

Western Corn Rootworm In Europe: Integrated Pest Management Is The Only Sustainable Solution

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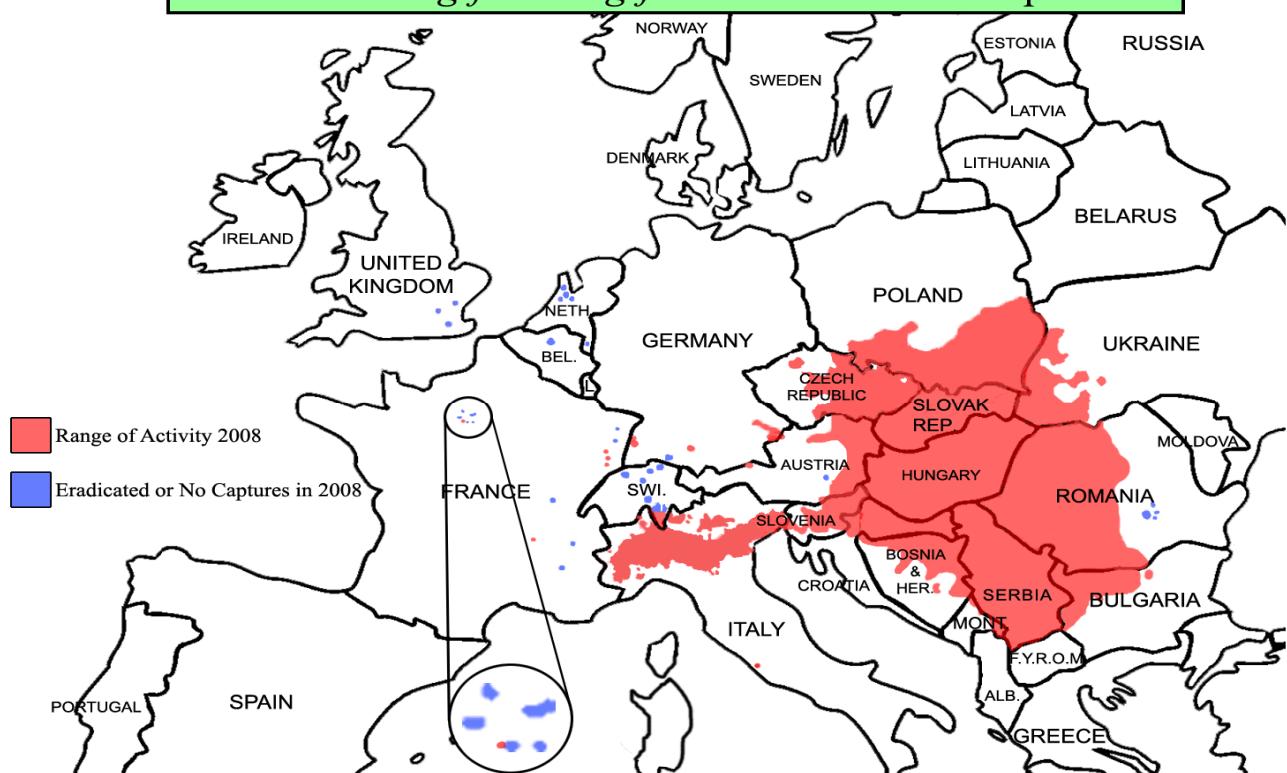
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Western corn rootworm in Europe

The western corn rootworm (WCR, *Diabrotica virgifera virgifera* LeConte, Coleoptera: Chrysomelidae) was first detected in Europe in 1992 when large numbers of larvae and adults of this pest were discovered in a small field continuously cropped for maize near Belgrade International Airport in what was Yugoslavia, now Serbia. In this field more than 10 beetles per plant were discovered and the first economic larval root damage was visible. It is assumed that beetles first arrived in Serbia around the mid-1980s. Consequent studies have proved this introduction was followed by several others into different parts of Europe. The spread of WCR across Europe is a continuous process and plant lodging and larval damage have been recorded in countries including Serbia, Bosnia and Herzegovina, Croatia, Romania, Slovakia, Czech Republic, Poland, Bulgaria, Hungary and, more recently, Italy. The presence of beetles has been reported from the Ukraine to the United Kingdom, including Germany, Poland and France (see map below). What can we do against the new pest? First we need to examine its morphology and biology before considering possible control options.

Diabrotica virgifera virgifera LeConte in Europe 2008



IWGO by C.R. Edwards and J. Kiss, based on data from Baufeld, Bažok, Bertossa, Boriani, Cean, Cobos, Cota, Eyre, Furlan, Grabenweger, Ivanova, Karic, Kubik, Konefal, Konstantinova, Markotić, Melnik, Palmieri, Potting, Ripka, Schaub, Sivec, Streito, Urek, Vahala, Van Eester, and Záruba

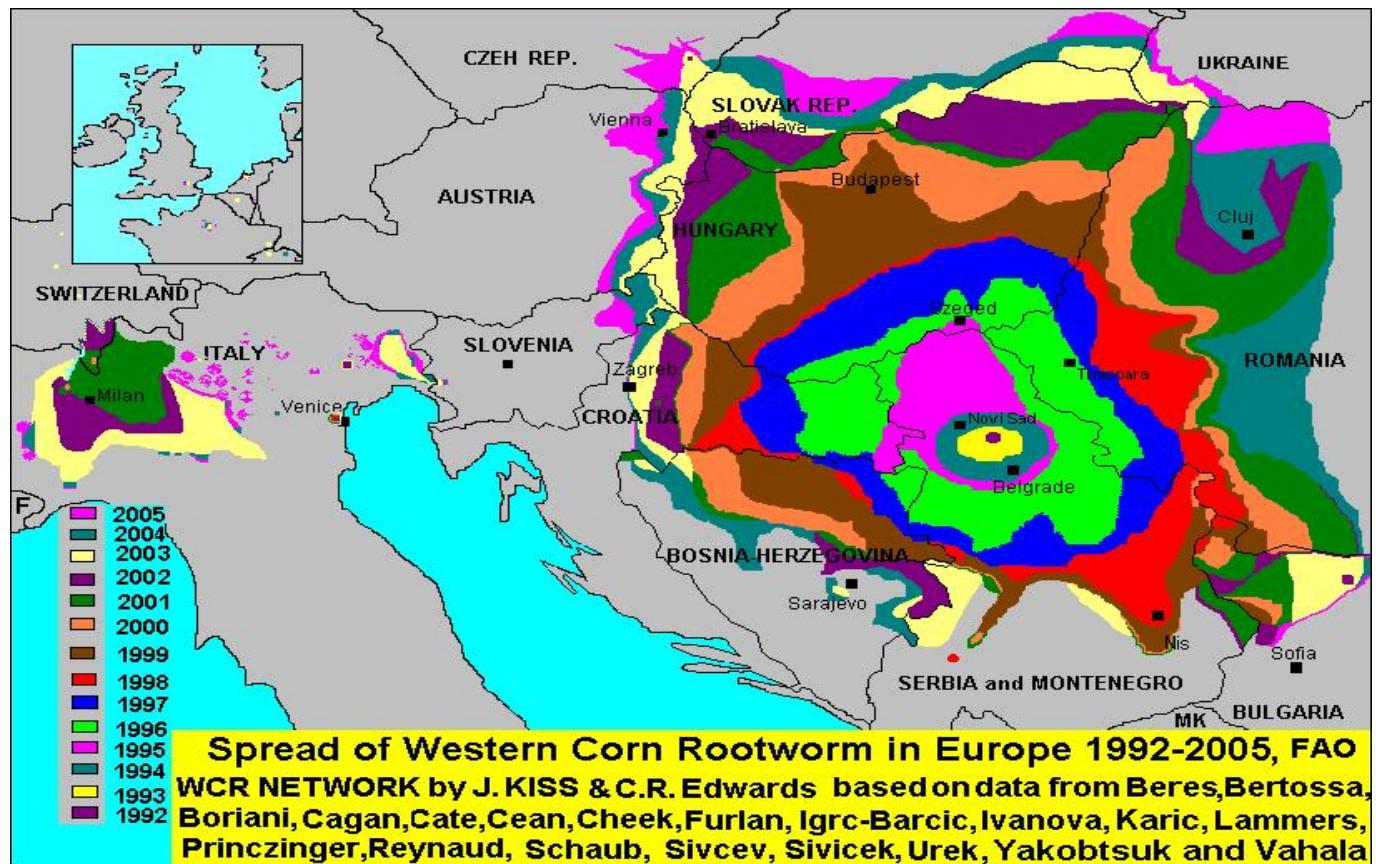
Morphology of WCR

WCR adults are between 5.5mm and 7.5mm in length and of a similar shape to cereal leaf beetles. WCR beetles are yellow and black in colour, with three black stripes running down the length of the wing covers. Sometimes these stripes converge and beetles appear almost entirely black. The beetle's head is black or dark brown, contrasting to its yellow pronotum. The legs and antennae of the adults are also black. The antennae of the males are always longer than half the length of the body. In the case of females, the antennae will reach a

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maximum of one-third the body length. **Eggs** are about 0.5mm in size (too small to be detected with the naked eye) and of whitish-yellow colour. **Larvae** are whitish-yellow in colour, with black head capsules. At the end of the abdomen there is a brownish dorsal plate. First instar larvae are 1.2mm, while third instar larvae can reach 1.5cm in length. **Pupae** are whitish-yellow in colour.



Lifecycle of WCR

The WCR is a leaf beetle (Chrysomelid) with one generation per year (univoltine). It overwinters in the **egg** stage in the soil of maize fields. In the subsequent year, the first **larvae** hatch from mid May onwards in Central Europe. There are three larval stages (L_1 , L_2 and L_3). Larvae are present mainly from late May until late July. Neonate (newly hatched L_1) larvae move among soil particles to find maize roots. Soil type effects WCR larval movement and survival. WCR larvae move further through light sandy soils compared to heavy soils. Larval development takes three weeks to complete. **Pupation** takes place in the soil and lasts about one week. First **adults** usually emerge from the soil of the maize fields in late June to early July. The time of the population peak of WCR adults varies from year to year and region to region, but is usually observed between mid July and early August in Central and South-eastern Europe. In some cases, WCR adult population peaks occur in late August or in other cases in early July, mainly in relation to the temperatures experienced by larvae in the first layers of the soil. WCR females begin egg laying from early to mid July. Most of the eggs are laid in the soil of maize fields and overwinter at a soil depth of 15-20cm. Adults are active in maize fields until autumn depending on the available food and timing of the first frosts.

Damage caused by WCR

Two developmental stages of WCR (larvae and adults) can cause economic damage on maize plants. Significant damage can occur from larval feeding on the maize root system. If neonate larvae are not able to find a suitable root within 24 hours, most of them will die as larvae feed almost exclusively on maize roots. When reaching a root, larvae start to feed on the hairy root parts. The first and second instar larvae tunnel from root tips

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upwards and can reach the plant base, leaving visible feeding scars. Third instar larvae generally feed on larger nodal roots near the plant stalk. Brace roots are often damaged once they enter the soil. WCR adults feed on leaves, pollen, silks and young kernels of maize plants (see damage details below).

WCR feeding on non-maize plants

WCR larvae can feed and develop on the roots of some grassy weeds. Based on the literature there are at least 36 grass species on which WCR larvae could complete their development. However, in these cases larval mortality is high and thus the percentage of adult emergence remains low. WCR adults feed on several grassy and broad-leaf plant species. Eighteen plant species were identified from the gut content and pollen analyses studies of WCR adults in Hungary. Some pollen originated from flowering weeds within maize fields and some from other cultivated crops such as sunflower and alfalfa. However, neither larvae nor adults have yet been reported to cause economic damage to any crop other than maize in Europe.

WCR adult and larval damage in first-year maize?

Although adults feed on plants other than maize, they generally remain in the maize fields from where they emerged. In the case of inter-field movements, adults tend to migrate to other maize fields for egg laying. Therefore, significant WCR larval damage can only occur in fields where maize is planted after maize. Negligible larval damage and lodging may appear in field edges of first-year maize fields if maize was cultivated in neighbouring fields the previous year. However, until 2009 no economic larval damage has been observed in first-year maize in Europe. Furthermore, there are no signs of WCR populations adapting to crop rotation in Europe, as has been observed in some regions of the USA.



Root damage caused by WCR larvae (above) and subsequent plant lodging (below). © Nora Levay, SZIU PPI, Hungary.

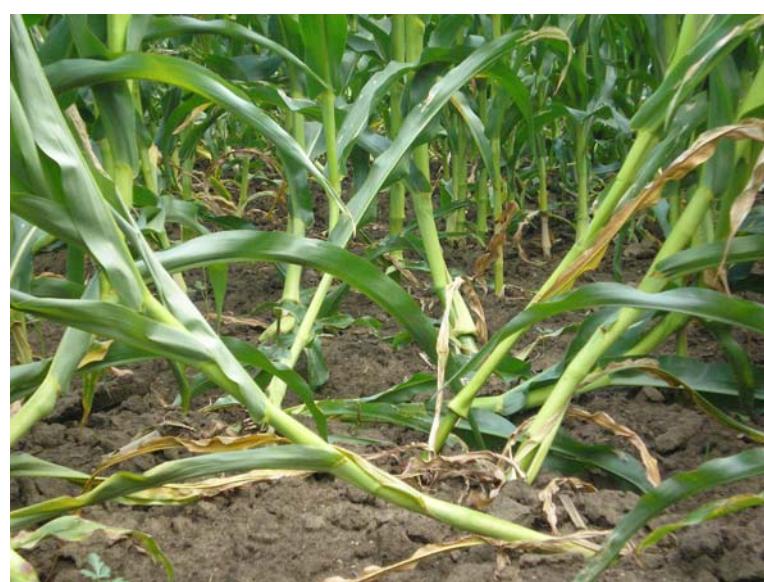
WCR larval damage

By feeding on maize roots larvae can significantly damage, even destroy, the root system. Due to this damage, plants will lodge and typical ‘goose neck’ symptoms will appear. Patches of lodged plants usually appear only in some parts of the field, reflecting heterogeneity in the distribution of WCR adults and thus egg deposition. We should again stress that larval damages are expected only in second-year and subsequent maize crops.

Identifying WCR larval damage

Lodged plants and/or damaged rows are not exclusively caused by western corn rootworm larvae. Maize plants can lodge due to various reasons, such as:

- > Wind, especially in maize rows at the field edge
- > Improper soil preparation



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- > Shallow root system due to environmental conditions
- > High plant density
- > Mechanical damage to roots caused by cultivators
- > Root and stalk damage caused by other pests.

Visual root examination is the best way to determine WCR larval damage. The intensity of larval damage can be measured using the IOWA 1 to 6 scale, or by the 0.00 to 3.00 node-injury scale.

WCR adult damage



Csalomon pheromone trap for capturing male WCR adults (above) and Pherocon AM Yellow sticky trap (below) for sampling male and female WCR adults. © Mikós Tóth, NKI and Jozsef Kiss, SZIU PPI, Hungary.



Before pollination, WCR adults feed on young maize leaves. Adults remove the epidermis in linear streaks similar to the cereal leaf beetle (*Oulema melanopus*), or chew linear holes into the leaf tissue. However, adults rarely cause significant economic damage unless they feed on the silks before or during pollination. This so called ‘silk clipping’ may result in poorly filled ears, thus loss of quality and quantity, especially in seed maize production. Furthermore, WCR adults also feed on young, milky kernels at the top of the maize ears.

Traps for WCR detection and population estimation

The first step for WCR management is for farmers and advisers to be aware of the presence of WCR adults or larvae in their fields. For detection and management purposes, several trap types are available. One of the trap types used for ‘early detection’ of adults is the pheromone-based trap that attracts male WCR adults (see photograph left). Occasionally, the pheromone is combined with a floral lure and can therefore attract both males and females to the trap.

Visual traps (non-baited, yellow-coloured traps) are less sensitive than pheromone traps but appropriate for population estimation (see photograph below left). However, various yellow-coloured traps currently available on the market differ in brightness and thus in their catching capacity. The correlation of the capture of WCR adults to larval damage in subsequent years is defined for only some of these traps and is not valid for other trap types.

Besides traps, visual counts (checking maize plants across the field during adult occurrence, specifically during pollination and silking) are also used by farmers and advisers for estimating populations. Most traps can only attract WCR from the immediately surrounding area (most likely a distance of around 2-10m). Because of the localised movements of adults only 0.1ha may be considered as correctly sampled by a trap to detect a recent and initial WCR settlement in a field. No adult captures does not mean that the field is completely free of WCR. The distribution and movement of WCR adults may not reach the trap in a large field and the population may not be large enough to be detected.

Management of WCR in Europe

Independent from geographic and climatic differences and varying WCR population levels, the best and most efficient WCR larval management in Europe is **crop rotation**. In regions where WCR populations have not yet been established, eradication and containment measures are obligatory. Contact the national plant protection services if any developmental stage of WCR or symptoms of WCR damage are detected. Plant protection services

are aware of the measures that need to be taken in line with EU regulations. In regions where WCR populations are well established, suppression measures are relevant. In these regions WCR is a constant element of local agro-ecosystems and should therefore be managed accordingly.

Management options in regions with well-established WCR populations

The primary management option for WCR is crop rotation. However, there are regions with well-established WCR populations where socio-economic demands make it difficult to interrupt continuous maize production. In these cases, insecticides should be applied only after accurate risk estimation. Sampling of WCR adult populations may be used to estimate larval damage in the subsequent year and thus the risk of economic damage occurring in the following year. Risk estimation should take into account regional characteristics including abiotic and biotic elements of maize fields and socio-economic aspects.

Observations in France from 2003 to 2009 showed that maize volunteers help to maintain larval and adult populations in subsequent crops. In Southern Europe, where sorghum is grown in rotation with maize, maize volunteers are very often observed in relatively high density. There is no chemical solution to destroy maize volunteers in a sorghum crop stand since all herbicides selective for sorghum are selective for maize as well.

Cultural practices

Besides crop rotation, in fields free from maize volunteers there are other cultural measures that may **enhance maize plant development** (sowing time, ridging, selection of hybrids, irrigation, fertilisation etc) and limit damage, consequently reducing the need for insecticide applications against WCR larvae. However, if the WCR adult population was high in the previous year (more than one beetle per plant in Central and Eastern Europe) in most cases these cultural options (except crop rotation) are not enough to manage WCR larvae.

Hibernating eggs in the soil easily tolerate harsh winter conditions with low temperatures. Hatching first instar larvae are, however, very susceptible to drought stress. Irrigation may therefore have two different (and contradictory) effects. On the one hand, irrigation strengthens the plant and increases its ability to regenerate damaged roots. On the other hand, moist soils during the hatching of first instar larvae lead to higher larval survival, therefore contributing to higher damage levels and yield loss.

Hybrid selection

Maize hybrids differ in their ability to regenerate roots in response to root damage. However, root regeneration strongly depends on water availability in the soil (thus rainfall and irrigation may favour re-growth). The first experiments concerning classical resistance breeding to WCR in Europe were carried out in Croatia. Various commercial maize hybrids were evaluated for WCR tolerance and the results showed there are some hybrids with better root regeneration (for more information see www.diabrect.org). Conventional breeding aims to develop hybrids with higher root re-growth, but at the present time we are not able to recommend commercially available hybrids with WCR tolerance/resistance.

Natural enemies and biological control

WCR adults are attacked by a wide range of natural enemies, such as entomopathogenic nematodes, fungi and predators. Such predators include grasshoppers, praying mantis, ground beetles and spiders. Based on our present knowledge, generalist natural enemies can contribute to decreasing WCR populations (in Mexico, where it originates, there are a number of specific natural enemies of WCR).

Supporting existing natural enemies of WCR and the natural regulating mechanisms in maize ecosystems in Europe are priorities for integrated management of WCR. Furthermore, biological control agents could be applied against WCR. Though entomopathogenic nematodes are currently the most tested option, biological control agents could also include fungi, bacteria and viruses. These biological control agents are in the research phase (laboratory and field tests) and are not yet being marketed. Hopefully, these products will be made available for use in the coming years.

Transgenic maize hybrids

Various coleopteran-resistant *Bt* transgenic maize hybrids, in which proteins against WCR larvae are expressed in the maize plant (including the root system) are widely used in the USA. Some of these hybrids are undergoing authorisation in Europe.

Insecticide applications

Several EU Member States have registered insecticides with different active ingredients for WCR control. In general, WCR larval damage could be decreased by:

- > Insecticide seed treatments
- > Insecticide (in-furrow) soil application at sowing time or during first mechanical weed control.

Effective insecticide application against larvae depends on the active ingredient of the insecticide, insecticide formulation, climate, date of planting, date of larval hatch, etc. In cases of high WCR larval populations, damage may appear even after seed treatment or soil insecticide application.

Based on our present experiences in Central and Eastern Europe, soil insecticide application is more effective than seed treatments in reducing WCR populations. Nevertheless, seed treatment is also suitable for management of WCR where populations are low. Neither measure, though, matches the efficacy of crop rotation. Furthermore, application of soil insecticides as well as the sowing of treated seeds must be conducted while avoiding emissions of insecticide-coating dust. Using unprotected pneumatic seeders has been identified since early 2000 to endanger bees. This reached a head in 2008 when particular weather conditions and the use of this machinery led to the banning of some insecticides in certain Member States.

Insecticide application against adult population may have two aims:

- > To prevent silk clipping by WCR adults, thus preventing yield loss through lack of pollination or
- > To decrease WCR adult populations in order to reduce egg laying and therefore larval populations and accompanying root damage the following year.

Consequently, insecticides may be applied during the first half of the silking period before pollination (if justified by the adult density) to prevent yield loss from silk clipping by adults or at the beginning of the peak oviposition period when gravid WCR females are ready for egg laying. In general, foliar insecticide applications are not effective enough to guarantee damage-free maize fields in the subsequent year, but could be effective in preventing yield and quality loss of maize seeds or grains from adult damage (silk clipping) in the given year if the foliar insecticide is applied at the appropriate time.

Foliar insecticide application can be conducted by:

- > Full rate dose insecticide or
- > Reduced rate insecticides with a feeding arrestant according to label instructions.

Registered insecticide formulations and rates against WCR differ from one country to another. Therefore advisers should contact plant health officers for the most recent information.

Considering the environmental as well as food and feed safety issues, **we highly recommend the application of reduced rate insecticide with feeding arrestant**. Nevertheless, no chemical measures will provide the appropriate results if the timing and technology are not properly chosen.

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Summary

The western corn rootworm (WCR, *Diabrotica virgifera virgifera* LeConte) was first detected in Europe in 1992, since when it has emerged as a serious pest of maize crops across a large number of countries. This leaflet, the second from ENDURE's Maize Case Study, examines the morphology and biology of WCR, examines the damage it causes and explores the possible control options. WCR can cause economic damage to maize plants at two developmental stages (larvae and adults). Larval feeding can cause significant damage to maize root systems while adults cause damage when feeding in the silks before and during pollination. This leaflet explains the lifecycle of WCR and concludes that the best and safest way to manage WCR larvae is through crop rotation, regardless of geographic and climatic differences or the degree of pest pressure. It explains how WCR should be detected and populations estimated. Where socio-economic factors make crop rotation impossible, insecticides should be applied only after accurate risk estimation. Other non-chemical options are also investigated, including cultural practices designed to enhance maize plant development, hybrid selection, natural enemies and biological control, and transgenic maize hybrids.

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About ENDURE

ENDURE is the European Network for the Durable Exploitation of Crop Protection Strategies. ENDURE is a Network of Excellence (NoE) with two key objectives: restructuring European research and development on the use of plant protection products, and establishing ENDURE as a world leader in the development and implementation of sustainable pest control strategies through:

- > Building a lasting crop protection research community
- > Providing end-users with a broader range of short-term solutions
- > Developing a holistic approach to sustainable pest management
- > Taking stock of and informing plant protection policy changes.

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Website and ENDURE Information Centre:

www.endure-network.eu

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