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Attractiveness of *Matthiola incana* (L.) R. Br. powder and its volatile compounds to *Lasioderma serricorne*

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Abstract

As a worldwide insect pest in stored tobacco, *Lasioderma serricorne* is harmful during the entire tobacco storage and processing. To effectively monitor the occurrence and damage of *L. serricorne*, 10 plant materials with different characteristic odours were used to test the attractiveness to *L. serricorne* adults. The results showed that the attractiveness of *Matthiola incana* (L.) R. Br. powder was the highest, and the selection index was more than 75%. The static headspace gas chromatography was used to analyze the volatile compounds from *M. incana* powder, and 46 volatile compounds were tested on *L. serricorne* adults. The results indicated that octanal exhibited the highest attractiveness to *L. serricorne*, with a 70.8% selection index at 11.32 nL/cm^2. Both *β*-Ionone and 2, 3-hexadione also had good attractiveness, and their selection indices were more than 60% at 11.32 nL/cm^2. Thus, *M. incana* and its volatile compounds could be used in tobacco storage to monitor the occurrence and damage of *L. serricorne*.

Keywords: *Matthiola incana* (L.) R. Br., Volatile compounds, *Lasioderma serricorne*, Selection index

Introduction

Lasioderma serricorne (Fabricius) (Coleoptera: Anobiidae) is a significant storage insect pest worldwide, which not only damages tobacco, but also infests other stored products, such as herbs, spices, and cereal grains (Mahroof et al., 2007; Ebadollahi et al., 2010; Yu et al., 2019). At present, the control of *L. serricorne* mainly relies on phosphine fumigation (Weizheng et al., 2014). However, the excessive use of this chemical fumigant causes many negative effects, such as high insecticide residue and insect resistance to the insecticide (Kim et al., 2003). Therefore, development of environmentally friendly pest control methods is critically important (Isman et al., 2006; Junyu et al., 2019).

Plant volatiles play important roles in insect host searching and oviposition site selection, and it has been reported that some plant volatiles are attractive to insects (Landolt et al., 1997). More and more studies focused on using plant attractants have been reported. For example, the attractiveness of mulberry leaf tea and chili to *L. serricorne* have been reported (Phoonan et al., 2014). In addition, to monitor the occurrence of pests, plant volatiles can be applied with sex pheromones to trap pests, which can enhance the trapping efficiency of the sex pheromone (Cox et al., 2004; Phoonan et al., 2014; Xintian, 2010). There is a need to identify more attractants for enhancing insect control strategies, and there is a lack of attractive effect analysis of plant volatiles.

In this study, we investigated the olfactory responses of *L. serricorne* to 10 plant materials and analyzed the volatile compounds extracted from the *M. incana.* Our results could pave a foundation for developing plant-based attractants to *L. serricorne*.

Materials and methods

Insect

The cigarette beetles collected from the tobacco storage laboratory, Zhengzhou Tobacco Research Institute of CNTC, Zhengzhou, China, and reared for several generations. The laboratory colony was reared at 28 ± 2°C and 70% ± 5% RH under dark conditions on whole oatmeal containing 30% wheat flour by weight. The adults used in the experiment were collected one week after emergence. The collected adults were starved for 24 h before the olfactory behavior test.

Plant materials

The leaves of following 10 plant materials were used for this study: *M. incana*, *Osmanthus fragrans* (Thunb.) Lour., *Nicotiana tabacum* L. (flue-cured tobacco), *Rubus corchorifolius* L. f., Camellia sinensis var. Assamica (Pu-erh tea), *Rosa rugosa* Thunb., *Rhododendron simsii* Planch (yellow), *Rubus idaeus* L., *Rosa multiflora* Thunb., *Aspidistra elatior* Blume and *Indocalamus* leaves. The leaves of these materials were crushed by using a high-speed grinder (FW100, Tianjin Tester Instrument Co. Ltd., Tianjin, China). The powder collected after this grinding was used for the attractant test.

Chemicals

The following chemicals were used in this study: 2-Methylbutyraldehyde (98%), 5-Methyl furfural (98%), 2-Methyltetrahydrofuran-3-one (98%), Furfuryl alcohol (98%), 2-Methylpyrazine (98%), 2,5-Dimethylpyrazine (98%), 2-Ethylfuran (98%), 2-Pentylfuran (98%), Benzaldehyde (98%), γ-Butyrolactone (98%), 2-Decanone (98%), 2(5H)-Furanone (98%), Neophytadiene (98%), Phenylacetaldehyde (98%), Palmitic acid (98%), Pyrrole-2-carboxaldehyde (98%), Octanal (99%), Nonanoic acid (98%), Furfuryl Acetate (98%), Methyl palmitate (98%), Maltol (99%), Methyl eugenol (98%), Nonadecane (98%), Nonanal (98%), β-Damascenone (98%), 2,3-Dimethylpyrazine (99%), Decanal (97%), Pentadecane (98%), Terpinyl Acetate (98%), Hexadecane (99%), Dodecane (99%), Acetoxyacetone (98%), 2,3-Heptanedione (98%), 1-Hexadecene (98%), Methyl glycolate (98%), DL-Pantolactone (98%), 2-Acetylpyrrole (98%), Methyl furan-2-carboxylate (98%), 4-Ethylguaiacol (98%), Nonane (98%), p-Tolualdehyde (98%), 2,3-Hexanedione (98%), 1,4-Dimethylpyrazole (98%), Propioin (98%), and β-Ionone (98%). Acetophenone (99%) was purchased from Innochem or J&K Co. Ltd., Beijing, China as model attractant and n-Hexane (98%) was used as a solvent.

Olfactory response of L. serricorne to plant powders

The area preference method (Shanshan et al., 2016) was used to test the attractiveness of the material powders to the cigarette beetle. Petri dishes (15 cm in diameter) were used to confine cigarette beetles during the experiment. Filter paper (15 cm in diameter) was cut in half, and one half (marked as A) was treated with 1.0 g of powder while the other half (marked as B) was blank as control. Sixteen mixed sex adults were released at the center of the petri dish. The petri dishes were then covered and transferred to a chamber set at constant temperature and humidity (28 ± 2℃, 70% ± 5% RH). The number of insects presenting on both halves were counted after 30 and 60 min. For each sample, three replicates were done.

The selection index (SI) was calculated using the following formula:

$$SI(\%) = [(A - B)/(A + B)] \times 100 \qquad (1)$$

Where; A and B are the insect numbers on the side A and B, respectively and SI is the selection index.

If SI is positive, the material has an attractive effect, otherwise has a repellent effect. The competitive olfactory response of *L. serricorne* to the plant materials and the tobacco was tested using the same procedure mentioned above, except that one half of the filter paper was treated with 0.5 g plant powder (marked as A) and the other half (control) was treated with 0.5 g tobacco powder (marked as B).

Analysis of volatile compounds in M. incana

Static headspace sampler (7697A, Agilent) was used to collect volatile compounds. Volatile components of the *M. incana* were analyzed by using a GC-MS (7890A/5977B, Agilent). The GC-MS was equipped with a DB-5ms (50 m × 0.25 mm i.d. × 0.25 µm film thickness) capillary column. The oven temperature started at 40°C for 1 min, then increased to 150°C at 2°C/min, increased to 250°C at 8°C/min and held for 10 min, and then increased at 20°C/min until the final temperature of 280°C. Helium (1.0 mL/min) was used as the carrier gas. Mass spectra were recorded from 50 to 550 amu with electronic impact ionization at 70 eV. The retention indices were determined by comparing their mass spectra with those stored in NIST 17.

Olfactory response of L. serricorne to volatile compounds

The area preference method was used to test the attractiveness of volatile compounds. Three solutions (56.62, 11.32 and 2.26 nL/cm^2) were prepared by diluting the model attractants (listed in *Chemicals*) with n-hexane. Each solution was evenly applied to the half of a filter paper using a micropipette. The other half was treated with 1000 µL n-hexane as the control. Both halves were air dried to completely evaporate the solvent. The two halves were attached with solid glue, so a full disk was kept during the operation. Other procedure was the same as that mentioned in 1.4. There were three replications for each concentration.

Statistics

One-Way ANOVA and Duncan's new multiple range test were conducted using SPSS 22.0.

Results and discussion

Olfactory response of L. serricorne to plant powders

All plant powders exhibited attractiveness to *L. serricorne* adults (Fig. 1). After 30 min, more than 75.0% adults of *L. serricorne* oriented to powders of *M. incana* and *R. simsii*, and 72.9% to flue-cured tobacco. These three materials showed a better attractancy than other tested materials. After 60 min, the SI associated with powders of *M. incana*, *R. idaeus,* and *Rosa rugosa* was 79.2%, 77.1%, 75.0%, respectively. Therefore, powder of *M. incana* had the highest attractiveness to *L. serricorne* adults.

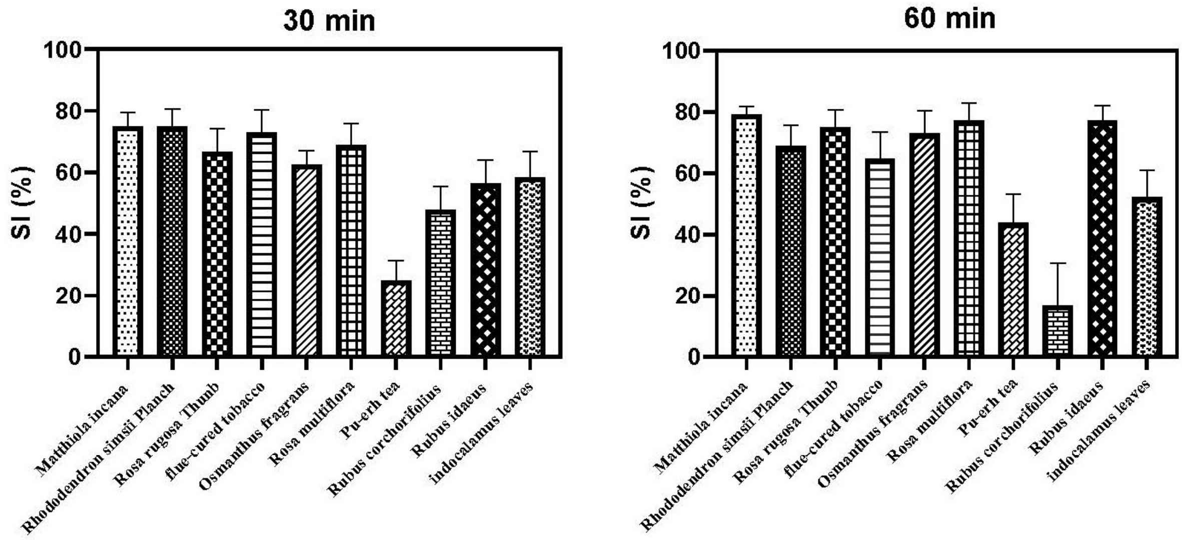

Fig.1. Olfactory response of *L. serricorne* adults to different plant powders.

Olfactory responses of L. serricorne to six plant powders when tobacco powder was the control

The six plant powders (*M. incana*, *R. rugosa*, *O. fragrans*, *R. simsii*, *R. idaeus, R. multiflora*) had a significant higher attractiveness than that of flue cured tobacco powder (Table 1). After 30 min, the SI associated with *M. incana* and *R. simsii* were 16.7% and 10.4%, respectively, which indicated that the attractiveness of these two plant powders was stronger than the flue cured tobacco. In the 60 min test, *M. incana* and *O. fragrans* powders were also more attractive than the flue cured tobacco. Thus, the attractiveness of *M. incana*, *R. simsii*, and *O. fragrans* powders was higher than that of flue cured tobacco.

Table 1. Olfactory responses of *L. serricorne* adults to six plant powders when tobacco powder was the control

Plant	30 min [a]			60 min [a]		
	A-adult	B-adult	SI (%)	A-adult	B-adult	SI (%)
Matthiola incana	9.33±1.75a	6.67±1.75b	16.67	9.00±2.00a	7.00±2.00a	12.50
Rhododendron simsii (yellow)	8.83±2.04a	7.17±2.04b	10.42	8.17±2.48a	7.83±2.48a	2.08
Rosa multiflora	7.83±1.94a	8.17±1.94b	-2.08	7.83±2.48a	8.17±2.48a	-2.08
Osmanthus fragrans	8.17±1.72a	7.83±1.72b	2.08	8.50±1.87a	7.5±1.87a	6.25
Rosa rugosa	7.67±3.01a	8.33±3.01b	-4.17	8.33±1.21a	7.67±1.21a	4.17
Rubus idaeus	4.83±1.72b	11.17±1.72a	-39.58	6.83±1.72a	9.17±1.72a	-14.58

[a]Different letter in the same row indicates a significant difference at $P < 0.05$. A, B were the number of *L. serricorne* adults in A and B side, respectively.

The identified volatile compounds from Matthiola incana (L.) R. Br.

One hundred and two volatile compounds were identified from the powder of *M. incana*. The total ion flow diagram is showed in Fig. 2. The components identified accounted for 89.3% of the total volatile compounds, including aldehydes (59.5%), ketones (6.5%), esters (2.9%), alcohols (2.3%), phenols (6.1%), organic acids (0.5%), hydrocarbon compounds such as alkanes and alkenes (2.4%), and heterocyclic compounds containing nitrogen and oxygen (9.1%).

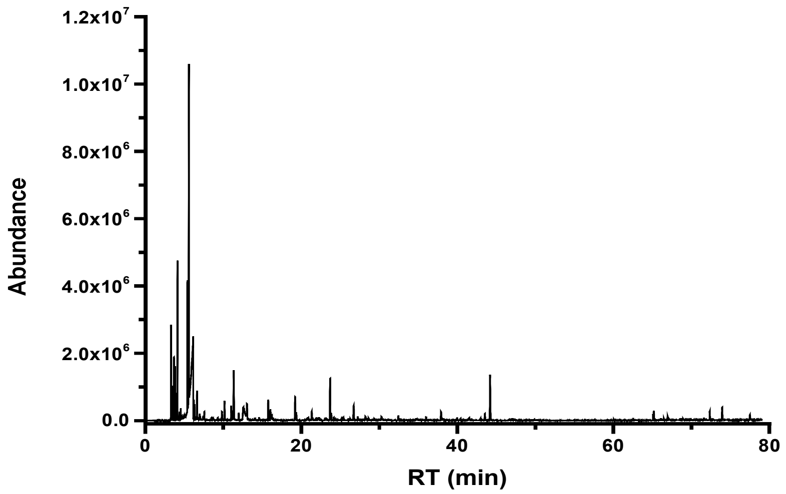

Fig. 2. The total ion flow diagram of *Matthiola incana* (L.) R. Br.

Attractiveness of volatile compounds to L. serricorne

Based on their safety, cost, and repellency, 46 kinds of volatile compounds extracted from *M. incana* were selected for the test (Table 2). The results revealed that the selection indices of Octanal, β-Ionone, and 2,3-Hexanedione were 70.8%, 66.7%, 62.5%, respectively, at 11.32

nL/cm^2, which showed higher attractiveness to *L. serricorne*. The selection indexes of Propioin and Neophytadiene were over 50% at 2.26 nL/cm^2, while 4-Ethylguaiacol and Methyl glycolate also reached 58.3% at 11.32 nL/cm^2 and 56.62 nL/cm^2. Therefore, these four materials also had stronger attractiveness.

Compared with other tested compounds, Octanal exhibited the highest attractiveness to *L. serricorne* at 11.32 nL/cm^2. Octanal might be the key volatile component that attracts adults of *L. serricorne* to *M. incana*, which has not been reported. However, the relative content of 2-Methylbutyraldehyde was the highest in the volatile compounds, so it should be noted that the active attractants were often not the major compounds. The attractiveness of volatile compounds was generally less than powders, therefore, synergistic activity of components extracted from *M. incana* might exist, which should be further studied.

Table 2. Attractiveness of *L. serricorne* to volatile components extracted from *M. incana* (SI (%))

Chemicals	Concentrations			Chemicals	Concentrations		
	2.26 nL/cm^2	11.32 nL/cm^2	56.62 nL/cm^2		2.26 nL/cm^2	11.32 nL/cm^2	56.62 nL/cm^2
2-Methylbutyraldehyde	4.17	-4.17	4.17	Methyl glycolate	16.67	12.50	58.33
5-Methyl furfural	8.33	16.67	8.33	4-Ethylguaiacol	37.50	58.33	-8.33
2-Methyltetrahydrofuran-3-one	4.17	16.67	12.50	2,3-Hexanedione	33.33	62.50	12.50
Furfuryl alcohol	4.17	-4.17	-25.00	Nonanoic acid	29.17	8.33	-8.33
2-Methylpyrazine	0.00	4.17	-12.50	Methyl furan-2-carboxylate	-16.67	-25.00	-25.00
2-Pentylfuran	-20.83	-25.00	-45.83	1,4-Dimethylpyrazole	-29.17	-25.00	-33.33
Benzaldehyde	-25.00	-41.67	-33.33	Propioin	54.17	-12.50	2.08
γ-Butyrolactone	-8.33	20.83	-16.67	p-Tolualdehyde	-8.33	4.17	-29.17
2-Decanone	-25.00	-20.83	-54.17	Acetophenone	4.17	-16.67	4.17
2(5H)-Furanone	4.17	4.17	0.00	DL-Pantolactone	4.17	-12.50	-29.17
Phenylacetaldehyde	4.17	8.33	-45.83	Methyl palmitate	25.00	12.50	4.17
Octanal	41.67	70.83	33.33	Nonadecane	8.33	4.17	-8.33
Furfuryl Acetate	8.33	12.50	4.17	Hexadecane	-8.33	12.50	4.17
Terpinyl Acetate	-37.50	-45.83	-54.17	Pentadecane	8.33	12.50	-8.33
Acetoxyacetone	20.83	8.33	12.50	Dodecane	4.17	8.33	-8.33
2,5-Dimethylpyrazine	16.67	25.00	4.17	Nonane	12.50	4.17	0.00
β-Ionone	33.33	66.67	41.67	2-Acetylpyrrole	20.83	16.67	8.33
2,3-Dimethylpyrazine	-54.17	0.00	-12.50	Maltol	20.83	25.00	8.33
Nonanal	20.83	4.17	20.83	Palmitic acid	-8.33	-4.17	-29.17
Decanal	12.50	-12.50	-8.33	Neophytadiene	50.00	37.50	12.50
2,3-Heptanedione	37.50	-4.17	-8.33	β-Damascenone	16.67	12.50	41.67
1-Hexadecene	25.00	-41.67	4.17	Methyl eugenol	8.33	4.17	-4.17
2-Ethylfuran	12.50	20.83	12.50	Pyrrole-2-carboxaldehyde	8.33	16.67	-12.50

Conclusions

Compared with other materials, *Matthiola incana* (L.) R. Br. had the highest attractiveness to *L. serricorne*, while *R. simsii* and *R. rugosa* were the next highest with SI > 65%. The *R. corchorifolius* and Pu-erh tea had relatively poor attractive effect, and their attractiveness fluctuated with the extension of time of the test time. *M. incana*, *Osmanthus fragrans*, *R. simsii*, *Rubus idaeus, Rosa multiflora*, and *Rosa rugosa* were tested when the flue cured tobacco was used as the control, and the results showed that *M. incana* had the highest attractiveness to the tobacco beetle. Furthermore, 46 volatile compounds extracted from *M. incana* were selected for attractive test, and the results indicated that the SI of Octanal, *β*-Ionone and 2,3-Hexadione reached more than 60% when the concentration was 11.32 nL/cm^2, while Octanal exhibited the highest attractiveness.

References

Cox PD (2004) Potential for using semiochemicals to protect stored products from insect infestation. J Stored Prod Res **40**(1): 1-25.

Ebadollahi A, Safaralizadeh M, Pourmirza A et al. (2010) Toxicity of essential oil of *Agastache Foeniculum* (Pursh) Kuntze to *Oryzaephilus Surinamensis* L. and *Lasioderma Serricorne*. J Plant Prot Res **50**(2): 215-219.

Isman MB (2006) Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. Ann Rev Entomol **51**(1): 45-66.

Junyu L, Shanshan Y, Jie X, Yingying Y (2019) Biological activity of *Ajania potaninii* essential oil against *Tribolium castaneum* and *Lasioderma serricorne.* Chem Ind Forest Prod (Chinese) **39**(06): 123-128.

Kim SI, Park C, Ohh MH et al. (2003) Contact and fumigant activities of aromatic plant extracts and essential oils against *Lasioderma serricorne* (Coleoptera: Anobiidae). J Stored Prod Res **39**(1): 11-19.

Landolt PJ, Phillips TW (1997) Host plant influences on sex pheromones behavior of phytophagous insects. Ann Rev Entomol **42**: 371-391.

Mahroof RM, Phillips TW (2007) Orientation of the cigarette beetle, *Lasioderma serricorne* (F.) (Coleoptera: Anobiidae) to plant-derived volatiles. J Insect Beh **20**(1): 99-115.

Phoonan W, Deowanish S, Chavasiri W (2014) Food attractant from mulberry leaf tea and its main volatile compounds for the biocontrol of *Lasioderma serricorne* F. (Coleoptera: Anobiidae). J Stored Prod Res **59**: 299-305.

Shanshan G, Wenjuan Z, Junyu L et al. (2016) Contact and repellent activities of the essential oil from *Juniperus formosana* against two stored product insects. Molecules **21**(4): 504.

Weizheng L, Yinyin F et al. (2014) Screening of plant-derived repellents against tobacco beetle, *Lasioderma serricorne* (Fabricius). Acta Tabacaria Sinica (Chinese) **20**: 93-97.

Xintian L (2010) The studies on the attractant to various stored grain pests and sustained release technique. Dissertation, Henan University of Technology, Zhengzhou, China.

Yu C, Giovanni B et al. (2019) Innate positive chemotaxis to paeonal from highly attractive Chinese medicinal herbs in the cigarette beetle, *Lasioderma serricorne*. Scientific Reports **9**(1): 1-11.