Testing the potential of White mustard (*Sinapis alba*) and Sweet alyssum (*Lobularia maritima*) as trap crops for the Diamondback moth *Plutella xylostella*

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Ideal characteristics of a plant species implemented in a trap cropping strategy are a high attractivity to ovipositing adults, and a low suitability for larval development. The potential of the crucifers *Sinapis alba* (L.) and *Lobularia maritima* (L.) as trap crops for the diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae) was evaluated. The larval performance on the trap crop plants compared to Brussels sprouts (*Brassica oleracea*) was examined in laboratory experiments. The relative preference of the trap crop plants was monitored in a field experiment. Results showed that *L. maritima* is a low quality host plant. *P. xylostella* larvae had a longer development time, lower survival and a lower weight on *L. maritima* compared to *S. alba* and *B. oleracea*. Interestingly, in the field experiment the density of *P. xylostella* moths was higher on *L. maritima* than on *S. alba*. Our study indicates that *L. maritima* is a good candidate as a trap crop for *P. xylostella* because it has a low preference-performance correlation: it is attractive for oviposition, but relatively unsuitable for larval development.

Keywords: dead-end trap cropping, oviposition preference, preference-performance correlation, *Plutella xylostella*, *Sinapis alba*, *Lobularia maritima*, development time

The diamondback moth *Plutella xylostella* (Lepidoptera: Plutellidae) is a pest occuring all over the world (Talekar & Shelton 1993). The species is oligophagous (Thornsteinson 1953) and all four larval stages feed specially on cruciferous plants (Happe *et al.* 1988). The diamondback moth threats the crucifer production and sometimes more then 90% of the crop, like cabbage (*Brassica oleracea*) is lost (Verkerk & Wright 1996). The decreasing effectiveness of pesticides and increasing pesticide resistance forces to search for alternatives like biological control (Lim *et al.* 1996) and habitat manipulation with repellent and attractive crops (Hooks & Johnson 2003).

The concept of trap cropping is based on the fact that virtually all pests show a distinct preference to certain plant species (Hokkanen 1991). Although many studies of other insects suggest that adults mostly choose a plant for oviposition, which is a suitable host for their offspring (DiTommaso & Losey 2003, Pöykkö & Hyvärinen 2003), this is not always the case (Charleston & Kfir 2000, Shelton & Naut 2004). An ideal trap crop should be highly preferred to oviposition and relatively unsuitable for larval development compared to the main crop. With other words, plants should feature a low (oviposition) preference –

(larval) performance correlation. There are several studies on potential trap crops for the diamondback moth, like *Brassica juncea* (Hooks & Johnson 2003) and *Barbarea vulgaris* (Shelton & Naut 2004). *B. juncea* appeared to be suitable as a trap crop in some cases, but the control effect on *P. xylostella* still remained unreliable (Hooks & Johnson 2003).

In studying the potentials and the risks of providing flowering field edges for pest control, the ornamental plant *Lobularia maritima* (L.) was found to be highly attractive for *P. xylostella* (Winkler *et al.* 2005). In the present study we compare the potential of the two crucifers *Sinapis alba* (L.) and *L. maritima* as trap crop for *P. xylostella*. We tested (1) larval performance on the two plants under laboratory conditions and (2) adult preference under field conditions. For both experiments we included the crop plant *Brassica oleracea* (Brussels sprouts) as a reference plant.

MATERIALS AND METHODS

Plants

For the experiment on larval performance *L. maritima*, Brussels sprout plants [*B. oleracea* (L.) var. *gemmifera*] and *S. alba* were grown in the greenhouse under controlled conditions. For the adult preference assessment five 3 × 3 m plots of Brussels sprouts [*B. oleracea* (L.) var. *maximus*] and *L. maritima* and 6 plots of *S. alba* were established in a randomised block design on an experimental field in the vicinity of the Laboratory of Entomology. Each plot was planted with 81 plants of *L. maritima* or *S. alba*, or 16 plants of Brussels sprouts. Plots were separated by a 1 m wide grass strip. The grass was mown regulary and the plots were handweeded.

Insects

Plutella xylostella were reared on Brussels sprout plants [*B. oleracea* (L.) var. *gemmifera*] at 24±2°C and 16:8 L:D. *P. xylostella* pupae were collected and transferred to a separate cage for further development.

Larval performance

One day old mated females were placed separately in petri dishes (diameter 9 mm), containing moistened filterpaper and leaf material of either *L. maritima*, *S. alba* or Brussels sprouts (var. *maximus*). After 24 h, leaves were distributed in the intention to get a maximum number of 5 eggs per Petri dish. Per plant species a minimum number of 39 eggs was followed (Brussels sprouts n=39, *S. alba* n=40, *L. maritima* n=65). Dishes were stored at 22±2°C, 70% r.h. and 16:8 L:D. When necessary, filter paper was remoistened and fresh leaves of the corresponding plant species added to the dishes.

Larval survival was recorded on a daily base and tested for differences with a general linear model. Upon completion of development, pupae were individually placed in glass vials and labelled (sample number, plant). To determine weight at emergence, pupae were checked every hour during daytime and every 3 h during night-time. Emerged adults were frozen immediately at -15°C. When all adults had emerged, they were dried at 80°C for 48 h and subsequently weighted on a precision balance to the nearest 0.1 μg (Satorius type 1801).

Development time (day of oviposition until adult emergence) was analysed using a General Linearized model and weight at emergence was analysed by a two way ANOVA. Based on development time and the dry weight at emergence the growth rate was calculated for each individual. Growth rates on the three plant species were compared with a General linear model and a Tukey post hoc test.

Adult preference

For the adult preference experiment cylindrical traps were constructed from clear acetate sheet (diameter 9 cm, height 30 cm). The outer surface was spread with Tanglefoot®. Traps were placed in the center of each plot at canopy height for 7 days in four consecutive weeks (weeks 25-28). For each trap, the number of diamondback moth was noted. Per sampling week the stage (flowering or not flowering) of each plot and the distance from the nearest plant to the trap was measured. Number of diamondback moths on the traps was ^{10}log-transformed to retreive normal distribution of the data. A general linear model was used to analyse the effects of plant species on moth distribution.

RESULTS

Larval performance

The percentage of larvae which survived on the plant was for *L. maritima* 28%, Brussels sprouts 29% and *S. alba* 56%. The number of surviving larvae was significantly higher on *S. alba* than on *L. maritima* (Fig. 1). The number of surviving larvae on Brussels sprouts did not differ from the number of surviving larvae on *L. maritima* and *S. alba*.

Larval development time was significantly longer on Brussels sprouts and *L. maritima* as compared to *S. alba* (Chi^2=-0.1868, p<0.001). Larvae fed on *L. maritima* were significantly lighter than larvae fed on Brussels sprouts and *S. alba* (F=16.67, p<0.001). Female weight was higher than male weight irrespectively of the plant species (F=23.072, p<0.001). The larval growth rate differed significantly between all plant species and was highest on *S. alba*, intermediate on Brussels sprouts and lowest on *L. maritima* (Fig. 2). There was an interaction between sex and plant species (F=0.247, p=0.782).

Adult preference

This year there was a low capture rate of the diamondback moth. The diamondback moth was affected by the distance from the first plant to the trap ($F=3.716$, $p=0.021$) and the different plant species ($F=29.622$, $p<0.001$) (Fig 3). There were significantly more diamondback moths found on traps placed in *L. maritima* plots than in *S. alba* and Brussels sprouts plots ($p<0.01$).

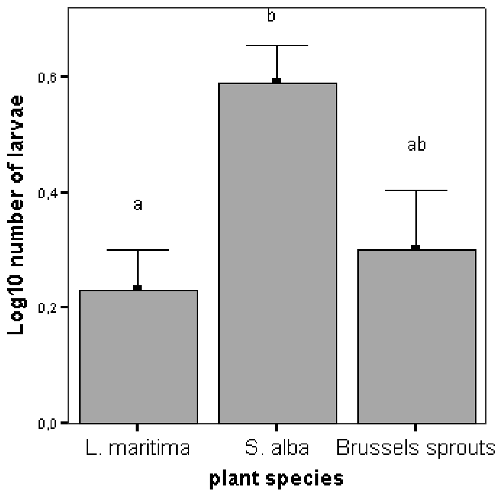

Figure 1. Survival of larvae in different plant species (different letters indicate statistical differences between plant species based on a General Linearized Model).

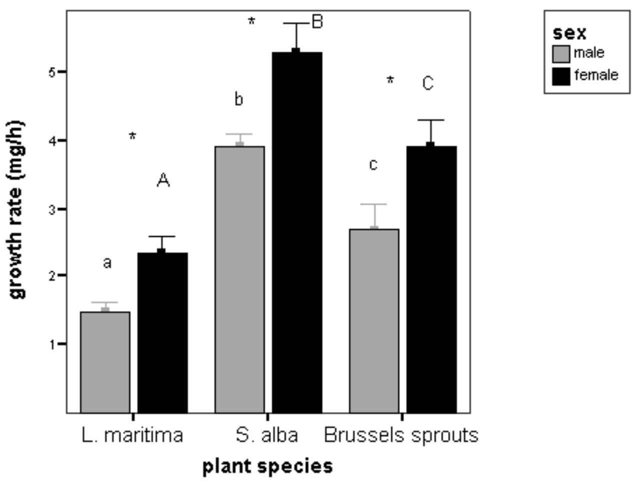

Figure 2. Growth rate of the larvae on different plant species (different letters indicate statistical differences between plant species based on a General Linearized Model, * indicates statistical differences between sexes).

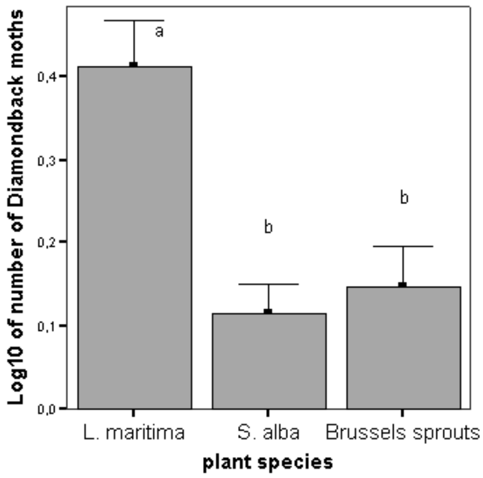

Figure 3. Abundance of moths on different plant species (different letters indicate statistical differences between plant species based on a General Linearized Model).

DISCUSSION

The results of our study indicate that *P. xylostella* shows distinct differences in larval performance as well as in adult preference on *L. maritima*, *S. alba* and Brussels sprouts. Based on these differences we can conclude on the potential of *S. alba* and *L. maritima* as trap crops to controle *P. xylostella* in Brussels sprouts plantings.

Larvae of *P. xylostella* showed higher survival rates and developed faster on *S. alba* as compared to Brussels sprouts and *L. maritima*. Adult abundance did not differ on *S. alba* and Brussels sprouts, indicating that *S. alba* is not more attractive to *P. xylostella* as compared to Brussels sprouts. For this plant, better larval performance is combined with equal attractiveness for the adults. With these charactieristics *S. alba* might even promote the development of *P. xylostella* and thereby unintentionally increase the total pest population.

In contrast, larvae of *P. xylostella* on *L. maritima* showed in tendency lower survival rates and developed significantly slower on *L. maritima* as compared to Brussels sprouts and *S. alba*. At the same time, significantly more adult moths were found on *L. maritima* as compared to Brussels sprouts and *S. alba*. Recently the term 'dead-end trap cropping' has been proposed to identify a plant that is highly attractive for oviposition by an insect pest, but on which offspring of the pest cannot survive (Shelton & Nault 2004). Even though some *P. xylostella* larvae were able to survive and complete their development on *L. maritima*, it might be legitime to suggest *L. maritima* for this concept of improved trap cropping.

An interesting and important question in this context is, whether larvae are able to correct for their mothers oviposition choice and actively search for a more suitable host plant. In that case larvae might migrate from unsuitable trap crops to the more suitable main cash crops. The first larval stage of *P. xylostella* is mining and migration at that stage is not very likely. Experiments on the arrestment response of L2 *P. xylostella* under laboratory conditions did not provide any indication of migration from unsuitable towards more suitable host plants (unpublished results).

Host plant quality has a direct impact on individual larval performance, but can also influence population dynamics. Shefali *et al.* (1996) found for *P. xylostella* a positive correlation between larval weight and female fecundity. As this is probably also true for the relation between weight at emergence and fecundity, females reared on *L. maritima* would be less fecund than females reared on *S. alba* and Brussels sprouts. This reduced fecundity would lead to decreased population growth and thereby lower pest pressure.

Differences in larval development time do not only influence population dynamics within the species, but can also have an impact on the third trophic level. The longer the development time, the longer is also the exposure time to natural enemies like predators and parasitic wasps. As larvae developed longer on *L. maritima* as compared to *S. alba*, pest supression by the third trophic level could be expected to be more effective in the former species.

The two plant species *S. alba* and *L. maritima* differ in their chemical composition. The amount of glycosinolates, which play a major role as oviposition stimulants (Thornsteinson 1953), is higher in *L. maritima* than in *S. alb*a (Hasapis *et al.* 1981). This information might help to make a preselection of cruciferous plants based on their chemical composition, before testing them for their potential as dead end trap crops.

The differences we found for the two potential trap crops *S. alb*a and *L. maritima* concerning attractiveness for adults, larval performance and weight at emergence clearly indicate that *L. maritima* is a promising candidate for successful trap cropping, while *S. alba* might even promote the development of *P. xylostella*. Implementing *L. maritima* as a trap crop could contribute to the sustainable control of *P. xylostella* in Brussels sprouts plantings.

REFERENCES

Charleston, D.S. & Kfir, R. 2000. The possibility of using Indian mustard, *Brassica juncea*, as a trap crop for the diamondback moth, *Plutella xylostella*, in South Africa. *Crop Prot.* 19: 455-460.

DiTommaso, A. & Losey, J.E. 2003. Oviposition preference and larval performance of monarch butterflies (*Danaus plexippus*) on two invasive swallow-wort species *Entomol. Exp. Appl.* 108: 205–209.

Happe, M., Kirchhoff, K., Wassenegger-Wittlich, G. & Madel, G. 1988. Die Biologie der Schlupfwespe *Diadegma semiclausum* Hellen (Hym., Ich.) und ihres Wirtes *Plutella xylostella* Curtis (Lep., Ypon.). *Mitt. Dtsch. Ges. allg. Angew. Ent.* 6: 146-149.

Hasapis, X., Macleod, A.J. & Moreau, M. 1981. Glucosinolates of nine cruciferae and two capparaceae species. *Phytochemistry* 20 (10): 2355-2358.

Hokkanen, H.M.T. 1991. Trap cropping in pest management. *Annu. Rev. Entomol.* 36: 119-138.

Hooks, C.R.R & Johnson, M.W. 2003. Impact of agricultural diversification on the insect community of cruciferous crops. *Crop Prot.* 22: 223-238.

Lim, G.S., Sivapragasam, A. & Loke, W.H. 1996. Crucifer insect pest problems: trends, issues and management strategies. In: *The proceedings of the Third International Workshop*, pp. 3-16. October 1996, Kuala Lumpur, Malaysia. Malaysian agriculture research and development institute.

Pöykkö, H. & Hyvärinen, M. 2003. Host preference and performance of lichenivorous *Eilema* spp. larvae in relation to lichen secondary metabolites. *J. Anim. Ecol.* 72: 383–390.

Schoonhoven, L.M., Jermy, T. & van Loon, J.J.A. 1998. *Insect-plant biology, from physiology to evolution*. Chapman & Hall, London.

Shefali, B., Tsukuda-Ritsuko, T., Kenji, F. & Fusao, N. 1996. The effects of wild cruciferous host plants on morphology, reproductive performance and flight activity in the diamondback moth, *Plutella xylostella* (Lepidoptera: Yponomeutidae). *Res. Popul. Ecol.* 38 (2): 257-263.

Shelton, A.M. & Nault, B.A. 2004. Dead-end trap cropping: a technique to improve management of the diamondback moth, *Plutella xylostella* (Lepidoptera: Plutellidae). *Crop Prot.* 23: 497-503.

Taleker, N.S. & Shelton, A.M. 1993. Biology, ecology and management of the diamondback moth. *Annu. Rev. Entomol.* 38: 275-301.

Thornsteinson, A.J. 1953. The chemotactic responses that determine host specificity in an oligophagous insect (*Plutella maculipennis* (Curt.), Lepidoptera). *Can. J. Zool.* 31: 62-72.

Verkerk, R.H. J. & Wright, D.J. 1996. Multitrophic interactions and management of the diamondback moth: a review. *Bull. Entomol. Res.* 86: 205-216.

Winkler, K., Wäckers, F.L., Buitriago, L. & van Lenteren, J.C. 2005. Herbivores and their parasitoids show differences in abundance on eight different nectar producing plants. *Proc. Neth. Entomol. Soc. Meet.* 16 [this volume].