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2-butyl 2-dodecenoate, a new sex attractant for *Jordanita* (*Tremewania*) *notata* (Zeller, 1847) and some other Procridinae species (Lepidoptera: Zygaenidae)

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Abstract

A property of 2-butyl 2-dodecenoate as a sex attractant for the males of *Jordanita* (*Tremewania*) *notata* (Zeller, 1847) was proven in field trapping tests and behavioural observations in the Crimean Peninsula. It was shown that this substance is also attractive for males of some other Procridinae species, viz. *Rhagades* (*Rhagades*) *pruni* ([Denis & Schiffermüller], 1775), *Adscita* (*Adscita*) *geryon* (Hübner, 1813), *Jordanita* (*Jordanita*) *graeca* (Jordan, 1907), *J.* (*J.*) *globulariae* (Hübner, 1793), and *J.* (*Solaniterna*) *subsolana* (Staudinger, 1862). The attractiveness of 2-butyl 2-dodecenoate for *Rh. pruni*, *A. geryon*, *J. notata*, and *J. subsolana* was found for the first time.
KEY WORDS: Lepidoptera, Zygaenidae, Procridinae, *Jordanita notata*, *J. graeca*, *J. globulariae*, *J. subsolana*, *Adscita geryon*, *Rhagades pruni*, 2-butyl 2-dodecenoate, sex attractant, Crimea.

2-butil 2-dodecenoato, un nuevo atrayente sexual para *Jordanita* (*Tremewania*) *notata* **(Zeller, 1847) y algunas otras especies de Procridinae (Lepidoptera: Zygaenidae)**

Resumen

2-butil 2-dodecenoato ha sido sintetizado y sus propiedades como atrayente sexual para los machos de *Jordanita* (*Tremewania*) *notata* (Zeller, 1847) fueron probadas en trampas de campo y observado el comportamiento en la Península de Crimea. Se ha demostrado que esta sustancia también es atractiva para los machos de algunas otras especies de Procridinae, véase *Rhagades* (*Rhagades*) *pruni* ([Denis & Schiffermüller], 1775), *Adscita* (*Adscita*) *geryon* (Hübner, 1813), *Jordanita* (*Jordanita*) *graeca* (Jordan, 1907), *J.* (*J.*) *globulariae* (Hübner, 1793) y *J.* (*Solaniterna*) *subsolana* (Staudinger, 1862).
PALABRAS CLAVE: Lepidoptera, Zygaenidae, Procridinae, *Jordanita notata*, *J. graeca*, *J. globulariae*, *J. subsolana*, *Adscita geryon*, *Rhagades pruni*, 2-butil 2-dodecenoato, atrayente sexual, Crimea.

Introduction

Currently, sex pheromones of insects are widely used for the detection and direct control of species (both protected and pest species) and for monitoring their numbers in various biotopes (MILLAR *et al*., 2010; OLEANDER *et al*., 2015; SUBCHEV, 2014; WITZGALL *et al.,* 2010). Most probably, female sex pheromones are the main factor in the attraction and recognition of females by conspecific males in some groups of Lepidoptera that are represented by habitually very

similar species, for example in the subfamily Procridinae of the family Zygaenidae (EFETOV, 1996, 1997a, 1997b, 1998, 2001a, 2001c, 2006, 2010; EFETOV *et al.,* 2004; EFETOV & TARMANN, 2013a, 2013b, 2014a, 2014b; TOSHOVA *et al*., 2007; ZAGATTI & RENOU, 1984). The Procridinae are divided into two tribes: Artonini Tarmann, 1994, and Procridini Boisduval, 1828 (TARMANN, 1994; EFETOV *et al*., 2000, 2006; EFETOV & HAYASHI, 2008). The Procridinae are represented only by the Procridini in the western Palaearctis (EFETOV, 2005; EFETOV & TARMANN, 2012).

One Procridini species, *Jordanita* (*Tremewania*) *notata* (Zeller, 1847), is distributed from Spain and Portugal through central and southern Europe to Ukraine, Crimea, Northern Caucasus, Transcaucasia, Turkey, and north-western Iran (EFETOV & TARMANN, 1999; EFETOV, 2004, 2005). Not long ago it was shown that (2*R*)-butyl (7*Z*)-dodecenoate, previously established as a female sex pheromone component of *Illiberis* (*Primilliberis*) *rotundata* Jordan, 1907 (SUBCHEV *et al*., 2009), is a sex attractant for the males of *J. notata* in the Crimea, Bulgaria (SUBCHEV *et al*., 2010) and Italy (EFETOV *et al*., 2012, 2015). In Eurasia the enantiomers of 2-butyl (7*Z*)-dodecenoate and/or their mixtures are also sex attractants for males of some other Procridini species, viz. *Rhagades* (*Rhagades*) *pruni* ([Denis & Schiffermüller], 1775), *Adscita* (*Adscita*) *geryon* (Hübner, 1813), *Adscita* (*Tarmannita*) *mannii* (Lederer, 1853) (SUBCHEV *et al*., 2010; EFETOV *et al*., 2012), *Zygaenoprocris* (*Molletia*) *taftana* (Alberti, 1939) (EFETOV *et al*., 2011), *Z.* (*Zygaenoprocris*) *eberti* (Alberti, 1968) (EFETOV *et al.*, 2014a), *J.* (*Praviela*) *anatolica* (Naufock, 1929) (EFETOV *et al*., 2010), and *J.* (*Rjabovia*) *horni* (Alberti, 1937) (EFETOV *et al*., 2011). The mixtures of (2*R*)-butyl (7*Z*)-dodecenoate and (2*R*)-butyl (9*Z*)-tetradecenoate are sex attractants for males of *I.* (*P.*) *rotundata* (SUBCHEV *et al*., 2012) and *I.* (*P.*) *pruni* Dyar, 1905 (SUBCHEV *et al*., 2013).

The aim of this work was to study the biological activity of another ester of sec-butanol and dodecenoate with a double bond in the second position in dodecenoate. This substance has been synthesized in our laboratory and its attractiveness for different species of the Procridinae was tested during field observations in the Crimea in 2013-2014.

Materials and methods

Sec-butanol (Sigma-Aldrich, Germany) and other reagents (Ukraine) were used for the synthesis of 2-butyl 2-dodecenoate (EFETOV *et al*., 2013, 2014b). The products of reactions were separated by vacuum distillation, the content of products was determined by a gas-liquid chromatography with a chromatograph "Tsvet-500", thermal conductivity detector (katharometer). The column of 3 m, SP-2250 on Supelcoports, temperature of the column is 90-130º C, of the evaporator - 130-220º C, of the detector - 90-190º C. A chemical nature of the synthesized substance was confirmed using a method of nuclear magnetic resonance spectroscopy (EFETOV *et al*., 2014b).

For preparing baits, 2-butyl 2-dodecenoate was applied onto vial caps (200 microlitres per cap without solvent) composed of grey rubber. The baits were tested in home-made sticky Delta traps with removable sticky layers covered with Tanglefoot® insect glue and hung on bushes or trees at a height of 1.0-1.5 m above the ground. In all sites we also placed control traps with rubber caps but without the attractant (distance to the baited traps was not less than 10 metres).

Sometimes we merely placed the lure on stones on the ground. In this case we collected attracted specimens by netting them near the lure.

Field observations were made in six localities in the mountain region of the Crimean Peninsula (Fig. 1). A list of studied localities and periods of observation is provided below.

Site I: vic. Dachnoye, N of Sudak, 110 m. Bushy mountain slope near decidous forest. Periods of observation: 16-VI-2013 - 18-VII-2013, one baited trap and one control trap; 3-V-2014 - 27-VII-2014, one baited trap and one control trap.

Site II: vic. Belogorsk, Mt. Sary-Kaya, 230-239 m. Grassy slope near steep calcareous edge of

the mountain. Periods of observation: 30-V-2013 – 27-VII-2013, two baited traps and one control trap; 3-V-2014 - 27-VII-2014, one baited trap and one control trap.

SITE III: vic. Simferopol, Bitak, 320 m. Grassy slope near steep calcareous edge of the mountain. Periods of observation: 28-IV-2013 - 27-VII-2013, two baited traps and one control trap; 13-V-2014 - 31-VII-2014, one baited trap and one control trap.

SITE IV: Mt. Chatyr-Dag, 466-514 m. Clearings in decidous forest. Periods of observation: 5-VI-2013 - 4-VIII-2013, one baited trap and one control trap; 17-V-2014 - 31-VII-2014, three baited traps and two control traps.

SITE V: vic. Izobilnoye, N of Alushta, 180 m. Bushy slope between a vineyard and decidous forest. Periods of observation: 4-V-2014 - 7-VIII-2014, two baited traps and one control trap.

SITE VI: vic. Luchistoye, NE of Alushta, 376-388 m. Bushy mountain slope near the lake. Periods of observation: 4-V-2014 - 7-VIII-2014, two baited traps and one control trap.

The nomenclature of the subfamily Procridinae follows the last revisions of the group (EFETOV, 2001b, 2001c; EFETOV & TARMANN, 2012).

All collected specimens have been determined by K. A. Efetov, based on examination of the genitalia.

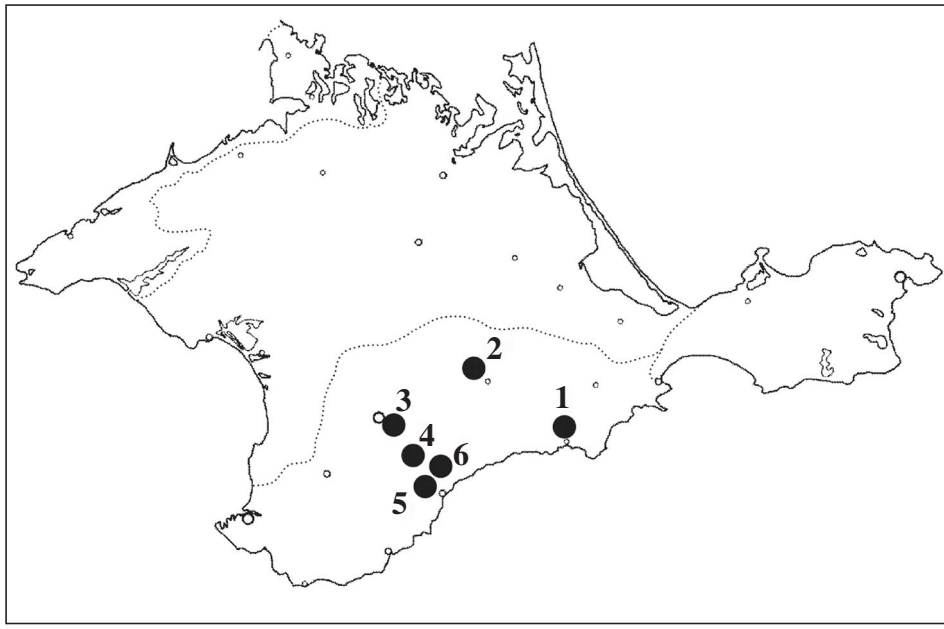


Figure 1.– Map of the Crimea showing the sites that were investigated using traps baited with 2-butyl 2-dodecenoate. 1. vic. Dachnoye, N of Sudak; 2. vic. Belogorsk, Mt. Sary-Kaya; 3. vic. Simferopol, Bitak; 4. Mt. Chatyr-Dag; 5. vic. Izobilnoye, N of Alushta; 6. vic. Luchistoye, NE of Alushta.

Results and discussion

The total number of specimens attracted is shown in Table 1. Dates of inspection of the traps in different biotopes and type of attraction of specimens (glued in trap or netted near lures) are listed below. Procridinae males were absent in control traps (without attractant) in all localities.

Table 1.– Total number of males of six Procridinae species attracted by traps baited with 2-butyl 2-dodecenoate in the Crimea. In all localities specimens were absent in control traps (without attractant).

Locality	vic. Dachnoye (site I)	vic. Belogorsk (site II)		vic. Simferopol (site III)		Mt. Chatyr-Dag (site IV)		vic. Izobilnoye (site V)	vic. Luchistoye (site VI)	Total number of males
Species	2014	2013	2014	2013	2014	2013	2014	2014	2014	
Rh. pruni									2	**2**
A. geryon					8					**8**
J. notata		*	125							**125**
J. graeca	1	36	10	1				1	46	**95**
J. globulariae						5	5			**10**
J. subsolana								1	2	**3**

* - In 2013 the traps were placed in site II after the flight period of *J. notata* had already finished.

Rhagades (*Rhagades*) *pruni* ([Denis & Schiffermüller], 1775)

vic. Luchistoye, NE of Alushta, 376 m, in trap with 2-butyl 2-dodecenoate: 1 ♂, 14-VI-2014; 1 ♂, 21-VI-2014.

Adscita (*Adscita*) *geryon* (Hübner, 1813)

vic. Simferopol, Bitak, 320 m, near lure with 2-butyl 2-dodecenoate: 4 ♂♂, 17-V-2014; 4 ♂♂, 27-V-2014.

Jordanita (*Tremewania*) *notata* (Zeller, 1847)

vic. Belogorsk, Mt. Sary-Kaya, 239 m, near lure with 2-butyl 2-dodecenoate: 1 ♂, 3-V-2014; in trap with 2-butyl 2-dodecenoate: 51 ♂♂, 18-V-2014; 17 ♂♂, 24-V-2014; 56 ♂♂, 1-VI-2014.

Jordanita (*Jordanita*) *graeca* (Jordan, 1907)

vic. Dachnoye, N of Sudak, 110 m, in trap with 2-butyl 2-dodecenoate: 1 ♂, 1-VI-2014. Vic. Belogorsk, Mt. Sary-Kaya, 230 m, near lure with 2-butyl 2-dodecenoate: 7 ♂♂, 30-V-2013; 26 ♂♂, 11-VI-2013, 2 ♂♂, 19-VI-2013; 10 ♂♂, 24-V-2014; in trap with 2-butyl 2-dodecenoate: 1 ♂, 11-VI-2013. Vic. Simferopol, Bitak, 320 m, in trap with 2-butyl 2-dodecenoate: 1 ♂, 24-V-2013. Vic. Izobilnoye, N of Alushta, 180 m, in trap with 2-butyl 2-dodecenoate: 1 ♂, 25-V-2014. Vic. Luchistoye, NE of Alushta, 376 m, near lure with 2-butyl 2-dodecenoate: 2 ♂♂, 29-V-2014; in trap with 2-butyl 2-dodecenoate: 1 ♂, 25-V-2014; 388 m, near lure with 2-butyl 2-dodecenoate: 21 ♂♂, 25-V-2014; 21 ♂♂, 29-V-2014; 1 ♂, 31-V-2014.

Jordanita (*Jordanita*) *globulariae* (Hübner, 1793)

Mt. Chatyr-Dag, 466 m, in trap with 2-butyl 2-dodecenoate: 5 ♂♂, 23-VI-2013; 1 ♂, 31-V-2014; 2 ♂♂, 14-VI-2014; 514 m, in trap with 2-butyl 2-dodecenoate: 1 ♂, 14-VI-2014; 1 ♂, 28-VI-2014.

Jordanita (*Solaniterna*) *subsolana* (Staudinger, 1862)

vic. Izobilnoye, N of Alushta, 180 m, in trap with 2-butyl 2-dodecenoate: 1 ♂, 29-V-2014. Vic. Luchistoye, NE of Alushta, 376 m, in trap with 2-butyl 2-dodecenoate: 1 ♂, 25-V-2014; 1 ♂, 29-V-2014.

An application of 2-butyl 2-dodecenoate demonstrated its high attractiveness for the males of *J. notata*. 125 male specimens were collected near Belogorsk from 3-V-2014 to 27-VII-2014, 124 of which were found in one sticky trap that was controlled once per week. The number of attracted males could have been higher, as the sticky layers during the maximum flight period every week were completely covered with specimens (Fig. 2).

Figure 2.– Sticky trap baited with 2-butyl 2-dodecenoate with 56 males of *J. notata*, vic. Belogorsk, Mt. Sary-Kaya, 1-VI-2014.

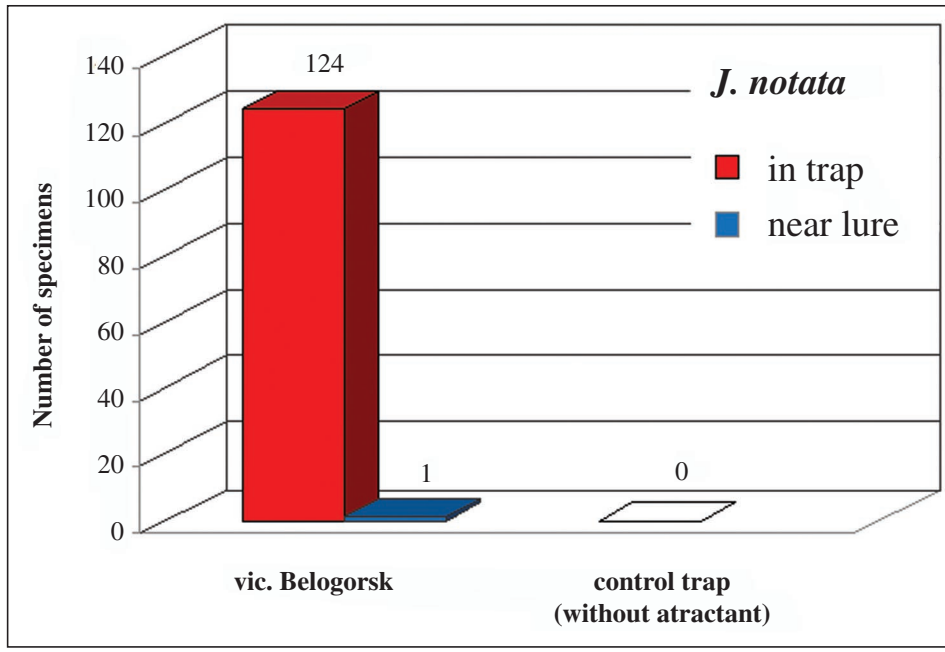
Except for *J. notata*, males of *Rh. pruni*, *A. geryon*, *J. graeca*, *J. globulariae*, and *J. subsolana* were also attracted during our field observations. We found two different types of attraction.

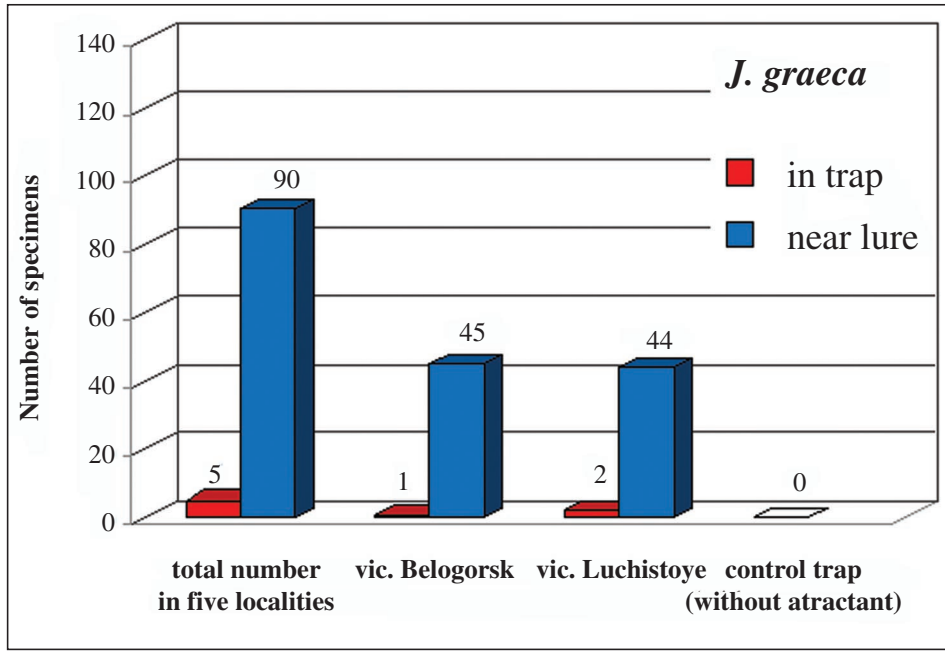
1. *J. notata* and *J. globulariae* were found as glued specimens on sticky layers. *Rh. pruni* and *J. subsolana* were also found in sticky traps but in small numbers (two and three specimens respectively).

2. The other two species, viz. *J. graeca* and *A. geryon*, came actively to the lures (rubber caps with 2-butyl 2-dodecenoate) that were placed in the biotope. Only five specimens (out of 95) of *J. graeca* were found in sticky traps. These differences in attraction are shown in Figs 3 and 4. Most probably the males (that came to the lure and did not adhere to the sticky layers) realized at a close distance that the 2-butyl 2-dodecenoate is not their natural pheromone.

Conclusion

It was shown that synthetic 2-butyl 2-dodecenoate attracts the males of *Jordanita* (*Tremewania*) *notata* and other Procridinae species: *Rhagades* (*Rhagades*) *pruni*, *Adscita* (*Adscita*) *geryon*, *Jordanita* (*Jordanita*) *graeca*, *J.* (*J.*) *globulariae*, and *J.* (*Solaniterna*) *subsolana*. This substance can be used for identifying the presence of Procridinae species in different regions and for seasonal monitoring of these moths. While the attraction of *J. graeca* and *J. globulariae* by 2-butyl 2-dodecenoate we have already registered earlier (EFETOV *et al*., 2014b), the attractiveness of this substance for *Rh. pruni*, *A. geryon*, *J. notata*, and *J. subsolana* was found for the first time.





Figures 3-4.– **3.** Attraction of *Jordanita notata* by 2-butyl 2-dodecenoate. **4**. Attraction of *Jordanita graeca* by 2-butyl 2-dodecenoate.

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