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THE ROLE OF INSECTS IN POLLINATION AND DISSEMINATION OF SOME PLANT SPECIES IN HIGH-MOUNTAINS OF THE UKRAINIAN CARPATHIANS

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On the example of 5 species of herbaceous flowering plants of the Ukrainian Carpathians it is shown that they are in close relationships with a number of insects, some of which are involved into pollination and hence in the formation of mature seeds. It was found out that the species composition of insects does not depend on plant species composition, but on the ecological conditions of their habitat. The highest number of insects is connected with Dipsacaceae (30 species) and Asteraceae plants (29 species), less with Apiaceae (21 species), and the least with Boraginaceae (13 species). A significant role of phytophagous insects in the reproduction of plant populations was established. For example, *Senecio carpaticus* is one of species that depends significantly on the amount of received damage from the leaf beetles (Chrysomelidae) in the higher parts of the Ukrainian Carpathians. By the example of a number of Formicidae species, the role of myrmecochory in plants seeds dissemination is shown. It was confirmed that successful reproduction of *Pulmonaria filarszkyana* mainly depends on the presence of ants which disperse the species' seeds over large area. *Formica cunicularia*, *F. lemani, F. cinerea, Myrmica ruginodis, Tetramorium caespitum* dominate among the ant species mentioned above.

Keywords: high-mountain plants, insect pollinators, Formicidae, myrmecochory, Ukrainian Carpathians.

INTRODUCTION

It is known that heterotrophic organisms have both positive (pollination and exchange of genetic information between the populations) and negative effect on the reproduction of plants (damaging vegetative and generative parts of the plants). The study on the role of heterotrophic organisms in plant pollination, seeds dispersal and damage to the reproductive organs of plants is a matter of particular interest.

The aim of the study was to establish the quantitative and qualitative composition of insects that are involved in the reproduction of plants, to determine the characteristics and importance of identified animals in their reproduction, and to clarify the role of ants in the dissemination of seeds of some high-mountain plant species in the Ukrainian Carpathians.

Long-term research of entomophilous plants and their pollinators' relationships on the example of some families of angiosperms showed the important role of flower morphology known as "the length of corolla tube" [3, 4]. The family Compositae is differentiated into species by inflorescence colour and length of flowers' corolla tube [3]. Species with white and yellow or yellow inflorescence have short corolla tube; insects with short proboscis (Diptera) dominate among the pollinators. Species with purple-violet inflorescence have long corolla tube; insects with long proboscis, primarily bees, dominate among the pollinators. The relevance of our work is about continuing research in this field through the example of consortial relationships of teasel plant family (Dipsacaceae) and other phylogenetically unrelated high-mountain plant families of the Ukrainian Carpathians [7, 8, 11–13].

Myrmecochory is one of the most interesting examples of the relationships between plants and insects. While seeds of plants have insignificant role in trophics of ants, such an aspect of herbaceous plants usage by ants resulted in important co-evolutionary effect, i.e. the origin of myrmecochory [1, 15]. Myrmecochory is characterized by the availability of specialties both in seeds morphology and instincts of ants, which are seed collectors mostly. In total the relationships between ants and plants are quite peculiar and aren't limited by collecting seeds or fruits only. Some plant species are "cultivated" by ants for aphids, which live on the plants. In some cases ants consume nectar and can pollinate flowers, but there is a lack of available information about the role of Formicidae in pollination for nowadays. At least it is known that species of *Formica* and *Leptothorax* genera pollinate some species of such families as Brassicaceae Burnett, Boraginaceae Juss. and Apiaceae Lindl. in alpine zone. The plant species have favorable morphological and biological features to be pollinated by ants, e.g. small simple flowers, scarce amount of nectar to compensate energy costs of flying pollinators etc. [6]. The investigations show that *Formica lemani* Bondroit, 1917 and *F. picea* Nylander, 1846 are active pollinators of *Vaccinium myrtillus* L., *V. vitis-idaea* L., and *V. uliginosum* L. [2].

To achieve the aim the following objectives were set: to identify the groups of insects that have consortial relationships with reproductive sphere of plants, to specify the activity of the studied animals (myrmecochory, entomophily, etc.), to evaluate the impact of animals on generative sphere of plants, and to establish specific insect taxa that have relationship to the studied plant species.

The resulting information will fill a significant gap in the variety of plants' pollinators in the Ukrainian Carpathians, since the data contained in the literature on pollinators of the families Compositae and Dipsacaceae are mainly related to one species of plants [9], and references to pollinators of most species of plants are fragmentary.

MATERIALS AND METHODS

Case study was conducted on 5 species of plants that grow in different habitats at the altitude of 1350-1700 m a.s.l. and belong to the different families. In particular they are *Knautia dipsitifolium* K. (Dipsacaceae), *Arnica montana* L. and *Senecio carpaticus* Koch. (Asteraceae), *Pulmonaria filarszkyana* Jav. (Boraginaceae) and *Astrantia major* L. (Apiaceae).

The material for the research was sampled and the observations were made during the vegetation seasons of 2009–2012 in the high-mountains of the north-east macroslope of Chornogora in the Ukrainian Carpathians near the summits of Pozhyzhevska (1710 m a.s.l.) and Breskul (1650 m a.s.l.) Mts, and in Tsybulnik kar (1320–1350 m a.s.l.).

The collection of insect pollinators was made by means of entomological net according to the methodology proposed by K. Fasulati [5]. Mirmecochore relationships of the plants were studied by the standard methods that intend to locate the seeds on 100 sq cm area with the following observation of their dispersal by ants [10].

Ratio between the specimen number of the certain insect species and the total number of counted individuals was determined using the system proposed by W. Tischler [14].

RESULTS AND DISCUSSION

Phoric relationships conducted mainly with the activity of insect pollinators are at the forefront among all the consortial relationships as they are tightly combined with the trophic ones. We found out 30 species of insects for the plants of family Dipsacaceae, 29 ones for the family Asteraceae, 21 species for Apiaceae and 13 insect species for Boraginaceae altogether (see Table).

Taxonomic diversity of insect pollinators of some species of the herbaceous flowering plants in high-mountains of the Ukrainian Carpathians

Таксономічне різноманіття комах-запилювачів деяких видів трав'янистих квіткових рослин високогір'я Українських Карпат

Insect taxon	Plant species				
	Arnica montana	*Astrantia major*	*Senecio carpaticus*	*Pulmonaria filarszkyana*	*Knautia dipsitifolium*
Order HYMENOPTERA					
Family *Andrenidae*					
Andrena minutula (Kirby,1802)	-	-	-	-	+*
Andrena hattoxfiana (Fabricius, 1775)	-	-	-	-	+
Andrena wilkella (Kirby,1802)	-	-	-	-	+
Andrena combinata (Christ, 1791)	-	-	-	+	-
Andrena dorsata (Kirby,1802)	-	-	-	+	-
Family *Halictidae*					
Halictus eurygnathus (Bluthg,1931)	-	-	-	-	+
Halictus laevigatus (Kirby,1802)	-	-	-	-	+
Halictus zonulus (Smith,1848)	-	-	-	-	+
Halictus leucozonius (Schrank,1781)	-	-	-	-	+
Halictus fulvicornis (Kirby, 1802)	-	-	-	-	+
Halictus pauxillus (Schenck, 1853)	-	-	-	-	+
Halictus morio (Fabricius, 1793)	-	-	-	-	+
Halictus albipes (Fabricius, 1781)	-	-	-	-	+
Sphecodes gibbus (Linnaeus, 1758)	-	-	-	-	+

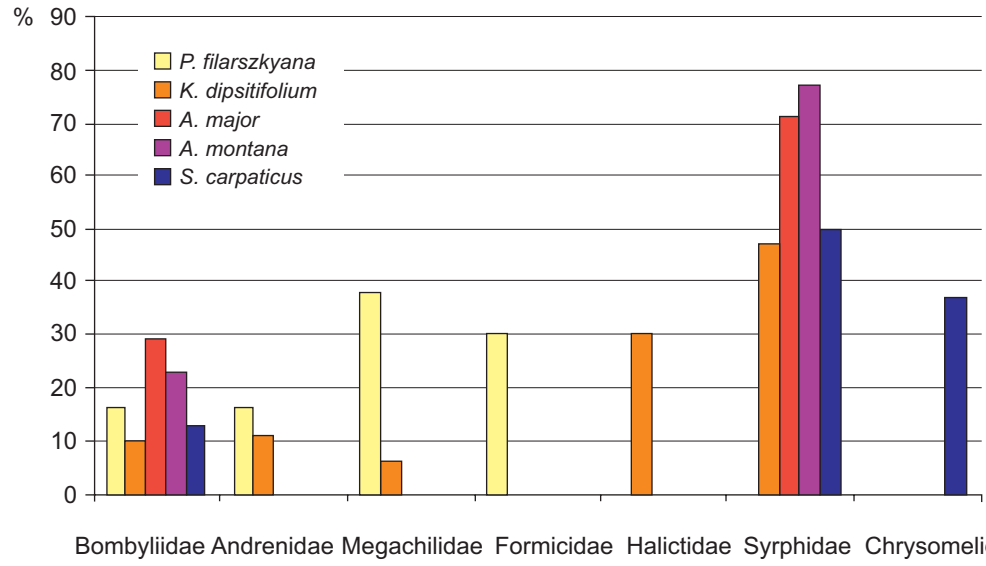
The end of the Table

Family *Megachilidae*					
Heriades truncorum (Linnaeus, 1758)	+	-	-	-	+
Heriades adunca (Panzer, 1798)	-	-	-	+	+
Megachile octosignata (Nylander, 1852)	-	-	-	+	-
Megachile ericetorum (Lepeletier, 1841)	-	-	-	+	-
Nomada sexfasciata (Panzer, 1799)	-	-	-	+	-
Anthophora vulpina **(**Panzer, 1798)	-	-	-	+	-
Family *Bombyliidae*					
Bombus lucorum (Linnaeus, 1761)	+	+		+	+
Bombus pratorum (Linnaeus, 1761)	+	+	+	+	+
Bombus pyrenaeus (Perez, 1880)	-	+	-	-	-
Bombus lapidarius (Linnaeus, 1758)	-	+	-	-	-
Bombus hortorum (Linnaeus, 1761)	+	+	+	-	-
Bombus campestris (Panzer, 1801)	-	+	-	-	-
Order DIPTERA					
Family *Syrphidae*					
Syrphus ribesii (Linnaeus, 1758)	+	+	-	-	+
Syrphus torvus (Osten Sacken, 1875)	-	+	-	-	-
Melanostoma scalare (Fabricius, 1794)	-	+	-	-	-
Eristalis tenax (Linnaeus, 1758)	+	+	+	-	+
Eristalis rupium (Fabricius, 1805)	+	+	+	-	+
Eristalis arbustorum (Linnaeus, 1758)	+	+	+	-	+
Eristalis jugorum (Egger, 1858)	+	+	+	-	+
Eristalis pertinax (Scopoli, 1763)	+	+	+	-	-
*Cheilosia impressa (*Loew, 1840)	-	+	-	-	-
Cheilosia variabilis (Panzer, 1798)	-	+	-	-	-
Cheilosia canicularis (Panzer,1801)	+	-	+	-	+
Scaeva pyrastri (Linnaeus, 1758).	-	+	-	-	+
Scaeva selentica (Linnaeus, 1758).		+	-	-	+
Episyrphus balteatus (De Geer, 1776)	+	+	-	-	+
Sphaerophora scripta (Linnaeus, 1758).	+	+	-	-	+
Eupeodes corollae (Linnaeus, 1758)	-	+	-	-	-
Volucella pellucens (Linnaeus, 1758)	-	-	+	-	+
Volucella bombylans (Linnaeus, 1758)	-	-	-	-	+
Myiathropa florea (Linnaeus, 1758)	+	-	+	-	+
Xylota sylvarum (Linnaeus, 1758)	-	-	-	-	+

Comments: * – presence (+) and absence (-) of insects on the plant

Примітки: * – наявність (+) і відсутність (-) комах на рослині

According to the obtained results, S. *carpaticus* flowers were visited by 16 insect species, while *A. montana* by 15 ones. Species composition both of them is similar (similarity coefficient 0.8). The dominant species are *Eristalis tenax*, *E. arbustorum*, *E. jugorum, Syrphus ribesii* and others. The minor ones respectively are *Eristalis pertinax*, *Cheilosia variabilis*, *Xylota sylvarum* etc. All the insect visitors of these plant species are presented by anthophilous (60 %) and phytophagous species (40 %); the latter ones are mostly represented by leaf beetles of the genus *Chrysochloa*. The species depends a lot on the amount of received damage from the *Chrysochloa* beetles (See Figure).



The percent corellation of the families of insect pollinators of some species of plants in high-mountains of the Ukrainian Carpathians

Відсоткове співвідношення родин комах-запилювачів деяких видів рослин високогір'я Українських Карпат

The generative sphere of plants of the family Apiaceae, which are exemplified by *Astrantia major* were visited by 21 species of insects. The dominant species are *Eristalis tenax*, *E. rupium*, *Cheilosia impressa* and others. Recedative and minor species are *Bombus pyrenaeus*, *B. campestris*, *Sphaerophora scripta*, *Eupeodes corolla* and others, which occurred with the frequency of 0.03–0.07.

During the research it was found out that *A. montana* consorts include 13 species, 85 % of which are anthophilous. They are as follows: *Bombus lucorum*, *B. pratorum,* and hoverflies of the genus *Eristalis*. 15 % of the species are presented by butterflies, namely *Gonepteryx rhamni* and *Erebia medusa*.

Lower number of insect species (11 ones) is typical for *Pulmonaria filarszkyana* due to the long flower corolla tube that is inaccessible for many insect species. Among the species observed there are typically polytrophic insects as *Sphecodes gibbus*, *Heriades truncorum*, *Bombus lucorum*, *B. pratorum* and the species-specific insects as *Andrena combinata* and *A. dorsata* with a visit frequency of 0.04–0.06. It was found out also that renewal of *P. filarszkyana* is tightly connected not only with typical insect pollinators

(reproductive process), but also with the significant activity of ants, that disperse seeds for a considerable distances from the maternal plant. *Formica cunicularia* Latreille, 1798, *F. lemani, F. cinerea* Mayr, 1853*, Myrmica ruginodis* Nylander, 1846*, Tetramorium caespitum* L., 1758 dominate among the recognized species. Due to the activity of ants (seeds dispersal) some loci of *P. filarszkyana* in the typical phytocoenoses of the Ukrainian Carpathians at the different altitude levels are established.

Obligate and facultative myrmecochors can be distinguished among the myrmecochorous plants in general. Their seeds usually have attractive greasy corpuscules or elaiosomes, which are consumed by ants. The seeds are covered by fuzz and fringe to liken them to insects and their larvae what is very attractive for ants. Myrmecochorous species are characterized by early flowering and fruitification. Their morphology has a row of adaptations for self-seeding as well. The elaiosomes of majority of seeds and fruits gathered in ant-hills after having been consumed by ants are removed from there being able to grow. So, that is the reason of different plant composition on the ant-hills of Formicidae and around them from the rest of the territory without the ant-hills and favorable soil conditions, accordingly.

The disruption of the relationships between plants and insects can, on the one hand, results in the extinction of populations of entomophilous plant species and in the loss of the food base for leaf beetles, for example, on the other hand. The bumblebees are one the most essential for the viability of plant populations of the Ukrainian Carpathian high-mountains among the other pollinators. We discovered that the pollinators' composition does not depend a lot on plant species, but depend on the ecological conditions of their habitat. A stable relationship between flowering plants and insect pollinators (they are mainly Hymenoptera) ensures successful reproduction, sufficient exchange of genetic material between populations of plants to form a mature seed.

Thus, after finding out the ways of pollination and seed dispersal of plants in the Ukrainian Carpathians it is now possible to explain the processes and mechanisms of plant population survival in the high-mountain regions and predict the dynamics of their populations.

CONCLUSIONS

It was found out that such high-mountain plant species of the Ukrainian Carpathians as *Knautia dipsitifolium*, *Arnica montana*, *Senecio carpaticus*, *Pulmonaria filarszkyana* and *Astrantia major* are tightly connected with a number of insect pollinators. The most numerous ones among them are representatives of Bombyliidae and Syrphidae, and the less numerous species are insects from the families of Andrenidae and Halictidae. The highest number of pollinator species is recorded for *K. dipsitifolium* (30 ones), and the lowest one – for *P. filarszkyana* (9 species).

The most significant influence of phytofagous insects over the vegetative sphere of the plants occurs for *S. carpaticus* where 40 % of the total amount of consorts belongs to the leaf beetles (*Chrysochloa*). The important role of such species of ants as *Formica cunicularia*, *F. lemani, F. cinerea, Myrmica ruginodis, Tetramorium caespitum* in the dissemination of *P. filarszkyana* seeds is established. This fact points at the lungwort as a typical myrmecochorous species in high-mountains of the Ukrainian Carpathians.

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РОЛЬ КОМАХ У ЗАПИЛЕННІ ТА РОЗПОВСЮДЖЕННІ РЕПРОДУКТИВНИХ ЗАЧАТКІВ ДЕЯКИХ ВИДІВ РОСЛИН ВИСОКОГІР'Я УКРАЇНСЬКИХ КАРПАТ

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На прикладі п'яти видів трав'янистих квіткових рослин Українських Карпат встановлено, що у тісних зв'язках із ними перебуває низка комах, частина з яких бере участь у їхньому запиленні, а відтак у формуванні повноцінного насіння. Було

встановлено, що видовий склад комах залежить від екологічних умов оселища більшою мірою, ніж від видового складу рослин. Найбільша кількість комах була пов'язана з рослинами родини Dipsacaceae – 30 видів, менша – з Asteraceae (29 видів) і Apiaceae (21 вид), а найменша (13 видів) – з Boraginaceae. Вказано на важливу роль комах-фітофагів у відтворенні популяцій рослин. Наприклад, *Senecio carpaticus* є одним із видів у високогір'ї Українських Карпат, який значною мірою залежить від ступеня пошкоджень листоїдами (Chrysomelidae). На прикладі низки видів Formicidae з'ясовано значення мірмекохорії у розповсюдженні насіння. Підтверджено істотну залежність ефективного розмноження *Pulmonaria filarszkyana* від наявності мурашок, які забезпечують розповсюдження насіння цього виду на значній території. З-поміж таких видів мурашок домінують *Formica cunicularia*, *F. lemani, F. cinerea, Myrmica ruginodis* і *Tetramorium caespitum*.

Ключові слова: рослини високогір'я, комахи-запилювачі, Formicidae, мірмекохорія, Українські Карпати.

РОЛЬ НАСЕКОМЫХ В ОПЫЛЕНИИ И РАСПРОСТРАНЕНИИ РЕПРОДУКТИВНЫХ ЗАЧАТКОВ НЕКОТОРЫХ ВИДОВ РАСТЕНИЙ ВЫСОКОГОРЬЯ УКРАИНСКИХ КАРПАТ

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На примере пяти видов травянистых цветковых растений Украинских Карпат установлено, что в тесных связях с ними находится ряд насекомых, часть из которых принимает участие в их опылении и, следовательно, в формировании полноценных семян. Установлено, что видовой состав насекомых зависит от экологических условий местообитания в большей степени, чем от видового состава растений. Наибольшее количество насекомых связано с растениями семейства Dipsacaceae – 30 видов, меньшее – с Asteraceae (29 видов) и Apiaceae (21 вид), а наименьшее (13 видов) – с Boraginaceae. Указана важная роль насекомых-опылителей в воспроизведении популяций растений. Например, *Senecio carpaticus* является одним из видов высокогорья Украинских Карпат, который значительно зависит от степени повреждений листоедами (Chrysomelidae). На примере ряда видов Formicidae показано значение мирмекохории в распространении семян. Подтверждена существенная зависимость эффективного размножения *Pulmonaria filarszkyana* от наличия муравьев, которые обеспечивают распространение семян этого вида на значительной территории. Среди таких видов муравьев доминируют *Formica cunicularia*, *F. lemani, F. cinerea, Myrmica ruginodis* и *Tetramorium caespitum.*

Ключевые слова: растения высокогорья, насекомые-опылители, Formicidae, мирмекохория, Украинские Карпаты.

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