RESEARCH REGARDING *DIABROTICA VIRGIFERA VIRGIFERA* LE CONTE (THE WESTERN ROOT WORM) CONTROL IN SUSTAINABLE AGRICULTURE

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ABSTRACT

Diabrotica virgifera virgifera **Le Conte has been present in Romania for over 10 years (1996) and has become a very dangerous pest for corn. Its spreading on a large area was favored by the ecological conditions and by the considerable share of corn in the crop structure, especially by corn monoculture.**

Taking into consideration that almost all the developing stages of the pest, except the adults, live in soil, limitation of area extension and of produced damage can only be achieved by crop management measures together with chemical methods.

The research performed during the period 2005 - 2007 in long term field experiments (since 1990) in various crop rotation types, in which corn is present in monoculture, in two and three years rotation (under irrigation and without irrigation) and in six years crop rotation (non-irrigated), has shown that monoculture is the most important factor responsible for the pest multiplication.

In corn monoculture the larvae number on the roots ranged between 4.91 and 8.23 and root attack degree in IOWA scale (with marks from 1 to 6 in which maximum attack is 6), had values between 3.84 and 5.62. The frequency of attacked plants with the symptom „goose neck" ranged between 16.4 and 31.2%, larval aggressiveness being higher under favorable soil moisture in irrigated conditions. The rotation with other crops interrupts the biologic cycle of the pest.

Planting corn later and utilizing lower plant density contributed to prevention of pest multiplication, while earlier sowing at high density favored the larvae developing. The results obtained in this field experiment showed that chemical control of larvae was necessary at moderate to high infestation pressure best control being obtained by utilizing granulated insecticides for soil at sowing (Force 1.5 G) or seed treatment (ST 280, Cruiser 350, Poncho 510). For chemical control of adults the best efficacy was obtained utilizing the insecticides: Actara 25 WG, Karate 5 EC, Calypso 480 SC and Talstar 10 EC.

Key words: *Diabrotica virgifera virgifera* Le Conte, corn (maize), attack degree, crop rotation, density and sowing periods, chemical control.

INTRODUCTION

Diabrotica virgifera virgifera Le Conte is a new pest, recently entered in Romania, and is very dangerous, because it attacks one of the most important agricultural crops - corn, and the attack is present on both roots and above-ground parts of the plant. The adults are responsible for the damage of leaves, corn silk, pollen and corn cob, and the larvae attack roots.

The damage intensity depends on the number of larvae in the soil, the type of soil, the type of harvesting and soil moisture. The larvae can completely destroy both secondary and the main roots. The attacked young plants present a stem typically tilted like a „goose neck" and roots damage at a level of over 50% lead to plant lodging and to growth stagnation (Branson et al., 1967). The yield may decrease by 50% in the case of a strong infestation with larvae (Spike and Tollefson, 1989).

Using a scale from 1 to 6 (after Ostlie and Noetzer, 1987), the damage of the roots at 2.5 value is considered the starting point of damages and over this value the yield level is significantly decreased (Turpin et al., 1972).

The yield losses caused by the adults are important when these are in large number on the plant – the economic damage threshold being 10 adults/plant in the case of commercial hybrids and 5 adults/plant for hybrid seed production (Sivcev et al., 1994).

The economic damage threshold in the case of silk corn attack was estimated at 1 - 3 adults/corn cob and this will lead to 13% yield loss because pollination reduction (Tuska et al., 2002).

It was noticed that the large areas cultivated with corn in continue culture for many years on the same area (monoculture) in favourable climatic conditions contributed at a huge multiplication and spreading of *Diabrotica virgifera virgifera* Le Conte.

This pest is spreading more and more because of monoculture (Chiang and Flaskert, 1969) and practicing a crop rotation can reduce the root attack to a minimum level, the larvae not being able to survive in soils cultivated with other plants (O'Neal et al., 1977) as their mobility is less than 50 cm.

Crop rotation of two, three or four years did not present any attack risk, as compared

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with corn monoculture where large losses were registered.

The corn crop protection in monoculture against larvae is made through insecticides soil application, during seeding or during the vegetation period (Sivcev and Draganic, 1996; Edwards et al., 2002), and through seed treatment (Lagundzig, 2002; Sivcev et al., 2000; Grozea, 2003; Ciobanu, 2007).

Taking into account these aspects and the fact that this pest is a new one and relatively little is known about its biology and control methods, in this paper we present new data about the specific problems of the control of *Diabrotica virgifera virgifera* Le Conte, through crop management and chemical measures.

MATERIAL AND METHODS

The presented researches have been made in a long term experimental field including different types of crop rotation in irrigated and non-irrigated conditions. The experiment was set up in 1990, on a preluvosoil having 1.8% humus content, medium provided with mobile phosphorus and potassium.

The corn was cultivated in: monoculture; two and three years crop rotation (wheat – corn, soybean – wheat – corn) in irrigated and non-irrigated conditions and a six years crop rotation non-irrigated (oat – clover – clover – corn – wheat – corn – sunflower).

In separate experiment the influence of seeding density on *Diabrotica virgifera virgifera* Le Conte adults and larvae and the influence of chemical control methods were studied.

The number of larvae/root was determined taking soil samples (18/18 cm) from around the corn plants and the attack degree was estimated by marks using a scale from 1 to 6 (1 = without attack, 6 = 3 or more plants knots complete destroyed) and by the percentage of the attacked plants with the specific „goose neck" symptoms or lying down plants.

The adults monitoring was made using traps with pheromones (Atravirg – type Cluj-Napoca), which were read weekly from ear appearance to October. The Fundulea 376 hybrid (FAO 500 - 600) was utilized.

RESULTS AND DISCUSSION

The data in table 1 demonstrate that the larvae attack is noticed only in corn monoculture beginning with 2005 (although the adults were present in fields of Agricultural Research and Development Station Oradea beginning with 2001).

Table 1. The influence of crop rotation and of water regime on *Diabrotica virgifera virgifera* Le Conte larvae attack. Oradea, 2005 - 2007

Crop rotation	Water regime	No. of larvae (average)	Root attack (note 1 - 6)	% plants with root attacked
Monoculture	Irrigated	8.23	5.62	31.2
	Non-irrigated	4.91	3.84	16.4
Wheat – corn	Irrigated	0	1	0
	Non-irrigated	0	1	0
Soybean – wheat – corn	Irrigated	0	1	0
	Non-irrigated	0	1	0
Oat (+ clover) – clover – corn – wheat – corn – sunflower	Non-irrigated	0	1	0

The average number of larvae and the root attack degree was higher in irrigated corn monoculture as compared with non-irrigated corn monoculture, the favourable moisture regime caused by irrigation being one of the factors which favour larvae growing and attack degree. This confirms the increased aggressiveness of the larvae in better humidity conditions found by other authors (Riedell, 1994). The percentage of lodged attacked plants was 31.2% in irrigated corn monoculture and only 16.4% in non-irrigated conditions.

The adults were present in all types of crop rotation, but their number varied in function of utilized rotation and water regime of the soil. The highest number adults were registered in irrigated monoculture (680 adults/trap).

Wheat – corn rotation contributed to reducing this number with 49.0% and soybean – wheat – corn with 58.3%. In non-irrigated conditions the reduction of adults number comparative with monoculture was of 50.8% in two years crop rotation, 60.3% in three years rotation, and 73.4% in six years rotation (Table 2).

Because the long term corn monoculture represents the main responsible factor for this pest extension, introducing corn in crop rotations is one of the most important measures for damage prevention.

Table 2. Adults number/trap in function of crop rotation in irrigated and non-irrigated conditions. Oradea, 2005 - 2007

Adults number/trap	Crop rotation						
	Corn monoculture		Wheat – corn		Soybean – wheat – corn		6 years crop rotation*
	Irrigated	non-irrigated	Irrigated	non-irrigated	Irrigated	non-irrigated	non-irrigated
Adults number	680	571	347	281	281	227	152
Reduction, %	100	100	49.0	50.8	58.3	60.3	73.4

* Oat (+ clover) – clover – corn – wheat – corn – sunflower

The highest percentage of plants with attacked roots was registered when corn was sown on April 15 (22.12%) while in the case of corn sown on May 25 there were only 9.51% attacked plants (Figure 1).

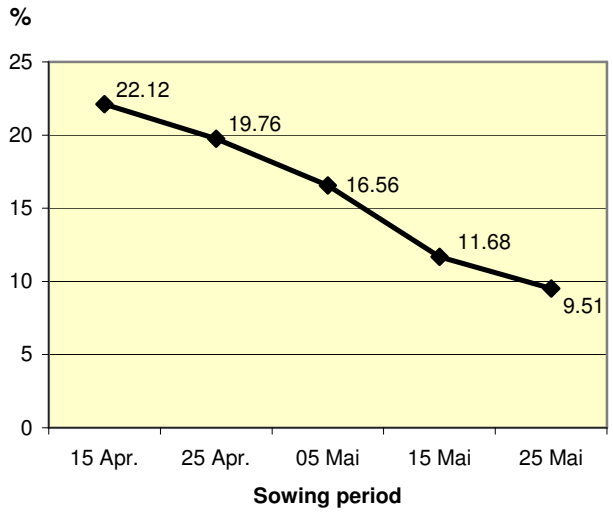

Figure 1. The percentage of attacked plants in function of sowing period. Oradea, 2005 - 2007

Earlier sowing determines a better developed root system which provide more food for larvae while sowing later than the optimum period (15 - 25 April) contributes to reducing the larvae number from soil because insufficient development of root system affects the larvae feeding and growing habitat.

However, despite the fact that later sowing can be one of the crop management methods for prevention of larvae multiplication (Gray at al., 2003), the corn should be planted in the optimum period for the zone, according to the hybrid requirements and the specific soil and climatic conditions.

The size of damage and the impact on yield, caused by this pest are also dependent on plant density. Our data demonstrate a positive correlation between the plants number/ha and the number of larvae/plant, (the number of larvae increases with increasing plant density and improving of water regime under irrigation) (Table 3).

Increasing density from 40,000 plants/ha to 85,000 plants/ha determined an increase of the number of larvae from 5.61 to 9.32 under irrigation, and from 2.31 to 5.25 larvae/ plant without irrigation. This aspect had also been shown by other authors (Weiss and Mayo, 1985).

Table 3. Larvae number/plant in function of plants density in irrigated and non-irrigated condition. Oradea, 2005 - 2007

Density pl./ha	Larvae number/plant		Limits of variation
	Non-irrigated	Irrigated	
40,000	2.31	5.61	1 - 10
55,000	4.12	6.90	2 - 11
70,000	5.06	7.21	1 - 13
85,000	5.25	9.32	1 - 17

	Soil water regime (a)	Density (b)	a x b	b x a
LSD 5%:	1.23	1.27	1.57	1.78

The percentage of plants attacked by larvae, with specific symptoms of stem inclined to soil, is higher in the case of irrigated corn as compared with non-irrigated corn and increases when plant density is higher (Figure 2).

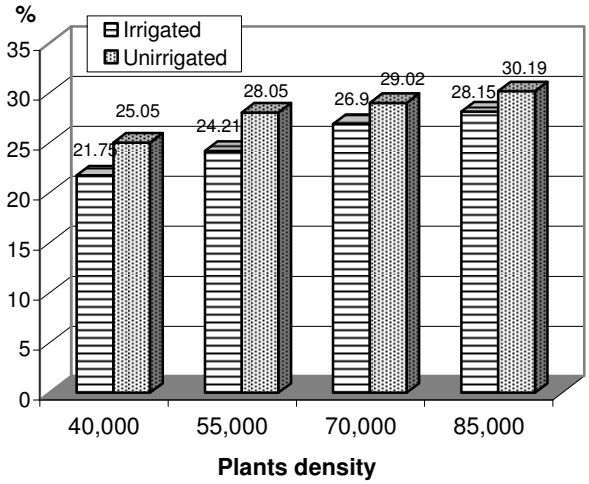

Figure 2. The percentage of plants attacked by larvae in function of plant density. Oradea, 2005 - 2007

The adults number also increased when density increased from 40,000 plant/ha to 85,000 plant/ha, and the number was higher under irrigation. The number of adults trap-captured in the period July – October increased from 526 to 702 in irrigated corn, and from 412 to 605 with no irrigation. This can be explained by the larger foliar, pollen and corn silk quantity and by more favourable soil moisture conditions (Figure 3).

Despite these results, the optimum plant density has to be established in function of others crop management conditions and of hybrid type, even if lower plant density reduces the pest attack.

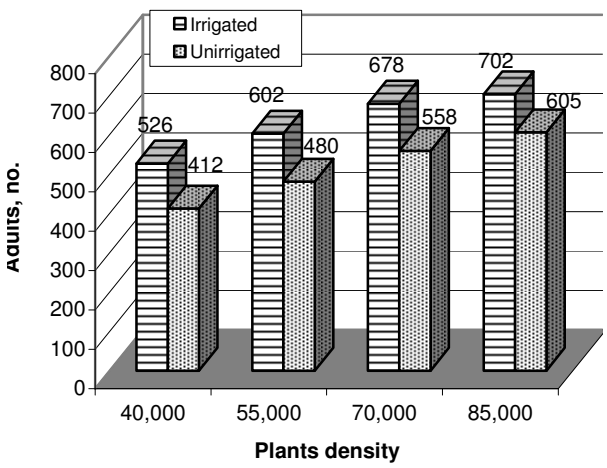

Figure 3. The number of captured adults/trap in function of plant density. Oradea, 2005 - 2006

The *Diabrotica virgifera virgifera* Le Conte control strategy includes chemical methods, which should be applied against adults and larvae especially in corn monoculture.

During the 2005 - 2007 period we tested some insecticides for larvae control through seed treatments: Poncho 510 (clotianidin), Cruiser 350 (tiametoxan) and ST 280 (tiametoxan + treflutrin) and the insecticide Force 1.5 G (teflutrin) applied at sowing. Their effect was estimated by determining the percentage of attacked plants and the characteristic aspect of root attack and damage degree (Table 4).

Table 4. Effect of insecticides used for larvae control. Oradea, 2005 - 2007

Variant	Rate l or kg/t or ha	Percentage of plants attacked	Root attacked (Scale IOWA)
Seed treatment			
Untreated	-	39.6	5.61
Poncho 510	12.5 l/t	7.4	2.60
Cruiser 350	10 l/t	6.9	2.48
ST 280	15 l/t	7.3	2.56
ST 280	25 l/t	5.8	2.21
Carbofuran	28 l/t	7.9	3.48
Soil treatment at seeding			
Force 1.5 G	12 kg/ha	4.5	2.29
Force 1.5 G	15 kg/ha	3.2	2.15

The best results in larvae control was obtained in the case of treatments with Force 1.5 G applied at sowing (on rows). The average of root attack, ranging between 2.29 -

2.15% correlated with tested rates. The seed treatment with ST 280 and Cruiser 350 determined a reduction of root attack from 5.61 to 2.21, and 2.48 respectively, while and utilizing the pesticide Poncho the root attack was decreased to 2.60.

The percent of plants which presented the characteristic aspects of root attack had the lowest values in the case of granulated insecticide Force applied at sowing on rows (4.5 - 3.2%), while in the case of insecticides utilized in seed treatment the percentage ranged between 5.8 and 7.4%.

Previous research by other authors also showed that the best results were obtained through application of insecticides at sowing (Sivcev and Draganic, 1996). It was established that the presence of two larvae/soil sample determines the necessity of soil application of insecticides (Bergman et al., 1981). The seed treatments with Gaucho FS, Poncho, also gave satisfactory results (Lagundzic, 2002.

The chemical control of adults through treatments with insecticides has to be applied at a density of pest higher than 8 - 10 adults/plant for commercial corn and 5 adults/plant in the case of corn for hybrid seed production (Higgins et al., 1988). We utilized the chemicals (Table 5), applying them during vegetation when the corn ears appeared and the number of adults/plant was from 14.21 to 16.07. The efficacy of insecticides was over 90%, ranging between 90.8 and 92.8%.

Table 5. Adults number/plant determined before treatment and efficiency of insecticides. Oradea, 2005 - 2007

Treatment	Rate/ha (kg or l)	Adults (no./plant)	Efficiency (%)	Adults (no/plant in August)
Actara 25 WG	0.080 kg	14.53	92.8	1.28
Karate 5 EC	0.25 l	14.21	92.6	1.32
Talstar 10 EC	0.200 l	14.86	92.5	1.41
Calypso 480 SC	0.100 l	14.76	92.0	1.33
Samurai	0.5 l	15.18	90.8	1.89
Fastac 10 EC	0.100 l	16.07	92.1	1.58
Fury 10 EC	0.200 l	15.01	91.0	1.41
Untreated	-	15.98	0	13.49

The number of adults/plant in treated plants in August ranged between 1.28 and 1.89, a number which can still cause economic damage. Some authors consider that 0.5 - 1 adult/plant represents a critical number in the top period of the pest (Wilson, 1992). It is therefore recommended to repeat the treatment at an interval of 10 days for obtaining a higher efficiency.

CONCLUSIONS

The western corn rootworm develops and survives only in corn monoculture and the larvae number and attack degree are favoured by the favorable moisture regime of soil under irrigation condition.

Crop rotations is the main option for a good control of *Diabrotica virgifera virgifera* Le Conte because larvae mobility in soil is limited (less than 50 cm) and survival is dependent on the presence of corn in previous year.

The larvae are capable to find the root for feeding only if the eclosion takes place in a corn field, crop rotation being the most efficient control method. Practicing a short crop rotation wheat-corn, corn - soybean – corn, can however lead to adaptation of the pest evolution to other host plants than corn. Future research regarding alternative host plants is necessary, being known that 22 plant species can be attacked by the *Diabrotica virgifera virgifera* Le Conte, even if now economic damages are only produced in corn.

The larvae and adults of *Diabrotica virgifera virgifera* Le Conte are favored by high levels of plant density and by the soil moisture in irrigated conditions, because higher number of plants and favorable soil moisture provides earlier food in larger quantity.

Later sowing at lower density contributed to decreasing of larvae and adults attack, but it is recommended to sow corn in the optimum period of the area and at recommended density, correlated with the type of the hybrid and with the specific soil and climatic conditions. The possibility of modifying sowing date for larvae multiplication prevention should constitute a direction for future research.

Chemical control measures are necessary especially in corn monoculture. When the larvae infestation is moderate to high, granulated insecticides application in soil at sowing (Force 1.5 G) is recommended.

Seed treatment with insecticides (ST 280, Cruiser 350, and Poncho 510) also significantly decreased the number of plants affected by the attack.

The chemical treatments against adults (Actara 25 WG, Karate 5 EC, Calypso 480 SC, and Talstar 10 EC) should be applied for decreasing the oviposition potential, which determines next year's larvae population.

Acknowledgements

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Western corn rootworm (Diabrotica virgifera virgifera LeConte) and the crop rotation systems in Europe. In S. Vidal, U. Kuhlmann, & C. R. Edwards (Eds.), Western corn rootworm: Ecology and management (pp. 189â€“220). Cambridge, UK: CABI.CrossRefGoogle Scholar. Krysan, J. L., & Smith, R. F. (1987). Systematics of the virgifera species group of Diabrotica (Coleoptera: Chrysomelidae: Galerucinae). Entomography, 5, 375â€“484.Google Scholar.Â Effect of insecticide treatments on root lodging and yields of maize in controlled infestations of western corn rootworms (Coleoptera: Chrysomelidae). Journal of Economic Entomology, 83, 2414â€“2420.CrossRefGoogle Scholar. Suttle, P. J., Musick, G. J., & Fairchild, M. L. (1967). Diabrotica virgifera Le Conte has been present in Poland since 2005. The range of its distribution increased in 2006 and 2007. D. virgifera is known from areas of nine voivodeships in Southern and partially Central Poland. Current control strategy is based on containment measures to limit the...Â The State Plant Health and Seed Inspection Service, Central Laboratory Å»wirki i Wigury 73, 87-100 ToruÅ„, Poland. 2. Institute of Plant Protection â€“ National Research Institute, Regional Experimental Station, Langiewicza 28, 35-101 RzeszÃ³w, Poland. CORRESPONDING AUTHOR. Tomasz KonefaÅ, The State Plant Health and Seed Inspection Service, Central Laboratory Å»wirki i Wigury 73, 87-100 ToruÅ„, Poland. Journal of Plant Protection Research 2009;49(1):129â€“134. The Western corn rootworm, Diabrotica virgifera virgifera, is one of the most devastating corn rootworm species in North America, especially in the midwestern corn-growing areas such as Iowa. A related species, the Northern corn rootworm, D. barberi, co-inhabits in much of the range and is fairly similar in biology. Two other subspecies of D. virgifera are described, including the Mexican corn rootworm (Diabrotica virgifera zeae), a significant pest in its own right, attacking corn in that country. Western corn rootworm (WCR) is one of the most significant insect pests of maize in North America. WCR has dramatically increased its range in the last century, invading key maize production areas in the US and abroad. In addition, this species has a history of evolving traits that allow it to escape various control options. Improved genetic and genomic resources are crucial tools for understanding population history and the genetic basis of trait evolution. Here we produce and analyze a transcriptome assembly for WCR.Â Siegfried BD, Waterfield N, ffrench-Constant RH: Expressed sequence tags from Diabrotica virgifera virgifera midgut identify a coleopteran cadherin and a diversity of cathepsins. Insect Mol Biol. 2005, 14: 137-143.