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Research Article

Insecticidal activity of selected essential oils

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The present work aimed to determine the insecticidal effects of three selected essential oils (EOs) of *Pogostemon cablin*, *Thymus vulgaris*, and *Citrus aurantifolia* against three insect species *Melolontha melolontha*, *Halyomorpha halys*, and *Pyrrhocoris apterus*. EO *P. cablin* showed very strong insecticidal effects against *M. melolontha* when it inhibited the insect species by more than 50% at concentrations of 50–6.25%. Against *H. halys* it also showed strong insecticidal effects at concentrations of 50–12.5%. The insecticidal activity against *P. apterus* was significantly lower than against the other insect species tested. The insecticidal activity of at least 50% was only observed at a concentration of 50%. EO *T. vulgaris* showed very strong insecticidal activity against *M. melolontha* which reached at least 50% at concentrations of 50–6.25%. When tested for its effect against *H. halys*, high efficacy was observed at concentrations of 50–12.5%. Against *P. apterus*, the efficacy was the lowest as 50% insecticidal activity was observed only at concentrations of 50% and 25%. EO *C. aurantifolia* showed only weak insecticidal activity against *M. melolontha* where the highest concentration tested killed 50% of the individuals. The very weak insecticidal activity was observed against *H. halys* where none of the tested concentrations had efficacy higher than 50%. The most pronounced effect of EO *C. aurantifolia* was observed against *P. apterus* where concentrations of 50% and 25% killed more than 50% of individuals. All tested EOs showed insecticidal effects and could potentially represent a natural alternative to synthetic insecticides.

Keywords: insecticidal activity, *Pogostemon cablin*, *Thymus vulgaris*, *Citrus aurantifolia*

1 Introduction

The use of botanical insecticides has also been promoted in recent years by the European Union (Andersson et al., 2018) because they have a very low likelihood of developing insect resistance and generally have several specific modes of action (Pavela, 2008). Essential oils of plant origin are volatile and lipophilic mixtures of small molecules that have recently been classified by the European Food Safety Authority (EFSA) as "low-risk active substances" (LARS) and potential botanical insecticides (Ikbal & Pavela, 2019).

Melolontha melolontha is considered to be an important pest in agriculture, horticulture, and forest nurseries. *M. melolontha* larvae feed underground on the roots of a wide range of plants and adults feed on the leaves of forest trees as well as fruit trees, causing damage to trees and crops (Ana-Cristina et al., 2015).

Halyomorpha halys are one of the important pests in agriculture. It attacks orchards where it feeds on fruit and also attacks various vegetables, soybeans, and many other crops. The problem is that insecticides are not sufficiently effective against this pest (Kuhar & Kamminga, 2017).

Pyrrhocoris apterus is not an agricultural pest but its availability and abundance make it a suitable model organism for a wide range of research (Lopatina et al., 2014).

The present work aimed to determine the insecticidal effects of three selected essential oils of *Pogostemon cablin*, *Thymus vulgaris*, and *Citrus aurantifolia* against three insect species *Melolontha melolontha*, *Halyomorpha halys*, and *Pyrrhocoris apterus*.

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2 Material and methods

2.1 Essential oils

Pogostemon cablin, *Thymus vulgaris*, and *Citrus aurantifolia* essential oils were purchased from Hanus s.r.o (Slovakia). They were kept in the dark at 4 °C during the experiment.

2.2 Model insect species

The tested insect species *Melolontha melolontha*, *Halyomorpha halys*, and *Pyrrhocoris apterus* were captured in the area of Nitra, Slovakia. Individuals of each species were placed in bottles with air vents and transported to the laboratory.

2.3 Insecticidal activity

The insecticidal activity of the tested essential oils was evaluated on the model organisms *Melolontha melolontha*, *Halyomorpha halys*, and *Pyrrhocoris apterus*. Thirty individuals of the respective insect species were placed in the Petri dish. A circle of sterile filter paper was placed in the lid of a 60 mm diameter petri dish. A circle of sterile filter paper was glued to the lid. Concentrations (50, 25, 12.5, 6.25, and 3.125%) were prepared by diluting tested essential oils with 0.1% polysorbate. Subsequently, 100 µl of a suitable concentration of tested essential oils was applied to sterile filter paper. The dishes were sealed around the perimeter with parafilm and left at room temperature for 24 hours. In the control group, 100 µl of 0.1% polysorbate was used. After 24 hours, the number of live and dead individuals was evaluated. The experiment was carried out in triplicate.

3 Results and discussion

P. cablin showed very strong insecticidal effects against *M. melolontha* when it inhibited the insect species by more than 50% at concentrations of 50–6.25% (Table 1). At the lowest concentration of 3.125%, the insecticidal activity was 30%. In the control group, all individuals survived.

Against *H. halys*, *P. cablin* also showed strong insecticidal activity at concentrations of 50–12.5% where insecticidal activity was more than 50% (Table 2). At a concentration of 6.25%, the insecticidal activity was also quite high at 40%. At the lowest concentration tested the activity was 10%. In the control group, all tested individuals survived.

The insecticidal activity against *P. apterus* was significantly lower than against the other insect species tested the insecticidal activity of at least 50% was only observed at a concentration of 50% (Table 3). With decreasing concentration, the insecticidal effect also decreased. At a concentration of 25%, the insecticidal activity was 40%, at 12.5% the insecticidal activity was 20% and at lower concentrations, the insecticidal activity was 0% as in the control group.

A study by Albuquerque et al. (2013) detected the insecticidal effect of *P. cablin* essential oil against urban ant species. A study by Machial et al. (2010) detected the insecticidal efficacy of *P. cablin* against termites,

Table 1 Insecticidal activity of *P. cablin* against *M. melolontha*

Concentration (%)	Number of living individuals	Number of dead individuals	Insecticidal activity (%)
50	3	27	90
25	9	21	70
12.5	12	18	60
6.25	15	15	50
3.125	21	9	30
Control group	30	0	0

Table 2 Insecticidal activity of *P. cablin* against *H. halys*

Concentration (%)	Number of living individuals	Number of dead individuals	Insecticidal activity (%)
50	0	30	100
25	6	24	80
12.5	12	18	60
6.25	18	12	40
3.125	27	3	10
Control group	30	0	0

caterpillars, and flies. Against *Musca domestica*, the study by Pavela (2008) recorded a strong insecticidal effect of *P. cablin* essential oil. These findings of the authors confirm the insecticidal properties of *P. cablin* essential oil detected by us. Studies on the insecticidal activity of *P. cablin* have not been carried out on the species tested by us.

The essential oil of *T. vulgaris* showed very strong insecticidal activity against *M. melolontha*, reaching at least 50% at concentrations of 50–6.25% (Table 4). The lowest concentration tested showed an insecticidal efficacy of up to 40%. In the control group, all individuals survived.

In testing its effect against *H. halys*, high efficacy was observed at concentrations of 50–12.5% (Table 5). At a concentration of 6.25%, an insecticidal activity of 20% was detected. At the lowest concentration, all individuals survived as in the control group.

Table 3 Insecticidal activity of *P. cablin* against *P. apterus*

Concentration (%)	Number of living individuals	Number of dead individuals	Insecticidal activity (%)
50	9	21	70
25	18	12	40
12.5	24	6	20
6.25	30	0	0
3.125	30	0	0
Control group	30	0	0

Table 4 Insecticidal activity of *T. vulgaris* against *M. melolontha*

Concentration (%)	Number of living individuals	Number of dead individuals	Insecticidal activity (%)
50	0	30	100
25	0	30	100
12.5	6	24	80
6.25	12	18	60
3.125	18	12	40
Control group	30	0	0

Table 5 Insecticidal activity of *T. vulgaris* against *H. halys*

Concentration (%)	Number of living individuals	Number of dead individuals	Insecticidal activity (%)
50	0	30	100
25	6	24	80
12.5	15	15	50
6.25	24	6	20
3.125	30	0	0
Control group	30	0	0

Table 6 Insecticidal activity of *T. vulgaris* against *P. apterus*

Concentration (%)	Number of living individuals	Number of dead individuals	Insecticidal activity (%)
50	0	30	100
25	12	18	60
12.5	21	9	30
6.25	24	6	20
3.125	27	3	10
Control group	30	0	0

Against *P. apterus*, the efficacy was the lowest as 50% insecticidal activity was only observed at concentrations of 50% and 25% (Table 6). At a concentration of 12.5%, the insecticidal activity was 30% and at the lowest concentration only 10%. In the control group, all individuals survived.

Isman et al. (2001) detected good insecticidal efficacy of *T. vulgaris* against *Spodoptera litura* in their study. Ríos et al. (2017) in their work tested 9 types of essential oils for larvicidal activity against *Aedes aegypti* with the highest efficacy detected for *T. vulgaris*. Sajfrtova et al. (2013) in their work recorded good insecticidal properties of *T. vulgaris* against *Spodoptera littoralis*, *Musca domestica*, *Culex quinquefasciatus* and *Leptinotarsa decemlineata*. These observations of the authors are in agreement with our results.

Essential oil of *C. aurantifolia* showed only weak insecticidal activity against *M. melolontha* where the highest concentration tested killed 50% of the individuals (Table 7). A concentration of 25% showed an insecticidal activity of 40%. At a concentration of 12.5%, an efficacy of 20% was observed, while a concentration of 6.25% had an insecticidal activity of 10%. At the lowest concentration, all individuals survived as in the control group, and hence insecticidal activity was 0%.

The very poor insecticidal activity was observed against *H. halys*, with none of the tested concentrations, having an efficacy greater than 50% (Table 8). The highest concentration tested had an insecticidal activity of 40%. The 25% concentration showed an insecticidal activity of 20% and the 12.5% concentration had an insecticidal activity of 10%. At lower concentrations, the insecticidal effect was 0% as in the control group.

The most pronounced effect of essential oil *C. aurantifolia* was observed against *P. apterus* where concentrations of 50% and 25% killed more than 50% of individuals (Table 9). The 12.5% concentration had insecticidal activity at 20% and the 10% concentration killed 10% of

Table 7 Insecticidal activity of *C. aurantifolia* against *M. melolontha*

Concentration (%)	Number of living individuals	Number of dead individuals	Insecticidal activity (%)
50	15	15	50
25	18	12	40
12.5	24	6	20
6.25	27	3	10
3.125	30	0	0
Control group	30	0	0

Table 8 Insecticidal activity of *C. aurantifolia* against *H. halys*

Concentration (%)	Number of living individuals	Number of dead individuals	Insecticidal activity (%)
50	18	12	40
25	24	6	20
12.5	27	3	10
6.25	30	0	0
3.125	30	0	0
Control group	30	0	0

Table 9 Insecticidal activity of *C. aurantifolia* against *P. apterus*

Concentration (%)	Number of living individuals	Number of dead individuals	Insecticidal activity (%)
50	9	21	90
25	15	25	50
12.5	24	6	20
6.25	27	3	10
3.125	30	0	0
Control group	30	0	0

the individuals. In the control group and at the lowest concentration, all individuals survived, and hence the insecticidal activity was 0%.

Siskos et al. (2007) in their work detected the insecticidal activity of *C. aurantium* against *Bactrocera oleae*. Siskos et al. (2009) in their work reported the efficacy of *C. aurantium* essential oil against *Ceratitis capitata*, they concluded that this essential oil has the potential to be used as a natural insecticide against agricultural pests. Adusei-Mensah et al. (2014) detected significant insecticidal efficacy of *C. aurantium* essential oil against *Camponotus nearcticus*. The authors' findings are consistent with our findings that *C. aurantium* essential oil has the potential to be used as an insecticidal agent in the future.

4 Conclusions

The results of our work show that all tested essential oils showed insecticidal effects and could potentially represent a natural alternative to synthetic insecticides. *P. cablin* and *T. vulgaris* showed more pronounced insecticidal effects than *C. aurantium*. In the future, it will be useful to complement our analyses with further evidence and concentrations.

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