Assessment of economic impacts of the western corn rootworm (*Diabrotica virgifera virgifera*) in Germany

*Bewertung der ökonomischen Auswirkungen des Westlichen Maiswurzelbohrers (*Diabrotica virgifera virgifera*) in Deutschland*

Hella Kehlenbeck

Julius Kühn-Institut, Institute for Strategies and Technology Assessment, Kleinmachnow, Germany
hella.kehlenbeck@jki.bund.de

DOI 10.5073/jka.2014.444.046

1. Introduction

The western corn rootworm *Diabrotica virgifera virgifera* is known to cause enormous damage to maize crops especially in regions with high maize densities and continuous maize production where the pest can build up high abundances (reported yield losses of 10-30% in south eastern Europe and 20-30% in Italy in 2009 to up to 50% under very favorable conditions for the beetle). Since 2007 *Diabrotica* has been observed in Germany and mandatory quarantine measures according to EC directives 2003/766/EC and 2006/564/EC have been implemented and are in place since that time. Small outbreaks could be eradicated successfully where measures had been taken immediately and consequently like in the federal states of Hesse and Northrhine-Westfalia (Dicke *et al*., 2014). In the federal states of Bavaria and Baden-Württemberg, eradication measures have in contrast not been successful and containment zones have been established in 2010. These zones where suppression measures should be applied now include rather big areas especially in Bavaria (Baufeld, 2014 and Kehlenbeck and Krügener, 2012). In 2012 the complete containment zone reached 1.8 M ha with an estimated maize production area of about 280,000 to 370,000 ha (15-20% maize). Direct yield losses by damage of the beetle, however, have so far not been observed in Germany.

The mandatory measures cause high costs for the Regional Plant Protection Organizations (RPPO) of the Federal States and as well for the maize growing farmers in regions with *Diabrotica* infestation. While RPPOs can claim a part of their expenditures for eradication measures from the EU solidarity funds, economic impacts due to yield losses of maize growers are not compensated. The aim was to evaluate the appropriateness of the plant health measures in comparison to other control strategies of the western corn rootworm in Germany.

2. Methods

Costs of different control strategies and plant health measures were compared to a "no control scenario" without any measures and a "no official control scenario" where maize growers start to apply soil insecticide applications five years after the infestation started and damage becomes obvious. The control strategies consisted of (1) an eradication strategy based on crop rotation with additional insecticide treatments, (2) a containment strategy with two insecticide applications against adults per year or a crop rotation (two times maize within three years) and (3) an integrated approach with measures applied according to injury levels with chemical and non-chemical control options.

Data analysis was based on observed experiences in Germany concerning costs of RPPOs and the range expansion of *Diabrotica* from 2007 to 2012 as well as on estimated data for the further spread of the beetle and expected yield losses. Simulations were performed for the different scenarios with respect to their effect on dispersal parameters according to the spatial explicit spread model developed by Krügener *et al*. (2013) for a period of up to 30 years.

3. Results

Spread, establishment and subsequent economic impact of *Diabrotica* depend on the availability of maize and are favored by non-rotated maize production. Maize production is an important sector of agriculture in Germany and has increased during the past 10 years by about 70% (Fig. 1). This increase could mainly be attributed to an enormous increase in silage maize production while grain maize production did not change significantly. The increase in silage maize runs parallel to an increase in biogas production. In 2012 about 800,000 ha of silage maize were grown for biogas production which represents 30% of the total maize acreage and 40% of the silage maize acreage (FNR, 2013). The main areas for maize production in southern Germany coincide with the regions where *Diabrotica* has established. In addition, *Diabrotica* may find favorable climatic conditions almost all over Germany.

The potential economic impact of the western corn rootworm and the measures to be applied in Germany were expected to be very high since maize growing areas still increase (about 40% from 2007 to 2012) and especially the high percentage of non-rotated cultivation of maize for biogas production supports the further establishment and spread of the beetle.

The costs of the official control measures in Germany are summarized in Table 1. Overall, costs for monitoring, insecticide treatments, and administration sum up to 2.8 M € for the period from 2007 to 2012. Costs of farmers depend very much from their production. Costs per ha can be very high in case of biogas or animal production and moderate in case of grain maize production.

The application of the spread model over a period of 30 years showed that both the "no control" and the "no official control" scenarios lead to the spread of *Diabrotica* all over Germany with high abundances of the beetle and with high potential economic impact (all German maize producing areas are infested and suffer from yield losses or control costs, Tab. 2). The official measures (1) and (2) are successful in avoiding or slowing down spread and therefore the potential impact will never or hardly be reached. Control costs depend on the percentage of maize in crop rotation. For the integrated approach (3) with an efficacy of 90% it took more than 30 years until the potential impact was reached.

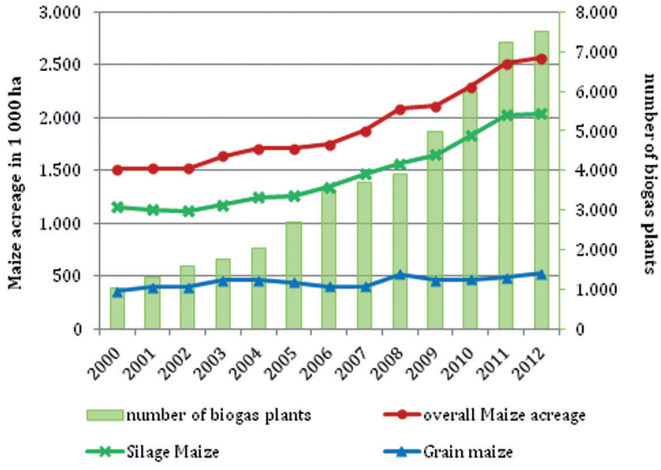

Fig. 1 Maize production and development of the number of biogas plants in Germany (sources: Deutsches Maiskomitee DMK, Fachagentur für nachwachsende Rochstoffe (FNR), Fachverband Biogas 2013).

***Abb. 1** Maisanbau und Entwicklung der Anzahl von Biogasanlagen in Deutschland (Quellen: Deutsches Maiskomitee DMK, Fachagentur für nachwachsende Rochstoffe FNR, Fachverband Biogas 2013).*

Tab. 1 Costs of official control measures incurred in Germany since 2007.

***Tab. 1** Kosten der Bekämpfungsmaßnahmen in Deutschland seit 2007.*

Year	Costs of RPPOs[1] (monitoring, insecticide treatment, administration, etc.)	Costs of farmers
2007	680,000 €	- no documented data available - up to now no yield losses reported (very low *Dvv* abundances) - If crop rotation is applied: in case of >50% continous maize: • grain maize about 150€/ha • silage/green maize about 250€/ha • maize for biogas 150– 350 €/ha (Bavaria: 650-800 €/ha, Köhler and Schätzl, 2014) • animal production – 100– 650 €/ha (Köhler and Schätzl, 2014)
2008	1,025,000 €	
2009	345,000 €	
2010	141,000 €	
2011	380,000 €	
2012	185,000 €	
Total	**2,756,000 €**	

[1] based on data from solidarity claims

Tab. 2 Estimation of spread and impact of *Diabrotica* with respect to different control options based on simulation results according to a spread model (Krügener et al., 2014) with a time horizon of 30 years and a reproduction rate of 10 for *Diabrotica*.

***Tab. 2** Abschätzung der Ausbreitung und der ökonomischen Auswirkungen von* Diabrotica *unter der Annahme unterschiedlicher Bekämpfungsmaßnahmen auf der Grundlage von Simulationen mit einem Ausbreitungsmodell (Krügener et al., 2014) über 30 Jahre bei einem Reproduktionsfaktor von 10 für* Diabrotica.

Control option	Expected efficacy	Direct costs of measures per ha and year	Yield loss	Indirect costs[1]	Number of years until potential impact[2] reached
Baseline: "no control"	0 %	0 €	high	----	30
"no official control" (maize growers start to apply control measures - soil insecticide application - after 5 years and if beetle numbers exceed EIL[3])	40%	70 €	high	depend on measure	30
(1) Crop rotation	100%	150– 650 (800) €[4]	very low	depend on measure	Never
(2) Maize growers start to apply control (e.g. two insecticide applications against adults or crop rotation) options immediately irrespective of the EIL	90% 60 %	90 € or >80 €/150 €	very low	depend on measure	------- (no beetles after 10 years) ------- (after 30 years area comparable to start area)
(3) Maize growers start to apply control options (e.g. two insecticide applications against adults or crop rotation) after 5 years and and if beetle numbers exceed EIL[3])	90 %	90 € or >80 €/150 €	low low	depend on measure	takes longer than 30 years

[1] Indirect effects are e.g. effects on bees, problems, with contracts for biogas production in case of crop rotation

[2] Potential impact = all German maize producing areas are infested and suffer from yield losses or control costs

[3] EIL= economic injury level; difficult to estimate; in literature: 1 beetle per plant (about 80,000 beetles per ha) -

[4] 10% maize in crop rotation: 8.64-13.56 M€, 50% maize in crop rotation: 11.61 - 19.74 M€, 70% maize in crop rotation: 13.10-22.83 M € (focus zone (1-2 km radius = 514 ha), safety zone (radius 5 km = 11,000 ha); measures: crop rotation with maize once within 3 years)

4. Conclusions

Eradication by crop rotation showed to be the most cost-effective strategy for single outbreaks and a low maize density in the safety zone (see as well Kehlenbeck and Krügener, 2012). The containment and the integrated approach depend on the efficacy of the measures and the consequent application of the control strategy. Control costs and yield losses are expected to be higher for the integrated approach (due to the later start of the measures and the further spread of the beetle). Crop rotation, however, still is expected to be the more sustainable strategy with less environmental impacts and resistance problems in the long term.

Acknowledgements

The project was funded by the German Ministry of Food, Agriculture and Consumer Protection (BMELV) within the German Diabrotica research program.

References

Baufeld P., 2014: The infestation situation of the Western corn rootworm (*Diabrotica virgifera virgifera*) in Germany and Europe. Julius-Kühn-Archiv **444**: 15.

Dicke D., 2014: First occurrence of Western Corn Rootworm in the federal states Hesse and Rhineland-Palatinate (Germany), 2011. Julius-Kühn-Archiv **444**: 17-19.

Köhler, K. and R. Schätzl, 2014: Die Bedeutung des Westlichen Maiswurzelbohrers (Diabrotica virgifera virgifera LeConte) in Bayern – regionale Relevanz und einzelbetriebliche Auswirkungen. Julius-Kühn-Archiv **444**: 191-197.

Krügener, S., T. Balschmiter, P. Baufeld, D. Rossberg, B. Golla and S. Vidal, 2014: Spreading predictions of the Western corn rootworm in Germany until 2021. Julius-Kühn-Archiv **444**: 41.

Kehlenbeck H. and S. Krügener, 2012. Costs and benefits of plant health measures against *Diabrotica*: Experiences and estimations for Germany. Journal of Applied Entomology, DOI:10.1111/jen.12011.