

Diversity of true bugs (Hemiptera: Heteroptera) on common ragweed (*Ambrosia artemisiifolia*) in southern Slovakia

PETER TOTH (✉ phytomyza@gmail.com)

Slovak University of Agriculture in Nitra

Veronika KRCHŇAVÁ

Slovak University of Agriculture in Nitra

Monika TÓTHOVÁ

Slovak University of Agriculture in Nitra

Research Article

Keywords: insect guild, habitat, invasive weed, vectors, carriers, Cimicomorpha, Pentatomomorpha, plant pathogens

Posted Date: April 24th, 2023

DOI: <https://doi.org/10.21203/rs.3.rs-2821032/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License. [Read Full License](#)

Abstract

Common ragweed (*Ambrosia artemisiifolia* Linnaeus 1800) is an exceptional invasive species. Information on true bugs occurring on ragweed plants is limited in the invasion region. The objective of this study was to determine the species composition of Heteroptera associated with *A. artemisiifolia*, assess their vectoring potential based on a literature review, and compare species similarity on the surveyed fields. Field surveys were conducted in 2020–2021 at 10 sites in southern Slovakia. Sweeping and visual observations were conducted in field margins, weedy agricultural fields, and mowed meadows infested with *A. artemisiifolia*. As part of the study, food specialization, abundance of each species, and their assignment to families were determined in detail. The Jaccard similarity index was used to evaluate the similarity of species composition among the sites studied. A total of 2,492 true bugs were recorded, representing 47 species of Heteroptera from 12 families. The most common phytophagous species were *Nysius ericae ericae* (Schilling 1829) (Pentatomomorpha, Lygaeidae), *Adelphocoris lineolatus* (Goeze 1778), *Lygus rugulipennis* (Poppius 1911), *Lygus pratensis* (Linnaeus 1758) (Cimicomorpha, Miridae), and a zoophagous species *Nabis (Dolichonabis) limbatus* (Dahlbom 1851) (Cimicomorpha, Nabidae). The similarity of species in paired localities was low, with highly migratory and polyphagous species dominating, able to cross the field from the adjacent landscape. *A. artemisiifolia* is a known host for plant viruses and phytoplasmas, and several Heteroptera species are carriers of these plant pathogens. *Halyomorpha halys* was the only detected carrier of phytoplasmas, and its abundance on *A. artemisiifolia* was extremely low.

Introduction

Common ragweed (*Ambrosia artemisiifolia* /Linnaeus 1800/Asteraceae) is an invasive North American plant in Europe and elsewhere (Essi et al. 2015; Chauvel and Cadet 2011; Guillemain and Chauvel 2011; Kazinczi and Novák 2014; Weber 2017). The species has serious negative impacts on agriculture (Kazinczi et al. 2008) and human health (Storms et al. 1997, Simard and Benoit 2010) and threatens biodiversity (Zisenis 2015). It produces allergenic pollen that is hazardous to the human respiratory system (Bordas-Le Floch et al. 2015; Smith et al. 2013) and is a major cause of allergic rhinitis (Hamaoui-Laguel et al. 2015). The native insect guild associated with common ragweed in Europe is mostly polyphagous and causes little damage. Only 18 insect species have been proposed as candidates for biological control of *A. artemisiifolia* in Europe (Gerber et al. 2011). True bugs/Heteroptera (Insecta: Hemiptera: Heteroptera) are a large, cosmopolitan suborder of Hemiptera that includes over 45,000 described species. This is a diverse, abundant, and globally successful group. Their trophic behavior is also diverse, ranging from herbivores to predators (Cassis 2019). Most true bugs are phytophagous (Dolling 1991), and habitat characteristics are important for the structure of their guilds (Zurbrugg and Frank 2006). Herbivorous species include some destructive pests, while predatory species can be useful in agriculture, horticulture, and forestry (Dolling 1991). Numerous sap-sucking bugs are involved in plant disease transmission (Mitchell 2004; Mitchell et al. 2018). Accurate data on true bugs are scarce, e.g., on sandy grasslands (Torma et al. 2017), in agricultural landscapes (Gibicsár and Keszthelyi 2023; Laterza et al. 2023), or on litter and soil (Abukenova et al. 2022), but the occurrence of heteropterans on common ragweed in its introduced range in Eurasia is an area that remains poorly studied (Maceljski and Igrc 1989; Kiss et al. 2008; Franin et al. 2021; Limonta et al. 2022). Because the occurrence of heteropterans on ragweed was common, we hypothesized that they might serve as carriers or vectors of ragweed diseases. Therefore, we decided to conduct a survey in southern Slovakia to determine the species composition of Heteroptera on *A. artemisiifolia*, their trophic preferences, and their ability to transmit and/or carry diseases. We also investigated the effects of geographic regions and local habitats on true bugs guild.

Materials And Methods

Heteropterans were collected with an insect net (30 cm diameter) by sweeping the canopy of *A. artemisiifolia* or beating the plants (3 x 30 plants per locality). Species caught in situ were euthanized in the field with ethyl acetate (C₄H₈O₂). Insects were monitored at 10 localities in southern Slovakia in 2020 and 2021 (Table 1, Fig. 1). Screening was conducted from mid-July (beginning of flowering) to mid-late August (end of flowering) in three habitat types - field margins, weedy agricultural fields, and mowed meadows. The localities had low elevation, had sandy-loam or loamy soils, warm to very warm climates, moderately moist to very dry areas, and mild to cool winters (Zaťko et al. 2002). As the crow flies, the distance between the westernmost (Balvany) and easternmost locality (Malé Trakany) was 310 km. The Jaccard similarity index was used to assess the true similarities in bug species composition between two localities (Fontoura Costa 2022; Glen 2023). Trophic preferences and vectoring ability were determined using information published in the literature. Relevant entomological identification keys were used to identify the true bugs, and the identification was confirmed by Heteroptera expert Jozef Cunev, Nitra, Slovakia.

Table 1. Geographical coordinates and habitat characteristics of the studied localities in southern Slovakia in 2020-2021.

Locations	Latitude, Longitude	Altitude (m/a.s.l.)	Habitats, Geo relief	Climate region
Western Slovakia				
Balvany	47°50'24"N, 17°59'57"E	110	Field margins, plane	Warm, very dry, mild winter
Malá nad Hronom	47°51'25"N, 18°40'40"E	140	Weedy agricultural field, hilly country	Warm, very dry, mild winter
Sikenička	47°55'42"N, 18°41'34"E	140	Field margins, hilly country	Warm, very dry, mild winter
Central Slovakia				
Gemerský Jablonec	48°11'57"N, 19°59'22"E	239	Mowed meadow, hilly country	Warm, moderate humid, cool winter
Tachty	48°09'23"N, 19°56'59"E	262	Field margins, hilly country	Warm, moderate humid, cool winter
Eastern Slovakia				
Brehov	48°29'59"N, 21°48'29"E	112	Field margins, hilly country	Warm, dry, cool winter
Malé Trakany	48°23'58"N, 22°07'54"E	110	Field margins, plane	Warm, dry, cool winter
Strážne	48°22'23"N, 21°50'47"E	100	Weedy agricultural field, plane	Warm, dry, cool winter
Svätuš	48°25'16"N, 21°55'10"E	110	Field margins, plane	Warm, dry, cool winter
Veľký Horeš	48°22'22"N, 21°54'10"E	100	Weedy agricultural field, plane	Warm, dry, cool winter

Results And Discussion

During field surveys in 2020–2021 at 10 localities throughout southern Slovakia, 2,496 Heteroptera individuals were detected in sweep samples from stands of invasive *A. artemisiifolia*. A total of 47 species from the 12 families Nabidae, Miridae, Tingidae (Cimicomorpha), Coreidae, Rhopalidae, Stenocephalidae, Berytidae, Lygaeidae, Oxycarenidae, Rhyparochromidae, Pentatomidae, and Scutelleridae (Pentatomomorpha) were detected (Table 2).

Table 2
True bugs (Hemiptera: Heteroptera) fauna of flowering *Ambrosia artemisiifolia* during 2020–2021 in southern Slov

Infraorder/ Family/Species	Food specialisation	References	Balvany	Malá nad Hronom	Sikenička	Gemerský Jablonec	Tachty	Brehov	Malé Trakany	Strážn
CIMICOMORPHA										
NABIDAE										
<i>Nabis (Dolichonabis) limbatus</i> Dahlbom, 1851	zoophagous	Wachmann et al. 2006 in Malenovský et al. 2011	53	185	4	7	14	2	25	12
<i>Nabis rugosus</i> (Linnaeus, 1758)	zoophagous	Wachmann et al. 2006 in Malenovský et al. 2011								
MIRIDAE										
<i>Adelphocoris lineolatus</i> (Goeze, 1778)	phyto, poly (Fabaceae, eggs are laid to some Asteraceae)	Puchkov 1972 in Saulich & Musolin 2020	70	149	5	32	20	6	53	35
<i>Adelphocoris vandilicus</i> (Rossi, 1790)	phyto, poly (incl. Asteraceae)	Yazıcı & Yildirim 2017		1						
<i>Adelphocoris seticornis</i> (Fabricius, 1775)	phyto, oligo (Fabaceae)	Wachmann et al. 2004: in Malenovský et al. 2011				1			3	
<i>Deraeocoris (Deraeocoris) ruber</i> (Linnaeus, 1758)	zoophagous	Collyer 1953							1	
<i>Deraeocoris (Camptobrochis) punctulatus</i> (Fallén, 1807)	phytozoophagous (mostly Solanaceae)	Chinajariyawong & Harris 1987 Sanchez et al. 2003	1	2						
<i>Lygocoris (Lygocoris) pabulinus</i> (Linnaeus, 1761)	phyto, poly	Southwood & Leston 1959 in Eyles 1999					1		1	
<i>Lygus pratensis</i> (Linnaeus, 1758)	phyto, poly (incl. Asteraceae)	Lu & Wu 2008 in Saulich & Musolin 2020	47	37	18	6	5	4	23	12
<i>Lygus rugulipennis</i> Poppius, 1911	phyto, poly (Asteraceae among the most important)	Holopainen & Varis 1991	54	92	2	3	6	1	2	3
<i>Orthops (Orthops) campestris</i> (Linnaeus, 1758)	phyto, oligo (Apiaceae)	Wachmann et al. 2004 in Malenovský et al. 2011		1			3	2	1	
<i>Orthotylus</i> sp.	various, indefinite			50						
<i>Stenodema (Brachystira) calcarata</i> (Fallén, 1807)	phyto, poly (Poaceae rarely Cyperaceae and Juncaceae)	Hradil et al. 2013		2		1				2
<i>Trigonotylus pulchellus</i> (Hahn, 1834)	phyto, poly (Amaranthaceae, Fabaceae, <i>Vitis vinifera</i>)	Lodos et al. 2003 in Kivan & Dirik 2016	3	11	1	1		3	6	2
TINGIDAE										
<i>Corythucha ciliata</i> (Say, 1832)	phyto, oligo (<i>Platanus</i> spp.)	Rabitsch 2008							1	
<i>Dictyla echii</i> (Schrank, 1782)	phyto, oligo (Boraginaceae)	Stehlík 2002							1	

Infraorder/ Family/Species	Food specialisation	References	Balvány	Malá nad Hronom	Sikenička	Gemerský Jablonec	Tachty	Brehov	Malé Trakany	Strážň
PENTATOMOMORPHA										
COREIDAE										
<i>Coreus marginatus marginatus</i> (Linnaeus, 1758)	phyto, poly (Polygonaceae, Asteraceae)	Putshkov 1962 in Pekár & Hrušková 2006		5					1	
<i>Gonocerus juniperi</i> (Herrich-Schaeffer, 1839)	phyto, oligo (Cupressaceae)	Rabitsch 2008		1						
RHOPALIDAE										
<i>Brachycarenum tigrinus</i> Schilling, 1829	phyto, poly (mostly Brassicaceae, Chenopodioideae, Amaranthaceae, Ericaceae)	Aukema 1993		7						
<i>Corizus hyoscyami hyoscyami</i> (Linnaeus, 1758)	phyto, poly (incl. Asteraceae)	Stewart et al. 2015		1						
<i>Chorosoma schillingii</i> (Schilling, 1829)	phyto, oligo (Poaceae)	Vilímová & Rohanová 2010		1						
<i>Myrmus miriformis miriformis</i> (Fallén, 1807)	phyto, oligo (Poaceae)	Stehlík & Vavřínová 1989		2						
<i>Stictopleurus abutilon abutilon</i> (Rossi, 1790)	phyto, oligo (Asteraceae)	Honěk et al. 2013		3	1					
<i>Stictopleurus punctatonevrosus</i> (Goeze, 1778)	phyto, oligo (Asteraceae)	Stehlík & Vavřínová 1989	1						4	
<i>Rhopalus (Rhopalus) parumpunctatus</i> Schilling, 1829	phyto, poly (incl. Asteraceae)	Stehlík & Vavřínová 1989, Ellis 2001–2022		7					1	1
<i>Rhopalus (Rhopalus) subrufus</i> (Gmelin, 1790)	phyto, poly (incl. Asteraceae, some preference for Lamiaceae)	Stehlík & Vavřínová 1989, Ellis 2001–2022		3						
STENOCEPHALIDAE										
<i>Dicranocephalus medius</i> (Mulsant a Rey, 1870)	phyto, oligo (<i>Euphorbia</i>)	Ellis 2001–2022		3						
BERYTIDAE										
<i>Berytinus (Berytinus) minor minor</i> (Herrich-Schaeffer, 1835)	phyto, poly (mainly Fabaceae)	Ellis 2001–2022, Gierlasiński et al. 2019	1							
LYGAEDIDAE										
<i>Lygaeus equestris</i> (Linnaeus, 1758)	phyto, mono (<i>Vincetoxicum hirundinaria</i>)	Laukkanen et al. 2014		1					1	
<i>Nysius ericae ericae</i> (Schilling, 1829)	phyto, poly (incl. Asteraceae)	Linnavuori 2011 Ellis 2001–2022	63	1004	1	2				11
<i>Nysius helveticus</i> (Herrich-Schaeffer, 1850)	phyto, poly (incl. Asteraceae)	Ellis 2001–2022								
<i>Nysius senecionis senecionis</i> (Schilling, 1829)	phyto, oligo (Asteraceae, preference for <i>Senecio</i>)	Ellis 2001–2022, Stehlík & Vavřínová 1997								

Infraorder/ Family/Species	Food specialisation	References	Balvany	Malá nad Hronom	Sikenička	Gemerský Jablonec	Tachty	Brehov	Malé Trakany	Strážň
OXYCARENIDAE										
<i>Metopoplax origani</i> (Kolenati, 1845)	phyto, oligo (Asteraceae)	Redei 2007							4	
RHYPAROCHROMIDAE										
<i>Rhyparochromus vulgaris</i> (Schilling, 1829)	phyto, poly (seed feeder)	Stehlík & Vavříňová 1998, Ellis 2001–2022		2						
PENTATOMIDAE										
<i>Aelia acuminata</i> (Linnaeus, 1758)	phyto, oligo (Poaceae)	Stehlík 1985		12					1	
<i>Aelia klugii</i> Hahn, 1833	phyto, oligo (Poaceae)	Halászfy 1959		1						
<i>Aelia rostrata</i> (Boheman, 1852)	phyto, oligo (Poaceae)	Kment et al. 2013		2						
<i>Carpocoris</i> (<i>Carpocoris</i>) <i>purpureipennis</i> (De Geer, 1773)	phyto, poly (incl. Asteraceae)	Stehlík 1986, Linnavuori 2008	2						1	
<i>Dolycoris baccarum</i> (Linnaeus, 1758)	phyto, poly (incl. Asteraceae)	Gözüačık & Konuksal 2019								
<i>Eurydema (Eurydema) oleracea</i> (Linnaeus, 1758)	phyto, oligo (Brassicaceae)	Stehlík 1986	1	4						
<i>Eysarcoris ventralis</i> (Westwood, 1837)	phyto, poly (incl. Asteraceae)	Hemala et al. 2014		1						
<i>Graphosoma italicum</i> (Müller, 1766)	phyto, oligo (Apiaceae)	Stehlík 1984					1		1	
<i>Peribalus (Peribalus) strictus strictus</i> (Fabricius, 1803)	phyto, poly (incl. Asteraceae)	Ghahari et al. 2014							2	
<i>Piezodorus lituratus</i> (Fabricius, 1794)	phyto, poly (mainly Fabaceae)	Ellis 2001–2022				1				
<i>Halyomorpha halys</i> Stål, 1855	phyto, poly (incl. Asteraceae)	Khadka et al. 2021		2						
<i>Zicrona caerulea</i> (Linnaeus, 1758)	zoophagous	Noge & Tamogami 2018		2					1	
SCUTELLERIDAE										
<i>Eurygaster testudinaria testudinaria</i> (Geoffroy, 1785)	phyto, poly (mostly Poaceae, Cyperaceae, incl. Asteraceae)	Stehlík 1995, Ellis 2001–2022								
			296	1594	32	54	50	18	134	78

Table 2

The phytophagous true bugs guild was the most abundant with 41 species (2,102 specimens). Polyphagous were 23 different species (2,029 specimens). These species were generalists with a wide range of host plants; therefore, it was difficult to determine their trophic preferences in detail. However, a more detailed analysis of trophic relationships revealed the dominance of polyphagous species with trophic affinity for Asteraceae (16 species, 1,979 specimens). The most common polyphagous species without trophic affinity to Asteraceae was *Trigonotylus pulchellus* (Hahn, 1834) which occurred at most of the localities examined in this study. The remaining polyphagous species occurred in low numbers and at random in the habitats studied. The abundance of specialized species (oligophagous and monophagous) was extremely low compared to generalists. A total of 17 oligophagous species (71 specimens)

The trophic preferences of monophagous species (2 specimens) were not associated with Asteraceae.

The four most abundant herbivorous species were *Nysius ericae ericae* (Schilling 1829) (Pentatomomorpha: Lygaeidae) 44.07%, *Adelphocoris lineolatus* (Goeze 1778) 19.27%, *Lygus rugulipennis* (Poppius 1911) 7.57%, and *Lygus pratensis* (Linnaeus 1758) 6.85% (Cimicomorpha: Miridae). All are polyphagous

with trophic relationships to Asteraceae, native and widespread in Europe (Saulich and Musolin 2020). In Italy, *N. ericae ericae* was common in dry grasslands with shrubs and invasive plant invasion (Limonta et al. 2022). *N. ericae* has also been identified as a forager on green mustard pods and a carrier of the plant pathogen *Nematospora coryli* (Burgess et al. 1993). According to Judd and Hodkinson (1998), this species is associated with Asteraceae on early successional sites, sand dunes, marshes, heaths, and wastelands and on abandoned or weedy agricultural fields. Despite their polyphagy, many species of mirid bugs (Miridae) show specific feeding preferences for host plants and plant parts (Wheeler 2001). *A. lineolatus* shows a strong preference for *Medicago sativa* - a host plant important for overwintering and early season development (Lu et al. 2011; Pan et al. 2013). Preferred host plants of *L. rugulipennis* are nitrophilous wild plants (*Urtica dioica*, *Artemisia vulgaris*, *Tripleurospermum inodorum*, *Matricaria matricarioides*, *Senecio vulgaris*) and the most reported cultivated host plants are Fabaceae (*Medicago sativa* and *Trifolium pratense*), which symbiotically fix nitrogen (Holopainen and Varis 1991). *L. pratensis* is biologically and ecologically close to *L. rugulipennis*, has a similar range of host plants, and often co-occurs with the latter, although usually in smaller numbers (Puchkov 1966). The four most common herbivore species are known to be vectors or carriers of plant pathogens (viruses, phytoplasmas, bacteria, fungi) (Table 3).

Table 3
Vectoring potencial and presence of viruses and Mollicutes in true bugs (Hemiptera: Heteroptera) associated with flowering *Ambrosia artemisiifolia* during 2020–2021 in Slovakia

Infraorder/Family/Species	Food specialisation	carrier/vector	References	Abundance (pcs)	Abundance (%)
CIMICOMORPHA					
MIRIDAE					
<i>Adelphocoris lineolatus</i> (Goeze, 1778)	phyto, poly (Fabaceae, eggs are laid to some Asteraceae)	<i>Ca. P. solani</i> (16Sr XII) (carrier) Aster yellows phytoplasma (16Srl-C and 16Srl-F) (carrier)	Šafářová et al. 2018 Korbášová 2012	481	19.27
<i>Lygocoris (Lygocoris) pabulinus</i> (Linnaeus, 1761)	phyto, poly	<i>Erwinia amylovora</i> (pear shoots) (vector)	Emmet & Baker 1971	3	0.12
<i>Lygus pratensis</i> (Linnaeus, 1758)	phyto, poly (incl. Asteraceae)	<i>Ca. P. solani</i> (16Sr XII) (mixed sample of <i>L. pratensis</i> and <i>L. rugulipennis</i>) (carrier) Potato leaf roll virus (PLRV), Potato virus Y (PVY), Potato virus S (PVS), Potato virus M (PVM), Potato virus A (PVA) (carrier)	Březíková & Linhartová 2007 Sobko et al. 2021, 2022	171	6.85
<i>Lygus rugulipennis</i> Poppius, 1911	phyto, poly (Asteraceae among the most important)	Potato leaf roll virus (PLRV), Potato virus M (PVM) (vector) X-disease 16SrlI-B (in larva) (carrier) <i>Ca. P. solani</i> (16Sr XII) (carrier) Aster yellows phytoplasma (16Srl-C and 16Srl-F) (carrier) <i>Pseudomonas syringae</i> pv. <i>aptata</i> (sugar beet) (carrier)	Turka 1978 in Mitchell 2004 Orságová et al. 2011 Šafářová et al. 2018 Korbášová 2012 Bilewicz-Pawińska 1967 in Wheeler 2001	189	7.57
<i>Orthops (Orthops) campestris</i> (Linnaeus, 1758)	phyto, oligo (Apiaceae)	<i>Stemphylium radicinum</i> (vector)	Bech 1967 Cite in Ratnadass & Deguine 2020	7	0.28
PENTATOMOMORPHA					
LYGAEIDAE					
<i>Nysius ericae ericae</i> (Schilling, 1829)	phyto, poly (incl. Asteraceae)	<i>Nematospora coryli</i> (on Brassica juncea) (carrier)	Burgess et al. 1993	1100	44.07
PENTATOMIDAE					
<i>Halyomorpha halys</i> Stål, 1855	phyto, poly (incl. Asteraceae)	Paulownia witches' broom phytoplasma (16Srl-D) (vector)	Hiruki 1999	2	0.08

Table 3

L. pratensis has been identified as a carrier of potato viruses - Potato leaf roll virus (PLRV), Potato virus Y (PVY), Potato virus A (PVA), Potato virus S (PVS), Potato virus M (PVM) (Sobko et al. 2021; Sobko et al. 2022). Recognized vectors for these viruses are aphids. PVRL is persistently transmitted circulative in a persistent circulative manner, all others are not persistently transmitted and spread via tubers and mechanically (Kumar et al. 2022; Lacomme et al. 2017; Agindotan et al. 2007; Fuentes et al. 2021). *A. artemisiifolia* served as a reservoir for PVY virus (Sobko et al. 2021; Sobko et al. 2022). *L. rugulipennis* and *A. lineolatus* were recently identified as new carriers of *Ca. Phytoplasma solani* (Šafářová et al. 2018). Although *Ca. P. solani* has a broad host plant range, including weeds (Quagliano 2022), direct evidence of *A. artemisiifolia* as a host plant has only recently been confirmed (Kosovac et al. 2023). Asteraceae

(including *A. artemisiifolia*) are known hosts for the Aster yellows phytoplasma (AYp). This phytoplasma was detected in *A. lineolatus* and *L. rugulipennis* collected in southern Moravia (Czech Republic) (Korbášová 2012). In another study conducted in vineyards in the same region, AYp was not detected in these two true bugs (Šafářová et al. 2018). The X-disease phytoplasma found in *L. rugulipennis* infects most *Prunus* species and potentially a wide host range of herbaceous plants including annual and perennial weeds (Jensen 1971). Recently, a phytoplasma of the X-disease group, ribosomal subgroup 16SrIII-B, was detected in some perennial herbaceous plants of the Asteraceae family, *Echinacea purpurea* (L.) Moench. from native to North America (Fránová et al. 2013), *Cirsium arvense* (L.) Scop. (Rančić et al. 2005), and *Arnica montana* L. native to Europe (Pavlovic et al. 2012) were found. It is important to note that isolation of phytoplasmas from *A. lineolatus*, *L. rugulipennis*, and *L. pratensis* does not guarantee that they can transmit the disease (Mitchel 2004). These true bug species belong to the infraorder Cimicomorpha (Heteroptera), which are characterized by a non-envelope-forming cell rupture type. Repeated intracellular penetration of their thicker stylet causes mechanical and enzymatic damage to plant tissue (Tingey and Pillemer 1977). Because phytoplasmas are obligate parasites that inhabit the living intracellular plant environment (Hogenhout et al. 2008), functional and undamaged cells are required for successful infection (Mitchel 2004). The ability of *Stephanitis typica* (Tingidae), the only Cimicomorpha species previously classified as a phytoplasma vector, to function as a vector has not been confirmed (Edwin and Mohankumar 2007). Non-phloem feeding *Lygus* species preferentially feed on plant meristem tissue or developing reproductive organs (Strong 1970). Plant meristematic tissue is usually free of pathogens (Laimer and Bertaccini 2019). Meristematic tissues in terminal buds are the main source of auxin (Müller and Leyser 2011). Loss of auxin producing tissues due to feeding by *Lygus* bugs can lead to altered vegetative growth. Altered plant architecture is a result of suppressed apical dominance and increased growth of lateral branches from axillary buds (Strong 1970). These morphological changes can be described as umbelliferous plant habits with an apartment-topped appearance, as described for inflorescences of *Arabidopsis thaliana* (L.) Heynh. (Suzuki et al. 2002). The witches' broom symptoms induced by phytoplasmas are also associated with the loss of apical dominance of shoots (Bertaccini et al. 2022), but the change in plant habit is due to the excessive proliferation of slender shoots arising at or near the same site (Kúdela et al. 2007).

Because phytoplasmas are phloem-limited, phloem-feeding insects can potentially ingest and transmit the pathogen (Weintraub and Beanland 2006). Phloem feeding is usually associated with the formation of stylet salivary sheaths (Backus 1988). In Heteroptera, the formation of salivary sheaths is a common feature of the infraorder Pentatomomorpha, but their targets include mesophyll or reproductive tissue (mature seeds, developing endosperm) in addition to vascular tissue. In the case of seed feeding, leaf sheath formation is minimal (Mitchel 2004). Aster yellows phytoplasma (ribosomal subgroup Srl-A) has recently been detected in seeds and seedlings of *Zea mays* L. (Nipah et al. 2007), *Brassica napus* L., and *B. rapa* L. (Olivier et al. 2010). Many Lygaeidae species feed on nutrient rich seeds, but also on plant sap (Schuh and Slater 1995). The most numerous seed-feeding species in our collection was *N. ericae ericae*. Their ability to acquire phytoplasmas from seeds or other plant parts is not known, but phytoplasma DNA was found in two Lygaeoidea species, *Nysius vinitor* Bergroth and *Oxycarenus maculatus* Stal (White et al. 1997; Wicczorek and Wright 2003). However, there is evidence that phytoplasmas may be pathogens or beneficial symbionts of hemipteran insects (Hogenhout et al. 2008). In Slovakia, the highly polyphagous invasive *Halyomorpha halys* Stål, 1855 (Pentatomomorpha: Pentatomidae) was present in the guild of species associated with *A. artemisiifolia*. *H. halys* transmits the Paulownia witches' broom phytoplasma. Phytoplasma isolates from China, Korea, and Japan belonged to ribosomal subgroup 16Srl (Aster yellows and related phytoplasmas) (Hiruki 1999).

The fifth most abundant species was the predatory true bug *Nabis (Dolichonabis) limbatus* Dahlbom, 1851 (Nabidae) with a relative abundance of 13.46%. Nabids are predators of leafhoppers (Auchenorrhyncha), aphids (Sternorrhyncha), leaf beetles (Coleoptera: Chrysomelidae), and eggs and larvae of Lepidoptera. Several species are also predators of Miridae, especially the genus *Lygus* (Lattin, 1989). *N. limbatus* occurred at all observed localities, except of Svätušie. In Svätušie, only one specimen of *N. rugosus* (Linnaeus, 1758) was found at the field margins. There is evidence that nabids respond to habitat manipulation. Higher populations are found in more diverse agroecosystems where insecticides are not used (Hammond and Stinner 1987). Because there is evidence that nabids feed on plants to obtain water (Ridgway and Jones 1968), the use of systemic insecticides may negatively affect their populations (Lentz et al. 1983).

A few specimens of *Zicrona caerulea* (Linnaeus, 1758) (Pentatomidae) found at two surveyed localities were predaceous. The species is usually associated with *Oenothera biennis* L. (Onagraceae) infested by herbivores outside of agricultural land. *O. biennis* may act as a companion plant that maintains this predatory true bug in the field margin and inside the crop field (Noge and Tamogami 2018).

The predominantly phytophagous Miridae included a zoophagous species, *Deraeocoris (Deraeocoris) ruber* (Linnaeus, 1758) and a few specimens of the zoophytophagous *Deraeocoris (Camptobrochis) punctulatus* (Fallén, 1807). *D. punctulatus* was most abundant on solanaceous plants (Sanchez et al. 2003) and frequently fed on the whitefly *Bemisia tabaci* (Gennadius, 1889) (Hemiptera: Aleyrodidae) (Stam and Elmosa 1990). *B. tabaci* is an important and versatile vector of plant viruses (Fiallo-Olivé et al. 2020). Zoophytophagous true bugs feed on plants and prey on arthropods, both of which can harbor plant viruses or phytoplasmas, for example. Zoophytophagous generalists such as *Macrolophus pygmaeus* (Rambur, 1839) and *Nesidiocoris tenuis* (Reuter, 1895) (Miridae) are widely used biological control agents. Feeding damage to potato plants caused by these mirid bugs did not result in transmission potato virus Y (Pazyuk and Fominykh 2019). On the other hand, phytophagy of *N. tenuis* or *M. pygmaeus* on pepper plants reduced Tomato Spotted Wilt Virus replication by activating of the jasmonate and salicylate pathways (Bouagga et al. 2020; Pérez-Hedo et al. 2022). Another efficient zoophytophagous predators used in biological control are from the genus *Orius* (Anthracoridae). Phytoplasma was detected in *Orius* sp. preying upon *Aceria proteae* (Acarina: Eriophyiidae) bearing a high concentration of the pathogen. *Orius* sp. is not thought to act as a vector, but it has not been studied (Wicczorek and Wright 2003).

The highest similarity of true bug species was observed in pair combination of distant localities with low species diversity - Sikenická, Gemerský Jablonec, and Strážne (60–70%). Most of the pair-wise combined localities had a low species similarity with the median of Jaccard index 28% (Table 4). This suggests the differences in Heteroptera species composition at the localities studied and a weak relationship with habitats and *A. artemisiifolia*.

Table 4
Jaccard similarity index (%) of true bug species on *Ambrosia artemisiifolia* by pairwise compared sites and quantitative characteristics of heteropteran guild. Heteroptera were collected throughout southern Slovakia in 2020–2021.

Sites	Balvany	Malá n/Hronom	Sikenička	Gemerský Jablonec	Tachty	Brehov	Malé Trakany	Strážne	Svätuše	Veľký Horeš
Balvany	•	24	50	43	28	33	28	46	17	37
Malá n/Hronom	9/28*	•	23	22	15	17	27	27	8	21
Sikenička	6/12	7/30	•	60	40	50	22	67	27	50
Gemerský Jablonec	6/14	7/22	6/10	•	33	40	17	70	12	42
Tachty	4/14	4/33	4/11	4/12	•	50	33	36	23	38
Brehov	5/12	6/30	5/8	5/10	5/8	•	23	44	18	33
Malé Trakany	7/25	11/37	5/23	5/24	7/21	6/20	•	26	25	28
Strážne	6/13	8/30	6/9	7/10	4/11	5/9	6/23	•	13	46
Svätuše	5/16	5/36	4/14	4/16	5/13	4/13	8/24	4/15	•	17
Veľký Horeš	6/16	7/34	6/12	6/14	5/12	5/12	7/24	6/13	5/17	•

* The number of same species on both sites / amount of all species in both sites

We studied three habitats, the most predominant ones were field margins, ragweed/weed infested agricultural fields and a mowed meadow, in three geographical areas of southern Slovakia (Table 1). We believe that the composition of the landscape surrounding each field studied had a stronger influence on the composition and abundance of insect species than the field vegetation itself. The main reason for this could be the prevalence of polyphagous species and the presence of oligophagous species without trophic affinity to Asteraceae (Table 2). Like other pest species, heteropterans are good fliers and colonisers that use and traverse different habitat types during their life cycle (Fauvel 1999), and in summer *A. artemisiifolia* provided a suitable food source (maturing seeds on the main inflorescence and terminal buds on side shoots) for both infraorder representatives. Weeds are an important alternative food source and play a significant role in promoting biodiversity in agroecosystems (Capinera 2005; Marshall et al. 2003).

Conclusion

The studied localities in southern Slovakia showed low species similarity of true bugs with Jaccard index averaging median 28% and weak relationship with habitats and *A. artemisiifolia*. The community of true bugs was composed of 16 species of the infraorder Cimicomorpha (51.48%) and 31 species of infraorder Pentatomomorpha (48.52%). The Cimicomorpha species, *Adelphocoris lineolatus* and *Lygus pratensis*, were recorded at all 10 localities, *Nabis limbatus* at 9, *Lygus rugulipennis* and *Trigonotylus pulchellus* at 8 localities. *Nysius ericae ericae* occurred at 6 localities and accounted for 90.83% of all Pentatomomorpha species. The remaining species occurred irregularly. Therefore, we assume that the landscape surrounding each studied field had a stronger influence on the species composition and abundance of the bugs than the vegetation of the field. 69.6% of the polyphagous species had trophic relationships with Asteraceae. The most numerous herbivorous Cimicomorpha species (*A. lineolaris*, *L. rugulipennis*, *L. pratensis*) are known to be carriers of plant viruses or phytoplasmas. The only documented carrier of phytoplasmas is *Halyomorpha halys* (Pentatomomorpha), which transmits Aster yellows and related phytoplasmas to Paulownia trees. *A. artemisiifolia* is a known reservoir for several plant viruses and phytoplasmas, including Aster yellows disease. From our results and the literature review, we can conclude that Heteroptera remains a less important vector of phytoplasmas. *A. artemisiifolia* serves as an important reservoir for plant pests and provides an alternative food source for true bugs in summer, after crop harvest. Therefore, it plays an important role in maintaining populations of polyphagous true bugs in the studied agricultural habitats in southern Slovakia.

Declarations

Acknowledgements

The research was supported by the Agency for Scientific Promotion of the Ministry of Education of the Slovak Republic VEGA 1/0467/22 and the Slovak Agency for Research and Development under contract number SK-SRB -21-0045.

Authors' addresses: Peter TÓTH (corresponding author: phytomyza@gmail.com), Monika TÓTHOVÁ, Veronika KRCHŇAVÁ, Slovak University of Agriculture in Nitra, Institute of Agronomic Sciences, Faculty of Agrobiological and Food Resources, Trieda A. Hlinku 2, 949 76 Nitra, Slovakia.

Author contributions: conceptualization, P.T.; methodology, P.T.; validation, P.T., M.T.; formal analysis, P.T., M.T.; investigation, P.T., V.K.; resources, P.T.; data maintenance, P.T., V.K.; preparation of original draft, P.T., M.T.; revision and editing, P.T., M.T.; supervision, P.T.; project management, P.T., M.T.; acquisition of funding, P.T. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

The authors have no relevant financial or nonfinancial interests to disclose.

References

1. Abukenova VS, Slavchenko NP, Kartbayeva GT, Myrzabayev A.B.; Yeshmagambetova, A.B.; Duzbayeva, N.M.; Kabbassova, M.T.; Abukenova, AK (2022) Composition and Ecological Structure of the Fauna of Litter and Soil True Bugs (Insecta, Heteroptera) in Kazakh Upland (Central Kazakhstan) Pine Forests. *Diversity* 14:618. <https://doi.org/10.3390/d14080618>
2. Agindotan BO, Shiel PJ, Berger PH (2007) Simultaneous detection of potato viruses, PLRV, PVA, PVX and PVY from dormant potato tubers by TaqMan real-time RT-PCR. *J Virol Methods* 142(1-2):1-9. doi: 10.1016/j.jviromet.2006.12.012
3. Aukema B (1993) *Rhopalus tigrinus* (Rhopalidae) en *Eurydema ornatum* (Pentatomidae) nieuw voor de Nederlandse fauna (Heteroptera). *Entomol ber* 53:19–22
4. Backus EA (1988) Sensory systems and behaviors which mediate hemipteran plant-feeding: a taxonomic overview. *J Insect Physiol* 34:151-165. [https://doi.org/10.1016/0022-1910\(88\)90045-5](https://doi.org/10.1016/0022-1910(88)90045-5)
5. Bertaccini A (2022) Plants and Phytoplasmas: When Bacteria Modify Plants. *Plants* 11:1425. <https://doi.org/10.3390/plants11111425>
6. Bordas-Le Floch V, Le Mignon M, Bouley J (2015) Identification of Novel Short Ragweed Pollen Allergens Using Combined Transcriptomic and Immunoproteomic Approaches. *PLoS One* 10: Article Number: e013625. DOI: 10.1371/journal.pone.0136258
7. Bouagga S, Urbaneja A, Depalo L, Rubio L, Pérez-Hedo M (2020) Zoophytophagous predator-induced defences restrict accumulation of the tomato spotted wilt virus. *Pest Manag Sci* 76:561-567. DOI: <https://doi.org/10.1002/ps.5547>
8. Březíková M, Linhartová Š (2007) First report of potato stolbur phytoplasma in hemipterans in southern Moravia – Short Communication. *Plant Protect. Sci.* 43:73-76. <https://doi.org/10.17221/2253-PPS>
9. Burgess L, Dueck J, Mckencie D (1993) Insect vectors of the yeast *Nematospora coryli* in mustard, *Brassica juncea*, crops in southern Saskatchewan. *Can. Entomol.* 115:25-30. DOI:10.4039/Ent11525-1
10. Capinera J (2005) Relationships between insect pests and weeds: An evolutionary perspective. *Weed Sci.* 53:892-901. DOI:10.1614/WS-04-049R.1
11. Cassis G (2019) True Bugs (Insecta: Hemiptera: Heteroptera): Evolution, Classification, Biodiversity and Biology, Reference Module in Life Sciences, Elsevier. DOI: <https://doi.org/10.1016/B978-0-12-809633-8.20710-3>
12. Chauvel B, Cadet E (2011) Introduction and spread of an invasive species: *Ambrosia artemisiifolia* in France. *Acta botanica Gallica: bulletin de la Société botanique de France* 158:309-327.
13. Chinajariyawong A, Harris VE (1987) Inability of *Deraeocoris signatus* (Distant) (Hemiptera: Miridae) to survive and reproduce on cotton without prey. *Aust J Entomol* 26:37-40. <https://doi.org/10.1111/j.1440-6055.1987.tb00255.x>
14. Collyer E (1953) Biology of some Predatory Insects and Mites Associated with the Fruit Tree Red Spider Mite (*Metatetranychus Ulmi* (Koch)) in South-Eastern England II. Some Important Predators of the Mite. *Hortic Sci* 28:85-97. DOI: 10.1080/00221589.1953.11513772
15. Dolling WR (1991) *Hemiptera*. Oxford Natural History Museum Publications, Oxford University Press
16. Duflot R, Georges R, Ernoult A, Aviron S, Burel F (2014) Landscape heterogeneity as an ecological filter of species traits. *Acta Oecol* 56:19-26. DOI: <https://doi.org/10.1016/j.actao.2014.01.004>.
17. Edwin BT, Mohankumar C (2007) Kerala wilt disease phytoplasma: Phylogenetic analysis and identification of a vector, *Proutista moesta*. *Physiol Mol Plant* 71:41-47. DOI: <https://doi.org/10.1016/j.pmpp.2007.10.002>
18. Elliott NC, Kieckhefer RW, Michels GJ, Giles KL (2002) Predator abundance in alfalfa fields in relation to aphids, within-field vegetation, and landscape matrix. *Environ Entomol* 31:253–26. <https://doi.org/10.1603/0046-225X-31.2.253>
19. Ellis WN (2001-2022) Leafminers and plant galls of Europe. *Plant parasites of Europe: leafminers, gallers and fungi*. <https://bladmineerders.nl>
20. Emmett BJ, Baker LAE (1971) Insect Transmission of Fireblight. *Plant Dis.* 20:41–45. <https://doi.org/10.1111/j.1365-3059.1971.tb00507.x>
21. Essl F, Biró K, Brandes D, Broennimann O, Bullock JM, Chapman DS, Chauvel B, Dullinger S, Fumanal B, et al. (2015) Biological Flora of the British Isles: *Ambrosia artemisiifolia*. *J Ecol* 103:1069-1098. <https://doi.org/10.1111/1365-2745.12424>
22. Fahrig L, Baudry J, Brotons L, Burel FG, Crist TO, Fuller RJ, Sirami C, Siriwardena GM, Martin J-L (2011) Functional landscape heterogeneity and animal biodiversity in agricultural landscapes. *Ecol Lett* 14:101-112. <https://doi.org/10.1111/j.1461-0248.2010.01559.x>
23. Fauvel G (1999) Diversity of Heteroptera in agroecosystems: role of sustainability and bioindication. *Agric Ecosyst Environ* 74:275–303. doi:10.1016/s0167-8809(99)00039-0.
24. Fiallo-Olivé E, Pan LL, Liu SS, Navas-Castillo J (2020) Transmission of Begomoviruses and Other Whitefly-Borne Viruses: Dependence on the Vector Species. *Phytopathology* 110:10-17. DOI: 10.1094/PHYTO-07-19-0273-FI.
25. Fontoura Costa L (2022) Further Generalizations of the Jaccard Index. [ffhal-03384438v4](https://hal.science/hal-03384438v4). DOI: <https://hal.science/hal-03384438v4>
26. Franin K, Kuštera Franin G, Maričić B, Marčelić Š, Pavlović M, Kos T, Barić B, Laznik Z (2021) True bugs (Heteroptera) assemblage and diversity in the ecological infrastructures around the Mediterranean vineyards. *Bull Insectology* 74:65-78.
27. Fránová J, Špak J, Šimková M (2013) First report of a 16SrII-B subgroup phytoplasma associated with leaf reddening, virescence and phyllody of purple coneflower. *Eur J Plant Pathol* 136:7–12. DOI: <https://doi.org/10.1007/s10658-012-0145-8>

28. Fuentes S, Gibbs AJ, Adams IP, Wilson C, Botermans M, Fox A, Kreuze J, Boonham N, Kehoe MA, Jones RAC (2021) Potato Virus A Isolates from Three Continents: Their Biological Properties, Phylogenetics, and Prehistory. *Phytopathology* 111:217-226. doi: 10.1094/PHYTO-08-20-0354-FI
29. Gallé R, Tölgyesi C, Császár P, Bátori Z, Gallé-Szpisjak N, Kaur H, Maák I, Torma A, Batáry P (2022) Landscape Structure is a Major Driver of Plant and Arthropod Diversity in Natural European Forest Fragments. *Ecosphere* 13: e3905. <https://doi.org/10.1002/ecs2.3905>
30. Gerber E, Schaffner U, Gassmann A, Hinz HL, Seier M, Müller-Schärer H (2011) Prospects for biological control of *Ambrosia artemisiifolia* in Europe: learning from the past. *Weed Res* 51:559–573. DOI: 10.1111/j.1365-3180.2011. 00879.x
31. Ghahari H, Moulet P, Rider DA (2014) An annotated catalog of the Iranian Pentatomoidea (Hemiptera: Heteroptera: Pentatomomorpha). *Zootaxa* 3837:1-95. DOI: 10.11646/zootaxa.3837.1.1
32. Gibicsár S, Keszthelyi S (2023) Topographical Based Significance of Sap-Sucking Heteropteran in European Wheat Cultivations: A Systematic Review. *Diversity* 15:109. <https://doi.org/10.3390/d15010109>
33. Gierlasiński G, Taszakowski A, Lis B (2019) Stilt bugs (Hemiptera: Heteroptera: Berytidae) of Poland: checklist, distribution, bionomics. *Fragm. Faunist.* 62:1-25. DOI: 10.3161/00159301FF2019.62.1.001
34. Glen S (2023) "Jaccard Index / Similarity Coefficient" From StatisticsHowTo.com: Elementary Statistics for the rest of us! DOI: <https://www.statisticshowto.com/jaccard-index/>
35. Gözüaçik C, Konuksal A (2019) Investigations on Heteroptera (Hemiptera) Species in Cereal Agroecosystem of Turkish Republic of Northern Cyprus. *Kafkas University Institute of Natural and Applied Science Journal* 12:56-67.
36. Guillemain JP, Chauvel B (2011) Effects of the seed weight and burial depth on the seed behavior of common ragweed (*Ambrosia artemisiifolia*). *Weed Biol. Manag.* 11:217-223. DOI: 10.1111/j.1445-6664.2011. 00423.x
37. Halászfy É (1959) Poloskák II. Heteroptera II. Magyarország Állatvilága (Fauna Hungariae), Hungary.
38. Hamaoui-Laguel L, Vautard R, Liu L, Solmon F, Viovy N, Khvorostyanov D, Essl F, Chuine I, Colette A, Semenov M, Schaffhauser A, Storkey J, Thibaudon M, Epstein M (2015) Effects of climate change and seed dispersal on airborne ragweed pollen loads in Europe. *Nat. Clim. Change* 5:766–771. DOI: 10.1038/NCLIMATE2652
39. Hammond RB, Stinner BR (1987) Soybean Foliage Insects in Conservation Tillage Systems: Effects of Tillage, Previous Cropping History, and Soil Insecticide Application. *Environ. Entomol.* 16:524–531. DOI: <https://doi.org/10.1093/ee/16.2.524>
40. Hemala V, Cunev J, Franc V (2014) On the occurrence of the stink bug *Eysarcoris ventralis* (Hemiptera: Heteroptera: Pentatomidae) in Slovakia, with notes on its distribution in neighboring countries. *Klapalekiana* 50:51-59.
41. Hiruki C (1999) Paulownia witches'-broom disease important in East Asia. *Acta Horti* 496: 63-68. DOI: <https://doi.org/10.17660/ActaHorti.1999.496.6>
42. Hogenhout SA, Oshima K, Ammar E, Kakizawa S, Heather N, Kingdom HN, Namba S (2008) Phytoplasmas: bacteria that manipulate plants and insects. *Mol Plant Pathol* 9:403-423. DOI: <https://doi.org/10.1111/j.1364-3703.2008.00472.x>
43. Holopainen JK, Varis AL (1991) Host plants of the European tarnished plant bug *Lygus rugulipennis* Poppius (Het., Miridae). *J Appl Entomol* 111:484-498. <https://doi.org/10.1111/j.1439-0418.1991.tb00351.x>
44. Honěk A, Štys P, Martinková Z (2013) Arthropod community of dandelion (*Taraxacum officinale*) capitula during seed dispersal. *Biologia* 68:330–336. <https://doi.org/10.2478/s11756-013-0157-7>.
45. Hradil K, Psota V, Štastná P (2013) Species diversity of true bugs on apples in terms of plant protection. *Plant Protect Sci* 49:73-83. <https://doi.org/10.17221/30/2012-PPS>
46. Judd S, Hodkinson I (1998) The Biogeography and Regional Biodiversity of the British Seed Bugs (Hemiptera: Lygaeidae). *J Biogeogr* 25:227–249. DOI:10.2307/2846214
47. Jensen DD (1971) Herbaceous Host Plants of Western X-Disease Agent. *Phytopathology* 61:1465.
48. Kazinczi G, Béres I, Pathy Z, Novák R. (2008) Common ragweed (*Ambrosia artemisiifolia* L.): a review with special regards to the results in Hungary: II. Importance and harmful effect, allergy, habitat, allelopathy, and beneficial characteristics. *Herbologia* 9:93-118.
49. Kazinczi G, Novák R (eds.) (2014) Integrated methods for suppression of common ragweed. National Food Chain Safety Office, Directorate of Plant Protection Soil Conservation and Agri-environment, Budapest
50. Khadka A, Hodges AC, Leppla NC, Tillman PG (2021) *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae) Nymph Survival and Adult Feeding Preferences for Crop Plants in Florida. *Fla Entomol* 104:136-139. <https://doi.org/10.1653/024.104.0210>
51. Kiss B, Koczor S, Rédei D (2008) Occurrence and feeding of hemipterans on common ragweed (*Ambrosia artemisiifolia*) in Hungary. *Bull. Insectology* 61:195-196.
52. Kment P, Hradil K, Baňář P, Balvín P, Cunev J, Ditrich T, Jindra Z, Roháčová M, Straka M, Sychra J (2013) New and interesting records of true bugs (Hemiptera: Heteroptera) from the Czech Republic and Slovakia. *Acta Mus Morav, Sci Biol* 98:495-541.
53. Korbášová Z (2012) Výskyt a variabilita fytoplasmy stolburu v *Hyalestes obsoletus* a dalších potenciálních vektorech. Diploma theses. Palackého University, Olomouc.
54. Kosovac A, Čurčić Ž, Stepanović J, Rekanović E, Duduk B (2023) Epidemiological role of novel and already known 'Ca. P. solani' cixiid vectors in rubbery taproot disease of sugar beet in Serbia. *Sci Rep* 13:1433. DOI: <https://doi.org/10.1038/s41598-023-28562-8>
55. Kúdela V, Braunová M (2007) Česko-anglická rostlinolékařská terminologie: Czech-English plant health terminology. Academia: Praha, Czech Republic
56. Kumar R, Tiwari RK, Sundaresha S, Kaundal P, Raigond B (2022). Potato Viruses and Their Management. In: Chakrabarti SK, Sharma S, Shah MA (eds) Sustainable Management of Potato Pests and Diseases. Springer, Singapore. https://doi.org/10.1007/978-981-16-7695-6_12

57. Lacomme C, Glais L, Bellstedt DU, Dupuis B, Karasev AV, (Eds.). (2017). *Potato virus Y: biodiversity, pathogenicity, epidemiology, and management* pp. 141-176). Basel, Switzerland: Springer International Publishing.
58. Laimer M, Bertaccini A (2019) Phytoplasma Elimination from Perennial Horticultural Crops. In: Bertaccini A, Weintraub P, Rao G, Mori N (eds) *Phytoplasmas: Plant Pathogenic Bacteria - II*. Springer, Singapore, 2019, 185-206. DOI: https://doi.org/10.1007/978-981-13-2832-9_9
59. Laterza I, Dioli P, Tamburini G (2023) Semi-natural habitats support populations of stink bug pests in agricultural landscapes. *Agric Ecosyst Environ* AGR 342. DOI: <https://doi.org/10.1016/j.agee.2022.108223>.
60. Lattin JD (1989) Bionomics of the Nabidae. *Annu Rev Entomol* 34:383–400. DOI:10.1146/annurev.en.34.010189.002123
61. Laukkanen L, Mutikainen P, Muola A, Leimu R (2014) Plant-species diversity correlates with genetic variation of an oligophagous seed predator. *PLoS One* e94105. <https://doi.org/10.1371/journal.pone.0094105>
62. Lentz GL, Chambers AY, Hayes RM (1983) Effects of Systemic Insecticide-Nematicides on Midseason Pest and Predator Populations in Soybean. *J Econ Entomol* 76:836–840. DOI: <https://doi.org/10.1093/jee/76.4.836>
63. Limonta L, Gaini P, Dioli P (2022) First Results on Heteroptera (Hemiptera) of Dry Grassland in Malpaga-Basella Nature Reserve (Italy). *Diversity* (Basel) 14:981. DOI: <https://doi.org/10.3390/d14110981>
64. Linnavuori RE (2008) Studies on the Acanthosomatidae, Scutelleridae and Pentatomidae (Heteroptera) of Gilan and the adjacent provinces in northern Iran. *Acta Entomol Mus Natl Pragae* 48:1-21. DOI: 10.5281/zenodo.5342454
65. Linnavuori RE (2011) Studies on the Cimicomorpha and Pentatomomorpha (Hemiptera: Heteroptera) of Khuzestan and the adjacent provinces of Iran. *Acta Entomol Mus Natl Pragae* 51:21-48.
66. Kivan M, Dirik E (2016) Edirne ili buğday ekiliş alanlarında tespit edilen Heteroptera türleri. *Türkiye Entomoloji Bülteni* 6:357-369. <http://dx.doi.org/10.16969/teb.1053>
67. Saulich AKh, Musolin DL (2020) Seasonal Development of Plant Bugs (Heteroptera, Miridae): Subfamily Mirinae, Tribe Mirini. *Entomol Rev* 100:135–156. doi:10.1134/S0013873820020013
68. Lu Y, Jiao Z, Li G, Wyckhuys KAG, Wu K (2011) Comparative overwintering host range of three *Adelphocoris* species (Hemiptera: Miridae) in northern China. *Crop Prot* 30:1455-1460. <https://doi.org/10.1016/j.cropro.2011.07.010>.
69. Maceljiski M, Igrc J (1989) The Phytophagous Insect Fauna of *Ambrosia artemisiifolia* in Yugoslavia. In: Proceedings of VII International Symposium on Biological Control of Weeds, Rome, Italy, March 6-11.
70. Marshall EJP, Brown VK, Boatman ND, Lutman PJW, Squire GR, Ward LK (2003) The role of weeds in supporting biological diversity within crop fields. *Weed Res* 43:77-89. <https://doi.org/10.1046/j.1365-3180.2003.00326.x>
71. Miles PW, Taylor GS (1994) 'Osmotic pump' feeding by coreids. *Entomol Exp Appl* 73:63-173. DOI: <https://doi.org/10.1111/j.1570-7458.1994.tb01852.x>
72. Mitchell PL (2004) Heteroptera as vectors of plant pathogens. *Neotrop entomol* 33 DOI: <https://doi.org/10.1590/S1519-566X2004000500001>
73. Mitchell PL, Zeilinger A, Medrano EG, Esquivel JF (2018) Pentatomoids as vectors of plant pathogens. In: McPherson JE (ed) *Invasive Stink Bugs and Related Species (Pentatomoidea): Biology, Higher Systematics, Semiochemistry, and Management*. Boca Raton, FL: CRC Press. pp 611-640
74. Müller D, Leyser O (2011) Auxin, cytokinin and the control of shoot branching. *Ann Bot* 107: 1203-12. DOI: 10.1093/aob/mcr069.
75. Nipah JO, Jones P, Hodgetts J, Dickinson M (2007) Detection of phytoplasma DNA in embryos from coconut palms in Ghana, and kernels from maize in Peru. *Bull Insectology* 60:385–386.
76. Noge K, Tamogami S (2018) Isovaleronitrile co-induced with its precursor, l-leucine, by herbivory in the common evening primrose stimulates foraging behavior of the predatory blue shield bug, *Biosci Biotechnol Biochem* 82:395-406. DOI: 10.1080/09168451.2018.1433019
77. Olivier CY, Galka B, Sèguin-Swartz G (2010) Detection of aster yellows phytoplasma DNA in seed and seedlings of canola (*Brassica napus* and *B. rapa*) and AY strain identification. *Can J Plant Pathol* 32:298–305. <https://doi.org/10.1080/07060661.2010.508616>
78. Orságová H, Březíková M, Schlesingerová G (2011) Presence of phytoplasmas in hemipterans in Czech vineyards. *Bull. Insectology* 64 (Supplement):S119-S120.
79. Pan H, Lu Y, Wyckhuys KAG (2013) Early-Season Host Switching in *Adelphocoris* spp. (Hemiptera: Miridae) of Differing Host Breadth. *PLoS One* 8:e59000. <https://doi.org/10.1371/journal.pone.0059000>
80. Panizzi AR, Lucini T, Mitchell PL (2021) Feeding sites of true bugs and resulting damage to plants. In: *Electronic Monitoring of Feeding Behavior of Phytophagous True Bugs (Heteroptera)*. Entomology in Focus 6. DOI: https://doi.org/10.1007/978-3-030-64674-5_3
81. Pavlovic S, Pljevljakusic D, Starovic M, Stojanovic S, Josic D (2012) First Report of 16SrII-B Phytoplasma Subgroup Associated with Virescence of *Arnica montana* in Serbia. *Plant Dis* 96:1691. DOI: 10.1094/PDIS-07-12-0650-PDN. PMID: 30727494.
82. Pazyuk IM, Fominykh TS (2019) The evaluation of potato virus Y transfer by some beneficial bugs (Hemiptera: Heteroptera). *Biodiversitas* 20:1222-1227. DOI: <https://doi.org/10.13057/biodiv/d200439>
83. Pérez-Hedo M, Bouagga S, Zhang NX *et al.* (2022) Induction of plant defenses: the added value of zoophytophagous predators. *J Pest Sci* 95:1501–1517. DOI: <https://doi.org/10.1007/s10340-022-01506-3>
84. Pekár S, Hrušková M (2006) How granivorous *Coreus marginatus* (Heteroptera: Coreidae) recognises its food. *Acta Ethol* 9:26–30. <https://doi.org/10.1007/s10211-006-0011-9>
85. Puchkov VG (1966) Glavneishie klopyslepnyaki – vrediteli sel'skokhozyaistvennykh kul'tur (Major Capsid Bugs Important as Agricultural Pests), Kyiv: Naukova Dumka

86. Quaglino F (2022) *Candidatus* Phytoplasma solani (Stolbur phytoplasma), CABI Compendium. CABI International. DOI: 10.1079/cabicompendium.108243.
87. Rabitsch W (2008) Alien True Bugs of Europe (Insecta: Hemiptera: Heteroptera). Zootaxa 1827:1–44. DOI:10.11646/zootaxa.1827.1.1
88. Rančić D, Paltrinieri S, Toševski I, Petanović R, Stevanović B, Bertaccini, A (2005) First report of multiple inflorescence disease of *Cirsium arvense* and its association with a 16SrIII-B subgroup phytoplasma in Serbia. Plant Pathol 54:561-561. DOI: <https://doi.org/10.1111/j.1365-3059.2005.01201.x>
89. Ratnadass A, Deguine JP (2020) Three-way interactions between crop plants, phytopathogenic fungi, and mirid bugs. Agron Sustain Dev 40:46. <https://doi.org/10.1007/s13593-020-00652-1>
90. Redei D (2007) True bug (Heteroptera) assemblages of medicinal and aromatic plants. Ph.D. thesis, Corvinus University, Budapest, Hungary
91. Ridgway RL, Jones SL (1968) Plant Feeding by *Geocoris pallens* and *Nabis americoferus*. Ann Entomol Soc Am 61:232–233. DOI:10.1093/aesa/61.1.232
92. Sanchez J-A, Martinez-Cascales JI, Lacasa A (2003) Abundance and wild host plants of predator mirids (Heteroptera: Miridae) in horticultural crops in the Southeast of Spain. IOBC/WPRS Bulletin 26:147-15.
93. Saulich AK, Musolin DL (2020) Seasonal Development of Plant Bugs (Heteroptera, Miridae): Subfamily Mirinae, Tribe Mirini. Entomol Rev 100:135–156. doi:10.1134/S0013873820020013
94. Schuh RT, Slater JA (1995) True bugs of the world (Hemiptera: Heteroptera): classification and natural history. Cornell University Press, Ithaca, New York
95. Simard MJ, Benoit DL (2010) Distribution and abundance of an allergenic weed, common ragweed (*Ambrosia artemisiifolia* L.), in rural settings of southern Quebec, Canada. Can J Plant Sci 90:549-557. DOI: <http://dx.doi.org/10.4141/CJPS09174>
96. Smith M, Cecchi L, Skjøth CA, Karrer G, Šikoparija B (2013) Common ragweed: a threat to environmental health in Europe. Environ Int 61:115-126. <https://doi.org/10.1016/j.envint.2013.08.005>
97. Sobko OA, Matsishina NV, Fisenko PV, Kim IV, Didora AS, Boginskay NG, Volkov DI (2021) Viruses in the agrobiocenosis of the potato fields, In: IOP Conference Series: Earth and Environmental Science. DOI:10.1088/1755-1315/677/5/052093
98. Sobko O, Matsishina N, Fisenko P, Kim I, Boginskaya N (2022). Phytoviruses in the Potato Field Tripartite Agroecosystem. In: Muratov A, Ignateva S (eds) Fundamental and Applied Scientific Research in the Development of Agriculture in the Far East (AFE-2021). Lecture Notes in Networks and Systems. Springer, Cham. https://doi.org/10.1007/978-3-030-91402-8_49.
99. Eyles AC (1999) New genera and species of the Lygus-Complex (Hemiptera: Miridae) in the New Zealand subregion compared with subgenera (now genera) studied by Leston (1952) and Niestama, Reuter, New Zealand. J Zool 26:303-354. DOI: 10.1080/03014223.1999.9518198
100. Stam PA, Elmosa H (1990) The role of predators and parasites in controlling populations of *Earias insulana*, *Heliothis armigera* and *Bemisia tabaci* on cotton in the Syrian Arab Republic. Entomophaga 35:315–327. DOI:10.1007/bf02375255
101. Stehlík JL (1984) Results of the investigations on Hemiptera in Moravia made by the Moravian Museum (Pentatomoidea 3). Acta Mus Morav, Sci Biol 69:163–185.
102. Stehlík JL (1985) Results of the investigations on Hemiptera in Moravia made by the Moravian Museum (Pentatomoidea 4). Acta Mus Morav, Sci Biol 70:147–175.
103. Stehlík JL (1986) Results of the investigations on Hemiptera in Moravia made by the Moravian Museum (Pentatomoidea 5). Acta Mus Morav, Sci Biol 71:147–178.
104. Stehlík JL (1995) Results of the investigations on Hemiptera in Moravia made by the Moravian Museum (Pentatomoidea VII). Acta Mus Morav, Sci Biol 79:85–96.
105. Stehlík JL (2002) Results of the investigations on Hemiptera in Moravia made by the Moravian Museum (Tingidae). Acta Mus Morav, Sci Biol 87:87-149.
106. Stehlík JL, Vavříňová I (1989) Results of the investigations on Hemiptera in Moravia made by the Moravian Museum (Coreoidea 2). Acta Mus Morav, Sci Biol 74:175–200.
107. Stehlík JL, Vavříňová I (1997) Results of the investigations on Hemiptera in Moravia made by the Moravian Museum. (Lygaeidae I). Acta Mus Morav, Sci Biol 81:231–298.
108. Stehlík JL, Vavříňová I (1998) Results of the investigations on Hemiptera in Moravia made by the Moravian Museum (Lygaeidae III). Acta Mus Morav, Sci Biol 83:21–70.
109. Stewart AJA, Bantock TM, Beckmann BC, Botham MS, Hubble D, Roy DB (2015) The role of ecological interactions in determining species ranges and range changes. Biol J Linn Soc Lond 115:647–663. DOI: <https://doi.org/10.1111/bij.12543>
110. Storms W, Meltzer EO, Nathan RA, Selner JC (1997) The economic impact of allergic rhinitis. J Allergy Clin Immunol 99:820-824. [https://doi.org/10.1016/S0091-6749\(97\)80042-5](https://doi.org/10.1016/S0091-6749(97)80042-5)
111. Strong FE (1970) Physiology of Injury Caused by *Lygus hesperus*. J Econ Entomol 63:808-814. DOI: <https://doi.org/10.1093/jee/63.3.808>
112. Suzuki M, Takahashi T, Komeda Y (2002) Formation of corymb-like inflorescences due to delay in bolting and flower development in the *corymbosa2* mutant of Arabidopsis. Plant Cell Physiol 43:298–306. DOI: <https://doi.org/10.1093/pcp/pcf036>
113. Šafářová D, Lauterer P, Starý M, Válová P, Navrátil M (2018) Insight into epidemiological importance of phytoplasma vectors in vineyards in South Moravia, Czech Republic. Plant Prot Sci. 54:234-239. DOI: <https://doi.org/10.17221/8/2018-PPS>.
114. Tingey WM, Pillimer EA (1977) Lygus Bugs: Crop Resistance and Physiological Nature of Feeding Injury. Bulletin of the Entomological Society of America 23:277-287. DOI: <https://doi.org/10.1093/besa/23.4.277>
115. Torma A, Bozsó M, Tölgyesi C, Gallé R (2017) Relationship of different feeding groups of true bugs (Hemiptera: Heteroptera) with habitat and landscape features in Pannonic salt grasslands. J Insect Conserv 21:645–656. <https://doi.org/10.1007/s10841-017-0007-y>

116. Vilímová J, Rohanová M (2010) The external morphology of eggs of three Rhopalidae species (Hemiptera: Heteroptera) with a review of the eggs of this family. *Acta Entomol Mus Natl Pragae* 50:75–95.
117. Malenovský I, Baňář P, Kment PA (2011) Contribution to the faunistic of the Hemiptera (Cicadomorpha, Fulgoromorpha, Heteroptera, and Psylloidea) associated with dry grassland sites in southern Moravia (Czech Republic). *Acta Mus Morav, Sci Biol* 96:41-187.
118. Weber E (2017) *Invasive Plant Species of the World: A Reference Guide to Environmental Weeds*, CABI 2nd Edition, 596 pages
119. Wheeler AG (2001) *Biology of the plant bugs (Hemiptera: Miridae): pests, predators, opportunists*. Cornell University Press
120. Weintraub P, Beanland L (2006) Insect vectors of phytoplasmas. *Annu Rev Entomol* 51:91-111. DOI: 10.1146/annurev.ento.51.110104.151039
121. White DT, Billington SJ, Walsh KB et al. (1997) DNA sequence analysis supports the association of phytoplasmas with papaya (*Carica papaya*) dieback, yellow crinkle, and mosaic. *Australas Plant Pathol* 26:28–36. <https://doi.org/10.1071/AP97005>.
122. Wieczorek A, Wright M (2003) PCR detection of phytoplasma from witches' broom disease on *Protea* spp. (Proteaceae) and associated arthropods. *Acta Hortic* 602:161–166. DOI:10.17660/ActaHortic.2003.602.23
123. Yazıcı G, Yildirim E (2017) Preferred host plants species by Miridae (Hemiptera: Heteroptera) species in Erzurum Province of Turkey. *Entomofauna* 38:193-212.
124. Zařko M (2002) Land Structure. In: Abaffy D, Miklós L (eds) *Landscape atlas of the Slovak Republic*; Slovak Environmental Agency, Banská Bystrica, Slovakia, 344 pp
125. Zisenis M. (2015) Alien plant species: A real fear for urban ecosystems in Europe? *Urban Ecosyst* 18:355-370. DOI: 10.1007/s11252-014-0400-1
126. Zurbrügg C, Frank T (2006). Factors influencing bug diversity (Insecta: Heteroptera) in semi-natural habitats. In: Hawksworth DL, Bull AT (eds) *Arthropod Diversity and Conservation*. Topics in Biodiversity and Conservation, Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-5204-0_17

Figures

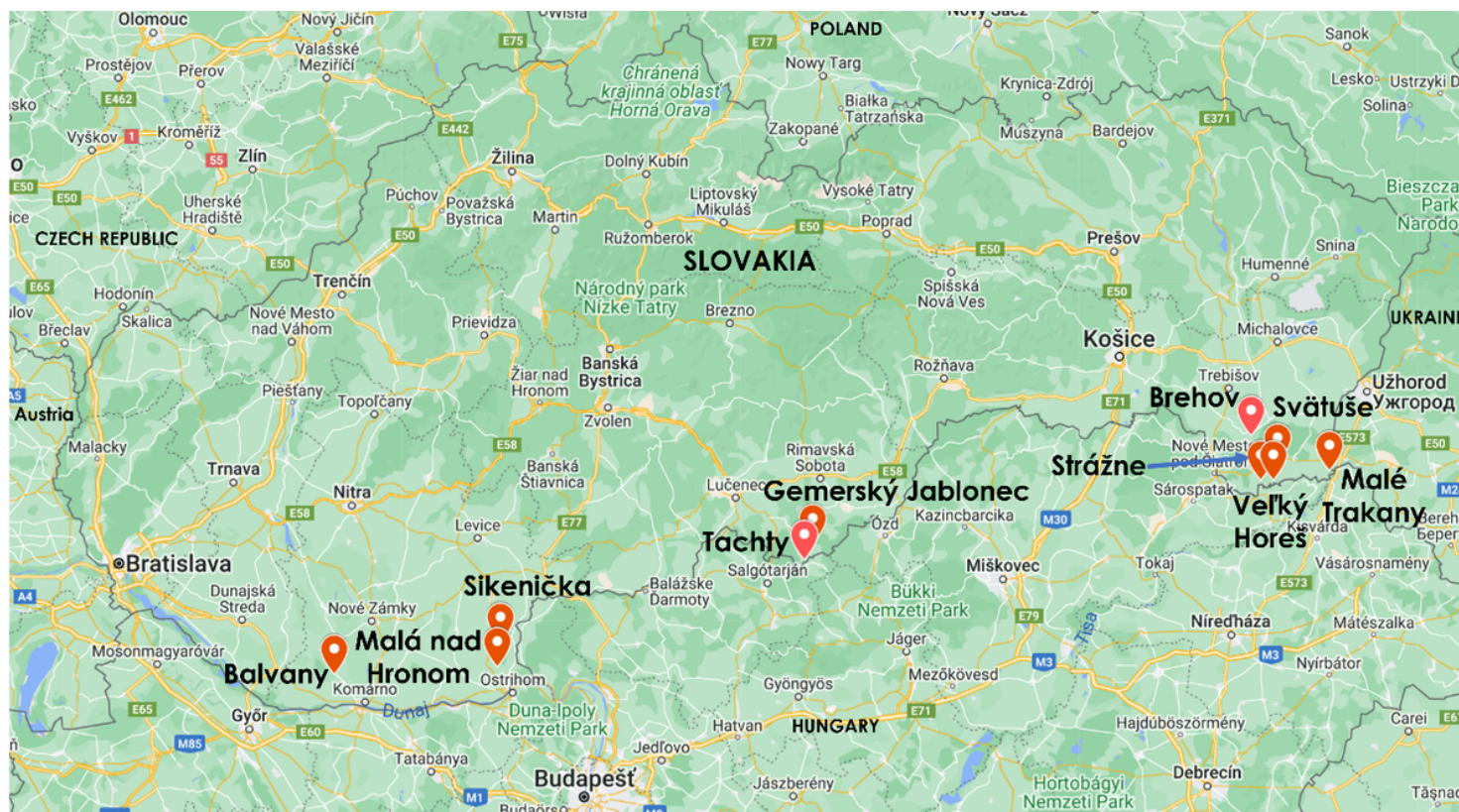


Figure 1

Location of research sites in Slovakia in 2020-2021. (Google maps 2022, edited by Peter Tóth 2023)