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IWGO – NEWSLETTER 29 / 1

EDITORIAL

Dear Colleagues, Dear IWGO –Members

At the Munich IWGO Conference (April 5-8; 2009), it was decided that I should take over the editorship of the IWGO – NEWSLETTER. As you may remember, I did this for many years.

Having been involved in IWGO for more than 20 years, it is a great pleasure for me to “return“ to the working group.

During the meeting in Munich, I realized how much IWGO changed during the 41 years of its existence. Not only has the number of participants increased significantly, but also the quality and quantity of scientific contributions. A large number of scientists presented excellent papers and posters at the Munich meeting and the number of young scientist presenting papers increased as well. The primary reason for this increase in participation is definitely the appearance of the Western Corn Root Worm (*Diabrotica virgifera virgifera*) in Europe and interest in collaborations by scientists from Europe, North America and Asia.

IWGO – NEWSLETTERS are suppose to appear twice a year with contributions covering all matters dealing with insect pests in maize. For those who were not able to attend the Munich meeting, we will include all meeting abstracts of posters in the next Newsletter issue. Later we plan to publish original papers dealing with maize pest problems. You are invited to send any information concerning these topics to the editor to be published. Also, short information and information about new publications in other journals are welcomed of course. Finally, we plan to inform you about “people in IWGO“ under the topic “IWGO – Personal Items“. Changes in your position, retirement and other personal items of interest should be sent to the Editor to be published and to inform colleagues and friends.

During the Munich meeting, the location of the next meeting was discussed. After long and lively discussion, the group decided to have the next meeting again in Europe. This is actually not what Global IOBC (IWGO is one of the oldest Global IOBC Working Groups) intends. Meetings should take place in all continents where maize pest problems exist and where IWGO members located. Since maize problems appear not only in Europe, meetings should take place from time to time also outside Europe. The last meeting outside Europe took place in 1986 in Beijing,

China. Earlier we were in North America (USA and Canada) in 1976. All the other meetings have taken place in Europe (see IWGO – home page: "Conferences"). Two out of 23 is not a good ratio! So, I suggest the Convenors of IWGO should think over this issue and find a solution for the location of IWGO meetings. It is remarkable that IWGO had an invitation to have the next meeting in Indianapolis, Indiana, USA, and turned down this opportunity. For sure, if the next meeting is in Europe, then the following one should be outside Europe!

I am looking forward receiving a lot of good contributions from our members for publication in the Newsletter!

I remain yours,

(Harald K. BERGER)
E - mail: newsletter@iwgo.org
Home – page: WWW.IWGO.ORG

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News Related to IWGO Matters

- **23rd IWGO Conference & 2nd International Conference of *Diabrotica* Genetics at Munich, Germany, successfully implemented**
  The Munich meeting was attended by 120 participants from 23 countries. To its end, a 12-session conference, with four to six speakers per session, was arranged. Sessions were designed to address the most interesting and relevant research topics in the field of maize insect pests that have current and broad international application and appeal. The oral sessions were complimented by poster presentations. Many thanks for such an interesting scientific programme and great outcome to everybody participate. Specials thanks to Dr Michael Zellner, Bavarian State Research Centre for Agriculture, Freising, Germany for hosting and greatly supporting the IWGO Conference. In addition, special thanks to all Scientific Session Organizers who supported greatly the IWGO Convenors to compile an interesting programme in collaboration with 2nd International Conference of Diabrotica Genetics.

- **Harald Berger Back in Business!**
  *Harald Berger has agreed to take over the responsibility of editing the IWGO NEWSLETTER, which he already did for many years previously, and thereby help the IWGO Convener to accomplish his working group duties. Please send all issues regarding the IWGO Newsletter directly to **Harald Berger at newsletter@iwgo.org** in the future. Welcome back Harald! Many thanks for contributing your time again to IWGO!*

- **Special Issue for IWGO in Journal of Applied Entomology**
  *For the second time we will have the opportunity to publish selected manuscripts presented at the IWGO Conference in a special issue of the Journal of Applied Entomology. The Editor-in-Chief of the Journal of Applied Entomology, Prof. Stefan Vidal, and the IWGO Convenors would like to encourage you to consider publishing your IWGO Conference paper in a special issue of this international journal. This special issue can have up to about 14 to 20 papers that will be selected after the peer-review has been completed. The journal offers an online submission system for authors and reviewers. **Please submit your manuscript latest until Monday 8 June 2009**. In addition, please ensure to note on the first page of the manuscript that this is a contribution from the IWGO Conference. The special issue of the IWGO Conference will be published approximately in January/February 2010. We would appreciate if you would use this opportunity to make the IWGO special issue of the Journal of Applied Entomology a success!*

- ***Diabrotica virgifera virgifera* eradicated from the Netherlands**
  *In 2003, Diabrotica virgifera virgifera was found for the first time in the Netherlands, near Schiphol Airport (EPPO RS 2003/142). In 2005, 5 specimens were caught at 4 locations. But since then, the pest has no longer been detected during regular surveys conducted in demarcated zones, maize-growing areas, and near airports. Since no specimens of D. virgifera virgifera have been caught for 3 consecutive years, the NPPO of the Netherlands now considers that the pest has been eradicated. The pest status of Diabrotica virgifera virgifera in the Netherlands is officially declared as: **Absent, pest eradicated, confirmed by surveys in 3 subsequent years** (Source: EPPO Reporting Service No. 5).*

- **German agriculture minister has banned the cultivation of MON810 *Bt* maize in Germany**
  The approval of MON810 maize is suspended with immediate effect. "With that, any cultivation and any further sale of MON810 maize in Germany is prohibited," said the German agriculture minister in a press release on 14 April 2009. The German states are responsible for monitoring the ban. Germans agriculture minister based her decision on a safeguard clause of the EU's release directive. According to that, a Member State may temporarily restrict the sale of a GMO product, when "new or additional information" gives "reasonable grounds to believe" that the GMO product

concerned presents a risk to either human health or the environment. As to what the risks are in the case of MON810 or on what new scientific evidence the German agriculture minister has based her decision, she didn't say. She referred to five other EU countries which had invoked the safeguard clause for banning the cultivation of MON810 maize. However, up to now, these national bans have not been upheld in the scientific assessments called for in the EU directives. The scientific GMO Panel of EFSA again came to the conclusion that there is no new scientific-based evidence to justify a national ban on MON810. These national cultivation bans, though, have received some political support recently. In a vote of the Council of Ministers there was no qualified majority reached to force Austria or Hungary to rescind their bans on MON810. The EU Commission had suggested the vote, as there was no scientific indication of any safety issue. Monsanto has announced the possibility of taking legal action against the ban (Source: GMO Compass).

- **Regional competitiveness of control options against Western Corn Rootworm damages in Central Europe**

  The damage of Diabrotica virgifera virgifera or western corn rootworm (WCR), an alien invasive species in European agriculture, in its host crop maize, is difficult both to assess and to predict. Several exogenous factors such as climate, soil and production system influence the outcome to a high extent. Therefore farmers in Central Europe face difficulties in designing appropriate damage abatement strategies. In this study we evaluate the competitiveness of different control measures: crop rotation, chemical control and biotechnology, in eight central European countries (Hungary, Czech Republic, Slovakia, the Ukraine, Romania, Poland, Serbia and Austria) assuming full infestation in these countries. The simulation approach, explicitly incorporating heterogeneity among farmers, determines the best control option in each possible situation within the country under research. In Hungary for example, we see that at the national level, from those farmers encountering costs from crop rotation, about 76% would opt for the biotechnology control, 22% for crop rotation and less than 2% for chemical control. In the absence of the biotechnological control option chemical control is optimal in about 40% of the modeled situation. Based on the simulation model, a multi-criteria adoption decision tool is developed. This set of decision parameters aids the farmer in selecting the appropriate control options in their given situation. For more information please contact K. Dillen, T. van Looy, E. Tollens; Agricultural and Food Economics Section, Katholieke Universiteit; Leuven; Koen.dillen@ees.kuleuven.be

- **Benefits and costs of Diabortica *virgifera virgifera* control in Europe**

  The spread of WCR in Europe and hence the damage costs do depend on time and space. An assessment of potential damage costs under a no control scenario combined with a number of scenarios about speed of spread, relative damage and prices for maize indicates substantial economic benefits can be gained by controlling Dvv. The average annual damage costs of the most likely scenario are about 472 million Euro per year in Europe. The potential damage costs differ between substantially between, which can be explained by the intensity as well as the value of maize production. Results show by and large France will be the main beneficiary of a successful control strategy. The high damage costs justify the eradication and containment strategies of the EU. While the study indicates high economic benefits of control, the payment and incentive compatibility of control measures still is a question that needs to be investigated further. For further information please contact Justus Wesseler, Environmental Economics and Natural Resources Group, Wageningen University, The Netherlands, at justus.wesseler@wur.nl

- **Estimating *Diabrotica virgifera virgifera* damage functions with field trial data: applying an unbalanced nested error component model**

  Western corn rootworm (Diabrotica virgifera virgifera) is one of the most problematic and costly insect pests of maize in the United States, and recently has become established in Europe. An integral part of many economic analyses of losses and control benefits for pests such as the western corn rootworm is a pest damage function linking the biological system with the economic system. A common data source for estimating such functions are field plot measures of pest damage and yield loss. Data of this sort are panel data (data for groups through time) and are commonly nested, i.e., can be grouped (nested) by more than one index (year, location, treatment,

etc.). These data are also often unbalanced—locations and treatments change over the experimental period so the number of observations by location and treatment changes. We apply a double-nested unbalanced panel data model from the published literature to estimate a damage function for Western corn rootworm using commonly available field data, accounting for the nesting structure and the unbalanced nature of the data. Using data from field trials in five US states at nineteen locations from 2002 to 2007, we estimate that on average, a one unit difference in the node injury scale is associated with a 14.8% difference in yield (the more damaged maize yields 14.8% less). However, tremendous variability exists around this average loss at the field level (the standard deviation is 13.7%). As such, it is more appropriate for regional and/or longer term economic assessments of yield losses. For further information please contact Paul D. Mitchell, Agricultural and Applied Economics, University of Wisconsin-Madison, at pdmitchell@wisc.edu

- **Costs and benefits of plant health measures to prevent establishment and spread of *Diabrotica virgifera virgifera* in Germany**

  The application of phytosanitary measures to prevent establishment and spread of plant pests is often criticised and for farmers not a very popular instrument. Therefore costs and benefits of different strategies for Diabrotica virgifera virgifera in Germany were analysed: costs of phytosanitary measures were compared to costs that would occur without official measures and lead to natural spread of Diabrotica. On a single farm scale an eradication strategy with higher costs in single years showed to be more beneficial compared to regularly applications of pesticides every year if the beetle establishes. The benefit of the plant health strategies on a long term scale over 15 years depends on the starting point of the infection: if the beetle enters into an area with high maize concentration and favourable growth conditions eradication strategies would be the most appropriate measure (cost/benefit ratio of about 1/5 up to 1/11) while containment strategies would in that case not be worthwhile and are more appropriate in regions with low maize concentrations. Since infestation with Diabrotica has in any case massive economic impact on maize production eradication and containment measures are considered to be very beneficial by slowing down spread thus giving monetary and temporal advantages (e.g. make use of technical progress concerning varieties, plant protection or crop rotation) to regions prevented from the beetle. For further information please contact Hella Kehlenbeck, Julius Kuehn Institute, Federal Research Centre for Cultivated Plants, Institute for National and International Plant Health, Kleinmachnow; Germany; at hella.kehlenbeck@jki.bund.de

Article:

Report from the IWGO Convenor to IOBC Global President about IWGO Activities from 2004 to 2008

by Ulli Kuhlmann

International Working Group on *Ostrinia* and other maize pests (IWGO)

The International Working Group on *Ostrinia* and other Maize Pests (IWGO) is a well-established, large Global-IOBC Working Group, which deals with integrated pest management options for all maize insect pests and pest resistance problems. The group is open to all scientists who are interested in working within an international organization dedicated to issues and activities related to maize pests. All the IWGO Conferences and meetings held to date have provided a valuable international platform for the exchange of research, experiences, and ideas on the integrated management of *Ostrinia*, and other maize pests through the use of chemical, cultural, and biological control measures. Based on these activities, IWGO is highly recognized by different stakeholders as an international and independent expert group.

Convenors during period 2004-2008:

- Dipl Ing Harald Berger, Vienna, Austria (convenor for 12 years)
- Dr Ulrich Kuhlmann, CABI Europe, Delemont, Switzerland (since Bratilava Meeting in 2005)

Estimated working group members:

- 300 to 400; regularly joining meetings approximately 120

Non-IOBC members:

- 90% (convenor raised the issue several times and provided information how to become a member)

Activities of Regional Section:

There are no regional sections but there is a sub-working group for *Diabrotica* since 1995 (1st IWGO Subgroup “Diabrotica” Meeting in Graz in 1995 where 20 persons attended).

Newsletter:

- IWGO Newsletter Vol 25 (1) March 2004 (hard copy sent to 500 persons)
- IWGO Newsletter Vol 25 (2) October 2004 (hard copy sent to 500 persons)
- IWGO Newsletter Vol 26 (1) May 2005 (hard copy sent to 500 persons)
- IWGO Newsletter Vol 26 (2) December 2005 (PDF only via distribution list or website)
- IWGO Newsletter Vol 27 (1) March 2006 (PDF only via distribution list or website)
- IWGO Newsletter Vol 28 (1) September 2007 (PDF only via distribution list or website)

Website:
www.IWGO.org since 2004

Since the beginning of March 2006 members can download the IWGO Newsletter from the newly designed website, where members can also find other older issues of the IWGO Newsletter as a PDF file.

Proposed activities: 2008-2012:

- 23rd IWGO Conference will be held in early spring 2009 in Germany (Munich). Papers published in an international scientific journal.
- IWGO will be the only global platform to discuss the follow up of the EU Project Diabr-Act which might lead to a number of new scientific projects for IWGO members on national, international and specifically on EU level.
- IWGO members will be contributing to the establishment of a new version of an EU Directive for managing *Diabrotica*.
- 24th IWGO Conference will be organized in early spring 2011 (locations to be confirmed in the 23 IWGO Conference).
- Starting to develop a General IPM Technical Guideline for maize production in order to define the minimum agronomic requirements.

Accomplishments during 2004-2008:

- In 2004, the 10th IWGO Diabrotica Subgroup Meeting took place between 14 to 16 January in Engelberg, Switzerland. As usual the meeting was held together with the EPPO ad hoc Panel on *Diabrotica* and the FAO – *Diabrotica p*roject group. Convenorship IWGO Harald Berger. Local organization by Ulli Kuhlmann from the CABI Europe-Switzerland Centre in Delémont in collaboration with Mario Bertossa from Agroscope in Contone, Switzerland. More than 100 participants (110) out of 24 countries attended this meeting and showed interest of – mainly European - scientists - in this "new" pest.
- In 2005, the 11th IWGO Diabrotica Subgroup Meeting took place in Bratislava, Slovak Republic, between 14 and 17 February; again together with the EPPO ad hoc Panel and the FAO –Network Group – Meeting (nearly 90 participants). Local organization by Mr. Jozef Kotleba, Slovakian Ministry for Agriculture; Agricultural and Trade Division Plant Commodities Department, and Dr. Ulli Kuhlmann was responsible for the scientific programme. Change of Convenorship from Harald Berger to Ulli Kuhlmann and Rich Edwards continues as Co-Convenor.
- In 2006, the 22nd IWGO Conference was held in Vienna, Austria between 5 and 8 November 2006. The "big" IWGO Conference was attended by 110 participants from 24 countries. Local organization by Harald Berger, Vienna, Austria and Ulli Kuhlmann and Rich Edwards were again responsible for the scientific programme. To its end, a 10-session conference, with five speakers per session, was arranged. Sessions were designed to address the most interesting and relevant research topics in the field of maize insect pests that have current and broad international application and appeal. The oral sessions were complimented by poster presentations. Prof. Wang Zhen-ying, Beijing, China was elected as a Co-Convenor to cover representation in Asia.
- In the past, IWGO published its own proceedings in which oral and poster presentations were included. In 2006, IWGO had for the first time the opportunity to publish nine

selected manuscripts from papers presented during the 22nd IWGO Conference in Vienna in the July 2007 issue of the Journal of Applied Entomology (131 (6): 378-440).

- Since 2006, a large number of IWGO members were part of the DIABR-ACT project (most of the project steering committee members belonged to IWGO), entitled Harmonizing Strategies to Control Western Corn Rootworm, *Diabrotica virgifera virgifera*, which is a specific support action within the European Union (EU) 6th Framework Programme, 'Policy Oriented Research'. The final project meeting in Göttingen 2008 presented proposals which will be submitted to the European Commission, featuring: (1) a coordinated European Research Plan, identifying priority areas for research and avoiding any duplication of effort, and (2) a coordinated European Action Plan for harmonized and more efficient *Diabrotica* control and prevention in Europe. Unfortunately IWGO was not able to arrange a joint meeting with the EU Project DIABR-ACT due to EU administrative issues, therefore the next 23rd IWGO Conference will be held in early spring 2009.

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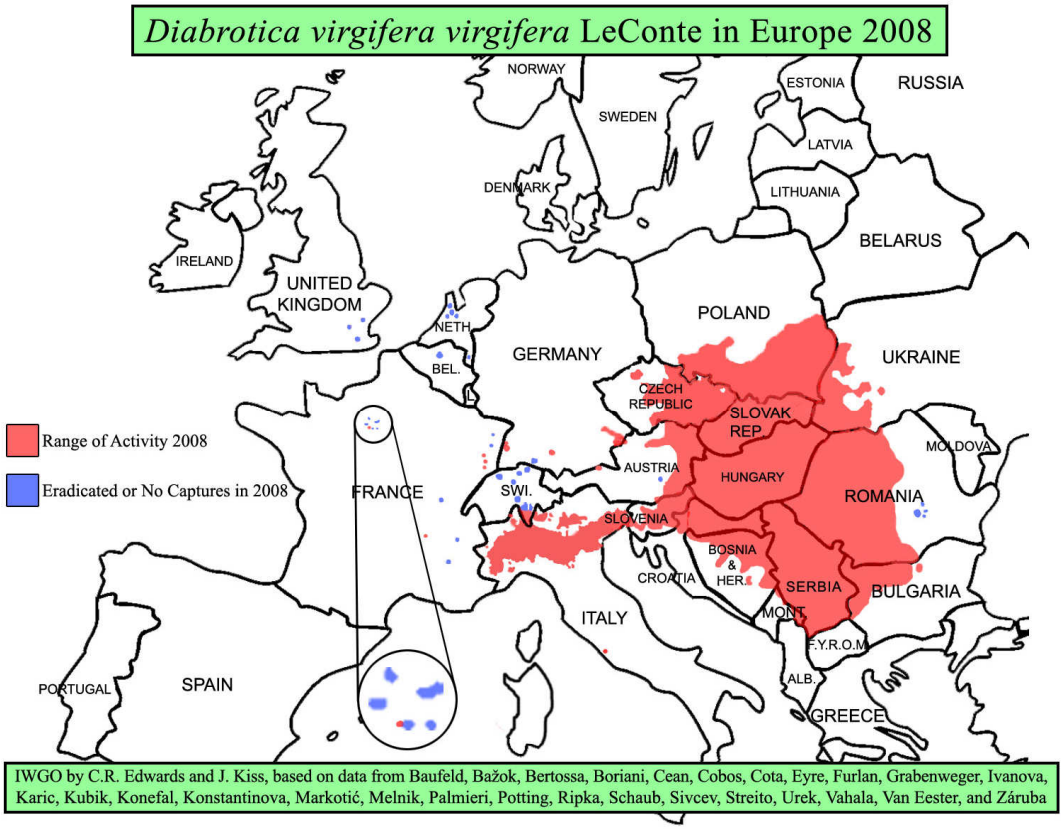
Article:

New WCR 2008 General Spread Map for Europe and North America

by C. Richard Edwards[1] and Jozsef Kiss[2]
[1]*Department of Entomology, Purdue University, W. Lafayette, Indiana 47907, USA*
[2]*Department of Plant Protection, Szent Istavan University, Gödöllö, Hungary*

Here is the new WCR 2008 general spread map for Europe and North America. Printable and downloadable maps showing the spread of WCR in Europe and North America as of 2004 can be found at http://www.entm.purdue.edu/wcr/. These are general spread maps within tolerance of the precision level for maps such as these. We appreciate all those listed on the maps for their input.



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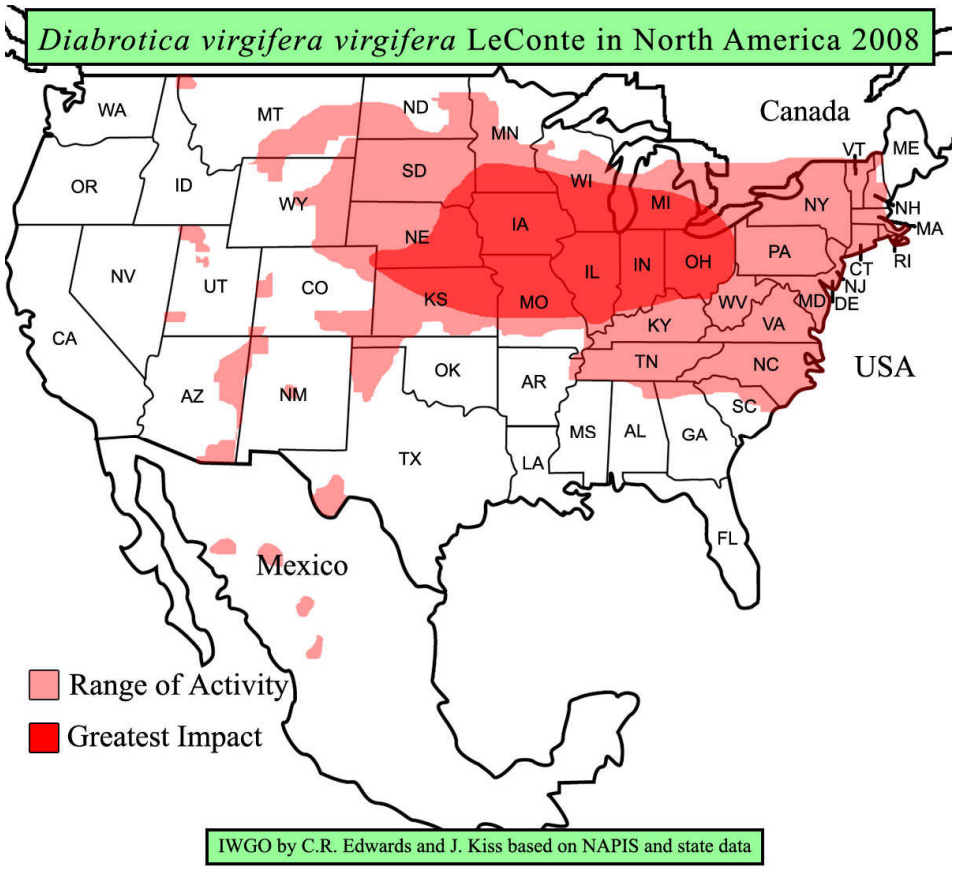

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Abstracts of Oral Presentations
23rd IWGO Conference
Munich, Germany
April 5-8, 2009

Session 1: Evaluation of *Diabrotica* eradication and containment measures

Session Organizers: Lukas SCHAUB, Agroscope Changins-Wädenswil ACW, Nyon, Switzerland

Current situation of the western corn rootworm, *Diabrotica virgifera virgifera*, in Europe

P. Baufeld

Julius Kühn-Institute (JKI), Kleinmachnow, Germany

The western corn rootworm was likely introduced into Europe at the end of the 80's, and in 1992 damage was first observed near the Belgrade Airport (Serbia). *Diabrotica* can spread through hitchhiking by means of traffic or by actively dispersal to non-infested areas (natural flight). Transportation by hitchhiking has allowed the beetle to reach new territories in spite of the ecological barriers (oceans, mountains, connected regions without maize, etc.).

Between 2002 and 2007 18 introductions of the Western corn rootworm were registered in so far non-infested areas in Europe. Furthermore in 2008 *Diabrotica* was introduced in 11 cases in France, Austria and Germany and a greater infested area with 238 beetles was registered in Lower Bavaria (Germany). In 13 cases the eradication measures were successful in the above mentioned period. In two cases (Paris and London) the probability of successful eradication is high.

16 countries of the European Union are no infested. In two cases, France and Germany, further introductions were noticed in 2008. In countries like Austria, Bosnia-Herzegovina, Bulgaria, Croatia, Hungary, Italy, Jugoslavia, Poland, Slovakia, Slovenia, Switzerland, Czech Republic and Ukraine the beetle is established in part or in the whole territory of the countries. The Western corn rootworm continues to spread within Europe and is impacting on more and more maize production areas from year to year. At the moment containment measures seems not very successful to contain the ongoing or slow down the spread.

Surveying for *Diabrotica virgifera virgifera* in the UK: 2003-2008

D.P. Eyre*, R.J. Cannon, R.H.A. Baker, G. Nettleton & J. Miller

*Food and Environment Research Agency, York, UK

Following the discovery of *Diabrotica virgifera virgifera* in France in 2002, the UK carried out a national survey for the pest in 2003 using pheromone traps and 92 D.v.v. were caught. A national survey has been repeated in each year since 2003 at approximately 300-450 sites. The maximum number of beetles occurred in 2005 when 481 were caught. Since 2005, the number of beetles caught has declined; from 27 in 2006, three in 2007 reaching zero in 2008. Most beetles have been trapped to the west of London, close to Heathrow airport, but there have been other foci to the north, south and south-west of London. The presentation will include illustrations of the climatic data to demonstrate that the UK is on the northern margin of the area suitable for this pest, plus maps showing the results of the surveys. In order to evaluate which airports are of greatest risk to future incursions of this pest, assessments have been made of the number of flights from infested areas, the amount of maize grown close to airports and their climatic suitability. A description of how this evaluation was conducted will be included.

The situation of *Diabrotica virgifera virgifera* in Baden-Wuerttemberg (BW) and experiences with eradication measures

M. Glas, H. Imgraben, R. Kaelberer & B. Staer*

*LTZ Augustenberg, 70197 Stuttgart, Germany

In July 2007, the western corn rootworm (WCR) first appeared in BW nearby the river Rhine. Within a few days six beetles were caught in pheromone traps. According to the EU-Directive 2003/766/EU a focus and a security zone were established and measures implemented. One month later the same problem emerged near Lake Constance (Bodensee): in a single trap 19 beetles were found. By October 2007 this number increased to 342 adults of the WCR in that region. Thus crop rotation became unalterable.2008 another spot appeared on the map: At the Autobahn 98 near Leutkirch/Allgaeu a single bug was caught in a trap. The region north of the Bodensee saw none, near the river Rhine 76 adults of WCR were found, where unfortunately in 2007 no trap was placed within a distance of one kilometer. BW had to deal with three different starting points and as a result, the decrees differ from each other, especially regulations in the security zone. Farmers in the Rhine valley with its few findings in 2007 were able to grow corn after corn by using insecticides, farmers near Lake Constance had to get on with crop rotation. As the situation changed in 2008, actions had to be adapted, the means of intense monitoring was carried out for the first time (according to the national guide of the Julius-Kuehn-Institute). A new national WCR directive from December 2008 and a different

situation concerning registration of insecticides will probably lead to a change in the struggle against WCR in Germany as well. The talk will compare the regions in BW and the results we got so far.

Diabrotica virgifera virgifera in Bavaria - current situation

U. Benker*, C. Boegel & M. Zellner

*Bavarian State Research Centre for Agriculture - Institute for Plant Protection, Freising, Germany

The western corn rootworm *Diabrotica virgifera virgifera (*Chrysomelidae, Coleoptera) seems to be the most important pest in maize worldwide. In Bavaria it was detected for the first time in the middle of August 2007, shortly after the first detection of *D. v. virgifera* for Germany in Baden-Wuerttemberg. Within three weeks beetles could be found in three different sites in pheromone traps. One single maize field on the outskirts of the town Passau was heavily infested - 212 beetles could be captured there. In the surrounding area of this hot spot 24 more beetles could be found in several maize fields. The second location was about 25 kilometer south of Passau in an area called Rottal/Inntal. Crop rotation does not happen in the Rottal/Inntal for many years and maize is the all-dominant crop in the landscape. In the Rottal/Inntal all in all four beetles were found, but two of them over the frontier to Austria. The third location was a maize field in Freising-Attaching, closely bordering to the airport of Munich. It was only one single beetle which was captured there in 2007. After the discovery of the beetles measures of eradication according to the regulations of the decision 2003/766/EC and the paragraphs 3 and 4 of the German plant protection act were conducted in the areas concerned. In the following year 2008 the interdiction of maize cultivation has to be observed in the infestation area. In the safety zone maize cultivation was only allowed with strict conditions. Both measures court the maize farmer's resentment. An intensive monitoring of the Bavarian plant protection service in 2008 showed that all measures did not prevent an expansion of the infested area in Southeast Bavaria. In the surrounding area of Munich airport no more beetles were captured in 2008.

The *Diabrotica virgifera virgifera* eradication in Venice focus area has been accomplished

L. Furlan*, G. Burgio, V. De Luigi V., S. Palmieri, Vettorazzo M. & G. Zanini

*Department of Agronomy, University of Padova, 35020 Legnaro, PD, Italy

After the first detection of the western corn rootworm (WCR), *Diabrotica virgifera virgifera*, in Italy (1998) near the International Airport of Venice, an eradication procedure have been continuously implemented over an 8-year period (1999-2006). This was based on: the monitoring of the WCR population, defining of focus and safe

areas, prohibiting continuous maize in focus area, applying insecticide treatments to maize fields to control WCR beetles, forbidding the movement of fresh maize or soil in which corn was grown the previous year outside of the focus area, prohibiting to harvest maize when still green. The effect of the eradication was evaluated by a referenced monitoring based on PAL sex pheromone traps during the implementation and two years (2007-2008) after the ceasing of the eradication procedure, inside and at increasing distances from the focus area. A geostatistic analysis of monitoring data allowed to optimize the sampling grid and to describe the spatial pattern of the pest demonstrating how the original focus area was kept free of beetles for years and that WCR populations did not get out of the focus area but, on the contrary, were moving towards the focus area from new infested areas west and east of the area where WCR was first detected. This despite eradication protocol implementation was stopped and then continuous maize cultivation had been reintroduced in the focus area since 2007. The strategies implemented in Veneto proved to be very effective in stopping on long term newly arrived WCR populations and prevent areas around from being infested.

Dispersal kernels of the western corn rootworm and assessment of the effectiveness of buffer zones in eradication and containment programmes in Europe.

L.R. Carrasco*, T.D. Harwood, St. Toepfer, A. MacLeod, N. Levay, J. Kiss, R.H.A. Baker, J.D. Mumford & J.D Knight.

Imperial College London, London, United Kingdom

Eradication and containment measures against the western corn rootworm in Europe include crop rotation and insecticide treatments within different types of buffer zones. However, quantitative estimates of the relationship between the probability of adult dispersal and distance from an introduction point have not been used to determine

the width of buffer zones. Dispersal models of the negative exponential and negative power law families in logarithmic and non-logarithmic form were fitted to recapture data from nine mark-release-recapture experiments of marked western corn rootworm adults in southern Hungary in 2003 and 2004. Non-baited sticky and pheromone-baited sticky traps were set concentrically around the release point for distances from 30 to 3500m. Both the negative exponential and negative power law models in non-log form presented the best overall fit to the data. The models suggested that half of the dispersing western corn rootworm adults will be found within a circle of radius ranging from 117 to 425 m and 1% of the adults will cover distances of over 775 to 8250 m after one day of dispersal from the release point. An individual-based model including dispersal and mortality over a generation of western corn rootworm adults was developed. The results showed that for eradication to be possible, the minimum required width for the focus zones should be increased to a minimum of between 4.5 km to 47 km for 99 % of the dispersing adults to remain

within the focus zone. The containment zone recommended by the European Commission appears to be of adequate magnitude.

Session 2: Economics and policy of *Diabrotica* control

Session Organizer: Justus WESSELER, University of Wageningen, The Netherlands

Benefits and costs of *Diabortica virgifera virgifera* control in Europe

J. Wesseler* & E. Fall

*Wageningen University, Wageningen, The Netherlands

The spread of the western corn rootworm (WCR) in Europe and hence the damage costs do depend on time and space. While a number of studies have been conducted at national level and hence are limited in space this is the first one for Europe. In this paper we model the spread of the pest in Europe over time based on standard entomological models for WCR. The damage costs are based on studies from the US, Belgium, Croatia, Germany, France, The Netherlands, The United Kingdom as well as results of a survey among European experts. The potential damage costs assessment indicates substantial economic benefits can be gained by controlling WCR. The economic benefits of control justify eradication and containment strategies of the EU. The environmental and socio-economic analysis of WCR control programs undertaken in this paper gives a global idea of what are the benefits and the inconvenient of each possible control strategy (chemical, biological, transgenic) in terms of economic, environmental and health impacts for the different stakeholders involved in such management program. The average economic benefits of the most likely scenario without any control are about 472 million Euro per year for all countries considered. The analysis shows by and large France will be the main beneficiary of a successful control strategy.

Socio-economic assessment of the invasive species *Diabrotica virgifera virgifera* in Central Europe.

K. Dillen, T. Van Looy & E. Tollens

*Katholieke Universiteit Leuven, Heverlee, Belgium

Diabrotica virgifera virgifera or western corn rootworm (WCR) was recently introduced into Europe, where it was first observed near Belgrade, Serbia in 1992.

The beetle spread through Central Europe since leading to a continuous population in 11 countries. In this paper an economic assessment of the possible control options: chemical control, *Bt* technology, crop rotation and biological control in eight of these countries is presented. The study uses a farm level model which estimates the created rents for all different control options compared to no control. A simulation approach is needed because of limited data availability, the ex ante part of the assessment and a high uncertainty about potential damage. This uncertainty, stemming from the low correlation between the pest's population pressure and yield loss, creates a risk for maize producers. Therefore risk behavior of farmers is incorporated in the model through the use of a utility function allowing for decreasing and constant absolute risk aversion, and risk neutral behavior. Furthermore, the model exploits the heterogeneity among farmers to determine the marginal adopter and endogenize the technology fee of the proprietary Bt maize innovation. The results can aid both policy makers and farmers to decide which control options should be taken in order to protect European maize production, from the WCR.

Estimating *Diabrotica virgifera virgifera* damage functions with field trial data

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We apply the double-nested unbalanced panel data model developed by Antweiler (2001) to estimate a damage function for Western corn rootworm (*Diabrotica virgifera virgifera*) using commonly available field trial data. Such trials collect maize yields and measures of root injury from larval feeding for different treatments, with multiple replicates at many locations over several years, creating nested panel data. However, the number of replicates, locations and duration often changes, so that the nested panel becomes unbalanced. Antweiler's method estimates random year and location effects for data that are nested and unbalanced both in years and locations and in the number of replicates. We estimate a damage function with data for rootworm control technologies (soil insecticides, seed treatments, Bt hybrids) from field trials in five US states at twenty locations for some or all six years from 2002 to 2007. With this damage function, the percentage of yield lost in a field can be estimated using the observed node injury scale for the field without conduct experiments. With comparable European data, this method could estimate a damage function for western corn rootworm for use in economic assessments of damage and to analyze the value of various control methods. The presentation will briefly overview the method and the type of data needed, and report estimation results. The primary focus will be illustrating application of the damage function to estimate yield losses in fields and to analyze the economic value of different control methods. Antweiler, W. 2001. Nested random effects estimation in unbalanced panel data. Journal of Econometrics 101:295-313.

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Costs and benefits of plant health measures to prevent establishment and spread of *Diabrotica virgifera virgifera* in Germany

H. Kehlenbeck* & W. Bokelmann

**Julius-Kühn Institute (JKI), Institute for National and International Plant Health, Kleinmachow, Germany*

The economic impact of different plant health strategies to prevent establishment and spread of the western corn rootworm *Diabrotica virgifera virgifera* in Germany was analysed with respect to different maize production sectors (grain maize, silage maize, corn maize, biogas production) and regional differences. Costs and benefits were assessed on single farm level as well as on an aggregated scale for Germany over 15 years for different scenarios for the spread of the beetle. Costs of phytosanitary measures were compared to costs that would occur without official measures and lead to natural spread of *Diabrotica.*

The benefit of the plant health strategies on a long term scale depends on the starting point of the infection: if the beetle enters into an area with high maize concentration and favourable growth conditions eradication strategies would be the most appropriate measure (cost/benefit ratio of about 1/5 up to 1/11) while containment strategies would in that case not be worthwhile and are more appropriate in regions with low maize concentrations.

On a single farm scale an eradication strategy with higher costs in single years is more beneficial compared to regularly applications of pesticides every year if the beetle establishes.

A special analysis of the impact of *Diabrotica* on maize production for biogas showed that any additional costs evoked by the beetle have considerable effects on the profitability of maize production for this sector. Therefore eradication and containment measures would help to slow down spread thus giving monetary and temporal advantages to regions prevented from infection.

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Session 3: Exposure of honey bees to insecticides released from abrasion of treated maize seeds during sowing: where do we go from here?

Session Organizer: Udo HEIMBACH, Julius Kühn Institute (JKI) - Institute for Plant Protection, Braunschweig, Germany

Insecticidal seed treatments and honeybee poisoning incidents in Germany 2008 – background and facts

J. Pistorius* & G. Bischoff

Julius Kühn-Institute (JKI), Braunschweig, Germany

In spring 2008 high numbers of bee poisoning incidents were recorded during seeding of maize in the Oberrheinebene and in parts of south Bavaria. More than 11500 honey bee colonies from about 700 beekeepers in the Oberrheinebene showed symptoms of insecticide poisoning. The poisonings were recorded in areas in southern Germany with an eradication program for the quarantine pest *Diabrotica virgifera virgifera,* where Poncho Pro was used at a high rate (max. 125 g AS /ha). The reason for the bee poisoning incidents was the abrasion of dust from maize seeds treated with the insecticide Poncho Pro during the seeding process and blowing out of this dust containing the active substance Clothianidin into the environment with pneumatic sowing machines. No correlation with any bee pathogens was found. An exceptionally high amount of dust of up to 40 g per 50000 kernels of maize was detected in some of the maize seed batches. Biological and chemical analysis of the bees, plant samples, bee bread and fresh pollen verified the drift of dust and poisoning with Clothianidin from seed-treated Maize.

Quality of maize seed treatments regarding dust

U. Heimbach* & M. Stähler

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In spring 2008 about 12.000 honey bee colonies in southern Germany showed symptoms of insecticide poisoning. The reason for this was the abrasion of dust and abraised dust in transport bags of maize treated with the insecticide Poncho Pro (a.s. clothianidin). Seeds and dust were filled together into the tanks of the sowing machines and the dust was released into the environment with the air stream of pneumatic sowing machines during sowing. 82 different batches of maize seeds

(each 50.000 to 80.000 seeds) were analysed for dust content by sieving whole seed bags. The amount of dust of a particle size smaller than 0.5mm was in average 3.61g/80.000 seeds and varied from 0.98 to 20.38g. Additionally larger insecticide coated dust particles originating from the seeds were detected with 4.88g/80.000 seeds in average (min. 0.51, max. 38.14g). Most batches having been treated with clothianidin were analysed for their clothianidin content. In average a very high residue content (a.s. clothianidin) of 25.6% of the finer dust (>0,5mm) was found (min. 10.5%, max. 59.1%). Less residues (average 13.4%) were detected on the larger dust particles.

Improving seed coating in maize is urgently needed. A quality insurance system was established in Germany in 2008 and insecticidal seed treatments of maize have to be analysed for abrasion after the seed treatment process using the Heubach test (www.jki.bund.de/heubachtest). At the moment only maize seed batches treated with methiocarb are permitted in Germany if they fulfill a maximum permissible value for particulate matter of 0.75g/100.000 seeds and if additionally only pneumatic sowing machines with an air outlet directed to the soil and a reduced drift profile are used.

Influence of sowing technique of maize on drift of dust

U. Heimbach*, D. Rautmann & H. Ganzelmeier

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Maize sowing machines used today are mostly precision air planters with vacuum singling. In southern Germany, Monosem sowing machines are widespread but Kuhn, Amazone and Gaspardo machines are also used.

The main problem with all sowing machines with vacuum singling is that abrasion dust containing a lot of seed treatment products is blown through the fan outlet into the air and may drift to flowering plants nearby (but also further away).

Together with the manufacturers JKI has established a drift test where modified sowing machines are tested against unmodified ones with high drift. In autumn 2008 machines of all well known manufacturers were tested by the Institute for Application Techniques and those modified proving a drift reduction of at least 90% were registered in the JKI-list “drift reducing maize sowing machines".

In the meantime the legal regulations were modified resulting in both a higher quality of seed coating as well as drift reduction. Maize seeds treated with Mesurol may not be sown by precision air planters with vacuum singling unless they have been modified so that a drift reduction of more than 90% is guaranteed. Precision air planters registered in the JKI-list mentioned above fulfill these demands. This requirement is not relevant for machines with mechanical or overpressure singling.

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An effective risk management approach to prevent bee damage due to the emission of abraded seed treatment particles during sowing of neonicotinoid treated maize seeds

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In spring 2008, a bee incident occurred in South-western Germany during the sowing of maize seeds treated with the insecticidal seed treatment product Poncho Pro® (a.s.: clothianidin). Due to a coincidence of several worst-case conditions, bees were exposed to greatly increased amounts of abraded particles of the seed coating ("dust") that contained clothianidin.

A thorough analysis of geo-referenced-data revealed the use of seed batches, improperly treated with the seed-dressing product to be the key factor behind the strongly increased exposure levels. The insufficient adhesion of the product to treated seeds resulted in a greatly increased abrasion of seed-coating particles. This dust was emitted to off-crop habitats via the outlet air stream of vacuum-pneumatic drilling machines, where it deposited on concurrently flowering, bee-attractive crops.

For an effective management of the risk posed by abraded seed coating particles to bees, considerable efforts have been made to ensure throughout Europe a consistently high seed-coating quality. In addition, in a co-operative approach, engineers and application specialists of Bayer CropScience and of various manufacturers of vacuum-pneumatic sowing equipment have developed during 2008 concepts of an effective machinery modification, in order to transform existing vacuum-pneumatic planters via modification-kits into low-drift sowing equipment.

Finally, the effectiveness of the initiated improvements was tested in the field, by conducting a series of dust-drift trials under realistic worst-case conditions with a series of modified vacuum-pneumatic planters. The results demonstrate that if modified vacuum-pneumatic machines are used, exposure of bees to dust from insecticidal seed treatments can be drastically reduced.

CRUISER in France - stewardship and monitoring results of the season 2008

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**Syngenta Agro S.A.S., 1, avenue des Prés, CS 10537, 78286 Guyyancourt, France*

CRUISER® (active ingredient: thiamethoxam) was first registered In France in season 2008 for the treatment of maize seeds. Syngenta established a stewardship program in season 2008 to ensure that treatment of seeds and sowing was conducted according defined quality criteria.

The launch of CRUISER® in France 2008 was a success. The product was welcomed by seed companies and farmers alike and used on more than hundred thousand hectares in its first year. Bee monitoring programs were run concurrently by French officials and Syngenta. In May 2008 the French Ministry for Agriculture issued a first press release stating that the program had not identified any negative effects of the use of CRUISER® on bees. A briefing by authorities in October on all the data available by that date confirmed that the use of CRUISER® had no negative effect on bees. The results of the monitoring re-confirmed that CRUISER® can be used safely.

Session 4: Toward a synthesis: recent advances in understanding Ostrinia adult behaviour

Session Organizers: Tom SAPPINGTON, USDA-ARS, Ames, Iowa, U.S.A. and Denis BOURGUET, INRA, Montpellier, France

C-isotope survey of natural refuge use by European corn borer pheromone races in the U.S.: implications for resistance management

M.E. O'Rourke*, T.W. Sappington & S.J. Fleischer

Cornell University, Ithaca, U.S.A.

The “high-dose/refuge strategy” is central to the insect resistance management (IRM) plan adopted by the United States Environmental Protection Agency (EPA) to slow resistance evolution of European corn borer (ECB), *Ostinia nubilalis*, to Cry proteins expressed in transgenic *Bacillus thuringensis* (*Bt*) corn. For polyphagous insects such as ECB, there is potential to substitute unstructured (non-corn) refuges for structured (non-*Bt* corn) refuges. However, there is debate over the contribution of unstructured refuges to ECB populations. We use stable carbon isotope analysis to directly determine the percentage of ECB populations from upstate New York that originated in unstructured refuges. We further examine other ecological factors important to refuge design including differential rates of unstructured refuge use by the E and Z pheromone races, reproductive consequences of developing on non-corn hosts, and the ranges of the two pheromone races. We found that the average contribution to populations from unstructured refuges was significantly higher for E (18%) than Z race ECB (4%). Furthermore, feeding on non-corn hosts is associated with decreased body mass and, thus, lower fecundity. We also show that the geographic range of Z race ECB completely overlaps that of the E race. While the rate of E race ECB developing in unstructured refuges is higher than previously assumed, low rates of unstructured refuge use by the Z race, evidence for reduced fecundity when reared on non-corn hosts, and complete sympatry within the E race

range, all argue against a relaxation of current IRM refuge standards based on alternative host use.

Male mating success is unrelated to direct fitness costs to females

P.G. Milonas* & D.A. Andow

Benaki Phytopahtological Institute, S. Delt, Kifisia, Greece

In recent years, the role of male age and mating history in mating success has come to have a central place in sexual selection theory, because the direct benefits from the male to the female can be compared with the indirect benefits. Direct benefits include increased female longevity, increased fecundity, and greater provisioning in eggs. Indirect benefits include "good genes" from the male, "sexy son", and other

fitness benefits to offspring not related to maternal effects. It is usually expected that the direct benefits are larger than the indirect ones, however, the empirical literature in the Lepidoptera suggests that the situation is complex. Here we present some evidence that the indirect benefits may be greater than the direct ones for European corn borer.

Mating success of males in relation to their age and their mating history, and fitness parameters for their female mates were investigated in the European corn borer *Ostrinia nubilalis*. Older, experienced males are ones that are more likely to have "good genes" than younger, inexperienced males.

Age had no significant influence on mating success for *O. nubilalis* males. 0 day old virgin males were equally likely to mate as 3-, 6- and 9-day old males. Mating experience had significant influence on mating success for *O. nubilalis* males. Experienced males acquired higher proportion of mates compared to virgin males. Mating with older males or with experienced males significantly reduced lifetime fecundity and longevity of females.

The role of European corn borer female movement in selection of oviposition sites, the preference-performance hypothesis, and pest management

D.D. Calvin*, K. Ellis & S.M. Spangler

Penn State University, University Park, PA, U.S.A.

Adult female behavior is extremely important in how eggs and larvae are distributed across a heterogeneous landscape and on individual plants. It also has significant impact on *Ostrinia nubilalis* management in maize. This paper is a synthesis of research conducted by the authors of the paper and research available in the literature. The Preference-performance hypothesis will be discussed as it pertains to how female *O. nubilalis* select host fields and plants to position their offspring for

success. Issues discussed will include the influence of host growth stage, plant height, distance from source population, and direction of movement. These factors will be discussed at the small plot level and the landscape level. The vertical distribution of egg mass deposition on plants and the subsequent distribution of larvae relative to food resources on the plant will also be discussed in relation to larval fitness variables. Finally, management implications will be discussed with regard to Insect Resistance Management (IRM) programs and non-GMO maize management.

Dispersal behavior and gene flow of European corn borer in France

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Bacillus thuringiensis (*Bt*) crops kill pest larvae but have led to resistance evolution in several target pests. The high dose-refuge (HDR) strategy aimed at delaying Bt resistance evolution depends on dispersal patterns of target pests. Examination of adult dispersal of the European corn borer *Ostrinia nubilalis*, the main target of Bt maize, can help to improve resistance management. We performed mark-release-re capture sessions in herbaceous maize field borders, where ECB adults rest during the day and mate at night to examine the influence of sex, release period and site on ECB dispersal. We also combined mark-recapture and biogeochemical marking to quantify precopulatory dispersal and the mating rate between resident and immigrant individuals, two features influencing the efficiency of the HDR strategy which have seldom been quantified in pests targeted by these toxins. Our results suggest that *O. nubilalis* probably mates at a more restricted spatial scale than previously assumed, a feature that may decrease the efficiency of the HDR strategy under certain circumstances, depending for example on crop rotation practices.

ECB dispersal at small and large scales: new insights, maddening mysteries, and the elusive unified theory of everything

T.W. Sappington* & K.S. Kim

USDA-Agricultural Research Service, Ames, Iowa, U.S.A.

Understanding the temporal and spatial relationship between European corn borer (ECB) mating and dispersal behavior is critical for understanding this insect's population ecology, which in turn is critical to developing and assessing the viability of insect resistance management strategies to protect the efficacy of Bt-transgenic corn. Despite intense study with a variety of methodologies and increased efforts in recent years, ECB movement has proven very difficult to characterize and synthesize into a coherent picture of adult population dynamics. Nevertheless, the combined efforts of many scientists over the years have led inexorably to significant advances

and valuable insights. One of the cumulative effects of this research has been to illuminate the complexity of behaviors underlying ECB adult movement. Three main categories of movement seem to be engaged in by ECB adults at different times and places during their adult life and are expressed differentially depending on sex. These are station keeping (including foraging and commuting), ranging, and migration. The complexity of adult ECB behavior has made progress difficult in attaining a holistic understanding of this species' movement and its consequences, because an unknown aspect of behavior can influence the results of an experiment, which may then render our interpretations and extrapolations inadequate. Despite the complexity and difficulties, we are getting closer to a reasonably-complete picture of adult ECB behavior.

Session 5: *Diabrotica* genomics: advances and prospects

Session Organizers: Tom SAPPINGTON, USDA-ARS, Ames, Iowa, U.S.A.

Genomics resources for WCR and prospects for a genome sequencing project.

N.J. Miller & T.W. Sappington*

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The main justification for pursuing a western corn rootworm (WCR) genome sequence is that it will be cheaper in the long term than for isolated labs to continue developing genomics tools and working on problems piecemeal. There are several laboratories researching the genetics, molecular biology and evolution of WCR. The availability of a complete genome sequence would dramatically reduce the costs of these laboratories' activities in the future. There are a number of resources still needed before a serious proposal can be made: an inbred line, a good estimate of WCR genome size, preliminary data on organization of the genome via sequencing BACs, a good linkage map, and expanded coverage of EST data. Most of these deficits are already being addressed, and it is hoped a WCR genome sequencing project will become a reality within two years.

Preliminary linkage map of the western corn rootworm genome and Quantitative Trait Loci (QTL) for growth

K. Oswald*, M. Bagley, B.W. French & C. Nielsen

*United States Environmental Protection Agency, Cincinnati, U.S.A.

Preliminary investigations into the organization of the western corn rootworm (*Diabrotica virgifera virgifera*; WCR) genome have resulted in low to moderate density gender-specific maps constructed from progeny of a backcrossed, short-diapause WCR family. Maps were based upon variation at microsatellite and amplified fragment length polymorphism (AFLP) loci. Total numbers of linkage groups recovered for each map corresponded very closely with counts of chromosome number within WCR as assessed by previous karyotype analyses. Total map distances varied between sexes, but male map size was very similar to total map size reported for a closely related beetle species with a similar number of chromosomes. Quantitative trait locus (QTL) interval mapping for growth on MON863 (Bt) corn and its isoline was performed for each map, with growth displaying strong correlations to specific genomic regions. Based upon these results, implications for the United States' high-dose, structure refuge insect resistance management strategy for Bt corn will be discussed.

Creating WCRbase: an interactive community-wide home for western corn rootworm genomics data

D. Grant

USDA-ARS, Ames, Iowa, U.S.A.

WCRbase is being developed as a central repository for *Diabrotica* genetic and genomic data. WCRbase is being modeled on SoyBase, the USDA-ARS soybean database, and will be available as an integrated set of web pages. Genetic and sequence maps will be displayed using CMap and GBrowse from the GMOD Project. Data will be stored in MySQL tables or text files as appropriate. WCRbase will be initially populated from the published literature and researchers will be encouraged to submit data for inclusion in WCRbase via either dedicated web pages or file uploads. A collection of common data analysis tools will be provided, and data will also be available for download for specialized analyses.

Session 6: Evolution and population genetics of *Diabrotica*

Session Organizer: Thomas GUILLEMAUD, INRA, Sophia Antipolis, France

Population structure and demography of western corn rootworm sampled from across its US range

K. Oswald, M. Bagley*, U. Stolz, B.W. French & C. Nielsen

United States Environmental Protection Agency, Cincinnati, U.S.A.

Western corn rootworm (*Diabrotica virgifera virgifera*; WCR) was sampled from across much of its US range for population genetic analyses. We assayed sequence variation at the mitochondrial cytochrome oxidase subunit I (COI) locus and allelic variation at multiple microsatellite loci, including markers within a cadherin-like gene, a locus shown to be correlated with resistance to *Bacillus thuringiensis* (*Bt*) in other insects. Patterns of variation among the mitochondrial and nuclear genomes produced largely concordant results. Midwestern and Eastern US populations were, for the most part, undifferentiated, suggesting high levels of gene flow, whereas Southwestern US populations displayed moderate to high levels of differentiation. Temporal analyses revealed that effective population sizes estimated at most sites were small, with substantial amounts of immigration, and two sites near the eastern and western edges of the WCR distribution expressed much smaller immigration. For Midwestern and Eastern US populations, evidence for a population bottleneck was found. Trends within our data also suggest that WCR is not native to the Midwestern US, but most likely is a recent immigrant into this region. Given the species' remarkable ability to evolve resistance to almost all control strategies that have been implemented, this dynamic demographic history does not appear to have strongly diminished its capacity for adaptation.

Increase of genetic variation during the colonization process of Central and South-Eastern Europe by *Diabrotica virgifera virgifera*

M. Ciosi, N. J. Miller, S. Toepfer & T. Guillemaud*

INRA Sophia-Antipolis, Sophia-Antipolis, France

We studied the expansion dynamics and migration pattern of the western corn rootworm (WCR) in its major invasive European outbreak in Central and South-Eastern Europe. For that purpose the genetic variation of WCR was analysed at eight microsatellite markers. Nineteen samples were studied along two transects representing populations of different ages from the first observation site to the

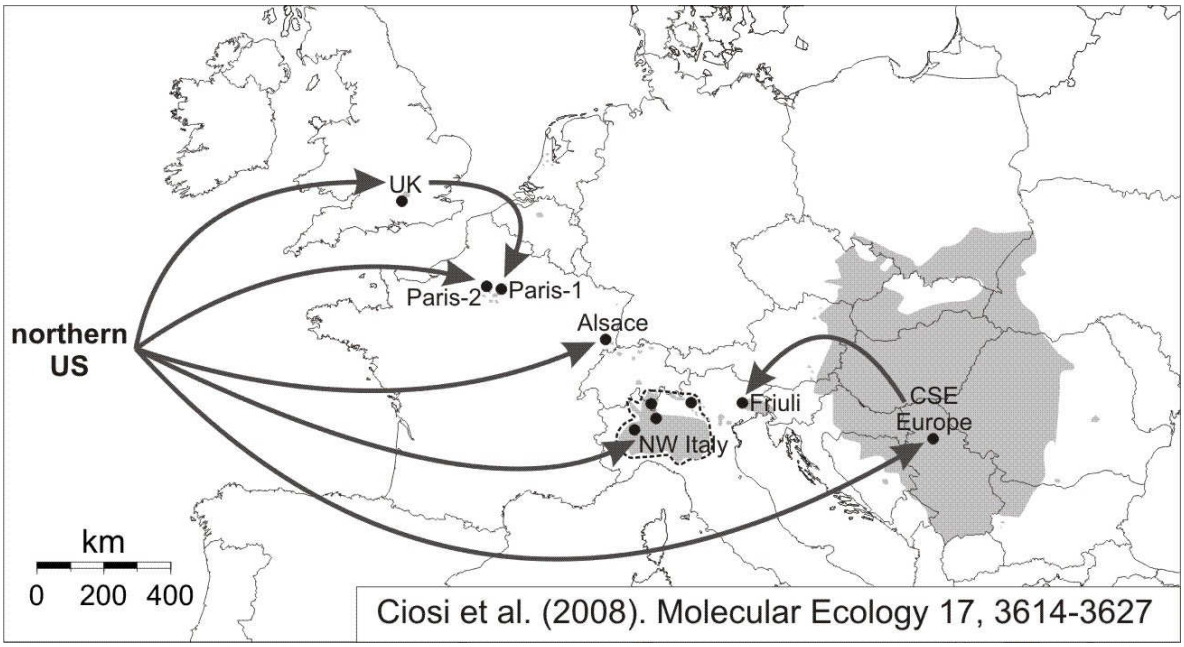
expansion front of 2003. We found a signal of genetic isolation by distance but no decrease of genetic variability along the colonization direction and thus no evidence for founder events at the front of the colonization area. On the contrary, we documented an unexpected increase of genetic variation from the centre to the edge. Inferences on the mode of dispersion and on the past population size are presented and discussed.

Invasion of Europe by the western corn rootworm: multiple transatlantic introductions with various reductions of genetic diversity

M. Ciosi*, N.J. Miller, K.S. Kim, R. Giordanno, A. Estoup & T. Guillemaud

INRA-Sophia Antipolis, Sophia Antipolis, France

The early stages of invasion involve demographic bottlenecks that may result in lower genetic variation in introduced populations than in the source populations. Previous population genetic studies of bio-invasions have reported different losses of genetic variability in comparisons of source and invasive populations. Descriptions of invasive species for which multiple introductions from a single source population have been demonstrated may be particularly informative to study this subject. The western corn rootworm (WCR), *Diabrotica virgifera virgifera*, native to Central America, is such an invasive species in which repeated introductions from North America into Europe were previously demonstrated. We investigated within- and between-population variation, at eight microsatellite markers, in WCR in North America and Europe, to investigate the routes of introduction of WCR into Europe and to assess the effect of introduction events on genetic variation. From 1992 to



2004, we detected five independent introduction events from the northern US to Europe and two intra-European foundations. The loss of diversity following these introductions differed between events, suggesting variation in introduction, foundation and/or establishment conditions. We also showed that, thanks to the multiple introductions, the genetic variability present in the American source population has been redistributed among the various introduction foci in Europe.

Differences between disparately invading as well as crossbred populations of *Diabrotica v. virgifera* in Europe

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CABI Europe - Switzerland, Delemont, Switzerland

European western corn rootworm populations, originating from single disparate introduction events, are known to have a lower neutral genetic diversity than the US or Mexican populations. The crossbreeding of disparate populations, such as between the Central and South Eastern European (CSE) and the North-west Italian (NWIT) population, can increase genetic diversity and thus may affect fitness, adaptability and invasiveness. Laboratory bioassays revealed that the variability of the life spans, fecundities, and body weights of the CSE population was similar to those of the NWIT population. Only flight activities as well as elytra lengths and widths were more variable in the CSE population than in the NWIT population. CSE adults were slightly bigger than the NWIT adults, but no differences were found for the life span, fecundity, elytra length and width. Crossed populations showed a similar variability in life span and fecundity as the pure CSE and NWIT populations. Crossed adults were more active fliers than the pure NWIT population and similar fliers as the pure CSE population. The body weights of the crossed populations were more variable than of pure populations. Elytra lengths of the crossed population were similarly variable as the CSE population and less variable than the NWIT populations. Elytra widths of the crossed populations were similarly variable as the NWIT population but more variable than the CSE population. In conclusion, crossed populations proved to be, for some traits, more variable than pure populations, which may result in an increased adaptability.

Landscape genetics of the invasive western corn rootworm *Diabrotica virgifera virgifera* (Coleoptera: Chrysomelidae) in Croatia

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The purpose of this project is to provide data that will help in the control of the western corn rootworm (WCR) in Croatia. Successful control efforts require a detailed

understanding of the mechanisms underlying invasion success, and these can be investigated by the field of landscape genetics. Understanding the landscape genetics of WCR in Croatia will: increase knowledge of how many populations exist; enhance understanding of WCR dispersal including where and when a WCR invasion is likely to occur; how populations might spread; the level of genetic diversity in populations; and assess the level of spatial and landscape dependence on the genetic structure, gene flow and dispersal of WCR. This talk will present the preliminary findings of the genetic structure, gene flow and dispersal patterns among six central and western Croatian WCR populations. Also, future research concerning the landscape genetics of WCR populations from across Croatia, and how this data will be used to improve integrated pest management strategies for WCR, will be discussed.

Session 7: Adaptations of *Diabrotica* to control practices in maize

Session Organizers: Blair SIEGFRIED, University of Nebraska, Lincoln, NE, U.S.A. & Tom SAPPINGTON, USDA-ARS, Ames, Iowa, U.S.A.

Western rootworm adaptation to genetically modified corn

B.E. Hibbard

USDA-ARS, Columbia, U.S.A.

To delay evolution of insect resistance to transgenic crops producing *Bacillus thuringiensis* (*Bt*) toxins, nearby "refuges" of host plants not producing Bt toxins are required in many regions. Such refuges are expected to be most effective in slowing resistance when the toxin concentration in *Bt* crops is high enough to kill all or nearly all insects heterozygous for resistance. However, *Bt* corn, *Zea mays*, introduced recently does not meet this "high-dose" criterion for control of western corn rootworm (WCR*), Diabrotica virgifera virgifera*. A greenhouse method of rearing WCR on transgenic corn expressing the Cry3Bb1 protein was used in which ~25% of previously unexposed larvae survived relative to isoline survival (compared to 1 to 4% in the field). After three generations of full larval rearing on Bt corn (Constant-exposure colony), WCR larval survival was equivalent on Bt corn and isoline corn in greenhouse trials, and in diet bioassays with Cry3Bb1 protein on artificial diet, the LC50 was 22-fold greater for the Constant-exposure colony than the Control colony. After six generations of greenhouse selection, the ratio of larval recovery on *Bt* corn to isoline corn in the field was 11.7-fold greater for the Constant-exposure colony than the Control colony. Removal from selection for six generations did not decrease survival on *Bt* corn in the greenhouse. The results suggest that rapid response to selection is possible in the absence of mating with unexposed beetles, emphasizing the importance of effective refuges for resistance management. Similar experiments

were conducted with mCry3A and will also be discussed for the first time in context of published data with Cry34/35Ab1-selected and the above Cry3Bb1 WCR colonies.

Behavioral characterization and differential gene expression of the rotation-resistant phenotype of western corn rootworm

L.M. Knolhoff

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Yearly rotation of corn (*Zea mays*) with another crop interrupts the life cycle of the western corn rootworm, but behavioral resistance to crop rotation is a major problem. Resistant adult females exhibit reduced fidelity to corn due to increased locomotor activity and lay their eggs in the soil of both in corn and soybean (Glycine max) fields. An overview of the rotation resistance trait at both the behavioral and molecular levels will be presented. Possible molecular mechanisms or markers were investigated by utilizing microarray analysis to find differences in gene expression. Rotation-resistant females have lower constitutive expression of genes involved in antibacterial defense, but many genes with higher expression have no matches to known proteins. Gene expression was also used as a method to study how soybean herbivory relates to the rotation resistance phenotype. Ability to compensate for proteinase inhibition due to soybean herbivory by increasing expression of digestive proteinases is not a trait shared exclusively by rotation-resistant western corn rootworms. The relationship of soybean herbivory to behavior was examined in a laboratory study, in which it was found that oviposition in resistant females was not influenced by feeding on soybean foliage. Furthermore, resistant females exhibiting increased locomotor behavior in the field were more likely in the laboratory to lay eggs away from corn. This multi-pronged approach to understanding the rotation-resistant phenotype will contribute to studies on the management and resistance management of this insect.

Fitness of *Bt*-resistant western corn rootworm on Mon863 and isoline corn

M. Bagley*, K. Oswald, W. French, C. Nielsen

United States Environmental Protection Agency, Cincinnati, U.S.A.

To help ensure that insect resistance management plans mandated by the US Environmental Protection Agency are based on the best science available, we evaluated fitness costs associated with resistance development in artificially selected laboratory lines of the western corn rootworm, *Diabrotica v. virgifera*. Five independent short-diapause lines were selected for resistance to MON863 (Bt) corn under either a moderate selection (3 lines) or intensive selection (2 lines) regime and

compared to randomly selected controls (2 lines). At the end of the study interval (10 generations of moderate selection, 7 generations of intensive selection) all selected lines achieved a high level of resistance. Fitness parameters selected and control lines were compared on *Bt* corn and its nontransgenic isoline to evaluate possible fitness costs. All selected lines achieved higher adult emergence on *Bt* corn compared to controls while emergence of selected lines was equivalent to controls on the isoline corn. Fecundity of emergent females was similar for selected and control lines, regardless of the type of corn. Thus, we found no evidence that resistant lines were less fit than control lines when reared on nontransgenic corn – an important result for resistance models and insect resistance management plans. Interestingly, fecundity of both resistant and control lines was higher when reared on MON863 compared to the isoline. It is not clear whether this is an artifact of the experimental design or whether this same phenomenon can occur in the field. This potential fecundity difference has implications for resistance management plans and requires further investigation.

Characterizing laboratory colonies of western corn rootworm, *Diabrotica virgifera virgifera*, selected for survival on maize containing event DAS-59122-7

A.P. Alves*, O. Dermody & S.D. Thompson

**Pioneer Hi-Bred International, Johnston, U.S.A.*

Chemical control tactics for *Diabrotica virgifera virgifera*LeConte (western corn rootworm, WCR) have significant financial and environmental costs. Transgenic corn

expressing the Cry34/35Ab1 *Bacillus thuringiensis* insecticidal toxins (event DAS-59122-7) has gained widespread acceptance in the U.S. as an effective, environmentally friendly control technology for use against *Diabrotica* spp., protecting corn roots and yield potential. In this study, WCR populations originating from two geographically distinct locations were reared separately in the laboratory on maize containing event DAS-59122-7. Colonies were evaluated for phenotypic change in larval development, injury potential and survival to adulthood across several generations. A shift in larval development, survival rates, and injury potential (although not economically significant) on DAS-59122-7 maize was observed in the F1 generation. Survival rates in F1 generations of both selected colonies corroborate field estimates of survival on DAS-59122-7 maize. Despite the absence of random mating, a putative major resistant allele was not found in either population after 15+ generations of selection. These results suggest that a major resistance gene(s) for DAS-59122-7 is rare in *D. v. virgifera* populations in the United States, and that a tolerance trait(s) conferring a low level of survival on DAS-59122-7 maize is present. The tolerance trait identified in this study was considered minor with respect to its impact on DAS-59122-7 maize efficacy. Furthermore, research involving an unselected colony characterized the interaction between WCR and event DAS-

59122-7 and generated important information that can be used to improve IRM strategies for this event.

Honorary Lecture

Induced changes of maize by foliar application of soluble carbohydrates, incidence on plant and *Ostrinia nubilalis*: outlooks for maize protection against *Diabrotica virgifera virgifera*

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Foliar applications of soluble carbohydrates induced systemic changes in the plant growth, leaf surface and tissue composition in primary metabolites. It has incidence on *Ostrinia nubilalis* Hbn egg-laying (numbers and distribution within the plant and leaf sides). Different modalities (frequency and plant growth stage) of foliar applications of one soluble carbohydrate on sweet corn were studied in green house and their incidence on *O. nubilalis* Hbn egg-laying. Extension was carried in fields to protect sweet corn against *Ostrinia nubilalis* Hbn damages. We focused also on the effects of carbohydrate treatments on a maize hybrid known for its lower susceptibility against *Diabrotica virgifera virgifera* larvae. Effects on plant growth and chemical analyses of leaf surface and tissues give indications of possible outlooks for maize protection against *D. v. virgifera*.

Session 8: Knowing your enemy: investigating maize pest ecology to improve control strategies

Session Organizer: Stefan TOEPFER, CABI Europe c/o Plant Protection Directorate, Hodmezovasarhely, Hungary

How to develop discrete spatiotemporal population models for the western corn rootworm at landscape level

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In order to develop integrated management strategies against the actively migrating western corn rootworm, (WCR), the estimation of its population dynamics are

required at landscape level. The biology of WCR permits the development of discrete spatiotemporal population models, because of being univoltine (discrete in time) and in close association with maize (discrete in space). The model becomes a cellular automaton when simplifying the landscape of a certain region into a grid, where fields become cells. The states of the cells are: continuous maize (D), first year maize (R) and non-maize (E). The yearly updater rules of the model are: R→D, R→E, D→D, D→E, E→R and E→E. The ratio of different states is constant for a region. The cells on the edges of the region are handled with toroidal arrangement. The density of WCR is calculated twice a year using two time steps: First, the adults are in their natal continuous maize fields. Second, the adults migrate and arrive in fields where their offspring will emerge if the updater rules provide maize in the following year. As for Europe, our model can be bound to a high fidelity of WCR to maize. Thus, WCR migrate into maize exclusively. The WCR density of the next generation can be calculated by multiplying the density for the R→D and D→D updates with an annual growth rate typical for WCR of a certain region. We suggest defining the model output as the ratio of maize fields with a population density above a defined threshold level.

Changes in western corn rootworm below ground distribution during larval development

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The distribution of root herbivores is difficult to asses as position and number of individuals in the soil can not easily be quantified. A better understanding of such ecological parameters would help to create more efficient management systems with below ground pests such as the larvae of the western corn rootworm. Using containers that simulate a microhabitat in a maize field (two rows with 10 maize plants each) we developed a specific soil stratification sampling scheme to evaluate western corn rootworm larval distribution within maize root systems and between maize plant rows during western corn rootworm larval development. Soil samples of equal volume from different depths, from between plants rows and directly at the plants were collected and larvae extracted with a Kempson extraction chamber at the

beginning, in the middle and at the end of their development. Our results show that the distribution of western corn rootworm larvae predictably changes during their development, with larvae expanding into new soil compartments during the last stages of their development, indicating a root dependent distribution. Implications for setting up new management systems using this system will be discussed.

Does chronological order matter?

Western corn rootworm larvae and their interactions with root infecting *Fusarium verticillioides*

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Recent experiments have shown that the feeding of western corn rootworm (WCR) larvae at the roots of maize can increase the colonization of roots by the mycotoxin producing fungus *Fusarium verticillioides* (Fv). For the interpretation of this result it is important to know how the chronological appearance of the insect and the fungus might influence (a) the increase in root colonization by the fungus that is induced by insect feeding and (b) larval growth that is influenced by root colonization of the fungus. An experiment was carried out in the greenhouse with maize plants infested with two different concentrations of spore suspensions of Fv and eggs of WCR differing in chronological order. Larvae were extracted using a high gradient Kempson extraction system and root samples were taken and analysed by real time PCR. Results will be presented that show the importance of the chronological occurrence of insect and fungi on their interaction. In addition we will demonstrate that fungal colonization of the roots influences larval development. This work shed light on the complex interactions between an invasive root herbivore and a soil born phytopathogenic fungus.

Root feeding by *Diabrotica v. virgifera* changes shoot-physiology and resistance against *Spodoptera littoralis* in maize- and vice versa

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Herbivore attack can have a profound systemic impact on plant physiology. Many shoot-active secondary metabolites are produced in the roots after aboveground attack, and root herbivores can change the shoot physiology of plants, thereby affecting aboveground yields. It is thus important to understand the plants systemic response upon herbivore infestation, and we investigated the impact of the root herbivore *Diabrotica v. virgifera* on shoot physiology and resistance of maize and -vice versa- the effects of the shoot herbivore *Spodoptera littoralis* on maize roots. Leaves of *D. v. virgifera* infested plants displayed increased resistance against the herbivore *S. littoralis* in the laboratory as well as the field. We observed little aboveground transcriptional changes in the early stage of root herbivore infestation, but prolonged infestation resulted in a loss of leaf-water, accumulation of abscicic acid (ABA), ABA-dependent defense gene expression and secondary metabolite synthesis. We conclude that *D. v. virgifera* induces resistance against *S. littoralis* by upsetting the plant's water balance, a phenomenon that is most likely a physiological

constraint resulting from the interaction between the root herbivore and its host plant. Roots of *S. littoralis* infested plants showed a dramatic increase of resistance against *D. v. virgifera.* Whereas leaf-herbivory did not dramatically change levels of known defense hormones in the roots, we found a complex transcriptional reprogramming belowground after shoot infestation. Further research will have to show if it is possible to exploit shoot herbivore induced root resistance for the development of novel pest control strategies.

Enhancing plant signals to optimize the control of maize pests

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Plants have evolved an elaborate arsenal of physical and chemical defenses that allow them to cope with their numerous attackers. An increasing number of studies suggest that, if properly understood, these natural plant defenses can be manipulated and exploited for the control of insect pests. We have been studying a form of indirect plant defense, whereby, in response to insect feeding, plants emit various volatile compounds that attract the natural enemies of their attackers. Using maize as our model plant, we recently found that these tritrophic interactions also occur belowground, where insects-damaged roots release attractants for entomophatogenic nematodes. The roots of many varieties of maize release the sesquiterpene (E)-β-caryophyllene when damaged by larvae of the ferocious western corn rootworm. Interestingly, most North-American maize varieties do not emit this signal. In field studies, the absence of the signal was shown to have major consequences for nematode attraction and resulted in dramatically lower nematode infection rates of pest larvae. Hence, the plants' natural defense signals show great potential for the enhancement of biological pest control. We have also found that endophytic bacteria can affect the volatile emissions to their advantage and that induced volatiles affect defense responses in neighboring plants. I will give an

overview of our work in these areas with an emphasis on the possibility to manipulate volatile emissions in maize plants in order to enhance direct and indirect resistance against pests.

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Session 9: Current issues with managing insect resistance to genetically modified maize

Session Organizers: Rick HELLMICH, USDA-ARS, Corn Insects and Crop Genetics Research Unit, Ames, Iowa, U.S.A. & Blair SIEGFRIED, University of Nebraska, Lincoln, NE, U.S.A.

Transgenic *Bt* corn, IRM, and IPM - issues and opportunities

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The impact of transgenic *Bt* corn hybrids on insect populations and their control has been dramatic, transforming the way we think about and implement insect management strategies. Bt corn hybrids are very effective against corn borers (both European and southwestern) and corn rootworms, and corn growers in North America have realized their benefits on tens of millions of acres annually over the past few years. Transgenic traits for control of both corn borers and corn rootworms have been "stacked" in elite corn hybrids with traits for herbicide tolerance, resulting in double-, triple-, and quad-stacked hybrids. Near-future developments (e.g., Optimum® AcreMaxTM 1 Insect Protection, Pioneer's "refuge in a bag;" and Monsanto's/Dow's SmartStaxTM, an 8-gene stacked combination) will result in even more acres planted to Bt corn.Despite the obvious benefits farmers have realized with transgenic Bt corn, there are issues associated with widespread reliance on only one management tactic. For the most part, corn growers in North America have complied with insect resistance management (IRM) guidelines for Bt corn, but growers have recognized the costs associated with growing non-Bt corn refuges. And it is likely that IRM guidelines and requirements will change, creating even more uncertainty about implementation and compliance. The thrust of the discussion will be how insect management and IRM have been influenced and will continue to be influenced by the widespread use of Bt corn. Where appropriate, "case studies" will be used to elucidate some of the complexities and drawbacks of using transgenic technology for insect management.

Possible new approaches to manage insect resistance for the next generation of *Bt* maize hybrids

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The high-dose/refuge strategy is commonly used to manage insect resistance to *Bacillus thuringiensis* (*Bt*) crops. The assumptions of this strategy are plants express a high dose of toxin, genes that confer resistance are rare, and there are many susceptible insects to mate with resistant insects. These assumptions are met with

many lepidopteran pests of maize, but certainly not all. With this strategy susceptible insects are produced through the use of structured or unstructured refuges. In the U.S.A. growers are mandated to grow at least 20% non-*Bt* maize as refuge. A new generation of transgenic maize that combines two or more toxins with different modes of action (pyramids) is in production. These plants will have a wider spectrum of insect control and could allow for new approaches for managing insect resistance. Reduced refuge amounts and seed mixtures are being considered. Currently seed mixtures are not recommended because interplant movement of larvae could violate high-dose assumptions. Studies are underway with European corn borer, *Ostrinia nubilalis*, to determine behavioral and genetic factors that influence larval movement among *Bt* and non-*Bt* maize plants. These experiments will help determine whether "refuge in the bag" is viable for *Bt* maize and help establish methods to similarly test other insect pests of transgenic crops.

Cross-resistance of Cry1Ab-selected Asian corn borer to other Cry toxins

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The Asian corn borer, *Ostrinia furnacalis* (Guenée) (Lepidoptera: Crambidae), is the most important insect pest of maize in China. Although insect resistant biotech Bt maize that have provided an effective mean to control lepidopteran pests such as the European corn borer O*. nubilalis* (Hübner) for last decade has not been commercialized in China, exotic Cry1Ab- and Cry1F-expressing maize derived from genetic transformation events MON810, Bt11, and TC1507 as well as domestic Cry1Ah-, Cry1A-, and Cry1Ac-Cry1Ie-expressing maize were evaluated to suppress *O. furnacalis* in field trials. The development of resistance in target pest is a major concern to threaten the use of *Bt* maize. A strain of *O. furnacalis* selected with Cry1Ab protein incorporated into artificial diet developed more than 100-fold resistance to Cry1Ab after 35 generations of selection and readily consumed Cry1Ab-expressing maize silks. Although LC50s of the selected strain were not progressively increased significantly or even decreased in the following generations, it could survive on Cry1Ab-expressing maize tissue after 51 generations of selection. In addition, it was significantly decreased in susceptibility to a number of other *Bt* toxins to which the selected strains were not previously exposed. Highest level of cross-resistance was observed with Cry1Ah (131-fold), followed by Cry1Ac (36-fold). A low level of cross-resistance (6-fold) to Cry1F was detected. In contrast, it was as susceptible to Cry1Ie as the unselected control strain. These results indicate that the

availability of multiple toxins could improve resistance management strategies, provided cross-resistance among toxins is not a factor.

Changes in pest occurrence due to the deployment of *Bt*-maize: the Spanish case

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Since 1998 when *Bt* maize cultivation was first authorised in Spain, its growing area has increased year by year attaining, in 2008, to 78,000 ha (21% of the total maize growing area). *Bt* maize provides an effective control of two key Lepidopteran pests, *Sesamia nonagrioides* (Lefèbvre) and *Ostrinia nubilalis* (Hübner). In addition to these two borers, several other lepidopteran species causing occasional but severe damage coexist in maize fields: *Helicoverpa armigera* (HA) and *Mythimna unipuncta* (MU). In this work the effect of different varieties of *Bt* maize on the larvae of both species has been studied in the field (HA) and laboratory (MU). Larvae of both species can survive and complete development when feeding on Bt maize. In field experiments performed in 2005, 2006, 2007 and 2008 there were no differences in the number or HA larvae per plant between *Bt* and their isogenic varieties. Although the mortality of MU larvae fed on *Bt* maize resulted to be higher than on the isogenic maize, a 15% of the larvae attained to pupate although with longer development times. Adults resulting from larvae fed on transgenic maize laid 13% less eggs than those fed on isogenic maize. When they had the choice, neonate MU larvae chose first Sorghum bicolor, later isogenic maize plants and finally *Bt* plants for feeding. These data indicate that when strategies for corn borer resistance management are planned, potential consequences for HA and MU must be considered.

Research needs from industry: understanding and minimising the potential for resistance development in target pests.

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Maize plants transformed with Bt traits offer another option for control of the key European pests, *Sesamia nonagriodes*, *Ostrinia nubilialis* and *Diabrotica virgifera virgifera*. This technology is considered an effective and environmentally safe alternative to chemical control. Therefore, to ensure the long term benefits and minimal impacts on biodiversity, industry works continually to minimize the potential for trait resistance evolution. The first action in this effort is to ensure that the baseline susceptibility to trait proteins is accurately quantified for a representative set of key pest populations. Sampling protocols for post commercial monitoring are designed to accurately identify changes in susceptibility and should also encompass,

where possible, population characteristics such as genetic variation within and among populations. Additionally, clear consensus on metrics for defining resistance is crucial to ensure broad relevance of baseline assessments. In the future, as plant insect-resistance traits are less likely to be based solely on high levels of toxins, the question of how refuges should be deployed to minimise resistance risk increases in importance. Especially pertinent, are the roles that mating, availability of alternative hosts, and dispersal patterns play in determining the optimal refuge configuration. In many cases, industry is moving towards pyramiding of genes, resulting in plants expressing multiple modes of action against the key pests, also impacting refuge strategy. Bt technology is a safe and efficient way to control serious insect pests, but ensuring the long term efficacy of this technology will be achieved only by open cooperation between private and public sector scientists.

Session 10: Inventory of maize pest of economic importance in Europe

Session Organizer: *Xavier PONS, University of Lleida, Spain*

The maize case study of ENDURE – current status of weeds, diseases and mycotoxins

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ENDURE is the European Network for the Durable Exploitation of Crop Protection Strategies since 2007. The overall objective is to restructure European's plant protection and to build a leading European Competence Centre for sustainable plant protection. ENDURE assembles 16 institutions from 10 European countries with some hundred plant protection specialists involved. To identify short term solutions crop specific case studies were started. The Maize Case Study (MCS) aims to analyse the impact of pests (arthropods, diseases and weeds) and control practices currently used in order to determine new control strategies for maize crop production that is less relying on pesticides. Partners are Spain, Italy, Hungary, France, Denmark, Poland, the Netherlands and Switzerland. Starting in 2008, the first action of the MCS was to design a survey questionnaire that was filled in of the involved partners providing a picture of the current status of pest incidence and pesticide use. The portion of maize grown in crop rotation varies between the countries from less than 21% (France Normandie, Hungary Békés County) up to 70% (Italy Po Valley). Since wheat is included in most maize rotation systems disease pressure in maize is increased. Seed dressing is widely used against diseases and pests. No fungicides are sprayed except in south-western France, but insecticide sprays are regularly

applied against pests in many countries. Mycotoxins derived from *Fusarium* spp. have a high significance in about half of the regions on a stable level during the last 5 years. A total of 52 weed species were mentioned; 21 of them with a high significance. Herbicides are used in all partner regions on more than 90% of the maize area. Weeds are recognised as a very relevant problem but also very predictable and often easy to handle, whereas diseases and arthropod pests are less predictable and less easy to handle. A multi-criteria methodology will be used in future to assess improved crop protection strategies.

Present status of maize arthropod pests in ENDURE countries

X. Pons*, J. Kiss, S. Otto, B. Melander, E. Czembor, S. Guillot, R.van der Weide, O. Zimmermann, F. Bigler & P. Mouron

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Information about occurrence, abundance and control practices of maize arthropod pests was obtained in eight countries participating in the ENDURE Network (Denmark, France, Germany, Hungary, Italy, the Netherlands, Poland, and Spain) from relevant local experts and from scientific and technical reports. This information was analyzed in order to recommend alternatives and changes in the control strategies and reduce the dependency on insecticides.

Arthropods that cause economic damages were mainly insects: corn borers, western corn rootworm (WCR), wireworms, cutworms, aphids, frit fly, leafhoppers and the cotton bollworm. The relative importance and significance of these pests greatly varied between countries. Other insects were present only in particular countries, but there are considered as important pests there (i.e. the maize leaf weevil in Hungary). Arthropod pest impact was potentially high in Spain, Italy, Hungary or France but low in Denmark or the Netherlands.

Corn borers cause, generally, the greatest economic impact. *Ostrinia nubilalis* was the most common corn borer, except in Spain where *Sesamia nonagrioides* was the prevalent. In Spain, where transgenic *Bt*-maize is commercially used, the populations of corn borers have decreased in the regions where Bt-maize is the main control strategy. Wireworms and cutworms constituted the second group in importance and the potential economic damage caused by these two pests is outlined. WCR was the most serious pest of maize in Hungary and partly Italy. However, the economic importance of this invasive species in the other countries where it has been recorded is still low. Information about other arthropod pest was also analyzed and the pest status determined.

An analysis of the current control methods and possibilities of implementing new control strategies is going ahead by the ENDURE Maize Case Study Working group.

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Maize pest status in Slovakia

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Animal pests of maize in Slovakia include *Ostrinia nubilalis*, Diabrotica *virgifera virgifera*, *Helicoverpa armigera*, *Agrotis* species, *Tanymecus dilaticollis* and elaterids. The other species (aphids, acarids or nematods) do not have real economic importance. During 2004-2008, *O. nubilalis*, long time the maize pest number one (producing the highest damage), was replaced by *D. v. virgifera*. The first economic damage of current number one (*D. v. virgifera*) was found in 2003 (information from agronomists). In 2004, exact data from scientists showed that there was economic damage in many maize fields. During 2005-2007, the level of infestation increased geometrically achieving at many fields 80 % of lodged plants (in 2007). In 2008 the farmers completely changed the system of maize growing. The level of infestation by No.1 went down. Population level of No.2 (*O. nubilalis*) was only partly influenced by farmer agrotechnics and it depended on the locality. There are zones with high occurrence of this pest every year and climatic conditions can change the level of infestation. In the year good for the pest in favorite locality could be found 90 % of damaged plants and in bad year there were nearly 50 % of damaged plants. At not favorite locality, the infestation could be in good year 30 % of damaged plants, and in bad year it could be on the level of 5 % damaged plants. Year 2008 was very good for No. 2 and probably it achieved back its former No.1 position. Competition for No.3 has not clear result. The last outbreak of *H. armigera* was in 2003 and damage of cobs was 40-60 %. The strongest damage by *Agrotis* spp. was in 2007 and at many fields they were destroyed more than 40 % of plants. The damage by elaterids depended on preceding crops, not by year. At some fields it was 20-30 % of destroyed plants. *T. dilaticollis* emerged at some fields in 2006 or 2007.

Session 11: Wireworms, cutworms and other soil pests: how to implement IPM in the early stages of maize production

Session Organizer: Lorenzo FURLAN, University of Padova, Legnaro, Italy

Female targeted floral lure for the click bettle *Agriotes ustulatus* (Coleoptera: Elateridae)

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Agriotes ustulatus Schaller is an important pest of maize in Europe. The pheromone produced by females has earlier been characterized as (E,E)-farnesyl acetate and traps baited with this synthetic compound have been used for trapping in many countries of Europe, capturing large numbers of males. Adults of *A. ustulatus* are frequently seen feeding on flowers, and we supposed that localization of flowers is assisted also in this species by floral scents. Through screening of synthetic floral compounds by electroantennography we found that several common floral scent components evoked high responses from the antennae of *A. ustulatus*. Comparative trapping tests yielded the blend of (E)-anethol and (E)-cinnamaldehyde as the most attractive combination, attracting predominantly females, and to a lesser extent also males. When the activity of the synthetic pheromone and of the floral lure was compared, we observed that the floral lure attracted much more females in the presence of the pheromone than when presented on its own. This observation raises the question whether the pheromone of *A. ustulatus* is a "classical" sex pheromone, as similar phenomena have been observed in other insects with aggregation pheromones and not with sex pheromones. From the practical point of view the trap catching largest numbers of females AND males of *A. ustulatus*, baited with both the floral bait AND the pheromone, might have two important implications for IPM: - assessing the correlation between male and female behavior;- properly timing interventions to increase the mortality of eggs and first larval instars.

Entomopathogenic nematodes for controlling maize insect pests

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Insect pathogenic nematodes of the genera *Steinernema* and *Heterorhabditis* are natural enemies of soil living insect larvae. Biocontrol products based on these

nematodes show excellent activity in controlling cutworms. In laboratory trials damage to lettuce could be reduced at a dose of as little as 5 nematodes per larva. Trials on maize seedlings corroborated their effectiveness at a comparatively small dosage. The efficacy of nematodes against *Diabrotica virgifera virgifera* is comparable to common chemical control measures. Wireworms, though among the natural hosts of nematodes, are difficult to control by inundative applications. Since nematodes have so far mainly been used in indoor environements or on high value crops where application costs are less critical, new ways of applying nematodes need to be developed for maize. Typically, nematodes are applied with large volumes of water which is often not possible in maize. First experiments with a waterless application by a sawable granular formulation for entomopathogenic nematodes showed good efficacy in controlling corn rootworm.

Recent developments in *Agriotes* wireworm monitoring and control

W.E. Parker

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Wireworms are important soil-dwelling pests. In Europe and parts of North America, they attack a wide range of crops from small grain cereals such as wheat through to maize, potato and a range of vegetable crops. Following a long hiatus in significant research in Europe on wireworms after the Second World War, the last 15-20 years has seen an upsurge in research into the biology and control of wireworms, as they have become to be perceived as more important pests. This is at least partly due to the loss of persistent soil insecticides such as aldrin and lindane, which formerly provided the mainstay of control programmes.Recent research on *Agriotes* has largely concentrated on improving monitoring systems for wireworms in the soil, but also on the development of methods for monitoring adults through the use of pheromone traps. This has led on to more fundamental questions about the temporal and spatial population dynamics of *Agriotes* infestations. At the same time, the search for novel, sustainable control measures to replace persistent soil insecticides has intensified. This work has largely centred on the development of biocontrol agents (principally *Metarhizium anisopliae*), and the use of green manures and de-fatted brassicas seed meals as 'natural' biofumigants. This paper will briefly review these developments, drawing principally on work done in the United Kingdom, mainland Europe and Canada.

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Agriotes feeding ecology and implications for wireworm control

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Although *Agriotes* larvae (wireworms) are severe pests in maize and other crops, little is known on their feeding ecology under natural conditions because direct observation of these fluid-feeding herbivores is difficult. In earlier studies stable isotope analysis has been used to assess the feeding ecology of wireworms in arable land. It was shown, that in contrast to soil organic matter, weeds are regularly eaten by *Agriotes* larvae. Moreover, *Agriotes* feeding behaviour varied at the individual level, as the population consisted of type A and B generalists. Some larvae seem even to have fed on animal prey. Currently, we are taking the analysis of *Agriotes* feeding ecology one step further: we aim to determine which plant species are consumed by these soil insects, employing a combined approach of stable isotope and molecular gut content analysis. In doing so we will identify how plant diversity affects the larval dietary choices, both under natural conditions in the field and within mesocosm experiments.The outcomes of our investigations will provide a better understanding of plant biodiversity–wireworm trophic interactions, allowing to create new ways of control strategies for these pests.

Monitoring and IPM strategies for wireworm in seedling maize.

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Several species of wireworm (family Elateridae) are occasional pests of seedling maize in the central region of the United States. Click beetles lay eggs in the soil with larvae feeding on roots of weeds, grasses and other crops for periods of two to six years depending on species. Lack of germinations is often the first evidence of wireworm problems in maize seedlings followed by wilting and possible plant death. Severely damaged seedlings often produce tillers which tend to be barren. Severe wireworm problems in maize are often observed in fields following sod or in fields with prolonged grassy weed problems. Monitoring of wireworm populations in maize is best accomplished by use of wireworm bait stations. Stations are placed in fields from three weeks to ten days prior to planting. Black and clear plastic covers placed over the bait stations increase trapping efficiency by collecting and retaining heat in the soil surrounding the bait station. Management strategies should be implemented if an average of one or more larvae are collected per station. Several different strategies are available for wireworm management in maize. At present, a large number of granule and liquid formulations of insecticides may be broadcast on the soil surface prior to planting or applied in furrow or over the row at planting. A limited number of liquid insecticide formulations may be mixed and applied with early season

fertilizer applications. High rate seed treatments typically provide good protection from wireworm infestations in maize. Seed treatments of lower rates often provide limited control in the presence of high numbers of wireworm. Transgenic corn hybrids may provide an additional option for management of wireworm in the future.

Can we produce maize without soil and seed treatment insecticides?

L. Furlan

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The widespread use of soil insecticides has been considered unavoidable in many European countries for many years despite extensive insecticide use brought about side effects like the enhanced degradation of active ingredients as well as non target effects and environmental impacts.

This, primarily, has been caused by a) the shortage of knowledge about the actual impact of the pests involved and b) the lack of feasible and inexpensive methods to find infested fields.

Over the past several years, this gap has been greatly reduced and what is necessary to implement effective IPM strategies have been made available.

Some of these follow:

a) Studies from samples of fields chosen to represent average agronomic conditions in several European countries have shown that the percentage of fields with soil pest populations above the economic threshold is low and that the use of insecticides seed coatings and granular insecticides frequently has small impact on maize stands and yields.

b) Experiments with sex pheromone traps have allowed for defining economic thresholds so as to reliably spot fields with economic pest populations. Thus, fields with high risks can be indentified at low costs. Multiple baited YATLORf traps proved to be suitable for this monitoring and easy for farmer use. General and applied protocols to implement IPM strategies for maize in different European conditions have been defined. These make possible a significant reduction of soil insecticides use.

Session 12: Practicing of IPM within modern maize production systems

Session Organizers: C. Richard EDWARDS, Purdue University, Lafayette, U.S.A. & Zhenying WANG, Institute of Plant Protection, CAAS, Beijing, China

DuPontTM Coragen® (Rynaxypyr®): a new standard with a novel mode of action for the control of the European corn borer (*Ostrinia nubilalis*)

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Ostrinia nubilalis is the major pest for corn in Europe. While there is widespread cultivation of Bt-corn in many parts of the world, most farmers in Europe rely on insecticides for the control of *Ostrinia.* Commonly used insecticides are from the MoA groups of pyrethroids, neonicotinoids, OP-esters, and the unique oxadiazine Steward® (indoxacarb). Coragen® (Rynaxypyr® 200 g/l SC, ISO: Chlorantraniliprole) is a novel insecticide for the control of *O. nubilalis*, and many other chewing insect pests in various crops. Rynaxypyr® is a novel molecule with a new MoA (Anthranilic diamides, IRAC group 28). The unique biochemical targets are the Ryanodine-receptors in the muscle tissues of the insects. No cross-resistance was found to any of the other insecticide classes. Rynaxypyr® penetrates into the plant tissue and has excellent rain-fastness. Insect uptake is primarily through ingestion. Very high intrinsic activity on multiple developmental stages (ovicidal, ovi-larvicidal and larvicidal activity), rapid feeding cessation, and long lasting crop protection effects are setting a new standard of pest control. Coragen® is non-toxic for mammals and is harmless to many beneficial arthropods and to pollinators, thus an excellent tool for IPM programs. Coragen will be registered on maize and sweet corn at 100-150 g/ha, BBCH 14-87 at ovicide timing. The average control achieved in numerous field tests across Europe (2006-2008) was 70-85%, compared to local standard products ranging 50-65%. ® Trademark of DuPont

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New Biotechnological tools potentially available for the control of maize pests in Europe

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*Monsanto, Brussels, Belgium

MON 88017 is genetically modified (GM) maize that combines two traits of agronomic interest: protection to corn rootworm, one of the most pernicious pests affecting maize crops in the US and Europe, and tolerance to the broad-spectrum herbicide glyphosate. MON 88017 expresses the *Bacillus thuringiensis* (*Bt*) Cry3Bb1 protein which is selective for coleopterans (Chrysomelidae) of the Diabrotica family. A method to control corn rootworm, compatible with integrated pest management (IPM) approaches, that offers improved pest control and higher yields, while at the same time being safe for humans and the environment. This is combined with a successful broad-spectrum weed control option in maize that provides flexibility to treat weeds on an "as needed basis". MON 89034 is a GM insect-protected maize, following the widely planted MON 810. MON 89034 expresses two Bt proteins, Cry1A.105 and Cry2Ab2. These protect the plants from feeding damage caused by the European corn borer (*Ostrinia nubilalis*) and other lepidopteran insect pests. By combining two proteins, this product enlarges the spectrum of pests controlled, and provides new possibilities for insect resistance management (IRM).The presentation will cover the latest state of the art technology available in controlling maize pests applicable to the U.S.A and E.U. conditions, as well as presenting industry's view on further developments in GM technology in the E.U.-27.

Impact of Cry3Bb1-expressing *Bt* maize on adult *Diabrotica v. virgifera*

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Corn rootworms are threatening maize production in North America and the Western corn rootworm (*Diabrotica virgifera virgifera*) has recently been introduced in Europe, where populations have been spreading rapidly. In contrast to larvae, it is still unclear if and under which conditions adult *D. v. virgifera* are affected by the Cry3Bb1 protein, when feeding on *Bt* maize. In the laboratory, we fed adult *D. v. virgifera* for more than 7 weeks with silk, leaves and pollen from Cry3Bb1-expressing maize and control maize to investigate how mortality and fecundity is affected by the *Bt* protein and by the nutritional quality of the different plant materials. Furthermore, we examined exposure of adult beetles to the *Bt* protein by measuring the concentration of Cry3Bb1 in silk, leaves and pollen as well as in beetles feeding on those food sources. Results will be presented and discussed.

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Theory and practice on applying *Trichogramma dendrolimi* to control Asian corn borer in northern China

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Applying *Trichogramma dendrolimi* as a prevalent method to control Asian corn borer (*Ostriniae furnacalis*) on the north part of china has been conducted for 40 years .a series of innovative theory and tactics were developed. It was approved that large scale release the parasitoid on long term resulted in the population suppression of the corn borer under the economical threshold in the mountainous region and the hilly area as well as the flat area with rich vegetation. Stabilization period can be maintained for 4 ～ 6 years. The suppression of the corn borer population under the economical threshold in plain area also be attained by means of the cover release for the area of the dispersion radius of Asian corn borer in large scale and in consecutive year release. Tactics on control corn borer in secondary generation occurrence area of corn borer is the combination of inundate release to control first generation of corn borer and inoculate release to control second generation of corn borer. Release time was minimized to one time by mixing the wasps which was on the different developmental stage to one egg-card to make the adult emergence successionally to cover whole egg stage period of corn borer. It was also proved that control corn borer by *Trichogramma* could be carried out to control one major damage generation in mountainous and hilly area however whole generations of corn borer in plain area must be controlled.

Biological control of western corn rootworm larvae with entomopathogenic nematodes

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Entomopathogenic nematodes (EPN) have great potential as biological control agents of arthropod pests and several species of the genera *Steinernema* and *Heterorhabditis* are able to infect the larvae of *Diabrotica virgifera virgifera*. However, field experiments using EPN to control rootworm larvae often produced poor results although nematodes caused high *Diabrotica* mortalities in laboratory tests. Among others, the host specificity and the host finding strategy of the nematode species, the environmental conditions in the soil and the timing and method of application are considered important factors influencing the field efficacy of EPN against *Diabrotica* larvae. Recent laboratory and field tests in Europe have shown that several EPN species have high potential to control rootworm larvae and can be produced in masses at reasonable cost. One of these species, Heterorhabditis bacteriophora,

was chosen as biocontrol agent against the western corn rootworm in field tests in eastern Austria in 2008. Maize plants in a field with continuous corn were infested with *Diabrotica* eggs during sowing. Approximately 35 000 EPN/plant were applied either at sowing time in mid April or during mechanical weed control in mid June. Nematodes were either shipped in clay and suspended in water prior to application, or formulated as a granulate and directly applied to the soil. The number of beetles emerging from nematode treated plants was significantly lower than that from control plants, irrespective of application time and nematode formulation. Moreover, the effect of the nematode treatments on the emergence of beetles was comparable to that of coating maize seeds with Clothianidin. However, an estimation of the root damage of the treated plants gave contradictory results. Only maize roots from Clothianidin-coated seeds were significantly less damaged, whereas nematode treated maize plants showed similar damage levels than untreated plants. It is suggested that EPN attack root worms late in their development, when roots have already been exposed to larval feeding for weeks. Nevertheless, EPN have proven their potential to significantly reduce root worm populations in the field. Improvements in the application technique of EPN for *Diabrotica* control will be the main focus of further experiments of the Institute for Plant Health at AGES.

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IWGO – PERSONAL ITEMS

Professor Dr. ZHOU Darong

Our former Chinese member of IWGO passed away in 2008. For those who had the possibility to attend the 2nd Vienna Meeting in 1982 and the Meeting in Beijing in 1986 will always remember Dr. Zhou. Besides his high scientific qualification we had the opportunity to learn his friendship and hospitality. Although it was very difficult in these days he invited us to his home in Beijing where he and his friends gave us a wonderful musical performance. Wendy, his wife moved to her son to US after the death of her husband.

Zhou Darong acting as singer during the 2nd Vienna IWGO Meeting in 1980.

Dr. Sylvie DERRIDJ:

Our longstanding IWGO – member Dr. Sylvie Derridj from INRA, Versailles, France, will retire at the end of 2009. For this reason, her presentation at the Munich IWGO Conference was titled as an Honorary Lecture. I am sure we will all miss Sylvie and her highly qualified contributions at future meetings but we wish her all the best for the future and hope that she will stop by to visit us from time to time.

Munich – Meeting

Downstanding you find some photos made during the meeting.

Joyful "come-together" after a hard day's work Beer-Party in the "Augustiner-Bräu": Prof. Rich Edwards and Dr. Lorenzo Furlan (left)

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Participants of the 23rd IWGO Meeting in Munich, Germany, April 2009

IWGO – Convenors with the hosts: Prof. Rich Edwards, Gen.Dir. Josef Huber (Bavarian State Ministry of Food, Agriculture and Forestry), Prof. Wang Zhen-ying, Dr Michael Zellner (Local Organizer; Bavarian State Research Centre for Agriculture), Dr. Ulrich Kuhlmann