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# Phenology and flower visitors of selected plant species with special respect to predators of the cabbage whitefly

**Sebastian Laurenz, Rainer Meyhöfer**
*Leibniz Universität Hannover, Institute of Horticultural Production Systems, Section Phytomedicine, Herrenhäuser Straße 2, 30419 Hannover, Germany*

**Abstract:** Floral resources represent essential nutrition for many natural enemies of important arthropod pests. However, they suffer severely from the lack of suitable flowering plants in modern agricultural landscapes in Central Europe and other parts of the world. This study investigated flower phenology and flower visitation by natural predators of the cabbage whitefly, *Aleyrodes proletella*, on selected flowering plants in order to find candidates for a tailored flower strip to improve whitefly pest control. Results show that *Lobularia maritima* was one of the first plants that started flowering, kept flowering for the entire growing season and, together with *Anethum graveolens*, covered the largest area with its flowers. Zoophagous hoverflies visited all evaluated plant species, but most tended to be found on *Berteroa incana*, *Fagopyrum esculentum* and *Ammi majus*. Ladybeetles preferred flowers of *An. graveolens* and visited them at least 4.7 times more frequently than any other flowers. Adult lacewings were abundant in low numbers, but only on *Am. majus*, *L. maritima*, *B. incana* and *F. esculentum*. Sampled zoophagous hoverflies, ladybeetles and lacewings were identified and the species composition for each plant is presented. Several plants have shown to possess promising properties in terms of flower phenology or promotion of different predatory groups. However, actual effects of these plants (individually and implemented in a tailored flower strip) on predator, *A. proletella* and other cabbage pest populations needs to be investigated in future research.

**Key words:** *Aleyrodes proletella*, Aleyrodidae, Chrysopidae, Coccinellidae, Syrphidae, conservation biological control, flowering field margin, tailored flower strip

## Introduction

The cabbage whitefly, *Aleyrodes proletella*, (Hemiptera: Aleyrodidae) has developed to an increasingly important cabbage pest in Europe within recent decades (Nebreda *et al.*, 2005). *Encarsia tricolor* is the most abundant parasitoid of this whitefly pest, but few is known about its predator spectrum. Naturally occuring predators associated with *A. proletella* in Germany predominantly comprise spiders, certain species of zoophagous hoverflies (esp. *Episyrphus balteatus*, *Melanostoma mellinum*, *Sphaerophoria scripta*), ladybeetles (esp. *Harmonia axyridis*, *Clitostethus arcuatus*) and to a minor extent lacewings (*Chrysoperla carnea*) (Laurenz & Meyhöfer, unpublished data).

Most of these beneficial arthropods depend on floral recources, i.e. nectar and pollen, for survival and reproduction. However, the modern agricultural landscape is often shaped by intensive land-use and large-scale monocultures lacking flower availability and diversity. The installation of flowering strips in these landscapes may counteract this issue and promote biological pest control services. Boosting a defined group of insects, i.e. predators of

*A. proletella*, demands a tailored flower composition containing flowering plants that meet certain requirements (Wäckers & van Rijn, 2012). First, flowers should attract the target insects and provide sufficient and suitable floral recources, which must be morphologically accessable for these specific insects. Second, flowers must be present in an adequate number when the predators of *A. proletella* are active. In an optimal case, all mentioned should not apply to cabbage pest insects which exploit floral recources as well (e.g. the lepidopterans *Pieris* spp. or *Plutella xylostella*).

This study aimed to evaluate annual flowering plant species in terms of flower phenology and flower visitation by main predatory groups of *A. proletella*, esp. hoverflies and ladybeetles.

## Material and methods

***Plant species***

Literature was reviewed in order to evaluate annual flowering plant species according to their beneficial effects on hoverflies, ladybeetles and/or lacewings (Hickman & Wratten, 1996; Brandes & Schrei, 1997; Kranz, 2002; Ambrosino *et al.*, 2006; Pontin *et al.*, 2006; Jacquemart *et al.*, 2007; Sadeghi, 2008; Adedipe & Park, 2010; Lixa *et al.*, 2010; Hogg *et al.*, 2011 a, 2011 b; Kopta *et al.*, 2012; Laubertie *et al.*, 2012; Wäckers & van Rijn, 2012; Wojciechowicz-Zytko & Wnuk, 2012; Amorós-Jiménez *et al.*, 2014; Barbir *et al.*, 2015; Van Rijn & Wäckers, 2015). Eleven plant species were selected to be used in this study. Since three species germinated insufficiently (*Pastinaca sativa*, *Reseda lutea*) or did not flower (*Carum carvi*), only eight flowering plant species were investigated in this study (Table 1). Seeds derived from Saatgut-Vielfalt, Weilheim, Germany (*Ammi majus*, *Anethum graveolens*), Treppens & Co. Samen GmbH, Berlin, Germany (*Vicia sativa*) and Appels Wilde Samen GmbH, Darmstadt, Germany (all remaining seeds).

***Experimental set up***

This study was conducted on an experimental field of the Insitute of Horticultural Production Systems, Leibniz Universität Hannover, Germany. Plant species were sown in 1.5 x 1.5 m plots with a densitiy of 1,000 seeds per m² on 6$^{th}$ May 2014. Soil was kept moist by irrigation until germination and plots were hand weeded if necessary. Each treatment (plant species) was replicated four times and plots were allocated in one row in a randomized block design. Plots were surrounded and separated by one row of Brussels sprouts (*Brassica oleracea* var. *gemmifera* cv. Maximus F1) planted in 50 cm distance from each other on 26$^{th}$ May 2014. One week after planting, the Brussel sprouts plants were already evenly infested with a natural population of *A. proletella* (1-5 adults & eggs on almost every plant). These cabbage whiteflies continuously served as prey throughout the experimental period to increase the abundance of its predators (esp. hoverflies and ladybeetles) at the experimental location. No pesticides were applied in this study to avoid any side-effects on the investigated insects and plants.

Table 1. Plant species evaluated in this study, their families, flower colours and type of offered nectar (FN = floral nectar, EFN = extra-floral nectar).

| Plant species (common name) | Family | Flower colour | Nectar |
|---|---|---|---|
| *Ammi majus* (bishop's weed) | Apiaceae | white | FN |
| *Anethum graveolens* (dill) | Apiaceae | yellow | FN |
| *Berteroa incana* (hoary alyssum) | Brassicaceae | white | FN |
| *Centaurea cyanus* (cornflower) | Asteraceae | blue | FN/ EFN |
| *Fagopyrum esculentum* (buckwheat) | Polygonaceae | white | FN |
| *Lobularia maritima* (sweet alyssum) | Brassicaceae | white | FN |
| *Phacelia tanacetifolia* (lacy phacelia) | Boraginaceae | purple | FN |
| *Vicia sativa* (common vetch) | Fabaceae | purple | FN/ EFN |

***Germination and flower phenology***

Germination and flowering were evaluated (yes/no) weekly to determine the germination time and flowering period, respectively, of each plant species. Standardized photos of flowering plots were taken monthly and the pixel size of all flowers in a central squared plot area of a certain size (160,000 pixels) was determined using Adobe Photoshop CS2. Based on these data the percentage of flower covered area was calculated for each plot.

***Flower visitors***

Insects that tend to let themselves drop when disturbed (e.g. ladybeetles) were initially collected by hand from each plot. Afterwards, all flying insects (visible with the naked eye) that visited the flowers of one plot within 3 minutes were caught with a sweep net (1 mm mesh size). All sampled insects were preserved in 70% ethanol. Zoophagous hoverflies, ladybeetles and lacewings were identified to species, non-zoophagous hoverflies to genus and all others to order level. Samples were taken on three sunny, dry and windless days (6$^{th}$ August, 12$^{th}$ August and 8$^{th}$ September 2014) between 9-11 am or 2-4 pm during a period in which all plant species flowered simultaneously. *Vicia sativa* did not flower at that time and flower visitors could therefore not be determined for this species.

***Statistics***

Data on flower visitors were pooled over the three sampling dates and analysed with IBM SPSS Statistics 23. The non-parametric Kruskal-Wallis test followed by a Mann-Whitney-U test, if required, was used to determine significant differences between the plant species regarding flower visiting hoverflies, ladybeetles and lacewings (alpha = 0.05).

## Results and discussion

***Germination and flower phenology***

All plant species germinated within seven (*C. cyanus*, *F. esculentum*, *L. maritima*, *P. tanacetifolia*, *V. sativa*) or 14 days (*Am. majus*, *An. graveolens*, *B. incana*). First flowers appeared between 10th June (*F. esculentum*, *L. maritima*; 35 days after sowing) and 1st July (*Am. majus, An. graveolens, B. incana*; 56 days after sowing). *Berteroa incana*, *L. maritima* and *P. tanacetifolia* showed with at least 140-161 days the longest flowering period (still flowering at the end of the experiment). Average and maximum flower covered areas were largest in *An. graveolens* (18.2% and 29.8%, respectively) and *L. maritima* (15.8% and 34.8%, respectively) (Table 2).

Table 2. Flowering period and flower covered area (%) of evaluated plant species (- = still flowering at the end of the experiment; bold numbers indicate highest values).

| **Plant species** | **Flowering period** | | | **Flower covered area (%)** | |
|---|---|---|---|---|---|
| | **Start** | **End** | **Days** | **Maximum** | **Average** |
| *Ammi majus* | 1st July | 23rd Sept. | 84 | 22.8 | 8.3 |
| *Anethum graveolens* | 1st July | 26th Aug. | 56 | **29.8** | **18.2** |
| *Berteroa incana* | 1st July | - | **>140** | 17.6 | 8.4 |
| *Centaurea cyanus* | 24th June | 23rd Sept. | 91 | 10.3 | 4.1 |
| *Fagopyrum esculentum* | **10th June** | 23rd Sept. | 105 | 15.9 | 7.6 |
| *Lobularia maritima* | **10th June** | - | **>161** | **34.8** | **15.8** |
| *Phacelia tanacetifolia* | 17th June | - | **>154** | 7.6 | 4.6 |
| *Vicia sativa* | 17th June | 1st July | 14 | 0.1 | 0.1 |

***Flower visitors***

A total number of 90 hoverflies was sampled. Thirty-six of them belonged to the zoophagous species *Sphaerophoria scripta* (53% of zoophagous hoverflies), *Melanostoma mellinum* (22%), *Syrphus ribesii*, *Sy. vitripennis* (both 8%), *Episyrphus balteatus* (6%) and *Sp. rueppellii* (3%). Abundances and species compositions of flower visiting zoophagous hoverflies on each plant species is displayed in Figure 1. Most zoophagous hoverflies, including species associated with *A. proletella* (*E. balteatus*, *M. mellinum* and *Sp. scripta*) (Laurenz & Meyhöfer, unpublished data), tend to be attracted by flowers of *B. incana* (0.25 per min), followed by *F. esculentum* (0.19 per min) and *Am. majus* (0.17 per min). In contrast, the fewest numbers were found on *P. tanacetifolia* (0.06 per min). These results confirm observations by Brandes & Schrei (1997) and Van Rijn & Wäckers (2015). Although, average numbers of total zoophagous hoverflies as well as the single species did not differ significantly between flowering plant species ($p > 0.05$). Fifty-four of the sampled hoverflies were non-zoophagous species (63% *Syritta* spp., 28% *Eristalis* spp., 6% *Helophilus* spp., 2% *Volucella* spp. and 2% *Cheilosia* spp.).

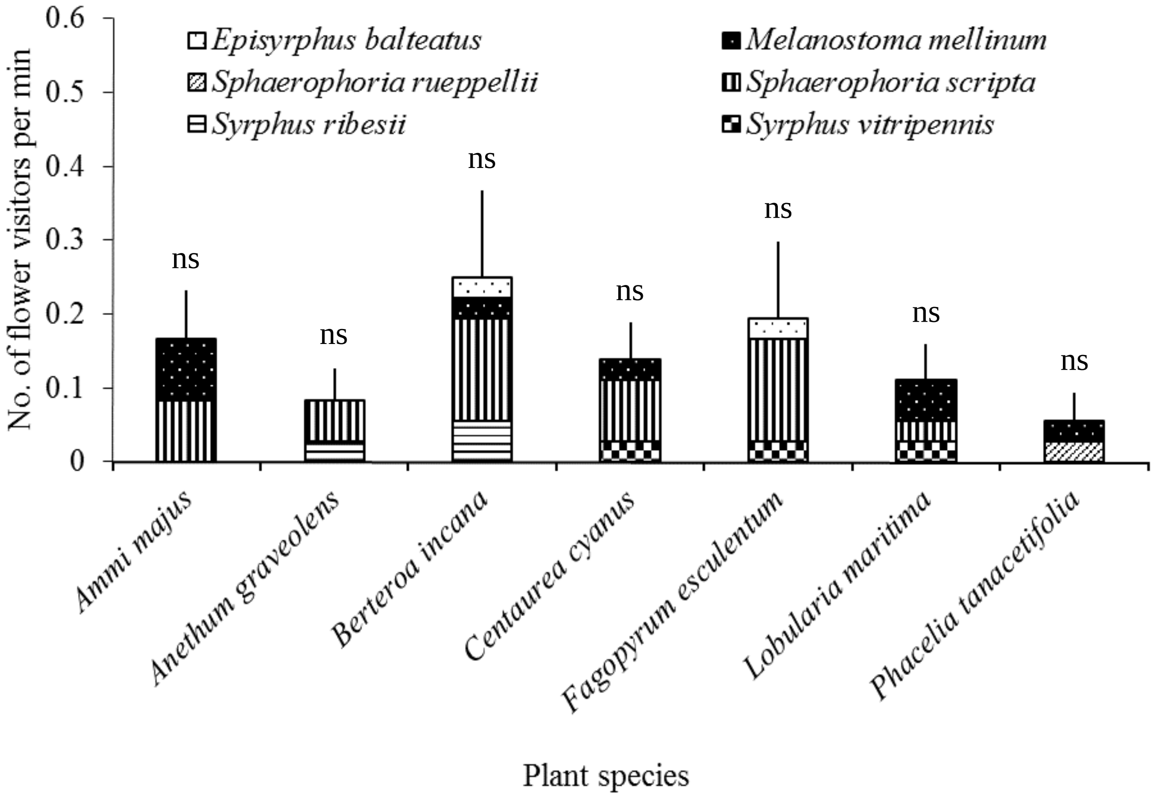


Figure 1. Average abundance (number per min ± SE) and species composition of zoophagous hoverflies on flowers of the evaluated plant species (ns = no significant differences, Kruskal-Wallis test, alpha = 0.05).

We caught a total number of 22 adult ladybeetles consisting of the following six species: *Coccinella quinquepunctata* (46% of ladybeetles), *C. septempunctata* (36%), *Adalia bipunctata* (5%), *Harmonia axyridis* (5%), *Hippodamia variegata* (5%) and *Propylea quattuordecimpunctata* (5%). Figure 2 shows the average abundances and species compositions of flower visiting ladybeetles for each plant species. *Anethum graveolens* flowers were visited by at least 4.7 times as many ladybeetles (0.39 per min) as any other plant species (≤ 0.08 per min). Lixa *et al.* (2010) also reported a high abundance of ladybeetles on *An. graveolens* compared to other Apiaceae. Attractiveness to this plant was also observed by Adedipe & Park (2010) for *H. axyridis*, which was exclusively sampled on *An. graveolens* in the present study and which is known to be a predator associated with *A. proletella* (Laurenz & Meyhöfer, unpublished data). Fewer ladybeetles than on *An. graveolens* were found on flowers of *Am. majus*, *B. incana* (both 0.03 per min), *L. maritima* (0 per min) and *P. tanacetifolia* (0.03 per min) ($p < 0.05$). The single ladybeetle species did not differ significantly between the treatments ($p > 0.05$).

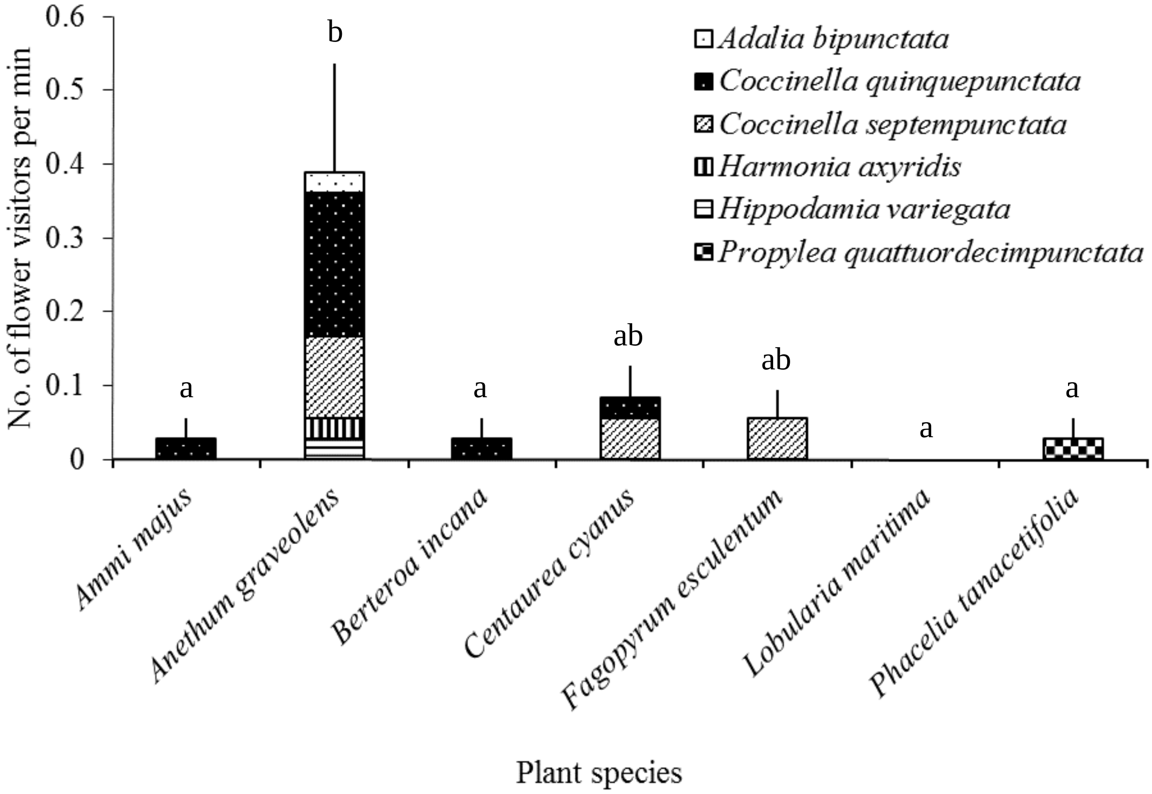


Figure 2. Average abundance (number per min ± SE) and species composition of ladybeetles on flowers of the evaluated plant species. Different letters indicate significant differences (Mann-Whitney-U test, alpha = 0.05).

Thirteen adult lacewings were sampled in total, all belonging to the species *Chrysoperla carnea*. Most of them visited the flowers of *Am. majus* (0.17 per min) followed by *L. maritima* (0.08 per min), *B. incana* and *F. esculentum* (both 0.06 per min). No lacewings were found on the other plants. Differences between the plant species were not significant.

Two species of cabbage pests were among the sampled flower visitors, *Pieris rapae* and *Plutella xylostella*. However, the total numbers of sampled individuals (two of each species) were too low to compute any significant differences between the treatments. The remaining sampled insects belonged to the orders Coleoptera (other than ladybeetles), Diptera (other than hoverflies), Hemiptera (Auchenorrhyncha), Heteroptera and Hymenoptera.

In conclusion, this study gives insight about the properties of selected annual flowering plant species in terms of flower phenology and attractiveness to predatory groups and species. These are promising results on flower choice of natural predators of *A. proletella*. However, morphometric, metabolic and life-table studies followed by more research on the effect of each plant species, individually and combined in a mix, on predator and pest populations are needed (Wäckers & Van Rijn, 2012).

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