A promising biotechnical approach to pest management of the western corn rootworm in Illinois maize fields shielded with a MCA kairomone baited trap line

Hans E. Hummel [1,2], John T. Shaw [2] & Detlef F. Hein [1]

[1] Department of Organic Agriculture, Gießen & [2] Illinois Natural History Survey, Champaign

Abstract: Umweltgerechter und nachhaltiger Pflanzenschutz erfordert eine Vielzahl verschiedener Strategien zum Management von Schadinsekten auf ihren Wirtspflanzen. Insekten- und pflanzeneigene Signalstoffe sowie ihre synthetischen Analoga bieten einen nahezu unerschöpflichen Vorrat spezifischer Lockwirkungen und Interventionsmöglichkeiten an, der bisher leider nur unzureichend genutzt wird. Kürzliche Entdeckungen sowohl neuer Kairomon-Lockstoffe als auch neuer Verfahrensschritte für das Management des Westlichen Maiswurzelbohrers *Diabrotica virgifera virgifera* LeConte (Coleoptera: Chrysomelidae) (*D.v.v.*) erweitern das Spektrum anwendbarer Management- Optionen für diesen schwer bekämpfbaren Schädling im nordamerikanischen Maisanbau. Seit seiner Einschleppung nach Europa (ČAMPRAG & BAČA 1995) wird *D.v.v.* neuerdings auch zunehmend zum Problemschädling an Mais in Europa. Die neue "MSD"-Technik besteht aus einer Kombination von Massenabfang ("*m*ass trapping"), Abschirmung ("*s*hielding") und Umlenkung ("*d*iversion") der Blattkäfer. Fallen hoher Fangkapazität, die das Kairomon 4-Methoxyzimtaldehyd (MCA) und Cucurbitacin- Pulver als fraßfördernden Stoff enthalten, können bei Aufstellung als "Fallenzaun" relativ geringer Dichte die Käfer so umlenken, dass zwischen den beiden Seiten dieses Zauns eine unsichtbare Geruchs-Barriere entsteht. Diese führt zu einer messbaren und signifikanten Verminderung der Käferzahl zwischen MCA behandelten Feldabschnitten gegenüber ihren unbehandelten Kontrollen. In 0,27 ha bzw. 0,12 ha großen Maisversuchsfeldern der Standorte Urbana und Champaign des US-Staates Illinois ließen sich während der Monate August und September 2003 und 2004 nach MCA-Behandlung gegenüber Kontrollen deutliche und signifikante Verminderungen von *D.v.v.* an Hand dreier Kriterien nachweisen: 1. Käferzahlen auf Maispflanzen innerhalb des "MSD-Feldes", 2. Käferzahlen in Sexuallockstoff-Fallen im MSD Feld und 3. die Zahl abgelegter *D.v.v.*-Eier im Boden des MSD Feldes nehmen ab. Der beobachtete Effekt läßt sich nicht allein auf die Populationsverminderung infolge hoher Abfangzahlen zurückführen. Es gibt darüber hinaus einen Abschirm- und Umlenkeffekt, dessen sinnes- und verhaltensphysiologische Mechanismen zusätzliche künftige Erforschungen erforderlich machen.

Key words: *Diabrotica virgifera virgifera* LeConte (Coleoptera: Chrysomelidae), *Zea mays*, 4-methoxycinnamaldehyde (MCA), kairomone, diversion technique

[1] H.E. Hummel, D.F. Hein, Justus-Liebig-University, Department ofOrganic Agriculture, Karl-Glöckner-Str. 21C, D-35394 Gießen, Germany; e-mail: Hans.E.Hummel@agrar.uni-giessen.de
[2] H.E. Hummel, J.T. Shaw, Illinois Natural History Survey, Center for Ecological Entomology, Champaign, Illinois, 61820, USA; e-mail: jtshaw@inhs.uiuc.edu

The leaf beetle *Diabrotica virgifera virgifera* (Coleoptera: Chrysomelidae), (*D.v.v.*), also called the western corn rootworm, is endemic to the New World and ranks among the top ten insect pests in worldwide grain production. *D.v.v.* causes annual damages of 1 billion US Dollars and is a notoriously difficult insect pest to control and manage, as entomological history of the past 50 years amply demonstrates (METCALF 1986). Considering recent emphasis on environmentally compatible and sustainable management strategies, entomologists and practitioners are encouraged to pay increased attention to novel approaches such as biotechnial methods which today are characterized by preferential use of signal compounds. Fortunately, both insect and plants provide a wide variety of such natural resources. In the case of *D.v.v.*, sex pheromones and plant kairomones as specific attractants and management tools are relatively well investigated through numerous contributions by GUSS et al. (1982), METCALF & METCALF (1992), METCALF (1994) and many recent publications on the advance and spread of *D.v.v.* within Europe (BERGER 1995-2004, HUMMEL 2003).

Principle of MSD method: In this paper, the plant kairomone 4-methoxycinnamaldehyde (MCA), a specific attractant for *D.v.v.*, is being used as a tool within the newly proposed "MSD" strategy. It combines a two pronge approach consisting as the well known *m*ass trapping with the novel *s*hielding and *d*eflecting, called in short "diversion" and introduced here for the first time. An invisible “curtain” or “fence” of MCA vapor released from a MCA trap line establishes a behavioral barrier which the flying beetles cannot easily pass without being 1. either caught in one of the high capacity traps or 2. being diverted elsewhere. The net effect is a significant reduction in adult population density and oviposition within the MCA treated field as compared to an untreated control field. These effects can be experimentally measured by 1. adult beetle counts on maize plants, 2. by counts in independent monitoring traps baited with the *D.v.v.* sex pheromone, and 3. by egg counts taken in soil samples.

Materials and methods

Fields: In 2003, a very late planted maize field of 2 x 0.27 ha size has been used. It was located on University of Illinois South Farm close to the intersection of Philo and Curtis Road in Southeast Urbana. A 2 m wide access path divided the two field sections serving as control and treatment, respectively. In 2004, a maize field of 0.27 ha size and located at First Street and Windsor Road within South Farm of Illinois Natural History Survey at Champaign was used and divided into two sections of 2 x 0.12 ha with a 0.03 ha maize buffer zone in between. The two field sites at Urbana and Champaign had a distance of 4 miles from each other.

Traps and lures: For the MSD technique, two types of high capacity *D.v.v.* traps were employed. The first, depicted in Fig. 1 (left), was developed and built by the authors in 2003. It was replaced in 2004 by the commercially available Uni-trap (see fig. 1 right), formerly used as Vario trap and purchased from Trifolio-M, D-35633 Lahnau.

Fig. 1: IRC-high capacity trap (left) and Uni-trap (right) used for both mass trapping and diversion of *D.v.v.* in Illinois maize fields during the growing seasons of 2003 and 2004, resp. Mass trapped beetles are collected in bottom containers where they can be counted, sexed, and weighed.

Both trap types were baited with MCA as a medium range *D.v.v.* attractant described by METCALF (1994). Beetles attracted to this kairomonal bait could feed on a substrate of bitter cucurbitacin powder known to keep the beetles compulsorily attracted while poisoning them with a tiny amount of carbaryl insecticide mixed in for quick knockdown into a bottom container, from which the dead beetles could be removed, weighed or counted. The specific properties and features of the traps will be described in a separate report by Hummel and Shaw. MCA was purchased from Lancaster Co., Frankfurt, catalog item 5467 in a purity of 98 %+, while *D.v.v.* sex pheromone came from Trifolio-M, D-35633 Lahnau. The bitter cucurbitacin kairomones in the powder originate from *Cucurbita foetidissima* (Buffalo gourd). In combination with the *D.v.v.* sex pheromone 8-methyldecane-2-olpropanoate (GUSS et al. 1982), the Metcalf traps (HUMMEL 2003, HUMMEL et al. 2003) were also useful as tools for monitoring and comparing population densities within the control and treatment sections of the field.

Evaluation of eggs in soil samples: After harvest of the maize plants in October, soil core samples of 1 kg each were obtained, prepared and washed in the corn rootworm egg separator and extraction machine described by SHAW & HUMMEL (2003). Recovered eggs were identified by their chorion sculpturing features.

Arrangement of "trap curtains" around perimeter of treated fields: A line of 14 traps was established in 2003 with an individual trap distance of 20 m from each other. In 2004, between each of the 16 traps an individual distance of 10 m was selected. Traps were fastened at ear height of maize plants, monitored and rebaited twice a week. Traps in 2003 were baited with 10 mg of MCA formulated with Tween-80 and Triton X-100 as a 0.5 % emulsion (see HUMMEL & SHAW 2004) and soaked into a small piece of synthetic sponge. Uni-Traps used in 2004 received 10 mg of solid MCA on a piece of filter paper.

Evaluation of D.v.v. populations: Beetle counts on plants and in central monitoring traps were recorded on a daily basis to see fluctuations. For counting beetles on maize plants, between 25 and up to 75 plants per field were selected at random once to twice a day. Not only beetles on or below the leaf surface, but also those hiding in the corn ear tip and in the whorls were counted.

Results and discussion

Immediately obvious are the significantly reduced beetle counts within the treated field section as depicted in Fig. 2a and 2b for the years 2003 and 2004. These counts have been taken on a daily basis, sometimes twice a day, from a representative sample of plants selected along a central line of the maize field and at least 10 m away from any large capacity trap. Differences between control and treatment are significant.

Less obvious but nevertheless significant are differences in daily beetle counts in kairomone (year 2003, 16 beetles per trap per day in treatment vs. 47 beetles per trap per day in control) and pheromone (year 2004) baited center traps (Fig. 3). The central trap location was chosen for making sure that the average beetle population was measured and not preferentially and primarily the influence of nearby mass trapping stations drawing beetles away from their immediate vicinity on the field perimeter.

More hidden but by far the most precisely measurable and practically significant effects are those on egg counts in the soil. Both in the fall of 2003 and 2004, egg numbers in samples taken from the treated sections were lower than in the untreated control section. While the differences in 2003, due to high variance, could not be statistically secured (17 eggs in treatment vs. 93 in control), in 2004 they were very highly significant (2 eggs in treated plot vs. 60 eggs in control plot). Thus, in conclusion, the MCA trapping fence surrounding the treated section has a clear effect on both beetle population and oviposition. For the practicing farmer, both effects are meaningful: Flying beetles like to feed on maize silk. By clipping pollen conducting tubes, the rate of kernel formation in the developing corn ears may be reduced. As to reduced oviposition, fewer eggs hatching in the coming growing season will immediately benefit the growing maize plants and will reduce the need for preventive or actual treatments. On the cost side, investments for traps and poles purchased may not be cheap but once purchased may last for many seasons. Treatment costs for the MCA kairomone and cucurbitacin powder are quite moderate. MCA costs for one month for ten rebaitings per trap are in the range of ten cents. More important will be the cost factor for labor. However, a number of technical measures for cost reduction through future advances in MSD technology are imaginable if not likely.

Results obtained so far with the MSD concept in small fields with sizes between 0.12 to 0.25 ha and a separation of trapping stations at 10 and 20 m, respectively, look quite promising. Since the natural communication distance of *D.v.v.* beetles is probably limited to about 20 m, very much wider spacing of trapping stations within the trapping fence may not produce much benefit. Narrower spacing is, of course, limited by the large number of traps required. However, it is possible that comparatively larger loads of the relatively inexpensive kairomone MCA could compensate for limits on the spacing of MSD stations. Also, extrapolation to and thus validation of results in larger field sizes will have to be shown in future research. One detailed experiment on flight elevation of beetles already has been undertaken. It ruled out that beetles to a large degree would try to "circumvent" the fence in the third dimension and just would fly higher in order

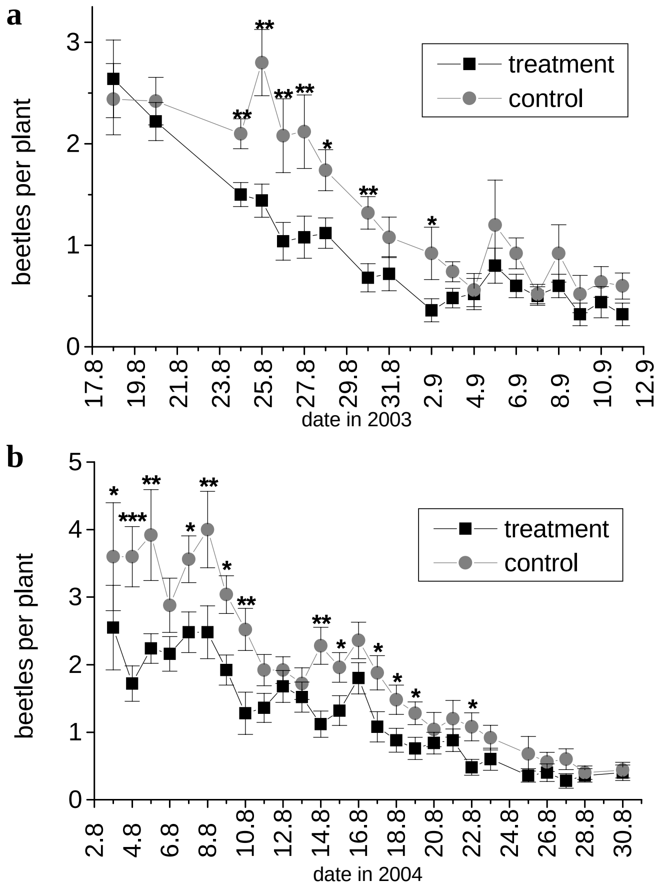

Fig. 2a and b: *D.v.v.* population counted on maize plants along central field line in Urbana 2003 (upper section) and Champaign 2004 (lower section).

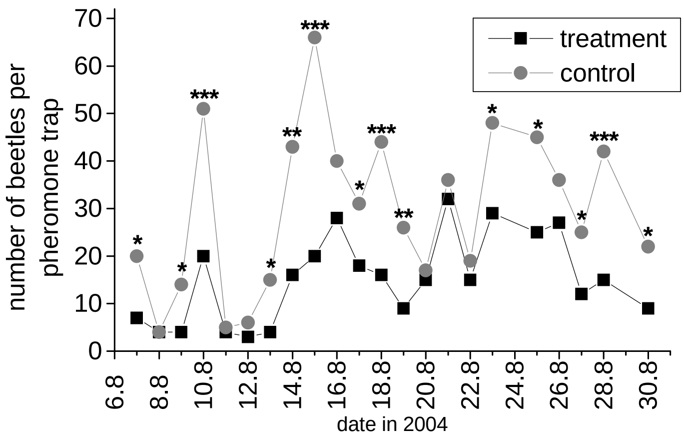

Fig. 3: *D.v.v.* numbers counted in sex pheromone baited Uni-traps in 2004.

to get over the fence into the treated section. They don't. During August and early September 95 % of the beetles flew within ground zero and 3 m high, as systematic trapping studies showed. Overall, mass trapping alone with documentation of number of beetles removed cannot fully explain the effect of population reduction observed so far. There must be an equally important sensory and behavioral diversion effect whose exact mechanism and nature also needs investigations.

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