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PRODUCTION EFFECTIVENESS OF POTATO PROTECTION USING SELECTED INSECTICIDES FOR POTATO BEETLE CONTROL (*Leptinotarsa decemlineata* Say)

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Abstract. Effectiveness of insecticide protection of very early edible potato cultivars against potato beetle was assessed in the years 2005-2006. The research used Prestige 290 FS, Regent 200 SC and Spruzit 04 preparations, as well as *Beauveria bassiana* entomopathogenic fungus spore suspension. The selection of preparations for potato beetle control significantly diversified the amount and structure of potato tuber yield. Average total tuber yield on the control, without insecticide protection, was 30.3 $t \cdot ha^{-1}$, whereas on the treatments where Spruzit 04E C and *B. bassiana* spore suspension were applied the yield was on the level of 36 $t \cdot ha^{-1}$, whereas potatoes protected by chemical preparations Regent 200 SC and Prestige 290 FS produced the largest yields, respectively on the level 41.0 and 41.8 $t \cdot ha^{-1}$. Potato beetle control in potato cultivation contributed to an increase in average tuber weight and the share of big tuber fractions in the yield. A significant rise in the marketable tuber fraction was registered only on treatments protected with *B. bassiana* spore suspension and by Prestige 290 FS preparation.

Key words: *Beauveria bassiana*, Colorado potato beetle, potato, protection, tuber yield, yield components

INTRODUCTION

Potato plantations are threatened with many agrophages causing more or less serious reduction in potential tuber yield and worsening their quality. Losses caused by pests are assessed at 50-80% [Radcliffe et al. 1993]. The most dangerous potato pests still include Colorado potato beetle, which occurs annually in the amount exceeding the threshold of economic harmfulness.

When observing changes that have occurred over several decades in selection of insecticides applied for potato beetle control, far-reaching evolution can be observed,

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from arsenic preparations in the fifties, chlorinated carbohydrates in the sixties, phosphoroorganic insecticides and carbaminians in the seventies and eighties, to pyrethroids, acyl urea preparations, neonicotinoids and biopreparations recommended today [Pawińska 2002, Pałosz 2005]. Currently, there is growing concern in potato protection about the problem of Colorado potato beetle becoming resistant to registered insecticides [Węgorek and Jörg 2003, Przybysz et al. 2004]. Although the application of biopreparations for pest control, including Colorado potato beetle, has a very long tradition, plant preparations became the object of scientists' interest again due to the fast development of biochemistry [Lamparski and Piesik 2000, Wawrzyniak and Wrzesińska 2002, Kühne et al. 2005, Wawrzyniak and Lamparski 2006]. Insecticidal fungi have been applied for a long time in plant protection for control of numerous pests. *Beauveria bassiana* is one of species which found wide application in noxious insect control [Bajan 2000, Boguś 2000].

The aim of this study was to estimate the effectiveness of edible potato protection using the preparations Prestige 290 FS, Regent 200 SC, Spruzit 04 EC and the spore suspension of the fungus *Beauveria bassiana* applied for the control of Colorado potato beetle. The research hypothesis assumes that a biopreparation containing spores of the fungus *Beauveria bassiana* protects potatoes against Colorado potato beetle equally efficiently as traditional insecticides.

MATERIAL AND METHODS

A field experiment was undertaken over 2005-2006 at the Experimental Station in Prusy near Kraków (50º11' N; 20º08' E) on degraded chernozem formed from loess, classified as the very good wheat complex and soil quality class I. The topsoil was characterized by a high abundance of phosphorus and magnesium, medium to high abundance of potassium and a slightly acid pH value.

The examination involved two very early cultivars of edible potato: Bard and Lord and four variants of protection against Colorado potato beetle: dressing Prestige 290 FS at a rate of 75 ml per 100 kg of seed-potatoes, insecticide Regent 200 SC at a rate of 0.1 $dm^3 \cdot ha^{-1}$, preparation Spruzit 04 EC at a concentration of 0.2% and the fungus *Beauveria bassiana* spore suspension at a rate of $10^{12} \cdot ha^{-1}$. The control – without protection - was also introduced in the experiment. The insecticidal fungus *B. bassiana* was cultured under laboratory conditions on the modified glucose-potato medium. Spore concentration in the suspension was determined by means of a Bürker chamber according to the Lipa and Śliżyński method [1973]. Gel preparation was obtained by mixing the spore suspension with polyacrymide gel in a dose of 2 g of gel per 1 dm^3 of spray liquid. Spore suspension of *B. bassiana* and the preparation Spruzit 04 EC were applied two times at a weekly interval, each time after the sunset.

The field experiment was established in the randomized complete block design in 4 replications. The size of a plot for harvesting was 16.2 m^2. Potatoes were planted from 10th to 20th April with spacing 67.5 x 35 cm. The forecrop was spring wheat. Fertilization with stable manure was applied at a rate of 30 $t \cdot ha^{-1}$ and mineral fertilization at rates of 90 kg $N \cdot ha^{-1}$, 26.2 kg $P \cdot ha^{-1}$ and 112 kg $K \cdot ha^{-1}$.

Seed-potatoes on control treatments and on those where preparations other than Prestige 290 FS were applied to control Colorado potato beetle were dressed with the preparation Monceren 250 FS before planting. Weeds were controlled with the mechanical and chemical method, applying two-time hilling and the herbicides Afalon Dyspersyjny 450 SC at a rate of 2 $dm^3 \cdot ha^{-1}$ and Targa Super 05 EC at a rate of 1.5 $dm^3 \cdot ha^{-1}$. Against potato blight, Ridomil Gold MZ 68 WG at a rate of 2 $kg \cdot ha^{-1}$ was applied for 1st measure and Tattoo 750 SC at a rate of 2 $dm^3 \cdot ha^{-1}$ for 2nd and 3rd measures. Before harvesting, tuber samples were collected from each plot in the amount of about 10 kg in order to estimate yield structure components, whereas after the harvesting, which fell in the second and third week of August, the height of total tuber yield was determined. The results obtained were evaluated statistically using the analysis of variance. The significance of differences between the treatments was verified with Tukey's test at the significance level $P = 0.05$.

Weather conditions in the course of the study were varied (Table 1). In 2005, the distribution of air temperature and precipitation in the period from April to August did not differ considerably from long-term values. The mean air temperature was higher by 0.6°C and the amount of precipitation was smaller by 35 mm than the average values in the analogous time of the long-term period. In 2006, in turn, the growing season of potato was characterized by precipitation lower by 113 mm and the mean air temperature higher by 1.6°C. July was especially warm and dry, with only 16.5% of the mean long-term precipitation noted and the temperature being higher by 4.1°C, as compared with the mean from the long-term period.

Table 1. Characteristic of climatic conditions in years 2005-2006 (April – August)
Tabela 1. Charakterystyka warunków klimatycznych w latach 2005-2006 (kwiecień – sierpień)

Year – Rok	Month – Miesiąc					Mean Średnia
	April Kwiecień	May Maj	June Czerwiec	July Lipiec	August Sierpień	
Temperature – Temperatura, °C						
2005	9.3	13.4	16.0	18.9	16.7	14.9
2006	9.2	13.2	17.4	21.6	17.7	15.8
Long-term period Wielolecie	8.0	13.0	16.1	17.5	17.0	14.3
Rainfalls – Opady, mm						Sum – Suma
2005	23	81	67	99	102	372
2006	46	52	89	14	93	294
Long-term period Wielolecie	53	83	95	85	91	407

RESULTS

The study carried out indicated the significant effect of weather conditions on the height and structure of tuber yield in the tested cultivars of edible potato (Table 2). In the two-year study period, the weather conditions which were more favourable for yield and setting tubers occurred in 2006, where nearly 12% higher yield and 78% higher number of set tubers was recorded, as compared with 2005. A large number of set tubers and an extremely small amount of precipitation at the high air temperature in July 2006 contributed to forming of smaller tubers by potato plants. This is proved both by the mean tuber weight and the percentage of commercial and large tuber fraction in the total yield, whose values were less than in 2005 by 26.1 g, 1.6% and 7%, respectively.

Table 2. Amount and structure of potato tuber yield
Tabela 2. Wielkość i struktura plonu bulw ziemniaka

Feature Cecha	Cultivar Odmiana	Year – Rok		Protection – Ochrona					Mean Średnia	$LSD_{0.05}$ $NIR_{0,05}$
		2005	2006	control – kontrola	Spruzit 04 EC	*B. bassiana*	Regent 200 SC	Prestige 290FS		
Tuber yield Plon bulw $t \cdot ha^{-1}$	Bard	30.7	34.7	27.1	31.9	31.7	35.6	37.1	32.7	1.27
	Lord	39.2	43.4	33.5	40.1	40.0	46.4	46.4	41.3	
	mean – średnia	35.0	39.1	30.3	36.0	35.9	41.0	41.8		
	$LSD_{0.05}$ – $NIR_{0,05}$	2.35				1.34				
	for interaction – dla interakcji: years x cultivar – lata x odmiana			ns – ni		protection x cultivar – ochrona x odmiana			1.90 / 2.11	
Number of tubers per plant, no. Liczba bulw z rośliny, szt.	Bard	10.5	19.4	14.2	14.6	15.1	14.9	15.9	14.9	ns – ni
	Lord	10.6	18.3	14.0	14.7	14.0	15.0	14.7	14.5	
	mean – średnia	10.6	18.9	14.1	14.7	14.6	15.0	15.3		
	$LSD_{0.05}$ – $NIR_{0,05}$	0.49				0.73				
	for interaction – dla interakcji: years x cultivar – lata x odmiana			0.78 / 0.86		protection x cultivar – ochrona x odmiana			ns – ni	
Mean tuber weight Średnia masa bulwy g	Bard	76.7	51.9	59.1	63.6	65.9	66.7	66.4	64.3	1.90
	Lord	94.2	66.8	69.8	78.9	82.1	87.0	84.8	80.5	
	mean – średnia	85.5	59.4	64.5	71.2	74.0	76.8	75.6		
	$LSD_{0.05}$ – $NIR_{0,05}$	3.68				3.91				
	for interaction – dla interakcji: years x cultivar – lata x odmiana			ns – ni		protection x cultivar – ochrona x odmiana			ns – ni	
Proportion of marketable tubers Udział bulw handlowych %	Bard	97.7	95.2	96.1	95.5	96.9	96.8	96.8	96.4	0.45
	Lord	97.9	97.2	96.6	97.3	98.5	96.9	98.3	97.5	
	mean – średnia	97.8	96.2	96.3	96.4	97.7	96.9	97.6		
	$LSD_{0.05}$ – $NIR_{0,05}$	0.90				1.16				
	for interaction – dla interakcji: years x cultivar – lata x odmiana			1.00 / 0.64		protection x cultivar – ochrona x odmiana			ns – ni	
Proportion of large tubers Udział bulw dużych %	Bard	56.2	48.3	43.3	53.5	52.4	54.9	57.0	52.6	2.39
	Lord	67.6	61.2	53.9	65.3	68.9	69.8	65.0	64.6	
	mean – średnia	61.9	54.9	48.6	59.4	60.6	62.3	61.0		
	$LSD_{0.05}$ – $NIR_{0,05}$	5.34				3.28				
	for interaction – dla interakcji: years x cultivar – lata x odmiana			ns – ni		protection x cultivar – ochrona x odmiana			ns – ni	

ns – ni – non significant differences – różnice nieistotne

Very early cultivars of edible potato Bard and Lord assessed in the study were harvested in full maturity and gave high yields. Mean total tuber yield of the cultivar Bard was 32.7 and that of the cultivar Lord 41.3 $t \cdot ha^{-1}$. Significant differences between cultivars were also noticeable in relation to the mean weight of 1 tuber and the percentage of commercial (with a diameter above 35 mm) and large (with a diameter above 50 mm) tuber fraction in the total yield. The cultivar Lord was characterized by higher values of the above-mentioned features. The results of the study indicated also a different response of potato cultivars to the weather conditions during the study period. Significant differences involved the number of tubers set by the plants and the percentage of commercial tuber fraction in yield.

Plant protection against Colorado potato beetle was the factor determining the potato yield level. The mean total tuber yield on the control treatment – without insecticide protection – amounted to 30.3 $t \cdot ha^{-1}$, and on treatments protected with biopreparations Spruzit 04 EC and spore suspension *B. bassiana* the yield was 36.0 $t \cdot ha^{-1}$, whereas potatoes protected chemically with the preparations Regent 200 SC and Prestige 290 FS gave the highest yields; respectively, 41.0 and 41.8 $t \cdot ha^{-1}$. Although the application of biopreparations in potato protection contributed to an increase in number of set tubers, this increase was not statistically proved. Nevertheless, the plants protected chemically set a significantly higher number of tubers in comparison with the control treatment. On all the treatments where potato beetle was controlled, a significant increase in the mean tuber weight and the percentage of large tuber fraction in yield were observed. The mean tuber weight on treatments without insecticide protection amounted to 64.5 g, whereas on treatments protected it ranged from 71.2 to 76.8 g. Large tuber fraction harvested on the control treatment accounted for 48.6% of the yield weight and on treatments where Colorado potato beetle was controlled the percentage of this tuber fraction fluctuated around 60.0%. Insecticides assessed in the study had also a diversifying effect on the amount of commercial tuber fraction. Significantly higher percentage of commercial tuber fraction in relation to the control was found only on treatments protected by spore suspension *B. bassiana* and the preparation Prestige 290 FS.

Production effectiveness of potato plant protection against Colorado potato beetle was differentiated within the cultivar factor and the years of the experiment. Significant interaction between insecticide protection applied and cultivars was found in affecting the amount of total tuber yield. In the cultivar Bard the weight of yield saved on the treatment protected with biopreparations was on average 4.7 t, and on treatments protected with the insecticides Regent 200 SC and Prestige 290 FS it was 8.5 and 10.0 $t \cdot ha^{-1}$, respectively, whereas in the case of the cultivar Lord the amount of potato tuber yield saved on the treatment protected with biopreparations amounted to 6.6 t, and on treatments protected chemically 12.9 $t \cdot ha^{-1}$.

The amount and structure of tuber yield of potato protected with some insecticides were to a larger extent diversified in 2005 than in 2006 (Fig. 1). In the first year of the experiment, the potatoes on the control treatment gave the lowest yield, and those on treatments protected with biopreparations yielded significantly higher. The plants protected chemically had the highest yield. No significant differences, however, were found between the effect of the preparation Spruzit 04 EC and spore suspension of entomopathogenic fungus and between the insecticides Regent 200 SC and Prestige 290 FS. In the second year of the experiment, the height of potato tuber yield on treatments where particular insecticides were applied was not differentiated and a significant increase in yield in comparison with the control was observed only on treatments protected chemically (Regent 200 SC, Prestige 290 FS).

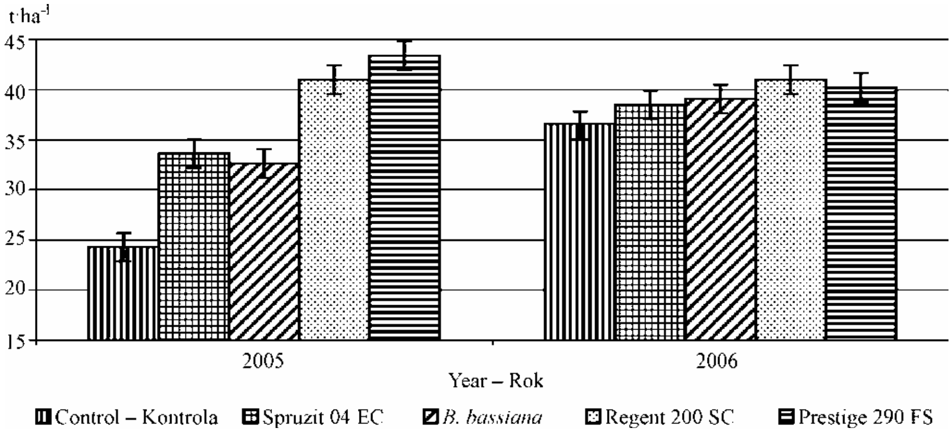

Fig. 1. Total tuber yield depending on the year of the experiment and insecticide control
Rys. 1. Plon ogólny bulw w zależności od roku badań i ochrony insektycydowej

Potato plants protected with the preparation Prestige 290 FS in 2005 set the largest and in 2006 the smallest amount of tubers (Fig. 2). On the other treatments no significant differences were found in the number of set tubers both in the first and second year of the experiment. Significant effect of the insecticide protection applied on the mean weight of 1 tuber was noticeable only in 2005 (Fig. 3). On treatments where insecticides were applied a significant increase in the mean tuber weight was found, as compared with the control, which was the largest for the preparation Regent 200 SC and the smallest after the application of Spruzit 04 EC.

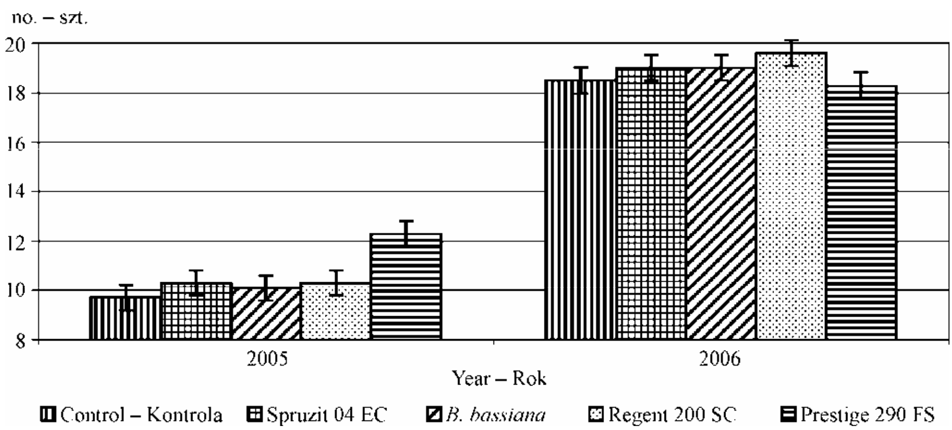

Fig. 2. Number of tubers per plant depending on the year of the experiment and insecticide control
Rys. 2. Liczba bulw z rośliny w zależności od roku badań i ochrony insektycydowej

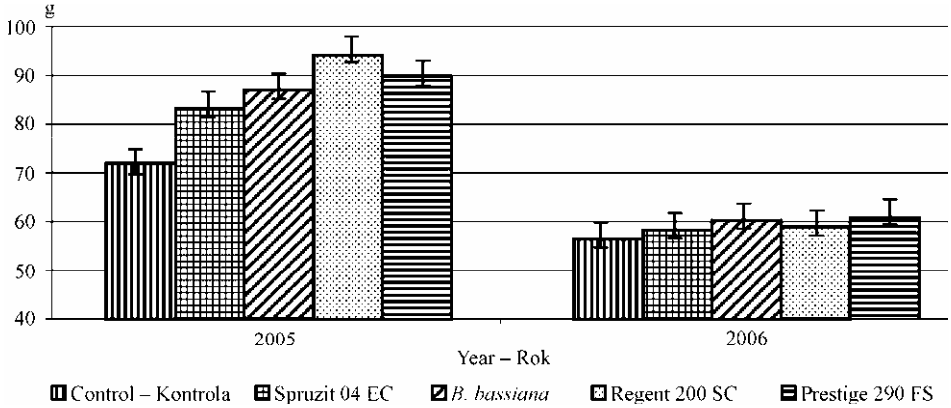

Fig. 3. Mean tuber weight depending on the year of the experiment and insecticide control
Rys. 3. Średnia masa bulwy w zależności od roku badań i ochrony insektycydowej

DISCUSSION

Yield level and potato tuber quality are determined by the genetic potential of particular cultivars and the effect of agricultural and site factors. The origin of potato makes the weather conditions, particularly the sum and distribution of precipitation and air temperature, play the significant role in the development and yield of this plant. Both the deficiency and the excess of precipitation decrease potato yields, yet precipitation deficiency more distinctly reduce yields on light soils in dry and warm years, whereas the excess of water is harmful on tight soils in humid and cool years [Nowak 1987]. Optimal amount of rainfall during the growing season of early potato cultivars grown in the soil conditions of the very good wheat complex ranges from 200 to 250 mm, and the period of particular sensitivity to precipitation deficiency occurs in June and at the beginning of July [Nowak 1989]. In the course of the present study, particularly unfavourable weather conditions, resulting from extremely small precipitation and high air temperatures, occurred in July 2006. Nevertheless, 12.0% higher tuber yields were harvested in that season than in 2005. A higher yield level was determined by an amount of set tubers higher by 78.0% at the mean tuber weight being less by 30.5%. A study by Kołodziejczyk [2000] indicates that the number of tubers set by potato plants determines the yield height to a larger extent than the tuber weight. According to Reszel [1988], a decrease in tuber yield is accompanied by worsening of its structure by the increase in the percentage of the smallest tubers. The present study does not confirm this relation, since in 2005, at a smaller tuber yield, a significant higher mean tuber weight and a higher percentage of commercial and large tuber fractions were recorded than in 2006.

Moreover, the study carried out indicated the significant effect of the cultivar factor on tuber yield height, tuber weight and the percentage of commercial and large tuber fractions in the total yield. The cultivar Lord was distinguished by higher values of the above-mentioned features. Pytlarz-Kozicka and Golinowska [2005], assessing the effectiveness of plant protection in cultivation of very early potato cultivars, indicated a significantly higher yield level, higher tuber weight and a higher percentage of commercial tubers of the cultivar Lord than of the cultivar Bard.

The direct aim of applying pesticides is not to increase the yield but to prevent its losses. According to Pawińska and Osowski [1998], the scale of losses in yield of early and semi-early potato cultivars not protected against potato beetle may reach 20-30%, and in extreme cases may exceed even 70.0%. In the present study, the yield level of very early potato cultivars depended significantly on the applied variant of insecticide protection. The highest tuber yields were obtained on treatments protected chemically with the preparations Prestige 290 FS and Regent 200 SC, and lower by 13.2% on treatments protected with the biopreparations Spruzit 04 EC and spore suspension of the fungus *B. bassiana*, whereas the lowest on treatments without protection. The difference in tuber yield gathered on this treatment and on the treatment where the preparation Prestige 290 FS, characterized by the highest yield-protective effectiveness, was applied was 27.5%. An increase in tuber yield ranging from several to several dozen per cent after the application of the fungicide-insecticide dressing Prestige 290 FS in potato cultivation was also shown by Erlichowski et al. [1998]. Although biopreparations Spruzit 04 EC and spore suspension of the enthomopathogenic fungus *B. bassiana* applied in the study for potato beetle control showed a smaller effectiveness than chemical preparations, an increase in tuber yield, as compared with the control treatment, was significant. Kühne et al. [2005], assessing the effectiveness of preparations Spruzit Neu, Neem Azal-T/S and Novodor FC, demonstrated that only the preparation Spruzit Neu did not reduce the number of potato beetle larvae.

Losses caused by feeding of potato beetle larvae result not only from a reduction in the potential tuber yield but also from worsening of its structure, that is from an increase in the percentage of small tuber fraction. Ziems et al. [2006], performing manually defoliation of potato plants which simulated damages caused by pests, showed losses in tuber commercial yield (51-102 mm) ranging from 4 to 38%, depending on the years of the experiment, defoliation degree and plant development stage at which defoliation was performed. The present study indicated that abandoning of potato plant protection against Colorado potato beetle results in a decrease in weight of one tuber from 9.4 to 16%, and in the percentage of large tuber fraction (with a diameter above 50 mm) from 10.8 to 13.7% depending on the variant of insecticide protection. The percentage of commercial tuber fraction depended in a smaller degree on the protection applied than that of large tubers. Significant increase in this feature values was found on treatments protected by the spore suspension of *B. bassiana* and by the preparation Prestige 290 FS. Favourable effect of fungicide and insecticide protection on tuber yield structure of very early potato cultivars is also reported by Pytlarz-Kozicka and Golinowska [2005].

CONCLUSIONS

1. Effectiveness of insecticide protection expressed by an increase in tuber yield in relation to the control treatment depended significantly on preparations applied. The highest tuber yields – irrespective of the year of the experiment and cultivar – were obtained in treatments protected chemically. The biopreparation applied in the study was characterized by a less production effectiveness and a significant increase in tuber yield was found only in the first year of study.

2. Colorado potato beetle control in potato cultivation contributed to a significant increase in mean tuber weight and the percentage of large tuber fraction. An increase in the percentage of commercial tuber fraction was found after applying spore suspension

of *B. bassiana* and the preparation Prestige 290 FS. Application of chemical preparations (Regent 200 SC and Prestige 290 FS) caused an increase in number of tubers per plant.

3. Genotype factor significantly diversified tuber yield height, tuber weight and the percentage of commercial and large tuber fractions in the total yield. The cultivar Lord was characterized by higher values of those features.

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EFEKTYWNOŚĆ PRODUKCYJNA OCHRONY ZIEMNIAKA Z WYKORZYSTANIEM WYBRANYCH INSEKTYCYDÓW DO ZWALCZANIA STONKI ZIEMNIACZANEJ (*Leptinotarsa decemlineata* SAY)

Streszczenie. W latach 2005-2006 w Prusach koło Krakowa (50º11' N; 20º08' E) oceniano efektywność insektycydowej ochrony bardzo wczesnych odmian ziemniaka jadalnego przed stonką ziemniaczaną. W badaniach wykorzystano preparaty Prestige 290 FS, Regent 200 SC, Spruzit 04 EC oraz zawiesinę zarodników owadobójczego grzyba *Beauveria bassiana*. Dobór preparatów do zwalczania stonki ziemniaczanej istotnie różnicował wielkość i strukturę plonu bulw ziemniaka. Średni plon ogólny bulw w obiekcie kontrolnym – bez ochrony insektycydowej – wynosił 30,3 $t \cdot ha^{-1}$, w obiektach, w których stosowano Spruzit 04 EC i zawiesinę zarodników *B. bassiana* plon kształtował się na poziomie 36,0 $t \cdot ha^{-1}$, najwyżej plonowały natomiast ziemniaki chronione chemicznie preparatami Regent 200 SC oraz Prestige 290 FS, odpowiednio na poziomie 41,0 i 41,8 $t \cdot ha^{-1}$. Zwalczanie stonki w uprawie ziemniaka przyczyniło się do wzrostu średniej masy bulwy oraz udziału frakcji bulw dużych w plonie. Istotny wzrost udziału frakcji bulw handlowych odnotowano tylko w obiektach chronionych zawiesiną zarodników *B. bassiana* oraz preparatem Prestige 290 FS.

Słowa kluczowe: *Beauveria bassiana*, ochrona, plon bulw, stonka ziemniaczana, struktura plonu, ziemniak

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