Halting the western corn rootworm by crop rotation – yes, but! Effects of oil pumpkin in Styria

Aufhalten des Westlichen Maiswurzelbohrers durch Fruchtwechsel – ja, aber!

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1. Introduction

The western corn rootworm - *Diabrotica virgifera virgifera* has invaded large parts of the maize growing areas of Central Europe since it was first detected in 1992 near Belgrade, Serbia (Edwards *et al.*, 2011). In 2002 the beetle arrived in the eastern parts of Austria and extended in 2012 into the southern and western parts. Only a few cases with observed economic damages have been recorded since in those areas. Official control measures according to EU Decision 2003/766/EG are in place to prevent the further spread of the western corn rootworm. Crop rotation as the most efficient strategy to suppress the western corn rootworm should be applied either alone or in combination with insecticide treatments. In our study we aimed to test the effects of Styrian oil pumpkin rotated with maize on the reproduction of *Diabrotica* in isolation cages in the field.

2. Material and methods

Several experiments in isolation cages have been set up to identify potential host plants of the western corn rootworm and those plants which would interfere with the development of the corn rootworm. These experiments were carried out on a maize site in Austria near Graz in the federal-state of Styria from 2009 to 2012. In specially designed well isolated cages (1.4 m x 1.4 m x 2.5 m) each planted with 20 maize plants a defined number of female and male beetles were released in 2009 (see this issue Foltin and Robier, 2013a, Population dynamics and host plant specificity of *Diabrotica virgifera virgifera*). Descendant generations i.e. hatching of beetles were recorded regularly. These studies resulted in beetles hatching with larval damage only when maize after maize was grown (variants 1 to 3) whereas in all other variants no descendants appeared. Beside cereals in these studies also oil pumpkin turned out to be definitely no host plant.

Learning from observations in commercially grown oil pumpkins („Styrian oil pumpkin“ Cucurbita pepo var. styriaca), its flowers - unlike soybeans - are highly attractive to *Diabrotica virgifera virgifera* beetles. In this context female beetles leave maize to feed in pumpkin flowers in autumn of adjacent plots. A significant proportion of them do not return into maize but lay their eggs into the soil of pumpkin fields.

Various flowering broadleaved weeds in soybeans, sunflowers and sugar beet are also attractive to *Diabrotica* (Moeser and Vidal, 2004). Our own observation cornfirm this for:

- common thornapple, *Datura stramonium*
- ragweed, *Ambrosia artemisiifolia*
- lambsquaters, *Chenopodium* sp.
- cocklebur, *Xanthium strumarium*
- bindweeds, *Convolvulus arvensis*, *Callystegia sepium*, etc.

Fig. 1 *Diabrotica* adults visiting pumpkin and bindweed flowers.

Abb. 1 *Adulte* Diabrotica *zu Besuch bei Kürbis- und Ackerwindeblüten.*

Field experiments in Bad Radkersburg district

Apart from the a.m. cage tests in Graz new experiments have been conducted 2011 and 2012 on 3 sites in southeast Styrian maize fields near Bad Radkersburg where maize and oil pumpkin is grown in alternating crop rotations (see scheme in Figure 3 below).

This second experimental series was designed to study oviposition behavior of the western corn rootworm.

Similarly isolation cages as in Graz were used and yellow sticky traps with pheromone and floral baits were placed in the cages.

In fall of 2011 soil was sampled from maize and adjacent oil pumpkins (Fig. 1). The number of eggs of *Diabrotica* was estimated within the soil samples to indicate the potential risk of the corn rootworm infestation in the following year.

Figure 1 shows the experimental design for oil pumpkin and maize. Maize was planted in spring 2012 all over both fields while in 2011 maize was planted adjacent to oil pumpkins. Experiments were conducted on two field sites near Bad Radkersburg.

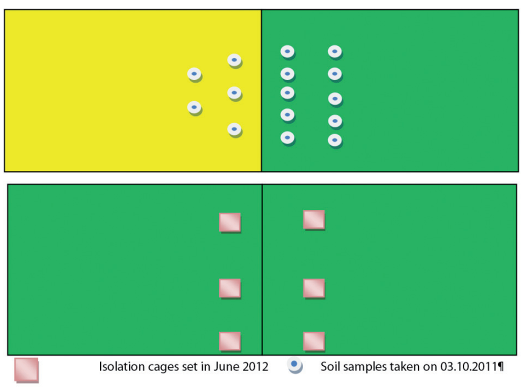

Fig. 2 Experimental design - isolation cages (pink squares) with yellow sticky traps and baits in maize 2012 planted after oil pumpkin (yellow plot in 2011 above) and after maize (green plot in 2011 above). White-blue spots indicate soil samples taken on 3rd October 2011. Field plots ca. 1 hectare each in 2011 maize (green) adjacent to oil pumpkin (yellow); same field plots planted with mais all over in 2012 (below); oviposition in oil pumpkin in autumn 2011 observed, soil sampled in October 2011; maize planted all over in 2012, number of hatching beetles recorded in cages with a ground area 2 m^2 and 2.5 m height.

Abb. 2 *Versuchsaufbau – Isolationskäfige (rosa Vierecke) mit Gelbtafeln und Ködern in Mais im Jahr 2012, der nach Ölkürbis (gelbes Feld im Jahr 2011 s. oben) und nach Mais (grünes Feld im Jahr 2011 s. oben) angepflanzt wurde. Die weiß-blauen Kreise stehen für Bodenproben, die am 3. Oktober 2011 genommen wurden. Die Schläge waren im Jahr 2011 jeweils ca. 1 ha groß für Mais (grün) und Ölkürbis (gelb); dieselben Schläge waren in 2012 vollständig unter Mais (unten); Untersuchung der Eiablage im Herbst 2011, Bodenbeprobung im Oktober 2011; Flächen vollständig unter Mais in 2012, Anzahl geschlüpfter Käfer in Käfigen mit einer Grundfläche von 2 m^2 und 2,5 m Höhe.*

3. Results and discussion

The results of the soil samples taken in 2011 (see Table 1) showed that the number of eggs detected was tenfold higher in maize fields compared to the adjacent oil pumpkin fields. A small proportion of eggs were laid into oil pumpkin fields, since flowering pumpkin is highly attractive to beetles (unlike soybean) although oil pumpkin is not a host plant of *Diabrotica*.

The experiments in the isolation cages resulted in ten times more beetles hatched in fields with maize after maize compared to those on field with maize after oil pumpkin (Tab. 1). In Styria (Southern Austria) there are regions with very small field units where an alternating crop rotation of oil seed pumpkin followed by maize is common practice. Particularly after the end of the maize flowering period in July mainly female *Diabrotica* beetles search for pollen in neighboring fields. Since oil pumpkin flowers from May until the end of September it is therefore strongly attracting *Diabrotica* adults. Oil pumpkin female flowers responsible for the yield appear long time before *Diabrotica* hatching. However, in autumn dozens of mostly female beetles invade male pumpkin flowers (Fig. 2) to collect their pollen. It is not known if all the females return from oil pumpkins to lay their eggs into maize fields. It is rather likely that oviposition partly occurs also in oil pumpkin fields (see Fig. 3).

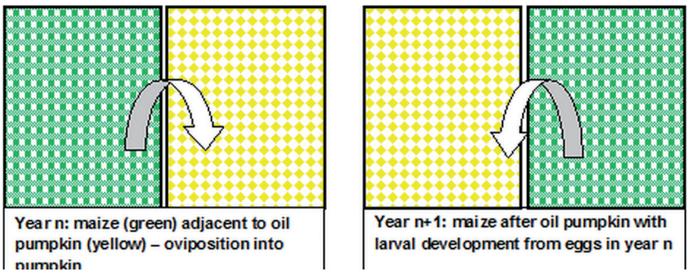

Fig. 3 Schematic *Diabrotica* dispersal and oviposition in maize and adjacent oil pumpkin fields.

Abb. 3 *Schematische Ausbreitung von* Diabrotica *und Eiablage in Mais- und benachbarten Ölkürbisfeldern.*

Tab. 1 Eggs dedected from soil samples in autumn 2011 near Bad Radkersburg (BTL Bio-Test Labor Sagerheide/D, LfL Freising, Versuchsreferat Stmk, AGES, Agro DS Österreich).

Tab. 1 *Eier, die in Bodenproben aus der Nähe von Bad Radkersburg vom Herbst 2011 gefunden wurden (BTL Bio-Test Labor Sagerheide/D, LfL Freising, Versuchsreferat Stmk, AGES, Agro DS Österreich).*

Location	**Date of sampling**	**Position of sample in the fields**	**No. of samples**	**No of eggs extracted**	**Ø No of eggs/ L**	**Sd Standard deviations**	**Max eggs L**	**Min eggs L**
Halbenrain*	03.10. 2011	edge maize	5	12	3.9	± 6.5	15.3	0.0
		centre maize	5	20	6.7	± 9.5	23.3	0.0
		edge pumkin	5	2	0.6	± 1.3	2.8	0.0
Zelting*	03.10. 2011	edge maize	5	163	48.3	± 25.4	69.2	4.2
		edge pumkin	5	7	2.0	± 1.9	4.3	0.0
Zelting	05.11. 2011	edge maize	9	37	9.1	± 11.8	33.3	0.0
		centre maize	10	19	4.2	± 3.5	11.1	0.0
		edge pumkin	10	1	0.2	± 0.7	2.3	0.0

* Sites in further tests with isolation cages in 2012

Tab. 2 Numbers of recorded adult western corn rootworm beetles hatched in maize after maize fields compared to maize after oil pumpkin fields.

Tab. 2 *Anzahl gefundener adulter* Diabrotica*-Käfer, die auf Flächen mit Mais-nach-Mais-Anbau geschlüpft sind, im Vergleich zu Flächen mit Mais-nach-Ölkürbis-Anbau.*

	Crop	
Year 2011	oil pumpkin	maize
Year 2012	maize	
	Beetles trapped/isolation cage	
Site 1 Halbenrain Ost	28	96
	122	155
	54	121
Site 2 Zelting	46	198
	39	309
	45	271
Mean	55.67	191.67
Ratio	3.44	
Risk-index for oil pumpkin	29.04	

* Risk-index for *Diabrotica* reproduction: Wheat =< 1%, maize=100%
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Alternating crop rotation of oil pumpkin and maize

Oviposition in oil pumpkin is less than 10% compared to maize (see Tab. 1).

On the same plots counts of hatching adults in isolation cages with yellow sticky traps + pheromone and floral baits in Southeast Styrian maize fields indicate however higher numbers:

- the average ratio between the pre-crops maize vs. oil pumpkin was 3.4 : 1,
- reproduction rates maize fb cereals (wheat) were <1%,
- reproduction rates maize fb maize were 100%,
- reproduction rates oil pumpkin fb maize were 29.04%.

Cereals are therfore:

- ca. 30x safer than alternating crop rotations with oil pumpkin,
- ca. 100x safer than mono maize crop rotations.

4. Conclusions

From our experiments we conclude that there is a risk of *Diabrotica* reproduction in oil pumpkin fields rotated with maize in alternation (15-30% of the rates compared to maize after maize). Compared to cereals on the other hand the risk is 15 to 30 times higher. Larval damage on maize roots could only be observed in fields with maize after pumpkin. Various other flowering broadleaved plant species can serve with their pollen as a food resource and female beetles may lay eggs to a limited extend into such fields of alternative crops.

Acknowledgements

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