Pheromone monitoring of click beetles as a basis of elaters harmfulness forecast and sustainable insecticide application

Monitoring feromonowy sprężykowatych jako podstawa do prognozowania szkód i celowości zabiegów chemicznych

Lyudmila Trepashko, Olga Ilyuk

Summary

Soil excavation results determined the structure of elater dominance in grain crops and corn in Belarus. Three click beetle species were dominant: *Agriotes sputator* L., *A. lineatus* L., and *A. obscurus* L. A high efficiency of click beetle sexual pheromone was obtained. The pheromone was synthesised at the Organic Chemistry Department of the Belarussian State University. Click beetle monitoring with the help of pheromone traps, and a technique for defining wireworm population density, and their harmfulness forecast on the caught beetles is developed. The economic thresholds of wireworm harmfulness in agriculture were calculated. Beetle numbers were defined according to those caught in pheromone traps and the beetle numbers corresponded to larvae threshold indicators. An assortment of effective insecticidal seed dressers against the given pests was formed.

Key words: Click beetles, elaters, insecticides, pheromone monitoring, pheromones

Streszczenie

W oparciu o wyniki analizy gleby pod kątem liczebności sprężykowatych, określono ich skład gatunkowy oraz udział poszczególnych gatunków w uprawach zbóż i kukurydzy. Wśród dominujących gatunków stwierdzono występowanie: *Agriotes sputator* L., *A. lineatus* L. oraz *A. obscurus* L. Na uwagę zasługuje wysoka efektywność atraktantu – syntetycznego feromonu płciowego opracowanego w Zakładzie Chemii Organicznej Państwowego Białoruskiego Uniwersytetu. Przedstawiono wyniki monitoringu sprężykowatych, dokonanego przy użyciu pułapek feromonowych, a także z zastosowaniem technik pozwalających na określenie nasilenia populacji szkodników i ich przewidywanej szkodliwości w oparciu o liczbę odłowionych chrząszczy. Liczebność chrząszczy określono na podstawie liczby osobników odłowionych w pułapkach feromonowych oraz liczby chrząszczy odpowiadającej liczbie larw w analizowanej glebie. Ponadto, obliczono progi ekonomicznej szkodliwości sprężykowatych w uprawach rolniczych. W pracy omówiono również asortyment skutecznych zapraw nasiennych do zwalczania sprężykowatych.

Słowa kluczowe: sprężykowate, insektycydy, monitoring feromonowy, feromony

Institute of Plant Protection
223011, Minsk region, p. Priluki, Mira Str.2, Belarus
entom@tut.by

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Introduction

Click beetle larvae (wireworms) have spread everywhere and can damage a wide range of cultivated plants in field crops, and where vegetables are grown, in woods and in garden nurseries. All over the world wireworm harmfulness and also crop protection against this pest are a part of ecology which have been given much attention. In Belarus, wireworms are the most important group of polyphagous, insect pests in field crops. Wireworms are widespread in agrocenosis of the Republic, making up to 59% in number of a soil mesofauna and 24% of a soil mesofauna biomass. In Belarus, wireworms particularly damage basic crops (corn, grain crops, potato, beet). The larvae cause crops thinning, damaged plants, a decrease in the marketability of the plants, deterioration of tuber and root crops, and decreases in yields. Corn, beet, and grain crop thinning can be so great that re-seeding considerable areas becomes necessary.

Chemical plant protection measures against wireworms must be highly effective and ecologically safe. The different insecticide applications must take into account the amount of the pests present. Till now, the labour-intensive method of soil excavation has been used to definition density of wireworms. The use of pheromone traps is the common method of monitoring and controlling these pests. The traps have been successfully used in a number of European countries (Germany, France), the USA and Canada (Vernon and Tóth 2007; Hicks and Blackshaw 2008; Cannaert *et al.* 2011; Vidal *et al.* 2011). Monitoring with the use of pheromones, allows for the possibility of finding out the number of pests beforehand. The harm wireworms could cause can then be predicted, and an economically proved plan of protective measures may then be enforced. In Belarus, click beetle imago numbers are recorded with the help of the pheromone traps developed by Pristavko (1979) and Guk (1991). However, no research has been done defining larvae numbers based on the caught beetles.

Materials and methods

The research was carried out in the 2006–2011 time period, on farms in the Republic of Belarus: in the districts of Minsk (the Minsk, Smolevichy and Slutsky region), Gomel (the Rogachev region), and Brest (the Brest region). Farm fields of winter wheat, spring wheat, oat and corn cultivated after different previous crops with unequal wireworm numbers, were selected. The soil was sod-podzolic or light-loamy.

The number of soil insects was determined by using a drill designed by G.K. Pjatnitsky, to dig to a depth of 30 cm and an area diameter of 11.3 cm (the area 0.01 m^2). The invertebrates were taken out layer by layer. A palette-knife was used to repeatedly put some soil aside on an oilcloth. The insects were then placed in test glasses. There was a 4% concentration of formalin solution in the glasses (Pristavko 1979).

On stationary fields of grain crops, a randomized soil sample selection was done on the whole field area at the following times: before sowing, up to the time of trapping, at the tillering stage, and after harvesting. At the same time the dynamics and plant severity were determined in the field diagonally, on test plots 50×50 cm (0.25 m^2) in 10 places on each plot.

On isolated fields, the number of wireworms was defined at the following times: before sowing, up to the time of trapping, at the seedling stage, at the stem formation stage, and after harvesting. Before sowing and after harvesting, soil samples were selected in the field diagonally in a checkerboard style. On plots that were up to 100 ha – 16 samples are taken. If there were more than 100 hectares an additional 4 samples per every 100 hectares were taken (Soroka 2005; Trepashko *et al.* 2009).

At the corn seedlings stage, samples of wireworms were taken from 10, one-linear-meter places. Simultaneously on these rows, corn severity dynamics were recorded. Where the total number of the dead and suppressed plants were determined, the percent of severity was defined.

The average density of wireworms settling on corn, taking into account the frequency of occurrence, was defined by the formula:

$$Y = ((X*0) + (X_1*1) + (X_2*2) + \ldots + (X_n*n)) * 9* 2/N*n$$

where:
Y – the average number of wireworms per 1 linear metre;
X – number of samples without wireworms;
X_1 – number of samples where wireworm numbers are equal to one unit;
X_2 – number of samples where wireworm numbers are equal to two;
X_n – number of samples where wireworm numbers are equals to n;
n – maximum wireworm numbers in a sample;
N – total number of samples.

The average density of wireworms settling on grain and other crops before sowing, while taking the frequency of occurrence into consideration, was determined by the formula:

$$Y = ((X*0) + (X_1*1) + (X_2*2) + \ldots + (X_n*n)) *100/N*n$$

where:
Y – the average number of wireworms per 1 sq. m;
X – number of samples without wireworms;
X_1 – number of samples where wireworm numbers are equal to one unit;
X_2 – number of samples where wireworm numbers are equal to two;
X_n – number of samples where wireworm numbers are equals to n;
n – maximum wireworm numbers in a sample;
N – total number of samples.

Wireworm determination by species was done using B.M. Mamayev's determinant (Mamaev 1972).

As recommended by E. Judenko, the harmfulness of elaters was estimated by the chemical control method and by developing models for plots, in which the plots had different degrees of plant severity. In crops, test plots with different severity were selected: in grain crops – an area of 0.25 m^2 (50×50 cm) was selected, in corn – 1 row

linear metre. In the same fields, near the test plots, soil excavation was carried out to determine click beetle numbers. The trials were done in 8 repetitions. The crop from each test plot was harvested separately and recalculated in cwt/ha.

Click beetle imago were caught in „Estron" traps. The traps were made of polystyrene, in the form of a hollow cone, closed at the bottom by a cover. In the top part of the traps there was a 2.5 cm^3 volume compartment where the pheromone source was located. The compartment had cracks for the evaporation of the synthetic attractant. The assembled trap height was – 7 cm, the bottom diameter – 16 cm, the weight – 140 g. Pheromones were provided by the Organic Chemistry Department of the Belarus State University (BSU).

The traps were located at the soil surface level, 30–50 m having receded from a field margin. On grain crop fields the traps were located randomized, in corn – in rows. The distance between traps was 100 m.

The traps were placed in winter crops, in the I–II decades of April corresponding to the start of crop vegetation. Traps were placed in spring grain crops, in the II–III decades of April (after crop sowing/start of seedlings). Traps were placed in corn crops, in the III decade of April – the I decade of May (after sowing crops). Trap records were made every decade up to the end of the beetles' flight.

The collected biological material was exposed to faunal processing. The specific structure of the elaters was defined using V.G. Dolin's, E.L. Gurevaya's, Z. Toth's determinants (Tóth 1984; Tarnawski 2000).

Results and discussion

In Belarus, during the 2005–2008 time period, the structure of elater domination in grain crops and corn was determined using the results of the soil excavation. Three species of click beetles were dominant: the sowing (*Agriotes sputator* L.), striped (*A. lineatus* L.) and dark (*A. obscurus* L.). From other elater species, there were representatives of the genus *Selatosomus* Steph. and *Athous* Eschz.

Based on the established structure of domination, the synthetic click beetle sexual attractants were synthesized at the Organic Chemistry Department of BSU. The attractiveness of 17 synthetic sexual pheromone experimental samples was studied during the 2006–2008 time period of the research. The estimation of the attractiveness of the pheromone compositions was estimated after using the „Estron" traps in corn, and spring and winter grain crops in the Republic of Belarus. The click beetle imago which were caught, were defined to species. The processing of the biological material which had been collected using pheromone traps, revealed the most attractive composition in relation to dominant click beetle species – Agvabat (25BO)10 (Hotko 1993; Purenok 2005).

The results of the research showed a close correlation dependence between wireworm number in the soil and beetle number caught by pheromone traps. The technique for explaining larvae population density by the number of beetles caught in pheromone traps was developed. On farms, the pheromone trap method had a 77–83% reliability.

Based on the long-term data from the entomology lab, the economic thresholds of expediency of insecticides application against elaters in corn cultivated for green mass and grain, and in spring and winter grain crops, was calculated (Table 1).

Statistical processing determined the beetle numbers caught by pheromone traps which correspond to EHT (Egg Harbor Township) wireworms, in different agricultural crops (Table 2).

Based on the established number of elaters, it is possible to predict beforehand what their harmfulness in agricultural crops would be. A decision on the expediency of plant protection product applications can then be made. For agricultural crop protection against elaters, the most ecologically friendly and economically effective is using insecticides in the pre-sowing seed treatment.

Table 1. Economic thresholds of wireworm harmfulness (EHT) in corn and grain crops

Crop	Economic thresholds of harmfulness [indiv./m^2]
Corn	
For grain	20–25
For green mass	25–30
Spring grain crops	
Barley for grain and fodder	30–35
Brewing barley	20–25
Wheat for food purposes	20–25
Oats	25–30
Winter grain crops	
Wheat for food purposes	25–30
Triticale	30–35
Rye	45–50

Table 2. Number of beetles caught by pheromone traps, corresponding to the economic thresholds of elater harmfulness in agricultural crops

The control crop	Planned crop for the next year					
	corn		spring grain crops		winter grain crops	
	for grain	for green mass	barley for brewing	barley for fodder	wheat	rye
	economic threshold of elater harmfulness [indiv./m^2]					
	20–25	25–30	20–25	30–35	25–30	45–50
	click beetles caught [indiv./trap]					
Winter grain crops	45–55	55–67	45–55	67–77	55–67	100–110
Spring grain crops	118–145	145–175	118–145	175–205	145–175	265–295
Corn	250–310	310–370	250–310	370–440	310–370	560–620

Table 3. Calculation of a suitable preparation application rate for the pre-sowing corn seed treatment by using the number of click beetle imagos caught in pheromone traps (the control examples)

Click beetles imago caught [indiv. / trap]	Predicted indicators:				Calculated rate of the insecticide gaucho application [l/t]
	number of click beetles [indiv./m^2]	plant damage [%]	green mass yield losses		
			[%]	[cwt/ha]	
50	15	13	5,2	15	is economically not expedient
110	35	25	10	30	4,5
150	45	38	17	51	4,7
180	55	47	21	63	5,0
280	90	76	45,6	137	5,8

Long-term research has come up with an assortment of effective insecticides as seed dressers, including 13 preparations in corn, and 9 – in grain crops. The insecticide applications reduced elater numbers, on the average, 45–60%, plant severity was reduced 78–95%.

The expediency of preparation applications, and the optimum rate of the application are defined based on the harmfulness forecast of calculated wireworm density by caught beetles. The control examples are presented in Table 3.

Conclusions

1. The structure of elater domination in grain and corn crops in Belarus was determined. Three species were dominant: sowing (*Agriotes sputator* L.), striped (*A. lineatus* L.) and dark (*A. obscurus* L.). Other elater species, showed representatives of the genus *Selatosomus* Steph. and *Athous* Eschz.
2. The attractiveness of 17 synthetic click beetle sexual pheromones synthesized at the Organic Chemistry Department of the Belarussian State University, was studied. The most effective one was determined.
3. A close correlation dependence was found between wireworm number in the soil and the quantity of beetles caught by pheromone traps. On the basis of the obtained results, a method for determining the formed larvae population density using the beetle numbers caught in pheromone traps, was developed.
4. Economic thresholds of the expediency of insecticide application against wireworm on corn cultivated for green mass and grain, and spring and winter grain crops, were calculated.
5. The beetle numbers caught by pheromone traps corresponding to wireworm EHT in different agricultural crops was determined using statistical processing.

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