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POSIBILITY TO LIMIT THE WIREWORMS (*Agriotes* spp.) DAMAGES ON POTATO CROPS

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ABSTRACT

Wireworms (*Agriotes* spp.) are the larvae of a group of beetles commonly known as click beetles. They feed on a large number of crops (wheat, barley, maize, potato, clover etc.) and the extent of the damage depends on the numbers present, the growth stage and the vigor of crops.

In recent years, a synthetic pyrethroid new insecticide became a choice for potato growers in their fighting with this voracious pest.

Field trials were conducted at NIRDPSB Braşov, Romania between 2017-2018, using Braşovia variety and the soil was chernozem with pH 6.7. From every plot samples of 2 plants were taken till the final harvest and the tubers washed and analyzed regarding wireworm damage using a rating scale from 0 to 3, corresponding to 0, 1-2, 3-5 and >5 holes per tuber.

Observations were made regarding the dynamics of the growth and development of the plants during the season. Statistical analysis was done using analysis of variance (ANOVA), the statistical and rating differences between mean values was performed by LSD test.

The objective of current study was to find and observe the potential of a new insecticide for wireworm control in potato. The insecticide application, due to the fertilizer compound ensured a vigorous crop with larger plants sizes and a high total biomass. In 2017 the recorded values were higher than in 2018, probably influenced by the climatic conditions.

Keywords: wireworms, potato, seed treatment, efficiency, yield.

INTRODUCTION

For the potato crop the larvae of click beetles (*Agriotes* spp., Coleoptera, Elateride) commonly known as wireworms are a serious pest.

They injure the crop by feeding on the seed piece resulting in poor or weak stands and by tunneling into tubers, which reduce yield quality. Wireworm tunneling also creates an entry point for certain plant pathogens which can rot the tuber (Kuhar et al., 2003).

The attack of wireworms is favored by the degree of soil moisture, the larvae moving vertically or horizontally depending on this particular element (soil moisture) as well as on the reaction of the soil, as these larvae grow in soils having an acid or a slightly acid reaction (Bucurean and Bunta, 2011).

In Romania the main *Elateridae* spp. are: *Agriotes ustulator* (40.1%), *A. obscurus* (17.3%), *A. flavicornis* (10.9%), *A. pilosus* (6.9%), *A. lineatus* (3.8%), *Limonius pilosus* (1.8%), *Synaptus filiformis* (1.6%), *Selatosomus latus* (1.5%) (Popov et al., 2001).

The degree of attack of the larvae of *Agriotes spp*. on different potato varieties depends directly on the content of the tubers in glycaloalkaloids. Laboratory experiments have shown that areas on potato slices with low sugar content and high glycalkaloids content are avoided by wireworms (Jonasson and Olsson, 1994).

The observations made regarding the feeding of the larvae showed that they prefer to dig holes up to the level of the vascular ring in tuber, an area where the sugar concentration is higher, and their continuous circulation is ensured (Molnar, 2003).

If there is not enough food or the density of the larvae is high, they also dig deeper galleries inside the tuber, thus causing qualitative damages.

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The species and feeding mode, as well as the age of the larvae, as well as the natural mortality of approx. 40%. Environmental factors are also important, especially the conditions from the previous year, during May-July, depending on the flight period of the dominant species (Jermy şi Balázs, 1990). Many products have been used in the fighting of this pest over time; an example is fipronil, used in seed treatment (Chaton et al., 2008).

Prophylactic control of wireworms began in 1950 with organoclorines and continue with organophosphates and carbamates. After, attention has focused in the research and registration of risk for wireworms control on various crops (Parker and Howard, 2001). Neonicotinoids (e.g., thiamethoxam, imidacloprid, and clothianidin), synthetic pyrethroids (e.g., tefluthrin, bifenthrin, lambda cyhalothrin and zeta-cypermethrin), and phenylpyrazoles (fipronil) were used for wireworm management in variety of crops (Traugott et al., 2014) and have provided effective control (Fuller and Boetel, 1999; Wilde et al., 2004; DeVries and Wright, 2005).

With many insecticides for wireworm control now disappearing worldwide, there is an urgent need for lower risk, efficacious and cost-effective alternative strategies.

Now a management of wireworm pays attention to the environmental risk and human health.

Potato retailers increase quality demands so that growers must justify their pesticide inputs.

The ban or withdrawal of many of the used soil insecticides and the trend to more conservative soil cultivation techniques led to both an increase of wireworm populations and limitation of the options for their control (Barsics et al., 2013; Ritter and Richter, 2013; Vernon et al., 2008, 2016).

The objective of our research was to study much needed alternative insecticides for wireworm control in potato. We used a granulated insecticide, applied to the soil, containing in the same granule lambda-cihalotrin 4 g/kg and starter microgranulated fertilizer (nitrogen 7% and phosphorus 35%). The active substance - lambda-cihalotrin, in a concentration of 0.4%, is one of the most efficient and lasting of all pyrethroids on the market. The product was applied to the planting and created a halo around the roots, thus preventing the wireworms attack.

MATERIAL AND METHODS

Field trials were conducted at NIRDPSB Braşov from 2017 to 2018, the potato cultivar was Braşovia variety and the soil was chernozem with pH 6.7. In 2017 the preceding crop was colza and in 2018 was winter wheat. The trial sites were ploughed to a depth of 35 cm during the winter and were tilled prior to planting. The compound fertiliser 15N:15P:15K was broadcast at the rate of 800 kg/ha using a fertiliser spreader. The sites were then rotovated and the rows opened in preparation for planting. The trials were planted manually. The design for each trial was a randomised complete block (RCB) with 4 replications per treatment. Each replicate consisted of 8 rows 9 m long. The row width was 0.75 m and the distance between tuber centres was 0.30 m. The total replicate size was 54 m^2 from which 13.5 m^2 were harvested across the centre 2 rows.

Cultivation and maintenance was in line with current good agricultural practice in both years.

Observations regarding the dynamics of the growth and development of the plants were made between June 26 - August 4 in 2017 and between June 25 - August 20 in 2018.

From every plot till the final harvest samples of 2 plants were taken and the tubers washed and analyzed regarding wireworm damage using a rating scale from 0 to 3, corresponding to 0, 1-2, 3-5 and >5 holes per tuber.

Statistical analysis was done using analysis of variance (ANOVA), the statistical and rating differences between mean values was performed by LSD test.

Table 1 shows the treatments performed.

Table 1. Information about the treatments

No.	Product	Dose /row
1	Untreated (control) (V1)	-
2	Insecticide at planting (V2)	10 g/row given to the soil along with the planting (15 kg/ha)
3	Insecticide ½ at planting + ½ at ridging (V3)	6.5 g/row given to the soil along with the planting (10 kg/ha) + 6.5 g/ha given to the soil before the ridging (10 kg/ha)
4	Insecticide at ridging (V4)	10 g/row given to the soil before the ridging (15 kg/ha)

RESULTS AND DISCUSSION

The temperatures and humidity greatly influence the life and the way the larvae move in soil, on variation of the two factors depending the phenomenon of vertical migration.

In 2017 during the vegetation period (May - September) was warmer on average by 1.6°C, compared with the MAA value (15.9°C). The average temperatures were higher in all months, with deviations between +0.7 and +2.6°C.

The amount of precipitation registered (406.2 mm) was similar with the multiannual average (411.9 mm). The distribution of rainfall was more uniform during the vegetation period of 2017. This year rainfall was registered in each month of the period, unlike previous years with months rainfall below normal of the zone (Table 2).

In 2018 during the vegetation period (May - September) the temperature was higher on average by 1.7°C, compared to the MAA. Between May 1 and August 31, the total rainfall exceeded the MMA value by 64.9 mm, with the mention that the distribution of rainfall was very uneven.

Because in May the amount of rainfalls was less with 47.2 mm (42.4% compared to the MAA), the potato planting was difficult and also the vegetation started with difficulty. In June and July, the thermo-hydric conditions were favorable for potato crops. The water necessary for the development of the plants and for the accumulation of potato production was provided from the abundant precipitations of 204.8 mm registered in June (211.8% compared to MAA) and 133.6 mm in July (133.9% compared to MAA). In August, the higher temperature with 2.7°C compared to MAA and less precipitation (46.6 mm, only 61.0% compared to MAA) hastened the drying of the foliage and the maturation of the tubers (Table 2).

Table 2. Average temperature (°C) and monthly distribution of rainfall (mm) during the potato crop vegetation period. Braşov 2017-2018

Year	Month					Average
	May	June	July	August	September	
	Temperature (°C)					
2017	14.3	19.1	19.4	20.0	14.8	17.5
2018	16.3	18.1	18.8	20.2	14.7	17.6
MAA	13.6	16.5	18.1	17.5	13.6	15.9
	Rainfall (mm)					Total
2017	84.2	74.2	111.6	67.6	68.4	406.0
2018	34.8	204.8	133.6	46.6	43.4	463.2
MAA	82.0	96.7	99.8	76.4	52.5	407.4

In 2017 first tubers with wireworms attack were observed on July, 11, in all variants. In the untreated (control) plot 21.3% of the tubers had holes caused by wireworms attack. To the treated variants (V2, V3 and V4) the percentage of tubers with attack varied between 1.1% and 2.5%. The evolution of the percentage of tubers with attack was similar in all variants, the maximum percentage of tubers with attack was recorded on August, 4 (Table 3).

To the untreated (control) variant percentage of tubers with attack increased significantly till July 24, up to 38.8%. The attack increased till August 4, when 42.7% of the tubers had holes due to wire worms. In the observations made after August 4, the percentage of tubers with attack was reduced, but remained above 10%.

A reduction in the percentage of tubers with attack was seen on July 24, when to the variant 4 the attack not exceed 5% (Table 3).

The attack was not as strong as initially expected, mainly due to the low soil moisture from August and September, which did not favor the attack.

In the year 2018 the first signs of the attack emerged to all variants in July, 12. The percentage of tubers with attack increased until the beginning of August. The effect was significant on August, 2 only to the variant 4 by a decrease in the percentage of tubers with attack up to 4.4% compared with untreated (control) (21.0 %).

After that, on August, 20 a decrease was registered, followed by a new wave of growth until the final harvest in September (Table 4).

Table 3. The dynamics of wireworms attack to the tubers in 2017

No.	Variant	% tubers with attack (Test Duncan p = 0.05)					
		June, 26	July, 11	July, 24	August, 4	August, 25	September, 18
1	V1 (control)	0.0	21.3 c	38.8 ab	42.7 a	15.0 cd	25.3 bc
2	V2	0.0	2.5 c	18.2 b	40.6 a	20.1 b	18.6 b
3	V3	0.0	1.3 c	7.8 bc	26.1 a	13.2 b	15.0 b
4	V4	0.0	1.1 cd	5.0 bcd	17.1 a	10.5 abc	11.8 ab
LSD		-	0.009	0.001	0.069	0.357	0.39

Table 4. The dynamics of wireworms attack to the tubers in 2018

No.	Variant	% tubers with attack (Test Duncan p = 0.05)					
		June, 25	July, 12	July, 26	August, 2	August, 20	September, 17
1	V1 (control)	0.0	2.5 a	15.7 a	21.0 a	9.7 a	17.6 a
2	V2	0.0	5.7 a	14.3 a	10.8 ab	4.2 a	9.9 a
3	V3	0.0	6.0 a	10.6 a	12.4 ab	1.3 a	14.2 a
4	V4	0.0	1.4 a	4.4 a	4.4 b	6.0 a	12.9 a
LSD		-	0.48	0.48	0.19	0.35	0.65

From a phenological point of view, during this period the potato plants reached the maximum foliage development and the intense growth of tubers. The measurements and observations made indicate a good vegetation status with vigorous plants. Observations done in July, 11, indicated an maximum average of foliage over 791 g g.m./plant and the roots had an average of 76 g/plant. Regarding the tubers the highest average value (1306 g/plant) was registered in August 4 (Table 5).

The number of main stems was constant throughout the period observed in all the studied variants. The increase in plant height was significant until July, 11. The average values from the subsequent measurements did not differ significantly. There were no significant differences between the growth rates of the plants from different variants. The number of tubers per plant did not differ significantly between June 26 - August 4, due to the favorable thermo-hydric conditions. Between June 25 - August 20, the biomass of potato plants increased from 1036 g g.m./plant to 1461 g g.m./plant. The increases were statistically significant, only in June, 25 (1036 g g.m./plant) and July, 12 (1358 g g.m./plant) (Table 6).

Table 5. Dynamics of biomass components between June 26 and August 4, 2017

Variant	Date	Aerial part g g.m. / plant	Roots + stolons g g.m. / plant	Tubers g / plant	Total fresh biomass g / plant
V1 (control)	26.06	690 abc	64 bc	330 h	1084 ef
	11.07	850 a	82 ab	675 fgh	1607 bcde
	24.07	774 ab	66 bc	1241 abcd	2082 abc
	04.08	479 c	53 c	1129 bcde	1651 abcde
V2	26.06	800 ab	70 bc	394 h	1264 def
	11.07	783 ab	67 bc	869 cdef	1718 abcd
	24.07	725 abc	63 bc	1327 abc	2114 abc
	04.08	612 abc	63 bc	1551 a	2226 a
V3	26.06	617 abc	52 c	305 h	973 f
	11.07	880 a	90 a	1021 cdef	1990 abc
	24.07	717 abc	69 bc	1250 abcd	2035 abc
	04.08	651 abc	63 bc	1502 ab	2216 ab
V4	26.06	711 abc	77 a	461 gh	1249 def
	11.07	650 abc	64 bc	796 efg	1510 cdef
	24.07	552 bc	53 c	1060 cdef	1664 abcde
	04.08	482 c	50 c	1052 cdef	1585 cde
Average values					
26.06		705 ab	65 ab	372 c	1142 b
11.07		791 a	76 a	840 b	1706 a
24.07		692 ab	63 b	1219 a	1974 a
04.08		556 b	57 b	1306 a	1919 a
LSD 5% (Data)		163 g	11 g	207 g	349 g
LSD 5% (Data * Var)		236 g	18 g	349 g	524 g

The favorable hydro-thermic conditions during the vegetation period are reflected by the dynamics of plant growth in 2018.

At the observations of July 12, the plants foliage was on average over 600 g g.m./plant, and the roots and stolons had weighing on average 75-83 g. The maximum development of the foliage overlaps with the accumulation of yield from 329 g to 660 g tubers/plant.

At the future harvest, from July 26 to August 2, the foliage decreased till 271 g g.m./plant, and the recovered roots and rhizomes decreased on average till 48 g mv/plant, and the yield accumulation reached 860-893 g/plant. The total fresh biomass of potato plants decreased from 1395 g g.m./plant to 1212 g g.m./plant (Table 6).

Table 6. Dynamics of biomass components between June 25 and August 20, 2018

Variant	Date	Aerial part g g.m. / plant	Roots + stolons g g.m. / plant	Tubers g / plant	Total fresh biomass g / plant
V1 (control)	25.06	558 abcd	65 abcdef	317 h	939 bc
	12.07	501 bcdef	71 abcde	539 fgh	1111abc
	26.07	441 cdefg	42 def	819 bcdef	1302 abc
	2.08	293 efgh	46 cdef	1016 abcde	1355 abc
	20.08	227 gh	29 f	1279 a	1534 abc
V2	25.06	625 abcd	79 abc	350 gh	1054 bc
	12.07	568 abcd	75 abcd	687 efg	1330 abc
	26.07	575 abcd	57 bcdef	1079 abcd	1710 a
	2.08	251 gh	45 cdef	836 bcdef	1133 abc
	20.08	193 gh	35 ef	1186 ab	1413 abc
V3	25.06	588 abcd	65 abcdef	307 h	959 bc
	12.07	738 ab	88 ab	745 def	1571 ab
	26.07	529 abcde	56 bcdef	796 cdef	1382 abc
	2.08	300 efgh	55 bcdef	885 bcdef	1241 abc
	20.08	271 fgh	34 ef	1133 abc	1440 abc
V4	25.06	757 a	91 ab	342 gh	1190 abc
	12.07	648 abc	99 a	671 efg	1418 abc
	26.07	392 defgh	46 cdef	748 def	1186 abc
	2.08	239 gh	44 cdef	836 bcdef	1119 abc
	20.08	172 h	32 f	1251 a	1456 abc
Medium values					
25.06		632 a	75 a	329 d	1036 b
12.07		614 a	83 a	660 cd	1358 a
26.07		484 b	50 b	860 b	1395 a
2.08		271 c	48 bc	893 b	1212 ab
20.08		216 c	33 c	1212 a	1461 a
LSD 5% (Data)		122 g	16 g	174 g	285 g
LSD 5% (Data * Var)		214 g	30 g	316 g	497 g

In 2017, the average percentage of attack in the untreated V1 (control) variant was 26.1% (Table 7).

The average percentage of attack was significantly reduced for the variant V4 (10 g/row, given to the soil before the ridging), being 11.0%. In the variants V2 (10 g/row, given to the soil along with the planting) and V3 (6.5 g/row, given to the soil with the planting + 6.5 g/row, given to the soil before the ridging) the average percentage of attack of 17.7%, respectively 18.2% were not differentiated significantly.

The significant reduction of attack percentage was only to the tubers of 35-60 mm size. To this size, in the variants V3 and V4 the percentage of yield with wireworms attack was 12.6%, respectively 11.5% compared to 25.3% registered in untreated variant V1 (Table 7).

Table 7. The percentage of the tuber production with wireworms attack to the final yield (Braşov, September 18, 2017)

No.	Variant	Average percentage (%) of attack on total production	Percentage of tuber wireworm attack (%) on size fraction		
			> 60 mm	35-60 mm	<35 mm
1	V1 (control)	26.1 a	29.6 a	25.3 a	23.5 a
2	V2	17.7 ab	21.5 a	17.8 ab	13.9 ab
3	V3	18.2 ab	21.9 a	12.6 b	20.1 a
4	V4	11.0 b	14.8 a	11.5 b	6.5 ab
LSD 5%		10.0%	16.9%	7.7%	12.3%

In 2018, the average percentage of yield with wireworm attack on final production ranged between 13.3 and 20.8 (Table 8).

The average percentage of attack on total production to the untreated V1 (control) variant was 20.8%. The total average percentage of attack was significantly reduced for the variant V2.

Between the treated variants there were no significant differences generally, but in the variant V3 (6.5 g/row, given to the soil with the planting +6.5 g/row, given to the soil before the ridging) for the fraction tubers >60 mm the percentage of attack was higher that in the other cases (Table 8).

Table 8. The percentage of the tuber production with wireworms attack to the final yield (Braşov, September 17, 2018)

No.	Variant	Average percentage (%) of attack on total production	Percentage of tuber wireworm attack (%) on size fraction		
			> 60 mm	35-60 mm	<35 mm
1	V1 (control)	20.8 a	23.5 a	20.4a	18.4 a
2	V2	11.0 ab	16.2 ab	10.5 b	6.4 b
3	V3	14.8 ab	25.6 a	10.9 b	8.0 b
4	V4	13.3 ab	19.0 ab	10.0 b	10.6 b
LSD 5%		16.2%	22.1%	14.5%	21.8%

CONCLUSIONS

Given the increasing degree of pest attack due to climate change, the control strategy must be rethought so as to obtain high yields in conditions of food safety and efficient environmental protection.

Wireworm populations were low to throught the experiment period. Insecticides application has demonstraded effect on tubers quality. The average percentage of yield with wireworm attack on final production ranged between 11% and 26.1% (untreated variant) in 2017 and between 13.3% and 20.8% (untreated variant) in 2018.

The insecticide application, due to the fertilizer compound, ensured a vigorous crop with larger plants sizes and a high total biomass. In 2017 were recorded higher value than in 2018, influenced by the climatic conditions.

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