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ECONOMICAL EFFECTIVENESS OF *PHYTOPHTHORA INFESTANS* CONTROL ACCORDING TO DECISION SUPPORT SYSTEMS

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Abstract: In the field experiments performed in 1999–2001 the profitability of late blight control in accordance with three decision support systems: NegFry, Simphyt and Stephan with routine fungicide program was compared. Potato protection carried out according to the recommendations of the decision support systems guaranteed higher profitability of late blight control than when potato was protected routinely. The highest profitability was recorded for susceptible variety Bekas protected according to NegFry.

Key words: *Phytophthora infestans,* decision support system, cost defrayal index

INTRODUCTION

Decision support systems became especially helpful in plant protection particularly in control of plant diseases that can cause high economic losses and genetic resistance of plants is not sufficient to lessen pathogen development. These conditions apply to *Phytophthora infestans*, the casual agent of potato late blight. Fry and Shitenberg (1990) have estimated that discontinuing chemical control of late blight on potato crops could result in yield losses at 75%. In some years and some regions and early pathogen infection or severe disease incidence late blight could cause entire lost of tuber yield.

Resistance of 53 potato varieties out of 93 registered in Poland is estimated below 4, based on the official 9-point scale where 2 means very susceptible and 9 very resistant. Resistance of 33 varieties ranges from 4 to 6 and only 8 varieties present high level of resistance, i.e. equal to 6.5 or higher (Głuska et al. 2000).

Possibility of great reduction of yield and unsatisfactory resistance of many potato varieties to late blight decides on necessity of chemical protection of potato

crops. According to Lacroix (2001) routine application at 7-day intervals guarantees effective protection of potato against *P. infestans*. However, such approach to chemical control is against principles of modern environment protection and also increases costs of late blight control.

Taking into consideration the above statement the most justified idea of chemical product application lies in treatments, only when real threat of infestation of plantation occurs. This principle sets up a foundation for all systems used for forecasting optimal timing of chemical application. The aim of the study was validation of cost effectiveness of potato protection according to selected DSS (Decision Support System).

MATERIALS AND METHODS

Trials were conducted at Winna Góra, 60 kilometers south of Poznań, in the years 1999–2001. The trial design was a randomised complete block with four replications per treatment. Each replicate consisted of 4 drills 20 m long. The drill width was 75 cm and distance between tubers was 20 cm. Weed control consisted of Titus 25 WP (45 g/ha), Sencor 70 WG (0.36 kg/ha) and Trend (0.1%). Fungicide application included Ridomil Gold MZ 68 WP (2 kg/ha), Acrobat MZ 69 WP (2 kg/ha), Dithane 75 WG (2 kg/ha) and Bravo 500 SC (2 l/ha). Details of fungicide treatments are given in table 1.

Routine fungicide application was compared to fungicide applications performed according to recommendations of three decision support systems: NegFry, Simphyt, and Stephan. NegFry consisted of two parts. First one was based on negative prognosis which calculated the epidemic free period for *P. infestans* and then recommended the first spray against the pathogen (Ullrich and Schrödter 1966). The second part of the system which, calculated subsequent spraying was based on the method developed by Fry et al. (1983). The *P. infestans* forecasting method developed by Gutshe and Kluge was used in Simphyt system which also recommended first and subsequent fungicide applications (Gutsche 1998). Stephan system, the third one validated in the experiment, belonged to the group of systems which recommend only the initial fungicide application. It means that the subsequent sprays had to be conducted routinely. In the experiment curried out at Winna Góra the first application on plots protected according to Stephan system was timed by Stephan method (Stephan 1968) and subsequent sprays were conducted in ten days intervals. First routine fungicide application was conducted 60 days after planting; the second one ten days later and the others at 7-day intervals. Two potato varieties were used in the experiment; Bekas – the susceptible and Mila – the moderate resistant. Profitability of chemical control was expressed as cost defrayal index amounted to quotient of saved yield value and costs of application.

The results were statistically analyzed with variance analysis and significant differences were determined at $p = 0.05$ using Fisher's and Tukey's tests.

RESULTS

In 1999 a cost defrayal index representing profitability of Bekas variety chemical protection ranged from 3.15 to 7.39. For Mila variety, an analyzed index ranged

Table 1. Fungicide treatment

Year	Variety	System	Fungicide			
			Ridomil Gold MZ 68 WP	Acrobat MZ 69 WP	Dithane 75 WG	Bravo 500 SC
1999	Bekas	Simphyt	18.06	29.06	6.07, 28.07	13.07
		NegFry	15.06	24.06	6.07, 4.08	16.07
		Stephan	24.06	5.07	15.07, 5.08	26.07
		Routine	24.06	5.07	12.07, 26.07	19.07, 2.08
	Mila	Simphyt	18.06	29.06	6.07, 28.07	13.07
		NegFry	15.06	24.06	6.07, 4.08	16.07
		Stephan	24.06	5.07	15.07, 5.08	26.07
		Routine	24.06	5.07	12.07, 26.07	19.07, 2.08
2000	Bekas	Simphyt	21.06	5.07	17.07, 4.08	26.07, 16.08
		NegFry	26.06	8.07	17.07, 4.08	26.07, 17.08
		Stephan	15.06	26.06	5.07, 27.07, 17.08	17.07, 7.08
		Routine	19.06	29.06	6.07, 20.07, 3.08, 17.08	13.07, 27.07, 10.08
	Mila	Simphyt	21.06	5.07	17.07,4.08	26.V, 17.08
		NegFry	26.06	8.07	17.07,4.08	26.V, 16.08
		Stephan	15.06	26.06	5.07, 27.07, 17.08	17.07, 7.08
		Routine	19.06	29.06	6.07, 20.07, 3.08, 17.08	13.07, 27.07, 10.08
2001	Bekas	Simphyt	28.06	6.07	16.07, 30.07	23.07, 6.08
		NegFry	22.06	2.07	17.07, 6.08	29.07
		Stephan	25.06	5.07	16.07, 6.08	26.07
		Routine	26.06	6.07	13.07, 27.07	20.07, 3.08
	Mila	Simphyt	28.06	6.07	16.07, 30.07, 13.08	23.07, 6.08, 20.08
		NegFry	22.06	2.07	17.07, 6.08	29.07, 14.08
		Stephan	25.06	5.07	16.07, 6.08	26.07, 16.08
		Routine	26.06	6.07	13.07, 27.07, 10.08, 23.08	20.07, 3.08, 17.08

from 3.75 to 5.90. Late blight control carried out according to the NegFry system resulted in the highest cost effectiveness of protection of both potato varieties. Simphyt turned out to be a little less effective, because costs defrayal index amounted to 6.91 for Bekas variety and 4.53 for Mila variety. In case of routine treatment the analyzed index amounted to 4.29 for Bekas and 4.08 for Mila. The worst cost effectiveness of chemical application was achieved when potato crop was protected according to Stephan system.

In 2000 a cost defrayal index was lower than in 1999 and ranged from 1.94 to 4.23 for Bekas variety and 2.08–3.42 for variety Mila. The highest effectiveness of variety Bekas protection against *P. infestans* was achieved when applications were performed according to NegFry system recommendations. The cost defrayal index representing profitability of Simphyt and Stephan systems was lower and amounted to 3.13 and 2.76, respectively. Chemical control was the least effective when applications were timed routinely. For variety Mila the highest effectiveness of *P. infestans* control was achieved in plots treated according to Simphyt system. The cost defrayal index for NegFry system amounted to 2.97. Based on that index, Stephan system was classified as the least effective one (Tab. 2).

In 2001 a cost defrayal index for Bekas and Mila varieties was 6.04 and 4.68, respectively. The highest efficacy of *P. infestans* control on variety Bekas was achieved

when potato plants were treated according to NegFry system. The other systems guaranteed little lower effectiveness of chemical control. The cost defrayal index describing profitability of routine application was 6.14, while for Stephan and Simphyt systems, 5.76 and 5.65, respectively. The highest effectiveness of *P. infestans* control was achieved for Mila variety in plots treated according to Stephan system. The cost defrayal index for potato protection conducted according to NegFry amounted to 4.69 and for Simphyt 4.45. The results enabled to classify these systems on second and third places. In this trial, routine applications turned out to be less effective (Tab. 2).

Table 2. Influence of decision support system on cost defrayal index of Bekas and Mila variety protection in 1999–2001

System	1999		2000		2001	
	Bekas	Mila	Bekas	Mila	Bekas	Mila
Simphyt	6.91	4.53	3.13	3.42	5.65	4.45
NegFry	7.39	5.90	4.23	2.97	6.61	4.69
Stephana	3.15	3.75	2.76	2.55	5.76	5.59
Routine	4.29	4.08	1.94	2.08	6.14	3.99

Analysis of variance (Tabs. 3, 4) did not show significant differences in cost defrayal index between tested varieties in 1999. However, significant differences in value of the index were found between validated systems. Protection indicated by NegFry resulted in significantly higher index than routine treatment and chemical

Table 3. Evaluation of differences in cost defrayal index in correlation to potato varieties and decision support system

Year	Index of significance		
	variety	system	interaction
1999	0.411	0.007	0.345
2000	0.710	<0.001	0.072
2001	<0.001	0.307	0.141
1999–2001	0.004	<0.001	0.106

Table 4. Economical effectiveness of chemical protection of Bekas and Mila varieties according to different decision support systems at Winna Góra in 1999–2001

Variety/System		Cost defrayal index			
		1999	2000	2001	1999–2001
Variety	Bekas	5.44 a	3.01 a	6.04 a	4.83 a
	Mila	4.57 a	2.75 a	4.68 b	4.00 b
System	Simphyt	5.72 ab	3.27 ab	5.05 a	4.68 ab
	NegFry	6.65 a	3.60 a	5.65 a	5.30 a
	Stephan	3.45 b	2.65 bc	5.67 a	3.93 bc
	Routine	4.18 b	2.01 c	5.06 a	3.75 c

Means within columns followed by the same letter do not differ at p= 0.05 according to Fisher's and Tukey's tests

application according to Stephan system. The other systems did not differ significantly in the value of this index.

In 2000 significant differences between varieties were not proved as well, but similarly to 1999 protection according to NegFry was more profitable than routine and indicated by Stephan system. Significant differences in analyzed index were recorded between routine applications and Simphyt system, but in other cases they were not proved (Tabs. 3, 4).

In 2001 protection of variety Bekas was more profitable than protection of variety Mila. However, validated systems did not differ in value of cost defrayal index (Tab. 4).

Statistical calculations of data from the years 1999–2001 proved significant differences in cost defrayal index between tested varieties. It turned out that protection of variety Bekas was more profitable than protection of variety Mila. Moreover, significant differences in profitability between validated systems were recorded. NegFry system turned out to be the most profitable system. The cost defrayal index representing effectiveness of chemical control indicated by that system was significantly higher than value of that index calculated for combinations protected routinely and according to Stephan system. However, significant differences between profitability of NegFry and Simphyt, Simphyt and Stephan, Stephan and Routine were not proved.

DISCUSSION

The results of experiments at Winna Góra proved that economical effectiveness of *P. infestans* control was dependent upon several factors such as potato variety resistance against the pathogen, the way of disease control and meteorological conditions in the growing season.

In 1999 at the beginning of the growing season the weather favored early occurrence of late blight but later suppressed pathogen development rate. Significant differences in profitability of *P. infestans* control between varieties Bekas and Mila were not proved. However, the method of chemical control in 1999 significantly modified the values of cost defrayal index. More profitable protection was achieved when plots were treated according to Simphyt and NegFry, than when applications were performed routinely or as Stephan system indicated. The more efficient protection resulted from correct indication of first treatment by Simphyt and NegFry and not enough accurate by the others systems. However, significant differences were only recorded between potato protection conducted according to NegFry and routine program and Stephan system. Lack of significant differences in economical effectiveness of *P. infestans* control in plots protected according to Simphyt, Stephan and routine systems suggests that in years with weather favoring quick pathogen development in spring, chemical applications should be initiated prior appearance of first symptoms.

In 2000, when drought and extremely high temperatures were recorded in spring but summer was wet and cool, no significant differences in profitability of *P. infestans* control between Bekas and Mila were found. However, the system of potato protection differed significantly the value of cost defrayal index. Significant dif-

ferences in profitability were found between protection of plots carried out according to NegFry and routine and Stephan program. It was the result of differences in the number of applications as less number of treatments accounted for higher value of cost defrayal index describing profitability of *P. infestans* control.

In 2001 with weather moderately favoring late blight development, profitability of variety Bekas protection against *P. infestans* was significantly higher than for variety Mila, but DSS did not modify the value of cost defrayal index.

Additional information about profitability of *P. infestans* control was provided by the results of analysis of variance that was conducted on data from 1999 to 2001. This time the results proved that both experimental factors: variety and system differ significantly the value of cost defrayal index. Statistical calculations indicate that protection of variety Bekas is more economically essential than protection of variety Mila. Pietkiewicz (1992) obtained similar results, which proved that protection of susceptible varieties resulted in higher yield increase than protection of moderately resistant variety. However, comparison of DSS allows drawing a conclusion that in that case profitability was dependent upon accuracy of chemical application timing. In regard to that routine treatment turned out to be the worse. Among remaining systems only Stephan system did not guarantee the achievement of significantly higher values of cost defrayal index than these calculated for routine *P. infestans* control. Probably it was the consequence of the fact that Stephan system turned out to be less precise in indicating first treatment than Simphyt and NegFry systems and dates of remaining applications indicated by Stephan system did not consider weather changes and treatments were carried out at exact intervals. Achieved results proved an importance of correctly determined dates of chemical application and a role they play in the profitability of *P. infestans* control.

Presented results of economical profitability of *P. infestans* control are similar to these obtained by Hinds (2000), Bugiani et al. (2000), Spits and Wander (2001), Leonard et al. (2001) who proved that DSS systems decreased number of applications and costs of chemical control of potato however, harvested yields did not differ from these collected from fields treated with higher number of application (routine program).

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POLISH SUMMARY

EKONOMICZNA EFEKTYWNOŚĆ OCHRONY ZIEMNIAKA PRZED *PHYTOPHTHORA INFESTANS* PROWADZONA WG WSKAZAŃ SYSTEMÓW DECYZYJNYCH

Rutynowe zabiegi fungicydami wykonane w odstępach siedmiodniowych gwarantują skuteczną ochronę plantacji ziemniaka przed zarazą. Stosowanie tak pojmowanej metody chemicznej jest jednak sprzeczne z współcześnie obowiązującymi wymogami ochrony środowiska oraz powoduje wzrost kosztów zwalczania patogena. Biorąc pod uwagę powyższe, najbardziej uzasadniona jest koncepcja stosowania zabiegów chemicznych tylko w wypadku rzeczywistego zagrożenia plantacji. Zasada ta stanowi fundament wszelkich systemów służących do wyznaczania optymalnych terminów wykonywania zabiegów chemicznych. Celem niniejszej pracy było porównanie opłacalności stosowania ochrony chemicznej ziemniaka wg wskazań wybranych systemów decyzyjnych z ochroną prowadzona rutynowo. Do badań wybrano dwie odmiany ziemniaka; Bekas podatną na *Phytophthora infestans* oraz Mila średnio odporną. Na podstawie wyników przeprowadzonych doświadczeń stwierdzono że ochrona chemiczna ziemniaka według wskazań systemów wspomagania decyzji, gwarantowała wyższą opłacalność zwalczania patogena niż w przypadku rutynowej ochrony ziemniaka. Największą opłacalność odnotowano w przypadku odmiany Bekas chronionej według zaleceń systemu NegFry.