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Banker plants promote functional biodiversity in cabbage

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Abstract: Natural enemies of the cabbage whitefly *Aleyrodes proletella* do currently not regulate whitefly populations sufficiently. Biological control methods in field crops have often been neglected, although offering promising tools to increase the abundance and diversity of natural enemies. For instance, the release and promotion of natural enemies with banker plants is one way to increase functional biodiversity and biological control services in field crops. This field study investigated the following two banker plant systems against *A. proletella*: (1) the greenhouse whitefly *Trialeurodes vaporariorum* on pumpkin and (2) the honeysuckle whitefly *A. lonicerae* on European columbine. Both systems were inoculated with the parasitoid *Encarsia tricolor*. We evaluated the effect of the banker plant systems on *A. proletella* parasitism rates as well as the abundances of adult *E. tricolor* and predators on neighbouring Brussels sprouts plants. Both, average parasitism rates and adult *E. tricolor* increased by at least 50% by either banker plant systems. Furthermore, the abundance of hoverfly larvae was 63% higher in the treatment with pumpkin as banker plant compared to the control, whereas 11-12% fewer spiders were found in both treatments with banker plants. In conclusion, especially the banker plant system with *T. vaporariorum* and *E. tricolor* on pumpkin promoted functional biodiversity on cabbage plants and showed promising potential as banker plant system in cabbage crops.

Key words: *Aleyrodes proletella*, Aleyrodidae, biological control, cabbage whitefly, *Encarsia tricolor*, natural enemies, predators

Introduction

The cabbage whitefly *Aleyrodes proletella* (Hemiptera: Aleyrodidae) has developed to a major pest on several *Brassica* crops in Europe (Trdan & Papler, 2002; Nebreda *et al*., 2005). Especially organic vegetable producers lack successful management strategies against this pest, mainly because the few efficient chemical agents on the market are restricted to conventional production (Richter & Hirthe, 2014). Furthermore, the impact of the dominating whitefly parasitoid *Encarsia tricolor* (Hymenoptera: Aphelinidae) and the abundance of important generalist predators like hoverfly larvae or whitefly specialists like *Clitostethus arcuatus* (Coleoptera: Coccinellidae) is currently not sufficient to downregulate *A. proletella* populations significantly (Bathon & Pietrzik, 1986; Pütz *et al*., 2000; Laurenz *et al*., 2016). Alternative or supplementary tools are desired to improve the efficiency of biological control of *A. proletella*. Banker plants for instance have proven to increase natural enemy abundances and biological control services in the greenhouse, but also in the field (Pickett *et al*., 2004; Huang *et al*., 2011). This study evaluates the potential of two newly composed banker plant systems with *E. tricolor* as natural enemy to promote the functional biodiversity of *A. proletella* natural enemies.

Material and methods

Banker plant production

European columbine (*Aquilegia vulgaris,* 324 plants) and pumpkin plants (*Cucurbita maxima* 'Uchiki Kuri', 36 plants) were grown in two separate gauze tents inside a greenhouse. As soon as 1-3 true leaves were fully developed, European columbine and pumpkin plants were evenly infested with the alternative hosts, i.e. 3,000 adult females of the honeysuckle whitefly *A. lonicerae* or the greenhouse whitefly *Trialeurodes vaporariorum*, respectively (Goolsby & Ciomperlik, 1999; Pickett *et al*., 2004). The natural enemies, i.e. 375 adult *E. tricolor* females per plant species, were introduced two weeks after infestation with the alternative hosts and allowed to deposit eggs for 11 days. Before transplanting them to the experimental plots, all banker plants were kept for five days under outdoor conditions for hardening.

Experimental design

Each experimental plot consisted of two Brussels sprouts fields (each 4 m x 2.4 m). The area between these two fields (2.4 m x 2 m) carried the three treatments. It was either covered with black mulch film for the entire experimental period (control treatment) or planted with one of the two banker plant systems, ***A***. *lonicerae* and ***E***. *tricolor* on European **c**olumbine (**AEC**) (54 plants per plot) and ***T***. *vaporariorum* and ***E***. *tricolor* on **p**umpkin (**TEP**) (six plants per plot). Plots were 14 m to 17 m apart and allocated in a randomized block design with six replicates. Grass was sown between and around the plots and was kept short by regular mowing.

Eight cabbage plants per plot were evaluated bi-weekly from 6^{th} July to 12^{th} October 2015. The numbers of parasitized and unparasitized whitefly puparia (last nymphal stage) were counted per plant to calculate parasitism rates. In addition, adult *E. tricolor* as well as the type and number of predators were determined for each plant.

Statistics

Data were processed in IBM SPSS Statistics 24. All determined parameters were analysed in a multivariate general linear model (GLM) with repeated measures over time followed by a post hoc test after Tukey for multiple comparison between treatments, if applicable.

Results and discussion

Parasitoids

Average parasitism rates of *A. proletella* nymphs were 51% and 53% higher in the AEC and TEP treatment, respectively, than in the control (both $p < 0.001$) (Figure 1). Additionally, the average numbers of adult *E. tricolor* per cabbage plant increased by 53% and 50% in the AEC and TEP treatment compared to the control (both $p < 0.001$). There was no difference in parasitism rates or adult *E. tricolor* between the two banker plant treatments ($p = 0.113$ and $p = 0.989$). An increase of whitefly parasitism (*Bemisia argentifolii*) on an outdoor crop (cantaloupe) by banker plants inoculated with parasitoids (*Eretmocerus* spp.) was also reported by Pickett *et al.*, 2004. They even observed three to five times higher parasitism rates by banker plants compared to a control.

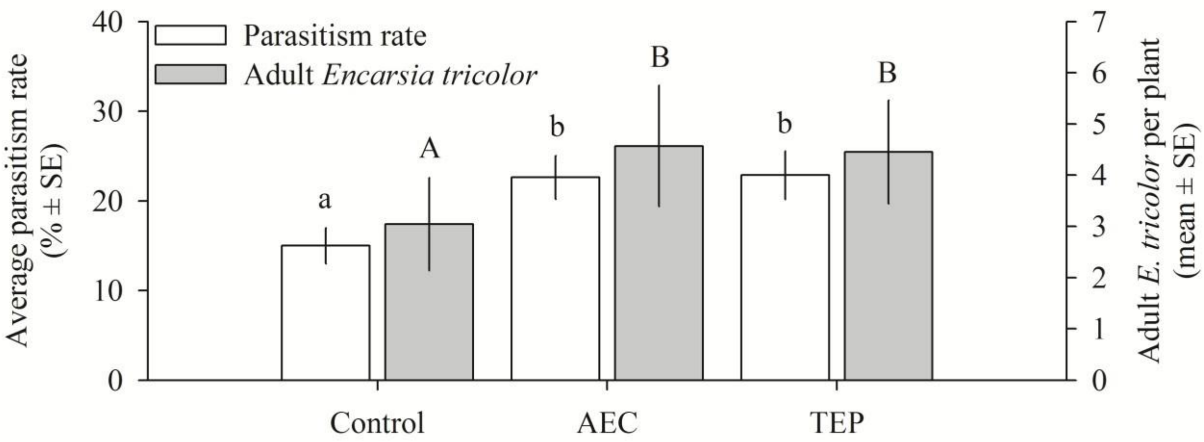

Figure 1. Parasitism rates and numbers of adult *E. tricolor* per cabbage plant and day as average values over the entire experimental period (AEC = banker plant system with *A. lonicerae*/ *E. tricolor* on European columbine, TEP = banker plant system with *T. vaporariorum*/ *E. tricolor* on pumpkin, different letters indicate significant differences between treatments, GLM with repeated measures over time and Tukey test, α = 0.05).

Predators

On the one hand, 63% more hoverfly larvae were found on cabbage in the TEP treatment compared to the control (p = 0.033) (Table 1). The AEC treatment did not differ from the control or the TEP treatments in respect to the number of hoverfly larvae (p = 0.751 and p = 0.162, respectively). On the other hand, spiders were 11% and 12% less abundant on cabbage in the AEC and TEP treatment than in the control (p = 0.018 and p = 0.042). Other predatory groups were not affected by the banker plants and only found in relatively low numbers.

Table 1. Average predator numbers per cabbage plant and day over the entire experimental period (mean ± SE) (AEC = *A. lonicerae*/ *E. tricolor* on European columbine, TEP = *T. vaporariorum*/*E. tricolor* on pumpkin, different letters indicate significant differences between treatments, GLM with repeated measures over time and Tukey test, α = 0.05).

Natural enemies		**Treatment**		
		Control	**Banker plant system**	
			AEC	**TEP**
Spiders		4.7 ± 0.7^{a}	4.2 ± 0.5^{b}	4.1 ± 0.6^{b}
Hoverfly larvae		0.27 ± 0.05^{a}	0.32 ± 0.05^{ab}	0.44 ± 0.08^{b}
Predatory bugs		0.13 ± 0.04^{a}	0.21 ± 0.05^{a}	0.13 ± 0.03^{a}
Gall midge larvae		0.11 ± 0.09^{a}	0.06 ± 0.05^{a}	0.11 ± 0.07^{a}
Predatory flies		0.05 ± 0.02^{a}	0.03 ± 0.01^{a}	0.01 ± 0.01^{a}
Lacewing larvae		0.04 ± 0.02^{a}	0.04 ± 0.01^{a}	0.04 ± 0.02^{a}
Ladybeetle	adults	0.02 ± 0.01^{a}	0.02 ± 0.01^{a}	0.06 ± 0.01^{a}
	larvae	0.01 ± 0.01^{a}	0.02 ± 0.01^{a}	0.01 ± 0.00^{a}

Conclusion

The TEP system promoted the functional biodiversity of *A. proletella* natural enemies by specifically increasing the abundance of *E. tricolor* and hoverfly larvae populations on cabbage. However, data on the effects on *A. proletella* populations or other pests, economic damage and cabbage yield as well as information on the effective distance of banker plants are still required for a final evaluation of the tested banker plant systems. Further improvements like the optimization and standardization of banker plants, combinations with other plant protection measures and the conduction of large scale farm trials and feasibility studies are needed before bringing banker plants to the market. Nevertheless, presented results are a promising first step to make sustainable management of field pests more effective.

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