Biological support of a potato protection system against the Colorado beetle (*Leptinotarsa decemlineata* Say) in Belarus

Systemy ochrony upraw ziemniaka przed stonką ziemniaczaną (*Leptinotarsa decemlineata* Say) na Białorusi

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Summary

In the article, the results of long-term research (2006–2010) on biological substantiation and the improved potato protection system against Colorado beetle in Belarus are presented. The system is based on age and the phenotypic structure of the phytophage population definition, and their resistance monitoring to pyrethroids by frequency of phenomorph №3 occurrence. The system includes a pre-planting tuber treatment, or spraying growing plants with different preparations. The economic expediency thresholds of insecticidal protection depending on weather conditions, varietal features, planned productivity, and a special-purpose designation of the crop cultivated in different agroclimatic zones were taken into account. Now, the improved system of potato protection against the pest is widely promoted on the farms of the Republic.

Key words: agroclimatic zone, Colorado beetle, insecticide, efficiency, phenotypic structure of populations, potato, resistance, variety

Streszczenie

Przedstawiono wyniki wieloletnich badań (2006–2010) nad systemami ochrony upraw ziemniaka przed stonką ziemniaczaną na Białorusi.

Rezultatem prowadzonych badań systemu ochrony upraw ziemniaka przeciwko stonce ziemniaczanej było jego zmodyfikowanie i obecnie obejmuje: fenotypową strukturę populacji szkodnika, monitoring odporności na pyretroidy w oparciu o nasilenie występowania fenotypu 3, zaprawianie bulw ziemniaka przed sadzeniem, zabiegi opryskiwania roślin w okresie wegetacji, biorąc pod uwagę opracowane ekonomiczne progi szkodliwości oraz potrzebę przeprowadzenia zabiegu w zależności od warunków pogodowych, cech odmianowych ziemniaka, przewidywanego plonu oraz przeznaczenia danej uprawy.

Słowa kluczowe: strefa agroklimatyczna, stonka ziemniaczana, insektycyd, skuteczność, fenotypowa struktura populacji, ziemniak, odporność, odmiana

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Introduction

The results of the phytosanitory monitoring of potato agrocoenosises indicate that Colorado beetle (*Leptinotarsa decemlineata* Say) can be found throughout the whole territory of Belarus. Based on the data from this research study, the pest colonizes 98–100% of the surveyed potato plantings annually (Brechko 2010) while 20 years ago, in the northern zone from 2 to 30% of the areas were colonized, in the central zone from 10 to 50, and in the southern zone about 60%. In the 1970–1980, a potato protection system against the phytophage (Kurilov 1979, 1989) was offered for pest suppression and crop loss prevention. At the same time, the offered system underwent changes which demanded a more detailed deeper analysis and recording.

At present, the most effective and economical means used against the potato beetle is still the chemical method (Pawińska 2005; Barcic *et al.* 2006; Oroian 2008; Hitchner *et al.* 2012). However, the intensive long term use of insecticides has caused resistant pest populations first to chloro-organic and then to phosphororganic preparations and pyrethroids (Bykhovets 2000). Chemical means cause a critical impact on microevolutionary transformations in phytophage populations. This can be seen in the external insect polymorphism which leads to genetic structural changes in insects. The Colorado beetle quickly adapts to a wide range of ecological conditions accompanied by the above listed or other phenotypic structural changes of its populations (Fasulati 2000; Vasilieva 2004).

It is necessary to point out, that at this time a change of agroclimatic zone borders has taken place, the assortment of cultivated potato varieties has been enlarged, and the assortment of plant protection products has improved. The Colorado beetle is an ecologically plastic and genetically polymorphic species (Ushatinskaya 1981; Fasulati 2000). The first objective of my work was to study the Colorado beetle populations' phenotypic structure, and resistance monitoring to insecticides. The second objective was to substantiate the expediency of the insecticide applications in the crop plantings in different agroclimatic zones of the Republic.

Materials and methods

The research was carried out in the 2006–2010 time period, in all the agroclimatic zones of Belarus. Supervision over number dynamics, specification of bioecological features, and the estimation of the efficiency of measures taken for decreasing the Colorado beetle were done on the experimental field of the RUC (Institute of Plant Protection) and on the main potato-producing farms. The industrial check of an advanced system of potato protection against pests was done in 2010, at the agricultural enterprises of the Minsk area.

The pest number definition was done by a method of registration platforms consisting of 5–20 plants next to each other (Volovik 1995). Potato plant leaf surface damage degree was noted on a scale (in points) (Pavljushin 1995).

The phens in the Figure 1 show the types of the imago; front, back (pronotum), and central part, for the comparative analysis of the phenotypic polymorphism of the Colorado beetle populations, 9 variations according to Fasulati (1985) classification were used:

- type №1 – stains A and stripes B are merged (phen AB), stain P is brightly expressed;
- type №2 – drawing is not symmetric (phen AB), stain P is brightly expressed;
- type №3 – stains B and stripes A are divided (phen B), stain P is brightly expressed;
- type №4 – stains B and stripes A are merged (phen AB), stain P is poorly expressed;
- type №5 – drawing is not symmetric (phen AB), stain P is poorly expressed;
- type №6 – stains B and stripes A are divided (phen B), stain P is poorly expressed;
- type №7 – stains B and stripes A are merged (phen AB), stain P is absent;
- type №8 – drawing is not symmetric (phen AB), stain P is absent;
- type №9 – stains B and stripes A are divided (phen B), stain P is absent (Fig. 1).

The potato planting expeditionary survey on the overwintered Colorado beetle imago collection was carried out in the 2007–2010 time period, according to the method of Zakharenko (2002). In the research, the imago collected on the agricultural establishments and smallholdings in all the agroclimatic zones were used. The beetle collection was carried out during the period of potato crop mass colonization at stage full germination – blossoming (June, July). During each recording, 120–250 beetles were collected. During the years of the research 407 beetle samples were analyzed; a total number of over 30 thousand individuals.

For Colorado beetle population resistance diagnostics to the chemical group pyrethroid insecticides, a morphotypical method is used according to the following gradation: if the №3 morph's share from total morphs is up to 15% – the population is sensitive; up to 20% – tolerant; up to 30% – resistant; up to 50% – highly-resistant (Vasilieva 2004).

The research was carried out in different regionalized groups of mature potato varieties. Working out of economic thresholds of expediency of insecticide applications was done on the basis of the harmfulness coefficients (Trepashko 2000). The biological efficiency of the insecticides is calculated according to Henderson and Tiltone's formula (1955):

$$E = 100 \times \left(1 - \frac{Ta \times cb}{Tb \times ca}\right)$$

where:

E – efficiency, expressed as pest number decrease percentage compared to the control;

Tb – the number of alive individuals before the trial treatment;

Ta – the number of alive individuals after the trial treatment;

cb – the number of alive individuals in the control during a preliminary recording;

Features (phens)	Stains A and B are merged: phen AB	Drawing is not symmetric: phen AB	Stains A and B are divided: phen B
Stain P is brightly expressed: phen (p)	 Type №1	 Type №2	 Type №3
Stain P is poorly expressed: phen (p)	 Type №4	 Type №5	 Type №6
P stains are absent: phen (–)	 Type №7	 Type №8	 Type №9

Fig. 1. The basic types of Colorado beetle imago. A front, back, and central part drawing of their sign constituents (phens) and arbitrary numbers

ca – the number of alive individuals in the control during a further recording (Dolzhenko 2004).

The economic efficiency of chemical measures was evaluated according to the recommendations of Sorochinsky *et al.* (1999). The statistic processing of the research results was done using a correlation-regression and dispersion method (Dospekhov 1985). The electronic phenomorph bank was created by means of the special programs of the database service Microsoft Access for Windows.

Results and discussion

By the results of phytosanitory potato agrocoenosises monitoring, a change in the degree of plant colonization, and the pest number dynamics depending on the agroclimatic zone is revealed. During the period of mass plant colonization, the phytophage number in the northern region varied within 8.1–9.8 indiv./registered plant, in the central – 10.1–71.5, in the southern – 19.6–93.5 indiv./registered plant. The plant colonization was 33.3–49.6%, 42.4–97.3 and 63.8–99.5%, accordingly. This situation is caused by the more favourable conditions for pest development in the southern region.

In connection with the zonal pest incidence, the differentiation in the carrying out of protective measures is possible. The specification of biological and phenological phytophage features in various ecological conditions is also necessary. In the southern region, potato plant settling by the pest takes place 1–2 weeks earlier, in separate years 3 weeks earlier in comparison with the central region, and 2–3 or more weeks earlier than in the northern region. The period of mass larvae hatching in southern regions is earlier by 5–15 days.

As a result, in the south of the Republic the phytophage developed in two generations. The last generation does not have a complete or full evolutionary cycle. In years with an air rise temperature of 0.8–7.1°C, the development of a third generation was observed. In the seventies of the last century, it was determined that in the south, only two generations (Arapova 1976) were developed. In the northern and central zones, during all of the research years, the first full and the second incomplete generations were marked.

Taking into account the age structure of populations, the pest number dynamics study has shown that during mass settling, the share of second age larvae was more than 40–50% from the total.

It is proved that abiotic factors: soil temperature both in winter and in the spring-summer periods, air temperature, and rainfall have a regulating influence on the dynamics of the pest number. For example, in 2007 in the Minsk district, at air temperatures in the I–II decades of June above a mean annual rate of 4.0–4.8°C and when there was an insignificant amount of precipitation, the pest mass development was noticed and the larvae number reached 42.1 indiv./plant. While in 2008, a lethal soil temperature decrease during the winter period (–12°C), and the air temperatures at the mean annual level meant a larvae decrease of 3.5 times, in comparison with the previous year.

Data analysis was done to reveal the plant settlings by the pest according to potato variety. It was determined, that early and mid-early varieties are colonized 5–7 days earlier in comparison with mid-ripening, mid-late, and late varieties. The maximum larvae number in early and mid-early varieties fluctuated within 23.0–65.1 indiv./plant which considerably exceeded the values in mid-ripening, mid-late, and late varieties – 12.0–45.3 indiv./plant.

While studying the Colorado beetle harmfulness, we have found that poor-resistant and unstable varieties are damaged by the pest to a greater degree. In early and mid-early potato varieties, the maximum coefficients of harmfulness on the productivity decrease were 1.04–1.19%

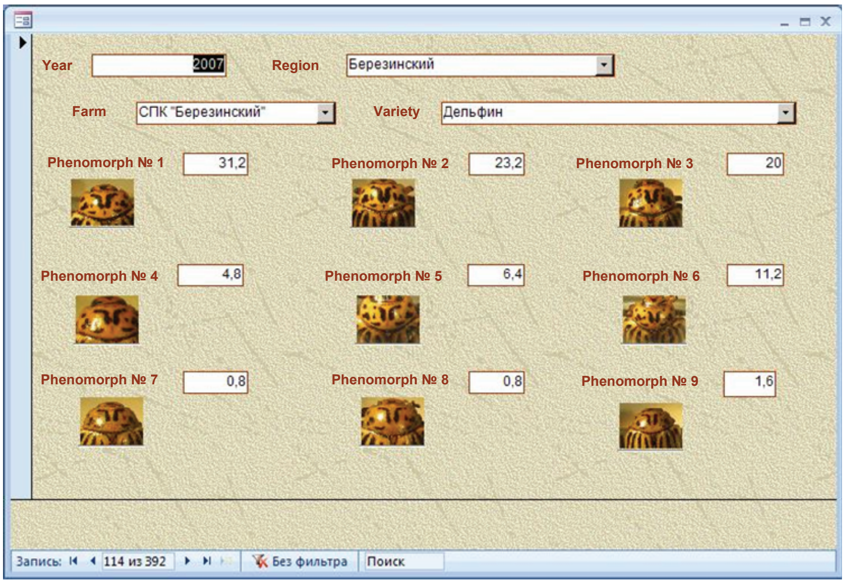

Fig. 2. Output form of the work with database on Colorado beetle imago phenomorph

(the central agroclimatic zone), and in mid-ripening, mid-late and late – 1.26–1.45% (the southern zone). In high-resistant and resistant varieties, the coefficients decrease was 0.42–0.78%. In the southern agroclimatic zone, the relative coefficients of harmfulness were higher than in the central zone.

The different degrees of potato planting settling and phytophage harmfulness by agroclimatic zones, and the intensive and long term use of the pyrethroid chemical class of insecticides (more than 20 years) mean that a necessity has arisen for the study of the phenotypic structures of populations. Phenomorph №1–3 domination was revealed, the phenomorphs №7–9 were seldom met; their domination reached 7.1%. According to the morphotypic method of estimation, phenomorph №3 incidence, being a resistance marker, varied from 14.0 to 25.4%, diagnosing the pest populations from sensitive to the resistant. During recent years, in the applied insecticides structure, l neonicotynoids (70–85%) prevailed in the southern zone, and populations resistant to pyrethroids were met. Based on the research results, a computer database was created (Fig. 2).

The information is structured by years, areas, farms, varieties, and frequency of phenomorph №1–9 incidence in percentages. The information shows the various degrees of pest population sensitivity to pyrethroids based on overwintered or young beetles. The accumulated information can help make the decision for well-founded choices of insecticides in concrete agrocoenosises. Tactics of insecticide application can be made from an assortment of chemical products to be purchased. Universal incidence of high Colorado beetle harmfulness and also the insignificant areas of cultivated varieties made it possible to improve the system of protective measures at the expense of the assortment expansion, technology, and methods of use (before planting or during vegetation) of the insecticides.

The pre-planting tuber treatment using insecticides from the neonicotynoid group was found to be an effective method against the pest development on potato. The long period of protective action (more than 80 days) provided a cancellation of product treatments during vegetation. The comparative estimation of insecticides Nuprid 600 SC (imidacloprid, 600 g/l, 0.15–0.3 l/t), Agrovital SC (imidacloprid, 600 g/l, 0.2–0.4 l/t), Pikus SC (imidacloprid, 600 g/l, 0.15–0.3 l/t), Cruiser SC (thiametoxam, 350 g/l, 0.14–0.22 l/t) used before the plant tuber treatment, showed the equivalent protective action against phytophage with biological efficiency at a 99.9–100% level. With the application of the studied preparations, there was found to be an additional 3.9–15.6 t/ha.

Phytosanitory monitoring was done of potato planting (2008–2010) in the central and southern agroclimatic zones after a pre-planting tuber treatment with insecticides from the neonicotynoid group. The monitoring revealed the sensitivity of 28 Colorado beetle populations at imago stage (at 100% biological efficiency).

For the purpose of resistance prevention in Colorado beetle populations, the efficiency of the preparations was studied and the insecticides assortment from different chemical classes was expanded (Table 1).

Within two weeks, a high larvae kill was noted with neonicotynoid application: Rexflor WP (acetamiprid, 200 g/kg); pyrethroids: Alterr EC (alfa-cypermethrin, 100 g/l), Break OE (lyambda-cygalothrin, 100 g/l), Wantex 60 MCS (gamma-cygalothrin, 60 g/l), Kaizo WG (lyambda-cygalothrin, 50 g/kg); antranilamids: Koragen SC (chlorantraniliprol, 200 g/l); combined insecticides: Karate Gold SC (tiametoxam, 141 g/l + lyambda-cygalothrin, 106 g/l), Borey SC (imidacloprid, 150 g/l + lyambda-cygalothrin, 50 g/l). Insecticides were applied when the pests mass settled plants, what resulted in a potato yield preservation from 4.0 to 22.7 t/ha.

Biological and economic efficiency of the preparations, and expenses for the carrying out of protective measures and coefficients of the Colorado beetle harmfulness were determined. Using this data, we calculated the expediency thresholds of insecticide applications of the chemical

Table 1. Biological efficiency of the insecticides using the potato vegetative plant spraying method to protect against the Colorado beetle (field trials, 2006–2010)

Chemical class	Insecticide	Active substance	Rate of application [l, kg/ha]	Number before treatment, larvae/registration plant	Number decrease in relation to initial by record days after treatment [%]		
					3	7	14
Neonicotynoids	Rexflor WP	acetamiprid, 200 g/kg	0.06	29.4–56.4	98.9–99.3	99.2–99.4	95.1–100
Pyrethroids	Alterr EC	alfa-cypermethrin, 100 g/l	0.1–0.15	10.9–15.1	84.2–92.7	97.2–98.7	96.7–98.6
	Break OE	lyambda-cygalothrin, 100 g/l	0.05	11.6–31.6	91.5–97.9	93.0–96.2	90.4–92.9
	Wantex 60 MCS*	gamma-cygalothrin, 60 g/l	0.04–0.07	34.2–38.7	79.6–83.3	74.2–79.6	92.1–96.2
	Kaizo WG	lyambda-cygalothrin, 50 g/kg	0.1–0.15	10.1–26.5	90.8–92.3	88.2–91.4	86.8–90.3
Antranilamids	Koragen SC	chlorantraniliprol, 200 g/l	0.04–0.06	47.1–59.4	75.5–80.7	97.3–98.6	94.7–99.0
Combined: Neonicotynoid + Pyrethroid	Karate Gold SC	tiametoxam, 141 g/l + lyambda-cygalothrin, 106 g/l	0.15	12.2–20.2	95.7–100	97.1–100	98.5–99.1
	Borey SC	imidacloprid, 150 g/l + lyambda-cygalothrin, 50 g/l	0.06–0.1	24.0–53.4	90.3–99.9	85.5–99.0	89.7–93.0

*the insecticide was applied twice

Table 2. Economic thresholds of the insecticides application expediency for potato protection against the Colorado beetle

Variety ripeness group	Larvae number, indiv./registered plant by agroclimatic zones			
	central		southern	
	special purpose potato cultivation			
	seed	food	seed	food
Chemical class – neonicotynoides				
Early, mid-early	7	15	5	10
Mid-ripening, mid-late, late	12	23	4	9
Chemical class – pyrethroids				
Early, mid-early	4	9	3	5
Mid-ripening, mid-late, late	7	14	2	4

Economic expediency threshold with an average day air temperature in June close to an average perennial one: in the central zone – 16°C, in the southern – 16.3°C and planned yield – 250 cwt/ha
The indices are presented for poor-resistant and unstable potato varieties

classes pyrethroids and neonicotynoids, while taking into consideration the variety, the special purpose of the potato, the designation, and the agroclimatic zone. It was found, that higher indicators of economic expediency thresholds were determined for neonicotynoids, when taking into consideration various potato growing purposes both in the central, and southern zones in comparison with the pyrethroids (Table 2).

We calculated the correction coefficients for economic expediency thresholds taking into account weather conditions and planned productivity. At higher air temperatures (0.9–2.7°C) during pest development the correction coefficients make 0.8–0.9; at planned productivity 350 cwt/ha – 1.4, at 400 cwt/ha – 1.6.

The industrial check of the potato protection system was done at the Agricultural-Production Establishment (Agroindustrial complex Snov) in the Nesvizh region. At Snovskaya, population diagnostics by frequency of №3 phenomorph incidence and its resistance to pyrethroids (21.4%) was determined to be caused by the potato tuber pre-planting treatment using neonicotynoid pikus, SC at the rate 0.2 l/t with the working solution rate use of 10 l/t. Application of the given method provided 100% biological efficiency and treatments could then be cancelled during plant vegetation. The preserved yield made a 17.9 t/ha, profitability level – 167.3%.

The method of growing plants cultivated for food purposes was used for the industrial check of the plant protection system, Spraying was done at the APE „Usha" Berezinsky district. To decrease the population number resistant to pyrethroids (phenomorph №3 frequency of occurrence – 21.5%) the acetamid-containing, neonicotynoid rexfor WP (0.06 kg/ha) was applied. Treatment was done at the budding stage when second age larvae dominance in the population number was 28.5 indiv./plant, which exceeded the threshold value. As a result, the biological efficiency reached 91.9–100%, the preserved yield was 11.6 t/ha, and the profitability level was 158.3%.

Conclusions

1. The advanced system represents the well-founded, practical, flexible, and effective algorithm of actions depending on phenotypic variability and the Colorado beetle populations' resistance to insecticides, varietal composition, planting appointments, level of planned productivity, and the agroclimatic zone of potato cultivation.
2. The industrial check of the advanced system meant to protect potato plants against the Colorado beetle, confirmed the system's high efficiency: population number decreased 91.9–100%, the preserved yield was 11.6–17.9 t/ha, and the profitability level was 158.3–167.3%.

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