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Aphid behaviour-modifying activity of essential oils from Lamiaceae and Apiaceae

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ABSTRACT

The effect of essential oils extracted from several plants of Apiaceae caraway *Carum carvi* L., giant hogweed *Heracleum mantegazzianum* Sommier & Levier, anise *Pimpinella anisum* L. and Lamiaceae marjoram *Origanum majorana* L., oregano *Origanum vulgare* L., rosemary *Rosmarinus officinalis* L., thyme *Thymus vulgaris* L., and summer savory *Satureja hortensis* L., on the settling behaviour of the pea aphid *Acyrthosiphon pisum* Harris and peach potato aphid *Myzus persicae* (Sulz.) was evaluated. Essential oils from caraway, oregano, summer savory, and rosemary had the strongest deterrent effect on *A. pisum*, while the oils from thyme and anise were the strongest deterrents for *M. persicae*.

KEY WORDS: aphid behaviour, essential oils, deterrents

INTRODUCTION

Aromatic plants, including Apiaceae and Lamiaceae, have been used as spices and flavouring agents due to their aromatic qualities, from prehistoric times to the present day. The strong odour emitted by these plants comes from essential oils that are formed as secondary metabolites. Essential oils of these plants are also known for their antiseptic (i.e., bactericidal, virucidal and fungicidal), and

medicinal (e.g., antioxidant and anticancer) properties (Dorman & Deans, 2000; Bakkali *et al*., 2008; Zu *et al*., 2010; Hussain *et al*., 2011). In fact, many aromatic plants and their essential oils have been used in traditional medicine since ancient times (Lang & Buchbauer, 2012). Moreover, aromatic plants and essential oils have also been applied for the protection of food, plants, and animals against pests and diseases (Bakkali *et al*., 2008). Nowadays, essential oils and their components are extensively studied to assess their repellent, deterrent and insecticidal properties in search for environmentally friendly insect control agents (Isman, 2006; Adorjan & Buchbauer, 2010). Essential oils or products based on oils are mostly nontoxic to mammals, birds, and fish (Koul *et al*., 2008).

The aim of the present study was to evaluate the effect of essential oils extracted from several Apiaceae plants (dried seeds of caraway *Carum carvi* L., giant hogweed *Heracleum mantegazzianum* Sommier & Levier, and fruit of anise *Pimpinella anisum* L.) and Lamiaceae (fresh green parts of marjoram *Origanum majorana* L., oregano *Origanum vulgare* L., rosemary *Rosmarinus officinalis* L., thyme *Thymus vulgaris* L., and dried summer savory *Satureja hortensis* L.), on the settling behaviour of the pea aphid *Acyrthosiphon pisum* Harris and the peach potato aphid *Myzus persicae* (Sulz.).

MATERIAL AND METHODS

The plant material for essential oils preparation was obtained from the Svedeponic Company (Kraśnicza Wola) and from Kawon-Hurt (Krajewice). Essential oils were obtained from plant material by hydrodistillation on Deryng apparatus, as described in Szumny *et al*., (2010). In brief, approximately 200 g of fresh or 50 g of dried plant material was placed in a 2 L round flask together with 900 mL of distilled water. The sample flask was heated for 2 h after the boiling point was reached. The vapours were condensed by means of cold refrigerant. After 120 min of distillation, depending on plant material, from 0.25 to 2.5 mL of essential oil containing the volatile compounds was collected in a 2.5 mL vial and kept at -15^{o}C until the biological tests were performed.

The laboratory culture of *A. pisum* was maintained on peas *Pisum sativum* L. and a culture of *M. persicae* on napa cabbage *Brassica rapa* L. subsp. *pekinensis* L. Aphids and plants were reared in the laboratory at 20°C, 65% r.h. and L16:8D photoperiod. Young, 2-3 days old viviparous apterous females were selected for experiments. The plants used in the bioassays were 5-6 weeks old.

Aphid settling was assessed using the two-leaf choice-test: compounds were applied on one leaf, while the other leaf was coated with ethanol and acted as a control. The essential oils were applied as 0.1% solutions in 70% ethanol to the test leaves of napa cabbage that were detached from plants grown in the laboratory, as described earlier. For uniform distribution, the leaves were immersed in the

studied solutions for 20 seconds. Control leaves were immersed in 70% ethanol. To avoid the wilting of the leaves, their petioles were covered with cotton wool saturated with water. The moisture of the cotton wool was monitored and water was added, if necessary. Control and treated leaves were placed in the Petri dish and the test aphids were placed at an equal distance from either leaf. Aphids were offered the leaves 1 hour after the application of the studied solutions to allow for the evaporation of the solvent. Aphids that settled on each leaf were counted 1, 2, and 24 hours after having access to the leaves (8 replicates, 20 adult apterous aphids/replicate). Aphids that did not settle on any of the leaves were discarded from calculations. The results were statistically analysed using the Student t-test: the number of aphids on control leaves was compared to the number of aphids on the test leaf for each experiment separately. The relative index of deterrence (ID) was calculated using the formula according to Nawrot *et al.* (1982): ID=(C-T/C+T), where C denotes the number of aphids settled on a control leaf and T – the number of aphids settled on the essential oil-treated leaf. If aphids showed significant preference ($p<0.05$; Student t-test) to the leaf treated with the studied extract ($ID<0$), the studied substance was described as having **attractant** properties, whereas if aphids settled mainly on the control leaf ($ID>0$), the studied substance was stated a **deterrent**.

RESULTS AND DISCUSSION

All essential oils of Apiaceae and Lamiaceae that were examined in the present study modified aphid settling behaviour in a significant way. However, the quality, potency, and stability of the behavioural effect varied depending on aphid species-essential oil combination (Tab. 1, 2, Fig. 1).

The settling behaviour of *A. pisum* was distorted by all essential oils studied, except the giant hogweed oil. Of the Apiaceae essential oils, the caraway oil deterred aphid settling as soon as 1 hour after treatment and until 24 hours later, which was the end of the experiment ($ID_{1,2,24}=0.7$). The anise essential oil had also a deterrent effect but its potency decreased in the course of time ($ID_1=0.6$, $ID_{24}=0.2$). Of the Lamiaceae essential oils, the strongest and the longest lasting deterrent effect was generated by the oregano and summer savory oils. The respective indices of deterrence remained very high during the whole period of observation, i.e. for at least 24 hours (oregano: $ID_{24}=0.7$, savoury: $ID_{24}=0.8$). The rosemary oil values of ID were relatively high ($ID_1=0.5$, $ID_{24}=0.4$). The essential oils from marjoram and thyme showed deterrent properties for two hours after treatment, but their activity ceased in the course of time (Fig. 1).

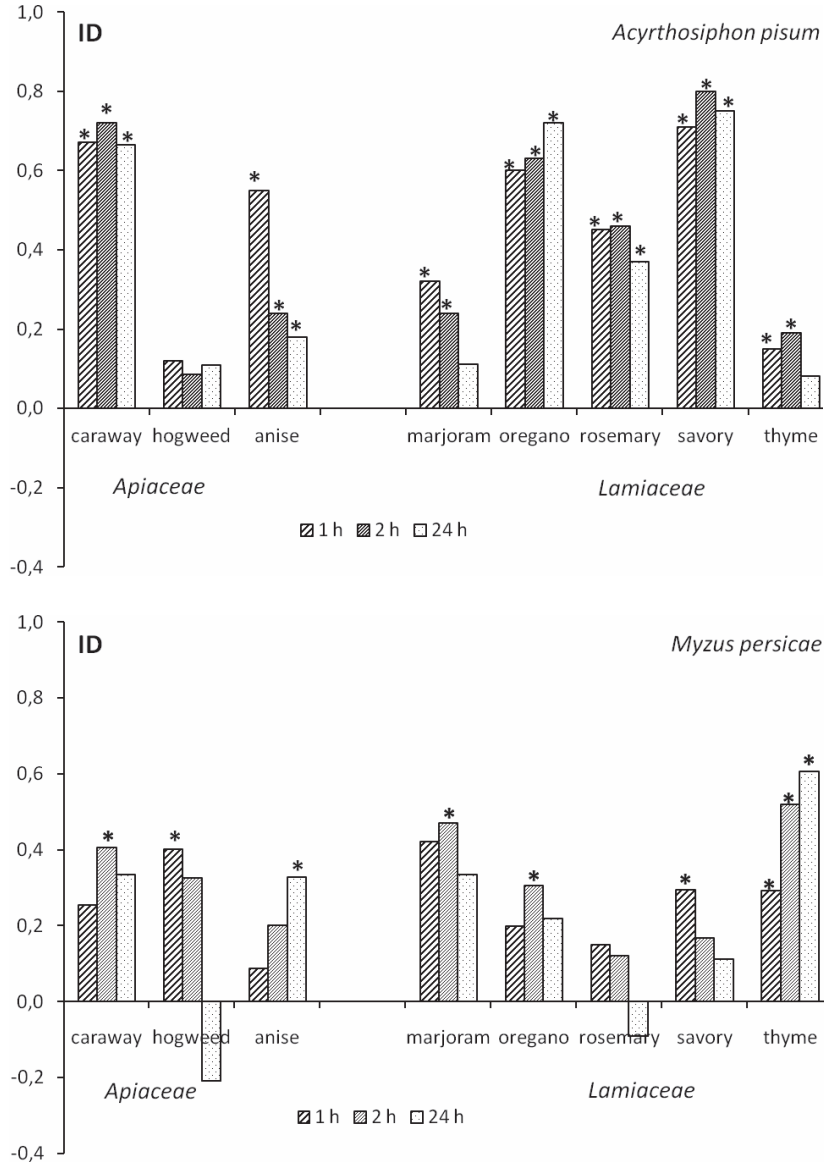

Figure 1. Relative index of deterrence (ID) in aphid settling choice-test after application of essential oils from Apiaceae and Lamiaceae. Asterisks indicate statistically significant difference between the number of aphids on treated and control leaves ($P<0.05$; Student t-test).

The essential oils examined in the present study had a varied deterrent effect on *M. persicae*. In the case of the Apiaceae essential oils, the deterrent activity was observed 2 hours after treatment, then it ceased (caraway and giant hogweed

oils) or 24 hours after treatment (anise oil, ID_{24}=0.3). Of the Lamiaceae essential oils, the rosemary oil did not prevent *M. persicae* from settling on plants and the marjoram, oregano, and summer savoury oils had a weak and transitory deterrent effect. The thyme essential oil caused the avoidance of the treated leaves by the peach potato aphid. The potency of the deterrent effect increased over time (ID_1=0.3, ID_{24}=0.6).

The present behavioural study showed that *A. pisum* was more sensitive to different essential oils from Apiaceae and Lamiaceae than *M. persicae*. Generally, the pea aphid was deterred by the oils just after it gained access to the treated leaf. Usually, the negative aphid response was observed for as long as 24 hours. In contrast, the peach potato aphid's behaviour was affected by a few essential oils from both, the Apiaceae and Lamiaceae, and the deterrent effect was usually temporary. The difference in sensitivity to the essential oils studied between the pea aphid and the green peach aphid may be a result of their different adaptations to herbivory. *A. pisum* is oligophagous and its host plant range is restricted to plants of certain tribes of the Fabaceae family (Blackman & Eastop, 2007). Oligophagous aphids are usually attracted by the compounds characteristic of their host plants (Del Campo *et al*., 2003; Tosh *et al*., 2003). Therefore, chemicals that do not represent plants of their host range may appear neutral or deterrent to the pea aphid, which was the case in the present study. In a previous study, *A. pisum* refused to accept *Vicia faba* as its host plant when it was infiltrated with sinigrin, the chemical typical of Brassicaceae (Gabryś & Tjallingii, 2002). *M. persicae* is considered the most polyphagous aphid species with secondary hosts in over 40 different plant families (Blackman & Eastop, 2007). Polyphagous insects can express a broad range of enzymes that assist in the detoxification of numerous xenobiotics including secondary metabolites from plants (Francis *et al*., 2005). It has been documented that generalist aphids select rather for the nutritional value of their host plants while being relatively insensitive to allelochemicals (Powell *et al*., 2006). Such adaptations for polyphagy may explain why the peach potato aphid was rather unresponsive to the essential oils examined in the present study.

Table 1. Deterrent effect of essential oils from Lamiaceae and Apiaceae on the peach potato aphid *Myzus persicae*. Numbers represent the mean number of aphids (n=8)(±SE) that settled on treated ('test') and control leaves monitored at 1, 2, and 24 hours after application. P: values of P according to Student t-test.

		Myzus persicae		
		1h	2h	24h
Apiaceae				
caraway	control	9.6 (±1.8)	10.4 (±1.4)	6.4 (±1.7)
	test	5.7 (±1.6)	4.4 (±1.4)	3.2 (±1.1)
	P	0.1270	0.0090	0.1513

		Myzus persicae		
		1h	2h	24h
Apiaceae				
hogweed	control	8.2 (±0.9)	6.1 (±0.9)	3.4 (±1.0)
	test	3.5 (±1.0)	3.1 (±1.4)	5.2 (±1.5)
	P	0.0033	0.0974	0.6362
anise	control	5.0 (±0.8)	6.0 (±0.9)	6.7 (±1.4)
	test	4.2 (±1.2)	4.0 (±1.6)	3.4 (±1.1)
	P	0.6242	0.1934	0.0491
Lamiaceae				
marjoram	control	5.9 (±1.6)	6.1 (±1.4)	2.8 (±0.5)
	test	2.4 (±0.7)	2.2 (±0.6)	1.4 (±0.6)
	P	0.0634	0.0282	0.1233
oregano	control	9.1 (±1.0)	7.7 (±0.5)	3.9 (±0.9)
	test	6.1 (±1.0)	4.1 (±0.8)	2.5 (±1.1)
	P	0.0557	0.0013	0.3365
rosemary	control	2.7 (±0.8)	1.4 (±0.6)	2.0 (±0.6)
	test	2.0 (±0.6)	1.1 (±0.3)	2.4 (±1.0)
	P	0.4637	0.7323	0.7551
savory	control	7.5 (±1.1)	6.6 (±1.4)	2.0 (±0.8)
	test	4.1 (±0.6)	4.7 (±0.9)	1.6 (±0.7)
	P	0.0190	0.2792	0.7222
thyme	control	8.4 (±1.0)	8.5 (±1.2)	11.0 (±1.2)
	test	4.6 (±0.9)	2.7 (±0.7)	2.7 (±0.7)
	P	0.0124	0.0014	0.0000

Table 2. Deterrent effect of essential oils from Lamiaceae and Apiaceae on the pea aphid *Acyrthosiphon pisum*. Numbers represent the mean number of aphids (n=8)(±SE) that settled on treated ('test') and control leaves as monitored at 1. 2. and 24 hours after application. P: values of P according to Student t-test.

plant essential oil		*Acyrthosiphon pisum*		
		1h	2h	24h
Apiaceae				
caraway	control	16.7(±0.7)	17.2(±0.8)	15.9(±1.2)
	test	3.3(±0.7)	2.8(±0.8)	3.2(±1.0)
	P	0.0002	0.0002	0.0002
hogweed	control	11.2(±1.3)	10.8(±1.2)	11.3(±1.2)
	test	8.8(±1.3)	9.1(±1.2)	9.1(±1.3)
	P	0.2395	0.0676	0.6197

plant essential oil		*Acyrthosiphon pisum*		
		1h	2h	24h
Apiaceae				
anise	control	15.5(±0.8)	12.4(±0.6)	11.8(±0.8)
	test	4.5(±0.8)	7.6(±0.6)	8.2(±0.8)
	P	0.0002	0.0003	0.0089
Lamiaceae				
marjoram	control	13.2(±1.1)	12.4(±0.6)	11.1(±0.8)
	test	6.8(±1.1)	7.6(±0.6)	8.9(±0.8)
	P	0.0016	0.0005	0.0907
oregano	control	16.0(±0.9)	16.3(±0.8)	17.2(±0.5)
	test	4.0(±0.9)	3.7(±0.8)	2.8(±0.5)
	P	0.0002	0.0002	0.0002
rosemary	control	15.4(±0.7)	14.6(±0.8)	13.7(±0.8)
	test	5.5(±0.7)	5.4(±0.8)	6.3(±0.8)
	P	0.0002	0.0002	0.0002
savory	control	17.1(±0.5)	18.0(±0.4)	17.5(±0.3)
	test	2.9(±0.5)	2.0(±0.4)	2.5(±0.3)
	P	0.0002	0.0002	0.0001
thyme	control	11.5(±0.9)	11.9(±0.6)	10.8(±0.5)
	test	8.5(±0.9)	8.1(±0.6)	9.2(±0.5)
	P	0.0184	0.0026	0.0509

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Wpływ olejków eterycznych roślin z rodzin *Lamiaceae* i *Apiaceae* na zachowanie mszyc

STRESZCZENIE

W pracy oceniono wpływ olejków eterycznych uzyskanych z kilku roślin z rodziny *Apiaceae* (kminek *Carum carvi* L., barszcz Mantegazziego *Heracleum mantegazzianum* Sommier & Levier, anyż *Pimpinella anisum* L.) i *Lamiaceae* (majeranek *Origanum majorana* L., oregano *Origanum vulgare* L., rozmaryn *Rosmarinus officinalis* L., tymianek *Thymus vulgaris* L. i cząber *Satureja hortensis* L.) na zasiedlanie roślin przez mszycę grochową *Acyrthosiphon pisum* Harris i mszycę brzoskwiniową *Myzus persicae* (Sulz.). Olejki eteryczne z kminku, oregano, cząbru i rozmarynu miały najsilniejszy wpływ odstraszający na *A. pisum*, natomiast oleje z tymianku i anyżu były najsilniej odstraszające dla *M. persicae*.