Comparisons of the weevil fauna (Curculionidae, Apionidae, Bruchidae) of fifteen legume hosts (Fabaceae) in South Sweden

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The legume host preference of species belonging to Curculionidae, Apionidae, and Bruchidae was studied in the province of Scania, South Sweden during 2010–2015. It was suggested that significant differences existed between host preferences reported from other parts of Europe and South Sweden. In total, 375 pure stands of 15 legume species (Fabaceae), 25 stands of each species, were carefully searched, each stand for 15 min., using a scoop net. A total of 68 species belonging to Curculionidae, Apionidae, and Bruchidae with known or suspected preference for legumes were found. Species with <10 individuals in the material as a whole were excluded from statistical analysis, leaving 44 species of these groups to be considered. Correspondence Analysis (CA) performed on plant-weevil species relationships closely reflected the phylogenetic relationships of the host plants and demonstrated that most weevils were distinctly related to one single legume species, or to a few species phylogenetically closely related. Comparisons with information from Central Europe, the British Isles, and Denmark showed that the host preferences for legume genera documented in Scania were often similar to those observed elsewhere, but that considerable differences existed within the same host genus, particularly in *Trifolium.*

Key Words: weevil fauna, legumes, Fabaceae, Sweden

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INTRODUCTION

This study is concerned with the preference of species belonging to the families Curculionidae, Apionidae, and Bruchidae for wild-growing legume hosts in Scania, the most southern province of Sweden. The few species of seed bugs, Bruchidae, that occur in Sweden were included because of their strict dependence on legumes.

The host preference of weevils and related groups has been intensively studied in various parts of Europe as is evident from, e.g., Freude et al. 1981, 1983 (central Europe), Morris 1990 (Britain), Hansen 1965, the Danish Data Centre for Biodiversity (Denmark, South Scandinavia), and the Swedish Species Gateway (Sweden). However, the results of such studies differ, although there are similarities as well. Incongruence among studies may be attributed to several reasons. The frequency of various host plants may differ among regions or studies may have been carried out in different ways, either as observations in the field or as feeding experiments using forage plants with higher or lower suitability for a particular species. Occasional observations of individuals “being on the wrong track” may have been included in the data, etc.

Still, these studies show that as far as the numerous weevil species feeding on legumes (Fabaceae) are concerned, a certain species is frequently restricted to host species of a single plant genus, sometimes even to a single species. But there is also a smaller share of weevils that is more polyphagous, occasionally even omniphagous, regarding plant species or plant material (cf., e.g., Hansen 1965).

Legumes and their weevils have a more or less southern-based distribution in Scandinavia (Swedish Species Gateway). Most of the legumes grow on soils with alkaline or neutral character – only slightly acidic. In symbiosis with nitrogen-fixing bacteria, they thrive on fresh soils that are still low in organic matter and nitrogen. They are therefore common colonisers of recently disturbed mineral soils.

The aims of this study were to describe and compare similarities and differences in the weevil fauna, as defined above, of 15 species of wild-growing legumes in South Sweden. Comparisons were made mainly with regard to host preferences of the legume weevil fauna according to the references given above.

MATERIAL AND METHODS

During the summer months (June–August) in the years 2010–2012 and 2014–2015, a total of 375 stands of 15 legumes (see Tables 1–2), 25 stands of each species, situated almost throughout the whole province of Scania, South Sweden, were searched using a scoop net. Scania (Skåne) is the southernmost province of Sweden, covering an area of ca 10 000 km^2 and having a population of ca 1.3 million people. The stands were situated in open land and were most often surrounded by meadows or pastures containing other species of legumes as well. Every stand occupied a total area of ca. 25 m^2, which was searched for 15 minutes. As criteria for acceptance of a stand, the legume host should dominate the vascular plant vegetation and no other legume species should be present in the stand, or in that part of the stand which was searched by the scoop net. As *Plantago lanceolata* is almost ubiquitous in all open land of the area and impossible to avoid completely, weevils known or considered to be bound to this plant were excluded from the study. The habitats of the stands differed to some extent, but were most often some type of abandoned land, road verge, or recently used agricultural field and pasture. Fields with actively cultivated legumes were avoided.

Nomenclature follows Freude et al. (1981, 1983). As these authors treat *Apion seniculus* Kirby, 1808 as one taxonomical unit, *Apion meieri* Desbrochers de Loges, 1901 (cf. Dieckmann 1989) was not discerned separately in this study. Moreover, the two closely related host plants, *Melilotus officinalis* (L.) Lam. and *Melilotus albus* Medik. have been considered as one host, as they are difficult to distinguish morphologically if not flowering, and often develop mixed stands.

STATISTICAL METHODS

Only species with e”10 individuals in the material as a whole were included in the statistical analysis of the data, leaving 44 of a total of 68 species to be treated. Further, to avoid the effects of some weevils being recorded in very large numbers, the data were normalised for each weevil across all host plants prior to analysis. Then, to visualise the choice of hosts of the weevils and the relationships between the faunas of the different host plants, Correspondence Analysis (CA) was performed using the program PAST (version 3.04 for Mac; Hammer et al. 2001). The two first axes resulting from this analysis, describing 10.6 % and 10.3 % of the total variance, respectively, together appeared to give a useful view of the distribution of those weevils shared by several host plants, while subsequent axes were each strongly associated with a single almost monophagous weevil species. These latter axes did thus not add much information to the basic data listed in Tables 1–2 and were consequently not presented in Fig.1.

RESULTS

Out of the 15 wild-growing host legumes (in the following text given in bold italics), studied in order to establish their weevil fauna in South Sweden, *Trifolium medium* was observed to have more species (n=32; 26) than any of the other legumes. Here, the first figure indicates the total number of species recorded, whereas the second figure states the number of species with e”10 individuals in the material. *T. medium* was followed by *T. pratense* (n= 25; 22) and *Melilotus officinalis / albus* (n=25; 20). The lowest number of species was found in *Ononis spinosa* (n=10; 9), *T. repens* (n=12; 11), and *Medicago falcata* (n=13; 10). The other host plants were intermediate in this respect.

The largest number of individuals was recorded in *T. hybridum*, *T. pratense*, and *T. repens* (Tab. 1), all dominated by one or a few species of Apionidae. Least rich in individuals were *Medicago falcata*, *Medicago lupulina*, and *Lupinus polyphyllus*. The high number of individuals in the *Trifolium* hosts was almost completely dependent on a few *Apion* species. Except for *Apion ononicola*, *O. spinosa* was poor in individuals. *Cytisus scoparius* was almost devoid of *Apion* species, except for a few omnivorous ones occasionally found. However, a single individual of *Apion fuscirostre* was recorded once (close to the town of Sjöbo, in 2011).

Most of these weevil species as well as individuals almost exclusively or preferentially occurred on only one, sometimes on two, of the 15 host plants. Most host plants housed at least one to three species that were closely or exclusively related to one particular host. Species found with >90 % of their individuals on only one of the host plants are indicated by an asterix (*) below and in Tab. 2.

The first two axes of the CA graph (Fig. 1) clearly separate most of the hosts. To the lower right there are three hosts with adjoining weevils. *L. polyphyllus* housed a single species, *Sitona gressorius**. This weevil was first reported from Sweden as late as 1999, but is already widespread in South Sweden (Swedish Species Gateway 2015). Positioned in the vicinity of *L. polyphyllus* in the graph is *C. scoparius* with *Bruchidius cisti**, *Sitona griseus**, *Phyllobius viridicollis**, and, somewhat less close, *Phyllobius maculicornis*, *Strophosoma melanogrammum*, and *Strophosoma capitatum*. However, these *Phyllobius* and *Strophosoma* species are considered more or less omnivorous (Hansen 1965), although apparently not or only rarely feeding on the other host plants of this study. Higher up in the right-hand side/lower part of the graph we find *Anthyllis vulneraria* with one single closely related weevil, *Hypera trilineata**, almost unknown from the other 14 hosts studied (Tab. 2).

Three host plants are located in the lower left portion of the graph (Fig. 1). Far out to the left is *O. spinosa* with *Apion ononicola**. It is notable that *Apion ononis*, common on this plant in Denmark, was only found with three individuals and therefore excluded from the statistical analysis. Closer together are *Vicia cracca* and *Lathyrus pratensis*, the former with *Apion cerdo**, *Apion viciae**, and *Apion spencei**, the latter with *Bruchus loti** and *Apion ervi**.

Melilotus officinalis/albus is located in the upper left-hand portion of the graph (Fig. 1), together with *Apion meliloti**, *Sitona cylindricollis**, and *Tychius meliloti**. Nearby is also *Tychius flavicollis*, although sometimes found on *Lotus corniculatus* as well. The latter host is otherwise only distinguished by *Apion loti**. The two *Medicago* hosts, *M. falcata* and *M. lupulina*, are barely separated by the CA analysis, but are together distinguished from all other host plants studied by the rather frequent

Tab. 1. Total number of individuals found per host. Each host includes 25 stands a 25 m^2. Host names in bold italics

Host	Apionidae	Curculionidae	Bruchidae
Anthyllis vulneraria	24	79	0
Cytisus scoparius	11	276	418
Lathyrus pratensis	56	71	114
Lotus corniculatus	270	33	2
Lupinus polyphyllus	17	68	0
Medicago falcata	24	31	0
Medicago lupulina	57	33	1
Melilotus offic./albus	114	217	1
Ononis spinosa	148	7	0
Trifolium arvense	222	13	0
Trifolium hybridum	1855	250	0
Trifolium medium	378	76	1
Trifolium pratense	1597	84	0
Trifolium repens	1300	327	0
Vicia cracca	181	40	1
Sum of individuals	6254	1605	538

presence of *Apion tenue*. In addition, *Sitona humeralis* was rather frequent on *M. lupulina* but never found on *M. falcata.*

The five *Trifolium* hosts are all located in the upper right-hand portion of the graph (Fig. 1), with *T. arvense* distinctly apart from the other four. It carried two *Apion* species, *A. dissimile** and *A. varipes,* both not rare on this host but seldomly found on the other hosts. The other four hosts were very rich in individuals of small species and are located rather close to each other in the upper right-hand portion of Fig. 1. *T. repens* and *T. hybridum* are clearly united by the common presence of numerous *Tychius (Miccotrogus) picirostris* and *Apion flavipes,* but separated by *Apion virens** in *T. repens* and by *Apion seniculus/meieri** in *T. hybridum.* The most species-rich hosts, *T. pratense* and *T. medium,* had several species more or less in common, such as *Hypera nigrirostris* and *Sitona sulcifrons.* However, *T. pratense* almost exclusively housed *Apion apricans** and *A. trifolii,* whereas *Apion gracilipes** was exclusively found on *T. medium.* According to literature, *Apion gracilipes* seems to have a distribution gap in Northern Germany and Denmark (Hansen 1965; Freude et al. 1983). In Scania, it was only found rather frequently in the northern part of the province.

Tab. 2. Host preference of species with ≥75 % of all individuals found on one single host. Asterisk (*) indicates that >90 % of all individuals were found on one single host. Host names in bold italics.

Host	Species
Anthyllis vulneraria	*Hypera trilineata**
Cytisus scoparius	*Bruchidius cisti*, Sitona griseus*, Phyllobius maculicornis, Phyllobius viridicollis**
Lathyrus pratensis	*Apion ervi*, Bruchus loti**
Lotus corniculatus	*Apion loti**
Lupinus polyphyllus	*Sitona gressorius**
Medicago falcata	*Apion tenue (*together with *Medicago lupulina)*
Medicago lupulina	*Apion tenue (*together with *Medicago falcata)*
Melilotus off./albus	*Apion meliloti*, Sitona cylindricollis*, Sitona lineatus, Tychius flavicollis, Tychius meliloti**
Ononis spinosa	*Apion ononicola**
Trifolium arvense	*Apion dissimile*, Apion varipes*
Trifolium hybridum	*Apion flavipes (*together with *Trifolium repens), Apion seniculus / meieri**
Trifolium medium	*Apion gracilipes**
Trifolium pratense	*Apion apricans*, Apion assimile, Apion trifolii*
Trifolium repens	*Apion flavipes, Tychius picirostris (*both together with *Trifolium hybridum), Apion virens**
Vicia cracca	*Apion cerdo*, Apion spencei*, Apion viciae**

DISCUSSION AND CONCLUSIONS

The relationships among the legume species shown by the CA analysis based on their weevil species (Fig. 1) clearly correspond to the phylogeny and taxonomy of these plants (LPWG 2013). The different species of *Trifolium* cluster relatively tightly together, and relatively close to the two species of *Medicago* as they belong to the same tribus, and in the same direction as *Melilotus* (all members of Trifolieae). Likewise, *Vicia cracca* clusters with *Lathyrus pratensis* (Fabeae), and *Cytisus scoparius* with *Lupinus polyphyllus* (Genisteae). The distant position of *Ononis* (Trifolieae) in the CA plot may be explained by the very low number of weevil species found on this host. Most probably, this pattern reflects that phylogenetically related plant species in general are both structurally similar and equipped with a similar chemical constitution, even if the production of secondary metabolites in Fabaceae has been shown to be largely independent of phylogenetic constraints (Wink 2013).

At least two of the host plants started to grow wild in Sweden rather late. *Cytisus scoparius* was probably introduced to the southern parts of Sweden around the middle of the 19th century or even later (Olsson & Tyler 2015). South Sweden suffers from occasional cold winters, particularly when the snow cover is scanty. In Jutland (Denmark), where the climate is milder and this host is often quite abundant, there are three species of *Apion* (*A. fuscirostre, A. striatum,* and *A. immune),* which are also widespread in that region and considered to be essentially bound to this host (Hansen 1965). In the present study, one individual of *A. fuscirostre* was recorded on *Cytisus* in a single stand. In addition, it was re-

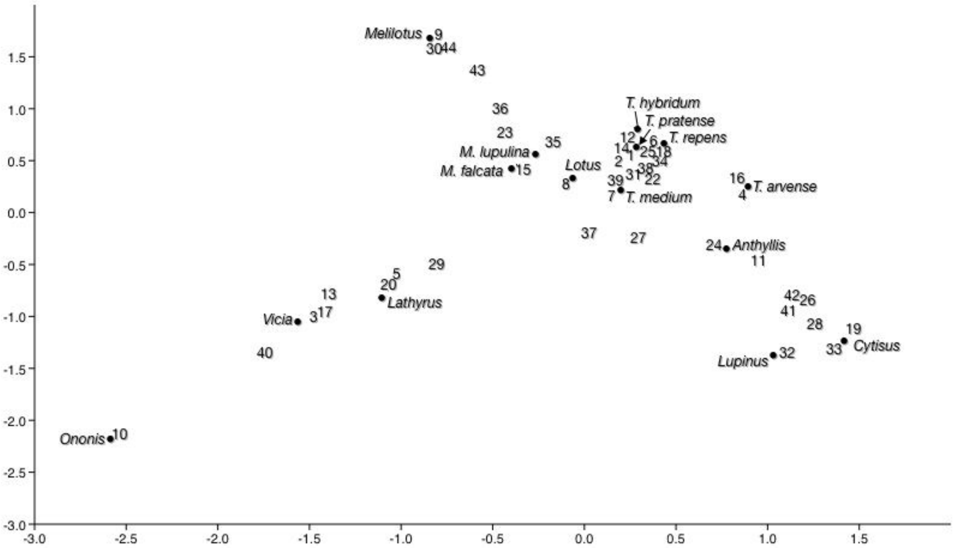

Fig. 1. Ordination plot showing the distribution of weevil species (numbers) and their host plants (dots + names; see Tab. 1 for full names) along the two first axes resulting from Correspondence Analysis (describing 10.6 % and 10.3 % of the total variance, respectively). The names of the weevils are replaced by numbers: 1 = *Apion apricans*, 2 = *A. assimile*, 3 = *A. cerdo*, 4 = *A. dissimile*, 5 = *A. ervi*, 6 = *A. flavipes*, 7 = *A. gracilipes*, 8 = *A. loti*, 9 = *A. meliloti*, 10 = A. *ononicola*, 11 = *A. pubescens*, 12 = *A. seniculus/meieri*, 13 = *A. spencei*, 14 = *A. trifolii*, 15 = *A. tenue*, 16 = *A. varipes*, 17 = *A. viciae*, 18 = *A. virens*, 19 = *Bruchidius cisti*, 20 = *Bruchus loti*, 21 = *Hypera meles* (hidden behind "25" in the plot), 22 = *H. nigrirostris*, 23 = *H. postica*, 24 = *H. trilineata*, 25 = *Miccotrogus (Tychius) picirostris*, 26 = *Phyllobius maculicornis*, 27 = *P. viridiaeris*, 28 = *P. viridicollis*, 29 = *Sitona ambiguus*, 30 = *S. cylindricollis*, 31 = *S. flavescens*, 32 = *S. gressorius*, 33 = *S. griseus*, 34 = *S. hispidulus*, 35 = *S. humeralis*, 36 = *S. lineatus*, 37 = *S. lineellus*, 38 = *S. puncticollis*, 39 = *S. sulcifrons*, 40 = *S. suturalis*, 41 = *Strophosoma capitatum*, 42 = *S. melanogrammum*, 43 = *Tychius flavicollis*, 44 = *T. meliloti*

cently (2013–2014) reported by the Swedish Species Gateway (2015) to occur in several places in Scania, which were the first findings in the province according to this source.

Lupinus polyphyllus is another recent immigrant to Sweden. Although first introduced as a garden plant in the 1830's (Lundquist 2007) it was rarely found wild-growing before the middle of the 20th century (Olsson & Tyler 2007). Nowadays it is spreading invasively, especially along roadsides, on waste sites, abandoned fields, and former pasture land. *Sitona gressorius* was first reported by the Swedish Species Gateway in 1999, but is already widely distributed on *Lupinus polyphyllus*, and closely related taxa, in South and Southeast Sweden.

Dispersal limitations of specialised parasites and pathogens are commonly regarded as a reason why some species become invasive when introduced to a new geographic range (Flory & Clay 2013). Even if it is doubtful whether or not weevils may limit their host spread, it is interesting to note that neither *Cytisus scoparius* nor *Lupinus polyphyllus* were particularly poor in weevil species in the present study. However, most of the weevils found on *Cytisus scoparius* were species generally reported as omnivorous (although not frequent on other legumes in the present study) while *Sitona gressorius* was the only species found that was clearly specialised on *Lupinus polyphyllus*.

Out of the 44 species considered frequent enough to be included in the statistical analysis, 20 species may be considered monophagous as they were exclusively or almost exclusively found on one single host (those indicated by * in Tab. 2). To a large extent, this host is the same, or at least one of closely related hosts, as in Central Europe according to Freude et al. (1981, 1983), or on the British Isles according to Morris (1990). Exceptions do occur, however. In the present study, *Apion ervi* was frequent on *Lathyrus pratensis* (90% of all individuals of this species), but an occasional guest on *Vicia cracca* (<5 %). In Denmark, it is also stated for *Vicia hirsula* (Hansen 1965). On the contrary, *Apion viciae* is stated to live on both *Lathyrus* and *Vicia* in Central Europe (Freude et al. 1981), but was only found on *Vicia* in the present study.

Aberrations between literature sources and this study are largest in the *Trifolium* hosts. In the work of Freude et al. (1981), many *Apion* species are indicated either as feeding on several *Trifolium* hosts or on this genus in general. Examples are *Apion flavipes, Apion trifolii, Apion varipes, Apion assimile, Apion pubescens,* and *Apion virens*. In the present study, these species seem concentrated on only one (*Apion flavipes*) or two *Trifolium* species. (Tab. 2).

Mechanisms conducting host preference in weevils are with few exceptions poorly known. A basic criterion is certainly that the insect must be able to find the host. One mechanism may involve the host plant exuding species-specific, often volatile substances which the sensory organs of the insect are able to react upon (Zwölfer & Harris 1971; Nyabuga et. al. 2015). Host preferences have probably developed as an interaction between plant and insect during a very long time. However, some invasive insects seem to suddenly be able to develop a preference for another host within a new geographical area. The preference may sometimes even develop within the same weevil generation. As an example, different individuals from a population of *Sitona flavescens* (or *S. lepidus*) preferring *T. repens* could be trained to prefer *T. pratense* as the host plant (Gerard & Crush 2003). Colonisation of a new host is often accompanied by gradual genetic changes that improve weevil performance (Messina & Pena 2012). The fact that host preference is not always wholly stable is also indicated by the finding that a species may prefer different hosts within different parts of its distribution range. A problem in evaluating host preference of weevils is that several wild-growing legume hosts may be genetically ‘contaminated’ by cultivated forms of the same species with a different resistance to weevil attacks (Murray 1996). Good examples are *T. repens* and *T. pratense*.

However, this does not explain why a particular plant species is suitable as a host for one insect species but not for another. Even closely related plants may contain different chemical compounds, on which insects may react in different ways, also when the structural properties of these plants seem very similar. Many weevils, particularly as larvae, feed on seeds, where great differences among plant species and genera are known, e.g. in composition and concentrations of lipids. Seeds of *Vicia* and *Lathyrus* have low concentrations of lipids, whereas lipid concentrations in *Melilotus* are ten times as high (Jones & Earle 1962). In addition, leaves of different legumes may differ chemically to a great extent; some species of *Lupinus* may even be toxic to many animals. The role of different alkaloids of cultivated genotypes was indicated by Ströcker et al. (2013). Flavonoids in the roots of some legumes may also explain host preferences of weevils (Crush et al. 2007). A comprehensive review of the organic chemical composition of legumes is found in, e.g., Hegnauer & Hegnauer (1994).

Summarising the main conclusions of the study, plant-weevil species relationships closely reflect the phylogenetic relationships of the host plants and demonstrate that most weevils are distinctly related to one single legume species, or to a few species phylogenetically closely related. Comparisons with information from Central Europe, the British Isles, and Denmark show that the host preferences for legume genera, here documented for Scania, are often similar to those observed elsewhere, but that considerable differences exist even within the same host genus, particularly in *Trifolium.*

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