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Review paper

Management of Western Corn Rootworm (*Diabrotica virgifera virgifera*)

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SUMMARY

Western corn rootworm (WCR) was registered for the first time in Europe near the Surčin international airport in Serbia in 1992. The spread of WCR on the territory of Serbia and its population density increased fast. The Serbian territory was entirely populated in the following few years, while major damages occurred on corn grown for two or more years in the same field. Data on damages caused to over 140,000 ha under corn until 1999 were collected by organized monitoring. After 2000 and 2003, population abundance of *D.v. virgifera*, as well as the number of damaged corn fields, significantly decreased due to drought and application of crop rotation. Corn rootworm has one generation per year. It overwinters in the egg stage. Under the climatic conditions of Serbia larvae hatching starts around May 15th. The highest number of larvae on root is observed around June 20th when feeding is most intensive and plants become lodged as they lose roots. First adults emerge by the end of June. Their abundance increases during July and reaches maximum by the end of the month. From the second decade of August the abundance decreases. Adults are present in the field until the first frosts. Larvae are much more harmful and significant than adults. Larvae feed on roots or into roots by boring. Roots can be entirely destroyed under heavy attack and the host plants lodged already at the end of June. Under our climatic and agrotechnical conditions, adults are sporadic pests. Adults are a threat only when sowing is done after the optimal sowing date or in case of stubble corn sowing.

Crop rotation is an efficient and most widespread means of WCR control. No damage on corn grown in crop rotation has been registered in Serbia for now. In the first year of production corn does not require protection from *Diabrotica virgifera virgifera* LeConte larvae.

Several insecticides have performed high efficacy by application at sowing and have been registered for commercial use. On the other hand, soil insecticides have never been applied on a significant area in Serbia.

Keywords: Western Corn Rootworm; Maize; Insecticides; Pest management

INTRODUCTION

Corn reached Serbia over 400 years ago, after Columbus brought it to Spain, whence it was introduced to France and Italy in 1550 and then brought to the neighboring Balkan countries by Venetian merchants (Stavrianos, 2000).

After centuries of cultivation in Serbia, corn has become a traditional crop that is mostly used as grain or silage fodder. Due to favorable climatic and soil conditions, as well as market demands, corn production is growing. In Serbia, corn is grown on 1.3 million ha, ranking the country among six European countries with over 1 million ha under corn. This crop is grown on about 15 million ha across Europe, out of which the region of Central and Eastern Europe accounts for about 7 million ha. Corn production is therefore of major importance for the economies of producing countries and a key plant in meat production.

Corn is commonly infested by various domestic insects known as pests of indigenous plants, such as click beetle and cockchafer larvae, corn beetle, corn borer, corn earworm, rodents, etc. (Čamprag, 1994). However, not a single of these organisms is a limiting factor for corn production.

The increasing needs for corn grain, accompanied by newly introduced mechanization, mineral fertilizers, pesticides and high yielding hybrids, have resulted in enlarged acreage under corn. In Serbia, the share of repeated sowing has been up to 30%, while at some villages of Southern Banat corn grown in monoculture accounted for as much as 83% (Stanković et al., 1998). As corn is tolerant to monoculture, no serious problem with pests or diseases has been recorded.

During its spread in the Serbian territory, the abundance of *Diabrotica virgifera virgifera* LeConte grew, particularly in areas with continuous corn. Damages occurred only in fields in which corn was grown over several consecutive years, which was a smaller share of Serbian corn production. The major share of corn production was not at all threatened by the appearance of the new pest. After the year 2000, damages were recorded on a very small number of corn fields. The results of our own activities in WCR control, as well as the relevant data obtained from international researches, are presented in this paper.

Emergence and spread of *Diabrotica virgifera virgifera* in Serbia and Europe

Western corn rootworm (WCR) was registered for the first time in Europe in 1992 when it appeared near the Surčin international airport in Serbia. An abundant population of adults of the new invasive insect

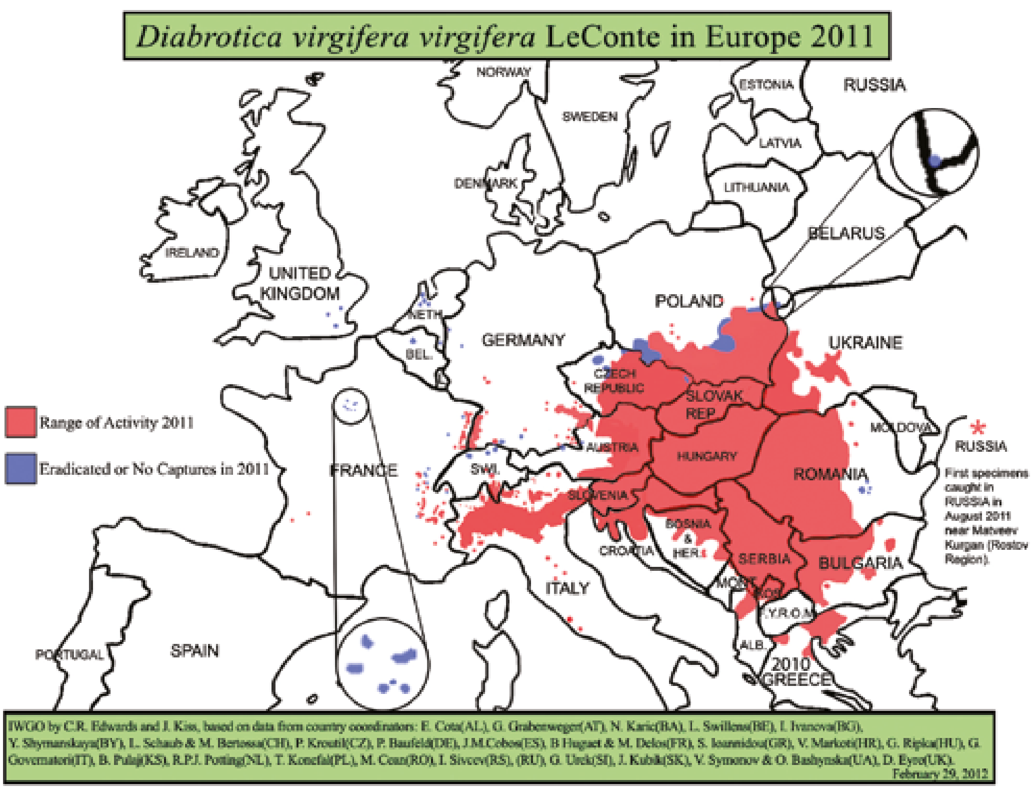

Figure 1. Distribution of *Diabrotica virgifera virgifera* in Europe in 2011 (Edwards, 2012) http://extension.entm.purdue.edu/wcr/

species and serious damage on roots were found on corn grown in monoculture near the airport (Bača, 1994). The emergence of *D. v. virgifera,* the most important corn pest in the USA (Metcalf, 1986), made Serbian farmers anxious because of the great importance corn has had for the economy. The fact that its population was already abundant at that time indicated that the insect had been brought in at some earlier date. Also, it was clear that the insect had all the necessary conditions for development in our region, such as favorable soil, climate and food. The spread of WCR in the territory of Serbia and its population density increase were therefore fast (Sivčev et al., 1994; Sivčev and Tomašev, 2002). The pest spread over the entire territory of Serbia during the following few years, while major damages occurred on corn grown for two or more years in the same field. Data on damaged corn were collected by organized monitoring on over 140,000 ha until 1999. After 2000 and 2003, population abundance of *D. v. virgifera*, as well as the number of damaged corn fields, significantly decreased due to drought and practiced crop rotation.

In the following years, *D. v. virgifera* rapidly spread to neighboring countries and then throughout the region (Kiss et al., 2005) (Figure 1). Csalomon type pheromon traps were an important tool in detection of the new pest (Toth et al., 1996, 2003). *D. v. virgifera* adults were found on several international airports in Europe, which was a motive to carry out a research of genetic variations in their populations. Miller et al. (2005) found that out of five analyzed populations, three were not related to the population introduced in Serbia. Based on these results, it was generally accepted that WCR was introduced in Europe from the USA in at least three independent introduction points after the initial one in Serbia.

Distribution and significance of *Diabrotica virgifera virgifera* in the USA

On the American continent, *D. v. virgifera* is one of ten economically most important species of the genus *Diabrotica*. Six species are present in tropical and subtropical regions of America, and four species in the temperate-continental part of North America, of which *Diabrotica virgifera virgifera* is the most important corn pest (Chiang, 1973; Krysan, 1982, 1986).

There are two subspecies of *Diabrotica virgifera* LeConte (Krysan et al., 1980): *Diabrotica virgifera virgifera* (western corn rootworm) and *Diabrotica virgifera*

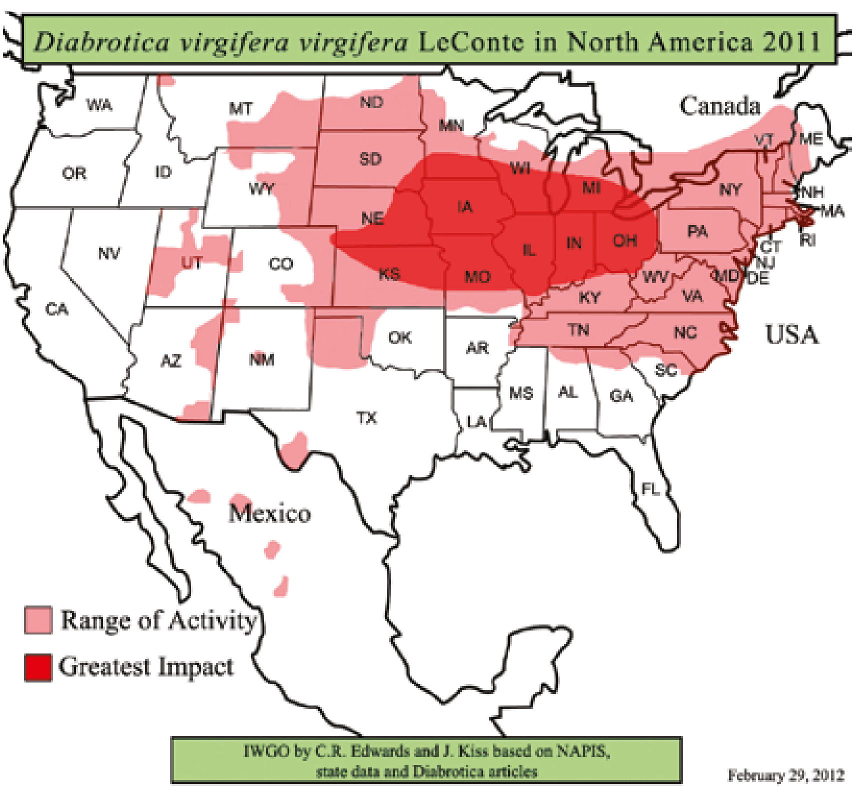

Figure 2. Distribution of *Diabrotica virgifera virgifera* in the USA in 2011 (Edwards, 2012) http://extension.entm.purdue.edu/wcr/

zeae (Mexican corn rootworm). *D. virgifera virgifera* populations have spread from Middle West to East and Southeast of the USA and as far as Lake Ontario (Canada) to the north (Figure 2), and have adapted to temperate climate. *D. virgifera zeae* has mostly spread from Texas and Oklahoma (USA) to Panama, and has adapted to warm climate. The subspecies *Diabrotica virgifera zeae* is not a particularly important pest because corn is not intensively cultivated in areas of its distribution.

Intensive production of corn in monoculture has led to a fast spread of *D. v. virgifera* in North America. Territorial expansion of this species reached its maximum in America during the 1980s and in Europe in the 1990s (Gray et al., 2009).

Factors that enabled massive reproduction and spread of the pest

Western corn rootworm originated from Central America, and it reached northern parts of the continent with corn (Krysan, 1982). As a pest, it was first mentioned in 1909 on sweet corn (Gillett, 1912).

First significant damages occurred in the USA after World War II. Continuous corn is the most important cause of massive reproduction and territorial expansion of this pest species (Chiang, 1973). In some corn growing areas in the USA, up to 60% of total corn acreage was under monoculture at the time. As it spread into new areas, this insect species became the most important pest of corn in the USA. The development of processing industry with a large number of products derived from corn as a raw material, increased the interest of farmers in its production.

High demands led to massive corn production in monoculture. As the crop was grown in the same fields for two or more consecutive years, favorable conditions were created for pest reproduction. When insects are present on host plants in high abundance, they cause significant damage. Such major damage on corn plants is caused by corn rootworm larvae and, due to the extent of damage, it is considered the most important corn pest in the USA. Total annual costs of chemical control of *Diabrotica* species, together with the damage they cause on corn, soon reached an amount of almost one billion dollars (Metcalf, 1986).

In corn growing areas where soybean and corn are rotated, insect adaptation and altered behavior have been recently observed with massively laid eggs in soybean crop too. Larvae normally do not survive on soybean, but their survival is possible on corn sown after it. This adaption caused many troubles for producers who do not want to give up the production of these two profitable crops. Although the problem can be easily solved, and the pest can be controlled by sowing non-host plants after soybean, which would stop pest development, the solution to this problem is sought in genetic engineering in the USA.

Biology of *Diabrotica virgifera virgifera*

D. v. virgifera (Figure 3) has one generation per year. It overwinters in the egg stage. Under the climatic conditions of Serbia, larvae hatching starts around May 15th. The highest number of larvae on roots is observed around June 20th when feeding is most intensive and plants become lodged as they lose roots. In years with warmer springs, hatching and development start earlier, as for example in 2000 when maximum larval abundance was recorded as early as on May 31st (Sivčev and Tomašev, 2002). Hatched specimens start to move through soil in search of corn roots. This is a critical period in their development because mortality of young larvae can exceed 90% (Toepfer and Kuhlman, 2006). Corn is a primary host for WCR larvae (Branson and Krysan, 1981; Clark and Hibbard, 2004; Wilson and Hibbard, 2004) which is why large areas under continuous corn are favorable for their survival and population growth (Hill and Mayo, 1980). Larvae pupate in soil chambers in the root zone. They remain in the pupal stage for 7-10 days. First adults emerge by the end of June. Their abundance increases during July and reaches maximum by the end of the month. From the second decade of August the abundance decreases. Adults are present in the field until first frosts (Bača et al., 1995).

Figure 3. *D.v. virgifera* female on corn leaf

Before flowering, they are usually found on corn leaves, and in the flowering period on corn tassels and silk. After flowering, adults are usually found hidden in high numbers in leaf axils because pollen is deposited there, or at the top of the corn ear where they feed on the remaining fresh silk. Therefore, in corn examination at this phenophase, special attention should be paid to these spots. The average life duration of adults is 5-6 weeks. Massive egg laying occurs in August.

Adults prefer feeding on pollen, silk and corn ear top which provides additional feeding for females and high egg production. Females lay from several hundred to one thousand eggs. When food is scarce, females can leave corn fields for additional feeding, but they usually come back for oviposition. Corn fields with late flowering attract large numbers of adults and massive oviposition occurs in such crops. This repeated oviposition scheme is different in areas where females massively lay eggs in soybean crops as well.

Noxiousness of western corn rootworm

Although adults feed on flowers of a large number of plants and larvae can feed on roots of many different grasses (Clark and Hibbard, 2004; Moeser and Vidal, 2004; Moeser and Hibbard, 2005; Cvrković, 2006) western corn rootworm is only known as a corn pest. When abundant, larvae are much more harmful and significant than adults. Larvae feed on roots or into roots by boring. Roots can be entirely destroyed under heavy attack and such plants become lodged already at the end of June (Figures 5 and 6). Corn stalks with partially damaged roots are lodged and have a distinctive look of goose neck. Damaged corn root cannot provide enough water and nutrients for the plant, which results in smaller grain yield. Such damage is characterized as direct and is much more severe under conditions of drought. Corn plants can regenerate their roots when soil has enough moisture and is fertile. However, indirect damage from plant lodging (Figure 4) is usually more important because harvesters cannot pick up ears from such corn plants.

Under our climatic and agrotechnical conditions, adults are sporadic pests. Adults are a threat only in cases of sowing after the optimal sowing date or in case of stubble corn sowing. Adults feed on corn pollen, silk, leaves and on young, juicy ears. Besides corn, adults can also feed on different cultivated or weed plants (sunflower, pumpkins, bean leaves, flowers of vegetables and weeds, etc.) where alternative pollen sources are available.

Figure 4. Lodged corn plants

Figure 5. Feeding scars on corn root

Figure 6. Heavily damaged corn root

Control of *Diabrotica virgifera virgifera* by crop rotation

After World War II, American farmers extensively used crop rotation for control of this pest, which gave good results throughout the corn producing area. In central parts of that region, corn and soybean rotation predominated under favorable climatic and soil conditions there. However, after a relatively short period, this rotation practice became insufficient. First damages on corn in crop rotation were recorded in Ford County, Illinois, in 1987 (Levine and Oloumi-Sadeghi, 1996; Gray et al., 1998; Levine et al., 2002). In that area, the pest appeared after 1966 and over the following 20 years it adapted to the applied crop rotation. American authors believe that the selection pressure of narrow rotation (corn-soybean) was very high in that part of Illinois and that it was there that resistance to crop rotation first occurred. In the region, 89% of the land is used for agriculture and 98% of that area is under corn in crop rotation with soybean (Onstad et al., 1999, 2001).

It was found that a behavioral change occurred (behavioral resistance) and that the insects began to lay eggs massively in soybean crops as well. As eggs laid in soil under a soybean crop hatch in the spring of the following year when corn is sown, damage on corn was observed in the first production year. By 1995, this type of crop rotation became inefficient in other parts of Illinois and Indiana as well. By 2007, damage on corn in crop rotation expanded to seven states of the central part of the corn producing region (Gray et al., 2009).

Notably, crop rotation is still efficient in most parts of that corn productng region where plants other than soybean are used in rotation. As *D. v. virgifera* causes damage and reduces corn yield both in crop rotation and in monoculture, damage caused by this pest in the USA has been estimated at more than one billion USD (Mitchell et al., 2004).

In America, crop rotation is considered to have limited value for WCR control because it has been proved that the insect can lay eggs also in alfalfa, winter wheat, rye, and it can also feed on roots of other grasses besides corn (Branson and Ortman, 1967, 1970; Rondon and Gray, 2003; Clark and Hibbard, 2004; Schroeder et al., 2005).

In Southeast Europe, WCR also lays eggs in winter wheat and alfalfa crops, but the number of surviving adults is low and is not a threat to corn roots (Kiss et al., 2001, 2002, 2005).

Based on the situation in Illinois, Onstadt et al. (2003) concluded that the expansion of territories with damaged corn in crop rotation decreased with increasing field diversity. The same process is considered inevitable in Europe but expected to have a slower pace. Onstadt et al. (2003) showed that increased application of crop rotation also increased the number of insects adapted to crop rotation. The authors expect rotation resistance to evolve in Europe after 15 years of crop rotation practice.

The relation between crop rotation and WCR abundance in Serbia is within limits of expected pest behavior. Population density decreases with an increase in crop rotation practice, i.e. population density increases when corn is grown for two or more years in the same field (Sivčev et al., 2009). This points to the fact that corn is still the primary host for WCR because females still lay eggs mostly on corn. Due to this insect behavior, crop rotation is efficient in Serbia. It is obviously the agrobiodiversity that explains the existing behavioral differences regarding the pest. No damage on corn grown in crop rotation has been registered in Serbia for now. In the first year of production, corn does not require protection from *D.v. virgifera* larvae.

The advantage of European agriculture is a significantly lower selection pressure as corn fields account for 13% of total agricultural land (Nieuwenhuyse et al., 2009). Where agricultural land with a significant share of corn is predominant, crop rotation is encouraged by administrative measures. A new agricultural subsidy system has been introduced in Hungary, and crop rotation is now a mandatory criterion for farmers to receive subsidies. These rotation systems are dominated by winter wheat and other cereal crops, while sunflower and oilseed rape are used as pre-crop plants (Hatala Zsellér, 2007). Crop rotation is the effective key element of pest eradication in the EU and the only control measure to eradicate *D. virgifera virgifera* in Switzerland (Baufeld, 2009). The economy of WCR management is very important and can lead farmers in different European countries to prefer one management option over another. A recent study (Dillen at all., 2010) has showed that, due to different costs of WCR control and its effects on yields, there is no unique WCR management option suitable for different corn producing countries in Europe.

Chemical control of *Diabrotica virgifera virgifera*

Corn was massively grown in monoculture in the USA as a result of high demand, so that control measures were applied on over 12 million ha of fields in some years (Sutter et al., 1989). During 1973, soil insecticides were applied to over 60% of total corn acreage in the USA (Chio et al., 1978). Some recent estimation suggests that corn rootworm is annually treated on 5.7-10.1 million ha of corn fields with organophosphates, carbamates, pyrethroids and phenyl pyrazole insecticides (Ward et. al., 2005).

Chemical treatments can be applied against larvae or adults of *D.v. virgifera*.

Control of larvae by soil insecticides

Soil insecticides are applied to control WCR larvae because they spend their whole life in soil feeding on corn roots. Insecticides can be applied prior to sowing, at the time of sowing or after it (during vegetation). The use of granulated soil insecticides has been widespread in practice (Hills and Peters, 1972) and they proved to be more efficient than liquid formulations (Ostlie and Noetzel, 1987).

When damage was observed in the post-World War II period, American farmers started to apply organochlorine insecticides to control larvae (Hill et al., 1948). Mass application of organochlorine insecticides began with benzene hexachloride around 1949, followed by aldrine and chlordane, while heptachlor was used as of 1954.

Lack of control efficacy was first registered in Nebrasca already in 1959, and during 1960 and 1961 the problem became widespread throughout the corn producing region (Ball and Weekman, 1962, 1963; Bigger, 1963; Blair et al., 1963; Hamilton, 1965; Patel and Apple, 1966).

The resistance proved to be stable because it was brought to Serbia although organochlorine insecticides have not been in use in the USA for over 20 years (Perić et al., 1996, 1998).

New insecticides, organophosphates and carbamates, were introduced into practice and the method of application was also altered. Application of soil insecticides simultaneously with sowing became the most common method for application of soil insecticides against corn rootworm larvae. Granulated insecticide products are placed in furrows or strips 15 cm in width, in a soil layer above the seed (Erbach and Tollefson, 1983). The insecticide is then incorporated in soil using ribbed wheel, or it is rolled over in the soil using a massive chain. Liquid formulations are applied by low pressure sprayers. This application method significantly reduces the quantity of applied insecticide because the treated area is much smaller. If an insecticide is not toxic to germinated plants, it can be deposited in the immediate vicinity of the seed. Application around and above the seed in the form of a T letter has also been developed and is known as T-band application. Depending on whether an insecticide is moderately or highly mobile, or the season is dry or high in precipitation, the insecticide applied to the surface layer of soil can remain there or be washed into deeper layers. In both cases, the efficacy would be lower than satisfactory.

New insecticides from the carbamate (carbofuran) and organophosphate (parathion, phorate, fonofos and diazinon) groups were commercialized in the 1970s and widely used to control western corn rootworm larvae (Peters 1964; Apple et al., 1969). The use of chlorpyrifos and terbufos and pyrethroids (tefluthrin) started somewhat later. A newly developed organophosphate insecticide, a combination of tebupirimphos and cyfluthrin, was registered for corn rootworm larvae in 2000 and is widely used in granule formulations (Gerber et al., 2005). In Serbia, only terbufos, and tebupirimfos plus cyfluthrin have shown good efficacy in years with normal conditions, but also in extremely wet or dry weather (Sivčev, 1997).

Insecticide application coinciding with strip sowing also led to adverse changes. Investigation into the effects of three most commonly used insecticides (carbofuran, chlorpyrifos and terbufos) applied in strips against *D.v. virgifera* showed that these insecticides provided good protection of corn roots from larval attack but did not reduce the population of corn rootworm. This explains why there is usually no damage on treated fields, but the population of surviving adults is very high (Levine and Oloumi-Sadeghi, 1991; Gray et al., 1992; Chandler, 2003; Furlan et al., 2006).

Several authors investigated the method of application and efficacy of different insecticides in Serbia (Sivčev, 1997, 1998; Bača et al., 1998; Sivčev et al., 1998, 2000). The results showed that high efficacy can be achieved by application at sowing, while treatment during vegetation proved to be less efficient. However, soil insecticides have never been applied to large areas in Serbia. The main reason for this is unprofitability of such practice because farmers find no economic intrest in buying and applying insecticides.

The following insecticides are currently in use in the USA (Indiana) for WCR control: bifenthrin, chlorethoxyphos plus bifenthrin, chlorpyrifos, clothianidin, tebupirimfos plus cyfluthrin, terbufos, tefluthrin (Krupke et al., 2011). Tefluthrin (Force) and tebupirimfos plus cyfluthrin (Aztec) formulated as granules are predominantly used. The same insecticides have been registered in the European Union. Due to legislation that does not support granules [Annex I of the Directive 91/414/ EEC (http://www.ec.europa.eu)], liquid formulations are preferred and recommended, but some efficient insecticides have been withdrawn from the market that way because of their toxicity, e.g. phorate, terbufos, chlorpyrifos granules and carbofuran (van Rozen and Ester, 2009).

Seed treatment

Before synthetic insecticides from the neonicotinoid goup appeared, insecticide seed treatments had been rarely applied for control of *D.v. virgifera* in the USA. Three neonicotinoid insecticides – clothianidin, thiamethoxam and imidacloprid – are currently available for corn protection. Corn seed treated with thiamethoxam and clothianidin is a widespread management tactic used even for transgenic corn seed (El Khishen et al., 2009).

However, the efficacy of insecticides applied to seeds, regardless of the type of active ingredient, is not always satisfactory (Tollefson, 2004, 2005, 2006; Obermeyer et al., 2006; Furlan et al., 2009). Therefore, this management method is recommended when the abundance of *D.v. virgifera* is low or medium. Treated seed is regarded as a root protection measure more than a tool for population abundance reduction (Obermeyer et al., 2006). Similarly to granules, insecticides intended for seed treatment, such as imidacloprid, fipronil, thiamethoxam and tefluthrin, do not reduce population of *D.v. virgifera* adults (Furlan et al., 2006). Besides, it was found that insecticides from the neonicotinoid group have adverse effects on honeybees (Girolami et al., 2012).

Adult management

Foliar treatment of corn was widely used in the USA in the 1980s. In 1973, air-treatment was conducted on 4 million hectares to control overpopulated adults (Chio et al., 1978).

Besides prevention of direct damage, the aim of adult control can be a reduction of their population to prevent oviposition in soil, i.e. to prevent larval damage in the following year. However, one treatment has been usually found insufficient for successful population control and a second treatment is therefore required, which makes the control more expensive. In practice, this control method has been suppressed by application of soil insecticides at sowing, which is a cheaper, more reliable and simpler method.

Because of the height of corn, treatment in August when plants are fully developed is possible only by high-clearance tractors or by airplanes. Air treatment is not allowed in some EU countries, while general EU standpoint is against the use of airplanes (van Rozen and Ester, 2010).

Under the agroecological conditions existing in Serbia, adults can rarely be harmful. Adult insects are regarded as pests only when they are found in high abundance during the pollination period. The peak of adult emergence in Serbia takes place only after the pollination phase of corn is over. However, if adult population is high, damage can also occur on corn plants of later blooming, at the end of July or beginning of August, as it is the case with late sowing or stubble corn. Massive adult feeding on silk, when silk is entirely eaten, causes partial bareness of ears. Shortened silk keeps its function and pollination is possible.

Transgenic resistant varieties of corn

In 2003, Bt corn got a permission in the USA to be used as a means of reducing damage caused by *Diabrotica virgifera virgifera* larvae. Since then, its use has rapidly spread, gaining a share of 45% of total production in 2009. However, fast occurrence of larval resistance and damages on Bt corn brough its further use for control of *D.v. virgifera* into question (Gassmann et al., 2011).

During 2011, fields under Bt corn were surveyed in Iowa and Illinois, and plant roots damaged by larvae and a high number of adults were found (Gray, 2011a, 2011b). An insufficient dose of Cry3Bb1 toxic protein crystalin in commercial corn was addressed as one of the reasons for this. Another factor that may have contributed to the evolution of resistance was insufficient refuge populations. Currently, only 50% of Bt corn planted in Midwest complies with the US EPA requirements for refuge size and proximity to Bt fields (Jaffe, 2009). Gray (2011a) regards that an enormous selection pressure on this insect species is responsible for this situation. The pressure comes in multiple forms: increased use of Bt hybrids, neonicotinoid insecticidal seed treatments, and broadcast treatments of corn and soybean fields with pyrethroid insecticides that are frequently tank-mixed with fungicides.

Presuming their good efficacy, Dillan et al. (2010) showed that Bt corn grown in monoculture is the best option as it creates the highest value in 78% of the cases. In Serbia, as well as in the European Union, Bt corn active against WCR is not deregulated.

Eradication of *Diabrotica virgifera virgifera* and its containment measures in Europe

Several European Union member-states have attempted to contain and eradicate western corn rootworm (WCR). Eradication and containment measures are regulated by EU directives and national regulations, and include crop rotation and insecticide treatments within different types of buffer zones surrounding new introduction points (Carrasco et al., 2010).

So far, several eradication actions have been organized throughout Europe. The first beetles in Italy were caught near the Marco Polo airport in Venice in 1998 and an eradication program was initiated immediately thereafter (Furlan et al., 1998). Despite the encouraging results, this area was in 2006 declared to have an established WCR population. (Vettorazzo, 2009). In 2002, *D. virgifera virgifera* was found for the first time in France near Paris airports and in 2003 on another location, and eradication measures were taken with success. In 2003 *D. virgifera virgifera* was found in London and was eradicated by 2008. In The Netherlands, 5 introductions were recorded in 2003 and 2005 and all WCR beetles were eradicated. In Belgium, WCR was recorded near Brussels in 2003 and also successfully eradicated. In Switzerland, WCR was registered on 6 different introduction sites in 2003, 2004 and 2006, and eradicated (Baufeld, 2009). In 2007, *D. virgifera virgifera* was detected for the first time in Germany (Baden-Württemberg and Bayern) and eradication measures were taken (Anonymous, 2012).

In South-Eastern Europe, no eradication campaigns have been organized against WCR. However, efforts were made in Serbia back in 1994 to organize eradication. The existing information on WCR distribution in the Serbian territory in 1993 and 1994 were a basis for a relevant government commission to invite international organizations to provide technical assistance in eradication of WCR. It was a timely action since WCR distribution in the Serbian territory was then limited to a relatively small area and was approaching a few neighboring countries. Unfortunately, no response came from the international organizations, so that other management options were used to contain WCR, primarily crop rotation. Pest containment focusing on prevention measures was successful and WCR damages were made sporadic.

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Suzbijanje kukuruzove zlatice *Diabrotica virgifera virgifera*

REZIME

Kukuruzova zlatica je prvi put registrovana 1992. godine pored međunarodnog aerodroma Surčin. Širenje zlatice po teritoriji Srbije i porast gustine njene populacije je bilo brzo. Celokupna teritorija Srbije je naseljena u narednih nekoliko godina, pri čemu su se značajne štete javile na kukuruzu u ponovljenoj setvi. Sakupljeni su podaci o štetama na preko 140.000 ha kukuruza u periodu do 1999. godine. Posle 2000. i 2003. godine brojnost populacije *D.v. virgifera* kao i broj oštećenih kukuruzovih polja je značajno smanjen zbog suše i masovne primene plodoreda. Kukuruzova zlatica ima jednu generaciju godišnje. Prezimljava u stadijumu jajeta. U klimatskim uslovima Srbije piljenje larvi počinje oko 15. maja. Najveći broj larvi se nalazi na korenu kukuruza oko 20. juna kada je ishrana larvi najintenzivnija. Zbog gubitka korena dolazi do poleganja biljaka. Odrasli insekti se javljaju krajem juna. Njihova brojnost raste tokom jula i dostiže maksimum krajem tog meseca. Od druge dekade avgusta brojnost imaga opada. Odrasli insekti se mogu naći u polju sve do prvih mrazeva. Larve se hrane na korenu ili se ubušuju u njega. U slučaju velikog napada koren može biti potpuno uništen i takve biljke već krajem juna poležu. U našim klimatskim i agrotehničkim uslovima odrasli insekti su sporadične štetočine. Oni mogu biti štetni u slučajevima kasnije setve ili postrne setve.

Plodored je efikasan i najrasprostranjeniji način suzbijanja kukuruzove zlatice. Do sada se u Srbiji nisu javile štete na kukuruzu u plodoredu. Stoga se u kukuruzu u plodoredu ne primenjuju zaštitne mere.

Više insekticida pokazuje dobre rezultate u suzbijanju kukuruzove zlatice kada se primenjuju sa setvom i imaju dozvolu za primenu u Srbiji. Međutim, zemljišni insekticidi nisu nikada do sada primenjeni na većim površinama za suzbijanje kukuruzove zlatice.

Ključne reči: Kukuruzova zlatica; kukuruz; insekticidi; suzbijanje