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RESEARCH ARTICLE

Relationship between the morphology of *Crambe tataria* and the functional groups of insects in northeastern Romania

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Abstract

Background and aims – The relationships between insect species and plant functional traits are complex but vital in their ecosystem structure and functioning. Our study examined functional traits of *Crambe tataria* to assess their influence on insect abundance and community composition.

Material and methods – The study was carried out in April–May 2024 and 2025 at four locations in Iași and Vaslui counties, Romania. We investigated the presence of insects on *C. tataria* inflorescences and their relationship to plant functional traits. To understand the relationships between plant functional traits (plant height and inflorescence circumference) and insect abundance, we applied a Kendall's rank correlation test. The vegetation was classified using agglomerative hierarchical clustering, while insect community clustering was based on Euclidean distances and complete linkage.

Key results – A total of 36 insect taxa were identified on *C. tataria*, including 30 taxa identified to species level and six identified only to the genus level. The predominant trophic group was represented by phytophagous insects. Rare or conservation-relevant species, such as *Clanoptilus affinis* and *Lixus canescens*, were also recorded. A positive correlation was found between plant height and the number of *Cercopis sanguinolenta*. The number of *C. sanguinolenta*, *Eurydema ornata*, and *Bibio hortulanus* significantly increased with inflorescence circumference. Cluster analyses (108 plots) revealed three plant associations and three distinct insect communities, mainly phytophagous or pollen-feeding. Alpha-diversity indices varied between locations: Horlești presented the highest richness, Miroslava and Vulturi presented moderate diversity, while Glodeni had lower diversity. The PERMANOVA test showed that plant height and inflorescence circumference in *C. tataria* significantly influenced the composition of the insect community, explaining 34.5% of the observed variation.

Conclusion – Plant height and inflorescence circumference of *C. tataria* were significantly correlated with the abundance of some phytophagous insect species, particularly *Cercopis sanguinolenta*, *Eurydema ornata*, and *Bibio hortulanus*.

Keywords

Crambe tataria, plant-insect interactions, insect communities, alpha diversity, steppe grasslands

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INTRODUCTION

Plant-insect relationships are continuously changing (Bruce 2015) and include both mutualistic interactions (Hale et al. 2020), such as pollination (Valdovinos 2019), and antagonistic interactions, primarily herbivory (Bascompte et al. 2003). These interactions shape the structure and dynamics of plant populations and influence overall ecosystem functioning (Bruce 2015). Pollinating insects play an important role in the reproduction of many plant species (Katumo et al. 2022), and antagonistic interactions, such as herbivory, can negatively affect plant fitness and adaptability (Schoonhoven et al. 2005). Pollination contributes to maintaining genetic diversity and ecosystem productivity (Willmer 2011). In addition, biotic and abiotic factors, resource availability, and habitat changes caused by human activities (Pincebourde et al. 2017) also influence plant-insect relationships. In some cases, alterations in plant-insect interactions lead to cascading effects on other ecosystem components (Ojija 2024).

Grasslands play a central role in maintaining biodiversity, as they support a high diversity of plant and animal species. Within these grasslands, steppe relict habitats play a critical role in maintaining biodiversity and supporting food webs (Dengler et al. 2014; Wesche et al. 2016). One plant species characteristic of these steppe relict grasslands is *Crambe tataria* Sebeók, considered vulnerable and rare in Romania (Oltean et al. 1994) and legally protected at national level, although listed as Least Concern in Europe (Kell 2011). Recognized as a postglacial steppe relict (Béres 1996), *C. tataria* is confined to mesoxerophilous to mesophilous grasslands. In Romania, its distribution is limited entirely to the Continental biogeographic region. Recent field data indicate that its populations are declining, primarily due to anthropogenic pressures and habitat degradation (Chirilă 2023). The grassland habitats where this species occurs are threatened by overgrazing, mechanized mowing, grassland conversion to agricultural lands, and the spread of invasive plant species. *Crambe tataria* occurs in areas with moderate to steep slopes, south-facing, annual mean temperature between 6 and 10°C, elevation between 21 and 500 m a.s.l., and annual precipitation between 450 and 700 mm. The species can also be found in other types of habitats, such as orchards, agricultural lands, and vineyards (Chirilă 2023).

Crambe tataria is characteristic of the following Natura 2000 habitats (Gafta and Mountford 2008; Oroian et al. 2015, 2017): 6210* Semi-natural xerophilous grasslands and scrub facies on calcareous substrates; 6250* Pannonian steppe grasslands on loess; 6240* Sub-Pannonian steppe grasslands; and 62C0* Ponto-Sarmatian steppes. In Romania, *C. tataria* can be identified in the following habitats (Doniță et al. 2005): R3131 Ponto-Pannonic thickets of dwarf almond (*Amygdalus nana* L.); R3404 Ponto-panonic grasslands of *Festuca rupicola* Heuff. and *Koeleria macrantha* (Ledeb.) Schult.; R3418 Ponto-panonic grasslands of *Agropyron cristatum* (L.) Gaertn. and *Kochia prostrata* (L.) Schrad.; and R3409 Pontic grasslands of *Stipa lessingiana* Trin. & Rupr., *S. pulcherrima* K.Koch, and *S. joannis* Čelak. Several grasslands from Moldova and Transylvania in Romania have undergone partial abandonment, shrub invasion, or local disturbances. Only a few grasslands are maintained by extensive grazing and periodic mowing.

Interactions with insects are important for understanding the ecology of some species (Herrera 1988). *Crambe tataria* depends largely on insects for pollination, and variation in pollen transfer efficiency, together with damage caused by herbivorous insects, can influence seed production.

Crambe tataria exhibits an active glucosinolate-myrosinase system, identified in the seeds and leaves of in vivo- and in vitro-regenerated seedlings as well as in two callus cell lines (Piovan et al. 2013). Hydrolysis of glucosinolates by myrosinase results in the formation of isothiocyanates and other sulfur compounds (Ettlinger and Hodgkins 1955; Halkier and Gershenzon 2006; Piovan et al. 2013). These products play an important role in plant-insect interactions, as they can shape how herbivorous insects feed on the plant and choose their host, and can also influence the way predators and parasitoids interact with herbivores (Hopkins et al. 2009). Some species from the genus *Crambe* produce various glucosinolates and volatile sulfur-containing derivatives, compounds with important roles in plant-insect interactions. For *C. tataria*, two major hydrolysis products have been reported: 4-Hydroxybenzyl isothiocyanate and 5-Vinyl oxazolidine-2-thione (Daxenbichler et al. 1991).

There are no published studies on pollination in *C. tataria*. However, other *Crambe* species are insect-pollinated, with bees (Hymenoptera) documented as key visitors in *C. abyssinica* Hochst. ex R.E.Fr. (Simioni et al. 2015), and insect pollination including flies and bees reported for *C. maritima* L. (Sanyal and Decocq 2015). In this context, *C. tataria* may follow the same type of pollination, as the floral structure is similar to that of other species in the genus *Crambe*. The relationship between *C. tataria* and phytophagous insects is supported by the presence of species, such as *Melanobaris carbonaria* and *Lixus canescens*, both associated with plant species in the genus *Crambe* (Yunakov et al. 2018).

Local microclimatic factors (temperature, humidity, wind) are influenced by topography (Bennie et al. 2008). These factors affect both insect activity (Willmer 1982) and plant phenology (Cleland et al. 2007). Local variations in topographic factors (aspect, slope, and elevation) modify the microclimate at the grassland level (Bennie et al. 2008) and can influence the composition and abundance of insect communities (Hodkinson 2005). These effects are relevant for *C. tataria* because insect activity, flowering time, and the intensity of plant–insect interactions are partly related to microclimate changes, which vary with topography. The species grows on slightly alkaline soils, with organic carbon content ranging from

low to high, showing high concentrations of phosphorus, potassium, and iron, low magnesium and sodium, and increased levels of aluminium, silicon, lead, and arsenic, along with moderate nitrogen content (Chirilă 2023).

This study investigates some of the interactions between *C. tataria* and insect communities across four locations in the Moldova region of Romania. For the first time, we identify some of the insect species associated with this plant and assess its impact on the diversity and abundance of local insect fauna. At the same time, this research contributes to biodiversity management strategies in areas affected by environmental change and anthropization. Moreover, the study is important for understanding plant-insect interactions, which, in turn, can form a basis for developing various strategies aimed at conserving rare plant and insect species.

Plant height determines floral visibility and insect accessibility within the vegetation (Herrera 2020), and inflorescence size is an indicator of floral resource availability and insect attractiveness (Murakoshi et al. 2024). We hypothesize that plants of *C. tataria* with greater height and larger inflorescences attract a greater number of insects and a greater diversity of species than plants in the vegetative stage or with smaller dimensions. To test this hypothesis, we studied plant height and inflorescence circumference.

MATERIAL AND METHODS

Study area

The study was conducted in the northeastern part of Romania, in the Moldova region, including locations in Iași County (Horlești, Miroslava, and Vulturi) and Vaslui County (Glodeni) (Fig. 1), during April–May 2024 and 2025. The study areas are characterized by elevation variation ranging from 60 to 270 m a.s.l. This topographic diversity influences local microclimates and, in turn, vegetation types and land use (Bernath-Plaisted et al. 2023). The Moldova region has a temperate-continental climate, with annual mean precipitation ranging from about 450 to 700 mm and annual mean temperatures ranging from 9 to 12°C (Fick and Hijmans 2017). These climatic conditions are essential for agricultural development, influencing the availability of water and the types of crops cultivated (Malhi et al. 2021). Chernozem soils predominate in the studied areas (IUSS Working Group WRB 2022). Topographic variables (slope °, aspect, and elevation m a.s.l.) were measured in situ at the level of each plant using the Clinometer 3.0 app for slope, and OsmAnd 4.7.17 for elevation and aspect (Suppl. material 1). The map was created using QGIS v.3.34.3 (QGIS Development Team 2023), and satellite imagery was obtained from Google Earth.

Functional trait measurement

During April–May 2024 and 2025, 125 individuals of *C. tataria* (Fig. 2) were sampled. For each individual, we measured functional traits (inflorescence circumference and plant height), using a tape measure. The plant associations in which each individual was identified were also recorded. The sampled individuals represent all *C. tataria* plants observed in the plots carried out at each location, and the plots covered the entire microhabitat occupied by the species.

Vegetation analysis

For the vegetation analysis, 108 plots (including 102 taxa; Suppl. material 2) were used to cover the entire microhabitat occupied by the 125 individuals; when individuals were located close to each other, joint relevés were applied. The size of the sample areas was 100 m^2.

Vegetation data were represented by the mean percentage values of the Braun-Blanquet (1964) cover-abundance scale, adapted from Cristea et al. (2004): r (0.05%), + (0.5%), 1 (5%), 2 (17.5%), 3 (37.5%), 4 (62.5%), and 5 (87.5%). Subsequently, the data were square-root transformed in the GINKGO program from the VegAna package (Bouxin 2005). Plots were carried out in the habitats 62C0* Ponto-sarmatic steppes, 6210* Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometea*), and 6240* Subpannonic steppic grasslands.

Vegetation classification was performed using the Agglomerative Hierarchical Clustering (ß-flexible method, ß = -0.25 and Bray-Curtis dissimilarity). The dendrogram was created using the GINKGO program from the VegAna package (Bouxin 2005). Diagnostic species were identified using Indicator Value (IndVal; Dufrêne and Legendre 1997) and validated by a permutation test (De Cáceres and Legendre 2009). For diagnostic plant species, two values were presented: the first value is the statistical value, and the second value is the p value. For example, in our study, *Elytrigia repens* (L.) Nevski has a statistical value of 0.980, indicating a strong association with Cluster 1. The p value for this species is 0.001, which is lower than the 0.05 significance threshold, confirming a significant association between *E. repens* and Cluster 1.

The EUNIS habitat type was identified using the EUNIS habitat expert classification system (Chytrý et al. 2020). The nomenclature of taxa (species and subspecies) followed Euro+Med database (2025), and the nomenclature and classification of plant associations at the level of higher syntaxa followed specialized literature (Chifu et al. 2014). The nomenclature of higher syntaxa follows Mucina et al. (2016).

Insect sample collection and specimen identification

Data on the number of insect species and individuals were collected from each vegetative or flowering *C. tataria* individual included in our study (Suppl. material 3), during repeated field visits carried out in April–May 2024 and 2025.

For each individual plant, insects were sampled using a standard protocol. All insects present on leaves, stems, buds, and inflorescences were recorded. Each plant was inspected for 3–5 minutes, during which time insects were collected directly by hand, using a hand net or an entomological pooter. The protocol targeted all insects interacting directly with the plant surface. As the insect species are most of the time hard or impossible to identify in the field, given the high diversity of (apparently) similar species and their small size, most of the individuals observed were collected, in order to be carefully determined in the laboratory.

All the observed insects were collected except for three species – *Carpocoris purpureipennis*, *Cercopis sanguinolenta*, and *Tropinota* (*Epicometis*) *hirta* – from which only a subset of individuals was sampled due to their high field abundance and the ease of assigning them to genus in situ. The collected individuals of these three genera were identified to species level in the laboratory, and this information was subsequently used to update the

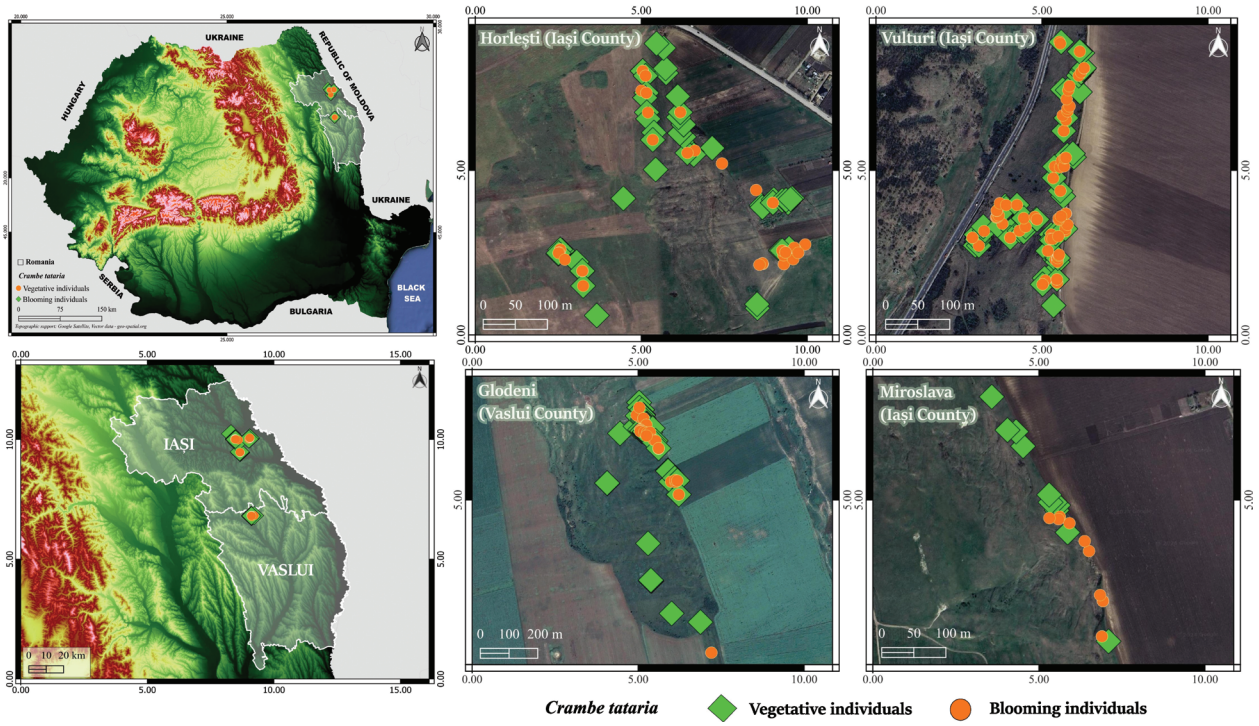


Figure 1. Study areas in northeastern Romania. Map created by Simona Dumitrița Chirilă in QGIS v.3.34.3 (QGIS Development Team 2023).



Figure 2. *Crambe tataria* inflorescence (**A**) and leaves (**B**). Photos by Simona Dumitrița Chirilă.

field records, assigning species-level identifications to all specimens initially recorded only at the genus level. One *Carpocoris* specimen remained unidentified to species level because it was fragmented and thus lacked the diagnostic characters required for identification. The specimens were identified as precisely as possible and deposited in the personal collection of Pintilioaie Alexandru-Mihai, housed in Agigea, Romania. Following this, each taxon was classified in terms of the trophic preferences of the adults into three categories: phytophagous insects (Ph), predatory insects (Pr), and omnivorous insects (Om). The scientific names given in the table are in accordance with Kovář (2007), Bezděk (2016), Yunakov et al. (2018), Liu et al. (2020), and Global Biodiversity Information Facility (GBIF 2025). In our statistics, only individuals identified at the species level were included (Tables 1–6).

Predatory insects (Pr) were included in this study because they reflect the local trophic structure and may indirectly influence the pressure exerted by phytophagous insects on *C. tataria*. It should also be noted that a distinct group of pollinators was not defined, as very few floral visitors were observed. Thus, the majority belonged to taxa that can act both as phytophagous species and as occasional pollen feeders.

Cluster analyses for entomofauna were performed in the GINKGO software (Bouxin 2005), applying the Agglomerative Hierarchical Clustering method (Euclidean distances and complete Linkage).

Relationships between plant traits and dominant insects

Statistical analyses were limited to seven highly abundant insect species: *Tropinota* (*Epicometis*) *hirta* – 566 individuals, *Cercopis sanguinolenta* – 237 individuals, *Carpocoris purpureipennis* – 77 individuals, *Bibio hortulanus* – 15 individuals, *Eurydema ornata* – 13 individuals, *Camponotus piceus* – 11 individuals, and *Dolycoris baccarum* – nine individuals, which allowed the application of non-parametric tests. Linear regressions were used as descriptive tools only, and inferential analysis was based on the Kendall's tau test.

We calculated the alpha-diversity indices, including Shannon, Simpson (1–D), Pielou's evenness, and Chao1, to characterize the insect diversity within the four sampled areas. We estimated the main effect of two functional plant traits (inflorescence circumference and plant height) on insect species composition using the non-parametric PERMANOVA test based on the Bray-Curtis distance matrix. Along with PERMANOVA, we tested homogeneity of multivariate dispersions (variance) using the betadisper function of the R package vegan v.2.8-0. The correlation between insect abundance and the two plant traits was explored by Kendall's tau correlation. Statistical analyses were performed in R v.4.1.4 (R Core Team 2024) with the R packages ggpubr v.0.6.0 (Kassambara 2023) and vegan v.2.8-0 (Oksanen et al. 2025).

RESULTS

Description of the plant associations

Crambe tataria was recorded in three plant associations (Fig. 3), which belong to the classes *Molinio-Arrhenatheretea* and *Festuco-Brometea*.

Cluster 1: Rorippo austriacae-Agropyretum repentis (Timár 1947) R. Tx. 1950

The diagnostic species were *Elytrigia repens* (IndVal = 0.980, $p < 0.01$), *Teucrium chamaedrys* L. (IndVal = 0.700, $p < 0.05$), *Vicia tenuifolia* Roth (IndVal = 0.559, $p < 0.05$), and *Salvia austriaca* Jacq. (IndVal = 0.509, $p < 0.05$).

In plots included in this cluster, *Elytrigia repens* predominated, which forms the *Rorippo austriacae-Agropyretum repentis* association. This association belongs to the alliance *Potentillion anserinae* Tx. 1947, within the order *Potentillo-Polygonetalia avicularis* Tx. 1947, and the class *Molinio-Arrhenatheretea* Tx. 1937.

Communities with *E. repens* were classified in the EUNIS habitat R36 Moist or wet mesotrophic to eutrophic pasture.

The association was recorded in some locations in Iași County, at moderate elevations (from 132 to 141 m a.s.l.), on steep slopes (from 8 to 21°) with northern and northwest aspect. *Crambe tataria* individuals show morphological differences between vegetative and flowering plants. Vegetative individuals had an average of ten leaves per plant, a height of 39–45 cm. Flowering individuals were leafless, a height of 94 cm, and had an inflorescence circumference of 223 cm.

The entomofauna was dominated by phytophagous species, the most numerous being *Tropinota* (*Epicometis*) *hirta*, with up to 27 individuals per plot, and *Cercopis sanguinolenta*, with a maximum of 65 individuals. In the case of *Carpocoris purpureipennis*, up to 16 individuals were recorded, and *Eurydema ornata* and *Coriomeris denticulatus* were recorded sporadically. Omnivorous and predatory species are poorly represented. Isolated ant species (*Camponotus piceus*, *C. aethiops*, and *Formica cunicularia*) were observed, with a maximum of two individuals per plot. Predatory species of the type *Orius* sp. and *Lygaeus* sp. were identified very rarely. The same pattern of the entomofauna was observed in both vegetative and flowering *C. tataria* individuals. The abundance was higher on flowering plants.

Cluster 2: Jurineo arachnoideae-Stipetum lessingianae (Dobrescu 1974) Chifu, Manzu et Zamfirescu 2006

The diagnostic species were *Stipa lessingiana* (IndVal = 0.977, $p < 0.01$), *Salvia nemorosa* L. (IndVal = 0.670, $p < 0.05$), and *Stachys recta* L. (IndVal = 0.663, $p < 0.05$).

The plots included in cluster 2 were characterized by the dominance of the species *Stipa lessingiana*, which forms the association *Jurineo arachnoideae-Stipetum lessingianae*. This association belongs to the alliance

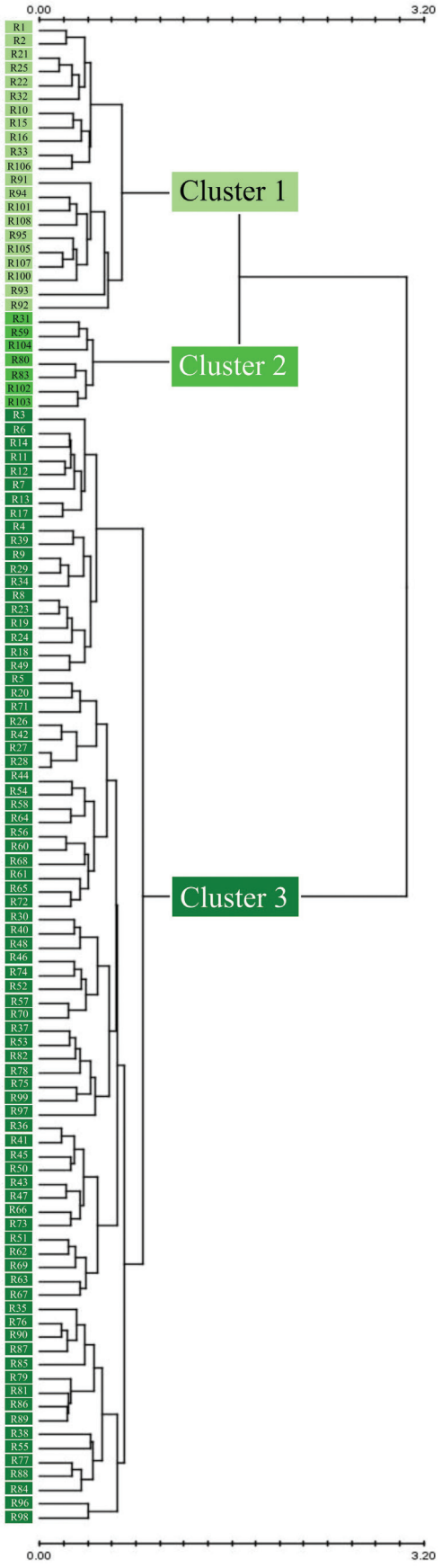


Figure 3. Dendrogram of vegetation plots with *Crambe tataria* in northeastern Romania.

Stipion lessingianae Soó 1947, within the order *Festucetalia valesiacae* Soó 1947, and the class *Festuco-Brometea* Br.-Bl. et Tx. ex Soó 1947. This cluster corresponds to the continental steppe communities, classified in EUNIS R1B Continental dry grasslands (true steppe). In terms of Natura 2000 habitats, the investigated communities are associated with Habitat 62C0* Ponto-Sarmatic steppes.

Stipa lessingiana communities were recorded in locations in Iași and Vaslui counties, at higher elevations than cluster 1 (from 137 to 201 m a.s.l.), on steep slopes (from 11 to 30°) with southwest, west and south aspects.

Crambe tataria individuals were well-developed, with heights exceeding 80 cm and inflorescence circumferences over 204 cm. No leaves were observed on flowering individuals.

The entomofauna was dominated by phytophagous species, but with a lower diversity and abundance compared to cluster 1. The most frequent insect species were *Tropinota* (*Epicometis*) *hirta*, in which five individuals were recorded, and *Cercopis sanguinolenta*, with nine individuals. Also, three individuals of *Protaetia* (*Philhelena*) *ungarica* and two individuals of *Carpocoris purpureipennis* were recorded. Omnivorous species were few, being represented by *Camponotus piceus* with one individual. *Dolycoris baccarum* was observed only once, and *Melanobaris carbonaria* was also recorded with a single individual.

Cluster 3: Taraxaco serotinae-Festucetum valesiacae (Burduja et al. 1956, Răvăruţ et al. 1956) Sârbu, Coldea et Chifu 1999

The diagnostic species was *Festuca valesiaca* Schleich. ex Gaudin (IndVal = 0.976, $p < 0.01$).

Cluster 3 was dominated by *Festuca valesiaca*, which is the characteristic species for the *Taraxaco serotinae-Festucetum valesiacae* association. This association belongs to the alliance *Stipion lessingianae* Soó 1947, within the order *Festucetalia valesiacae* Soó 1947, and the class *Festuco-Brometea* Br.-Bl. et Tx. ex Soó 1947.

Festuca valesiaca communities are characteristic of continental steppe grasslands, being classified in the EUNIS habitat R1B Continental dry grasslands (true steppe), and according to the Natura 2000 classification, the investigated communities correspond to the habitat 62C0* Ponto-Sarmatian steppes.

The association in this cluster was observed in grasslands from Iași and Vaslui counties, at relatively low elevation (from 132 to 139 m a.s.l.), on steep slopes (from 11 to 21°) with a northern and northwestern aspect. The average number of leaves per plant was five in flowering individuals and seven in vegetative individuals. The height of the plants ranged from 26 to 116 cm, likely reflecting variation in light availability and local soil moisture within the microhabitat. The inflorescence circumference has a large amplitude, with values ranging from 82 to 420 cm.

The entomofauna associated with this cluster is dominated by phytophagous species, of which *Tropinota* (*Epicometis*) *hirta* has the highest number of records.

Cercopis sanguinolenta (from 2 to 225) and *Carpocoris purpureipennis* (from 1 to 38) were constantly present, with a moderate to high number of individuals. Omnivorous and predatory species, such as *Formica cunicularia*, appear rarely and in small numbers. Pollinating species, such as *Andrena flavipes*, were observed only as isolated individuals.

Description of the associated insect communities

The insect communities associated with *C. tataria* were grouped into three clusters (Fig. 4): Cluster A – *Cercopis sanguinolenta*, *Carpocoris purpureipennis*, and sporadic participation of other phytophagous, predatory, and omnivorous species; Cluster B – monodominated by *Cercopis sanguinolenta*; and Cluster C – dominated by *Tropinota* (*Epicometis*) *hirta*.

A small number of floral visitors were recorded on *C. tataria*, such as *Apis mellifera* and *Andrena flavipes*. Although rare, these insect species confirm that *C. tataria* is visited by potential pollinators, but their low abundance did not allow statistical analysis.

Cluster A: Cercopis sanguinolenta-Carpocoris purpureipennis phytophagous community

In this cluster, the entomofauna was dominated by phytophagous species, with *Cercopis sanguinolenta* present in several plots. Other Hemiptera species were occasionally recorded (*Carpocoris purpureipennis*, *Dolycoris baccarum*, and *Eurydema ornata*), without becoming dominant. *Tropinota* (*Epicometis*) *hirta* and *Valgus hemipterus* were only observed in plots with larger inflorescence circumferences of *C. tataria*. For *Andrena flavipes* (four individuals), *Apis mellifera* (two individuals), *Camponotus piceus* (11 individuals), *C. aethiops* (two individuals), *Melanobaris carbonaria* (one individual), and *Teucriogethes distinctus* (eight individuals), only a few individuals were recorded, all of them being associated with plants bearing inflorescences.

Cluster B: Cercopis sanguinolenta monodominant community

Cluster B was characterized by the high abundance of *Cercopis sanguinolenta* (Hemiptera: Cercopidae). The species had densities of 65 to 71 individuals per plot on the inflorescences of *C. tataria*. The high density of *C. sanguinolenta* individuals was recorded on plants with large inflorescences (with a circumference from 290 to 295 cm) and greater height (from 111 to 125 cm). Other insect species, such as *Coccinella septempunctata* and *Camponotus piceus*, were also recorded, but in much lower numbers.

Cluster C: Tropinota (Epicometis) hirta pollen-feeder community

Cluster C was characterized by *Tropinota* (*Epicometis*) *hirta* (Coleoptera: Cetoniidae), which had very high densities of individuals on *C. tataria* inflorescences. *Tropinota* (*Epicometis*) *hirta* reached very high densities

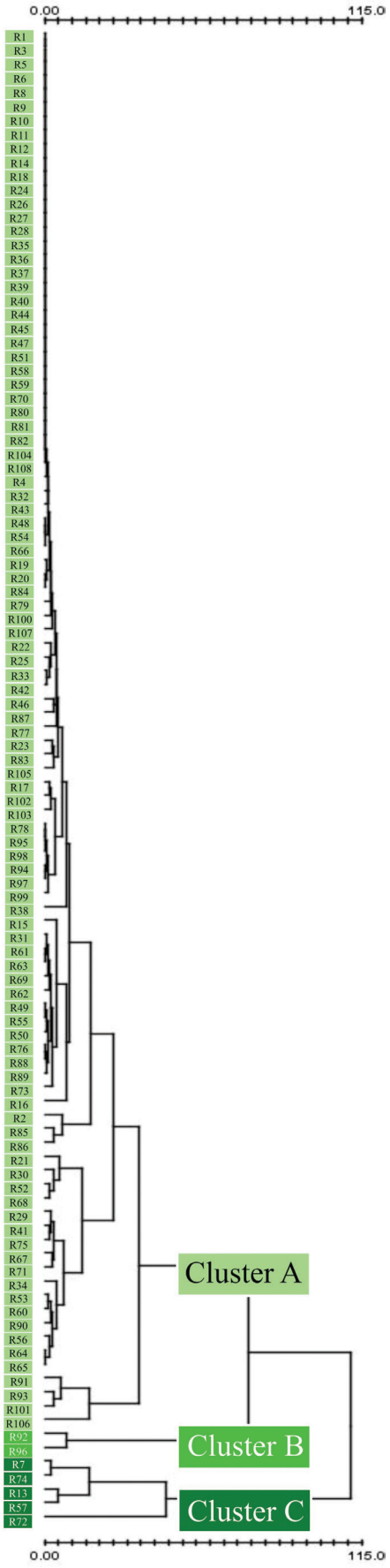


Figure 4. Dendrogram of plots with insect communities in northeastern Romania.

Table 1. The composition of the insect communities according to order.

Order	Family		Species		Individuals	
	No.	%	No.	%	No.	%
Coleoptera	8	40	12	40	602	61
Diptera	2	10	2	7	17	2
Hemiptera	5	25	9	30	343	35
Hymenoptera	3	15	5	17	22	2
Lepidoptera	1	5	1	3	1	0.1
Orthoptera	1	5	1	3	1	0.1

Table 2. Insect composition in the four locations in Iași and Vaslui counties.

Location	Order	Family	Species	Individuals
Horlești	4	12	15	87
Miroslava	3	8	10	247
Vulturi	4	12	15	260
Glodeni	5	10	14	392

Table 3. Distribution of insect trophic groups in the four studied locations.

Trophic group	Horlești		Miroslava		Vulturi		Glodeni	
	No.	%	No.	%	No.	%	No.	%
Om, omnivorous insects	2	13	0	0	2	13	1	7
Ph, phytophagous insects	12	80	9	90	11	73	12	86
Pr, predatory insects	1	7	1	10	2	13	1	7

on *C. tataria*, and was most frequently recorded on plants with large inflorescences (circumference 182–280 cm) and intermediate plant height (69–99 cm). Species such as *Carpocoris purpureipennis*, *Spermophagus sericeus*, *Teucriogethes distinctus*, and *Bibio hortulanus* were rarely observed. However, we currently lack sufficient field data to determine whether their low abundance is related to the phenology of their host plants species.

Composition of the insect communities

The insects identified on the *C. tataria* specimens have a diversified pattern, being dominated by certain orders (Table 1). Thus, of the six orders, the best represented were Coleoptera and Hemiptera. Coleoptera includes eight families (40%) and 12 species (40%), and Hemiptera includes five families (25%) and nine species (30%). A lower diversity was recorded in the case of the orders Hymenoptera, Diptera, Lepidoptera, and Orthoptera. In terms of abundance, Coleoptera dominated (602 individuals), followed by Hemiptera with 343 individuals (35%). The orders Diptera, Hymenoptera, Lepidoptera, and Orthoptera were represented by a very small number of individuals, partly due to the limited number of fieldwork sessions.

Horlești recorded the highest species richness (15 species; Table 2), although the number of individuals was relatively low (87 individuals). Miroslava had the lowest richness (10 species) but a comparatively high abundance (247 individuals). Vulturi showed similar richness (15 species) and intermediate abundance (260 individuals). Glodeni had the highest number of individuals (392) with 14 species.

Trophic structure of the insect communities

According to the data collected in the field, phytophagous insects (Ph) were dominant. This trophic group represents the largest proportion of the total number of insects studied. Since the pollinating species were very few in number and present in small numbers, they were treated within the Ph group. The omnivorous species (Om) is rare or absent in some locations. Regarding predatory species (Pr), they are in relatively low proportions in the analysed locations (Table 3).

Across all analysed locations, a decrease in the diversity of predatory insect species was observed. One species (*Coccinella septempunctata*) was recorded in Glodeni, Horlești, and Miroslava, and two species (*Coccinella septempunctata* and *Phymata crassipes*) from this group were recorded in Vulturi. In terms of the number of individuals, the highest values were found in Glodeni and Vulturi, and the lowest in Horlești and Miroslava. The phytophagous insects were dominant in all locations, both in terms of diversity and abundance. Thus, the highest diversity and abundance were recorded

Table 4. Alpha-diversity of insect communities across the four study sites.

Location	Shannon	Simpson	Pielou's	Chao Index		
				Observed	Chao1	SE_Chao1
Miroslava	0.97	0.45	0.42	10.00	13.00	4.13
Glodeni	0.65	0.22	0.23	17.00	31.00	13.15
Horlești	1.97	0.75	0.64	22.00	48.25	18.74
Vulturi	0.74	0.26	0.27	15.00	16.67	2.20

Table 5. PERMANOVA with two grouping factors (main effects only).

Source variability	d.f.	Sum of Squares	R^2	F value	Pr (>F)	Signif.
Model	11	10.377	0.34486	3.3976	0.001	***
Residual	71	19.714	0.65514			
Total	82	30.091	1			

Table 6. Check dispersion homogeneity – plant height.

Source variability	d.f.	Sum of Squares	Mean Sq	F value	Pr (>F)	Signif.
Groups	10	3.0949	0.309487	7.6148	3.71E-08	***
Residual	72	2.9263	0.040643			

Table 7. Check dispersion homogeneity – inflorescence circumference.

Source variability	d.f.	Sum of Squares	Mean Sq	F value	Pr (>F)	Signif.
Groups	1	0.2403	0.240295	10.194	0.002007	**
Residual	81	1.9094	0.023572			

in Glodeni. Moderate species richness and moderate number of individuals were recorded in Horlești, Vulturi, and Miroslava. Omnivorous insect species were recorded only in Horlești, Vulturi, and Glodeni.

Alpha-diversity

Miroslava was characterized by moderate insect diversity with uneven species distribution. Glodeni exhibited low observed diversity (Shannon and Simpson), whereas the Chao1 estimator suggested a higher underlying species richness, implying the likely presence of additional undetected species. At Horlești, the highest overall insect species richness was observed, and the Chao1 index suggested that even many more species would be found here. Vulturi was characterized by an average insect diversity with Chao1 index very close to the observed value (Table 4).

Plant functional traits and insect community composition

The PERMANOVA test ($p = 0.001$) indicated that inflorescence circumference and plant height of *C. tataria* are significantly associated with changes in insect species composition. The effect size (R2) explains some 34.5% of the total variation in the insect species composition. The homogeneity of dispersion test for the two plant traits (plant height, $p < 0.001$; inflorescence circumference, $p = 0.002$) was also significant. This means that the insect species composition, to some extent, is also driven by heterogeneous dispersion, which implies that variable and unpredictable insect communities also exist (Tables 5–7).

The relationship between inflorescence circumference and the presence of the species *Dolycoris baccarum*, *Carpocoris purpureipennis*, *Camponotus piceus*, and *Tropinota* (*Epicometis*) *hirta* is not statistically significant, while the presence of the species *Bibio hortulanus* ($p = 0.0091$), *Eurydema ornata* ($p = 0.029$), and *Cercopis sanguinolenta* ($p = 0.027$) is significantly and positively correlated with inflorescence circumference (Table 8; Suppl. material 4).

The relationship between plant height of *C. tataria* and the presence of *Bibio hortulanus*, *Camponotus piceus*, *Carpocoris purpureipennis*, *Dolycoris baccarum*, *Eurydema ornata*, and *Tropinota* (*Epicometis*) *hirta* is not statistically significant. In contrast, the relationship between plant height and *Cercopis sanguinolenta* is statistically significant and positively correlated (Table 8; Suppl. material 5).

Despite the limited data on insect assemblages associated with *C. tataria* due to the short duration of fieldwork, it still provides significant insights into species diversity and their interactions with the plant. We

Table 8. Kendall test results for the relationship between the functional traits of *Crambe tataria* and the associated insect species. Statistically significant relationships are in bold.

	Plant height			Inflorescence circumference		
	z value	**p value**	**Kendall's Tau (τ)**	**z value**	**p value**	**Kendall's Tau (τ)**
Bibio hortulanus	1.5929	0.1112	0.1289	2.6082	**0.009101**	0.211
Camponotus piceus	0.17072	0.8644	0.0139	0.40975	0.682	0.0333
Carpocoris purpureipennis	-1.2014	0.2296	-0.0948	1.7462	0.08078	0.1377
Cercopis sanguinolenta	3.3349	**0.000853**	0.2623	2.2137	**0.02685**	0.174
Dolycoris baccarum	0.36805	0.7128	0.0302	1.075	0.2824	0.0881
Eurydema ornata	-0.09461	0.9246	-0.0077	2.1872	**0.02872**	0.1774
Tropinota hirta	-0.31826	0.7503	-0.0234	-0.37641	0.7066	-0.0276

identified 30 different taxa to species level and six of them to genus level (Table 9).

DISCUSSION

Plant-insect relationships are key elements in the functioning of ecosystems, influencing both plant reproductive success and the structure of invertebrate communities (Bruce 2015; Valdovinos 2019). Differences in insect communities between locations can reflect classical community assembly processes (Kraft et al. 2015). Mutualistic interactions with insects can support long-term persistence of plant populations with restricted ranges (Hale et al. 2020). *Crambe tataria*, a relict species of postglacial steppe (Béres 1996), grows in Romania in mesoxerophilous and mesophilous grasslands, belonging mainly to plant associations from the *Molinio-Arrhenatheretea* and *Festuco-Brometea* classes (Chirilă 2023).

Analyses conducted in four locations in the Moldova region showed that the structure of insect communities varied depending on the type of plant association, topographic characteristics (elevation, aspect, and slope), and functional traits of *C. tataria*. Inflorescence circumference and plant height showed significant positive correlations with the abundance of some species, such as *Cercopis sanguinolenta*, *Eurydema ornata*, or *Bibio hortulanus*, suggesting that these functional traits have probably a role in attracting certain trophic groups.

In this context, it has been shown in the literature that species such as *Melanobaris carbonaria* feed on vegetative parts of *C. tataria* (Yunakov et al. 2018). The dominance of phytophagous insects suggests that *C. tataria* functions primarily as a trophic resource within steppe grasslands. This shows that *C. tataria* serves as an essential food resource. For example, *Melanobaris carbonaria* (Yunakov et al. 2018) and *Eurydema ventralis* (Stankevych et al. 2021), could be associated with the reduction of vegetative biomass and the increase of the vulnerability of the host plant to other ecological pressures. On the other hand, the vegetative parts have an essential role for the survival of some rare or vulnerable species, such as *Protaetia* (*Philhelena*) *ungarica* and *Lixus* (*Eulixus*) *canescens*. Omnivorous and predatory species, such as *Orius* sp. or *Coccinella septempunctata* were less abundant, reflecting a possible trophic imbalance caused by resource competition or habitat disturbances. An important aspect to mention is the presence of potential pollinators, such as *Apis mellifera* and *Andrena flavipes*, which suggests that *C. tataria* may contribute to supporting pollination-related ecosystem functions. The presence of these species highlights the need to conserve habitats that can support such mutualistic interactions. However, *Apis mellifera* originates from apiaries near the investigated location and is not a wild pollinator. Therefore, it cannot fulfil the role of *Andrena flavipes* as an indicator of mutualistic interactions, since *A. flavipes* is a wild pollinator, whose foraging patterns are naturally integrated with the local flora. Pollination processes operate within a structured ecological network in which the asymmetry of interactions and the degree of nesting influence the stability of plant-pollinator systems (Jordano 2016).

Statistically significant relationships between plant height and inflorescence circumference and certain insect species, such as *Bibio hortulanus* and *Cercopis sanguinolenta*, suggest that morphological traits of *C. tataria* influence habitat selection and resource use by these species. This may reflect a specific ecological association or a preference for larger floral displays. In contrast, the lack of significant relationships for species, such as *Camponotus piceus* and *Tropinota* (*Epicometis*) *hirta* indicates that other ecological or behavioural factors likely drive their occurrence.

Beyond trait–insect relationships, the overall insect assemblage highlights the conservation value of habitats hosting *C. tataria*. Although most species were relatively common, two rare or vulnerable taxa (*Lixus canescens* and *Clanoptilus affinis*) were recorded, one of which was confirmed in the Romanian fauna after more than a century (Petri 1912; Yunakov et al. 2018). These findings emphasize the importance of continued monitoring of steppe grasslands.

Most of the species are relatively common; however, a few are particularly noteworthy, especially in relation to the vegetative parts of *C. tataria*. *Clanoptilus* (*Clanoptilus*) *affinis* (Coleoptera: Malachiidae) is a small beetle species typically found in steppe habitats, classified as a Euro-Asiatic taxon. Like other members of the Malachiidae

Table 9. The insect species identified in this study. Individuals only identified at the genus level were not included in the statistics.

Insect	Order	Family	Trophic group	Location			
				Miroslava	Glodeni	Horlești	Vulturi
Andrena flavipes Panzer, 1799	Hymenoptera	Andrenidae	phytophagous	0	1	1	2
Apis mellifera Linnaeus, 1758	Hymenoptera	Apidae	phytophagous	0	0	0	2
Bibio hortulanus (Linnaeus, 1758)	Diptera	Bibionidae	phytophagous	0	14	1	0
Camponotus aethiops (Latreille, 1798)	Hymenoptera	Formicidae	omnivore	0	0	0	2
Camponotus piceus (Leach, 1825)	Hymenoptera	Formicidae	omnivore	0	0	4	7
Carcharodus alceae (Esper, 1780)	Lepidoptera	Hesperiidae	phytophagous	0	1	0	0
Carpocoris purpureipennis (De Geer, 1773)	Hemiptera	Pentatomidae	phytophagous	38	1	30	8
Cercopis sanguinolenta (Scopoli, 1763)	Hemiptera	Cercopidae	phytophagous	10	0	2	225
Cidnopus pilosus (Leske, 1785)	Coleoptera	Elateridae	phytophagous	0	0	4	0
Clanoptilus (*Clanoptilus*) *affinis* (Ménétriés, 1832)	Coleoptera	Melyridae	phytophagous	0	0	0	1
Coccinella (*Coccinella*) *septempunctata* (Linnaeus, 1758)	Coleoptera	Coccinellidae	predatory	1	4	1	2
Coriomeris denticulatus (Scopoli, 1763)	Hemiptera	Coreidae	phytophagous	1	1	0	0
Dolycoris baccarum (Linnaeus, 1758)	Hemiptera	Pentatomidae	phytophagous	2	3	2	2
Eurydema oleracea (Linnaeus, 1758)	Hemiptera	Pentatomidae	phytophagous	0	2	0	0
Eurydema ornata (Linnaeus, 1758)	Hemiptera	Pentatomidae	phytophagous	11	0	0	2
Formica cunicularia Latreille, 1798	Hymenoptera	Formicidae	omnivore	0	3	0	0
Isophya zubovskii Bey-Bienko, 1954	Orthoptera	Tettigoniidae	phytophagous	0	0	0	1
Lixus (*Eulixus*) *canescens* Steven, 1829	Coleoptera	Curculionidae	phytophagous	0	0	2	0
Melanobaris carbonaria (Boheman 1836)	Coleoptera	Curculionidae	phytophagous	0	0	1	0
Peribalus strictus subsp. *vernalis* (Wolff, 1804)	Hemiptera	Pentatomidae	phytophagous	0	1	0	0
Phymata crassipes (Fabricius, 1775)	Hemiptera	Reduviidae	predatory	0	0	0	1
Protaetia (*Philhelena*) *ungarica* (Herbst, 1790)	Coleoptera	Scarabaeidae	phytophagous	3	0	0	0
Psyllobora (*Thea*) *vigintiduopunctata* (Linnaeus, 1758)	Coleoptera	Coccinellidae	omnivore	0	0	1	0
Spermophagus calystegiae Lukjanovitch & Ter-Minassian, 1957	Coleoptera	Chrysomelidae	phytophagous	0	1	0	0
Spermophagus sericeus (Geoffroy, 1785)	Coleoptera	Chrysomelidae	phytophagous	1	4	1	0
Teucriogethes distinctus (Sturm, 1845)	Coleoptera	Nitidulidae	phytophagous	0	7	0	1
Tropinota (*Epicometis*) *hirta* (Poda, 1761)	Coleoptera	Cetoniidae	phytophagous	179	349	35	3
Peleteria rubescens (Robineau-Desvoidy, 1830)	Diptera	Tachinidae	phytophagous	1	0	1	0
Metopoplax origani (Kolenati, 1845)	Hemiptera	Oxycarenidae	phytophagous	0	0	1	0
Valgus hemipterus (Linnaeus, 1758)	Coleoptera	Scarabaeidae	phytophagous	0	0	0	1
Cantharis sp.	Coleoptera	Cantharidae	omnivore	0	1	1	0
Lygaeus sp.	Hemiptera	Lygaeidae	phytophagous	0	0	1	0
Orius sp.	Hemiptera	Anthocoridae	predatory	0	0	1	0
Carpocoris sp.	Hemiptera	Pentatomidae	phytophagous	0	1	0	0
Ceutorhynchus sp.	Coleoptera	Curculionidae	phytophagous	0	3	0	0
Polistes sp.	Hymenoptera	Vespidae	omnivore	0	0	1	0

family, adults primarily feed on pollen (Franzini 2019). It is a rare species in our fauna, likely overlooked due to its small size and the challenges associated with identifying it at the species level. There are only historical records before 1911 (Petri 1912) in Hunedoara and Sibiu counties, and the species was omitted in Mayo's catalogue (Mayo 2007). Thus, this new record confirms the presence of this species in Romanian fauna after more than 100 years.

Another noteworthy species associated with the vegetative parts of *C. tataria* is *Protaetia* (*Philhelena*) *ungarica* (Coleoptera: Cetoniidae). This beetle species is found across Central Europe and Asia, typically inhabiting steppe-like habitats (Panin 1957). In contrast to most *Protaetia* species, the larvae typically develop in the burrows of mammals, particularly those inhabited by *Spermophilus* species (Panin 1957). The adults feed on various plants, including the shoots of *C. tataria*, as observed in this study (Fig. 5). Although the species has a wide range, its distribution is restricted due to several factors, including the presence of *Spermophilus* and other similar small mammals, as well as the integrity of steppe-like habitats, that are often overgrazed or burned, thus it is considered a vulnerable species.

Lixus (*Eulixus*) *canescens* (Coleoptera: Curculionidae) inhabits xerothermic, steppe or coastal habitats and it is distributed only in Romania, Moldova, Ukraine and the European part of Russia (Yunakov et al. 2018). Being oligophagous and developing exclusively on *Crambe* species, it has a relatively scattered distribution, closely linked to the distribution of its host plants. In our study, only a single pair of this species was found at one site (Horlești, Iași County), and additional fieldwork is required to confirm its presence at other locations. *Lixus* (*Eulixus*) *canescens* is mentioned in the Red List of Ukraine, as nearly threatened (Yunakov et al. 2018). As it is not listed in the Red Book of Invertebrates of Romania (Murariu and Maican 2021), we propose this species to be included in a future version of the book.

CONCLUSION

This is the first study to present an assessment of the insect community associated with *C. tataria* in Romania. The results showed that phytophagous species dominate insect communities, and the variation in functional traits is linked to the abundance of several insect species. Although insect diversity was moderate, two rare or vulnerable species were observed, highlighting the conservation value of the habitats where *C. tataria* occurs. Horlești and Miroslava differ the most from the other sites in insect species composition. The collected data show the importance of this steppe relict as a structural and trophic resource in dry grasslands. Further long-term studies are needed to clarify the pollination interactions, seasonal variation of insect communities, and the ecological mechanisms linking functional traits to insect visitation patterns.

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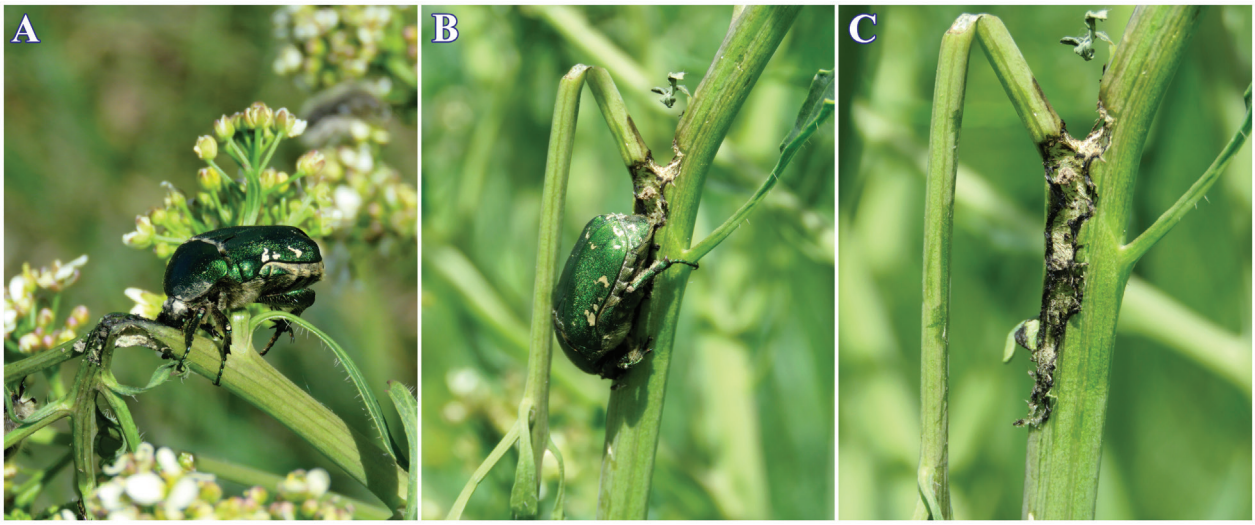


Figure 5. *Protaetia* (*Philhelena*) *ungarica* feeding on the stem of *Crambe tataria* (A. B, and C).

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SUPPLEMENTARY MATERIALS

Supplementary material 1

Environmental and morphological characteristics of plots with *Crambe tataria*.
https://doi.org/10.5091/plecevo.169013.suppl1

Supplementary material 2

List of plant species from plots with *Crambe tataria*.
https://doi.org/10.5091/plecevo.169013.suppl2

Supplementary material 3

List of insect species collected on *Crambe tataria* inflorescences.
https://doi.org/10.5091/plecevo.169013.suppl3

Supplementary material 4

Relationship between inflorescence circumference of *Crambe tataria* and associated insect species. Statistical details are described in the Materials and Methods section (Kendall's tau correlation).
https://doi.org/10.5091/plecevo.169013.suppl4

Supplementary material 5

Relationship between plant height of *Crambe tataria* and associated insect species. Statistical details are described in the Materials and Methods section (Kendall's tau correlation).

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