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DYNAMIC MANIFESTATIONS OF DIABROTICA VIRGIFERA VIRGIFERE LE CONTE IN THE CONTEXT OF THE EXCLUSION OF NEONICOTINOID TREATMENTS IN MAIZE CULTIVATION

Ács Péter-Balázs[1]*, Goga Nicolae[1], Mondici Susana[1], Andraș Beniamin-Emanuel[1], Ursan Patrick[1], Chiver Olivian[2], Butnar Lucian[2], Giurgiulescu Liviu[3]
[1]*Agricultural Research and Development Station (ARDS) Livada, 7 Baia Mare Street, Livada, Romania
[2]Technical University of Cluj Napoca, Faculty of Engineering, Victor Babes 62A, Baia Mare, Romania
[3]Technical University of Cluj Napoca, Faculty of Sciences, Victoriei, 76, Baia Mare, Romania
* *Correspondence author. E-mail*: acsbalazs24@gmail.com

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ABSTRACT

The suspension of neonicotinoid-based seed treatments in 2025 in Romania has renewed concern regarding the population resurgence of the western corn rootworm (Diabrotica virgifera virgifera LeConte), one of the most destructive pests of maize. This study, conducted at the Agricultural Research and Development Station (ARDS) Livada, evaluates the short-term consequences of eliminating neonicotinoid insecticides on maize root damage, adult density, and lodging incidence. Data from prior experiments (2011) and field observations in 2025 were analyzed to assess pest dynamics under varying climatic and agronomic conditions. Results showed that treatments with neonicotinoids such as clothianidin and imidacloprid (e.g., Poncho 600 FS, Nuprid AL 600 FS) significantly reduced larval populations (up to −34 %) and minimized plant lodging (<1 %). In contrast, the 2025 observations revealed renewed plant lodging (up to 3–4 %) and increased signs of root damage, likely associated with mild winter temperatures and the absence of chemical seed protection. Although differences among green manure types and fertilization treatments were statistically insignificant, these factors showed potential for integration into ecological control strategies. The findings emphasize the need for integrated pest management (IPM) approaches that combine crop rotation, soil amendment, biological control, and resistant hybrids to mitigate the expected resurgence of D. v. virgifera populations following the withdrawal of neonicotinoids.

INTRODUCTION

Until the late 1990s, significant yield losses in maize crops across Romania were predominantly attributed to soil pests of the *Agriotes* sp. genus (wireworms), which displayed a preference for podzolic clay-illuvial soils. Currently, however, severe damage is observed on all soil types, primarily caused by *Diabrotica v. v.* species (the western corn rootworm). The insect was first reported in Europe in 1992, near Belgrade, Serbia (former Yugoslavia), and since then its range has expanded at an estimated rate of 25–30 km/year. It was first reported in Romania in 1996 (Nădlac area, Arad County) and later, in 2000, in Satu Mare County (Pișcolt locality). Each subsequent year, the pest has exhibited increased spatial distribution and attack intensity. (Kiss et al., 2005; Ciosi et al., 2008).

Biologically, *Diabrotica* species develop one generation per year under Romanian conditions, overwintering in the egg stage at depths of 15–20 cm (rarely 20–35 cm). Larval development begins when the soil temperature threshold of approximately 11.7 °C is reached. The maintenance of winter diapause requires a minimum of 12–14 days with temperatures above 11 °C following oviposition. Egg-laying generally begins in mid-July, peaks in August, and gradually decreases through September or early October.

Exposure of freshly laid eggs to low temperatures (−5 °C or below) without a preceding cooling period proves lethal: egg and larval mortality increases significantly—egg viability decreases by approximately 50% after seven days at −10 °C and reaches 100 % mortality at −15 °C. Under current climatic conditions, such extreme soil temperatures at oviposition depth are rare, allowing the pest to survive within maize-growing regions.

Larvae usually emerge from mid-May to early August and feed on fine maize roots, sometimes reaching depths of 50–60 cm. In the absence of maize, larvae can feed on the roots of other plants (e.g., soybean, cucurbits). Compact and relatively dry soils (moisture below half field capacity) favor larval mortality; in the first three days after hatching, the absence of a food source leads to over 90–95 % mortality. Under optimal feeding (maize roots) and temperature conditions (20–23 °C), larvae pass through three instars in about 30 days, followed by a pupal stage lasting around 10 days. (Gray et al., 2009)

Adult emergence generally coincides with the pre-flowering stage of maize. Adults live for over 50 days, sometimes up to 80. In the early phases, they feed on the leaf mesophyll, causing leaf bleaching (often in association with flea beetles, *Phyllotreta* spp.). As tassels and silks develop, adults migrate toward these nutrient-rich parts, affecting pollination and, consequently, kernel filling. After oviposition, adults return to the soil surface, continuing their polyphagous feeding on *Gramineae*, *Xanthium* spp., cucurbits, and other plants.

MATERIALS AND METHODS

Beginning in 2025, the use of neonicotinoid-based insecticidal seed treatments in maize cultivation was suspended in Romania, marking the first year in decades in which these substances were no longer applied at sowing. The elimination of seed treatment had visible consequences in numerous field experiments conducted within the Agrotechnics Laboratories of ARDS Livada, where significant maize plant lodging was observed due to larval attacks by *Diabrotica virgifera virgifera* (western corn rootworm).

This study aims to analyze the immediate effects of discontinuing neonicotinoid seed treatments after only one year of non-use and to assess the medium- and long-term trends regarding pest population dynamics. It is anticipated that, in the absence of such treatments, the intensity of both larval and adult attacks by *D. v. virgifera* will increase exponentially, particularly in production systems that disregard crop rotation and maintain continuous maize monoculture. This situation poses major challenges for production sustainability and underscores the necessity of implementing alternative control measures based on integrated pest management (IPM) principles.

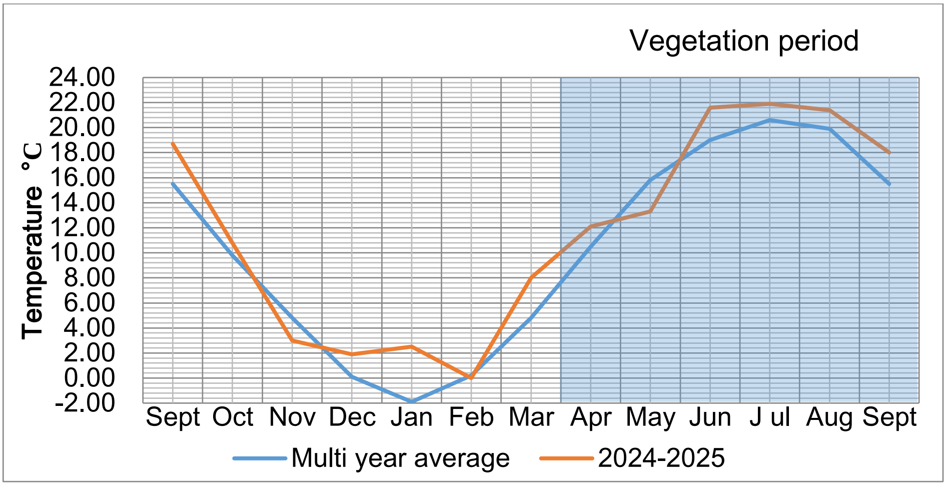

Figure 1. The temperature evolution of the observed period

As previously discussed regarding the biological cycle of *D. v. virgifera*, the absence of severe subzero temperatures during winter favors the survival of a larger number of eggs in the soil. Analysis of climatic data for the observation period indicates that in January, the average temperature was approximately 4 °C higher than the multiannual mean, with significant positive deviations also recorded in September 2024 and March 2025. This situation likely contributed to reduced egg mortality and, consequently, higher larval population densities in the spring of 2025.

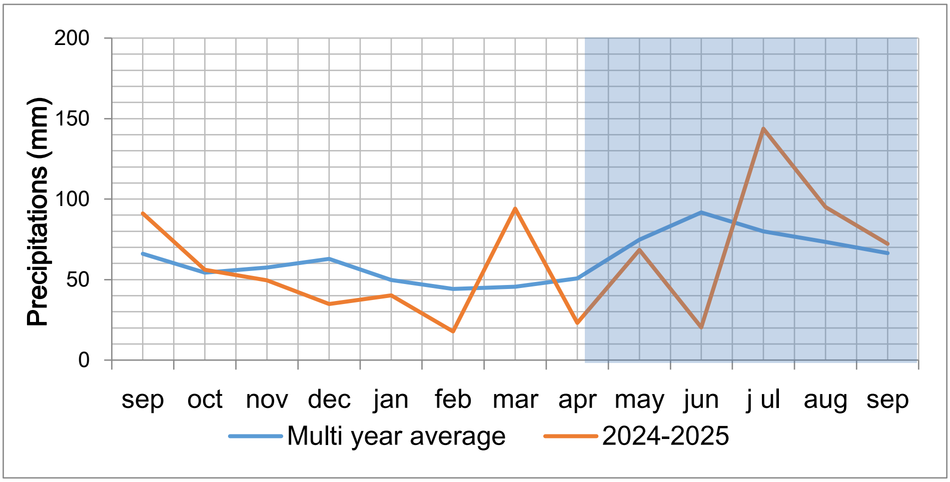

Figure 2. The precipitation evolution of the observed period

Furthermore, analysis of precipitation patterns in recent years reveals a declining trend in total rainfall, which constitutes an additional stress factor for maize crops. Reduced water input affects both germination and early plant development, as well as the plants' ability to compensate for root damage caused by *D. v. virgifera* larvae—particularly in heavy-textured soils with low moisture content.

RESULTS AND DISCUSSION

In 2011, a series of experiments were conducted to test insecticides applied both as seed treatments and in-furrow at sowing for the control of soil pests. The evaluation of a new range of insecticides, primarily from the neonicotinoid group, was necessitated by the withdrawal of older insecticides—either due to their high toxicity (e.g., carbofuran group) or due to cumulative chlorinated residues in the trophic chain.

The obtained results showed that all tested insecticides significantly reduced larval attack intensity on maize roots. The best performance was recorded with the product Nuprid AL 600 FS, which marked y decreased both larval density and root damage intensity.

The table below presents the main pest species of maize crops, along with their economic threshold levels (ETL), estimated yield losses, and recommended control measures. The most important pest identified is the western corn rootworm (*Diabrotica virgifera virgifera*), with an ETL of 2–5 larvae/plant or 5–10 adults/plant in maize for consumption, and 4–5 adults/plant in seed maize. Losses caused by this species range from 10–30 %, depending on population density and hybrid susceptibility. Recommended control measures include crop rotation, soil and seed treatments, and the use of tolerant hybrids (including GM varieties).

Table 1

Economic threshold level of soil pests

No.	Pest	ETL (Economic Threshold Level)	Damage (%)	Control Measures
1	Western corn rootworm (*Diabrotica virgifera virgifera*)	2–5 larvae/plant 5–10 adults/plant (grain maize) 4–5 adults/plant (seed maize)	30–50 10–15 20–25	Crop rotation Soil and seed treatment Tolerant hybrids GMO varieties
2	Wireworm (*Agriotes* sp.)	3–5 larvae/m²	2–20	Soil and seed treatment Crop rotation with repellent plants (e.g., flax)
3	Turnip moth (*Agrotis* spp.)	2 larvae/m²	2–5	Crop rotation Seed treatment
4	European corn borer (*Ostrinia nubilalis*)	50 % of plants attacked at whorl stage	5–7	Stalk residue destruction Resistant hybrids GMO varieties
5	Maize leaf weevil (*Tanymecus dilaticollis*)	3–5 adults/m²	5–10	Crop rotation Seed treatment

For wireworms (*Agriotes* spp.), the ETL is 3–5 larvae/m², with potential yield losses between 2–20 %. Control relies on soil and seed treatments, as well as rotations with repellent crops (e.g., flax). In the case of the turnip moth (*Agrotis* spp.), the ETL is 2 larvae/m², with potential losses of 2–7 %; preventive measures such as crop rotation and seed treatment are recommended.

The European corn borer (*Ostrinia nubilalis*) becomes economically significant when 50 % of plants in the whorl stage are infested, with losses reaching 5–7 % ; control measures include stalk destruction, resistant hybrids, and GM technologies.

Finally, the maize leaf weevil (*Tanymecus dilaticollis*) has an ETL of 3–5 adults/m², causing estimated losses of 5–10 %. Preventive measures include crop rotation and seed treatment prior to sowing.

The data indicate that, compared to the untreated control variants, each insecticidal treatment had a highly significant effect in reducing the larval infestation rate of *Diabrotica virgifera virgifera*.

The best results were recorded for the variants treated with **Poncho 600 FS** (−32.4 %) and **Nuprid AL 600 FS** (−34.0 %) (van Rozen & Ester, 2010; Toth et al., 2021). (Table 2).

Table 2

Larvae attack on maize roots 21.06. 2011

Nr.crt	Variant	Dose Kg,l/to	Number or larvae/100 plante			Degree of attack %		
			Media	Dif	Semnif	Media	Dif	Semnif
1	Untreated	Ct.	147,0	-	-	41,2	-	-
2	Poncho 600 FS	8,7	82,6	-64,4	OOO	17,8	-32,4	OOO
3	Clothianidin+ Imidacloprid 600FS	4,38	65,7	-81,3	OOO	15,4	-25,8	OOO
4(1Dv)	Untreated	-	101,8	-45,2	OO	38,2	-3,0	-
5(2Dv)	Nuprid Al 600 FS	10,0	39,3	-107,7	OOO	7,2	-34,0	OOO
6(3Dv)	Cruiser 350 FS(Std)	18,0	104,4	-42,6	OO	11,9	-29,3	OOO
			LSD5 % 12,8 % LSD 1 % 17,7 % LSD 0,1 % 24,4 %			LSD5 % 10,9 % LSD1 % 15,7 % LSD0,1 % 21,6 %		

Adult *Diabrotica* cause the greatest damage during the maize silking stage. Regarding adult density and activity, a decreasing trend in attack intensity was observed in the treated variants, indicating an overall efficiency of the seed and early-stage insecticide treatments.

Leaf feeding was recorded at the onset of silk emergence, on the leaves situated immediately below the ear.

Although seed treatment was applied, the analyzed data reveal that its effect extends over time, as the adult population density of *D. virgifera virgifera* was significantly reduced in several treated variants (Tabel 3).

Table 3

Influence of insecticide treatment applied to maize seed on adult attack on leaves

No.	Variant	Dose Kg,l/to	Degree of attack %			Frequency %		
			m.	d.	s	m.	d.	s
1	Untreated	-	6,4	-	-	33,1	-	-
2	Poncho 600 FS	8,7	2,6	-3,8	O	22,6	-10,5	OOO
3	Clothianidin+ Imidacloprid 600FS	4,38	2,9	-3,5	O	25,7	-7,4	OO
4(1Dv)	Untreated	-	9,9	+3,5	X	40,1	+7,0	X
5(2Dv)	Nuprid Al 600 FS	10,0	5,5	-0,9	-	26,7	-6,4	OO
6(3Dv)	Cruiser 350 FS(Std)	18,0	4,9	-1,5	-	28,0	-5,1	OO
			LSD 5 % 2,9 % LSD 1 % 4,1 % LSD 0,1 % 5,6 %			LSD 5 % 5,1 % LSD 1 % 7,1 % LSD 0,1 % 9,8 %		

Another aspect evaluated in 2025 was the rate of plant lodging caused by this pest. The results demonstrate that seed treatment remains an irreplaceable protective measure, as each insecticidal variant significantly reduced the percentage of maize plants that lodged, both during the ear formation period and at a later phenological stage, recorded on August 18 (Table 4).

Table 4

Maize lodging at the period of ear formation

Nr.crt	Variant	Dose Kg,l/to	Maize lodging%					
			At ear formation			18.aug.2011		
			m.	D.	s	m.	d	s
1	Untreated	-	3,5	-	-	13,2	-	-
2	Poncho 600 FS	8,7	0,0	-3,5	OOO	2,3	-10,9	OOO
3	Clothianidin+ Imidacloprid 600FS	4,38	0,2	-3,3	OOO	4,4	-8,8	OOO
4(1Dv)	Untreated	-	3,4	-0,1	-	12,1	-1,1	-
5(2Dv)	Nuprid Al 600 FS	10,0	0,0	-3,5	OOO	0,3	-12,9	OOO
6(3Dv)	Cruiser 350 FS(Std)	18,0	0,0	-3,5	OOO	0,2	-13,0	OOO
			LSD 5% 1,7% LSD 1% 2,4% LSD 0,1% 3,3%			LSD 5% 4,5% LSD 1% 6,2% LSD 0,1% 8,5%		

The results of these experiments formed the basis for the registration of the insecticide **Nuprid AL 600 FS**. However, the use of this product together with all other compounds in the neonicotinoid class has been suspended in the current year. Following the prohibition of seed treatments, maize crops this year have exhibited plant lodging caused by *Diabrotica* attacks, as well as additional plant losses attributed to *Agriotes* spp., reaching up to 3–4 %.

In 2025, due to the suspension of neonicotinoid use—including the fungicide-insecticide Nuprid AL 600 FS—no seed treatments were performed. Consequently, the phenomenon of maize plant lodging reappeared, a situation rarely observed in recent years owing to the previous use of treated seed.

As this was the first year of suspension, no new field trials were established specifically for monitoring soil pests. However, visual observations and lodging assessments were carried out within two ongoing agrotechnical experiments. The first experiment investigated the use of green manures and their combination with mineral fertilizers across several agricultural crops over a three-year period. The experimental factors were as follows: Factor A: Type of green manure, with six levels: control (no green manure), rapeseed, sunflower, soybean, pea, and triticale; Factor B: Application of nitro-limestone (CAN, 27 % N), which also provides a significant calcium input beneficial for the acidic soils typical of the ARDS Livada area.

It should be noted that the following table (Table 4) does not present results per experimental year, since the use of the insecticide Nuprid was only suspended starting in 2025. Rather, the years indicate the elapsed time since the incorporation of green manures, serving to analyze their cumulative effects over time. Regarding the percentage of maize plant lodging, the highest value was recorded in the variants one year after green manure incorporation (2.55 %), while the lowest (0.89 %) occurred in variants two years after incorporation. However, these differences were not statistically significant compared with the overall mean across years.

Table 5

Influence of the experimental year

Variant	Maize lodging	%	Difference	Signification
Years average	1,54	100,0	0,00	Ct.
Year 1	2,55	165,4	1,01	-
Year 2	0,89	57,5	-0,66	-
Year 3	1,19	77,1	-0,35	-
LSD (p 5 %) 2,64 LSD (p 1 %) 4,36 LSD (p 0.1 %) 8,16				

Similarly, the type of green manure used did not produce statistically significant differences in maize lodging percentage. However compared to the control unit only one green manure, specifically sunflower obtained negative result with the difference of -0,61 % (Table 6).

Table 6

Influence of the green manure species

Variant	Maize lodging	%	Difference	Signification
Control	1,05	100,0	0,00	Ct.
Rapeseed	1,62	154,6	0,57	-
Sunflower	0,44	42,1	-0,61	-
Soybean	1,78	170,3	0,74	-
Peas	1,72	164,6	0,68	-
Triticale	1,63	155,	0,58	-

LSD (p 5 %) 1,11
LSD (p 1 %) 1,49
LSD (p 0.1 %) 1,98

In relation to this experiment, the smallest deviation from the mean was observed in the chemical fertilizer treatment, with a nonsignificant value of only 0.08 %.(Table 7).

Table 7

Influence of the chemical fertilizer

Varianta	Maize lodging	%	Difference	Signification
Average	1,54	100,0	0,00	Ct.
Fertilized	1,62	105,3	0,08	-
Unfertilized	1,46	94,7	-0,08	-
LSD (p 5 %) 0,96 LSD (p 1 %) 1,29 LSD (p 0.1 %) 1,70				

Analysis of the data did not reveal statistically significant differences among the experimental variants regarding the percentage of plant lodging. Nevertheless, some variations were observed, which may serve in the future as a basis for developing ecological control strategies for *Diabrotica*.

`A second experiment in which plant lodging was observed consisted of a field trial evaluating various commercial amendment- and fertilizer-based products. This experiment was also established on the experimental fields of ARDS Livada and arranged according to the randomized block design.

Due to confidentiality agreements, the commercial names of the tested products are not disclosed.

However, it can be stated that each product was applied at a uniform rate of 500 kg/ha.

Two products were tested, each in two different granulations, resulting in four treatment variants, along with a control variant that followed only the standard local technological practices.

In the second experiment as well, no statistically significant differences were obtained. However, it was observed that soil amendments exerted a moderately positive effect in reducing the activity of soil-dwelling pests. (Table 8).

Table 8

Influence of different soil amendments

Varianta	Maize lodging	%	Difference	Signification
A5	1,33	100,0	0,00	Ct.
A1	1,06	79,8	-0,27	-
A2	1,69	127,0	0,36	-
A3	0,66	49,3	-0,68	-
A4	2,50	187,3	1,16	-
LSD (p 5 %) 2,43 LSD (p 1 %) 3,53 LSD (p 0.1 %) 5,30				

CONCLUSIONS

The results obtained at ARDS Livada clearly demonstrate that the exclusion of neonicotinoid seed treatments leads to an immediate increase in maize plant lodging and visible pest damage associated with *Diabrotica virgifera virgifera*. Previous multi-year experiments confirmed the high efficacy of neonicotinoid products in reducing both larval density and adult feeding, while their current suspension exposes crops to renewed infestation risks.

Although climatic conditions (especially warmer winters) have further favored pest survival, the experiments also indicate that ecological alternatives such as crop rotation, soil fertility management, and the incorporation of green manures can moderately reduce damage intensity. However, their effect alone is insufficient to maintain pest populations below the economic threshold.

Consequently, the sustainable management of *Diabrotica virgifera virgifera* requires the adoption of comprehensive IPM strategies. These include alternating crops, using tolerant or genetically modified hybrids, encouraging natural enemies, and monitoring adult activity to optimize control timing (Levine et al., 2002; Haegele et al., 2023). The long-term viability of maize production in Romania depends on the effective integration of these methods to replace chemical seed treatments while ensuring yield stability and environmental protection.

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