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Targeted flower strips effectively promote natural enemies of aphids

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Abstract: Sown wildflower strips are increasingly established within agri-environmental schemes in Europe and worldwide. Their goals include the promotion of biodiversity, pest control or pollination services. Here, we tested whether a new type of flower strip targeted to promote natural enemies controlling aphids and other wheat pests are more effective in achieving this goal than an already implemented wildflower strip type aimed at biodiversity conservation. We found two to five times higher numbers of key aphid antagonists, Syrphidae, Coccinellidae and *Chrysoperla carnea* (Chrysopidae), in the targeted flower strip compared to wildflower strips designed for biodiversity conservation. The targeted use of flowering plants, providing fundamental resources for natural enemies of crop pests, might significantly contribute to an efficient integrated pest management.

Key words: agri-environment schemes, conservation biological control, ecosystem services, flower resources, functional biodiversity, pest, semi-natural habitats

Introduction

Sown wildflower strips are implemented in agri-environment schemes (AES) in Europe and worldwide with two main specific goals: 1) To enhance farmland biodiversity *per se* (Haaland *et al.*, 2011) and 2) To foster ecosystem services like pollination and conservation biological pest control (Haaland *et al.*, 2011). Sown wildflower strips seem to be rather effective in combining these two goals (Haaland *et al.*, 2011, Korpela *et al.*, 2013). Flower strips containing plants offering rich nectar and pollen sources were repeatedly found to be superior to other types of wildflower strips in terms of promoting insect abundance and the linked ecosystem services (Haaland *et al.*, 2011).

As they depend on nectar and pollen sources in at least one stage of their life cycle, natural enemies of aphids and other wheat pests were found to profit from selected pollen and nectar plants in terms of attraction and biological fitness (Laubertie *et al.*, 2012, Wäckers, 2004). Here, we tested wheather a targeted flower strip with a new nectar and pollen mixture is more effective in promoting natural enemies of aphids than biodiversity promoting wildflower strips as already implemented in Swiss AES.

Material and methods

Flower strips and study design

The newly tested type of flower strip ("targeted flower strip", hereafter TFS) is an annual linear element, which composition is tailored to requirements of specific natural enemies within a cropping system. It is sown with wildflower species (*Anthemis arvensis, Anthriscus cerefolium, Centaurea cyanus, Papaver rhoeas*) and herbs (*Anethum graveolens, Coriandrum sativum, Fagopyrum esculentum*) which were selected based on a review of existing evidence for positive effects of floral and extra-floral resources provided by the species on fitness traits

and/or populations of natural enemies of aphids (i.e. aphidophagous Syrphidae, Coccinellidae and *Chrysoperla carnea*) (e.g. Haaland *et al*., 2011, Pineda & Marcos-Garcia, 2008, Wäckers & van Rijn, 2012, Wäckers, 2004). TFS are designed as annual strips that provide resources and shelter during the entire growing season of the crop (e.g. winter wheat). Thus, TFS are sown together with the crop and ploughed under before the following culture is sown or planted within the crop rotation system. Ten TFS were sown in spring 2012 as 3m-wide strips adjacent to winter wheat fields in the central Swiss plateau. At the time when natural enemy sampling was done (see below) TFS were dominated by flowering plants of *F. esculentum* and *C. cyanus* and to a lower extent of *P. rhoeas* and *C. sativum*.

Wildflower strips aimed at general biodiversity conservation and restoration in crop-dominated landscapes ("biodiversity promoting wildflower strips", hereafter BWS) are part of the Swiss agri-environment scheme (Bundesrat, 2013). BWS are perennial ecological corridor elements sown with 24 to 37 indigenous forbs and legumes (Pfiffner & Wyss, 2004). Ten BWS were selected according to their linear shape, similar area and their age (between 2 to 5 years) in the same study region. As control plots, three-meter wide winter wheat strips (n = 15) were randomly selected in the same study region. Winter wheat strips were managed according to the guidelines of extensive cereal production, where no pesticides except herbicides are allowed (Bundesrat, 2013). Likewise, in TFS and BWS no pesticide treatment except targeted application to individual plants, and no fertilization are permitted (Bundesrat, 2013). During sampling time flowers of *A. millefolium*, *H. perforatum* and *O. vulgare* were predominant in BWS followed by a notable amount of *C. jacea*, *A. tinctoria* and *M. moschata*.

Sampling of natural enemies

Natural enemies were sampled using standardized sweep netting (60 sweeps) in each flower and control strip at the beginning of July 2012. The target natural enemy groups were Syrphidae, Coccinellidae and *Chrysoperla carnea* (Chrysopidae), as they are well-known as key enemies of aphids and other wheat pests (e.g. Rusch *et al.*, 2010). In a recent study of similar habitats in the same region 89% of all Syrphidae were aphidophagous and results of were qualitatively identical for the two response variables (Senn *et al*., in prep.), indicating that total Syrphidae is a good proxy for aphidophagous Syrphidae in our study system.

Data analysis

Individual numbers of adults of the different natural enemy groups were analyzed using R statistical software. To evaluate the influence of 'treatment' (i.e. Control strip, BWS, TFS) on number of Syrphidae, Coccinellidae and *Chrysoperla carnea* we fitted linear models using the lm() function and using a square root transformation of the response variable to achieve normality and homogeneity of variances of residuals. Model selection was done following recommendations of Zuur *et al.* (2009) and inference on treatment differences was based on model contrasts.

Results and discussion

For all three natural enemy groups we found significantly more individuals in targeted flower strips (TFS) compared to BWS and/or control strips (Figure 1, Table 1). Moreover, numbers of Syrphidae (Figure 1A) were higher in BWS than in wheat control strips, while those of Coccinellidae (Figure 1B) and *C. carnea* (Figure 1C) did not differ significantly between BWS and control strips.

Syrphidae seem to respond strongest to the flower strips. This is indicated by the amount of variance that is explained by the different models (R^2, see Table 1) and the almost tenfold number of individuals that is found in flower strips compared to the other two natural enemy groups (notice the different y-scale in Figure 1A compared to B and C).

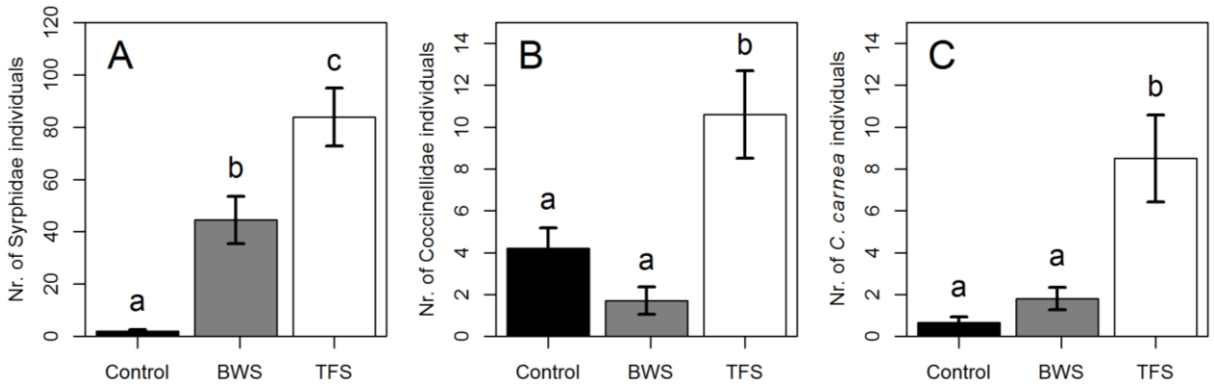

Figure 1. Mean (± 1 SE) of adult numbers of Syrphidae (A), Coccinellidae (B) and *Chrysoperla carnea* (Chrysopidae) (C) across the three treatments. Control (wheat) strips are represented by black bars, biodiversity promoting wildflower strips (BWS) by grey bars and targeted flower strips (TFS) by white bars. Different letters indicate significant treatment differences ($P \leq 0.001$).

Table 1. Effects of treatment (Control strip, BWS, TFS) on Syrphidae, Coccinellidae and *Chrysoperla carnea* (Chrysopidae) individuals.

	DF	F	P	R^2
Syrphidae	2, 32	76.91	< 0.001	0.83
Coccinellidae	2, 32	10.99	< 0.001	0.21
Chrysoperla carnea	2, 32	17.57	< 0.001	0.49

Our findings show that a targeted selection of flowers aiming at improving nectar and pollen resources for natural enemies is indeed a suitable way for improving natural enemy abundance in the field. Data about visitation rates of the flowering plant species by the target natural enemies and the effects of the same plants on natural enemy fitness show that some flowering plant species (e.g. *Coriandrum sativum* or *Fagopyrum esculentum*) are clearly preferred and show positive fitness effects (Tschumi *et al.*, unpublished data). As main target groups of natural enemies are fostered to a higher extend by TFS than with existing wildflower mixtures, we suggest that TFS should be used in agri-environment schemes to direct biological pest control services to the focal areas.

Existing wildflower strips should not compete with new elements, as they are highly valuable for biodiversity conservation (Aviron *et al.*, 2009; Herzog *et al.*, 2005). Aviron *et al.* (2009) found between 8% and 60% more species of ground beetles and spiders in BWS compared to arable crops and the total expected numbers were higher for plants, spiders and ground beetles. Further, TFS are designed for annual use only. They are aimed at attracting natural enemies to the focal crop area or field and provide resources during the growing

season. However, perennial elements are indispensable to ensure that sufficient resources are provided for natural enemies in all live stages (e.g. overwintering). Thus the conjoint use of several elements might be the best solution for ensuring ecosystem services on a long term perspective.

The sole abundance of natural enemies is only an indicator for pest control services. To ensure that the conservation biological control is increased, we need to look directly at pest populations and pest reduction in the focal areas. Data that was collected in surrounding fields of flower strips indicate that the use of targeted flower strips (TFS) can indeed promote natural pest control services in adjacent winter wheat crops (Tschumi *et al.*, in prep.).

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