www.czasopisma.pan.pl PAN POLSKA AKADEMIA NAUK www.journals.pan.pl

JOURNAL OF PLANT PROTECTION RESEARCH Vol. 54, No. 3 (2014)

DOI: 10.2478/jppr-2014-0034

The effect of potato ridge height and harvest date on tuber injuries

Katarzyna Rymuza, Antoni Bombik, Dariusz Stopa, Zbigniew Pawlonka*

Department of Quantitative Methods and Spatial Planning, University of Natural Studies and Humanities in Siedlce, Prusa 14, 08–110 Siedlce, Poland

Received: March 18, 2014
Accepted: July 18, 2014

Abstract: A potato experiment was conducted from 2004 to 2006 at the Zawady Experimental Farm. The farm is part of the University of Natural Sciences and Humanities in Siedlce, Poland. Tuber infection and injury by diseases and pathogens of three potato cultivars were assessed according to the potato ridge height and harvest date. The weight of mechanically injured tubers was also determined depending on the potato ridge height and harvest date. The weight of potato tubers infected by fungal and bacterial diseases was influenced by the cultivar, growing season, harvest date, and ridge height. Potatoes grown to their standard height and height ridges, were significantly less infected by diseases at the first harvest date. The weight of tubers in which the tubers were injured by soil pests, was affected by the cultivar and ridge height. Potatoes cultivated in a ridge which was 20 cm high, had tubers with significantly less mechanical injuries compared with a low (16 cm) ridge and high (24 cm) ridge.

Key words: bacterial diseases, fungal diseases, potato, ridge height, soilborne pathogens

Introduction

Diseases and pathogens infecting growing potatoes, reduce tuber yields. The reason is that diseases and pathogens destroy the assimilating structure of the plants and cause tuber defects; mainly skin and flesh defects (Nowacki 2006; Kostiw 2011; Mandour *et al*. 2012). The majority of these defects are due to infection by *Streptomyces scabies* (symptoms are various-sized irregular brown scrubs on tubers), *Rhizoctonia solani* (which may cause e.g. black scurf of potato skin), *Alternaria solani* and *Phytopthora infestans* (causing spots on tuber skin) and *Helminthosporium solani* (infected tubers develop shining silver-grey spots during storage). Moreover, defective tubers may be formed due to injuries of tuber flesh caused by owlet moth caterpillars (Agrotinae), wireworms (Elateridae) as well as grubs (Melolonthinae) (Nowacki 2006). Resistance to diseases and pathogens is cultivar dependent but also affected by environmental and agrotechnological factors (Gawińska-Urbanowicz 2007; Mańkowski and Laudański 2009). The latter factors include harvest date and ridge height (Jabłoński 2001; Gąsiorowska and Zarzecka 2002; Sekutowski and Badowski 2010). Inappropriate agrotechnology may cause tuber deformation, greening, cracks, size reduction, hollow hearts, bruises, and other mechanical injuries (Nowacki 2006). Mechanical injuries occurring at harvest are the main cause of tuber diseases during storage (Peters 1996). In the field, potato tubers usually become infected through wounds (Kuźniewicz-Czerko *et al*. 1993).

The objective of the work was to determine the share of tubers with mechanical injuries as well as injuries caused by potato diseases and pathogens as influenced by ridge height, harvest date (which was soil temperature dependent), and cultivar.

Materials and Methods

A field experiment was carried out from 2004 to 2006, at the Zawady Experimental Farm (52°06′N; 22°56′E) which is part of the University of Natural Sciences and Humanities in Siedlce, Poland.

Temperatures and precipitation during the study period are presented as Sielianinov's hydrothermal coefficients (Table 1). Each year, weather conditions were different. In 2004 and 2006, the total precipitation over the growing season was much higher than the long-term mean, whereas 2005 was dry, although k = 0.92 did not differ much from the mean.

The experiment was a split-split-plot arrangement with four replicates. The following factors were examined:

- edible potato cultivar (factor A): Sante, Romula, Żagiel;
- ridge height (factor B): low ridge (16 cm), standard ridge (20 cm), high ridge (24 cm);
- harvest date determined based on soil temperature (16, 12 and 8°C) averaged over three consecutive days before potato tuber harvest, and measured at the depth of 10 cm, at 8 a.m.

*Corresponding address:
katarzyna.rymuza@uph.edu.pl

Table 1. Sielianinov's hydrothermal coefficients (*k*) during the study period

Years	Months						Over the whole potato growing season
	April	May	June	July	August	September	
2004	1.49	2.70	1.14	0.90	1.14	0.50	1.31
2005	0.47	1.60	0.92	1.38	0.83	0.35	0.92
2006	1.18	0.93	0.46	0.23	4.08	0.45	1.22

$k \leq 0.50$ very dry, $0.50 \leq k \leq 0.69$ dry, $0.70 \leq k \leq 0.99$ slightly dry, $k \geq 1$ not dry; according to Baca *et al*. (1980)

At harvest, 10 kg of tuber samples were taken from each plot to determine the weight of tubers infected by diseases and soil pathogens. The following tubers were classified as infected: tubers affected by *S. scabies* and *R. solani*, severely damaged by soil pests (owlet moth caterpillars, wireworms, grubs), with morbid spots, and partially or completely decayed due to *P. infestans, Erwinia* spp., *Fusarium* spp. infections.

In addition, the weights of cracked tubers, injured tubers with wounds deeper than 1.7 mm, and crushed tubers were determined.

The results were statistically analysed by means of variance analysis. The following fixed model was used (Trętowski and Wójcik 1991):

$$y_{ijlp} = m + a_i + g_j + e_{ij}^{/1/} + b_l + ab_{il} + e_{ijl}^{/2/} +$$

$$+ c_p + ac_{ip} + bc_{lp} + abc_{ilp} + e_{ijlp}^{/3/},$$

where: y_{ijlp} – value of the trait for the *i*-th effect of factor A, *l*-th effect of factor B, *p*-th effect of factor C in the *j*-th block (replicate), *m* – overall (population) mean, a_i, b_l, c_p – main effects of factors, g_j – effect of j-th block, ab_{il}, ac_{ip}, bc_{lp}, – 2-factor interaction effects, abc_{ilp} – 3-factor interaction effect, $e_{ij}^{/1/}$, $e_{ijl}^{/2/}$, $e_{ijlp}^{/3/}$ – random effects which were assumed to be homogeneous and normally distributed.

Comparison of means and assessment of interactions were based on HSD (Honest Significant Difference) values which were calculated using Tukey's test at the significance level $\alpha = 0.05$. Linear and polynomial regressions were used to examine the nature of the effect of harvest date and ridge height on the traits studied (Trętowski and Wójcik 1991).

All calculations were performed in Statistica 9.0.

Results and Discussion

The study years and cultivars significantly affected an occurrence of tubers with fungal and bacterial diseases (Table 2). The weight of infected tubers was significantly lower in the second and third years *vs.* the first study year. Also, the weight was lower in Sante and Żagiel *vs.* Romula, which supports the findings of other authors claming that resistance to diseases is a cultivar dependent trait (Nowacki 2002; Zarzyńska and Goliszewski 2012). Resistance to fungal and bacterial diseases was affected by study years. Żagiel had the lowest weight of infected tubers in 2004 whereas in 2005 it was Sante. All the cultivars had a similar weight of tubers infected by fungal and bacterial diseases in 2006. According to Gawińska-Urbanowicz (2007), the climate in Poland is conductive to the following diseases affecting potato skin: common scab, silver scurf, and black scurf (the morbid phase of *Rhizoctonia* disease). Nowacki (2002) claimed that environmental factors are predominant determinants of an occurrence of common scrub affecting potato tubers. Studies by Głuska (2004) revealed a relationship between common scrub infection and the amount of precipitation in June at the tuber set stage. In turn, Szutkowska (1998) has reported that as soil temperature rises, tuber infection by common scrub increases.

Table 2. Weight of tubers infected by fungal and bacterial diseases (t/ha) depending to the study year, potato cultivar, and harvest date

Years	Cultivars			Mean
	Sante	Romula	Żagiel	
2004	0.190	0.303	0.115	0.203
2005	0.009	0.049	0.087	0.048
2006	0.034	0.017	0.016	0.022
Mean	0.078	0.123	0.073	0.091
HSD (0.05) for: years 0.040; cultivars 0.040; year × cultivar 0.069				
Years	Harvest date (soil temperature)			Mean
	I (16°C)	II (12°C)	III (8°C)	
2004	0.130	0.241	0.238	0.203
2005	0.056	0.046	0.042	0.048
2006	0.017	0.010	0.039	0.022
Mean	0.068	0.099	0.106	0.091
HSD (0.05) for: year × harvest date 0.069				

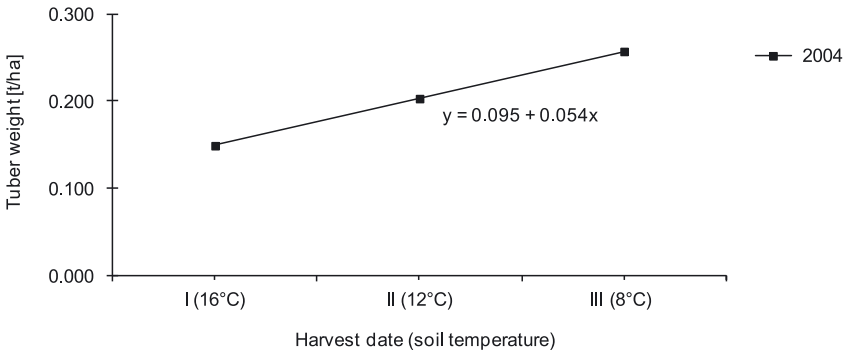

Fig. 1. Relationship between the weight of infected tubers, study year and harvest date (°C)

Infection by fungal and bacterial pathogens depended on harvest date. In the first study year, the weight of infected tubers was significantly lower at the first *vs.* the other two harvest dates. At the second and third harvest dates, the weight of infected tubers was similar (Table 2). The effect of the harvest date on the weight of the infected tubers was linear. When the harvest was delayed (soil temperature fell by 4°C), the weight of infected tubers increased by 0.054 t/ha in 2004. In the remaining study years, no significant differences between the weights of the infected tubers were found for the harvest dates (Fig. 1). Rudkiewicz and Zakrzewska (1987) found a positive relationship between soil temperature and extent of infection of tubers by common scrub. Similar findings have been reported by Szutkowska (1998), who observed more extensive infections of tubers as soil temperature increased.

No significant differences were found for the weight of infected tubers cultivated in low ridges at each harvest date (Table 3). Infected tubers harvested from potatoes cultivated in ridges which were 20 cm high, weighed significantly less at the first *vs.* third harvest date. Edible potato plants grown in high ridges (24 cm) had significantly less infected tubers at the first *vs.* second harvest date. The weight of tubers infected by fungal and bacterial diseases harvested from standard ridges was linearly affected by temperature at harvest. As the temperature decreased by 4°C (harvest date was delayed), the weight of infected tubers increased by 0.042 t/ha. The effect of harvest date on the weight of infected tubers grown in high ridges was parabolic. A decrease in temperature from 16 to 12°C was followed by an increased in the weight of infected tubers. However, when temperature dropped further, the weight of infected tubers decreased. Potato cultivation in standard ridges and delaying of the harvest date resulted in an increase (by 0.042 t/ha) in the weight of tubers with infection symptoms. The maximum value calculated for high-ridge cultivation indicated that 11.3°C was the least favourable temperature of harvest as the weight of tubers infected by fungi and bacteria was the highest (Fig. 2).

The weight of tubers injured by soil pests depended on the growing season, cultivar, and ridge height. What is more, a study year *x* cultivar interaction and a study year *x* ridge height interaction were found. A significantly lower weight of tubers injured by soil pathogens was obtained in 2005 and 2006 *vs.* 2004 (Table 4); the shares of these tubers were 0.87 and 0.26% total yield in 2005 and 2006, respectively. According to Zarzyńska and Goliszewski (2012) as well as Ridgeer and Thorton (2008), dry years are conducive to an occurrence of tuber injuries caused by soil pests, in particular owlet moth caterpillars, wireworms, and grubs.

A significantly lower weight of pathogen-injured tubers was determined for Romula and Żagiel *vs.* Sante in 2004 (Table 4), whereas in the remaining study years no significant differences between cultivars were found.

A lower weight of tubers injured by soil pathogens was determined for potatoes grown in standard *vs.* the remaining ridges, and in 2004 *vs.* the remaining study years. The relationship between ridge height and weight of pathogen-injured tubers was parabolic (Fig. 3). Also, the weight of such tubers decreased as ridge height increased from 16 to 20 cm, and then weight increased when the height ridges increased to 24 cm. The regression function calculated for 2004 reached its minimum at 20.5 cm. This means that edible potatoes would have the lowest weight of pest-injured tubers when cultivated in standard ridges and the theoretical weight of defected tubers would be 0.325 t/ha.

Mechanical injuries influence potato tuber resistance to diseases during storage (Kuźniewicz and Czerko 1993).

Table 3. Relationship of the weight of infected tubers (t/ha) with ridge height (cm) and harvest date (°C)

Ridge height	Harvest date (soil temperature)			Mean
	I (16°C)	II (12°C)	III (8°C)	
Low (16 cm)	0.111	0.069	0.094	0.091
Standard (20 cm)	0.050	0.093	0.134	0.092
High (24 cm)	0.043	0.136	0.091	0.090
HSD (0.05) for: ridge height × harvest date 0.069				

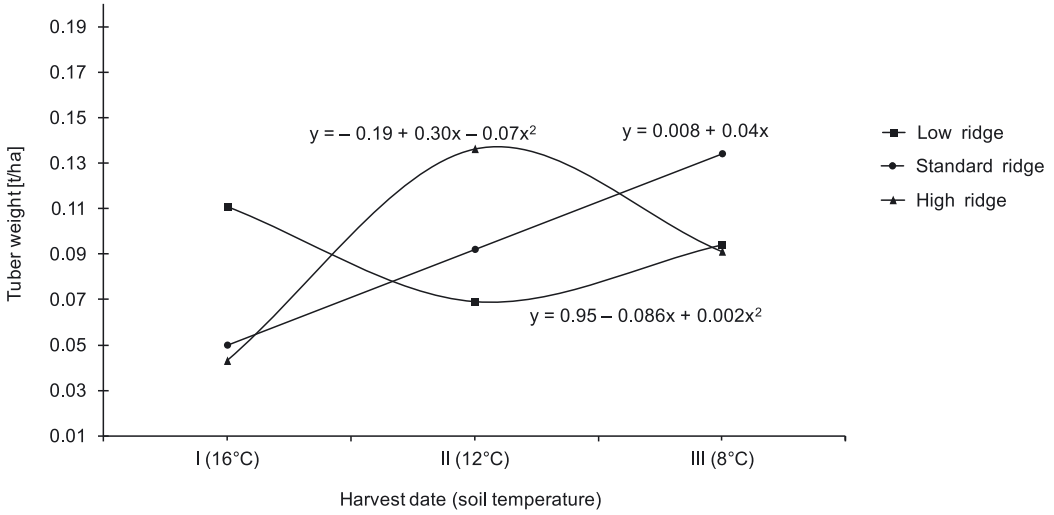

Fig. 2. Relationship between the weight of infected tubers, ridge height (cm) and harvest date (°C)

Table 4. The weight of tubers destroyed by soil pathogens (t/ha) depending on study year, potato cultivar, and ridge height

Years	Cultivars			Mean
	Sante	Romula	Żagiel	
2004	0.697	0.248	0.439	0.461
2005	0.165	0.114	0.185	0.155
2006	0.057	0.035	0.158	0.083
Mean	0.306	0.132	0.261	0.233
HSD (0.05) for: study years 0.112; cultivars 0.112; study year × cultivar 0.193				
Years	Ridges			Mean
	low (16 cm)	standard (20 cm)	high (24 cm)	
2004	0.580	0.326	0.478	0.461
2005	0.149	0.103	0.213	0.155
2006	0.109	0.054	0.086	0.083
Mean	0.279	0.161	0.259	0.233
HSD (0.05) for: ridge height 0.072; study year × ridge height 0.125				

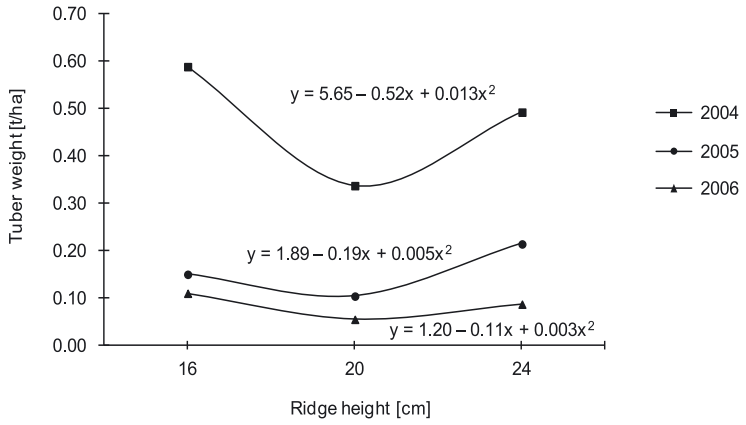

Fig. 3. Relationship of ridge height with weight of tubers injured by soil pests

In the experiment discussed here, the share of mechanically injured tubers was significantly affected by the study years and ridge height.

Injured tubers harvested in 2006 weighed significantly less than in 2005 (Table 5). Production of edible potato in standard *vs.* low or high ridges yielded significantly less injured tubers. Potatoes grown in either low or high ridges had weights similar to the weights of injured tubers. In the three-year study period, the effect of ridge height on the trait discussed was parabolic (Fig. 4). When the ridge height was

Table 5. The weight of potato tubers with mechanical injuries depending on study year and ridge height (cm)

Years	Ridges			Mean
	low (16 cm)	standard (20 cm)	high (24 cm)	
2004	0.309	0.163	0.298	0.257
2005	0.290	0.216	0.351	0.286
2006	0.215	0.100	0.200	0.172
Mean	0.271	0.160	0.283	0.238
HSD (0.05) for: study years 0.097; ridge height 0.083				

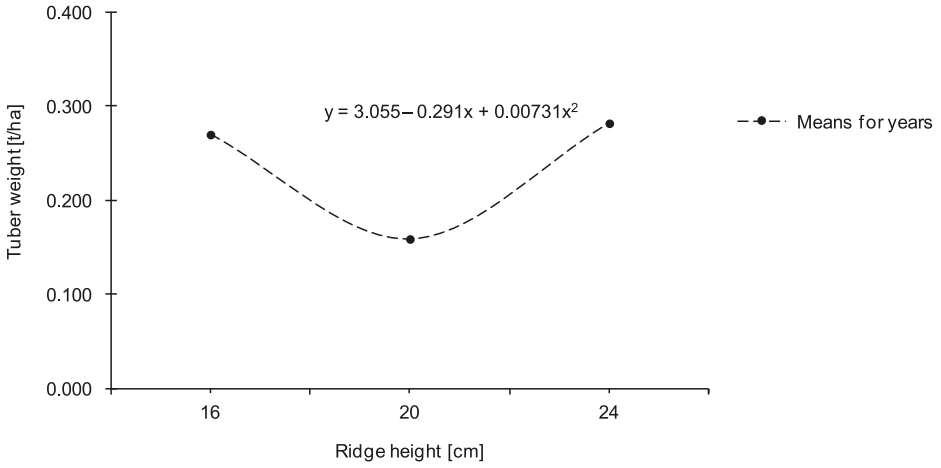

Fig. 4. Relationship between ridge height and weight of mechanically injured tubers

increased from 16 to 20 cm, the weight of mechanically injured tubers decreased. The regression function yielded the optimum ridge height of 19.9 cm; at this height, the mechanically injured tubers would weigh the least (0.159 t/ha). In the study discussed here, tuber resistance to mechanical injuries was not affected by the soil-temperature-dependent harvest date, which does not agree with findings reported by Prośba-Białczyk (2002) who claimed that minimum soil temperature at tuber harvest should range from 12 to 15°C because then the index of mechanical injuries is the lowest. In the study by Gruczek (1997), a 1°C increase in soil temperature measured at the depth of 10 cm was followed by a 3.5% decrease in the value of the index of mechanical injuries.

References

Bac S., Koźmiński Cz., Rojek M. 1998. Agrometeorologia. [Agrometeorology]. PWN, Warszawa, Poland, 167 pp.

Erlichowski T. 2004. Szkodniki glebowe w uprawie ziemniaka i ich zwalczanie. Instrukcja upowszechnieniowa. [Soil-borne Pests in Potato Cultivation and Their Control. Dissemination manual]. IHAR, Bonin, Poland, 22 pp.

Gawińska-Urbanowicz H. 2007. Ocena występowania chorób grzybowych i bakteryjnych ziemniaka w warunkach polowych. [Evaluation of the incidence of fungal and bacterial diseases in potatoes under field conditions]. Biul. IHAR 243: 191–197.

Gąsiorowska B., Zarzecka K. 2002. Wpływ terminu zbioru na plon i cechy jakościowe bulw ziemniaka uprawianego w rejonie Siedlec. [The influence of harvest date on the yield and quality characteristics of potato tubers cultivated in the Siedlce region]. Zesz. Probl. Post. Nauk Rol. 489: 319–325.

Głuska A. 2004. Wpływ zmiennego rozkładu opadów na cechy bulw ziemniaka (*Solanum tuberosum* L.) w warunkach polowych oraz wyznaczenie okresu krytycznego wrażliwości na niedobór wody u odmian w różnej długości okresu wegetacji. [Reaction of potato (*Solanum tuberosum* L.) to rainfall distribution under field conditions and to testing drought imposed at different phases of bulking stage in cultivars of different vegetation length in a pot experiment]. Zesz. Probl. Post. Nauk Rol. 496: 217–227.

Gruczek T. 1997. Ograniczenie uszkodzeń mechanicznych w czasie zbioru podstawowym warunkiem poprawy jakości produkowanych bulw. [Reduction of mechanical injuries during harvest is a key to improved quality of produced tubers]. Ziemniak Polski 3: 11–18.

Jabłoński K. 2001. Agrotechniczne efekty stosowania nowych maszyn do pielęgnacji ziemniaków. [Agronomic effects of usage of new machines for potato cultivation]. Biul. IHAR 220: 227–235.

Kostiw M. 2011. The occurrence of major potato viruses in Poland. J. Plant Prot. Res. 51 (3): 205–209.

Krzysztofik B., Marks N., Baran D. 2009. Wpływ wybranych czynników agrotechnicznych na ilościowe cechy plonu bulw ziemniaka. [The impact of selected agrotechnical factors on the quantitative characteristics of potato tuber crop]. Inżynieria Rolnicza 5 (114): 123–129.

Kuźniewicz-Czerko M., Bittner K., Fechter E. 1993. Wpływ uszkodzeń mechanicznych na trwałość przechowalniczą bulw ziemniaka oraz na zdrowotność i plonowanie roślin odmian Beryl i Duet. [The effect of mechanical injuries on

tuber storage life and plant health status and yield of Beryl and Duet cultivars]. Biul. Inst. Ziem. 42: 69–76.

Mandour N.S., Sarhan A.A., Atwa D.H. 2012. The integration between *Trichogramma evanescens* West. (Hymenoptera: Trichogrammatidae) and selected bioinsecticides for controlling the potato tuber moth *Phthorimaea operculella* (Zell.) (Lepidoptera: Gelechiidae) of stored potatoes. J. Plant Prot. Res. 52 (1): 40–46.

Mańkowski D., Laudański Z. 2009. Postęp biologiczny w hodowli, nasiennictwie i produkcji ziemniaka w Polsce. Część V. Ocena postępu technologicznego w produkcji polowej ziemniaka w latach 1986–2003. [Biological progress in breeding, seed technology and production of potato in Poland. Part V. Estimation of technological progress in potato field production within the years 1986–2003]. Biul. IHAR 254: 95–119.

Nowacki W. 2002. Parametry jakości ziemniaka konfekcjonowanego, genetyczne i środowiskowe ich uwarunkowania. [Quality parameters of table potatoes, genetical and environmental effect determinations]. Zesz. Probl. Post. Nauk Rol. 489: 335–345.

Nowacki W. 2006. Straty plonu handlowego ziemniaków powodowane przez choroby i szkodniki w 2005 roku. [Losses in potato market yield caused by diseases and pests]. Prog. Plant Prot./ Post. Ochr. Roślin 46 (1): 193–201.

Peters R. 1996. Damage of potato tubers. Potato Res. 39: 479–484.

Prośba-Białczyk U. 2002. Uprawa ziemniaka z uwzględnieniem aspektów rolnictwa ekologicznego. [Potato cultivation and ecological agriculture]. Zesz. Probl. Post. Nauk. Rol. 489: 33–45.

Ridgeer L.K., Thornton R.E. 2008. Managing physiological disorders. p. 235–245. In: "Potato Health Management" (D.A. Johnson, ed.). Am. Phytopathol. Soc. Press, St. Paul, Minnesota, USA, 272 pp.

Rudkiewicz F., Zakrzewska B. 1987. Wpływ niektórych elementów pogody na porażenie parchem zwykłym i ocena reakcji odmian na tę chorobę. [The effect of some weather components on infection and assessment of response of cultivars to common scab]. Biul. Inst. Ziem. 35: 91–102.

Sekutowski T., Badowski M. 2010. Wpływ zachwaszczenia, warunków meteorologicznych i ochrony herbicydowej na plon i poszczególne frakcje bulw ziemniaka. [Ability to protect giant silver grass (*Miscanthus giganteus*) plantations against monocotyledonous weeds]. Prog. Plant Prot./Post. Ochr. Roślin 50 (3): 1390–1394.

Szutkowska M. 1998. Porażanie się bulw ziemniaka parchem zwykłym zależnie od warunków wilgotnościowo-termicznych i składu granulometrycznego gleby. [Common scab infection of potato tubers depending on moisture and thermal conditions as well as soil granulometric composition]. Fragm. Agron. 2 (58): 106–119.

Trętowski J., Wójcik A.R. 1991. Metodyka doświadczeń rolniczych. [Methodology of Agricultural Experiments]. Wyższa Szkoła Rolniczo-Pedagogiczna, Siedlce, Poland, 538 pp.

Zarzyńska K., Goliszewski W. 2012. Zróżnicowanie jakości plonu ziemniaków uprawianych w systemie ekologicznym i integrowanym w zależności od odmiany i warunków glebowo-klimatycznych. Część I. Udział wad zewnętrznych i wewnętrznych bulw. [Tuber quality differentiation of potatoes grown in organic and integrated farming system depending on cultivar and soil – climatic conditions. Part I. Share of external and internal tuber injuries]. Biul. IHAR 266: 73–79.