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Evaluation of the aphicidal activity of *Salvia microphylla* (Lamiaceae) aqueous extracts against *Aphis pomi* (Aphididae)

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Abstract: The aphid *Aphis pomi* represents an important pest of apples. The use of botanical extracts may be a safe and effective way to control this pest. In this context, we studied the aphicidal and repellent effects of aqueous extracts of *Salvia microphylla* against *A. pomi*. Five concentrations were tested on two main aphid parameters: mortality rate and percentage of repellency. The results showed that concentrations of 10% recorded the highest mortality rate (73.33%) and percentage of repellency (62.59%). After further field investigations, the use of *S. microphylla* may constitute a component of the integrated management of aphids.

Keywords: repulsive effect, apple aphid, corrected mortality rate, extract concentrations, bioinsecticides

1. Introduction

There will be an estimated 9 billion people on the planet by the year 2050, which will increase the demands on agriculture [1]. However, many biotic factors, including insect pests, cause significant losses to crops each year. Among these insects, aphids influence plant production either directly, by sap sucking, or indirectly, through virus transmission. Aphids have a very high rate of multiplication due to parthenogenesis and viviparity, and therefore their attacks frequently result in total crop damage [2]. During the last decades, pesticides constitute the main tool to control aphid populations. Among the most commonly used chemicals, pesticides have greatly benefited humankind by increasing food production and promoting nutrition [3]. Without the use of pesticides, an important portion of agricultural production in developing countries would be obliterated by pests, according to the Food and Agricultural Organization [4]. However, in certain cases, they pose serious threats to the environment, animals, and humans [5].

In recent years, there has been a growing apprehension among both producers and consumers due to the excessive and unscientific utilization of pesticides [6]. This concern centres on their residues and the potential health consequences such as nerve disorders, skin and eye irritation, and the emergence of long-term chronic ailments such as cancer [7]. Additionally, the persistent application of synthetic pesticides available in the market has led to the emergence of significant levels of resistance in numerous insect pests [8]. This resistance phenomenon now affects over 550 species, rendering most existing insecticide categories ineffective and creating a pressing need for innovative insecticide targets [9].

Thus, the growing concerns and regulations surrounding the utilization of various pesticides because of their detrimental impacts and toxicity have increasingly encouraged the exploration of botanical insecticides as an alternative means of managing insect pests [8]. Consequently, numerous researchers from both the industrial and academic sectors are actively engaged in the quest for valuable compounds derived from plants to serve as novel, eco-friendly insecticides [9].

Biopesticides encompass a category of naturally existing protective agents, typically characterized by their gradual onset of action, and they are generally considered safer for humans and have fewer long-lasting effects on the environment when compared to traditional pesticides [10]. In addition, plant-derived insecticides are associated with a range of merits such as sustainability [11, 12]. Encouraging networking and strong connections within the farmer community, small and medium-sized enterprises, and the industry will further stimulate the biopesticide market [13].

It is clear that plants are highly desirable for the development of novel botanical pesticides for the control of insect pest infestations; however, only a small fraction of the over 250,000 species of plants found on Earth have been adequately studied for this purpose [11].

Thus, the main objective of the present study is to assess the aphicidal and repellent effects of aqueous extracts of *Salvia microphylla* (Kunth) against *Aphis pomi* (DeGeer) under laboratory conditions, as the insecticidal activities of this plant have not been reported against aphid species to date.

2. Materials and methods

2.1 Used insect and plant solutions

The plant material used in this experiment consists of uninfected leaves taken from apple (*Malus domestica* Borkh., cv. Golden Delicious) in addition to the aerial part of *S. microphylla*. *Salvia* is the major genus of Lamiaceae and includes members whose secondary metabolites, such as terpenoids and flavonoids, have therapeutic activities [14]. *S. microphylla*, native to Central America, is a scarlet-flowered ornamental plant [15].

To obtain aqueous extracts, the infusion method was used. Then five concentrations (1, 3, 5, 7, and 10 %) were prepared.

The animal material, however, was made up of the apple aphid *A. pomi* individuals. This pest, commonly referred to as the "green apple aphid", is a major infestation of *Malus spp.* trees grown in and around the Pacific Northwest [16].

2.2 Toxicity test

A total of 18 Petri dishes were prepared in triplicates for each solution.

Apple leaves were dipped in each concentration for a few seconds. Then the treated leaves were kept in the Petri dish with ten apple aphids in each replicate. Mortality was observed after 24 hours. The percentage mortality was corrected using Abbott's formula [17]:

$$\text{Corrected mortality rate} = [(\text{Tmp} - \text{Cmp})/(100 - \text{Cmp})] \times 100,$$

where: *Tmp*: mortality percentage on the treated leaf; *Cmp*: mortality percentage on the control (dipped in distilled water).

2.3 Repellency test

For each replicate (Petri dish), two leaves free from aphids were used. Then a leaf was introduced for a few seconds in the treatment solution. Leaves introduced in the treatment were placed on one side and the control on the other side. Ten apple aphids were placed in the middle of each dish. The procedure was replicated three times for each of the five examined solutions. After 24 hours, the number of aphids in each side was recorded.

Percentage of repellency was calculated according to the following equation:

$$\text{PR} = [(\text{NC} - \text{NT}) / (\text{NC} + \text{NT})] \times 100 \text{ [18]},$$

knowing that NC is the number of apple aphids attracted to the control, and NT is the number of apple aphids attracted to the treated leave.

2.4 Statistical analysis

The comparison of aphid mortality averages on each treatment was carried out by ANOVA one-way analysis and Student–Newman–Keuls test, using SPSS software. In addition, a *Probit* analysis was performed using the same software to determine Lethal Concentration (LC) 50 of the plant extract.

3. Results and discussions

3.1 Toxicity test

The statistical analysis indicated significant differences in insect mortality rates between the different solutions. The mortality rate of aphids was low for treatments 1, 3, and 5% (≤ 30%), while the mortality exceeded 50% for treatments 7 and 10% (*Table 1*). The LC 50 value of the studied extract was 7.09%.

Table 1. Corrected mortality percentages of apple aphids on different aqueous extracts of *S. microphylla*

Extract concentrations	**Corrected mortality percentages after 24 hrs (Mean ± Standard error)**
1%	3.33 ± 3.33 a
3%	20.00 ± 5.77 b
5%	30.00 ± 7.77 c
7%	50.83 ± 5.77 c
10%	73.33 ± 3.33 d
Significance	0.000 *

Note: * significant at P < 0.05.

Similarly, Balog et al. [19] revealed that all extracts from five tested plant species with 6% concentrations had significant effects on apple aphid, and the mortality was high compared with control. Moreover, other investigations showed potential insecticidal activities of aqueous extracts against different aphid pests, including damas (*Conocarpus lancifolius*) against sorghum aphid, *Rhopalosiphum maidis* [20], *Aloe zebrina*, *Melia azedarach*, and *Capsicum annum* against cotton aphid, *A. gossypii* [21], *Thymus algeriensis* [22], and *Artemisia campestris* against black bean aphid, *A. fabae* [23] and common bean (*Phaseolus vulgaris*) against cabbage aphid, and *Brevicoryne brassicae* [24] and neem (*Azadirachta indica*) was found to reduce aphid infestations similarly to the tested chemical insecticide [25].

On the other hand, some previous studies confirmed the insecticidal potentialities of many plant species belonging to *Salvia* such as *S. microphylla* against the fall armyworm *Spodoptera frugiperda* [26], *S. officinalis* against the woolly apple aphid *Eriosoma lanigerum* [27], and the methanolic extracts of 21 *Salvia* species and/or their cultivars against the moth *Spodoptera littoralis* [28].

In the present study, it was noticed that the mortality rates increased with the dose. Additionally, Benoufella-Kitous et al. [29] found that the insecticidal effect of sage *S. officinalis* against *A. fabae* seems to depend on the dose.

It is suggested that the aphicidal activity expressed in our case is due to the presence of some secondary metabolites in plant extracts. Secondary metabolites seriously affect aphid behaviour, physiology, and metabolism [30]. For instance, a prior study investigating the insecticidal properties of Amaryllidaceae alkaloids confirmed that N-Allylnorgalanthamine effectively inhibited acetylcholinesterase in *A. citricola* [31]. Besides, saponins are known for their toxicity to detrimental insects, which includes actions such as deterring feeding, disrupting the molting process, regulating growth, and causing mortality [32]. Furthermore, *in vitro* bioassays demonstrated that among the native flavonoids, quercetin and isorhamnetin exhibited significant inhibitory effects on aphid reproduction [33].

3.2 Repellency test

Results presented in *Figure 1* revealed that the extract concentration of 10% of *S. microphylla* was the most repellent to apple aphids (PR = 62.59%), followed by the concentration of 7% (PR = 60.48%).

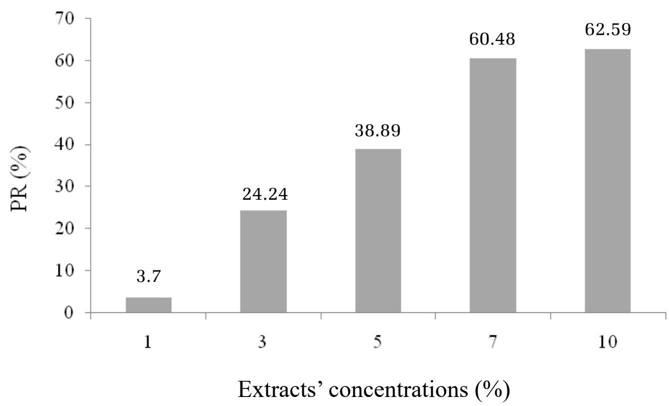

Figure 1. Repellency of the aqueous extracts of *S. microphylla* against the apple aphids

Likewise, Assis et al. [34] found that the garlic extract presented a repellent effect on aphids. Furthermore, the results of Mina [35] indicated that the aqueous extract of marigold (*Tagetes erecta*) flower showed effective repellency against *A. gossypii* and *Myzus persicae* populations. Moreover, watery extracts of five medicinal species demonstrated significant repellency against wingless rose aphid

Macrosiphum rosae in comparison to control [36]. Further, the neem seed aqueous extract recorded a medium repellence index for the concentration of 10% [37].

The selection of host plants by aphids is influenced by a range of physiological and chemical cues but is primarily influenced by gustatory signals observed during the stylet's penetration into the plant's peripheral tissues [38]. It seems that the tested plants deploy some of their components as repulsive to aphids, and their effects change according to the concentrations in the solutions. Thus, triticale hybrids with higher phenolic concentrations were less appealing to cereal aphids compared to non-transgenic varieties [39].

4. Conclusions

The potential insecticidal and repulsive effects of aqueous extracts of *S. microphylla* on *A. pomi* were screened *in vitro*. The findings demonstrated that extracts at higher concentrations had significant aphicidal and repellent properties. As a result, using these extracts could offer suitable alternatives to chemical pesticides for aphid management. It is strongly advised to carry out field bioassays to confirm the results obtained.

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