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New food plants for insects *Vilbasteana oculata* (Hemiptera: Cicadellidae) and *Otiorhynchus smreczynskii* (Coleoptera: Curculionidae) in the Baltic region

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Abstract

Vilbasteana oculata (hemipteran) and *Otiorhynchus smreczynskii* (beetle) are alien species in countries around the Baltic Sea, and they are continuing to spread. Sometimes when entering new areas where other plant species are found, herbivores tend to add to their range of food plants. Knowledge of the feeding trends of particular insect species can be useful in predicting possible changes in insect-plant trophic relationships in other regions where they expanding in range. This study looks at the feeding trends of two insect species – *V. oculata* and *O. smreczynskii*. The study was carried out mainly in Latvia, as well as in other expeditions in Estonia, Lithuania, Poland and Sweden. In this study, four *Fraxinus* and four *Ligustrum* species were confirmed as the new food plants for *V. oculata*. The main food plants for adults of *O. smreczynskii* probably originally belonged to the genera *Ligustrum* and *Syringa*. In this study, a number of alternative food plants have been recorded for the first time, generally woody and some herbaceous plants. Most of the newly registered food plants for *O. smreczynskii* belong to the families Oleaceae and Rosaceae. Other food plants belong to the families Adoxaceae, Celastraceae, Elaeagnaceae, Ericaceae, Grossulariaceae, and Rhamnaceae. *V. oculata* was confirmed in Poland (2017) and Sweden (2019) for the first time.

Key words: alien species, Baltic Sea region, exotic species, feeding behaviour, food diversity, plant pests.

Introduction

It is already well-known that, as a result of human activity, many species have entered new regions where the species did not exist before. In new areas, species come into contact with new organisms that were not present in their regions of origin. As a result, the ecological relationships of newly arrived species may change, which in the case of animals may mean the selection of new food items. Ecological and trophic changes in the behaviour of each species can also pose risks to the economy or to local habitats. Therefore, it is important to study the behaviour of each arriving species in their new distribution areas. Such studies can provide more information about each specific species and make it possible to predict the behaviour of the species and the potential risks in the future if the species continues to expand.

Often, several species share the same food sources, which can increase economic or ecological risks (pressure) if more and more species with a similar food base enter a new territory. Two insect species – *Vilbasteana oculata* (Lindberg, 1929) (Hemiptera: Cicadomorpha: Cicadellidae) and *Otiorhynchus smreczynskii* Cmoluch, 1968 (Coleoptera: Curculionidae) – are interesting because the range of food plants belonging to the Oleaceae family overlaps for both insect species. In the past, *V. oculata* has been observed to shift to new food plants outside its natural range (e.g. Söderman 2005; Stalažs 2013). Therefore, both species were interesting for additional research in this regard.

Both insect species are alien to several European countries, and only *O. smreczynskii* originates from Europe. So far in Europe *V. oculata* has been registered from Belarus, Estonia, Finland, Latvia, Ukraine, and the European part of Russian Federation (Söderman 2005; Söderman et al. 2009; Stalažs 2013; Meshkova 2021). *V. oculata* is treated as potentially invasive for Latvia and Lithuania, as it could be a potential vector of plant pathogens harmful to native *Fraxinus excelsior* (European ash) stands and seriously reduce the green leaf surface of young ash plants growing in the forest understorey (Stalažs 2013). This is a sap-feeding insect, which is known so far in a trophic relationship with certain plant species of the Oleaceae family, and originally originated from eastern Asia (Söderman 2005; Stalažs 2013).

So far *O. smreczynskii* is considered native in Moldova, Romania, and Ukraine; and it has been unintentionally introduced to Belarus, Czech Republic, Denmark, Estonia, Germany, Hungary, Latvia, Lithuania, Poland, the Netherlands, Norway, the Russian Federation, Sweden, and Switzerland (Dieckmann 1980; Sprick 1989; Yunakov 2003; Anderson 2009; Fägerström et al. 2010; Balalaikins, Bukejs, 2011; Yunakov et al. 2012; Gederaas et al. 2012; Dedyukhin 2014; Podlussány et al. 2014; Heijerman, Burgers 2015; Benedikt et al. 2016; Sautkin, Meleshko 2016; Benedikt et al. 2017).

The recent reviews on the feeding habits of both insects have been published by Balalaikins and Bukejs (2011), and Dedyukhin (2014) for *O. smreczynskii* and Stalažs (2013) for *V. oculata*. Food plants of *V. oculata* [formerly as *Igutettix oculatus*, see Ohara, Hayashi (2022)] belong to three genera – *Fraxinus, Ligustrum*, and *Syringa* (lilacs) – within the family Oleaceae, but species of lilac that was fed on was not always previously reported, and thus feeding behaviour of *V. oculata* on particular lilac species remains unclear (Söderman 2005; Stalažs 2013). Balalaikins and Bukejs (2011) have reported seven plant species from six genera, *Chaenomeles* (originally as *Cydonia*), *Ligustrum*, *Ribes*, × *Sorbaronia* (originally as *Aronia*), *Spiraea*, and *Syringa*, as food plants for adult *O. smreczynskii* weevils in the Baltic countries, and '*Cydonia oblonga*' (Balalaikins, Bukejs 2011). However, the image provided in Balalaikins and Bukejs (2011) clearly shows the leaf of *Chaenomeles japonica*, and not of *Cydonia oblonga*. Consequently, feeding of *O. smreczynskii* on genuine *Cydonia oblonga* remains unconfirmed. The same is true for *Aronia* species, since × *Sorbaronia fallax* nothosubsp. *mitschurinii* was the taxon named in the previous studies and not true *Aronia* [for the correct use of plant names see Stalažs (2021) and Stalažs and Bādere (2023)]. *Chaenomeles japonica*, as well as some other plant species of the genera *Cotoneaster, Crataegus, Lonicera*, and *Ribes* were later confirmed as alternative food plants for *O. smreczynskii* in Latvia by Rupais et al. (2014) and Stalažs (2014). Balalaikins and Bukejs (2011) and Dedyukhin (2013) also provided a bibliographic review on feeding plants for *O. smreczynskii*, listing the following genera: *Convolvulus, Cornus, Crataegus, Lonicera, Laburnum, Robinia*, and *Symphoricarpus*. Dedyukhin (2014) supplemented this list with *Acer, Betula, Brunnera, Caragana, Populus, Prunus*, and *Ulmus*. As far as is known, adult *O. smreczynskii* weevils feed on the leaves of various woody plants and two herbaceous species, *Brunnera sibirica* and *Convolvulus* sp.

It was previously suggested that *V. oculata* (lilac leafhopper) could feed on other plants (Stalažs 2013), but the bionomics of this species is generally too little studied. Before this study, it was observed that *O. smreczynskii* adult beetles also feed on leaves of plants that were not previously mentioned in publications dealing with food plants of this species. Therefore, this study tested the hypothesis whether *V. oculata* has other food plants outside the genera *Fraxinus, Ligustrum* and *Syringa*, and documented other possible food plants for *O. smreczynskii*. This paper summarizes the results of eight years of observations on the feeding of these two species. The study was carried out mainly in Latvia, but in separate expeditions also in Estonia, Lithuania, Poland and Sweden.

Materials and methods

The feeding behaviour of both target species, *V. oculata* leafhoppers (adults and nymphs) and adult *O. smreczynskii* weevils was studied from 2014 to 2021 in Estonia, Latvia, Lithuania, Poland, and Sweden. In some localities, observations were made regularly every year (Table 1). In Sweden, only *V. oculata* was studied. Plant collections such as parks (see Table 1) were also used in the present study, as they contain a larger number of different plant taxa concentrated in a small locality, and the owners of the collections had more accurate information about the identity of plant taxa planted, which is particularly important for less frequently cultivated exotic plant species. In Latvia, the study was also been carried out in some smaller settlements, in the greenery of individual country houses, and these sites are not listed in Table 1.

Feeding of *V. oculata* was registered based on the specific character of damage – presence of yellowish dots resulting from feeding by *V. oculata*, when leaves lost their natural green colour (Stalažs 2013; Fig. 1), and based on presence of *V. oculata* specimens (adults, nymphs as well as skin moulds), particularly if the food plant species was a new country or locality record. Feeding of *O. smreczynskii* was registered based on presence of specific leaf-cuts made by adult weevils as described in the literature (Anderson 2009; Balalaikins, Bukejs 2011; Fig. 2). Feeding of the *O. smreczynskii* in the larval stage was not studied.

The APG system (APG IV 2016) was used for plant taxonomy. Family Oleaceae classification on a tribe and subtribe level followed Wallander and Alber (2000). Since in plant collections plants belonging to the *Syringa pubescens* complex sometimes were deposited under various names, the Jin-Yong et al. (2009) taxonomy of this lilac group was used.

Results

Habitat and niche preference of V. oculata *and* O. smreczynskii

Of the two species, *O. smreczynskii* was restricted mainly to anthropogenic habitats, or was found in natural or semi-natural habitats immediately adjacent to populated areas. In contrast, *V. oculata* was found on food plants in wild habitats as well, mainly on native *Fraxinus excelsior*, as well as on wild escaped *Ligustrum vulgare* and *Syringa* spp. Long-term observations made in Dobele allow suggesting that over the years, the density of *O. smreczynskii* populations has been growing, as the amount of visually

Table 1. The list of sites where field trips have been carried out (including the immediate surroundings outside the administrative boundaries of some settlements). Greenery includes parks, gardens, street/roadsides, cemetery plantings, etc.

Locality	Year	Habitat
Estonia		
Tartu	2017	Greenery, wild, plant collection of the Tartu Botanical Garden
Latvia		
Baloži (near Riga)	2017	Greenery
Bauska	2013, 2017	Greenery
Bērzupe railway station surroundings	2016	Greenery, wild
Carnikava	2017	Greenery
Cēsis	2017	Greenery
Dobele (inclusing surrounding areas)	2014 – 2021	Greenery, wild, plant collections of the Institute of Horticulture
Ģipka	2017	Greenery, wild
Grobiņa	2017	Greenery
Iecava	2017	Greenery
Ilmāja railway station	2017	Greenery
Jelgava	2014 – 2017	Greenery
Jūrmala	2019, 2021, 2022	Greenery, wild
Kandava	2017	Greenery
Kolka	2020	Greenery, wild
Krimūnas	2018	Greenery
Lāči (Babītes pagasts)	2017	Greenery
Liepāja	2018, 2019	Greenery, wild
Olaine	2017	Greenery
Pāvilosta	2017	Greenery, wild
Plieņciems	2017	Greenery, wild
Pūre	2018	Greenery
Rīga (including surrounding areas)	2014 – 2018	Greenery, wild
Roja	2017	Greenery, wild
Rude	2017	Greenery
Rūjiena	2018	Greenery
Salaspils	2014 – 2017	Plant collections of the National Botanic Garden
Saldus	2017	Greenery
Sējējciems	2017	Greenery, wild
Sigulda	2017	Greenery
Skrunda	2017, 2021	Greenery, wild
Subate	2017	Greenery
Talsi	2017	Greenery
Tērvete	2017	Greenery, wild
Tukums	2017, 2019	Greenery, wild
Upmalas (near Kadaga)	2017	Greenery, wild
Valmiera	2017	Greenery
Vilce	2017	Greenery, wild
Zaļenieki	2017	Greenery, plant collections
Lithuania		
Trakėnai	2017	Greenery
Vilnius	2017	Greenery, plant collections of the Vilnius University Botanical Garden
Žagare	2017	Greenery
Poland		
Augustów	2017	Greenery
Białystok	2017	Greenery
Grudki (near Białowieża)	2017	Greenery
Pruszków	2017	Greenery
Sejny	2017	Greenery
Skierniewice	2017	Greenery
Suwałki	2017	Greenery
Sweden		
Rimbo	2019	Greenery
Stockholm	2019	Greenery, wild
Uppsala	2019	Greenery, wild

observed damage of food plants increased year to year. It was observed that beetles passively spread to surrounding territories from the initial place of their introduction. The weevil distribution along roads and streets clearly showed the potential corridors of their passive movement in urbanized habitats.

Food plants of V. oculata

A total of 30 new plant taxa (including cultivars and infra-specific taxa) were confirmed for the first time as new food plants for *V. oculata*. A number of the plant taxa reported as new food plants were confirmed in only one or two plant collections (Table 2).

In cases of some food plants, intensive feeding of *V. oculata* resulted in loss of the natural green colour of leaves affecting more than 50% of the leaf surface, but for some leaves affecting up to 90% of the surface (e.g., Fig. 1). Most abundantly, *V. oculata* was observed on the following lilacs: *Syringa × chinensis* s.l., *Syringa josikaea, Syringa komarowii, Syringa persica* 'Alba', *Syringa pubescens* s.l., *Syringa reticulata* subsp. *amurensis, Syringa × swegiflexa, Syringa tomentella* subsp. *sweginzowii, Syringa villosa* s.l., *Syringa* 'Lark Song' and *Syringa × prestoniae* cultivars: 'Anna Amhoff', 'Miss Canada', 'Silvia' and 'Telimena'. In some cases, the lilacs were heavily affected, including plants growing in open and sunny conditions. On other plant species growing in open and semi-open conditions, *V. oculata* was mainly observed on leaves located in shady conditions or lower parts of the

Fig. 1. Intensive damage caused by *Vilbasteana oculata*. Damaged leaves of *Ligustrum vulgare* in cultivation (A) and *Fraxinus excelsior* in forest (B). Both photos: September 3, 2019, Stockholm, Sweden.

Fig. 2. Intensive damage caused by *Otiorhynchus smreczynskii*. Damaged leaves of escaped *Ligustrum vulgare*, Latvia, 31 August 2017 (A) and *Euonymus europaeus* in wild, Bauska, Latvia, August 14, 2017 (B).

plant crown. On *Fraxinus excelsior, Ligustrum vulgare* and *Syringa vulgaris*, intensive damage by *V. oculata* was usually observed in shady or semi-shady places or the plant crown, but not in open and sun-exposed areas.

Usually, *V. oculata* occurs up to three meters high in the plant foliage, which was observed, for example, on shrubs of *Syringa josikaea/villosa* complex and on *Fraxinus excelsior*. Possibly, *V. oculata* can feed on upper parts of larger trees and shrubs as well, but it was impossible to confirm it during this study.

Other related Oleaceae species were also investigated for presence of *V. oculata*. Although *Forsythia* spp. (tribe Forsythieae) individuals were present at many of the surveyed sites, *V. oculata* was never found on *Forsythia*. Leafhoppers were also not found on *Chionanthus virginicus* (tribe Oleeae, subtribe Oleinae) and *Fontanesia philliraeoides* s.l. (tribe Fontanesieae). The latter two species were observed in the collection of the National Botanic Garden of Latvia, and only two plants of *Chionanthus virginicus* and four of *Fontanesia philliraeoides* were available for the study in 2017, and these plants were not revisited later.

In some localities in Latvia, especially if populations of leafhoppers were numerous, adult *V. oculata* were frequently observed in spider webs spun in crowns of lilacs or close to them. This demonstrates that alien *V. oculata* supplements the diet of spiders. However, as this was not the aim of the study, the role of *V. oculata* in the diet of spiders was not investigated in detail.

Feeding of O. smreczynskii *weevils*

In this study, *O. smreczynskii* weevil feeding was not observed for the following plant species previously mentioned in the literature as food sources: *Acer negundo, Amelanchier × spicata, Brunnera sibirica, Caragana arborescens, Convolvulus* sp., *Cornus sanguinea, Crataegus crus-galli, Laburnum vulgare, Lonicera tatarica, Malus baccata, Populus balsamifera, Prunus spinosa, Prunus virginiana, Ribes sanguineum, Robinia pseudoacacia, Rosa majalis, Spiraea chamaedrifolia, Spiraea japonica, Spiraea*

Table 2. Confirmed food plants of *Vilbasteana oculata*. EE, Estonia; LT, Lithuania; LV, Latvia; PL, Poland; SE, Sweden. [1]Information source: Stalažs (2013). [2]As *Syringa* spp. in Stalažs (2013). [3]Including many cultivars of *Syringa vulgaris*

Plant species, cultivar	Previous studies[1]	This study (country)	Comments
Fraxinus chinensis subsp. *rhynchophylla*		▪ (LV)	One plant collection
Fraxinus excelsior	▪	▪ (EE, LV, PL, SE)	Common locally
Fraxinus excelsior 'Aurea'		▪ (LT)	One plant collection
Fraxinus latifolia		▪ (LV)	One plant collection
Fraxinus nigra		▪ (LV)	One plant collection
Fraxinus pennsylvanica s.l.		▪ (EE, LV)	Two cases
Fraxinus sp.		▪ (EE)	One plant collection
Ligustrum lindleyi		▪ (LV)	One plant collection
Ligustrum ovalifolium		▪ (LV)	One plant collection
Ligustrum sinense		▪ (LV)	One plant collection
Ligustrum tschonoskii		▪ (LV)	One plant collection
Ligustrum vulgare	▪	▪ (EE, LT, LV, PL, SE)	Very often
Ligustrum vulgare 'Aureum'		▪ (LV)	One plant collection
Syringa × *chinensis* s.l.		▪ (EE, LV)	Two plant collections
Syringa emodi		▪ (LV)	One plant collection
Syringa × *henryi*	▪	▪ (LV)	One plant collection
Syringa × *hyacinthiflora* cultivars		▪ (LV)	One plant collection
Syringa × *josiflexa* 'James Macfarlane'		▪ (LV)	One plant collection
Syringa josikaea	▪	▪ (EE, LV)	Very often
Syringa josikaea / *villosa* complex		▪ (EE, SE)	Very often
Syringa komarowii s.l.	▪	▪ (LT, LV)	Two plant collections
Syringa 'Lark Song'		▪ (LV)	One plant collection
Syringa 'Minuet'		▪ (LV)	One plant collection
Syringa 'Miss USA'		▪ (LV)	One plant collection
Syringa persica	▪	▪ (LV cultivar 'Alfa')	One plant collection
Syringa × *prestoniae* cultivars		▪ (LT, LV)	One plant collection
Syringa pubescens		▪ (LV, SE)	Several localities
Syringa pubescens subsp. *microphylla*		▪ (LT)	One plant collection
Syringa pubescens subsp. *patula*		▪ (LV)	One plant collection
Syringa pubescens subsp. *pubescens* (syn. *S. meyeri*)		▪ (LV)	One plant collection
Syringa reticulata s.l.	▪	▪ (LV)	One plant collection
Syringa reticulata subsp. *amurensis*	▪	▪ (LV)	One plant collection
Syringa reticulata subsp. *pekinensis*		▪ (EE, LV)	Two plant collections
Syringa × *swegiflexa*		▪ (LV)	One plant collection
Syringa tomentella		▪ (LV)	One plant collection
Syringa tomentella subsp. *sweginzowii*		▪ (LV)	One plant collection
Syringa tomentella subsp. *yunnanensis*		▪ (LV)	One plant collection
Syringa villosa s.l.	▪[2]	▪ (LV)	Very often
Syringa villosa subsp. *wolfii*		▪ (LV)	One plant collection
Syringa vulgaris[3]	▪	▪ (EE, LT, LV, PL, SE)	Very often

salicifolia, and *Ulmus* sp. (see also summary in Table 3). Some of mentioned plant species were available for this study in limited quantity (*Brunnera sibirica, Laburnum vulgare, Populus balsamifera, Prunus spinosa, Prunus virginiana, Ribes sanguineum*), and in some genera species were not identified to level of species (*Crataegus, Lonicera, Spiraea*), but *Rosa majalis* was not covered by this study. Part of the food plants mentioned in earlier literature was also confirmed in this study, some in a few cases, and others in many localities (Table 4).

No information was found in the reviewed literature on possible alternative food plants for this species from many plant genera, which are listed in Table 5. In general, it was found out that adult weevils prefer a wide range of food plants, allowing to recognize *O. smreczynskii* as a highly polyphagous species. It seems that adult weevils prefer plants from certain families (Table 3), as well as woody plants, there are only a few species of herbaceous plants that

Table 3. Plant families represented by food plants for adult *Otiorhynchus smreczynskii* weevils (in generic level)

Plant family	Represented genera/species (underlined not observed in this study)
Adoxaceae	*Viburnum*
Betulaceae	*Betula pendula*
Boraginaceae	*Brunnera sibirica*
Caprifoliaceae	*Lonicera, Symphoricarpos, Weigela*
Celastraceae	*Euonymus*
Convolvulaceae	*Convolvulus* sp.
Cornaceae	*Cornus*
Ericaceae	*Rhododendron* sp.
Elaeagnaceae	*Elaeagnus umbellata*
Fabaceae	*Caragana, Laburnum, Robinia*
Grossulariaceae	*Ribes*
Hydrangeaceae	*Philadelphus* sp.
Oleaceae	*Forsythia, Fraxinus, Ligustrum, Syringa*
Rhamnaceae	*Rhamnus cathartica*
Rosaceae	*Amelanchier, Chaenomeles, Cotoneaster, Crataegus, Cydonia, Fragaria, Geum, Malus, Physocarpus, Prunus, Pyrus, Rosa, Sorbaria, Sorbus,* × *Sorbaronia, Spiraea*
Salicaceae	*Populus balsamifera*
Sapindaceae	*Acer negundo*
Ulmaceae	*Ulmus* sp.

these adult beetles use as food (Table 4, 5). In this study, only three herbaceous plant species (*Fragaria* × *ananassa*, *Fragaria vesca*, and *Geum urbanum*) was registered as food sources for adult weevils.

Combining the results of this study and the published information, it is possible to group all *O. smreczynskii* adult weevil food plants into two groups, main and alternative (or other). On the main food plants, characteristic leaf-edge cuts made by adult weevils are usually very numerous (Fig. 2), but on the alternative food plants, the number of leaf-edge cuts are not numerous, and generally these plants are consumed less intensively. The main food plants that were known previously are *Ligustrum vulgare, Syringa villosa*, and *Syringa vulgaris* (Oleaceae). Several other *Syringa* species (*Syringa* × *chinensis, Syringa josikaea, Syringa* × *prestoniae, Syringa pubescens* s.l., *Syringa reticulata* s.l., and *Syringa tomentella* s.l.) as well as *Euonymus europaeus* (Celastraceae), *Prunus cerasifera* (Rosaceae), *Rhamnus cathartica* (Rhamnaceae), *Ribes alpinum* (Grossulariaceae), and *Symphoricarpos albus* (Caprifoliaceae) were also categorized as main food plants, because they were more often and intensively consumed by adult *O. smreczynskii* weevils. The same food plant species was not damaged intensively at all localities, but the level of damage was similar on *Ligustrum* and *Syringa*. At some sites, young *Fraxinus excelsior* seedlings were also actively used by weevils as a food source. However, since *Fraxinus excelsior* grows as a tall tree, these plants appear suitable for *O. smreczynskii* only when young or have branches close to the ground or reaching other food plants, as the beetles usually do not climb higher than 2.5 m. The same was observed for other woody plants that grow as taller trees (e. g. *Malus* spp., *Prunus avium, Prunus cerasus, Pyrus communis, Sorbus aucuparia*) but form root shoots or whose branches may be positioned close to the ground. In general, *O. smreczynskii* weevils feed on plants by climbing up to 2-m height, sometimes up to 2.5 m, but the larger part of the damaged leaves was observed up to 1.0 – 1.5 m from the ground.

Table 4. *Otiorhynchus smreczynskii* adult food plants previously mentioned in reviewed literature and confirmed in this study. EE, Estonia; LT, Lithuania; LV, Latvia; PL, Poland. *This plant in literature is named incorrectly as *Aronia melanocarpa* and *Aronia* × *prunifolia*

Plant species	Country	Comments
Betula pendula	EE	One locality (Tartu)
Chaenomeles japonica	LV, PL	Several localities
Cornus alba, including cultivars	LV, PL	Several localities
Cotoneaster lucidus	EE, LV, PL	Often
Crataegus spp.	EE, LV	Several localities
Ligustrum vulgare, including cultivars	EE, LV, PL	Often
Lonicera spp.	LV	Several localities
Prunus cerasus	LV, PL	Several localities
Prunus padus	LV	One locality (Dobele)
Ribes alpinum	EE, LV, PL	Quite often
Ribes aureum	LV	One locality (Dobele)
× *Sorbaronia fallax* nothosubsp. *mitschurinii**	LV	Several localities
Spiraea spp.	EE, LV, PL	Quite often
Symphoricarpos albus	EE, LV, PL	Quite often
Syringa josikaea	LV	Several localities
Syringa villosa	LV	One locality (Dobele)
Syringa vulgaris	EE, LT, LV, PL	Often
Syringa josikaea / villosa complex	EE, PL	Several localities
Syringa reticulata subsp. *amurensis*	LV	One locality (Dobele)
Weigela spp.	LV, PL	Several localities

The herbaceous plant species *Brunnera sibirica* (Boraginaceae), mentioned in literature as a food plant for weevils, grew in one particular garden in Dobele. Presence of *O. smreczynskii* was observed in this garden from 2017 to 2021 (*Brunnera sibirica* occurred here until 2018). Although *Brunnera sibirica* was close to *Syringa vulgaris* and *Euonymus fortunei* consumed by *O. smreczynskii* weevils,

Table 5. *Otiorhynchus smreczynskii* adult food plants, which are not mentioned in the reviewed literature sources, but was observed in this study. EE, Estonia; LT, Lithuania; LV, Latvia; PL, Poland

Plant species	Country	Comments
Cotoneaster dammeri	LV	One locality (Dobele)
Cotoneaster sp. (not *Cotoneaster lucidus*)	EE	One locality (Tartu)
Cydonia oblonga	LV	One locality (Dobele)
Elaeagnus umbellata	LV	One locality (Dobele)
Euonymus europaeus	LV, PL	Several localities
Euonymus verrucosus	LT	One locality (Vilnius)
Euonymus fortunei	LV	Several localities
Forsythia intermedia	LV	One locality (Dobele)
Forsythia spp.	LV, PL	Several localities
Fragaria × ananassa	LV	One locality (Dobele)
Fragaria vesca	LV	One locality (Bauska)
Fraxinus excelsior, including cultivars	LV, PL	Several localities
Fraxinus pennsylvanica	EE, PL	Several localities
Geum urbanum	LV	One locality (Dobele)
Ligustrum sp. (not *Ligustrum vulgare*)	PL	One locality (Pruszków)
Lonicera caerulea	LV	One locality (Dobele)
Lonicera caprifolium	LV	One locality (Dobele)
Malus spp., including *Malus prunifolia* 'Pendula'	LV	Several localities
Philadelphus sp.	LV	One locality (Dobele)
Physocarpus opulifolius	PL	One locality (Białystok)
Prunus avium	LV	One locality (Dobele)
Prunus cerasifera	LV, PL	Quite often
Prunus domestica	EE, LV, PL	Several localities
Prunus mahaleb	LV	One locality (Dobele)
Prunus tenella	LV	One locality (Valmiera)
Pyrus communis	LV	One locality (Dobele)
Rhamnus cathartica	LV	Several localities
Rhododendron sp.	LV	One locality (Dobele)
Ribes, blackcurrant group	LV	One locality (Pāvilosta)
Ribes, redcurrant group including *Ribes spicatum*	LV, PL	Several localities
Ribes uva-crispa	LV, PL	Several localities
Rosa spp.	LV, PL	Several localities
Rosa spinosissima	LV	One locality (Dobele)
Rosa rugosa	LV	Some cases
Rubus caesius	EE, LV	Quite often
Sorbaria sorbifolia	LV	One locality (Dobele)
Sorbus aucuparia	LV	Several localities
Symphoricarpos sp. (not *Symphoricarpos albus*)	PL	One locality (Skiernewice)
Syringa × chinensis	LV	One locality (Dobele)
Syringa emodi	LV	One locality (Dobele)
Syringa × hyacinthiflora	LV	One locality (Dobele)
Syringa × josiflexa	LV	One locality (Dobele)
Syringa 'Lark Song'	LV	One locality (Dobele)
Syringa persica 'Alba'	LV	One locality (Dobele)
Syringa × prestoniae	LV	One locality (Dobele)
Syringa pubescens s. l.	LV, LT	Several localities
Syringa tomentella s. l.	LV	One locality (Dobele)
Viburnum lantana 'Aureovariegatum'	LV	One locality (Zaļenieki)
Viburnum opulus	LV	One locality (Dobele)

their feeding on *Brunnera sibirica* was not observed.

Weevil feeding on leaves of true *Cydonia oblonga* (not *Chaenomeles japonica*) was confirmed for the first time during this study at three localities in Dobele and its surroundings. Weevil feeding on *Cydonia oblonga* can be described as facultative, since the adjacent food plants (*Prunus cerasifera* and *Rubus caesius* at the same locality) were damaged much more intensively.

In addition to the main and alternative food plants that were recorded, there were other woody plant species (e.g. *Acer negundo, Acer platanoides, Caragana arborescens, Caragana frutex, Quercus robur, Robinia pseudoacacia, Tilia* spp., and *Ulmus glabra*) at many of the sites surveyed, often even in contact with food plants of *O. smreczynskii*. However, feeding was not recorded on leaves of these species.

At one site (Dobele, edge of Upes street, LV) an accidental feeding of *O. smreczynskii* on leaves of *Philadelphus* sp. was observed in 2017. With no doubt this feeding can be considered accidental, as in many localities surveyed, especially in Latvia and Poland, *Philadelphus* spp. plants grew together with various food plants normally preferred by adults *O. smreczynskii*, but beetle feeding on *Philadelphus* spp. was never observed. The mentioned hedgerow line, located next to the *Philadelphus* sp. shrub was surveyed several times from 2014 to 2017. This line was formed of the following woody plants: *Caragana arborescens, Caragana frutex, Fraxinus excelsior* (small plants), *Ligustrum vulgare, Prunus cerasifera, Spiraea* sp., *Symphoricarpos albus*, and *Syringa vulgaris*. All of these woody species (with the exception of both *Caragana* species) were used as food plants by *O. smreczynskii*, as identified by the presence leaves that were damaged at different intensities.

Discussion

V. oculata and *O. smreczynskii* are interesting insect species for study, as both have alien origin to the area of this study (Baltic countries, Poland, and Sweden), as well as their initial food plants are of an alien origin to this territory. The original food plant of *V. oculata* in its natural distribution area seems to be *Syringa reticulata* s.l. (Matsumura 1931; Matsamura 1932).

According to the previous studies, all food plants of *V. oculata* belong to the three genera, *Fraxinus, Ligustrum*, and *Syringa* (Söderman 2005; Stalažs 2013), all from the tribe Oleaee, family Oleaceae (Wallander, Alber 2000). The particular *Fraxinus, Ligustrum* and *Syringa* species, which previously were not identified to a species level, are listed in the results section (Table 1) for the first time as food plants for this species. It was expected that other species from the mentioned plant genera could act as additional food plants for *V. oculata*, which was confirmed in this study. However, during a previous study, the feeding of *V. oculata* on *Forsythia* sp. of the same family Oleaceae was not observed (Stalažs 2013). Similarly, in this study, when a larger number of *Forsythia* plants were inspected, the feeding of *V. oculata* on this genus was also not confirmed. This let us to conclude that *V. oculata* only feeds on a range of Oleaee species and not on plants from different tribes. Tribe Oleaee also includes *Chionanthus virginicus* (subtribe Oleinae), of which one relatively small specimen was also surveyed. It was surveyed only once and therefore it was not possible to obtain sufficient data to confirm *V. oculata* feeding on plants of this genus. Considering that in general *V. oculata* feeds on plants belonging to the Oleaee tribe, can be assumed that *Chionanthus virginicus* could, however, be a food plant of *V. oculata*.

The presence of *V. oculata* in north-eastern Poland and in Sweden (this study) and in Ukraine (Matsiakh, Kramarets 2020) demonstrates that this leafhopper species has continued to spread to the west of Europe. Previously it was postulated that *V. oculata* could act as a potential vector of plant pathogens (Stalažs 2013). Unfortunately, research in this area has not yet been done. As *V. oculata* continues to spread in Europe, this leafhopper species could be a dangerous potential vector of bacteria-like plant pathogens, e.g. phytoplasmas. It is known that other leafhoppers belonging to the family Cicadellidae are potential vectors of different phytoplasma species (e.g. Arocha-Rosete et al. 2011; Galetto et al. 2011; Ivanauskas et al. 2014). One of phytoplasma species, '*Candidatus Phytoplasma asteris*', has also been reported as a pathogen of a native and important forest tree, *Fraxinus excelsior* (Kamińska, Berniak 2009), which is also one of the food plants of *V. oculata*. Recently the pathogen *Hymenoscyphus fraxineus* (syn. *Hymenoscyphus pseudoalbidus*), an agent of European ash dieback, has caused an outstanding economic and ecological loss in the whole of Europe (e.g. Baral, Bemmann 2014; Bengtsson et al. 2014). As negative influence of *V. oculata* on young *Fraxinus excelsior* plants has been observed in forests in Latvia and Sweden (Stalažs 2013, and this study), and since hypothetically, *V. oculata* is able to transmit bacterial pathogens, this may increase the loss of *Fraxinus excelsior* forests that are already deteriorating due to the negative impact of several emerging pathogens, including *Hymenoscyphus fraxineus*, spreading in Europe over the last decades.

The results of this study confirm high polyphagy of *O. smreczynskii* weevils at their imaginal stage. As far as it can be seen from the reviewed literature sources (reviewed in the Introduction chapter), as well as from the observations of this study, adult weevils are generally limited to feeding on leaves of woody plants, but not on herbaceous ones. Perhaps this is due to the fact that woody plants are perennials, which can provide food resources and shelter for these beetles for many generations. This is the only way to explain why adult weevils feed directly on woody plants. An evolutionary preference for woody as opposed to herbaceous plants can be explained by persistence of the foliage of woody plants until autumn, while the foliage of many herbaceous plants dies back already in the second part of summer. Long-term observations allow concluding that not only members of Oleaceae are the most preferred food plants by weevils, since several plants of other families are also commonly and intensively consumed, which was well demonstrated by intensively damaged plant leaves. However, from a bionomic point of view, it is important that polyphagy of adult beetles remains restricted to particular plant families, especially Oleaceae and Rosaceae, as it has also been established previously (e.g. Balalaikins, Bukejs 2011; Dedyukhin 2014).

As all *Otiorhynchus* weevils are apterous (Wanat et al. 2011), this explains polyphagy of a number of species in this genus. Moreover, evident preference of food plants is known for particular species (Wanat et al. 2011), as in *O. smreczynskii*, since adult weevils choose particular plant species, especially some of the most favoured ones. As the species is polyphagous, it can survive if the main food plants are absent, since apterous beetles cannot easily fly away to find the most favoured plants. This can also explain why *O. smreczynskii* are more attracted to woody plants. This study found that if the main food plants grow together with the alternative food sources, then the plant preference was clearly noticeable. If food plants were equally attractive to beetles, the intensity of damage was similar, for example, when *Euonymus europaeus* occurred next to *Syringa vulgaris*, both plants were very attractive to beetles. This was a reason for broadening the list of the main food plants by including not only *Ligustrum* and *Syringa* on this list, but also *Euonymus europaeus, Prunus cerasifera, Rhamnus cathartica, Ribes alpinum* and *Symphoricarpos albus*. *Forsythia* spp. and some *Lonicera* species could also be potential main food plants. If alternative food plants occurred together with the main ones, it was possible to observe a difference of food preference between ‘main’ and ‘alternative’ food plants, as alternative ones usually were consumed with lower intensity, like some *Rosa* species, especially *Rosa rugosa* and *Rosa spinosissima* when even occasional or facultative feeding was observed. However, occasional feeding is important for survival of the species when weevils are forced to switch to plants that are the only ones available in their habitat, as observed when weevils fed on *Philadelphus* sp. leaves.

Some of food plant species from the genera *Forsythia, Lonicera, Spiraea* and *Weigela* were not identified to species level, but from each of these genera, several species were found to be food plants for *O. smreczynskii*. Feeding association with *Lonicera* was known previously (Yunakov 2003). Plants from this genus were common in many localities, including the shrub-like and liana-like species, *Lonicera caprifolium*. Leaves of *Lonicera* plants usually were not intensively consumed, as compared to the main food plants, but beetles seem to have preference for particular *Lonicera* species. These plants are related to *Symphoricarpos albus*, which now has been listed as the main food plant. Dedyukhin (2014) reports feeding of *O. smreczynskii* on *Lonicera tatarica*, and Yunakov et al. (2012) provides records of finding adult beetles in leaf litter under *Lonicera tatarica* shrubs. In this study, *Lonicera* plants mainly occurred close to the main food plants.

Balalaikins and Bukejs (2011) pointed out that *O. smreczynskii* should not be treated as a rare species, but rather as an understudied one. In Latvia, this species was already in 1976 mentioned as *Otiorhynchus* sp. by Rupais (1976). He describes the specific cut marks on damaged leaves and remarks that locally this weevil species seriously damages leaves of *Ligustrum vulgare, Syringa josikaea, Syringa reticulata* subsp. *amurensis* (as *Syringa amurensis*) and *Syringa vulgaris*. Observations from this study demonstrate that *O. smreczynskii* is a widely distributed species in Latvia, and the species generally occurs in anthropogenic habitats. However, *O. smreczynskii* was not observed at all surveyed sites, as in some localities only V. *oculata* occurred on the conjunctive food plants of both insects. As apterous *O. smreczynskii* spreads only passively, this species strongly depends on human activities or natural phoronts, in contrast to *V. oculata*, which is able to spread in flight. This explains why in Latvia the beetles are not present consistently in all places where suitable feed plants are available.

Dedyukhin (2014) reported that if *O. smreczynskii* occurs massively then weevils can feed even on *Acer negundo* (Sapindaceae) and *Betula pendula* (Betulaceae). However, this was not confirmed in this study, although these tree species, as well as *Acer platanoides*, were present in many of the sites surveyed. The only exception was *Betula pendula*, where the feeding of beetles was recorded in one site in Estonia (Tartu). It can be assumed that *O. smreczynskii* prefers maples only if another food source is unavailable. The same pattern was observed with other food plants reported by Dedyukhin (2014) – *Ulmus* sp. (Ulmaceae) and *Caragana arborescens* (Fabaceae). As two *Caragana* species were common in Dobele, and *Caragana arborescens* in number of other localities, these plants were also specially observed, but beetles feeding on these plants were not observes.

In new territories, both *V. oculata* and *O. smreczynskii* have been found feeding on several plant species that do not occur in their native distribution areas. It is known that in native areas *V. oculata* is associated only with *Syringa reticulata* s.l. (Matsumura 1931; Matsamura 1932). In Europe, this species switched to feeding on other lilac species, and even to plants belonging to other genera – *Fraxinus excelsior* and *Ligustrum vulgare* (Stalažs 2013). There are no studies performed in the natural distribution area of *V. oculata* and as a result there is no information about its other potential food plants in its native region. As *V. oculata* can develop on plants from subtribes

Fraxininae and Ligustrinae within Oleeae tribe (Oleaceae); it is possible that *V. oculata* can feed also on other related species, including *Olea europaea*, an important crop plant in southern Europe belonging to the same tribe (Wallander, Albert 2000). It can be expected that *V. oculata* will continue to spread to the south of Europe. As *O. smreczynskii* is a more polyphagous species, this weevil has a larger number of new main and alternative food plants in the new distribution areas of weevils, where these particular types of food plants have been introduced by humans. In Latvia most of the food plants of *O. smreczynskii* have an alien origin.

The results of this study provide information on only the feeding of adult weevils, and the feeding of larval stage still remains insufficiently studied. However, given that adult beetles do not fly, and that the amount of damage to the surface parts of plants has increased from year to year (as observed over a longer period in Dobele, Latvia), it is safe to assume that the larvae also feed on the roots of the same plants as adult beetles, but this was not addressed in this study and needs to be further examined in the future. In the future, not only the range of larval food plants should be studied, but also their possible economic importance and also the possible negative impact on the plants themselves should be investigated.

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