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NATURAL AGENTS LIMITING DISEASES ON POTATO TUBER PEEL

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Abstract

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During a three-year field experiment (2009 – 2011), we investigated the influence of preparations based on natural substances used during the potato vegetation period on the infection of tubers by the following pathogens causing peel diseases: *Helminthosporium solani*, *Rhizoctonia solani* and *Streptomyces* spp. The following treatments or combinations were included chitosan, grapefruit extract, orange oil, dimethomorph + mancozeb, control. After harvesting, 100 tubers were randomly picked from each field and put in storage. The infestation rate and percentage of tubers with sclerotia from *R. solani* and infections by *Streptomyces* spp. were estimated directly after harvesting. An analysis of the rate of infestation and percentage of tubers infected with *H. solani* was carried out after a three-month storage period. Based on the obtained results, we found that preparations used during the potato vegetation period lowered the incidence and degree of tuber infection with *H. solani*, *R. solani* and *Streptomyces* spp.

Key words: biological agents, protection, *Rhizoctonia solani*, *Helminthosporium solani*, *Streptomyces* spp.

Introduction

The potato is one of the most economically important cultivated plants. It is attacked by many pathogens at every stage of its development, beginning from seed tubers to the storage of the harvested tubers. The presence of disease in a potato crop decreases the plant population density (both wet rot (*Erwinia carotovora* subsp. *carotovora*) and silver scurf (*Helminthosporium. solani*) play an important role in this), slows plant development (sprout damage by *Rhizoctonia solani*), lowers crop yield by decreasing the assimilation rate, (potato leaf damage by *Phytophthora infestans, Alternaria* spp.) and causes both quantitative and qualitative stored crop losses (wet rot (*Erwinia carotovora* subsp. c*arotovora*) and dry rot (*Fusarium* spp.), potato blight (*Phytophthora infestans*)).Blemish diseases such as common scab (*Streptomyces scabies*), powdery scab (*Spongospora subterranea*) and black scurf (*Rhizoctonia solani*) can affect skin finish and are the cause of downgrades in the fresh market. The dominance of washed and packed potatoes within the fresh market means that producing and maintaining tubers with a good visual appearance is vital for securing premium returns in this sector (Peters and Wiltshire, 2006). According to Iritani and Sparks (1985) claim the level of losses is influenced by stress, maturity, vine killing, soil temperature, harvester operation, bruise control, obtaining proper environmental conditions immediately after harvest, humidity, ventilation and holding period.

The fungus *Rhizoctonia solani* is a major potato pathogen, causing black scurf of the tuber peel, among other things. Fungal sclerotia present on seed tubers may be a source of infestation of plants and descendant tubers, thus deteriorating their quality. There is not a unanimous opinion about *H. solani* overwintering in plant residues in the soil. According to Hall (1996), the discussed fungus does not demonstrate an ability to winter directly in the soil or to produce effective inoculum sources. Whereas Rouse (1997) claims that this pathogen can survive in the soil between

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consecutive potato cultivations. The pathogen is capable of causing seedling damping-off, root rot, collar rot, stem canker, crown rot, bud and fruit rots, and foliage blight on a variety of susceptible agriculturally important crops (Baker, 1970; Anderson, 1982). Rhizoctonia diseases in field, vegetable, ornamental nursery and greenhouse crops cause large economic losses to growers (Baker, 1970), which result in increased costs to consumers (Herr, 1995).

Initially considered a disease of minor importance, silver scurf is now becoming a disease of high economic consequence (Errampalli et al., 2001). Silver scurf, which usually has a cosmetic effect on tubers, can affect fresh market, processing and seed tuber potatoes (Errampalli et al., 2001). Silver scurf may have a transient effect on potato growth and tuber yield (Mooi, 1968; Denner et al., 1997). The light brown lesions increase the permeability of the tuber skin, causing shrinkage/water loss and therefore weight loss (Hunger and Mclntyre, 1979; Read and Hide, 1984). Although initial infection of progeny tubers occurs during the growing season, much of the actual increase in the disease and the resulting quality problems take place in storage. *H. solani* sporulates on potatoes in storage and, as a result, spreads to healthy tubers (Rodriguez et al., 1996). Due to fungal infection, the tuber peel becomes separated from the tissues beneath. As a result of tuber peel damage, evaporation increases and tubers wilt and dry, and then the tuber flesh becomes darker, thus reducing the potato's commercial value. The seed tubers infested with the pathogen cannot sprout, or they sprout poorly, thus leading to crop reduction. The fungus can infect potato tubers during the growing season and in storage. Infection in russet cultivars is usually not visible at the time of harvest, but symptoms on tubers begin to appear after three to four months in storage (Frazier et al., 1998). Seed tubers are the primary source of inoculum. Rodriguez et al. (1995) found tubers could be naturally inoculated by exposing them to the air circulated in commercial potato storage.

Common scab (*Streptomyces* spp.) is a widely spread disease of the tuber peel. Scab symptoms on potatoes are caused mainly by the following fungal species: *Streptomyces scabies*, *S. acidiscabies, S. aureofaciens* and *S. caviscabies* (Valkonen, 1998). The source of infection is microorganisms in soil or present on the infested seed tubers. Scholte (1989) claims that all potato cultivars undergo infection, but their susceptibility differ from one another in different cases. A number of authors (Davis et al., 1974) think that soil and climatic conditions, especially rainfall during the entire process of tuberisation, have an important effect on tuber infestation by *Streptomyces* spp. The harmfulness of this disease consists in the reduction of edible potato market value, quality deterioration of the raw material designed for processing and the reduction of the value of seed tubers.

In connection with EU requirements on the amount of synthetic plant protection agents that can be used to protect potatoes against pathogens it is necessary to find new substances that can control the most important diseases. The results of previous investigations conducted by the authors of this paper indicated that the prophylactic use of biological agents reduces not only infestation of potato leaves by economically important pathogens, but also has an effect on the extent of tuber infestation by *R. solani, H. solani* and *Streptomyces* spp. (Kurzawińska and Mazur, 2008a, 2008b, 2008c).

The aim of this study is an assessment of the effects of repeated plant spraying during vegetation in the years 2009-2011 with preparations containing the following active substances: chitosan (Biochikol 020 PC), grapefruit extract (Grevit 200 SL) and orange oil (Prev-AM 060 SL) (Table 1) on tuber infestation by *Helminthosporium solani* (silver scurf), *Streptomyces* spp. (common scab) and *Rhizoctonia solani* (tuber black scurf). A fungicide containing Dimethomorph + Mancozeb (Acrobat MZ 69 WG) was used as a comparative agent.

Materials and Methods

The field experiments were carried out on the potato cultivar Vineta N in the years 2009–2011. This cultivar features good storage durability and has moderate resistance to mechanical damage. Winter wheat was used as a forecrop. Manure in the dose of 30 t/ha, triple superphosphate 46% P_2O_5 (80 kg/ha) and potassium salt 60% K_2O (170 kg/ha) were applied in the autumn. Nitro chalk 27% N in the amount of

Table 1
Characteristic of preparations

Preparation	Components	Participation	Recommended concentration, %	Manufacturer
Biochikol 020 PC	chitozan - poli[β-/1,4/-2amino-2deoxy-D-glukopiraoza]	20 g/1000 ml	2.5	Gumitex Poli – Farm Sp. z o.o.
Grevit 200 SL	grapefruit ekstract	200 g/1000 ml	0.2	Avis Naturall Polska Sp. z o. o.
Prev-Am 060 SL	orange oil	60 g/1000 ml	0.4	Citrus Oil Products Inc.

Table 2
Estimation of seed tuber health

Disease	Infected tubers, %			Mean
	2009	2010	2011	
Helmithosporium solani	4.8	5.5	5.1	5.1
Rhizoctonia solani	8.3	9.2	8.8	8.8
Streptomyces spp.	6.6	7.1	6.7	6.8
Phytophthora infestans	1.6	1.8	1.8	1.7

200 kg/ha was applied before planting in the spring. After ridging, spraying was carried out as recommended with the herbicide Sencor 70 WG. Treatments were used in accordance with standard agricultural practices. In each season, before setting up the experiment, the percentage of seed tubers infested with *H. solani, R. solani, Streptomyces* spp. and *P. infestans* was determined on 4 x 100 tubers. The experiment was set up in a space between 62.5 cm rows in April (24.04.2009, 23.04.2010, 22.04.2011). The method of random squares in four replications was applied and the experimental combinations were as follows:

- Plants without protection (the control),
- Potato plants sprayed with the preparation Biochikol 020 PC at a concentration of 2.0%,
- Potato plants sprayed with the preparation Grevit 200 SL at a concentration of 0.2%,
- Potato plants sprayed with the preparation Prev-AM 060 SL at a concentration of 0.4%,
- Potato plants sprayed with the standard preparation Acrobat MZ 69 WG (dimethomorph + mancozeb) in the dose of 2.5 kg/ha.

Every year seven treatments were made. The first spraying in 31 301 phase BBCH scale (16.06.2009, 10.06.2010, 13.06.2011) with the agents mentioned above was carried out when the first *Alternaria* spp. symptoms occurred and the next ones every 10–14 days depending on weather conditions.

The characteristics of the meteorological conditions for the vegetation periods in the years 2009–2011 are summarised in Table 3. After harvesting, 100 tubers were taken at random from each plot and placed in disinfected plastic boxes in storage at 5–6°C and relative humidity of 80–85%. The incidence (percentage of tubers carrying sclerotia) and degree of infestation with *R. solani as* well *as* the incidence and degree of tuber infestation with *Streptomyces* spp. were estimated visually directly after lifting (September). The degree and percentage of tuber infestation with *H. solani* were analysed after three-month storage (December). The average degree of tuber infestation was estimated on the following four-level scale for each pathogen individually:

- disease symptoms on 5–25% of the surface,
- disease symptoms on 26–50% of the surface,
- disease symptoms on 51–75% of the surface,
- disease symptoms cover over 75% of the surface.

The obtained results were subject to statistical computations by using ANOVA variance analysis (Statistica 10). The significance of differences between the means was estimated by performing the Tukey range test.

Table 3
Average temperatures and rainfall sums during the vegetation period in 2009–2011 at Krakow. Poland

Year	Month	Average air temperature, ºC				Rainfall sum, mm			
		for ten-day period			monthly	for ten-day period			monthly
		I	II	III		I	II	III	
2009	May	12.9	13.1	13.6	13.2	0.2	58.4	65.3	123.9
	June	13.7	15.3	17.9	15.6	31.0	62.6	121.6	215. 2
	July	19.4	19.2	19.4	19.3	61.5	45.3	40.3	147.1
	August	19.3	18.4	17.3	18.3	1.3	12.3	56.6	70.2
	September	15.8	14.1	13.5	14.5	22.6	16.5	3.0	42.1
2010	May	12.7	10.9	14.5	12.7	79.4	188.0	35.0	302.4
	June	18.6	17.9	16.9	17.8	1.6	28.0	22.0	51.6
	July	19.8	23.6	21.3	21.6	8.6	31.6	72.2	112.4
	August	19.9	19.6	18.6	19.4	27.8	38.0	72.4	138.2
	September	11.7	13.4	12.1	12.4	49.6	0.4	1.2	51.2
2011	May	9.6	15.4	17.2	14.1	16.0	12.2	26.4	54.6
	June	19.4	18.4	17.9	18.6	26.0	29.6	11.4	67.0
	July	17.3	20.1	16.4	17.9	45.0	62.2	55.8	163.0
	August	18.7	19.2	20.3	19.4	23.0	5.8	8.4	37.2

Results and Discussion

The average percentage of infected seed tubers used for the field experiments was 5.1% for *H. solani*, 6.8% for *Streptomyces* spp. and 8.8% for *R. solani* – see Table 2. A low percentage of the seed tubers was also infected with *P. infestans* (Table 2).

Based on the results obtained from the three-year research, we found an advantageous effect of spraying the potato plants with the tested preparations. All reduced the incidence of black scurf on descendant tubers (Table 4). The standard chemical preparation was most effective in reducing both the degree of tuber infection and the percentage of tubers with sclerotia from *R. solani*. Statistical computation showed a significant effect of all tested preparations in reducing the rate of tuber infection in 2009 and 2010 and the percentage of tubers with sclerotia from *R. solani* in 2009, 2010 and 2011 (compared to the control) (Table 4).

In all years of the field experiment, the highest degree of tuber infection and percentage of tubers infested with *Helminthosporium solani* was observed for the control Preparations used significantly decreased the degree and percentage of tuber infestation by the pathogen (Table 5).

The rate of tuber infestation by *Streptomyces* spp. was diversified in the years of the experiment. In all years of the experiment, the highest percentage of tubers infested with *Streptomyces* spp. was recorded for the control (34.7–40.3%), while the lowest was observed for the treatment with the standard agent Acrobat MZ 69 WG (Table 6). In the second year of the experiment (2010), an increased per-

Table 4
Influence of tested preparations on tuber infestation by *R. solani* at Krakow, Poland

(Treatment)	Degree (1 – 4 scale) *			Incidence (% infested tubers) *		
	2009	2010	2011	2009	2010	2011
Untreated	1.9 c*	2.2 c	2.5 a	30.5 b	33.3 c	23.9 d
Biochikol 020 PC chitosan	1.4 a	1.7 a	2.1 a	18.0 a	22.0 a	18.6 b
Grevit 200 SL extract of grapefruit	1.4 a	1.6 ab	2.2 a	17.5 a	21.5 a	15.3 a
Prev – AM 060 SL orange oil	1.5 a	1.8 a	2.1 a	18.3 a	22.8 a	17.2 ab
Acrobat MZ 69 WG dimethomorph + mancozeb	1.1 b	1.4 b	2.0 a	16.3 a	17.5 b	13.1 c

* means of 4 x 100 tubers rated directly after harvest.
**means within columns with the same letter do not differ significantly according to the Tukey test at p = 0.05

Table 5
Influence of tested preparations on tuber infestation by *H. solani* at Krakow, Poland

Treatment	Average rate of tuber infestation in scale			Percentage of infested tubers		
	2009	2010	2011	2009	2010	2011
Control (untreated)	2.4 b*	4.6 c	2.8 b	26.5 c	61.5 a	36.5 b
Biochikol 020 PC chitosan	2.0 a	3.9 b	2.0 ab	16.0 ab	58.0 ab	13.4 a
Grevit 200 SL extract of grapefruit	1.8 a	3.3 a	1.7 a	14.0 a	53.5 b	12.6 a
Prev- AM 060 SL orange oil	1.8 a	4.0 b	1.7 a	16.5 b	60.3 a	14.4 a
Acrobat MZ 69 WG dimethomorph + mancozeb	1.8 a	3.2 a	1.8 a	13.8 a	39.8 c	15.1 a

*means within columns with the same letter do not differ significantly according to the Tukey test at p = 0.05

Table 6
Influence of tested preparations on tuber infestation by *Streptomyces* spp. at Krakow, Poland

Treatment	Average rate of tuber infestation in scale			Percentage of infested tubers		
	2009	2010	2011	2009	2010	2011
Control (untreated)	2.0 b*	2.5 c	2.6 b	36.3 d	40.3 d	34.7 c
Biochikol 020 PC Chitosan	1.8 a	2.0 b	2.2 a	28.5 c	32.0 c	27.3 a
Grevit 200 SL extract of grapefruit	1.7 a	1.9 ab	2.2 a	26.0 ab	29.0 ab	24.7 a
Prev-- AM 060 SL orange oil	1.7 a	1.9 ab	2.3 a	27.3 bc	30.5 bc	26.1 a
Acrobat MZ 69 WG dimetomorf + mancozeb	1.7 a	1.8 a	2.1 a	25.0 a	27.5 a	20.4 b

*means within columns with the same letter do not differ significantly according to the Tukey test at p = 0.05

centage of potato tubers infested with *Streptomyces* spp. for all treatments was observed (Table 6), thus suggesting that this was connected with a dry summer (17.8–21.6°C), and the lowest rainfall total was recorded in June and July 2010 (Table 3).

The results of the three-year field experiments indicate an advantageous effect of spraying plants with the preparations under investigation on reducing the infestation of daughter tubers by *Streptomyces* spp. (Table 6). Based on the results of statistical computations, we found that in all years of the experiment, both the percentage of infested tubers and the average rate of infestation by *Streptomyces* spp. in all combinations with the use of natural and chemical agents were significantly lower than those of the control (Table 6). Based on the results of the three-year investigations, we found an advantageous effect of potato plant spraying seven times with the preparation under examination on reducing the incidence of tuber peel diseases caused by each *R. solani, H. solani* and *Streptomyces* spp. (Figures 1 and 2).

Among natural preparations (biologicals) tested, the lowest percentage of tuber infested with sclerotia from *R. solani* was recorded for the combination where a grapefruit-based agent was used. The use of biological preparations, including natural ones, which hamper the growth of many plant pathogens have become more and more important, especially in the light of constraints on chemical protection measures (Kurzawińska, 2008). In recent years there has been an increasing interest in finding alternatives to chemical bactericides and fungicides considered as safe, and with negligible risk to human health and the environment. Among these strategies, some satisfactory results have been reported using natural compounds such as chitosan (Muzzarelli, 1983). Chemical protection of potato against hazardous pathogens is an important measure for increasing the amount of high quality crops. Acrobat MZ 69 WG (dimetomorph+mancozeb) is a fungicide of translaminar action (Frazier et al., 1998; Geary et al., 2007). In our study it was most effective in hampering the growth of *R. solani* on tubers of the tested potato cultivar Vinieta. Combinations of fungicides including mancozeb have also been reported to be effective against silver scurf (Frazier et al*,* 1998; Geary et al., 2007).

Grapefruit seed extract (Grevit, 200SL) is known to be highly effective against pathogens (Kiełkiewicz et al., 2008). The grapefruit flesh and seed extracts feature fungicidal and bactericidal properties (Orlikowski et al., 2001). Among all of the natural preparations, the lowest rate of tuber infection and percentage of tubers infested with *H. solani* was recorded for the combination where plants were sprayed with Grevit 200 SL. Cultural practices in potato farming are known to affect the incidence and severity of silver scurf. Disease

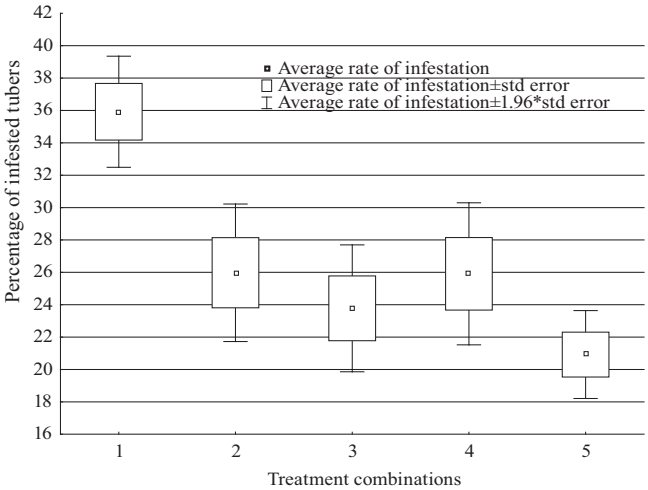

Fig. 1. Percentage of tubers infected with altogether examined pathogens according to treatment P ≤ 0.05 mean significant

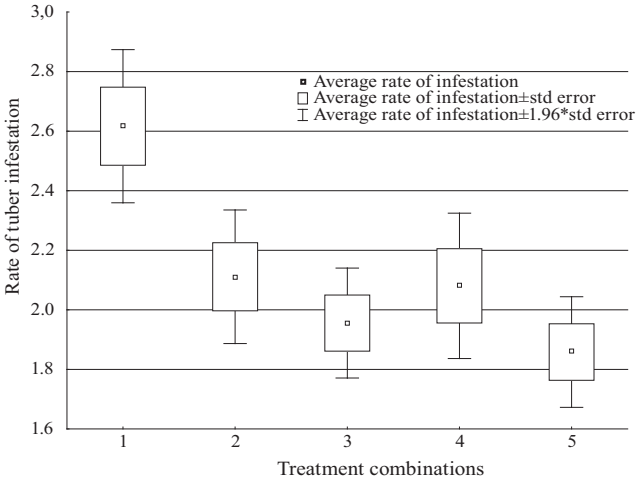

Fig. 2. Average rate of tuber infestation with altogether examined pathogens according to treatment P ≤ 0.05 mean significant

status of tubers, planting dates and densities, harvest dates, and storage conditions are among the more common factors impacting *H. solani* development (Avis et al. 2010). The year 2010 was especially advantageous for tuber infestation by *H. solani*. The month of August 2010 featured a large amount of precipitation and the strongest tuber infestation by *H. solani* in that year (compared to those of the years 2009 and 2011).

Cultivar resistance can effectively limit the development of the disease, but in the driest years infection can occur even in highly resistant cultivars (Stalham et al., 2010). In the third year of the experiment (2011), a decrease in the percentage

of tubers infested with *Streptomyces* spp. was observed for all combinations. Among the natural preparations the lowest percentage of tubers showing common scab symptoms was found for the combination where plants were sprayed with the grapefruit extract-based preparation (Grevit 200 SL).

The observed reduction of the infestation of daughter tubers by *Streptomyces* spp. by spraying plants with the preparations in the current experiment is consistent with previous results obtained by other authors Kurzawińska and Mazur (2008c). In addition, Kurzawińska and Gajda (2004) showed a relationship between the amount of *Streptomyces* spp. inoculum on seed tubers and the degree of infestation of descendant tubers. The authors also found that the rate of tuber infection and percentage of tubers infested with *Streptomyces* spp. were modified significantly by meteorological conditions prevailing in each year of the experiment and they observed an increase of common scab symptoms in the year 1999, which featured a dry summer.

Conclusion

Treatment with all of the tested preparations resulted in a significantly lower percentage of infested tubers (compared to the control) and a lower average rate of infestation by *H. solani, R. solani* and *Streptomyces* spp. The grapefruit extract-based preparation (Grevit 200 SL) was most effective in reducing potato infestation by pathogens that cause diseases of the tuber peel. In addition to direct action on many pathogens, they also strengthen the immune system of the treated plant.

The use of biological preparations, including those based on natural substances, allows for chemical protection measures to be eliminated or reduced, improves the quality of the raw material for ecological food production, environmental protection through a weaker effect of such agents in environment and easier biodegradation with comparable to synthetic agents effects for plant protection. There is a chance that the tested agents will be used in organic potato production.

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