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THE EFFECT OF CHEMICAL AND BIOLOGICAL CONTROL ON THE WESTERN CORN ROOTWORM LARVAE (*Diabrotica virgifera virgifera* LeConte) IN FIELD TRIALS

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ABSTRACT

The western corn rootworm *(Diabrotica virgifera virgifera* LeConte) is one of the most important harmful corn pests in Hungary, currently it is essential to control both larvae and imagos in monoculture cultivation. The control of larvae is costly and the use of large quantities of soil disinfectants places an increased burden on the environment. Since 2018, the European Union has been extracting more and more active substances, so the number of insecticides that can be used against larvae has greatly decreased, thus increasing the value of environmentally friendly biological products that provide effective protection. In our experiments, in 2018, we compared the larval killing effect of Force 1.5 G (tefluthrin) soil disinfectant and Poncho pro (clothianidin) seed coating under field conditions. We examined whether the efficiency of more cost-effective, easier-to-treat dressing achieves the results produced by the more expensive soil disinfectant. Force 1.5 G soil disinfectant was applied at a rate of 12 kg / ha and Poncho pro (clothianidin) was applied to the seed surface at a dose of 1.25 mg. After the approval of the seed coating with neonicotionoid in bread was revoked, in 2019 we started to study the larvalicidal effect of a biological procedure (Heterorhabditis bacteriophora entomopathogenic nematode). We wondered if this biological product could take up the fight against the larvae of the American corn borer, whether it could achieve the effectiveness of the commonly used Force 1.5 G (tefluthrin) soil disinfectant. In the 2019 experiment, the

dose of soil disinfectant was the same as in the previous year, the nematodes were applied in 2 doses, the lower dose was 2 billion / ha and the higher dose was 3 billion / ha.
The experiments were carried out in Győr-Moson-Sopron county on the border of Gyömöre village on a large field plot, in 4 replicates. In the evaluation of the experiment, the plants were excavated with a 20x20 cm earth ball, the larval counts were recorded, and then the roots were washed and the value of root retention was determined using the modified Iowa scale. Data were evaluated by statistical analysis.
We found that each experimental material significantly reduced the number of rootworms compared to the control. Root damage caused by larves remained below the economic threshold (modified IOWA scale: 3.5). The larvicidal effect of insect pathogenic nematodes is practically the same as that of tefluthrin, no verifiable difference was found between their effects.
Keywords: western corn rootworm, *Diabrotica virgifera virgifera* LeConte, entomopathogenic nematode, *Heterorhabditis bacteriophora* Poiner, root damage, modified IOWA scale.

INTRODUCTION

In addition to wheat/*Triticum aestevum*/ and rice/ *Oryza sativa*/, corn /*Zea mays*/ is the most important cereal of mankind. The world has a sown area of 140-160 million hectares. It is the largest planted area in Hungary, 1.2 million ha including silage corn. Due to the large production area, it is in many cases grown in monoculture. In addition to the appropriate agrotechnical processes (tillage, nutrient supply, number of sown plants, weed control), the control of western corn rootworm (*Diabrotica v. virgifera*) is becoming an increasing challenge during maize production.

There are two subspecies of the species, *Diabrocita virgifera zeae,* and *Diabrotica virgifera virgifera,* which is also common in Europe (*Krysan et al.* 1980). The insect has a tropical (Mexican) gene center (*Krysan* 1982), from where it conquered the area of the corn belt in North America. The first economic damage was caused by the XX. century on sweet corn (*Gillette*1912). It crossed the Hungarian border in 1995 (*Tóth and Nagy* 1995, *Princzinger* 1996). Our economic damage was first observed in 1998 (*Ripka et al*. 2000).

The main damage is caused by the larves in the soil, which hatches around mid-May (*Luckmann et al*. 1974, *Bergman és Turpin*, 1984) and begin to damage the roots (*Pálfay 2001*). As a result of the chewing, the plants are tilted and their stems are typically curved, it is a typical gooseneck-like shape also called goose necking *(Chiang 1973*). Damage of imagos is similar to damage of *Oulema* species, but because their oral organs are stronger and they chew through the larger veins of the leaves, their damage image thus becomes like a hole (*Čamprag et al.* 1994). After leaf damage, the damage images can be observed on the coat of arms of the plant and then on the pistils that appear later (*Mouser* 2003, *Ludwig and Hill* 1995). The *D.v.v.* chews the anthers on male inflorescences (*Krysan* 1986), but this does not endanger fertilization due to the intensive pollen production of corn. The main and the most dangerous damage of imagos is the chewing of pistils (*Tuska et al.* 2002). In the case of large numbers, the pistils are chewed on a brush, resulting in reduced fertility and thus a significant decrease in yield (*Culey et al.* 1992). With the spread of the pest, the cost of control against it increased in direct proportion. In Hungary today, the costs of controlling the corn borer are the highest among the pests. Chemicals are used against both larves and imagos and their combined cost (insecticide + application) rivals the price of hybrid seed.

Pest control methods are common on our continent, such as soil disinfection (*Széll et al.* 2005, *Sutter et al.*1989, *Sutter et al.* 1990, *Fuller et al.*1997), seed dressing and insecticide spraying (*Hataláné et al.* 2004, *Horváth 2003*), but experiments have also been started in the field of biological control and the development of long-lasting insecticide preparations. The most effective chemical control against larvae in Hungary (*Komáromi et al.* 2001) and in the United States too (*Rice* 2004) is the application of soil disinfectant simultaneously with sowing (*Pálfay* 2001). The most common granular soil insecticid is tefluthrin (Force 1.5 G) (*Tímár,* 2003), which has a good killing effect on rootworms, but problematic is its toxicity and/or non-target effects and the high cost per ha. The Force 1.5 G is not harmful for the young plant, there is no weed control restriction and it is a sure solution even in case of large numbers of larvae. In a smaller area, they are protected by sowing simultaneously with chlorpyrifos, a liquid application device applied to the seedbed, but this active ingredient can no longer be used from February 2020. Coating the seed with an insecticide also provides protection against the *D.v.v.*and other soil-dwelling pests from the moment of sowing (*Čamprag and Baöa* 1995). In Hungary, the neonicotinoid active substances (clothianidin, thiamethoxam, imidacloprid) have been successfully used as dressings against rootworms. They had the advantage of having a long duration of action when absorbed into the seedling, providing protection for up to six weeks. On the 31st of December 2018, the European Union banned dressing with neonicotinoids.

The chemical possibilities of control of the corn beetle have been becoming increasingly scarce, which is why research has focused on biological solutions that destroy only the target species without harmful side effects, such as the entomopathogenic nematodes (EPN). They are generally easy to apply, and safe to humans as well as non-target organisms (*Toepfer et al.* 2009). Such species include *Steinernema glaseri, S. arenarium, S. abassi, S. bicornutum, S. feltiae, S. kraussei, S. carpocapsae,* and *Heterorhabditis bacteriophora*. Using them as a biocontrol agents to control *D. v.v.* rootworm shows much promise (*Kurtz et al*. 2009). From among the species studied former, *Heterorhabditis bacteriophora* Poinar reduced the larvae of the *D.v.v.* by 81% in field trials compared to the negative control (*Toepfer et al*. 2008). The efficacy of EPN is depend on a range of biotic and abiotic factors for example the species/strain, dose used, timing of application, developmental stage of the pest, and soil characteristics (e.g. soil temperature, moisture, texture) (*Petzold et al*. 2013).

Infectious juvenile larvae of nematodes enter the rootworms through body openings using their mouth bayonets. In their closed mouth, they carry symbiont bacteria (*Photorhabdus luminescens*) with them, which, by liquefying the larval body, make it easily absorbed by the nematode. Within 2-3 days of entry, the attacked larva dies (*Ciche and Ensign* 2003). Based on production conditions and costs, *H.b.*is the most suitable insect pathogenic nematode for biological control (*Toepfer et al.* 2005). The aim is to select nematode strains that are as drought tolerant and infectious as possible. The new strains are tested in field experiments, ensuring that they do not lose their key traits and that their effectiveness against the *D.v.v.* is maintained or improved.

Within the framework of the CABI project *(URL 1*) domestic experiments were carried out between 2004 and 2007 and the efficacy of nematodes was evaluated using various application techniques (injection into the soil and spraying on the soil)(*Toepfer et al*. 2010/a). Both methods reduced the level of damage of the larvae of *D.v.v.* by more than 50%. The best effect (68% larval mortality) was observed when nematodes were injected into the soil at the same time as sowing. In further experiments, *Toepfer et al.* (2010/b) found that *H. b.* due to nematodes, root damage according to the Iowa scale decreased by

3-15%, according to the scale showing damage to root floors (0.00-3.00), the damage decreased by 14-54%. Both the increase in nematode dose and the wash precipitate improved the efficiency of nematodes. In 2012 managed to solve the mass breeding of *H. b*.(*URL 2*) and make the product produced in this way commercially available under the name Dianem (*URL 3*). The Hungarian distributor of Dianem is the Biocont Magyarország Kft. The bioagent can be used in corn and delicacy corn against the larvae of *D.v.v.*, the recommended dose is 2 billion nematodes / ha (4 packages of 500 million) sprayed with 200-400 l / ha into the soil. A dose of 2 billion nematodes / ha is already enough to prevent the damage of the *D.v.v.* (*Toepfer et al.* 2018). According to *Tóth et al.* (2019) *H. b.*'s effect remains proportional against time (less reduction compared to insecticides), which may suggest that nematodes are able to multiply in the soil, thus reducing the number of imagos that hatch later. The use of insect pathogenic nematodes against the larvae of *D.v.v.* is a promising biological solution, but their efficacy in field conditions has not yet been sufficiently demonstrated. In our tests, the insect pathogen *H. b.* nematode larvicidal effect is compared to tefluthrin soil disinfection and untreated control.

We wondered if this biological product could take up the fight against the larvae of the American corn borer, whether it could achieve the effectiveness of the commonly used Force 1.5 G (tefluthrin) soil disinfectant.

MATERIAL AND METHOD

The tests were performed near Gyömöre village (Győr-Moson-Sopron county) in 2018-2019. The experiment was set up on a dedicated third-year monoculture maize field. The average gold crown value of the area is 13.2 AK / ha. The size of the experimental plots was 1.2 ha (18 × 670 m) in both years. Treatments were performed in 4 replicates. Three types of active substances were tested against the corn borer's larve:

- tefluthrin: soil disinfection with Force 1.5 G in 2018 and 2019
- clothianidin: dressing with Poncho Pro in 2018
- insect pathogenic nematode (*Heterorhabditis bacteriophora*) sprayed on soil Dianem preparation in 2019

Force 1.5 tefluthrin-containing soil disinfectant was applied simultaneously with sowing using a granulate sprayer at a dose of 12 kg / ha on 28th of April 2018 and on the

2nd of May 2019. Seed treated with Poncho Pro (clothianidin) dressing was purchased ready, sown on the 2nd of May 2019. Control plots did not receive any insecticide treatment. The insect pathogenic nematode Dianem containing *H.b.*was applied on the 2nd of May 2019. A stock solution of the powder formulation was prepared by adding water with gentle agitation. (figure1). The stock solution was further diluted in the 3000 L sprayer by removing the mixing and pressure filters in the sprayer (to avoid damage of nematoda). The mixed formulation was sprayed at a dose of 400 l / ha on the entire soil surface (figure 2) and then applied to the soil with a spade harrow. The sowing also took place on this day. Two doses were used in the experiment:

- low dose: 2 billion nematodes / ha
- high dose: 3 billion nematodes / ha

The nematodes reach the upper 20-30 cm depth of the soil and migrate within a 30 cm radius. As these are living organisms, more attention needs to be paid to several things when applying. Appropriate ecological conditions are needed for their survival and reproduction. They require a minimum soil temperature of 10 ° C and a water amount of 200-400 l / ha for field application. After application, it is important to cover them with soil because they are sensitive to light. The nematode requires gentle mixing and dilution, so sprayer filters should be removed to avoid injury (*Toepfer et al*. 2019).

We evaluated the experiment on the 12th of July 2018 and 10th of July 2019. We determined the number of larves/plant (by digging the roots of 10 plants per plot, after soaking for 3 hours) and evaluated the degree of root recoil on the modified Iowa scale. Statistical analyses were performed using the Statistica (version 13.2; StatSoft, Inc. 1984-2016 DELL) software.

Figure 1: Mixing of entomopathogenic nematodes (Dianem)

Figure 2: Application of entomopathogenic nematodes (Dianem)

RESULTS

Larval number per plant

In 2018, we found a total of 32 larvae of *D.v.v.* on the dug 120 corn roots, and in 2019, a total of 33 larvae of *D.v.v.* on the dug 160 roots. There were significantly fewer larvae in the plots of the treated areas than in the control plots (*Table 1*). The number of larvae in the root zone of 40 maize plants from one treatment varied between 2 and 22 (representing an average of 0.05 to 0.55 larvae per plant). The fewest larvae were in the Force 1.5 G-treated plot (2018-4pcs, 2019-2pcs). Slightly more larvae occurred in the case of nematode-treated (5-6 plants / 40 plants) and dressed plants (6 plants / 40 plants). However, significantly more larvae (20 and 22 larvae / 40 plants) occurred in the untreated control areas.

Table 1: Number of corn rootworm (*Diabrotica v. virgifera*) per plant according to treatments 2018-2019

Number of larvae/plant									
		2018					2019		
Repli-cates	Samp-led plants number	Pon-cho pro	Cont-rol	Force 1,5G		Control	Dianem 2 billion/ha dose	Force 1,5G	Dianem 3 billion/ha dose
I.	10	2	8	1		7	2	1	1
II.	10	1	6	1		5	1	1	2
III.	10	1	3	2		3	1	0	1
IV.	10	2	5	0		5	1	0	2
Sum.	40	6	22	4		20	5	2	6

Figure 3 shows that the number of larvae per plant is on average higher in the two control plots than in the treated plots, but their value is low (only 0.55 in 2018, 0.5 in

2019), the 2 already dangerous per plant does not even approach the value. The average larval numbers in the treated areas are even lower, ranging from 0.05 to 0.15 / plant. According to the results of the statistical analysis (paired t-test) (*Table 2*), each treatment is statistical significantly different from the control in terms of the average number of larvae. (There is a statistical significant difference between treatment pairs marked in red).

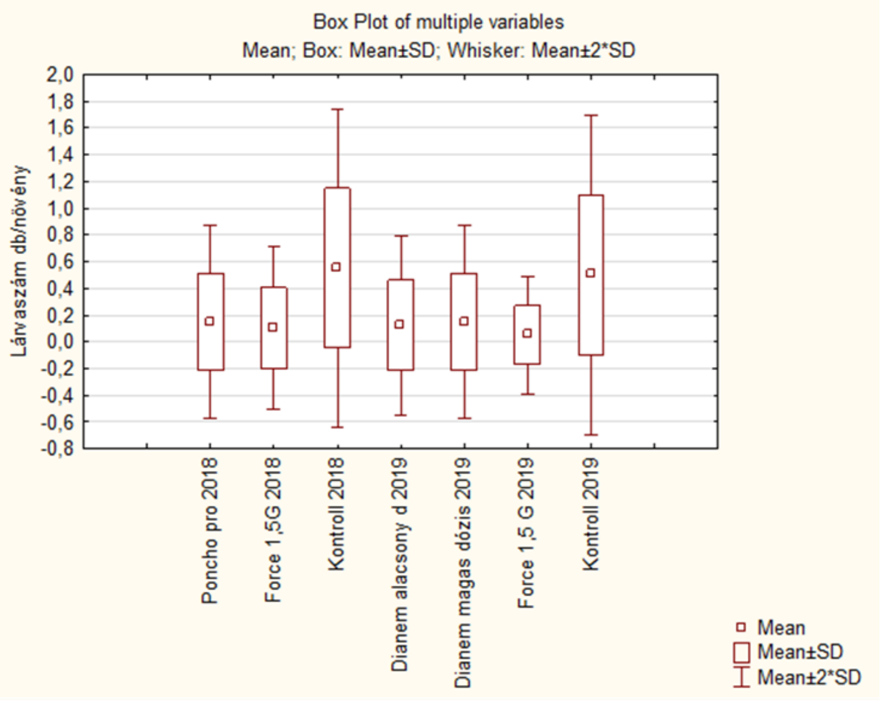

Figure 3: Average numbers of larvae (*Diabrotica v. virgifera*) per plant 2018-2019

Table 2: The comparison of average numbers of larvae *(Diabrotica v. virgifera)* with paired t-test

Group 1 vs. Group 2	T-test for Independent Samples (Vörös Levente lárva Note: Variables were treated as independent samples				
	Mean Group 1	Mean Group 2	t-value	df	p
Poncho pro 2018 vs. Poncho pro 2018	0,150000	0,150000	0,00000	78	1,00000
Poncho pro 2018 vs. Force 1,5G 2018	0,150000	0,100000	0,66953	78	0,50513
Poncho pro 2018 vs. Kontroll 2018	0,150000	0,550000	-3,62448	78	0,00051
Poncho pro 2018 vs. Dianem alacsony d 2019	0,150000	0,125000	0,32078	78	0,74923
Poncho pro 2018 vs. Dianem magas dózis 2019	0,150000	0,150000	0,00000	78	1,00000
Poncho pro 2018 vs. Force 1,5 G 2019	0,150000	0,050000	1,49284	78	0,13951
Poncho pro 2018 vs. Kontroll 2019	0,150000	0,500000	-3,16311	78	0,00222
Force 1,5G 2018 vs. Poncho pro 2018	0,100000	0,150000	-0,66953	78	0,50513
Force 1,5G 2018 vs. Force 1,5G 2018	0,100000	0,100000	0,00000	78	1,00000
Force 1,5G 2018 vs. Kontroll 2018	0,100000	0,550000	-4,24870	78	0,00005
Force 1,5G 2018 vs. Dianem alacsony d 2019	0,100000	0,125000	-0,34965	78	0,72754
Force 1,5G 2018 vs. Dianem magas dózis 2019	0,100000	0,150000	-0,66953	78	0,50513
Force 1,5G 2018 vs. Force 1,5 G 2019	0,100000	0,050000	0,84208	78	0,40232
Force 1,5G 2018 vs. Kontroll 2019	0,100000	0,500000	-3,76588	78	0,00032
Kontroll 2018 vs. Poncho pro 2018	0,550000	0,150000	3,62448	78	0,00051
Kontroll 2018 vs. Force 1,5G 2018	0,550000	0,100000	4,24870	78	0,00005
Kontroll 2018 vs. Kontroll 2018	0,550000	0,550000	0,00000	78	1,00000
Kontroll 2018 vs. Dianem alacsony d 2019	0,550000	0,125000	3,92665	78	0,00018
Kontroll 2018 vs. Dianem magas dózis 2019	0,550000	0,150000	3,62448	78	0,00051
Kontroll 2018 vs. Force 1,5 G 2019	0,550000	0,050000	4,96825	78	0,00000
Kontroll 2018 vs. Kontroll 2019	0,550000	0,500000	0,37388	78	0,70950
Dianem alacsony d 2019 vs. Poncho pro 2018	0,125000	0,150000	-0,32078	78	0,74923
Dianem alacsony d 2019 vs. Force 1,5G 2018	0,125000	0,100000	0,34965	78	0,72754
Dianem alacsony d 2019 vs. Kontroll 2018	0,125000	0,550000	-3,92665	78	0,00018
Dianem alacsony d 2019 vs. Dianem alacsony d 2019	0,125000	0,125000	0,00000	78	1,00000
Dianem alacsony d 2019 vs. Dianem magas dózis 2019	0,125000	0,150000	-0,32078	78	0,74923
Dianem alacsony d 2019 vs. Force 1,5 G 2019	0,125000	0,050000	1,18254	78	0,24058
Dianem alacsony d 2019 vs. Kontroll 2019	0,125000	0,500000	-3,45525	78	0,00089
Dianem magas dózis 2019 vs. Poncho pro 2018	0,150000	0,150000	0,00000	78	1,00000
Dianem magas dózis 2019 vs. Force 1,5G 2018	0,150000	0,100000	0,66953	78	0,50513
Dianem magas dózis 2019 vs. Kontroll 2018	0,150000	0,550000	-3,62448	78	0,00051
Dianem magas dózis 2019 vs. Dianem alacsony d 2019	0,150000	0,125000	0,32078	78	0,74923
Dianem magas dózis 2019 vs. Dianem magas dózis 2019	0,150000	0,150000	0,00000	78	1,00000
Dianem magas dózis 2019 vs. Force 1,5 G 2019	0,150000	0,050000	1,49284	78	0,13951
Dianem magas dózis 2019 vs. Kontroll 2019	0,150000	0,500000	-3,16311	78	0,00222
Force 1,5 G 2019 vs. Poncho pro 2018	0,050000	0,150000	-1,49284	78	0,13951
Force 1,5 G 2019 vs. Force 1,5G 2018	0,050000	0,100000	-0,84208	78	0,40232
Force 1,5 G 2019 vs. Kontroll 2018	0,050000	0,550000	-4,96825	78	0,00000
Force 1,5 G 2019 vs. Dianem alacsony d 2019	0,050000	0,125000	-1,18254	78	0,24058
Force 1,5 G 2019 vs. Dianem magas dózis 2019	0,050000	0,150000	-1,49284	78	0,13951
Force 1,5 G 2019 vs. Force 1,5 G 2019	0,050000	0,050000	0,00000	78	1,00000
Force 1,5 G 2019 vs. Kontroll 2019	0,050000	0,500000	-4,45735	78	0,00002
Kontroll 2019 vs. Poncho pro 2018	0,500000	0,150000	3,16311	78	0,00222
Kontroll 2019 vs. Force 1,5G 2018	0,500000	0,100000	3,76588	78	0,00032
Kontroll 2019 vs. Kontroll 2018	0,500000	0,550000	-0,37388	78	0,70950
Kontroll 2019 vs. Dianem alacsony d 2019	0,500000	0,125000	3,45525	78	0,00089
Kontroll 2019 vs. Dianem magas dózis 2019	0,500000	0,150000	3,16311	78	0,00222
Kontroll 2019 vs. Force 1,5 G 2019	0,500000	0,050000	4,45735	78	0,00002
Kontroll 2019 vs. Kontroll 2019	0,500000	0,500000	0,00000	78	1,00000

The damage of root

Root damage values did not exceed 3.5 on the modified IOWA scale, the damage threshold, where the pest was already causing a loss of profit in none of the treatments or control areas (*Table 3*). The highest value of 2.83 occurred in the 2018 control area. The least root damage was observed in 2019 with the Force 1.5 G soil disinfection treatment. Dianem showed relatively good results at a low dose (2 billion/ha) with minimal damage according to IOWA, only 1.45. Based on the data in *Table 3* can be concluded that treatments performed in both 2018 and 2019 reduced root damage to larvae. The fact that the larval number in the control area did not reach (only strongly approached) the hazard value is due to the fact that in the year before the experiment we paid a lot of attention to the control of imagos. We do not dare to risk not protecting against the imagos of *D.v.v.* from the second year onwards in the case of monoculture maize production.

In 2018, the degree of root recurrence as a result of the treatments shows a clear significant difference compared to the control (*Figure 4, Table 4*). This year, the best results were obtained with tefluthrin treatment, but Poncho pro treatment was also far from the economic harm thresholds on the scales.

In 2019, all treatments proved to be effective and showed a significant difference from the control in terms of the degree of root recoil. No significance was observed between low (2 billion/ha) and high (3 billion/ha) dose Dianem nematode treatments. We also found no demonstrable difference between low-dose (2 billion/ha) Dianem and Force 1.5 G treatment, demonstrating that the biologically active agent killed larvae to the same extent as tefluthrin. The formulations applied to the plots kept the root damage of the larvae below the economic threshold (3.5).

Table 3: Extent of root damage (modified IOWA scale) per treatment 2018-2019

		Number of the plants											
		1	2	3	4	5	6	7	8	9	10	Av	Average of 40 plants
Treatments	Number of repeats												
Poncho Pro 2018	I.	2	2	2,5	1,5	1,5	2	2,5	1	3	1	1,9	1,98
	II.	2,5	2,5	3	1	1	3	1,5	2,5	1,5	1,5	2	
	III.	2	2	2	2,5	2	1,5	2,5	1,5	1,5	2,5	2	
	IV.	1,5	1,5	3	2,5	1,5	2	2	2,5	2	1,5	2	
Control 2018	I.	2,5	3	2,5	3	3	3,5	3,5	2,5	3	3	2,95	2,83
	II.	3,5	3,5	3,5	3	2,5	3	2,5	2	3	1,5	2,8	
	III.	2,5	2,5	2,5	3,5	3,5	4	3,5	2,5	2,5	3	3	
	IV.	2	2,5	1,5	3	2,5	3,5	3,5	2,5	2	2,5	2,55	
Force 1,5G 2018	I.	1,5	1,5	1	1	2	1	2,5	1,5	2	1	1,5	1,55
	II.	2	1,5	2	1	1,5	1	1	1	2	2	1,5	
	III.	1	1	1,5	1,5	1,5	2,5	2	1	1,5	1,5	1,5	
	IV.	2	2	1,5	1,5	2,5	1	2	2	1	1,5	1,7	
Dianem 2 billion/ha dose 2019	I.	3	2,5	1	1	1	1	1	1	1,5	1,5	1,45	1,45
	II.	2	2	2	2,5	2,5	1,5	1,5	1	1	1	1,7	
	III.	1	1	1	1	1	1	1	2	1,5	1,5	1,2	
	IV.	2,5	2	1,5	1,5	1,5	1,5	1	1	1	1	1,45	
Control 2019	I.	2,5	2,5	2,5	2,5	2	2	2	1	1	1	1,9	2,15
	II.	1,5	1,5	1,5	2,5	2,5	2,5	2,5	3	2	1	2,05	
	III.	3,5	4	4	2,5	2,5	2	1,5	1,5	1	1	2,35	
	IV.	2,5	2,5	1,5	1,5	3	3	2,5	2	3	1,5	2,3	
Force 1,5G 2019	I.	1	1,5	1	1,5	1	2	1	1,5	1	1	1,25	1,36
	II.	1	1,5	2	1	1,5	2,5	1,5	1	1	1	1,4	
	III.	1,5	2	2	1,5	1	1,5	1,5	2,5	1	1	1,45	
	IV.	1	2	1	1	2	2	1,5	1	1	1	1,35	
Dianem 3 billion/ha dose 2019	I.	2,5	2,5	2	1,5	2	3	1,5	2	1	2,5	2,05	1,7
	II.	1	1,5	2	1	1	1,5	2	1	1	1	1,3	
	III.	2	3	2,5	1,5	2	2,5	2,5	2	1	2,5	2,15	
	IV.	1	1	2	1	2	1,5	1,5	1	1	1	1,3	

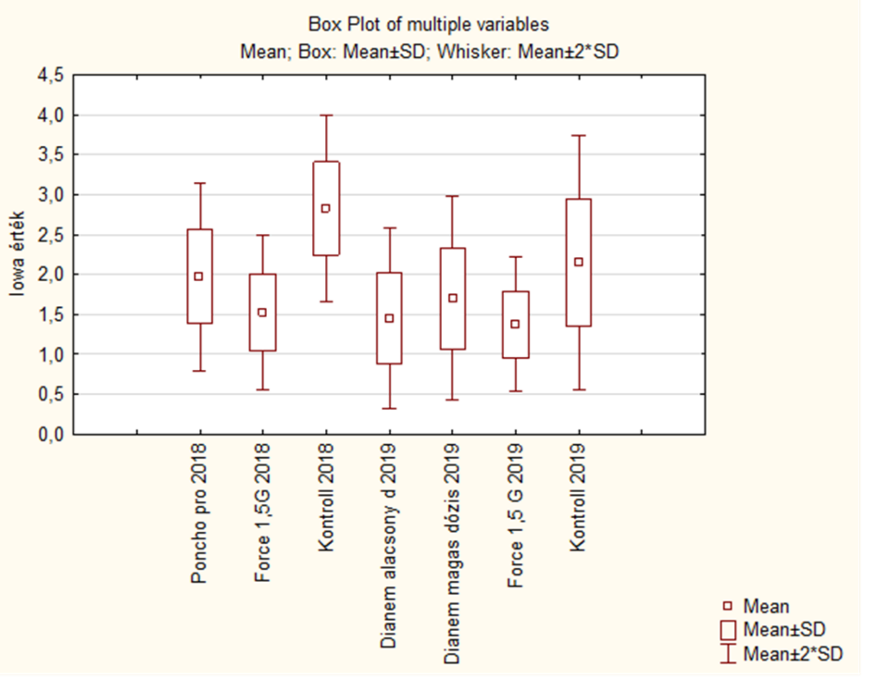

Figure 4: Extent of root damage (modified IOWA scale) 2018-2019

Table 4: Statistical analysis of root damage values (modified IOWA scale) by paired t-test

Group 1 vs. Group 2	T-test for Independent Samples (Vörös Levente low Note: Variables were treated as independent sampl				
	Mean Group 1	Mean Group 2	t-value	df	p
Poncho pro 2018 vs. Poncho pro 2018	1,975000	1,975000	0,0000	78	1,0000
Poncho pro 2018 vs. Force 1,5G 2018	1,975000	1,525000	3,7512	78	0,0003
Poncho pro 2018 vs. Kontroll 2018	1,975000	2,825000	-6,4911	78	0,0000
Poncho pro 2018 vs. Dianem alacsony d 2019	1,975000	1,450000	4,0764	78	0,0001
Poncho pro 2018 vs. Dianem magas dózis 2019	1,975000	1,700000	2,0040	78	0,0485
Poncho pro 2018 vs. Force 1,5 G 2019	1,975000	1,375000	5,2533	78	0,0000
Poncho pro 2018 vs. Kontroll 2019	1,975000	2,150000	-1,1202	78	0,2660
Force 1,5G 2018 vs. Poncho pro 2018	1,525000	1,975000	-3,7512	78	0,0003
Force 1,5G 2018 vs. Force 1,5G 2018	1,525000	1,525000	0,0000	78	1,0000
Force 1,5G 2018 vs. Kontroll 2018	1,525000	2,825000	-10,8853	78	0,0000
Force 1,5G 2018 vs. Dianem alacsony d 2019	1,525000	1,450000	0,6407	78	0,5235
Force 1,5G 2018 vs. Dianem magas dózis 2019	1,525000	1,700000	-1,3859	78	0,1697
Force 1,5G 2018 vs. Force 1,5 G 2019	1,525000	1,375000	1,4881	78	0,1407
Force 1,5G 2018 vs. Kontroll 2019	1,525000	2,150000	-4,2602	78	0,0000
Kontroll 2018 vs. Poncho pro 2018	2,825000	1,975000	6,4911	78	0,0000
Kontroll 2018 vs. Force 1,5G 2018	2,825000	1,525000	10,8853	78	0,0000
Kontroll 2018 vs. Kontroll 2018	2,825000	2,825000	0,0000	78	1,0000
Kontroll 2018 vs. Dianem alacsony d 2019	2,825000	1,450000	10,7179	78	0,0000
Kontroll 2018 vs. Dianem magas dózis 2019	2,825000	1,700000	8,2264	78	0,0000
Kontroll 2018 vs. Force 1,5 G 2019	2,825000	1,375000	12,7583	78	0,0000
Kontroll 2018 vs. Kontroll 2019	2,825000	2,150000	4,3320	78	0,0000
Dianem alacsony d 2019 vs. Poncho pro 2018	1,450000	1,975000	-4,0764	78	0,0001
Dianem alacsony d 2019 vs. Force 1,5G 2018	1,450000	1,525000	-0,6407	78	0,5235
Dianem alacsony d 2019 vs. Kontroll 2018	1,450000	2,825000	-10,7179	78	0,0000
Dianem alacsony d 2019 vs. Dianem alacsony d 2019	1,450000	1,450000	0,0000	78	1,0000
Dianem alacsony d 2019 vs. Dianem magas dózis 2019	1,450000	1,700000	-1,8561	78	0,0672
Dianem alacsony d 2019 vs. Force 1,5 G 2019	1,450000	1,375000	0,6747	78	0,5018
Dianem alacsony d 2019 vs. Kontroll 2019	1,450000	2,150000	-4,5453	78	0,0000
Dianem magas dózis 2019 vs. Poncho pro 2018	1,700000	1,975000	-2,0040	78	0,0485
Dianem magas dózis 2019 vs. Force 1,5G 2018	1,700000	1,525000	1,3859	78	0,1697
Dianem magas dózis 2019 vs. Kontroll 2018	1,700000	2,825000	-8,2264	78	0,0000
Dianem magas dózis 2019 vs. Dianem alacsony d 2019	1,700000	1,450000	1,8561	78	0,0672
Dianem magas dózis 2019 vs. Dianem magas dózis 2019	1,700000	1,700000	0,0000	78	1,0000
Dianem magas dózis 2019 vs. Force 1,5 G 2019	1,700000	1,375000	2,6898	78	0,0087
Dianem magas dózis 2019 vs. Kontroll 2019	1,700000	2,150000	-2,7928	78	0,0065
Force 1,5 G 2019 vs. Poncho pro 2018	1,375000	1,975000	-5,2533	78	0,0000
Force 1,5 G 2019 vs. Force 1,5G 2018	1,375000	1,525000	-1,4881	78	0,1407
Force 1,5 G 2019 vs. Kontroll 2018	1,375000	2,825000	-12,7583	78	0,0000
Force 1,5 G 2019 vs. Dianem alacsony d 2019	1,375000	1,450000	-0,6747	78	0,5018
Force 1,5 G 2019 vs. Dianem magas dózis 2019	1,375000	1,700000	-2,6898	78	0,0087
Force 1,5 G 2019 vs. Force 1,5 G 2019	1,375000	1,375000	0,0000	78	1,0000
Force 1,5 G 2019 vs. Kontroll 2019	1,375000	2,150000	-5,4561	78	0,0000
Kontroll 2019 vs. Poncho pro 2018	2,150000	1,975000	1,1202	78	0,2660
Kontroll 2019 vs. Force 1,5G 2018	2,150000	1,525000	4,2602	78	0,0000
Kontroll 2019 vs. Kontroll 2018	2,150000	2,825000	-4,3320	78	0,0000
Kontroll 2019 vs. Dianem alacsony d 2019	2,150000	1,450000	4,5453	78	0,0000
Kontroll 2019 vs. Dianem magas dózis 2019	2,150000	1,700000	2,7928	78	0,0065
Kontroll 2019 vs. Force 1,5 G 2019	2,150000	1,375000	5,4561	78	0,0000
Kontroll 2019 vs. Kontroll 2019	2,150000	2,150000	0,0000	78	1,0000

CONCLUSIONS

Studies over two years showed that each treatment significantly reduced the number of larves per plant and the degree of root recoil compared to the control. All of the treatments are suitable for controlling corn bug's larves in monocultural growing. In the exact years, the number of chemicals that can be used against Diabrotica larves has greatly decreased, thus increasing the value of environmentally friendly, effective protective biological preparations.

Further studies are needed to clarify how the efficacy of the nematode formulation varies under different weather conditions and different soil types and how the application process could be simplified for large-scale use.

KÉMIAI ÉS BIOLÓGIAI VÉDEKEZÉS HATÁSA AZ AMERIKAI KUKORICABOGÁR LÁRVÁRA (*Diabrotica Virgifera Virgifera* LeConte) SZABADFÖLDÖN

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ÖSSZEFOGLALÁS

Az amerikai kukoricabogár (*Diabrotica virgifera virgifera* LeConte) hazánk egyik legveszélyesebb kukoricakártevője, jelenleg monokultúrás termesztésben elengedhetetlen mind a lárva, mind az imágók elleni védekezés. A lárvák irtása költséges és a nagy mennyiségben felhasznált talajfertőtlenítő szerek fokozott terhelést jelentenek a környezetre nézve. Az utóbbi években a lárvák ellen használható inszekticidek száma nagymértékben leszűkült, így felértékelődnek a környezetkímélő, hatásos védelmet nyújtó biológiai készítmények. Kísérleteink során 2018-ban összehasonlítottuk a Force 1,5 G (teflutrin) talajfertőtlenítő készítmény és a Poncho pro (klotianidin) csávázószer lárvaölő hatását szántóföldi körülmények között. Vizsgáltuk, hogy a költséghatékonyabb, könnyebben kezelhető csávázás hatásfoka eléri-e a drágább talajfertőtlenítő által produkált eredményeket. Miután a neonikotionoidos csávázószerek engedélyét kukoricában visszavonták, 2019-ben egy biológiai eljárás (*Heterorhabditis bacteriophora* entomopatogén fonálféreg) lárvicid hatását kezdtük el vizsgálni. A kísérletek Győr-Moson-Sopron megyében Gyömöre község határában folytak nagy parcellán, 4 ismétlésben.

Megállapítottuk, hogy mindegyik kísérleti anyag a kontrollhoz képest szignifikáns mértékben csökkentette a kukoricabogár lárvák számát. A lárvák okozta gyökérkárosítás a gazdasági küszöbérték (módosított Iowa skála: 3,5) alatt maradt. A rovarpatogén fonálférgek larvicid hatása gyakorlatilag a teflutrinnal megegyező, hatásuk között nem találtunk igazolható különbséget.

Kulcsszavak: amerikai kukoricabogár, *Diabrotica virgifera virgifera* LeConte, rovarpatogén fonálféreg, *Heterorhabditis bacteriophora* Poiner, gyökérkártétel, módosított IOWA skála

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