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INFLUENCE OF NPK FERTILIZATION ENRICHED WITH S, Mg, AND MICRONUTRIENTS CONTAINED IN LIQUID FERTILIZER INSOL 7 ON POTATO TUBERS YIELD (*SOLANUM TUBEROSUM* L.) AND INFESTATION OF TUBERS WITH *STREPTOMYCES SCABIES* AND *RHIZOCTONIA SOLANI*

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Abstract

Elemental sulphur and Kieserite fertilization have been demonstrated to improve potato tuber (*Solanum tuberosum*) yield quality and resistance against *Streptomyces scabies*; the bacterial effect was attributed to reduced soil pH. So far, no information has been available about the influence of S, Mg and supply of micronutrients on bacterial and fungal diseases of potato plants. Field trials performed in a split-plot design with varied fertilization treatments (NPK with/without S and Mg and microelements B, Zn, Mn, Cu fertilization) including three potato cultivars were conducted in the south eastern region (near Zamość) of Poland in 2004-2006. The application of S and Mg and micronutrients decreased the tuber infection rate and severity of *Streptomyces scabies* and *Rhizoctonia solani*, while increasing potato tuber yield. Generally, tuber yield and wholesomeness were mostly related to a genotype (cultivar), mineral fertilization treatments and their interaction with a cultivar.

Key words: potato tuber, mineral fertilization treatments, *Streptomyces scabies*, *Rhizoctonia solani.*

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WPŁYW WZBOGACENIA NAWOŻENIA NPK DODATKIEM S, Mg I MIKROELEMENTÓW ZAWARTYCH W PŁYNNYM NAWOZIE INSOL 7 NA PLON I PORAŻENIE BULW ZIEMNIAKA (*SOLANUM TUBEROSUM* L.) PRZEZ *STREPTOMYCES SCABIES* I *RHIZOCTONIA SOLANI*

Abstrakt

Nawożenie ziemniaka siarką elementarną i kizerytem podwyższa plon bulw, poprawia ich jakość i odporność na porażenie przez *Streptomyces scabies*. Obniżenie odczynu gleby (pH) wskutek nawożenia S-elementarną może ograniczać wpływ chorób grzybowych. Jednakże brak jest szerszych informacji o bezpośrednim wpływie łącznego nawożenia S i Mg na wzrost odporności na porażenie bulw ziemniaka przez choroby bakteryjne i grzybowe. Eksperyment polowy na glebie brunatnej wyługowanej przeprowadzono w latach 2004-2006 w płd.-wsch. rejonie Polski (k. Zamościa). Pod 3 odmiany ziemniaka zastosowano następująco zróżnicowane nawożenie mineralne: NPK oraz NPK z dodatkiem S, Mg i mikroelementów: B, Zn, Mn, Cu. Wzbogacenie NPK w S i Mg oraz mikroelementy spowodowało zmniejszenie porażenia bulw przez *Streptomyces scabies* i *Rhizoctonia solani* oraz zwiększenie plonu bulw ziemniaka. Generalnie zdrowotność i plon bulw były najsilniej zależne od odmiany, następnie od nawożenia mineralnego oraz jego współdziałania z odmianami.

Słowa kluczowe: bulwy ziemniaka, poziom nawożenia mineralnego, *Streptomyces scabies*, *Rhizoctonia solani.*

INTRODUCTION

Mineral nutrients are routinely applied to boost crop yields and improve overall plant health and quality. The nutrition of plants largely determines their resistance or susceptibility to disease, histological or morphological structure and properties, and the virulence or ability of pathogens to survive. Mineral nutrients are frequently the first and foremost line of defence against plant diseases and influence all parts of the disease “pyramid” (HUBER, HANEKLAUS 2007, DATNOF et al. 2007). Plants have developed different forms of resistance. Nutrient-induced resistance was observed for phosphate, silicone and sulphur (KLIKOCKA et al. 2005, SALAC 2005). The mineral plant nutrition can potentially improve the stress resistance of plants. The mechanisms for the sulphur-induced resistance (SIR) of plants against fungal diseases include the increased synthesis of natural components, degradation of glycosides, synthesis of new components and the hypersensitive response (HANEKLAUS et al. 2002). LAMBERT et al. (2005) report that nutrient balance can decrease the severity of many important potato diseases and that certain practices, such as maintaining low pH for scab control, have been followed for this purpose.

Sulphur and magnesium fertilization increased yield of potato tubers, improved tuber quality and resistance against *Streptomyces scabies*, whereby the bactericidal effect was attributed to a reduced soil pH by elemental S applications (GRZEBISZ, HÄRDTER 2006, LAMBERT et al. 2005, PAVLISTA 1995, PRA-

KASH et al. 1997, ROGOZIŃSKA 1991). SAWICKA and KROCHMAL-MARCZAK (2008) studied influence of liquid fertilizer Insol 7 on diseases of potato tubers. So far, however, no information has been available about the influence of S and Mg supply on bactericidal and fungal diseases in potato. The aim of the present research has been to quantify the influence of fertilization treatments (with and without S and Mg and fertilization with micronutrients: B, Zn, Mn, Cu) on the tuber yield and infestation of three potato tuber cultivars with *Streptomyces scabies* and *Rhizoctonia solani* as a contribution of plant nutrition strategies for healthier plants.

The pathogens Streptomyces scabies and Rhizoctonia solani

The skin disease „common scab" is caused by the bacterium *Streptomyces scabies*. Virulent species of these otherwise saprophytic filamentous bacteria produce a toxin, thaxtomin, which kills patches of periderm cells and elicits production of newly suberized layers, which leave raised or pitted scabs on the tuber surface (BŁASZCZAK et al. 2005, FAUCHER et al. 1992, LAMBERT et al. 2005). The disease occurs in all regions of potato cultivation, particularly on light, friable, dry and alkaline soils (BRAZDA 1995, ELPHINSTONE 2007). In Poland, as well as in other countries, up to 70% of tubers may be infested by potato scab subject to the cultivation region and variety (GUGAŁA et al. 2007, KEINATH, LORIA 1989, KLIKOCKA et al. 2005, PUŁA, ŁABZA 2007, SALAZAR 2006). The optimum conditions for common scab development are air temperatures of 23-25°C. An Insufficient nutrient supply (Mn, K, Mg, Zn, B) favours infestation with *Streptomyces scabies* (BRAZDA 1995). LAMBERT et al. (2005) suggested a positive relationship between higher periderm Ca content and scab, despite the general benefits of increasing calcium availability in alkaline soils. A reduction of soil pH by gypsum and elemental S or ammonium sulphate applications reduced infestation with *Streptomyces scabies* (KLIKOCKA et al. 2005, LAMBERT et al., 2005, PAVLISTA 1995). BARNES (1972) applied 0.5 MT ha^{-1} elemental sulphur and reduced scab by 27% with a pH change of 6.1 to 5.4. In a subsequent trail, 0.5 or 1 MT ha^{-1} elemental S reduced common scab by 50% with the pH reductions from 5.2 to 4.6 and 4.2. The author, however, cautioned against over-application of elemental S. Reduction of elemental sulphur to hydrogen sulphide, which is toxic to *S. scabies in vitro*, has been considered as a possible mechanism of S-induced scab reduction. This conversion requires anaerobic conditions, such as might result from waterlogging, and its practical significance under typical field conditions is unknown (LAMBERT et al. 2005). DAVIS et al. (1976a) report that growing potatoes without any P fertilizer substantially increased scab compared to the other four P treatments, which ranged from 84 to 336 kg ha^{-1} P_2O_5. Scab could not be reduced by increasing or decreasing the standard rate of phosphorus. In another study, various rates of elemental sulphur decreased scab when irrigation thresholds were 100 kPa or above. Elemental S increased yield by an average of 20% and sulphur treatment also increased petitole P (DAVIS et al. 1976b). Other elements have been investigated for control of common scab, particularly manganese (Keinath, Loria 1989), whose availability in soil increases with acidity and soil moisture, supporting the hypothesis that Mn toxicity to *Strpetomyces scabies* is a major mechanism in the pH and irrigation effects and that Mn applications would further reduce scab. Lambert et. al. (2005) concluded that Mn improves host resistance to tuber pathogens, possibly in its role as a cofactor with enzymes involved in oxidation/reduction or with direct oxidation of phenolics. In this case, plant manganese concentration adequate for yield may be suboptimal for disease resistance.

In compliance with the standards and norms for the international trade within the European Union, which Poland observes, the area of the tuber surface affected by *Streptomyces*. Gus may not exceed 1/5 of total tuber surface. For potato seeds, infection by scab cannot exceed 5% of the total surface (Zgórska, Frydecka-Mazurczyk 2002).

Rhizoctoniose or „stem cancer" caused by the fungus *Rhizoctonia solani* is known as one of the most widespread diseases of cultivated plants, particularly potatoes, root vegetables, cabbage, tomatoes, cereals and grasses. *R. solani* is a soil borne pathogen. The symptoms characteristic for potato infestation include rotting sprouts, stem dry rotting and smallpox (Read et al. 1889, Yao 2002). The fungus *R. solani* is tuber coloniser, most easily identified by small black sclerotia (black scurf stage) on the tuber surface. Błaszczak et al. (2005) used scanning electron microscopy to investigate different types of necroses in potato tubers infected by rhizoctoniose. Cultivar Irga showed superficial necrotic symptoms caused by *Rhizoctonia* ssp. Fungal necrosis caused strong disintegration of cell walls with cell lysis. Additionally, tubers are small in size, often deformed and smallpoxed (Read et al. 2005).

Usually, about 14-20% of the tubers show symptoms of the infestation with rhizoctoniose with variations dependent on the cultivation region and variety (Kurzinger 1995, Salazar 2006). In Poland, however, up to 40% of the tuber surface may be affected by infestation with this pathogen (Klikocka 2001, Puła, Łabza 2007).

Rhizoctonia solani survives in the soil during winter in form of sclerotia or mycelia on residues of infested plants and on potato seedlings, respectively. The optimum temperature for plant infestation is 15-18°C (Błaszczak et al. 1997). Under disadvantageous growing conditions, such as high moisture and low temperature in the soil combined with poor plant growth, the disease spreads soon after planting potatoes. Early planting of potatoes increases the risk of rhizoctoniose. For planting, only those tubers should be selected which are covered with no more than 20% sclerotia on the surface (Häni et al. 1976). Common agronomic measures to reduce the infestation risk include the choice of suitable forecrops, careful application of herbicides (Radtke 1994, Puła, Łabza 2007) and optimum planting depth (Stachewicz 1996). Jabłoński (2006) observed that rhizoctoniose of tubers increased after simplification of soil cultivation. Although the disease may cause important losses, little work has been done on nutritional effects. Manganese at 62 kg ha^{-1} reduced from 25% to 11%. the incidence of *Rhizoctonia solani* black scurf on tubers No differences in number of stem lesions were obtained over a range of 0 to 250 kg N ha^{-1} (LAMBERT et al. 2005), but RĘBARZ and BORÓWCZAK (2007) reports that increase of nitrogen doses from 0 to 180 kg N ha^{-1} cased the decrease of occurrence of black scurf. KLIKOCKA et al. (2005) observed that sulfur application reduced the fungal pathogen of potato tubers. Other observations also emphasize the preventive role of sulfur against the fungal diseases (DATNOFF et al. 2007, HUBER, HANEKLAUS 2007, SALAC 2005, HANEKLAUS et al. 2002). The agronomic measures, beside the chemical methods and cultivation of resistant varieties, are of the utmost importance in prevention of plant diseases. It has been shown that mineral fertilization (with macro- and micronutrients) promotes natural plant resistance mechanisms, similarly to application of silicon, aluminum and sulfur (DATNOFF et al. 2007, HUBER, HANEKLAUS 2007).

MATERIAL AND METHODS

The description of experiment sites

The field experiments on potatoes were conducted at Malice (N 50°42'; E 23°15'), a village near Zamość in Poland, in the years 2004-2006. The experiment was carried out on leached brown soil with loamy silty soil texture. The soil characteristics (according to SILANPÄÄ 1982) were 13% clay, 29% silt, 58% sand, 8.4 g kg^{-1} of total-C content (by dry combustion; LECO EC-12®, model 752-100) and pH 5.3 (potentiometrically in 0.01 M $CaCl_2$ suspension using a Methrohm 605 pH-meter). Total-N was on average 0.8 g kg^{-1} (by Kjeldahl extraction method), plant available P 72.6 mg kg^{-1} and K 63.1 mg kg^{-1} (vanadium-molybdene by Egner-Riehm method), phosphorus (by the colorometric method) and potassium (by photometry), plant available Mg 37.0 mg kg^{-1} (by Schachtschabel method), plant available S-SO_4 – 11.5 mg kg^{-1} (extracted by 0.025 m KCl and determined in an ion chromatograph) (BLOEM 1998).

Throughout the last two decades, the air temperature sum and the total precipitation in the growing seasons averaged 2344°C and 386 mm. The total rainfall in the seasons of 2005 and 2006 was lover than the long-term sum. In 2004, the total rainfall was similar to the long-term sum. The monthly means of the air temperatures in the growing seasons in 2004-2006 were much higher than over the long term. June, July and August were particularly hot months. Generally, the growing season in 2004 was very warm and wet, while the vegetation seasons of 2005-2006 were very hot and dry (Table 1).

Table 1

Sums of rainfalls (mm) and mean air temperature (^{o}C) in 2004-2006 and in the long- term period 1971-1988 (research station Zamość)

Monts							
Years	Apr	May	June	July	Aug	Oct	Sum Apr-Oct
Precipitation (mm) – month sum							
2004	46.3	50.1	34.9	145.0	71.9	36.3	384.5
2005	45.4	98.2	69.5	33.6	52.7	15.8	315.2
2006	58.4	54.0	43.5	28.3	144.8	0.8	329.8
1971-1988	39.0	62.0	90.0	80.0	60.0	55.0	386.0
Temperature (^{o}C) – month mean							
2004	9.6	13.5	18.1	19.4	19.7	14.3	2890
2005	9.7	15.4	17.5	21.8	18.7	13.3	2948
2006	10.5	14.8	18.4	23.3	19.0	16.8	3144
1971-1988	7.2	13.4	15.8	17.4	16.8	12.6	2544

Experimental design and treatments

The experiment was carried out with two factors in a split plot design, with four replications. The first factor consisted of two treatments of fertilization: basic – NPK (A) and enriched NPK in S, Mg and micronutrients (B), while the second one comprised three medium-early potato cultivars: Irga (1), Mila (2) and Sante (3). The plot size was 30 m^2, the central part (19.5 m^2) of each plot was harvested. The row-space was 67.5 cm with 44.000 tubers ha^{-1} planted. Having harvested the forecrop, spring triticale, the straw was cut (5 $t \cdot ha^{-1}$) supplemented with 50 kg N in the form of urea (1 kg N per 100 kg straw) and winter rapeseed sown. In the third decade of March, the rapeseed was sprayed with 36% isopropylamine salt of glyphosate (Roundup 360 SL, 0.360 g a.i. kg^{-1} Monsanto) in dose 1080 g a.i. ha^{-1}. In the second decade of April, prior to the potato planting, the following two levels of mineral nutrition were applied:

A – basic (NPK): (kg ha^{-1}) N–100 (as urea), P_2O_5–90 (as mineral superphosphate), K_2O–140 (as potash salt),

B – enriched (NPK + SMg + micro-nutrients): ($kg \cdot ha^{-1}$) N–100 (as urea), P_2O_5–90 (as mineral superphosphate), K_2O–140 (as potash salt balanced with potassium sulphate), MgO–30 (as magnesium sulphate balanced with bitter-salt), S–25 (as potassium sulphate balanced with magnesium sulphate and with bitter-salt), INSOL-7-Potato (as N–14.0, B–0.50, Zn–1.5, Mn–1.5, Cu–0.50%) (2 l ha^{-1}).

The NPK fertilizers, partly S and Mg were applied before the potato planting. Bitter-salt and INSOL-7 – Potato mixed up with Miedzian 50 WP and Decis 2,5 EC were used for the foliar nutrition of potato plants at the growth stage determined by BBCH-scale: 49/55 (combined treatment for late blight and potato beetle control). Potato planters are not equipped with attachments to apply materials for *Rhizoctonia solani* control. The weed control was mechanical and chemical: from potato planting until emergence: harrowing, earthing up, weeding, while after emergence: herbicide metribuzin (Sencor 70 WP, 700 g a.i. kg^{-1}, Bayer) in dose 0.350 g a.i. ha^{-1}.

Fungicides for the control of *Phytophthora infestans* and other foliage diseases were applied four times:

1) oxadiksyl + mancozeb (Sandofan Manco 64 WP, 80 g a.i. kg^{-1} of oxadiksyl + 560 g a.i. kg^{-1} of mancozeb, Syngenta) in dose 160 g a.i. ha^{-1} + 1120 g a.i. ha^{-1};
2) copper (oxachloride form) (Miedzian 50 WP, 500 g a.i. kg^{-1}, Organika) in dose 1250 g a.i. ha^{-1}, 3. mancozeb (Dithane 75 WG 750 g a.i. kg^{-1}, Dow AgroSciences) in dose 1500 g a.i. ha^{-1};
4) fentin (hydroxide form) (Brestanid 502 SC., 502 g a.i. kg^{-1}, Aventis) in dose 251 g a.i. ha^{-1}.

The control of potato beetle (*Leptinotarsa decemlineata*) consisted of triple application of safe, inexpensive insecticides:

1) teflunenzuron (Nomolt 150 S.C., 150 g a.i. L^{-1}, BASF) in dose 37.5 g a.i. ha^{-1};
2) deltametryna (Decis 2,5 EC, 25 g a.i. L^{-1}, Aventis) in dose 7.5 g a.i. ha^{-1};
3) acetamiprid (Mospilan 20 SP, 200 g a.i. kg^{-1}, Nippon Soda) in dose 20 g a.i. ha^{-1}.

The chemical practices (the second and the third one) against late blight and chrysometids as well as fertilization feeding were performed jointly in order to reduce the number of crossings through the field (the preparations were mixed: Miedzian 50WP with Decis 2.5 EC with Bitter-salt and INSOL-7-Potato (2) and Dithane 75 WG with Mospilan 20 SP (3). The fourth protective treatment, a combined one, was carried out three weeks before the potato harvest. Brestanid 502 S.C. (for the protection of tubers against spores of potato blight) with dikwat desicant (in ion form) (Reglone Turbo 200 SL, 200 g s.a. L^{-1}, Syngenta) in dose 600 g s.a. ha^{-1}. Pesticides were applied by a 12-m-wide tractor-mounted sprayer that delivered 200 L ha^{-1} spray solution through 80-02 flat fan nozzles (model PILMET – P-412, Polen) at a spray pressure of 200 kPa.

The central part (19.5 m^2) of each plot was harvested in the second decade of September. From 2004 to 2006, in the 2nd decade of September, the tubers were visually rated for infection rate and infestation severity with *Streptomyces scabies* and *Rhizoctonia solani,* 1 to 9 scores corresponding to 0 to >25% and 0 to >50% infestation rate with *Rhizoctonia solani* and *Streptomyces scabies,* respectively. The visual score was carried out for a subset of samples (100 tubers or 10 kg, respectively) – Table 2 (ROZTROPOWICZ 1999).

Table 2

Scoring of infestations with Rhizoctonia solani and *Streptomyces* scabies on potato tubers (acc. ROZTROPOWICZ 1999)

Scoring	Infestation with *Streptomyces scabies* (percentage of scabs covering the tuber surface)	Infestation with *Rhizoctonia solani* (number/percentage of sclerotia covering the tuber surface)
9	none	none
8	< 5	< 10
7	6-10	~ 12
6	11-15	< 5%*
5	16-20	5 - 10%**
4	21-25	11 - 15%**
3	26-35	16 - 20%**
2	35-50	21 - 22%**
1	>50	>25%**

*small sclerotia; **small and big sclerotia

Statistical analysis

The results were analyzed statistically using the variance analysis with the F-Snedecor test function, then its distribution was computed (KLIKOCKA, SACHAJKO 2007). The significance of differences was indicated by Tukey«s HSD test at significance levels of $p<0.05$ and $p<0.01$. The coefficient of variation (*CV%*), a dispersion measure, was calculated as the quotient between the standard deviation (SD) and the mean. To establish the dependences and relationships between the elements studied, the analysis of correlation, determination and linear regression was applied (TRĘTOWSKI, WÓJCIK 1988). The comparison and summary of results was performed using Excel 7.0 worksheet and Statistica program (StatSoft Polska '97).

RESULTS AND DISCUSSION

The variance analysis revealed that differences in the potato tuber yields as well as *Streptomyces scabies* and *Rhizoctonia solani*–induced infection rates proved statistically significant.

The results given in Tables 3 and 4 show that the mineral fertilization levels (A–basic: NPK and B–enriched: NPK improved with S, Mg and microelements supplied as foliar and soil fertilizers) and the potato genotype type (1–Irga, 2–Mila, 3–Sante) influence the characteristics investigated. In this case, probability distribution of the F-test function at α=0.05 as well as dif-

Table 3

Results of statistical computation for investigated features

Investigated features (n=72, df_{error}=55	Variable	SED	CV%	Estimation F	p-value	LSD α=0.05*
Tuber yield (t ha^{-1})	F (df=1)	1.46	4.22	4.03*	0.049	1.46
	C (df=2)	4.46	13.19	42.80**	6.2E-12	1.79/2.38
	FC (df=2)	5.55	15.99	3.36*	0.042	2.53
	Y (df=2)	1.34	3.87	2.26	0.114	n.s.
Streptomyces scabies (infection rate %)	F	1.42	8.77	4.86*	0.032	1.29
	C	3.40	23.95	32.06**	5.9E-10	1.58/2.11
	FC	4.20	25.91	0.81	0.450	n.s.
	Y	3.00	18.54	14.46**	8.9E-06	1.58/2.11
Streptomyces scabies (infection severity 1-9)	F	0.24	4.20	4.45	0.039	n.s.
	C	0.76	13.22	39.29**	2.5E-11	0.28/0.38
	FC	0.83	14.31	1.57	0.217	n.s.
	Y	0.65	11.13	20.84**	1.8E-07	0.28/0.38
Rhizoctonia solani (infection rate %)	F	0.92	24.07	53.67**	1.1E-09	0.25/0.34
	C	0.88	22.10	29.69**	1.8E-09	0.31/0.41
	FC	1.12	29.17	9.13**	3.8E-04	0.44/0.58
	Y	0.66	17.15	18.15**	8.8E-07	0.31/0.41

Variable: F – fertilization treatments, C – cultivars, FC – fertilization treatments x cultivars, Y – years, df – degrees of variable freedom, df_{error} – degrees of error freedom, SED – standard error, CV% – coefficient of variation, estimation F of variance analysis: significant difference at (*α=0.05, ** α=0.01), p-value of F-variance ratio, LSD – significant difference, n.s. – not significant

ferences measured by Tukey«s test were significant. It was only potato tuber infection developed by *Streptomyces scabies* (scored 1-9) that appeared to be independent from the mineral fertilization. Generally, the analysed potato traits proved to be most highly varied (*CV%*) and differentiated (LSD) by the genotype (cultivar), then the mineral fertilization level and the cultivar response to fertilizers rather than the weather factor (Tables 3, 4).

The analysis of the research results confirmed a positive effect of the NPK fertilization improvement with sulphur, magnesium and Insol-7-Potato preparation (as N, B, Zn, Mn, Cu) – Table 3. NPK fertilization enriched with S and Mg and micronutrients in liquid fertilizer Insol 7 (B) increased potato tuber yield about 5.8% in comparison to NPK fertilization (A). The highest tuber yield was recorded for cv. Sante, which was justified by the genotype. The cultivars Sante and Irga responded in a highly positive manner to NPK fertilization (A), while the cultivar Mila exhibited a slight decrease in yield, although it was within the statistical error limits. Figure 1 shows the relationship between tuber yields of particular potato cultivars and tuber diseases (percentage infection rate) in dependence on fertilization. In plots where basic NPK fertilization (A) was used no significant relationship between tuber yield and tuber diseases occurred. Where enriched NPK

Table 4

Value of investigated features (means in years 2004-2006)

Investigated features (n=72)	Fertilization treatments (F) / / Year (Y)	Cultivars (C)			Mean
		Irga	Mila	Sante	
Tuber yield (t ha^{-1})	basic (A)	31.77	30.54	38.65	33.65
	enriched (B)	34.37	29.10	43.70	35.72
	2004	32.82	25.96	40.76	33.18
	2005	33.29	29.74	42.38	35.14
	2006	33.10	33.76	40.38	35.75
	mean	33.18	29.82	41.17	34.69
Streptomyces scabies (infection rate %)	basic (A)	22.58	15.85	13.17	17.20
	enriched (B)	19.28	15.37	10.92	15.19
	2004	17.24	11.00	10.00	12.75
	2005	23.61	18.75	12.38	18.25
	2006	21.93	17.07	13.77	17.59
	mean	20.93	15.61	12.05	16.19
Streptomyces scabies (infection severity 1-9)	basic (A)	4.64	5.94	6.38	5.65
	enriched (B)	5.16	5.87	6.97	6.00
	2004	5.71	6.85	7.16	6.57
	2005	4.21	5.36	6.63	5.40
	2006	4.78	5.51	6.24	5.51
	mean	4.90	5.91	6.68	5.83
Rhizoctonia solani (infection rate %)	basic (A)	5.84	3.33	4.26	4.48
	enriched (B)	3.47	2.63	3.42	3.17
	2004	5.52	3.93	3.44	4.29
	2005	4.53	3.60	4.19	4.10
	2006	3.93	1.41	3.89	3.08
	mean	4.66	2.98	3.84	3.82
Rhizoctonia solani (infection severity 1-9)	basic (A)	5.60	7.12	6.76	6.49
	enriched (B)	6.61	7.48	7.16	7.08
	2004	5.73	6.95	7.02	6.57
	2005	6.32	6.57	7.10	6.66
	2006	6.27	8.38	6.76	7.13
	mean	6.11	7.30	6.96	6.79

fertilization with S and Mg and micronutrients (B) was used, the yield of potato tuber of cv. Mila was significantly negatively correlated (r = -0.62) and determined (R^2 = 37) to be infected by *Rhizoctonia solani*. In this case, enriched fertilization NPK (B) increased yield of tubers simultaneously decreasing infection of tubers by rhizoctoniose. SALAZAR (2006) reports that the fungus *Rhizoctonia solani* was found in Peru and Bolivia and attacks be-

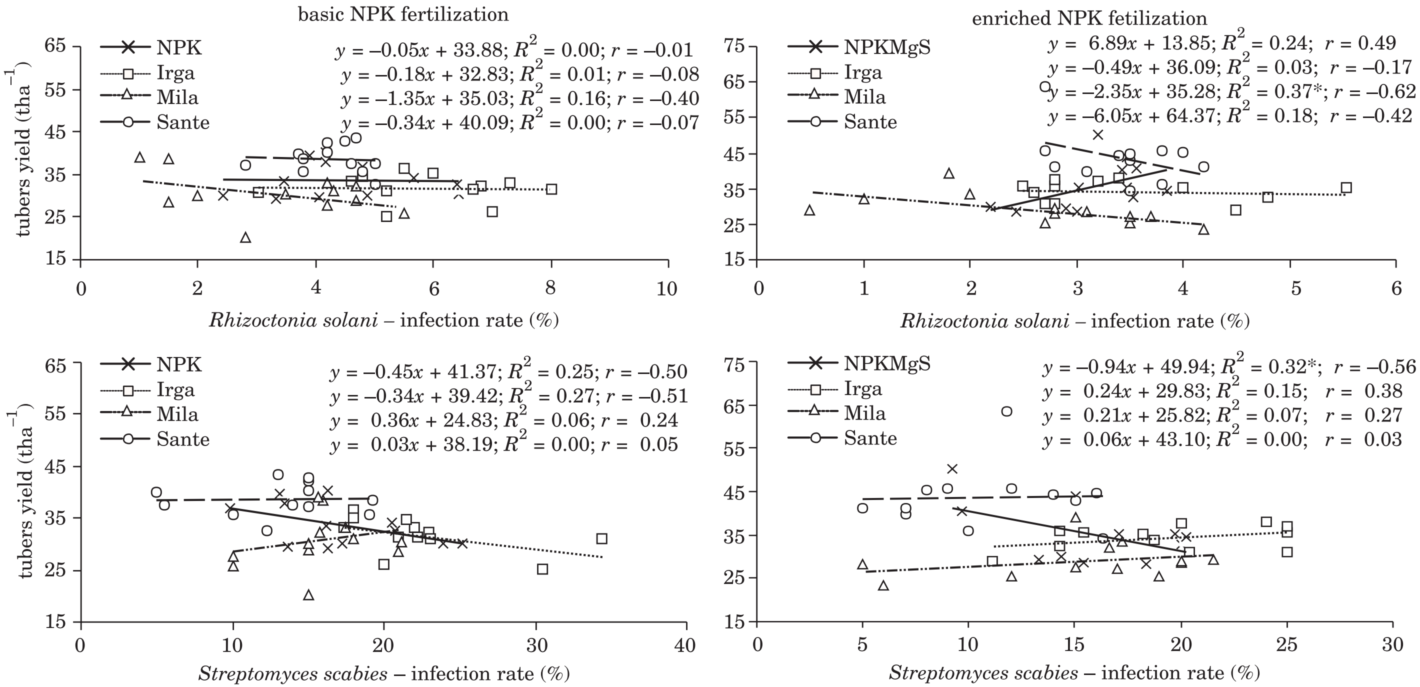

Fig. 1. The relationship between tuber yield and infection of tubers by Rhizoctonia solani and Streptomyces scabies

tween between 2 and 35% of tubers. Losses due to black scurf were estimated at 5 to 10%. In our experiment, when plots received enriched NPK fertilization (B) the tuber yield of all the three cultivars was significantly negatively correlated (r = -0.56) and determined (R^2 = 32%) to suffer from *Streptomyces scabies*-induced infection. Also, in this case enriched fertilization NPK (B) increased yield of tubers and decreased at the same time infection of tuber by scab. SALAZAR (2006) wrote that *S. scabies* occurred in Bolivia and incidences of infections varied between 28 to 40% causing yield losses up to 20% (Figure 1). LAMBERT et al. (2005) reports that nutrient effects could include alternations in the physiological or structural components of the plant's defense system, increased antagonistic microbial activity, or direct toxity to the pathogen. GRZEBISZ and HÄRDTER (2006) states that potato plants respond with high yielding and wholesomeness to sulphur and magnesium fertilization.

The mean infection rate of potato tubers by *Streptomyces scabies* reached 16.2%, whereas the mean infection severity (scored 1-9) was assessed at 5.83% (Table 4). The highest infection rate developed by this pathogen (percentage and 1-9 score) occurred on the NPK fertilized plots (A) On the objects with enriched NPK fertilization (B), incidence and infection severity of common scab-induced infection were significantly reduced: 11.7% and 5.8% (1-9 score). A statistically significant difference, though, has been confirmed only for infection rate. GROCHOLL and SCHEID (2002) as well as PICKNY and GROCHOLL (2002), who studied experimental plots fertilized with elemental sulphur and $CaSO_4$ did not find any direct relation between sulphur application and consistent reduction of potato tuber infection by *Streptomyces scabies*. Only a decreased soil pH value due to sulphur supplementation may enhance potato tuber resistance to this pathogen (GROCHOLL, SCHEID 2002, PAVLISTA 1995, PICKNY, GROCHOLL 2002). KLIKOCKA (2005)demonstrated that bringing soil pH down through sulphur dressing alleviated the symptoms of tuber infection by common scab by approximately 22%, and by 15% on the 1-9 scale. Some authors believe (GRZEBISZ, HÄRDTER 2006, ROGOZIŃSKA 1991) that magnesium supplementation, especially in the form of Kieresite, reduces potato tuber infection by common scab. Moderate N fertilization, at a well balanced N:P:K rate, e.g. 1:1:1.5, may suppress the pathogen development. Common scab is likely to be severe in soils of pH 5.5-8.0; in more acid soils the disease is reduced. Besides, a range of 13-15°C temperature under field conditions favours infection of potato tuber (FOTYMA, ZIĘBA 1988). Green manure ploughed into soil favours activation of microbes antagonistic to pathogenic strains of scab (BORÓWCZAK, GŁADYSIAK 1997). The cultivar Irga tubers were most susceptible to common scab: infection rate 20.93% and severity 4.90 (1-9 score). The tubers of cv. Mila and Sante proved to be less infected than those of cv. Irga: infection rate of 25.4% and 42.2% and infection severity 17.1 and 26.6% (1-9 score), respectively. The cultivar Mila responded weakly to enriched NPK fertilization (B) as no reduction in the infection rate developed by the pathogen was established. However, potato tubers of the cultivars Irga and Sante were significantly less infected by scab under NPK fertilization with sulphur, magnesium and microelements.

Generally, the infection of potato tubers by common scab was more strongly related to the cultivar (the cultivars Mila and Sante) than mineral fertilization. Also the weather conditions had n important effect because the variation for infection rate reached 18.54% and for severity 11.13% (1-9 score). SZUTKOWSKA (1998), GŁUSKA (2002) and LUTOMIRSKA (2002) report that high precipitation rate during the potato tuber formation period (especially in June) suppresses common scab incidence in potato tubers as rainfalls at that time is antagonistic to *S. scabies* bacteria penetrating soft potato skin. The highest susceptibility to infection was demonstrated by potato tubers during the stage of tuber initiation until the tuber diameter reached 1 cm. Therefore, the most efficient way to depress or even eradicate common scab disease is to keep soil moist during the active growth period (GŁUSKA 2002). Besides, a more severe *S. scabies*-induced infection of the cv. Mila tubers results from the widespread use of Sencor herbicide (metribusine) (KLIKOCKA 2000). Due to a great variability of the causal agents involved in the infection and development of this disease, no efficient common scab control strategy has been elaborated yet, so as to obtain plants free from this disease. Application of fungicides (comprising sulphur or its compounds) for the potato seed material dressing is highly recommendable. Fungicides have beneficial effects on potato plants, mainly in their early growth stage. However, they do not ensure complete protection against potato tuber infection induced by soil-borne *Streptomyces scabies*. in the later stages of the vegetation season. At that time, elemental sulphur should be implemented, which lowers the soil pH and may alleviate the symptoms of potato infection produced by this pathogen (KLIKOCKA 2005).

The mean infection rate of potato tubers by *Rhizoctonia solani* was 3.82%, while the mean infection severity (1-9 score) reached 6.79 (Table 3). In Germany, the highest tuber infestation by rhizoctonioza varied within 14-20% (KURZINGER 1995). The highest infection incidence in potato tubers produced by the pathogen was recorded in the samples obtained from the NPK fertilized plots (A). NPK fertilization improved with foliar and soil application of S, Mg and microelements (B) has significantly increased potato tuber wholesomeness in the three cultivars, reducing the disease incidence by 29.2% and severity by 8.3% (1-9 score). DATNOFF et al. (2007), HUBER, HANEKLAUS (2007), SALAC (2005), KLIKOCKA (2005) and HANEKLAUS et al. (2002) emphasize the preventive role of sulphur against fungal diseases. Beside chemical methods and cultivation of resistant varieties, agronomic practice is of the utmost importance for prevention of plant diseases. It has been shown that the mineral fertilization (with macro- and microelements) promotes natural plant resistance mechanisms, just like application of silicon, aluminium and sulphur (DATNOFF et al. 2007, KLIKOCKA et al. 2005, SALAC 2005, HANEKLAUS et al. 2002).

Potato tubers produced by cv. Irga appeared to be most severly infected by rhizoctonioza (infection incidence 4.66% and infection severity 6.11 (1-9 score). The cultivars Mila and Sante were healthier than the Irga (36.0 and 17.6% as expressed by infection rate and 16.3 and 12.2% by infection severity (1-9 score), respectively). On the whole, *R. solani* infestation of potato tubers varied subject mainly to the cultivar and mineral fertilization, while being less dependent on the climatic conditions, where the variability reached 18.15% for infection rate and 9.87% (1-9 score) for severity.

As high moisture and low soil temperature favour rhizoctoniose progression, the potato planting date is expected to be the optimal agrotechnical time concerning traits of a planted variety, soil conditions, climatic features of the region as well as regional weather forecasts (KLIKOCKA 2001). LUTOMIRSKA (2007) reported testing thirty two potato cultivars of various maturity groups for black scurf. The most important factor affecting disease symptoms was soil temperature in full growth of plants and 30 days before harvest. The temperature of air seems to be less important. There was no influence of rainfall on sclerotia occurrence. The cultivars differ in their susceptibility to *R. solani* development on tubers. SOWA-NIEDZIAŁKOWSKA and KRZYSZTOFIK (2008) state that the genotype (cultivars) is the main factor which affects losses by infection of tubers with diseases. Healthy potato seed material should be planted in which sclerotia infestation of tubers does not surpass 20% of the total surface (HÄNI et al. 1976). Besides, inappropriate forecrops like legumes, cruciferous plants and grasses should be avoided (PUŁA, ŁABZA 2007). KEMPENAAR and STRUIK (2007) reports that green-crop harvesting, i.e. vine removal and lifting, followed by a field period during which skin set can take place, can be very useful in controlling *Rhizoctonia solani*. Recent-

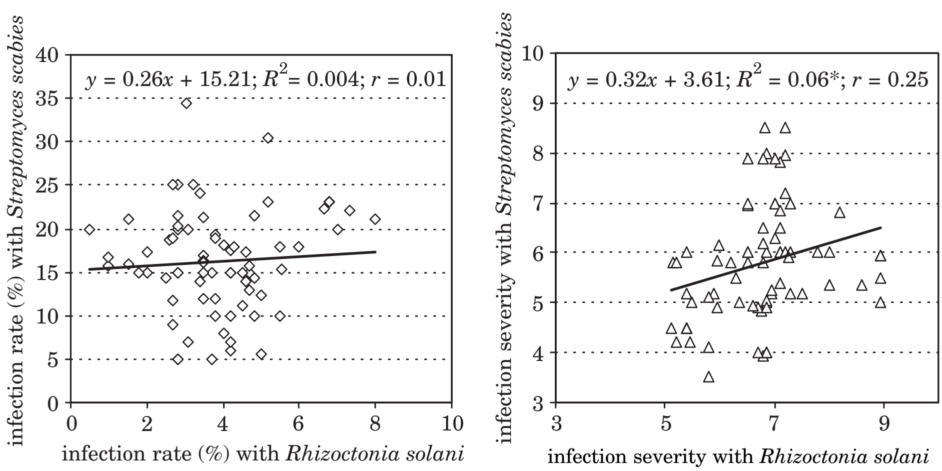

Fig. 2. Relationships between infection – rate and severity between *Rhizoctonia solani* and *Streptomyces scabies* on potato tubers

ly, efforts have been undertaken to use microorganisms (*Trichoderma viride, Bacillus sp.*) for potato protection against *Rhizoctonia solani* (KURZAWIŃSKA, GAJDA 2001). HAMM (2007) proposed control of soil-borne fungi (also *R. solani*) by the use of soil fumigants and/or seed treatments. Resistance in newly developed potato cultivars shows a promise for controlling many of these plant pathogens and will be the principal mechanism for controlling soil-borne fungi and fungal like organisms in the future.

Significant relationships between the infection severity of *Rhizoctonia solani* versus *Steptomyces scabies* on potato tubers were found (Figure 2). The results presented in Figure 2 reveal that the infestation of the tubers with both pathogens run linearly and any measure improving the natural resistance of the plant will supposedly combat both pathogens.

CONCLUSIONS

1. The potato characteristics analyzed (skin infection of tuber, yield) proved to be mostly affected and differentiated by the genotype (variety), less so by mineral fertilization and its interaction with a variety. That has been confirmed by the statistical analysis performed.

2. Enriched fertilization – B (NPK supplemented by soil and foliar application of sulphur, magnesium and microelements) has significantly reduced potato tuber infection by *Streptomyces scabies* for the cultivars Irga and Sante. Each potato cultivar responded in a different way to infection by this pathogen, the most severe infestation by common scab was demonstrated by the cultivar Irga, significantly less infected were the cultivars Mila and Sante; the cv. Mila did not react positively to enriched fertilization (B). Enriched fertilization decreased significantly tuber infection by *Rhizoctonia solani* of all the three potato cultivars. The cultivars Mila and Sante proved to be healthiest, whereas the tubers of cv. Irga were more infected with rhizoctoniose.

3. Both diseases are interrelated since generation of one of them induces development of the other, therefore sulphur, magnesium and microelement dressing may control the activity of both pathogens.

4. Potato tuber yield was significantly higher after application of enriched fertilization (B) as compared to basic fertilization (A). The highest tuber crop was recorded for the cultivars Sante, which is justified by its genotype.

REFERENCES

BARNES E.D. 1972. *The effects of irrigation, manganese sulphate, and sulphur applications on common scab of potato.* Rec. Agric. Res. 1971, Minist. Agric. Nth Ir, 20: 35-44.

BLOEM E. 1998. *Schwefel-Bilanz von Agrar-Õkosystem unter besonderer Beruecksichtigung hydrologischer und bedenphysikalischer Standorteigen-schaften*. Sonderheft Landbauforschung Vőlkenrode, 192: 1-156.

BŁASZCZAK W., WEBER Z., MAŃKA M. 1997. *The effect of temperature upon the pathogenicity and chemical control of Rhizoctonia salani K. on potato tubers (Solanum tuberosum L.).* Acta Agrobot., 30(2): 159-165.

BŁASZCZAK W., CHRZANOWSKA M., FORNAL J., ZIMNOCH-GUZOWSKA E., PALACIOS M.C., VACEK J. 2005. *Scanning electron microscopic investigation of different types of necroses in potato tubers.* Food Control, 16: 747-752.

BOROWCZAK F., GŁADYSIAK S. 1997. *Porażenie bulw ziemniaka chorobami w zależności od deszczowania, nawożenia azotowego i technologii uprawy [Disease infections of potato tubers depending on irrigation, nitrogen fertilization and cultivation techniques].* Prog. Plant Protect. (Post. Ochr. Rośl)., 37(2): 210-212.

BRAZDA G. 1995. *Kartoffelschorf (Streptomyces scabies). Besonderheiten des Befalls und des Auftretens.* Kartoffelbau*,* 46(4): 150-152.

DATNOFF LE., ELMER W., HUBER DM (eds). 2007. *Mineral nutrition and plant disease.* St. Paul., Minn. APS press. 278pp, ISBN 0-89054-346-1.

DAVIS J.R., MC DOLE R.E., CALLIHAN R.H. 1976a. *Fertilizer effects on common scab of potato and the relation of calcium and phosphate-phosphorus.* Phytopathology, 66: 1236-1241.

DAVIS J.R., MCMASTER G.M., CALLIHAN R.H., NISSLEY F.H., PAVEK J.J. 1976b. *Influence of soil moisture and fungicide treatments on common scab and mineral content of potatoes.* Phytopathology, 66: 228-233.

ELPHINSTONE J.G. 2007. *The canon of potato science:* 11. *Bacterial pathogens.* Potato Res., 50: 247-249.

FAUCHER E., SAVARD T., BEAULIEU C. 1992. *Characterizations of actinomycetes isolated from common scab lesions of potato tubers.* Can. J. Plant Pathol., 14(3): 197-202.

FOTYMA M., ZIĘBA S. 1988. *Przyrodnicze i gospodarcze podstawy wapnowania gleb [Natural and economic basis of soil liming].* PWRiL, Warszawa.

GŁUSKA A. 2002. *Uprawa ziemniaków w warunkach nawadniania.* W: *Produkcja i rynek ziemniaków jadalnych.* CHOTKOWSKI J. [*Potato cultivation under irrigation.* In: *Edible Potato production and market.* CHOTKOWSKI J. (Ed)]. Wyd. Wieś Jutra, Warszawa, 169-184.

GROCHOLL J., SCHEID L. 2002. *Effect of sulfur on yield and quality.* 15th Triennial Conf. EAPR. 14-19.07.2002. Hamburg, p. 240.

GRZEBISZ W., HÂRDTER R. 2006. *ESTA. Kizeryt, naturalny siarczan magnezu [Kieserite, natural manganese sulphide].* K + S KALI GmbH, Agricultural Advisory Departament Kassel, ISBN-3-9801577-6-8, 5-81.

GUGAŁA M., ZARZECKA K., RYMUZA K. 2007. *Wpływ uprawy roli i sposobu odchwaszczania ziemniaka na porażenie bulw parchem zwykłym (Streptomyces scabies Thaxt) [Effect of soil tillage type and weeding method on potato tuber infection with scab (Streptomyces scabies Thaxt).* Biul. Inst. Hod. Rośl., 246: 127-134.

HAMM P.B. 2007. *The Canon of Potato Science:* 9. *Soil-borne Fungi.* Potato Res., 50: 239-241.

HANEKLAUS S., BLOEM E., SCHNUG E. 2002. *The Significance of Sulphur Induced Resistance (SIR) for Sustainable Agricultural Production Systems".* 13th Int. Reinhardsbrunn Symp. "Modern Fungicides and Antifungal Compounds", 14-18 Mai 2001, Friedrichroda, Germany, pp. 365–372.

HÄNI F., GINDRAT D., MUNSTER J., WALTHER U., CORNU P. 1976. *Bekaempfung der Kartoffelpocken (Rhizoctonia solani): quecksilberfreie Beizmittel und Bekaempfungsschwelle*. Schweizer Landwirtschaftliche Forschung, 15: 473-487.

HUBER DM., HANEKLAUS S. 2007. *Managing nutrition to control plant disease.* Landbauforschung Völkenrode, 4(57): 313-322.

JABŁOŃSKI K. 2006. *Agrotechniczne i ekonomiczne efekty uproszczonej uprawy roli pod ziemniaki [Agronomic and economic effects of reduced soil tillage under potato].* Inż. Rol., 3:21-30.

KEINATH A.P., LORIA R. 1989. *Population dynamics of Streptomyces scabies and other actinomycetes as related to common scab of potato.* Phytopathology, 79: 681-687.

KEMPENAAR C., STRUIK P.C. 2007. *The Canon of Potato Science:* 33. *Haulm Killing.* Potato Res., 50: 341-345.

KLIKOCKA H. 2000. *Wpływ stosowania różnych metod pielęgnowania i uprawy roli na porażenie bulw ziemniaka parchem zwyklym (Streptomyces scabies Thaxt. Waksman et Henrici) [Effect of different cultivation and soil tillage methods on potato tuber infection with scab (Streptomyces scabies Thaxt. Waksman et Henrici)].* Prog. Plant Protec./Post. Ochr. Rośl., 40(2): 656-637.

KLIKOCKA H. 2001. *Wpływ sposobów uprawy roli i metod pielęgnowania roślin na porażenie bulw ziemniaka przez Rhizoctonia solani Kühn [Effect of soil tillage and cultivation methods on potato tuber infection with Rhizoctonia solani Kühn].* Biul. Inst. Hod. Rośl., 217: 243-247.

KLIKOCKA H. 2005. *Wpływ nawożenia siarką na wielkość plonu i stopień porażenia bulw ziemniaka przez Streptomyces scabies i Rhizoctonia solani [Effect of sulphur fertilization on yield and extent of potato tuber infection with Streptomyces scabies and Rhizoctonia solani].* Fragm. Agron., 4(88): 38-50.

KLIKOCKA H., HANEKLAUS S., BLOEM E., SCHNUG E. 2005. *Influence of sulfur fertilization on infection of potato tubers with Rhizoctonia solani and Streptomyces scabies.* J. Plant Nutrit., 28 (5): 819-833.

KLIKOCKA H., SACHAJKO J. 2007. *Wpływ nawożenia ziemniaka siarką na plon bulw handlowych i sadzeniaków [Effect of sulphur fertilization on marketable and seed potato tubers].* Acta Agroph., 152, 10(2): 383-396.

KRZYSZTOFIK B. 2008. *Wpływ miejsca przechowywania na zmiany cech jakościowych bulw ziemniaka [Effect of storage place on modifications of quality characteristics of potato tubers].* Acta Agroph., 11(2): 449-456.

KURZAWIŃSKA H., GAJDA J. 2001. *Wykorzystanie mikroorganizmów (Trichoderma viride, Bacillus sp. S13) w ochronie ziemniaka przed Rhizoctonia solani [Use of microorganisms (Trichoderma viride, Bacillus sp. S13) for protection of potato from Rhizoctonia solani]. Biologiczne i agrotechniczne kierunki rozwoju warzywnictwa.* Konf. Nauk., Skierniewice 21-22.06.2001, p. 160.

KURZINGER W. 1995. *Beizen erhöht Ertrag und verbessert Qualität.* Neue Landwirtschaft, 3: 37-39 .

LAMBERT D.H., POWELSON M.L., STEVENSON W.R. 2005. *Nutrional interactions influencing diseases of potato.* Amer. J Potato Res., 82: 309-319.

LUTOMIRSKA B. 2002. *Wpływ temperatury gleby i opadów w czasie wegetacji na porażenie bulw ziemniaka ospowatością i parchem zwykłym [Effect of soil temperature and rainfall during vegetative growth on potato tuber infection with rhizoctoniose and scab].* Zesz. Prob. Post. Nauk Rol., 481: 491-495.

LUTOMIRSKA B. 2007. *Wpływ odmiany i czynników meteorologicznych okresu wegetacji na ospowatość bulw ziemniaka [Effect of cultivar and meteorological conditions during the vegetative growth on rhizoctoniose of potato tubers].* Prog. Plant Protect. / Post. Ochr. Rośl., 47(2): 173-177.

PAVLISTA A.D. 1995. *Kontrolle des Kartoffelschorfes mit Schwefel und Ammoniumsulfat.* Kartoffelbau, 46: 154-157.

PICKNY J., GROCHOLL J. 2002. *Kartoffelschorf-Lässt sich der Befall durch eine Schwefeldüngung vermindern?* Kartoffelbau, 3(53): 76-78.

PRAKASH O., SINGH S., SINGH V. 1997. *Fertiliser*. News, 42(2): 23-24 .

PUŁA J., ŁABZA T. 2007. *Porażenie bulw ziemniaka patogenami w zależności od nawożenia i terminu oceny [Infection of potato tubers depending on fertilization and evaluation date]*. Prog. Plant Protect. / Post. Ochr. Roś., 47(2): 284-286.

RADTKE W. 1994. *Rhizoctonia solani: Ein Pilz, der die Kartoffelqualität aufffalig minder*. Der Kartoffelbau, 45: 92-96.

READ P.J., HIDE G.A., FIRMAGER J.P., HALL S.H. 1989. *Growth and yield of potatoes as affected by severity of stem canker (Rhizoctonia solani)*. Potato Res., 32: 9-15.

RĘBARZ K., BORÓWCZAK F. 2007. *Porażenie patogenami bulw ziemniaków odmiany Bila w zależności od deszczowania, technologii uprawy i nawożenia azotowego [Infection of cv. Bila potato tubers with pathogens depending on irrigation, cultivation technology and nitrogen fertilization]*. Prog. Plant Protect. / Post. Ochr. Roś., 47(2): 294-298.

ROGOZIŃSKA I. 1991. *Einfluss der Magnesiumdungung auf die Gutemerkmale der Kartoffel*. Kartoffelbau, 42: 257-259.

ROZTROPOWICZ S. (Ed). 1999. *Metodyka obserwacji, pomiarów i pobierania prób w agrotechnicznych doświadczeniach z ziemniakami [Methods of observation, measurements and sampling in agronomic experiments on potatoes]*. Inst. Hod. Aklim. Rośl., Jadwisin, pp. 50.

SALAC I. 2005. *Influence of sulphur and nitrogen supply on S metabolites involved in the Sulphur Induced Resistance (SIR) of Brassica napus L.* Landbauvorschung Vőlkenrode. Sonderheft 277: 1-121.

SALAZAR L. 2006. *Emerging and Re-emerging Potato Diseases in the Andes*. Potato Res., 49:43-47.

SAWICKA B., KROCHMAL-MARCZAK B. 2008. *Wpływ stosowania nawozu dolistnego Insol 7 i bioregulatora Asahi SL na zdrowotność bulw kilku odmian ziemniaka [Effect of foliar application of the foliar fertilizer Insol 7 and bioregulator Asahi SL on the health of tubers of several potato cultivars]*. II Ogóln. Konf. Nauk. Dolistne dokarmianie roślin. UP Lublin, s. 40.

SILLANPÂÂ M. 1982. *Micronutrients and the nutrient status of soils: a global study*. FAO Soils Bulletin. Rome, pp. 9-12.

SOWA-NIEDZIAŁKOWSKA G., ZGÓRSKA K. 2005. *Wpływ czynnika termicznego i odmianowego na zmiany ilościowe w czasie długotrwałego przechowywania bulw ziemniaka [Effect of the thermal and cultivar factors on quantitative changes during long-term storing of potato tubers]*. Pam. Puł., 139: 233-243.

STACHEWICZ H. 1996. *Bekaempfung der Rhizoctonia-Krankheit*. Kartoffelbau, 47(3): 68-71.

SZUTKOWSKA M. 1998. *Porażenie się bulw ziemniaka parchem zwykłym zależnie od warunków wilgotnościowo-termicznych i składu granulometrycznego gleby*. Fragm. Agron., 2 (58): 106-118.

TRĘTOWSKI J., WÓJCIK A.R. 1988. *Metodyka doświadczeń rolniczych [Methodology of agricultural experiments]*. WSRP Siedlce, 124-459.

YAO M.K., TWEDDELL R.J., DESILETS H. 2002. *Effect of two vesicular-arbuscular mycorrhizal fungi on the growth of micropropagated potato plantlets and on the extent of disease caused by Rhizoctonia solani*. Mycorrhiza, 12: 235-235.

ZGÓRSKA K., FRYDECKA-MAZURCZYK A. 2002. *Normy i wymagania jakościowe ziemniaków jadalnych oraz do przetwórstwa spożywczego*. W: *Produkcja i rynek ziemniaków jadalnych* CHOTKOWSKI J. (Red.): *[Norms and quality standards for edible potatoes and potato processing*. In: *Edible potato production and market*. CHOTKOWSKI J. (Ed)*]*. Wyd. Wieś Jutra, Warszawa, 183-191.