

The suitability of field margin flowers as food source for zoophagous hoverflies

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Abstract: Hoverflies with zoophagous larvae are among the most common natural enemies of pests in Dutch arable fields. Their effectiveness is partly limited by the availability of nectar and pollen for the adults. In this study we examined the suitability of flowers of *ca.* 30 plant species as food source for the common *Episyrphus balteatus*, both with choice tests and with non-choice survival tests. Many common field margin flowers appear to be unsuitable, as they do not allow the hoverflies to survive up to their reproductive age. The results can well be explained by flower morphology: only flowers with nectar available at a depth of less than 2 mm are suitable. Choice tests indicate that the hoverflies mainly select flowers with accessible nectar. Moreover, field studies showed that field margins with a higher proportion of flowers with accessible nectar attract higher numbers of zoophagous hoverflies. These results stress the importance of laboratory bioassays for selecting the right plants for functional field margins.

Key words: natural pest control, conservation biological control, field margins, sustainable agriculture, pesticides, flower morphology, nectar, pollen, Diptera: Syrphidae

Introduction

Many insect carnivores that play a role in the suppression of pests require nectar, and sometimes also pollen, during their adult life stage (Wäckers et al., 2005). The scarcity of flowering plants in modern agricultural fields may therefore prohibit an effective performance of these beneficial insects. In the second stage (2008-2011) of the Functional AgroBiodiversity (FAB2) project in the Netherlands (Van Rijn et al., 2008), both annual and perennial field margins are being developed. The botanical composition of these margins is chosen to optimize support for natural enemies of pests, without compromising other functions of arable field margins, such as aesthetic quality and the support of birds and bees and general biodiversity.

In our region, aphids and thrips are the most important insect pests in arable crops such as potato and onion. Hoverflies (Syrphidae) with zoophagous larvae are, together with lacewings, the most common natural enemies in these crops, making up *ca.* 50% of all predators found on potato leaves. Adult hoverflies require nectar and pollen as a food source, the first mainly for movement and survival, and the second mainly for reproduction.

The relatively short proboscis of zoophagous hoverflies (Syrphinae) will likely limit the range of flowers suitable for providing nectar compared to other hoverflies (Gilbert, 1985) and hymenopteran pollinators (bees and bumblebees). In order to learn which types of flowers are suitable, we tested *ca.* 30 flower species in laboratory bioassays with the marmalade fly *Episyrphus balteatus*. To check the validity these results in the field, the pollinator fauna of several flower mixtures in field margins were investigated in summer.

Material and methods

To test the suitability of flowers for hoverflies, both longevity and flower choice of *E. balteatus* adults were measured. The plant species were selected on reported visitation by hoverflies in general. The plants were obtained from seed or from field margins and road sides, and were left for 2 days in cages before testing.

Adult longevity was measured in gauze cages (210 dm³) under controlled conditions (22 °C, 80% RH, 16L:8D). Each cage contained flowering plants of a single species and a 12 ml bottle with wet cotton wool for free water supply. In each cage one male and two females of *E. balteatus* were released, within 24 hours after emergence from their pupae. The pupae were reared and provided by Koppert B.V. The survival of the hoverflies was checked at least every other day. Per plant species on average 18 hoverflies were tested, in minimally two different years.

Flower choice was tested in large gauze cages (1.2 m³) in experimental greenhouses with four different plant species in each cage. Each species provided *ca.* 1 dm² of fresh flowers. In each cage 2 young hoverflies (1 male and 1 female) were released and observed for 30 minutes, recording the time spend on each type of flower by each individual. Each plant species was tested in at least 6 different combinations and positions.

Nectar accessibility was determined by making HR digital scans of vertically dissected flowers and flower heads. The depth at which the nectar is produced ('flower depth') is measured as the distance between the nectary and nearest side that is big enough for the hoverfly to enter with its body.

Field margin strips (n=12) with 5 different annual flower mixtures were repeatedly sampled on for flower composition and insect visitation between June 24 and July 21, 2009. On quiet and sunny days representative quadrants of 3 x 1.5 m were observed for 5 minutes each, to estimate the number of flower visiting insects within different functional groups.

Results

Adult longevity and nectar accessibility

In absence of any food (water only) the adult hoverflies survive for 1.9 (\pm 0.2) days. The classification of the flowers based on nectar accessibility correlates well the suitability of flowers based on hoverfly longevity (see Figure 1). A survival of more than 8 days is observed with all 6 umbelliferous species (Apiaceae) tested, as well as with buckwheat, buttercup and borage. In all these plants the floral nectaries are well exposed. The plant species of the legume family (Fabaceae) do not allow the hoverflies to live longer than with water only, except for *Vicia faba*, a species with extrafloral nectaries (EFN) on the stipules. Only larger insects such as honeybees have enough weight to lower the keel petals of the legume flowers and to open access to the nectaries and the stamen. Among the 15 species tested within the composite family (Asteraceae) large differences are observed. These differences appear to be highly correlated with the depth of the tubular florets (see Figure 1). Since under optimal conditions these hoverflies start ovipositing from the 6th day onward (Van Rijn et al., 2006) a mean longevity of *ca.* 6 days is used as critical value to separate suitable from insufficiently suitable food sources. All flowers with a corolla depth of 1.6 mm or less appear to be suitable. When the corolla depth is between 1.6 and 2.1 mm the survival is insufficient, but still better than with water only (T-tests, $p < 0.05$). Flowers with deeper florets are not better than water, despite the availability of pollen. Also composites with EFN's (*Centaurea cyanus* and *Helianthus annuus*) allow hoverflies to survive for more than 6 days, despite deep corollas.

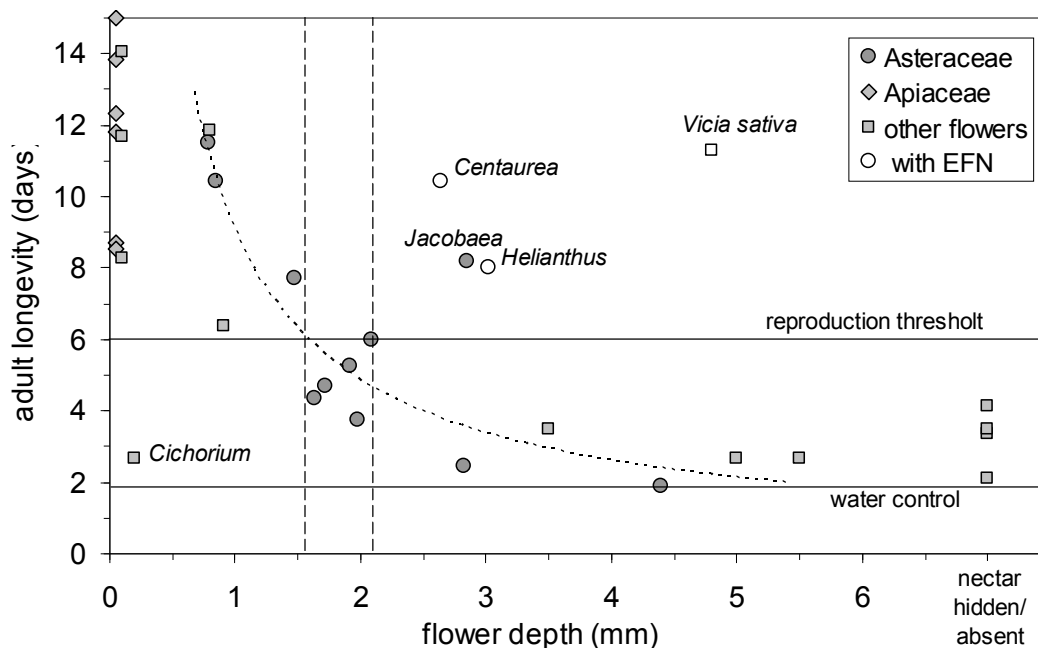


Figure 1. The adult longevity of *Episyrphus balteatus* (males and females combined), in relation to the flower depth of the plant species provided. Dotted curved line represents hyperbolic regression line for the subset of Asteraceae with tubular florets, excluding those with extrafloral nectaries ($R^2=0.63$, without *Jacobaea vulgaris* $R^2=0.89$). Other lines: see text.

Flower choice

The mean time spent on the flowers of the different plant species in the choice test was clearly correlated with the longevity shown in the non-choice tests ($R^2=0.28$, $n=24$, $p<0.01$). Based on the choice test the plant species are classified in 'preferred', 'neutral' and 'avoided', where 'neutral' plants are visited as expected from random choice ($= 1/4$ of the time). Within the 14 tested plant species with accessible floral nectar only 2 are avoided, 6 are neutrally selected and 6 are visited more. Within the 10 species with apparent inaccessible nectar 8 are avoided, 1 is neutral and only 1 is visited disproportionately more. These data indicate that flower choice mainly reflect nectar accessibility.

Hoverfly numbers in flowering field margins

The mean number of zoophagous hoverflies in each field margin (mainly *Episyrphus*, *Eupeodes*, *Syrphus*, *Sphaerophoria* and *Melanostoma* species, on average 6.7/quadrant) is nearly significantly correlated with the mean coverage of flowers ($R^2=0.21$, $p=0.07$). However, when restricting to flowers with accessible nectar (flower depth < 2 mm or EFN), the correlation increases to $R^2=0.83$ ($p=0.001$). In contrast, for the number of pollinators with longer proboscises (bees, bumblebees and saprophagous hoverflies) the correlation remains below $R^2=0.02$ in both cases. These results indicate that in the field zoophagous hoverflies are mainly attracted to plants which have proven to have accessible nectar in the bioassays.

Conclusions and Discussion

This study has shown that the suitability of flowers as food source for the hoverfly *E. balteatus* (based on adult survival) is largely determined by the accessibility of the nectar,

more specifically the flower depth. Also flower choice is strongly related to nectar accessibility. The critical flower depth seems to be 1.6 mm (see Figure 1), which would rule out most of the composite flowers with tubular florets. However, among common zoophagous hoverfly species, *E. balteatus* has the shortest proboscis (Gilbert, 1985). Taking the differences in proboscis size into account the other zoophagous hoverflies can probably use flowers that are 0.4–0.5 mm deeper. Field observations support this assumption.

These results contrast with the long standing conviction, based on Gilbert (1985), that *E. balteatus* and related hoverflies are mainly foraging on pollen, rather than nectar. This conviction has also led to the recommendation of *Phacelia tanacetifolia* as field margin plant (Hickman & Wratten, 1996). However, these plants are visited for pollen only, and result in an adult longevity of *ca.* 4 days, which is too short for any reproduction. Under field conditions the hoverflies may be able to forage on more than one plant species. At sufficient aphid densities the hoverflies may even use aphid honeydew as sugar source (Van Rijn et al., 2006). However, the need to boost the hoverflies before aphids reach high numbers, and the much smaller range of flowers with accessible nectar than with accessible pollen, will make it especially important to add plants with accessible nectar.

Hoverflies are not the only natural enemies of importance in arable crops. The selected plant species should therefore also be checked on suitability for e.g. lacewings and hymenopteran parasitoids. Moreover, similar bioassays should be performed with pest insects such as thrips and root flies (see Wäckers et al., 2007), to ensure that the flower strips are selectively enhancing the beneficial insects over the herbivores.

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