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SEVERITY OF POTATO TUBERS DISEASES IN TREATMENTS WITH FOLIAR FERTILIZATION

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K e y w o r d s: potato tubers, diseases, foliar fertilization, mineral fertilization.

A b s t r a c t

The study was conducted over the years 2004–2006 in experimental plots located in Bałcyny. A multi-purpose, late potato cultivar, Jasia, was grown. The experimental factors were as follows: I – mineral fertilization levels: *A* (N – 80 kg ha^{-1}, P – 80 kg ha^{-1}, K – 120 kg ha^{-1}), *B* (N – 120 kg ha^{-1}, P – 144 kg ha^{-1}, K – 156 kg ha^{-1}), II – foliar fertilization: *1* (Basfoliar 12-4-6 – 8 dm^3 ha^{-1}), *2* (ADOB Mn – 4 dm^3 ha^{-1}), *3* (Solubor DF – 2 dm^3 ha^{-1}), *4* (ADOB Mn – 2 dm^3 ha^{-1} + Basfoliar 12-4-6 – 4 dm^3 ha^{-1}), *5* (ADOB Mn – 2 dm^3 ha^{-1} + Solubor DF – 1 dm^3 ha^{-1}), *6* (Basfoliar 12-4-6 – 4 dm^3 ha^{-1} + Solubor DF – 1 dm^3 ha^{-1}), *7* (Basfoliar 12-4-6 – 2.7 dm^3 ha^{-1} + ADOB Mn – 1.3 dm^3 ha^{-1} + Solubor DF – 0.7 dm^3 ha^{-1}), *8* (control treatment without foliar fertilization).

The health status of potato tubers was studied after five-month storage. The rates of tuber infection by *Streptomyces scabies* and *Rhizoctonia solani* were estimated on 100 tubers selected randomly of particular treatments, according to a nine-point scale, and were presented as a percentage infection index. The symptoms of soft rot (*Pectobacterium carotovorum* subsp. *carotovorum*), late blight (*Phytophthora infestans*) and dry rot (*Fusarium* spp.) were evaluated in 5 kg samples for each treatment. The results were expressed as a percentage of the mass of infected tubers.

Foliar fertilization and the levels of mineral fertilization NPK did not affect the severity of common scab symptoms. Significantly higher rates of infection by *R. solani* were observed in tubers from the control treatment without foliar fertilization and from the treatment with a lower level of mineral fertilization (*A*). The symptoms of soft rot (4.6% of the mass of infected tubers) and late blight (1.3%) were strongest in 2006, while the symptoms of dry rot (2.7%) – in 2005. The severity of diseases caused by the above pathogens was greater in tubers grown in plots with a higher level of mineral fertilization (*B*) – N 120 kg ha^{-1}, P 144 kg ha^{-1}, K 156 kg ha^{-1} (1.3 to 4.1% of the mass of infected tubers) than in tubers grown in plots with a lower level of mineral fertilization (*A*) – N 80 kg ha^{-1}, P 80 kg ha^{-1}, K 120 kg ha^{-1}, (0.8 to 3%). The combined application of foliar fertilizers reduced the percentage mass of tubers infected by *P. carotovorum* subsp. *carotovorum* and *P. infestans* to the highest degree.

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NASILENIE WYBRANYCH CHORÓB BULW ZIEMNIAKA NAWOŻONEGO DOLISTNIE

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S ł o w a k l u c z o w e: bulwy ziemniaka, choroby, nawożenie dolistne, nawożenie mineralne.

A b s t r a k t

Badania przeprowadzono w latach 2004–2006 na poletkach doświadczalnych w Bałcynach. Uprawiano wszechstronnie użytkowaną, późną odmianę ziemniaka Jasia. W doświadczeniu uwzględniono dwa czynniki: I – poziomy nawożenia mineralnego: *A* (N – 80 kg ha^{-1}, P – 80 kg ha^{-1}, K – 120 kg ha^{-1}), *B* (N – 120 kg ha^{-1}, P – 144 kg ha^{-1}, K – 156 kg ha^{-1}) i II – nawożenie dolistne: *1* (Basfoliar 12-4-6 – 8 dm^3 ha^{-1}), *2* (ADOB Mn – 4 dm^3 ha^{-1}), *3* (Solubor DF – 2 dm^3 ha^{-1}), *4* (ADOB Mn – 2 dm^3 ha^{-1} + Basfoliar 12-4-6 – 4 dm^3 ha^{-1}), *5* (ADOB Mn – 2 dm^3 ha^{-1} + Solubor DF – 1 dm^3 ha^{-1}), *6* (Basfoliar 12-4-6 – 4 dm^3 ha^{-1} + Solubor DF – 1 dm^3 ha^{-1}), *7* (Basfoliar 12-4-6 – 2,7 dm^3 ha^{-1} + ADOB Mn – 1,3 dm^3 ha^{-1} + Solubor DF – 0,7 dm^3 ha^{-1}), *8* (kontrola bez nawożenia dolistnego). Po 5-miesięcznym przechowywaniu bulw przeprowadzano ocenę ich zdrowotności. Nasilenie parcha zwykłego (*Streptomyces scabies*) i ospowatości bulw (*Rhizoctonia solani*) określano na 100 bulwach z kombinacji, według 9^o skali, a wyniki podano w % jako indeks porażenia. Objawy mokrej zgnilizny (*Pectobacterium carotovorum* subsp. *carotovorum*), zarazy ziemniaka (*Phytophthora infestans*) i suchej zgnilizny bulw (*Fusarium* spp.) oceniano w 5-kilogramowej próbie bulw z każdej kombinacji. Wyniki przedstawiono w procentach masy porażonych bulw.

Nawożenie dolistne oraz poziomy nawożenia mineralnego NPK nie różnicowały nasilenia objawów parcha zwykłego. Istotnie wyższe porażenie *R. solani* zanotowano na bulwach w kombinacji kontrolnej bez nawożenia dolistnego i z nawożeniem mineralnym w niższej dawce (poziom *A*). Największe objawy mokrej zgnilizny bulw (4,6% masy porażonych bulw) i zarazy ziemniaka (1,3%) stwierdzono w 2006 r., a suchej zgnilizny (2,7%) – w 2005 r. Zanotowano silniejsze objawy chorób powodowanych przez wymienione patogeny na bulwach pochodzących z roślin uprawianych w kombinacji z zastosowanym wyższym nawożeniem mineralnym doglebowym *B* – N 120 kg ha^{-1}, P 144 kg ha^{-1}, K 156 kg ha^{-1}, (1,3 do 4,1% masy porażonych bulw) niż u roślin w kombinacji z niższym nawożeniem *A* – N 80 kg ha^{-1}, P 80 kg ha^{-1}, K 120 kg ha^{-1} (od 0,8 do 3%). Łączne stosowanie nawozów dolistnych najbardziej ograniczało procent masy bulw porażonych *P. carotovorum* subsp. *carotovorum* i *P. infestans*.

Introduction

Next to chemical control, the soil and foliar application of mineral fertilizers is the main determinant of the health status of potato plants and the yield and quality of tubers (GRZEŚKIEWICZ, TRAWCZYŃSKI 1999, LAMBERT et al. 2005, MILLER, ROSEN 2005, STACHOWICZ 2007, MALAKOUTI 2008). In Poland, the following foliar fertilizers are most commonly applied to potato plants: Plonvit K, Wuxal Top N, Ekosol, Insol ZBR, Basfoliar, Solubor, Tytanit, and ADOB (WIERCZEWSKA, SZTUDER 2004). The foliar application of mixed microelement fertilizers is advisable under stress conditions. According to KAPSA (2002), MILLER and ROSEN (2005), the combined application of fertilizers and

crop protection chemicals allows to reduce total production costs and contributes to potato protection against pathogenic factors, including *P. infestans*. OSOWSKI (2005) reported that Basfoliar 12-4-6 used together with the fungicides Antracol 70 WG and Unikat 75 WG reduced the incidence of Alternaria blight on potatoes during the growing season. The effects of foliar application of mixed fertilizers on the health status of potato tubers have been discussed by, among others, BORÓWCZAK and GŁADYSIAK (1999), JABŁOŃSKI (2003), RĘBACZ and BORÓWCZAK (2007). The objective of this study was to determine the effect of two levels of mineral fertilization and foliar fertilizer types on the severity of selected diseases on the tubers of potato cv. Jasia, stored for five months.

Material and Methods

The experimental materials comprised potato tubers stored for five months at a temperature of 5°C, harvested during a three-year exact plot experiment (randomized split-plot design, four replications) established in 2004 in Bałcyny, on grey-brown podsolic soil developed from light silty loam of complex 4, class III, by the Department of Agrotechnology and Crop Production Management, University of Warmia and Mazury in Olsztyn. A multi-purpose, late potato cultivar with a high starch content, Jasia, was grown. The experimental factors were as follows:

I – mineral fertilization levels:
- *A* (N – 80 kg ha^{-1}, P – 80 kg ha^{-1}, K – 120 kg ha^{-1}),
- *B* (N – 120 kg ha^{-1}, P – 144 kg ha^{-1}, K – 156 kg ha^{-1}),

II – foliar fertilization:
- *1* (Basfoliar 12-4-6 – 8 dm^3 ha^{-1}),
- *2* (ADOB Mn – 4 dm^3 ha^{-1}),
- *3* (Solubor DF – 2 dm^3 ha^{-1}),
- *4* (ADOB Mn – 2 dm^3 ha^{-1} + Basfoliar 12-4-6 – 4 dm^3 ha^{-1}),
- *5* (ADOB Mn – 2 dm^3 ha^{-1} + Solubor DF – 1 dm^3 ha^{-1}),
- *6* (Basfoliar 12-4-6 – 4 dm^3 ha^{-1} + Solubor DF – 1 dm^3 ha^{-1}),
- *7* (Basfoliar 12-4-6 – 2.7 dm^3 ha^{-1} + ADOB Mn – 1.3 dm^3 ha^{-1} + Solubor DF – 0.7 dm^3 ha^{-1}),
- *8* (control treatment without foliar fertilization).

Healthy, certified seed tubers purchased from a seed production company were planted. Cereal crops were grown as a forecrop. The same agricultural practices (recommended by the Institute of Soil Science and Plant Cultivation in Puławy) and protection measures against agrophages (recommended by the Institute of Plant Protection in Poznań) were carried out in all plots.

The rates of tuber infection by *Streptomyces scabies* and *Rhizoctonia solani* were estimated on 100 tubers selected randomly of particular treatments, according to a nine-point scale (1 – no symptoms, 9 – most severe symptoms, *Metodyka obserwacji*... 1999), and were presented as a percentage infection index. The symptoms of soft rot (*Pectobacterium carotovorum* subsp. *carotovorum*), late blight (*Phytophthora infestans*) and dry rot (*Fusarium* spp.) were evaluated in 5 kg samples collected from particular plots in each treatment. The results were expressed as a percentage of the mass of infected tubers.

Meteorological data for the experimental period are shown in Table 1. The growing seasons of 2004 and 2006 were characterized by higher precipitation totals than the growing season of 2005, in which mean monthly precipitation remained within normal limits over the summer, reaching the upper limit in July. Precipitation was accompanied by moderate temperatures, only in July in the last two years temperatures ranged from 19 to 21°C.

The results were verified statistically by an analysis of variance for a randomized block design (STATISTICA® 8.0 2007–2008 software). Means were compared by Duncan's test (significance level 0.05).

Table 1

Meteorological data according to Meteorological Station Bałcyny

Month	Mean monthly temperature °C			Mean for 1960–90	Mean monthly rainfall in mm			Σ rainfall 1960–90
	2004	2005	2006		2004	2005	2006	
May	11.0	12.5	12.5	12.4	87.1	68.2	93.2	56.7
June	14.5	14.9	16.0	15.7	90.6	35.4	83.5	68.3
July	16.2	18.9	21.0	15.3	78.8	83.9	27.1	81.3
August	18.2	16.8	17.3	17.9	89.3	39.6	141.7	78.1

Results and Discussion

Significantly higher intensity of soft rot, common scab, late blight and rhizoctoniosis was observed on potato tubers harvested in 2004 and 2006, compared with 2005, while weather conditions during the growing season of 2005 contributed to higher rates of infection by *Fusarium* spp. Disease occurrence on stored tubers is affected by growing season weather conditions (REPSIENE, MINEIKIENE 2006).

The severity of tuber diseases was determined by the experimental factors, i.e. NPK fertilization levels and foliar fertilizer types. The highest infection rates were noted for common scab and rhizoctoniosis. During the wet growing seasons of 2004 and 2006, the degree of tuber infection by *S. scabies* was

similar at both NPK fertilization levels. The values of infection indices increased along with an increase in fertilizer rates only in 2005, when precipitation totals were below normal limits (Table 2). REPSIENE and

Table 2

Intensity of common scab *S. scabies* and black scurf *R. solani* (index of infestation in %)

Level NPK	Foliar fertilization	Common scab				Black scurf			
		2004	2005	2006	X	2004	2005	2006	X
*A**	*1***	13.8^{b-h***}	13.3^{b-h}	14.2^{a-g}	13.8^{a-d}	13.7^{jkl}	6.3^{mn}	17.8^{d-h}	12.6^{c-f}
	2	13.2^{b-h}	12.2^{f-i}	14.4^{a-f}	13.3^{bcd}	15.7^{g-k}	6.7^{mn}	21.8^{ab}	14.7^{b}
	3	15.2^{a-e}	10.3^{i}	15.4^{a-d}	13.6^{a-d}	15.5^{g-k}	7.2^{mn}	18.4^{c-g}	13.7^{bc}
	4	12.8^{c-i}	11.4^{ghi}	13.3^{b-h}	12.5^{cd}	15.6^{g-k}	7.5^{mn}	19.9^{b-e}	14.3^{b}
	5	13.4^{b-h}	11.0^{hi}	13.8^{b-h}	12.7^{cd}	14.3^{i-l}	6.1^{mn}	19.1^{b-f}	13.2^{b-e}
	6	14.5^{a-f}	12.8^{c-i}	14.6^{a-f}	14.0^{abc}	14.7^{h-l}	5.7^{mn}	20.5^{a-d}	13.7^{bc}
	7	13.7^{b-h}	10.3^{i}	13.8^{b-h}	12.6^{cd}	13.2^{jkl}	5.8^{mn}	17.5^{d-h}	12.2^{c-g}
	8	15.1^{a-e}	13.3^{b-h}	16.7^{a}	15.0^{a}	18.5^{c-g}	8.9^{m}	23.3^{a}	16.9^{a}
X for treatments		14.0^{ab}	11.8^{d}	14.5^{a}	13.5^{a}	15.2^{c}	6.8^{e}	19.8^{a}	13.9^{a}
B	*1*	13.3^{b-h}	12.5^{e-i}	13.9^{b-g}	13.2^{bcd}	11.8^{l}	6.4^{mn}	16.3^{f-j}	11.5^{efg}
	2	12.8^{c-i}	13.2^{b-h}	14.2^{a-g}	13.4^{bcd}	13.7^{jkl}	6.8^{mn}	19.3^{b-f}	13.3^{bcd}
	3	14.5^{a-f}	13.0^{c-i}	15.9^{ab}	14.5^{ab}	13.0^{kl}	7.1^{mn}	17.3^{e-i}	12.5^{c-g}
	4	12.7^{c-i}	12.4^{e-i}	13.4^{b-h}	12.8^{cd}	13.9^{jkl}	6.0^{mn}	16.3^{f-j}	12.1^{c-g}
	5	12.2^{f-i}	12.7^{c-i}	12.7^{c-i}	12.5^{cd}	12.7^{kl}	5.8^{mn}	14.8^{h-l}	11.1^{fg}
	6	14.2^{a-g}	13.4^{b-h}	13.8^{b-h}	13.8^{a-d}	12.0^{l}	5.2^{n}	15.2^{h-k}	10.8^{g}
	7	12.6^{d-i}	12.6^{d-i}	11.8^{f-i}	12.3^{d}	11.9^{l}	6.0^{mn}	17.7^{d-h}	11.9^{d-g}
	8	14.0^{a-g}	14.2^{a-g}	15.5^{abc}	14.6^{ab}	15.6^{g-k}	7.4^{mn}	21.2^{abc}	14.7^{b}
X for treatments		13.3^{bc}	13.0^{c}	13.9^{b}	13.3^{a}	13.1^{d}	6.3^{e}	17.3^{b}	12.2^{b}
X for foliar fertilization									
1		13.6^{c-f}	12.9^{c-g}	14.1^{bcd}	–	12.8^{cd}	6.4^{ef}	17.1^{b}	
2		13.0^{c-g}	12.7^{d-g}	14.3^{a-d}	–	17.7^{c}	6.8^{ef}	20.6^{a}	
3		14.9^{abc}	11.7^{fg}	15.7^{ab}	–	14.3^{cd}	7.2^{ef}	17.9^{b}	
4		12.8^{d-g}	11.9^{efg}	13.4^{c-g}	–	14.8^{c}	6.8^{ef}	18.1^{b}	
5		12.8^{d-g}	11.9^{efg}	13.3^{c-g}	–	13.5^{cd}	6.0^{f}	17.0^{b}	
6		14.4^{a-d}	13.1^{c-g}	14.2^{bcd}	–	13.4^{cd}	5.5^{f}	17.9^{b}	
7		13.1^{c-g}	11.5^{g}	12.8^{d-g}	–	12.6^{d}	5.9^{f}	17.6^{b}	
8		14.6^{a-d}	13.8^{cde}	16.1^{a}	–	17.1^{b}	8.2^{e}	22.3^{a}	
X for years		13.6^{b}	12.4^{c}	14.2^{a}	–	14.1^{b}	6.6^{c}	18.5^{a}	

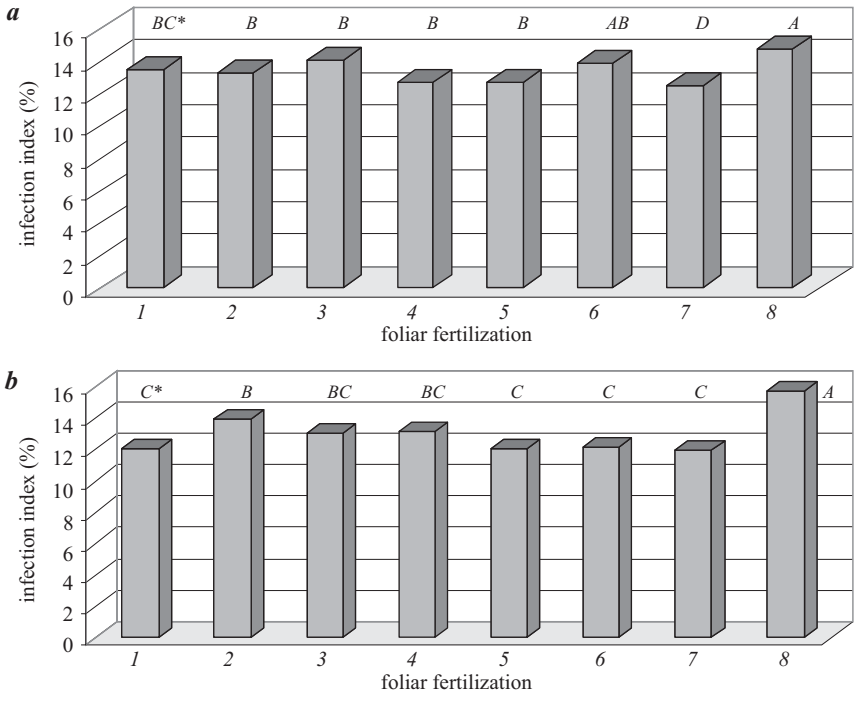
* level of NPK: *A* – N 80 kg ha^{-1}, P 80 kg ha^{-1}, K 120 kg ha^{-1}; *B* – N 120 kg ha^{-1}, P 144 kg ha^{-1}, K 156 kg ha^{-1});

** foliar fertilization: *1* – Basfoliar 12-4-6, *2* – ADOB Mn, *3* – Solubor DF, *4* – ADOB Mn + Basfoliar 12-4-6, *5* – ADOB Mn + Solubor DF, *6* – Basfoliar 12-4-6 + Solubor DF, *7* – Basfoliar 12-4-6 + ADOB Mn + Solubor DF, *8* – control without fertilization;

*** homogeneous groups according to Duncan test for comparison of means within factors and their interactions

MINEIKIENE (2006) observed no differences in the severity of common scab on fertilized and non-fertilized potato tubers, but found that mineral fertilization reduced the incidence of rhizoctoniosis. In the present study significantly lower rates of potato infection by *R. solani* (except for the year 2005) were noted in the treatment with a higher level of NPK fertilization, compared with that with a lower fertilization level. PUA and ABZA (2005) demonstrated that mineral and organic fertilizers alleviated the symptoms of rhizoctoniosis. However, in a study conducted by HONEYCUTT et al. (1996) nitrogen rates of 0 to 250 kg ha^{-1} had no effect on the intensity of infection caused by *R. solani*. KLIKOCKA et al. (2005) reported that sulfur fertilization at a rate of 50 kg ha^{-1} significantly reduced tuber infection by *S. scabies* and *R. solani*.

The foliar fertilizers applied in this experiment had no significant effect on the severity of common scab on potato tubers. However, an analysis of the mean values obtained for both levels of mineral fertilization (*A* and *B*) and for foliar fertilization shows that the infection rates were lower in the treatments in which ADOB Mn was applied together with Basfoliar 12-4-6 (treatment *4*) or with Solubor DF (*5*), and when all three foliar fertilizers were applied (*7*), compared with the other treatments (Figure 1a). The results regarding the effect of mixed foliar fertilizers on the health status of potato tubers, reported in literature, are inconclusive. According to KEINATH and LORIA (1989), the application of manganese can alleviate the symptoms of common scab. JABŁOŃSKI (2003) demonstrated that ADOB Mn and Basfoliar 36 E had no significant effect on the severity of common scab, internal rust spot, brown center and hollow heart. On the other hand, BOLIGŁOWA (2003) reported that the combined application of Insol 7 and urea increased the rates of tuber infection by *S. scabies*. The results of other studies suggest that common scab severity was affected neither by the foliar application of lime salpeter /$Ca(NO_3)_2$/ (SZUTKOWSKA and LUTOMIRSKA 2002) nor by potato growing with or without foliar fertilization (BORÓWCZAK and GŁADYSIAK 1999). BORÓWCZAK and GŁADYSIAK (1999) noted stronger symptoms of rhizoctoniosis on tubers from non-fertilized plants. RĘBACZ and BORÓWCZAK (2007) observed the weakest symptoms of rhizoctoniosis in a high-input production system with the foliar application of Mikrosol U, compared with medium- and low-input systems without foliar fertilization. In the present experiment the strongest symptoms of rhizoctoniosis were noted in the treatment without foliar fertilization, and the mean infection indices for both levels of mineral fertilization were significantly higher, compared to the treatment with the application of foliar fertilizers. The mean values obtained in treatments with foliar fertilization are indicative of similar results (Figure 1b).



* homogeneous groups according to Duncan test for comparison of means

Fig. 1. Infection of tubers: *a* – *S. scabies, b* – *R. solani; 1* – Basfoliar 12- 4-6, *2* – ADOB Mn, *3* – Solubor DF, *4* – ADOB Mn + Basfoliar 12-4-6, *5* – ADOB Mn + Solubor DF, *6* – Basfoliar 12-4-6 + Solubor DF, *7* – Basfoliar 12-4-6 + ADOB Mn + Solubor DF, *8* – control without fertilization

In this study potato tubers showed symptoms of rot caused by *P. carotovorum* subsp. *carotovorum* and species of the genus *Fusarium*, as well as symptoms of infection caused by *P. infestans*. These symptoms were more severe in treatments with higher rates of mineral fertilizers (*B* – N 120 kg ha^{-1}, P 144 kg ha^{-1}, K 156 kg ha^{-1}), in comparison with treatments with lower fertilization rates (*A* – N 80 kg ha^{-1}, P 80 kg ha^{-1}, K 120 kg ha^{-1}). The percentage mass of tubers infected by particular pathogens was as follows: *P. carotovorum* subsp. *carotovorum* – 4.1 and 3.0%, *P. infestans* – 1.3 and 0.8%, *Fusarium* spp. – 2.6 and 1.4% (Table 3 and Table 4), and the respective differences were statistically significant. The effect of foliar fertilizers on the severity of the above diseases varied (Figure 2). Higher rates of mineral fertilizers affected the symptoms of soft rot in treatments with foliar fertilization. The highest percentage mass of infected tubers – 4.7 (mean of the experimental period) was noted in the control treatment, and the difference between this treatment and the remaining fertilization treatments was

Table 3

Intensity of soft rot *P. carotovorum* subsp. *carotovorum* and of late blight of potato tubers *P. infestans* (percentage of mass of infected tubers)

Level NPK	Foliar fertilization	Soft rot				Late blight			
		2004	2005	2006	X	2004	2005	2006	X
A	*1*	3.0^{opq}	1.5^{wz}	3.8^{i-n}	2.8^{fg}	1.3^{f-i}	0.6^{l-o}	1.2^{f-j}	1.0^{bcd}
	2	2.8^{pqr}	2.1^{s-w}	4.2^{f-k}	3.0^{ef}	1.5^{d-g}	0.3^{op}	0.9^{i-m}	0.9^{cde}
	3	3.5^{mno}	1.4^{z}	5.1^{bcd}	3.3^{e}	0.6^{l-o}	0.6^{l-o}	1.0^{h-l}	0.7^{e}
	4	3.3^{nop}	1.7^{uwz}	3.3^{nop}	2.8^{fg}	0.7^{k-o}	0.5^{mno}	1.2^{f-j}	0.8^{de}
	5	4.0^{h-k}	2.2^{r-u}	3.5^{mno}	3.2^{e}	1.1^{g-k}	0.4^{nop}	0.7^{k-o}	0.7^{e}
	6	3.8^{i-n}	1.8^{t-z}	4.1^{g-l}	3.2^{e}	0.7^{k-o}	0.3^{op}	1.0^{h-l}	0.7^{e}
	7	2.4^{qrs}	1.7^{uwz}	3.2^{nop}	2.4^{g}	0.8^{j-n}	0^{p}	0.5^{mno}	0.4^{f}
	8	2.8^{pqr}	2.0^{t-z}	4.8^{b-f}	3.2^{e}	1.3^{f-i}	0.5^{mno}	0.7^{k-o}	0.8^{de}
X for treatments		3.2^{d}	1.8^{f}	4.0^{c}	3.0^{b}	1.0^{c}	0.4^{d}	0.9^{c}	0.8^{b}
B	*1*	4.5^{d-h}	2.2^{r-u}	4.7^{c-g}	3.8^{d}	1.0^{h-l}	0.8^{j-n}	0.9^{i-m}	0.9^{cde}
	2	3.8^{i-n}	2.7^{p-s}	6.3^{a}	4.3^{bc}	1.8^{b-e}	1.4^{e-h}	1.9^{bcd}	1.7^{a}
	3	4.6^{d-h}	2.3^{r-u}	4.7^{c-g}	3.9^{d}	1.5^{d-g}	1.3^{f-i}	2.4^{a}	1.7^{a}
	4	4.8^{b-f}	3.3^{nop}	5.4^{b}	4.5^{ab}	1.1^{g-k}	1.0^{h-l}	1.4^{e-h}	1.2^{b}
	5	4.4^{e-i}	2.7^{p-s}	5.0^{b-e}	4.0^{cd}	1.2^{f-j}	1.1^{g-k}	1.0^{h-l}	1.1^{bc}
	6	3.7^{j-n}	3.5^{mno}	6.0^{a}	4.4^{ab}	0.8^{j-n}	0.9^{i-m}	1.6^{c-f}	1.1^{bc}
	7	3.5^{l-o}	2.1^{s-w}	4.2^{f-k}	3.3^{e}	1.0^{h-l}	1.1^{g-k}	1.4^{e-h}	1.2^{b}
	8	5.1^{bcd}	3.6^{j-o}	5.3^{bc}	4.7^{a}	2.0^{abc}	0.4^{nop}	2.2^{abc}	1.5^{a}
X for treatments		4.3^{b}	2.8^{e}	5.2^{a}	4.1^{a}	1.3^{b}	1.0^{c}	1.6^{a}	1.3^{a}
X for foliar fertilization									
1		3.8^{cd}	1.9^{i}	4.3^{b}	–	$1.2^{bc}d$	0.7^{f-i}	1.1^{cde}	
2		3.3^{ef}	2.4^{h}	5.3^{a}	–	1.7^{a}	0.9^{d-g}	1.4^{ab}	
3		4.1^{bcd}	1.9^{i}	4.9^{a}	–	1.1^{cde}	1.0^{def}	1.7^{a}	
4		4.1^{bcd}	2.5^{h}	4.3^{b}	–	0.9^{d-g}	0.8^{e-i}	1.3^{bc}	
5		4.2^{bc}	2.5^{h}	4.3^{b}	–	1.2^{bcd}	0.8^{e-i}	0.9^{d-g}	
6		3.8^{cd}	2.7^{gh}	5.1^{a}	–	0.8^{e-i}	0.6^{ghi}	1.3^{bc}	
7		3.0^{fg}	1.9^{i}	3.7^{de}	–	0.9^{d-g}	0.6^{hi}	1.0^{def}	
8		4.0^{bcd}	2.8^{gh}	5.1^{a}	–	1.7^{a}	0.5^{i}	1.5^{ab}	
X for years		3.8^{b}	2.3^{c}	4.6^{a}	–	1.2^{b}	0.7^{c}	1.3^{a}	

Explanations as in Table 2

statistically significant. At both levels of mineral fertilization, the weakest symptoms of soft rot were observed in the treatment with combined application of foliar fertilizers. According to BAIN et al. (1996), the optimum rates of mineral fertilizers (e.g. calcium and magnesium) may reduce plant infection by *P. carotovorum* subsp. *carotovorum*, thus decreasing the incidence of soft rot on stored tubers. CZAJKA et al. (2006) demonstrated that nitrogen applied at excessive rates stimulated the development of selected potato diseases,

Table 4

Intensity of dry rot *Fusarium* spp. (percentage of mass of infected tubers)

Level NPK	Foliar fertilization	2004	2005	2006	X
A	*1*	1.6^{lm-p}	1.9^{j-m}	1.8^{j-n}	1.8^{cd}
	2	1.2^{o-s}	1.7^{k-o}	0.6^{tu}	1.2^{g}
	3	1.4^{m-q}	2.2^{h-k}	1.6^{l-p}	1.7^{cde}
	4	1.4^{m-q}	2.0^{i-l}	1.0^{q-u}	1.5^{ef}
	5	1.1^{p-t}	2.3^{g-j}	1.4^{m-q}	1.6^{def}
	6	0^{w}	1.0^{q-u}	0.5^{u}	0.5^{h}
	7	0.8^{r-u}	0.7^{stu}	0.7^{stu}	0.7^{h}
	8	2.1^{i-l}	1.8^{j-n}	2.0^{i-l}	2.0^{c}
X for treatments		1.2^{e}	1.7^{d}	1.2^{e}	1.4^{b}
B	*1*	0.8^{r-u}	1.7^{k-o}	1.0^{q-u}	1.2^{g}
	2	3.1^{def}	4.8^{ab}	3.4^{d}	3.8^{a}
	3	3.3^{de}	4.2^{c}	3.6^{d}	3.7^{a}
	4	0.8^{r-u}	2.0^{i-l}	1.2^{o-s}	1.3^{fg}
	5	2.7^{fgh}	4.5^{bc}	2.5^{ghi}	3.2^{b}
	6	2.8^{efg}	5.2^{a}	3.1^{def}	3.7^{a}
	7	1.2^{o-s}	3.3^{de}	1.4^{m-q}	2.0^{c}
	8	1.3^{n-r}	3.1^{def}	1.4^{m-q}	1.9^{c}
X for treatments		2.0^{c}	3.6^{a}	2.2^{b}	2.6^{a}
X for foliar fertilization					
1		1.2^{hi}	1.8^{ef}	1.4^{gh}	–
2		2.2^{cde}	3.3^{a}	2.0^{def}	–
3		2.4^{bcd}	3.2^{a}	2.6^{b}	–
4		1.1^{hi}	2.0^{def}	1.1^{hi}	–
5		1.9^{ef}	3.4^{a}	2.0^{ef}	–
6		1.4^{gh}	3.1^{a}	1.8^{ef}	–
7		1.0^{i}	2.0^{def}	1.1^{hi}	–
8		1.7^{fg}	2.5^{bc}	1.7^{fg}	–
X for years		1.6^{b}	2.7^{a}	1.7^{b}	–

Explanations as in Table 2

including soft rot. MILLS et al. (2006) reported that potassium sorbate, potassium alum and copper sulfate exerted a fungistatic effect on the above bacteria under *in vitro* conditions. Potato tubers treated with the above compounds before storage showed weaker infection symptoms than control tubers.

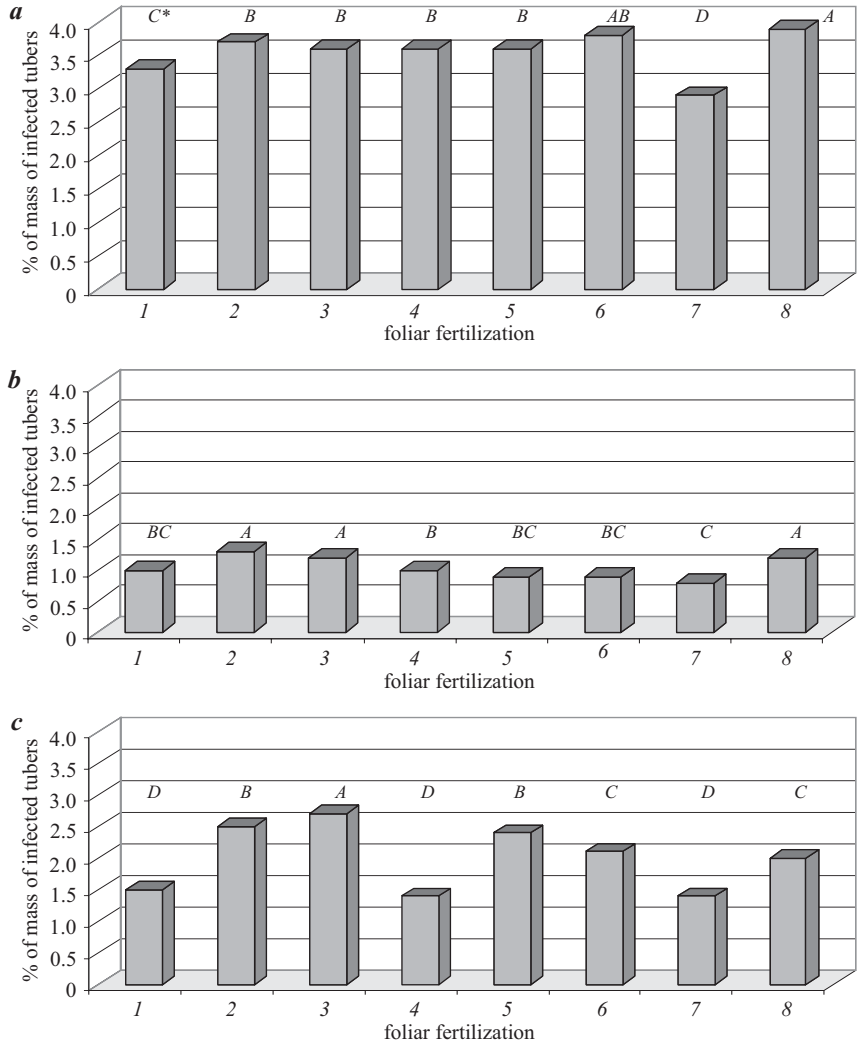


Fig. 2. Infection of tubers: *a* – *P. carotovorum* subsp. *carotovorum*, *b* – *P. infestans*, *c* – *Fusarium* spp. Explanations as in Figure 1

In the present experiment, late blight symptoms were noted on 0.4 to 1% of potato tubers, in the treatment with the application of all three foliar fertilizers and in that with the application of Basfoliar 12-4-6 and ADOB Mn respectively (Table 3). Slightly higher infection rates (significant differences) were reported in treatments with a higher level of mineral fertilization and the application of ADOB Mn or Solubor DF and in the control treatment (1.5–1.7%), compared with the other treatments.

Mineral fertilization, including the application of mixed foliar fertilizers, affects late blight occurrence both during the growing season and storage. The foliar application of phosphorus reduces the incidence of infection caused by *P. infestans* (COOKE, LITTLE 2002) and *P. erytroseptica* (JOHNSON et al. 2004). RĘBACZ and BORÓWCZAK (2007) demonstrated that nitrogen applied at rates comparable to those used in this experiment had no effect on the percentage of tubers infected by *P. infestans,* while a significant decrease in their percentage share was noted at higher nitrogen rates (180 kg N ha^{-1}). ANN (2001) found that the infection of potato plants by the above pathogen was reduced following the combined application of fungicides and the foliar fertilizers Nur-Phite P and Guard PK. Also KAPSA (2002) reported that foliar fertilizers applied together with fungicides protected potato plants against *P. infestans*. The authors of earlier studies (BÓROWCZAK and GŁADYSIAK 1999) observed comparable severity of late blight symptoms in treatments with and without foliar fertilization.

The highest rates of infection by fungi of the genus *Fusarium* (5.2% of the total mass of tubers) were noted on potato tubers harvested in 2005 in the treatment with a higher level of mineral fertilization and foliar application of Basfoliar 12-4-6 and Solubor DF (treatment *6*, Table 4). The strongest symptoms of dry rot were observed in treatments with a higher level of mineral fertilization and the application of ADOB Mn or Solubor DF. The weakest disease symptoms were reported in treatments with the application of Basfoliar 12-4-6, ADOB Mn together with Basfoliar 12-4-6, and the combined application of all three foliar fertilizers (Figure 2c).

Some species of the genus *Fusarium* (*F. avenaceum, F. culmorum, F. equiseti, F. sambucinum, F. solani* var. *coeruleum*) are dangerous pathogens causing substantial tuber yield loss and tuber quality deterioration during storage (KURZAWIŃSKA 1997, PETERS et al. 2008, STEVENSON et al. 2001). The findings of MECTAU et al. (2002) indicate that certain salts (sodium carbonate, aluminum chloride) inhibit the development of dry rot on potato tubers.

Conclusions

1. Higher rates of tuber infection by *P. carotovorum* subsp. *carotovorum, P. infestans* and fungi of the genus *Fusarium*, and lower rates of infection by *R. solani* and *S. scabies* were noted in treatments with a higher level of mineral NPK fertilization, compared with treatments with a lower fertilization level.

2. Foliar fertilizers exerted a varied effect on the severity of tuber diseases. Lower rates of infection by *R. solani* were observed in fertilized treatments than in the control treatment.

3. The combined application of three foliar fertilizers had the most beneficial effect on the health status of potato tubers.

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