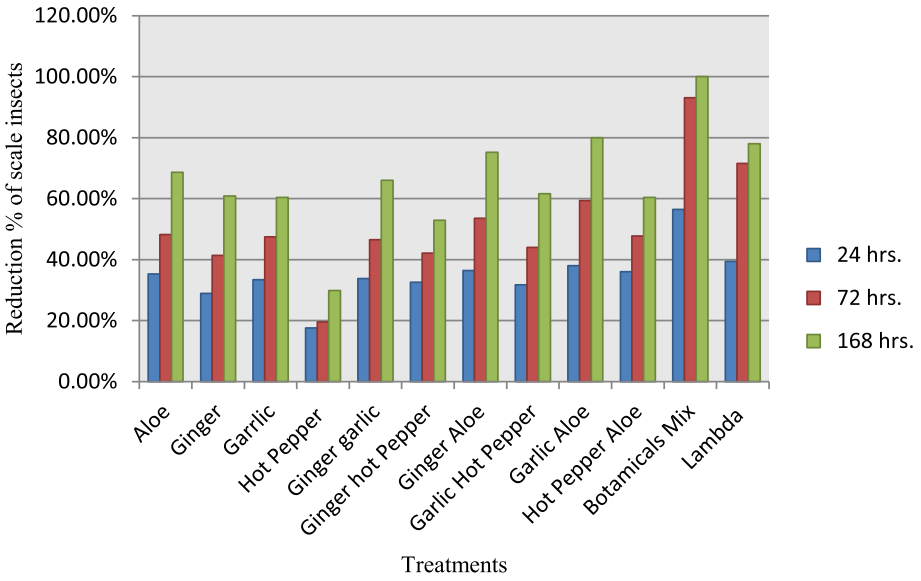

Fig. 1 Reduction percentage of mango scale insect, *Aulacaspis tubercularis*, after different treatments by plant extracts in season of 2017

decreased the scale insects ratio to 37.98, 59.35, and 80.002% and 39.28, 61.61, and 81.16% after 1, 3, and 7 days, respectively (Figs. 1 and 2).

Arutselvi et al. (2012) tested *A. vera* as a natural product on thrips and reported that *A. vera* showed a lethal effect on that insect. Teklay et al. (2012) assessed the efficacy of certain plants including *A. vera* and garlic against different insects and reported that *A. vera* extract was more effective in repelling than killing insects because of its bitter taste. Garlic bulbs extract had an insecticidal effect referred to its content of salphone hydroxyl ion, which penetrates the barrier of the insect blood brain acting as a poison to the insect (Douiri and Boughdad 2013). Many papers worked on different plant sources for pest control safely, as those of Wang 2015 who reported that ginger essential oil and rhizomes had a bio activity on agricultural stored product insects. Also, Okonkwo and Ohaeri (2013) tested *Capsicum annum* and *Zingiber officinale* on brown plant hopper and found that those plants had insecticidal properties against treated insects. Also, many trials using natural plants were conducted to control scale insects and mealy bugs like those of Ibrahim et al. (2001); Hollingsworth (2005); Alice (2008); Dubey and Srivastavab (2008); Cloy et al. (2009); and Amany et al. (2011) who tried to fight scales on citrus trees with natural products.

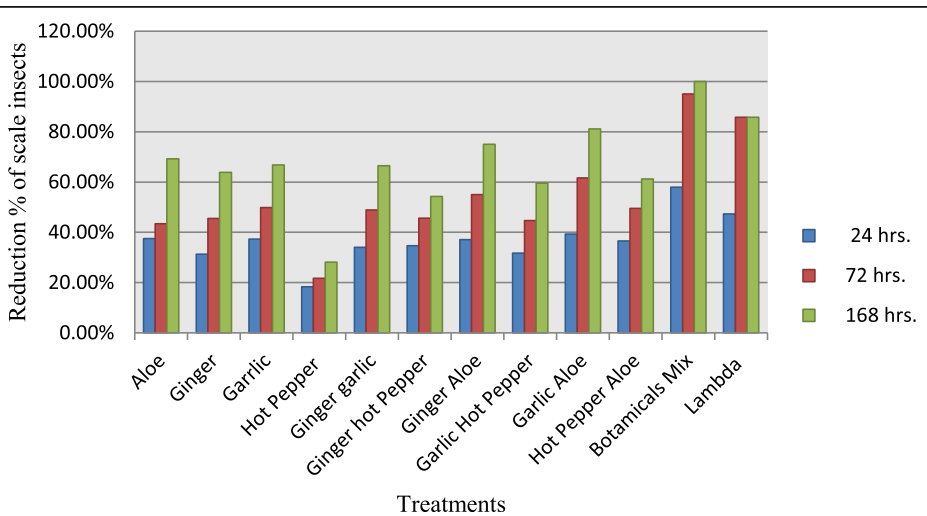

Fig. 2 Reduction percentage of mango scale insect, *Aulacaspis tubercularis*, after different treatments by plant extracts in season of 2018

Conclusion

Botanical extracts of aloe, ginger, garlic, and hot pepper had potentials to control scale insects on mango trees as those plants are available locally and can be prepared easily. The safe use of such extracts can be alternative to the chemical pesticides saving farmer efforts, money, and time facing and controlling of such pests.

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Authors' contributions
The authors were cooperating in all the experiments, statistical analysis of the data, and reading and approval of the final manuscript.

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The data and materials of this study have been presented in the manuscript.

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Not applicable

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Competing interests
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