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# How can seed feeders regulate dispersion of thistles, *Cirsium arvense* and *C. heterophyllum*?

**Wie können samenverzehrende Arten die Ausbreitung der Disteln *Cirsium arvense* und C. *heterophyllum* regulieren?**

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## Summary

Thistles (Asteraceae) are permanent or biennial (up to perennial) weeds, which are highly competitive and invasive, and well spread in the whole area of the Czech Republic. Despite the thistles are relatively adequately armored by spines, they support a rich and varied fauna of insect herbivores with their associated predators and parasitoids. Herbivores can significantly reduce reproductive potential of the host plant.

Two studied thistle species (*Cirsium arvense* and *C. heterophyllum*) can propagate by two ways – vegetative (by the roots) and generative (by the seeds). Our study is focused on the occurrence of seed-feeding insects (pre-dispersal seed predators) in flower heads of both thistle species. Despite some species spread particularly vegetative, the role of pre-dispersal seed predators is highly important because of precluding their dispersion on other localities. The main groups of pre-dispersal predators are as follows: Tephritidae (Diptera), Curculionidae (Coleoptera) and Tortricidae (Lepidoptera). The presence and number of seed-head feeding insects were recorded in flower heads (parameters prevalence, intensity, abundance), and these data were compared with literature sources.

**Keywords:** Curculionidae, parasitoids, pre-dispersal seed predators, Tephritidae, Tortricidae, weed

## Zusammenfassung

Disteln (Asteraceae) sind ausdauernde, zwei- bis mehrjährige, sehr konkurrenzstarke Stauden. Sie sind im gesamten Gebiet der Tschechischen Republik verbreitet. Trotz ihrer Bestachelung beherbergen sie eine artenreiche, mannigfaltige Fauna herbivorer Insekten und der mit ihnen assoziierten Prädatoren und Parasitoide. Herbivore können das Reproduktionspotenzial der Wirtspflanze erheblich vermindern.

Die beiden untersuchten Distelarten (*Cirsium arvense* und *C. heterophyllum*) breiten sich auf folgende Weise aus: vegetativ über die Wurzeln oder generativ über die Samen. Unsere Studie behandelt das Vorkommen samenverzehrender Insekten in den Blütenkörben beider Distelarten, und zwar solcher, die die Samen vor deren Ausbreitung fressen. Obwohl sich einige Disteln vor allem vegetativ verbreiten, wird die Rolle dieser Insekten als bedeutsam angesehen, da sie die Ausbreitung an neue Orte verhindern können. Die wichtigsten Gruppen sind Bohrfliegen (Diptera: Tephritidae), Rüsselkäfer (Coleoptera: Curculionidae) und Wickler (Lepidoptera: Tortricidae). Vorkommen und Anzahl der in den Blütenkörben festgestellten phytophagen Insekten wurden anhand der Parameter Dominanz, Intensität der Besiedlung und Dichte ermittelt und mit Literaturangaben verglichen.

**Stichwörter:** Curculionidae, Parasitoide, samenverzehrende Insekten, Stauden, Tephritidae, Tortricidae

## 1 Introduction

*Cirsium* is a large genus of plants from the family Asteraceae. Recently are known more than 250 species of this genus occurring primarily in the subtropical and boreal regions of Eurasia and North America. The occurrence in the southern hemisphere is probably only secondary (Bureš 2004). The majority of thistle species is categorized as important and serious weeds (Bureš 2004). Two of them, *Cirsium arvense* (L.) Scop. (Canada thistle) and *C. heterophyllum* (L.) Hill. (Melancholy thistle), were chosen for our studies because of their harmfulness and their native and common occurrence in the Czech Republic.

Canada thistle is native to Europe and northern Asia. This well-known weed has been introduced to the remaining parts of the world (North and South America, Africa and Australia) (Bureš 2004). *C. arvense* can propagate mainly by the vegetative way (forming extensive clonal colonies from an underground root). Generative reproduction (by plumed seeds) is known from meadows, pastures and non-agricultural land. One flower head of Canada thistle has up to 80 seeds, but most of them are unripe or parasited (by weevils, fruit flies).

*C. heterophyllum* is less harmful, but still not insignificant. Plants occur mostly at meadows without management, pastures and also peatbogs. Clonal colonies of *C. heterophyllum* can decrease quality of fodder and make the forage more difficult. The propagation of Melancholy thistle is common by both ways (vegetative or generative). Seeds are highly parasited and therefore generative reproduction potential is reduced.

One of the significant factors causing seed mortality on the mother plant is pre-dispersal predation which has been intensively studied in many Asteraceae (eg. Hon□k and Martinková 2005, Koprdová and Martinková 2006).

Flower heads of thistles contain the most varied, specific and well-known insect fauna of any part of the plant. They are rich source of food, packed with achenes, and their inhabitants are protected from vertebrate predators by the tough spiny bracts (Redfern 1995). Importance of pre-dispersal predators of thistles is well documented (Scherf 1964, Redfern 1995, Nakamura and Nakamura 2004, www pages: Fitter and Ford 2007, BioImages 2007). The main goal of our study was to find out the spectrum of pre-dispersal seed predators, which use thistle flower heads for their development.

Weeds provide refugia and food for beneficial insects in agroecosystems (Batra 1982). Biological control is the deliberate use of naturally occurring organisms to delimit the distribution and abundance of a target weed (Wilson and Randall 2003). Increased interest in seed-feeding insects is based on their role in biological control. They may kill the weed directly (by weakening or stressing) or indirectly (secondary infection from pathogens) (e.g. Wilson and Randall 2003). In Europe, many insects feed on thistles (Zwölfer 1965) and help to reduce the size of populations. Many Tephritidae species have been established and act as reliable and successful biological control agents in many areas in the USA and Canada, e.g. *Urophora cardui* (L.) for the control of *C. arvense*, *U. stylata* (F.) substantially reduced seed production of *C. vulgare* (White 1988). Weevils have been also used as a successful biological control agents in different parts of USA and Canada and can also reduce plant vigour, e.g. *Hadroplontus litura* (F.), *Cleonis pigra* (Scop.), *Larinus planus* (F.) and *Rhinocyllus conicus* (Fröl.) (Redfern 1995).

The aims of our study were: (1) to find out the occurrence of seed-head feeding insect, (2) to record their abundance in flower heads; (3) to compare obtained data with literature sources and (4) to evaluate the utilizability of pre-dispersal predators as significant biological agents of thistles. Next studies will be focused on the effects of pre-dispersal predators and on the weight and germination of all seeds categories (riped, unripe and damaged), and the studies will compare thistles with their associated insects from geographically different localities. All this knowledge can be used as basal data for biological control of weeds.

## 2 Materials and methods

### *2.1 Plant material*

The study was focused on the occurrence and abundance of seed-feeding insect of thistle heads. 250 flower heads from 250 randomly chosen *C. heterophyllum* plants were collected at a meadow "Pralouka" in the "Jizerské hory" mountains (Bohemia borealis, Liberec env., 50°48'N, 15°21'E, altitude 895 m a.s.l.) at the beginning of July 2007.

The same amount of *C. arvense* flower heads was harvested one week later in the field in the area of Crop Research Institute (Bohemia centralis, Prague – Ruzyn, 50°06'N, 14°17'E, altitude 340 m. a.s.l.). *C. arvense* plants were purposely planted in the field 25 years ago. The flower heads were collected from 50 plants (5 marginal flower heads per plant). All complete and ripe flower heads of both thistle species were each put in paper bag and stored under laboratory conditions (25 °C, 40% relative humidity).

### *2.2 Seed predation*

Two months after collecting the diameter of the receptacle and length of the bract of each flower head was recorded. Consequently the presence and number of pre-dispersal seed predators and their associated parasitoids were established. All developmental stages of predators were first identified visually, then according to the following keys: Freude et al.1983, Merz 1994, Razowski 2003. All material (pre-dispersal predators, parasitoids, seeds) is deposited in the collections of Crop Research Institute in Prague – Ruzyně.

### *2.3 Data processing*

Importance and utilizability of each pre-dispersal predator was assessed according to following parameters: **prevalence** (percentage of infested hosts in population), **prevalence of attacked flower heads** (ratio of prevalence of insect group to total prevalence), **intensity** (mean number of parasites per infested host) and **abundance** (mean number of parasites per potential host). All calculations were done using Excel for Windows.

Tab. 1: Pre-dispersal seed predators on Cirsium arvense (L.) Scop., literature and observed data.
*Tab. 1: Samenverzehrende Insekten an Cirsium arvense (L.) Scop., Literatur und ermittelte Daten.*

| Groups | Literature data | Observed data |
|---|---|---|
| Diptera: Tephritidae | *Acanthiophilus helianthi* (Ross.), *Chaetostomella cylindrica* (Robineau-Desvoidy), *Tephritis cometa* (Loew), *Terellia ruficauda* (F.), *T. serratulae* (L.), *Xyphosia miliaria* (Schr.), *Urophora stylata* (F.) | *Terellia ruficauda* (F.) |
| Diptera: Cecidomyiidae | *Dasineura sp., Clinodiplosis sp., Lestodiplosis sp.* | *Dasineura* sp. |
| Coleoptera: Curculionidae | *Larinus planus* (F.), *L. turbinatus Gyll.*, *Rhinocyllus conicus* (Fröl.) | *Larinus planus* (F.), *Rhinocyllus conicus* (Fröl.) |
| Coleoptera: Bruchidae | *Bruchidius* sp. | |
| Lepidoptera: Cosmopterygidae | *Pyroderces argyrogrammos* (Z.) | |
| Lepidoptera: Tortricidae | *Cochylis hybridella (Hübner)* | |
| Auchenorrhyncha: Cercopidae | *Philaenus spumarius* (L.) | |
| Sternorrhyncha: Aphididae | *Aphis fabae* Scop., *Brachycaudus cardui* (L.), *Dactynotus cirsii* L. | |

Tab. 2: Pre-dispersal seed predators on Cirsium heterophyllum (L.) Hill., literature and observed data.
*Tab. 2: Samenverzehrende Insekten an Cirsium heterophyllum (L.) Hill., Literatur und ermittelte Daten.*

| Groups | Literature data | Observed data |
|---|---|---|
| Diptera: Tephritidae | *Chaetostomella cylindrica* (Robineau-Desvoidy), *Tephritis conura* (Loew) | *Chaetostomella cylindrica* (Robineau-Desvoidy), *Terellia ruficauda* (F.) |
| Diptera: Cecidomyiidae | | *Dasineura* sp. |
| Coleoptera: Curculionidae | *Larinus turbinatus* Gyll., *Rhinocyllus conicus* (Fröl.) | *Larinus turbinatus* Gyll., *Rhinocyllus conicus* (Fröl.) |
| Lepidoptera: Tortricidae | | *Eucosma cana* (Haw.) |

Tab. 3: Values of observed parameters in Cirsium arvense (L.) Scop.
*Tab. 3: Werte der beobachteten Parameter an Cirsium arvense (L.) Scop.*

| Parameters | Predators | Curculionidae | Tephritidae | Cecidomyiidae | Parasitoids |
|---|---|---|---|---|---|
| Prevalence | 0.508 | 0.084 | 0.332 | 0.136 | 0.020 |
| Prevalence of attacked flower heads | | 0.165 | 0.654 | 0.268 | 0.039 |
| Intensity | 1.717 | 1.000 | 1.422 | 2.324 | 1.400 |
| Abundance | 0.872 | 0.084 | 0.472 | 0.316 | 0.028 |

Tab. 4: Values of observed parameters in Cirsium heterophyllum (L.) Hill.
*Tab. 4: Werte der beobachteten Parameter an Cirsium heterophyllum (L.) Hill.*

| Parameters | Predators | Curculionidae | Tephritidae | Cecidomyiidae | Lepidoptera | Parasitoids |
|---|---|---|---|---|---|---|
| Prevalence | 0.964 | 0.032 | 0.372 | 0.640 | 0.408 | 0.128 |
| Prevalence of attacked flower heads | | 0.033 | 0.386 | 0.664 | 0.423 | 0.133 |
| Intensity | 3.929 | 1.375 | 3.538 | 2.981 | 1.275 | 3.313 |
| Abundance | 3.788 | 0.044 | 1.316 | 1.908 | 0.520 | 0.424 |

## 3 Results

### *3.1 Observed parameters*

**Prevalence** in *C. arvense* was significantly higher than in *C. heterophyllum* (**50.8** % vs. **96.4** %), see Tab. 3 and 4. Both parameters, **intensity** and **abundance**, were higher in *C. heterophyllum* than in *C. arvense* (**3.9** vs. **1.7** parasites per infested host and **3.8** vs. **0.9** parasites per potential host); Tab. 3 and 4.

### *3.2 Pre-dispersal predators*

In our experiments we determined seed-feeding species belonging to these insect families: Diptera: Tephritidae, Diptera: Cecidomyiidae, Coleoptera: Curculionidae, Lepidoptera: Tortricidae. In Tab. 1 and 2 literature and observed data on seed-feeding species are compared. Tab. 3 and 4 summarize all studied parameters.

**Fruit flies** (Tephritidae) were the dominant seed predators. Their **prevalence** was similar in both thistle species, **around 30%.** But the **prevalence of attacked flower heads** reached up higher values in *C. arvense* than in *C. heterophyllum* (**65.4%** vs. **38.6%**). **Abundance** and **intensity** in *C. arvense* was almost thrice lower than in *C. heterophyllum* (**0.48** vs. **1.3** fruit flies per potential host, **1.4** vs. **3.5** fruit flies per infested host), see Tab. 3 and 4.

The **intensity** of **Gall midges** (Cecidomyiidae) did not significantly differ between both species (Tab. 3 and 4). The highest level of **prevalence** (**64%**) and **abundance** (**1.91** Gall midges per potential host) was recorded in *C. heterophyllum*.

**Weevils** (Curculionidae) had the lowest value of **prevalence, abundance** and **intensity** in both species and parameters differed between *C. arvense* and *C. heterophyllum*, see Tab. 3 and 4.

**Tortrix moths** (Tortricidae) occurred only in *C. heterophyllum* flower heads. All parameters were relatively high; e.g. **prevalence 40.8%** (Tab. 3 and 4).

### *3.3 Parasitoids*

**Parasitoids** of pre-dispersal predators were classified to several groups: Chalcidoidea (Eulophidae, Eurytomidae, Pteromalidae), Ichneumonoidea (Braconidae, Ichneumonidae). All values of observed parameters were several fold higher in *C. heterophyllum* than in *C. arvense* (Tab. 3 and 4).

## 4 Discussion

Seed-feeding insect have an important role in biological control (Redfern 1995). Recently, several groups of pre-dispersal seed predators on thistles are studied as potential biological control agents: Curculionidae (Louda and O'Brien 2002; Louda et al. 2003, Nakamura and Nakamura 2004), Tephritidae (Redfern 1995, Nakamura and Nakamura 2004, Brändle et al. 2005).

In our study we identified two new pre-dispersal predators of *C. heterophyllum* seeds: *Terellia ruficauda* (F.) (Tephritidae) and *Eucosma cana* (Haw.) (Tortricidae) (Tab. 2). We confirmed the occurrence of several well-known pre-dispersal predators (weevils, fruit flies) for both thistle species (Tab. 1 and 2). Surprisingly, only one fruit fly species, *Terellia ruficauda*, was present in *C. arvense* flower heads in comparison with seven fruit fly species known from literature (Tab. 1). Although the abundance of weevils in flower heads was relatively very low (Tab. 3 and 4), their importance and use as suitable biological control agents for thistles (Louda et al. 2003) is supported by their life strategies. Weevil larvae can destroy almost whole receptacle and could prevent seeds from maturing, but this fact will be verified in next studies. The most effective biological control seem to be a combination of two and more bioagents which together create multiple stresses on the plant; e.g. Tephritidae + Curculionidae in *C. arvense* and Tephritidae + Tortricidae (sometimes + Curculionidae) in *C. heterophyllum*.

Unfortunately, our knowledge of the gall midges is not comprehensive as for other predator groups. Despite their high abundance in flower heads of both thistle species we presuppose that their importance is not high as importance of fruit flies or weevils. Some genera could be also predators feeding mainly on other cecidomyiids and immature stages of fruit flies, weevils and tortrix moths in the flower head (Redfern 1995).

Seed predation in *C. heterophyllum* was severalfold higher than in *C. arvense*, what was confirmed by all values of observed parameters. Only value of "prevalence of attacked flower heads" was lower, meaning that the pre-dispersal seed predators attacked more flower head of *C. heterophyllum*. Seed predation reduces dispersal of thistles to new niches, but does not reduce existing stands (Redfern 1995). The occurrence of Melancholy thistle is confined to several localities, where plants create big colonies which are connected by roots.

*C. arvense*, which due to its root system possesses a highly effective system for propagation and persistence, additionally invests a remarkable part of resources into generative reproduction (Hettwer and Gerowitt 2004). Pre-dispersal predators could limit its propagation to new niches.

Since much basic information on seed predation of both thistle species is lacking, there is still an urgent need to learn more about their seed predators.

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