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THE EFFECT OF MINERAL FERTILIZATION ON FUNGI COLONIZING POTATO (*Solanum tuberosum* L.) TUBERS AFTER HARVEST AND AFTER STORAGE

Bożena Cwalina-Ambroziak[1], Bożena Bogucka[2]

[1] Department of Phytopathology and Entomology, University of Warmia and Mazury, Prawocheńskiego 17, 10-720 Olsztyn, Poland
[2] Department of Agrotechnology and Crop Management, University of Warmia and Mazury, Oczapowskiego 8, 10-719 Olsztyn, Poland
e-mail: bambr@uwm.edu.pl

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A b s t r a c t

The paper presents the results of a three-year exact experiment conducted in Bałcyny, in which a late potato cultivar, Jasia, was grown. The objective of the study was to determine the effect of different levels of mineral fertilization: A (N 80 kg × ha^{-1} P 80 kg × ha^{-1} K120 kg × ha^{-1}) and B (N 120 kg × ha^{-1} P 144 kg × ha^{-1} K156 kg × ha^{-1}), and foliar fertilization (Basfoliar 12-4-6, ADOB Mn and Solubor DF) on the quantitative and qualitative composition of fungal populations colonizing potato tubers. Fungi were isolated immediately after harvest and after a five-month storage period. After seven days of incubation, fungal colonies were transferred onto agar slants for microscopic identification.

Over the entire experimental period, more pathogenic fungi were obtained from potato tubers analyzed after storage (62.9% of the total fungal population after storage) than from those analyzed immediately after harvest (39.1%), and the greatest number of fungi was reported in 2004. Rhizoctonia solani was isolated most frequently, followed by Colletotrichum coccodes and Alternaria alternata. Pathogens of the genus Fusarium and the species Helminthosporium solani were not numerous. In the treatment A with soil mineral fertilization with lower NPK rates, larger numbers of pathogenic fungi were noted in 2004 after harvest and after five-month storage, and in 2005 after harvest. At the remaining dates of analysis, pathogens were more frequently isolated from potato tubers in experimental variant B with higher NPK rates.

Immediately after harvest, the highest number of pathogenic fungi was isolated in the treatment with foliar application of ADOB Mn and Basfoliar 12-4-6. After five-month storage, pathogens most often colonized potato tubers in experimental variant B with foliar application of Solubor DF, Solubor DF and ADOB Mn, and in experimental variant A with a combination of fertilizers. In the other fertilization variants, including in the control treatment, the population size of pathogenic agents remained at a similar level.

Key words: potato tubers, mineral fertilization, foliar fertilization, fungi

INTRODUCTION

Multi-component fertilizers applied to leaves are an important element of modern potato production technologies (H o n e y c u t t et al. 1996; H a b e r l a n d , 2000; B o l i g ł o w a , 2003). Under stress conditions, such as drought or excessive soil acidification, foliar fertilization can replace traditional organic and mineral fertilization. Apart from its yield-forming effect, foliar fertilization also affects the quality of potato tubers (it contributes to an increase in starch and vitamin C content and influences protein concentration and quality) and their storage life (K o z e r a et al. 2006).

In addition, mixed fertilizers applied to leaves determine the composition of pathogenic and saprotrophic fungal communities colonizing the aboveground parts of potato plants. K a p s a (2002) demonstrated that the foliar application of Insol 7 to potato plants enabled to decrease the rate of fungicides in the control of *P. infestans*. According to O s o w s k i (2005), the combined Basfoliar 12-4-6 and fungicide treatment helped to reduce the severity of infection caused by fungi of the genus *Alternaria.* A previous study conducted by the author of this paper (C w a l i n a - A m b r o z i a k et al. 2007) produced ambiguous results with regard to the effect of foliar fertilizers on the frequency of occurrence of pathogens in the phyllosphere of potato plants. Foliar application of fertilizers also alters the composition of fungal communities colonizing potato tubers (K u r z a w i ń s k a , 1997; R ę b a c z and B o r ó w c z a k , 2007).

The objective of the present laboratory study was to determine the effect of mineral soil fertilization and of foliar fertilization of potatoes on the structure of fungal communities colonizing tubers directly after harvest and after five-month storage.

MATERIALS AND METHODS

The experimental materials comprised potato tubers of late cultivar Jasia, harvested during a three-year experiment established in 2004 (investigation period 2004-2006) at the Agricultural Experimental Station in Bałcyny, on gray-brown podsolic soil developed from light silty loam, of complex 4 class III, in four replications. Tillage treatments and agricultural measures (as recommended by the Institute of Soil Science and Plant Cultivation in Puławy) as well as the methods of plant protection against agrophages (as recommended by the Institute of Plant Protection in Poznań) were identical in all experimental plots.

The following experimental factors were considered:

I – levels of mineral fertilization:
A (N 80 kg × ha^{-1} P 80 kg × ha^{-1} K120 kg × ha^{-1}),
B (N 120 kg × ha^{-1} P 144 kg × ha^{-1} K156 kg × ha^{-1}),
II – foliar fetilization:
a (Basfoliar 12-4-6 – 8 l × ha^{-1}),
b (ADOB Mn – 4 l × ha^{-1}),
c (Solubor DF – 2 l × ha^{-1}),
d (ADOB Mn – 2 l × ha^{-1} + Solubor DF – 1 l × ha^{-1}),
e (ADOB Mn – 2 l × ha^{-1} + Basfoliar 12-4-6 – 4 l × ha^{-1}),
f (Basfoliar 12-4-6 – 4 l × ha^{-1} + Solubor DF – 1 l × ha^{-1}),
g (Basfoliar 12-4-6 – 2.7 l × ha^{-1} + ADOB Mn – 1.3 l × ha^{-1} + Solubor DF – 0.7 l × ha^{-1}),
h (control treatment, no foliar fertilization).

Laboratory samples consisted of 30 tubers collected randomly in four replications per treatment, directly after harvest and after five-month storage at 5°C. Following disinfection with 50% ethanol and 1% sodium hypochlorite, blocks (0.5 × 0.5 × 1.5 cm) were cut from tubers and placed on PDA medium. After seven days of incubations, fungal colonies were inoculated onto agar slants for later microscopic identification according to keys and monographs (Arx, 1970; Booth, 1971; Ellis, 1971; Domsch et al. 1980).

The results were processed statistically and subjected to variance analysis (STATISTICA®8.0 2008), the Duncan's test (p=0.01) was used for comparison of the averages.

RESULTS AND DISCUSSION

The fungal population (1809 isolates) was represented by 31 species and yeast-like fungi and non-sporulating fungi (Tab. 2, 3). More fungi (by 9.3%) were isolated from newly-harvested tubers, compared with tubers stored for five months. However, the proportion of pathogens was higher in stored tubers, reaching 88.2%, 48.0% and 63.1% in the successive years of the study (Fig. 1). The species isolated most frequently over the entire experimental period was *Rhizoctonia solani*, followed by *Colletotrichum coccodes*, which was isolated primarily in the first and third year, with single isolates obtained in the second year. *Alternaria alternata* was less abundant, but it colonized potato tubers in all analyzed periods, reaching the highest abundance in the second year after five-month storage. High precipitation rates and moderate temperatures noted over the growing seasons of 2004 and 2006 probably contributed to frequent infections caused by *R. solani*, whereas weather conditions in 2005.

(Tab. 1) stimulated invasions by fungi of the genus *Alternaria*, which is consistent with the findings of other authors (Czajka et al. 1999; Bernat, 2005; Repsiene and Mineikiene, 2006). The rate of potato tuber colonization by the fungus *C. coccodes* was the same (15%) at both dates of analysis, while *R. solani* was isolated more frequently after storage (34%) than after harvest (20.4%) (Tab. 2, 3). The other potentially pathogenic fungi of the genus *Fusarium* (*F. culmorum, F. concolor, F. oxysporum* and *F. poae* which colonized tubers in all analyzed periods (except

Table 1
Meteorological data according to the Bałcyny Meteorological Station.

Month	Mean monthly temperature (°C)			mean for 1960-90	Mean monthly rainfall (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

Table 2
Fungi isolated from potato tubers after harvest in study period 2004-2006.

Fungi	Treatments															
	A[1] a	Ab[2]	Ac	Ad	Ae	Af	Ag	Ah	Ba	Bb	Bc	Bd	Be	Bf	Bg	Bh
Acremonium strictum W. Gams	1		2				1	2					1			
Alternaria alternata (Fr.) Keissler *	1	1	1	1	2		2				1	1	1	4		
Arthrinium sphaerospermum Fuckel	1		2	1			2		9			2		2	3	2
Chaetomium puliliferum Kunze ex Fr.	1	1						1		1			4		2	1
Cladosporium cladosporioides (Fres.)	1	1		1	3				1	1		1	1		2	
Cladosporium herbarum Link ex Fries										1						
Colletotrichum coccodes (Wallr.) Hughes *	10	10	6	18	15	11	11	8	9	7	10	5	7	2	8	9
Endothia spp.	2	5	6	11		11	5	6	4	9	10	16	13		1	14
Epicoccum purpurascens Ehrenb.ex Schlecht	2		1		2	2						1		1		1
Fusarium concolor Corda*											1					
Fusarium culmorum (W.G.Sm.) Sacc.*											1					1
Fusarium oxysporum Schlecht *									1		4	1				1
Fusarium poae (Peck) Wollenweber *						1										
Gliocladium catenulatum Gilman et Abbott**					1		1					1	2			
Gliocladium fimbriatum Gilman et Abbott **			5		1										1	2
Gliocladium penicillioides Corda **				1				2								
Gliomastix murorum (Corda) Hughes	2	1				2	1	3				3			1	
Helminthosporium solani Dur et Mont.*					1			1	1		1	1		3		
Mortierella alpina Peyronel						2	1			3	1			4	3	3
Mortierella isabelina Quademans	2	2	2	1	1				2	1	2			2	1	2
Mucor hiemalis Wehmer	3	2	9	3	2	9	5	2	5	4	6	5	12	4	8	
Penicillium spp.	12	4	7	17	6	6	5	6	6	5	11	6	16	7	9	1
Rhizoctonia solani Kuhn *	11	14	11	8	17	11	6	10	13	20	8	11	14	22	10	11
Rhizopus nigricans Ehrenberg	7	9		1		13	7	6	4	9		1	5	6	3	3
Sporormia spp.			2	1		1	1	1			3					2
Trichoderma harzianum Rifai **	6							11						2	1	
Yeast-like fungi		2	1	2			7					1				2
Non sporulating fungi			4		4				1	1		3			4	3
Total	62	52	59	66	55	69	55	59	56	62	61	59	76	59	57	58

[1] A, B – level of mineral fertilization (A-N 80 kg × ha^{-1} P 80 kg × ha^{-1} K120 kg × ha^{-1}, B-N 120 kg × ha^{-1} P 144 kg × ha^{-1} K156 kg × ha^{-1}),
[2] a, b, c, d, e, f, g, h – foliar fertilization (a-Basfoliar 12-4-6, b-ADOB Mn, c-Solubor DF, d-ADOB Mn+Solubor DF, e-ADOB Mn+ Basfoliar 12-4-6, f-Basfoliar 12-4-6+Solubor DF, g-Basfoliar 12-4-6+ADOB Mn+Solubor DF, h-control (no foliar fertilization)
* – pathogenic fungi, ** – antagonistic fungi

Table 3
Fungi isolated from potato tubers after 5-monthly storage in study period 2004-2006.

Fungi	Treatments															
	Aa	Ab	Ac	Ad	Ae	Af	Ag	Ah	Ba	Bb	Bc	Bd	Be	Bf	Bg	Bh
Acremonium strictum W. Gams													4		1	
Alternaria alternata (Fr.) Keissler *	10	3	2	4	8	8	6	5	7	6	2	14	4	2	8	3
Arthrinium sphaerospermum Fuckel					5	1	1		4				1	2		
Chaetomium puliliferum Kunze ex Fr.				1												
Cladosporium cladosporioides (Fres.)	1	2	4	2	1	1	1	2	3	2	2	3	3			1
Colletotrichum coccodes (Wallr.) Hughes *	3	8	7	11	13	7	10	3	16	5	16	2	10	4	10	5
Endothia spp.	1								1	1					1	
Epicoccum purpurascens Ehrenb.ex Schlecht								1								
Fusarium concolor Corda *								1		6	2			1		
Fusarium culmorum (W.G.Sm.) Sacc. *			1	1	2			3			1		1			
Fusarium oxysporum Schlecht *	1		1								2					
Gilmaniella humicola Barron																1
Gliocladium catenulatum Gilman et Abbott**			1	1	3	1		1					6		2	
Gliocladium fimbriatum Gilman et Abbott **														2		
Gliocladium roseum Link (Thom) **	8					1									4	
Mortierella alpina Peyronel								1								
Mucor hiemalis Wehmer	4	1	3	6	4		2				4		3	4		
Penicillium spp.	8	3	1	1	1	4	1	8	4	3	1	6	13	14	3	14
Rhizoctonia solani Kuhn *	4	21	16	11	16	24	21	17	12	11	18	30	17	24	23	21
Rhizopus nigricans Ehrenberg	10		4		2	1	2	7		1				5	2	1
Spicaria divaricata (Thom)Gilman et Abbott**											1					
Sporormia spp.						1									1	
Trichoderma aureoviride Rifai **	4	1			2	4					1		1		1	
Trichoderma hamatum (Bon) Bain **														1		
Trichoderma harzianum Rifai **					1											
Yeast-like fungi		9	8	9	1	2			2	14					1	5
Non sporulating fungi				1						1						
Total	54	48	48	48	59	55	49	49	49	50	50	55	63	59	57	51

Explanations as in Table 2
* – pathogenic fungi, ** – antagonistic fungi

for the year 2006 directly after harvest) constituted less than 4% of all isolates, and *Helminthosporium solani* accounted for only 1% of the total fungal population. The above species are considered typical potato pathogens (Weber, 1990; Kurzawińska, 1997; Cwalina-Ambroziak, 2002).

An analysis of the levels of mineral soil fertilization showed that more pathogens were isolated in treatment A with lower NPK rates (N – 80 kg × ha^{-1}, P – 80 kg × ha^{-1}, K – 120 kg × ha^{-1}) in 2004 both after harvest and after storage and in 2005 after harvest, and in treatment B with higher NPK rates (N – 120 kg × ha^{-1}, P – 144 kg × ha^{-1}, K – 156 kg × ha^{-1}) in the other experimental periods (Fig. 1). Czajka et al. (1999) pointed to a significant impact of excessive nitrogen fertilization on the stronger infection of potato tubers by pathogenic fungi. The most abundant saprotrophic fungi were members of the order *Mucorales* and of the genus *Penicillium*. In the present study, they were more frequently isolated from tubers after harvest (19.5% and 12.8% respectively) than after storage (7.8% and 10.1%) (Tab. 2, 3). Differences in the abundance of these fungi between particular fertilization treatments were non-significant, except for *Mucorales* after storage (Tab. 4). Fungi, represented by species of the genera *Gliocladium, Paecilomyces* and *Trichoderma*, were most frequently isolated from stored tubers in the second year of the study – 7.7% of all isolates (Fig. 1). The least pathogens were obtained during the above growing season. The above antagonistic microorganisms contribute to reducing of pathogenic fungi population (Hoitink and Boehm, 1999; Pastucha, 1999). As regards the levels of NPK fertilization, more fungi were isolated from treatment "A", with a lower fertilization level, at both dates of analysis.

The present study revealed that the structure of pathogenic fungal communities colonizing potato tubers was affected by foliar fertilization. The most pathogens were isolated from newly-harvested tubers in treatment Ae, where the foliar fertilizers ADOB Mn and Basfoliar were applied (63.6% of all fungi in this treatment). Fungal pathogens were less abundant in treatment Ab with ADOB Mn and in treatment Bf with Basfoliar 12-4-6 and Solubor DF (approx. 48%) (Fig. 2). In the remaining treatments with foliar fertilization, the abundance of pathogens colonizing tubers was at a comparable, low level of 30%. After storage the largest fungal population (82% to 85.7%) was reported in treatments Bc, Bd (ADOB Mn + Solubor DF) and Ag (combined fertilization) (Fig. 3). In the control

Table 4
Most frequently isolated fungi from potato tubers (mean numbers of isolates for years).

Treatments	After harvest				After storage			
	pathogens	antagonists	*Mucorales*	*Penicillium* spp.	pathogens	antagonists	*Mucorales*	*Penicillium* spp.
Aa	7.00 a[3]	2.00 ab	4.00 a	4.33 a	6.00 b	4.00 a	4.67 a	2.67 a
Ab	8.33 a	0 b	4.33 a	1.33 a	10.67 ab	0.33 b	0.33 ab	1.00 a
Ac	6.00 a	1.67 ab	3.67 a	2.33 a	9.00 ab	0.33 b	2.33 ab	0.33 a
Ad	9.00 a	0.33 b	1.67 a	5.67 a	9.00 ab	0.33 b	2.00 ab	0.33 a
Ae	11.33 a	0.67 b	1.00 a	2.00 a	13.00 ab	2.00 ab	2.00 ab	0.33 a
Af	7.67 a	0 b	8.00 a	2.00 a	13.00 ab	2.00 ab	0.33 ab	1.33 a
Ag	6.33 a	0.33 b	4.33 a	1.67 a	14.00 a	0 b	1.33 ab	0.33 a
Ah	6.00 a	4.33 a	2.67 a	2.00 a	9.67 ab	0.33 b	2.67 ab	2.67 a
Ba	8.00 a	0 b	3.67 a	2.00 a	11.67 ab	0 b	0 b	1.33 a
Bb	9.00 a	0 b	5.67 a	1.67 a	9.33 ab	0 b	0.33 ab	1.00 a
Bc	8.67 a	0 b	3.00 a	3.67 a	13.67 a	0.67 ab	1.33 ab	0.33 a
Bd	6.33 a	0.33 b	2.00 a	2.00 a	15.33 a	0 b	0 b	2.00 a
Be	7.33 a	0.67 b	5.67 a	5.33 a	10.67 ab	2.33 ab	1.00 ab	4.33 a
Bf	9.33 a	0.67 b	6.33 a	2.33 a	10.33 ab	1.00 ab	3.00 ab	4.67 a
Bg	6.00 a	0.67 b	4.00 a	3.00 a	13.67 a	2.33 ab	0.67 ab	1.00 a
Bh	7.33 a	0.67 b	2.67 a	0.33 a	9.67 ab	0 b	0.33 ab	4.67 a

Explanations as in Table 2

[3] means with the same letter do not differ significantly (Duncan's test, p=0.01)

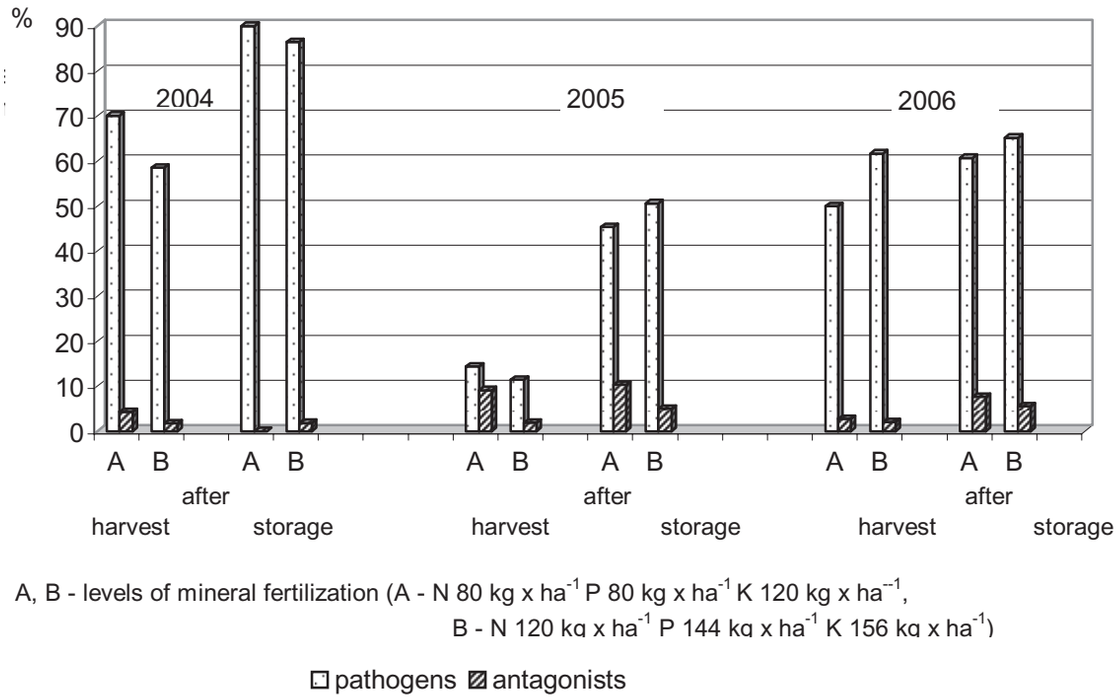

Fig. 1. Fungi isolted from potato tubers during investigation**.**

treatment, pathogens constituted less than 60% of all isolates. The fewest colonies of fungi responsible for potato diseases were noted in treatment Aa (Basfoliar 12-4-6 – 33.3%) (Fig. 3); the differences in numbers of pathogens were significant as compared to combinations Ag, Bc, Bd and Bg (Tab. 1). Other authors demonstrated that neither Basfoliar 36 E and ADOB Mn (Jabłoński, 2003) nor $CuCO_3$ applied to leaves (Szutkowska and Lutomirska, 2002) influenced the severity of potato infestation by *Streptomyces scabies.*

An analysis of pathogen species colonizing newly-harvested tubers indicated that the dominant species, *R. solani*, constituted from 10.9% in treatment Ag to 37.3% in treatment Bf (Fig. 2). In general, more isolates of this fungus were obtained in treatment B than in treatment A (except for treatments with Solubor DF, and with ADOB Mn and Basfoliar 12-4-6). As regards stored tubers, the population size of *R. solani* was at a similar level in both treatments with mineral soil fertilization, A and B, except for the treatment with foliar application of ADOB Mn and for the treatment with combined foliar fertilizers, where more pathogens were isolated following the application of higher rates of mineral soil fertilizers. Honeycutt et al. (1996) demonstrated that nitrogen fertilization at a rate of 0 to 250 kg × ha^{-1} did not affect the severity of plant infection by the above pathogen. Ritchie et al. (2006) conducted an *in vitro* study in which potassium was added to PDA medium and found that this macronutrient had an inhibitory effect on mycelium growth as well as on the production and germination of sclerotia. Rębacz and Borówczak (2007) demonstrated that foliar fertilization with Mikrosol reduced the level of tuber infection by *R. solani*.

Mineral NPK fertilization and foliar application of fertilizers affected also the abundance of the fungus *C. coccodes* which colonized both newly-harvested and stored tubers. This pathogen is known to infest potato tubers (accounting for up to 90% of all fungal isolates – Tsror /Lahim/ et al. 1999), but also roots, stolons and stems (Andrivon et al. 1998). In the present experiment, this species was isolated more frequently from tubers in treatment A (with lower mineral fertilization levels) than in treatment B (with higher fertilization levels), with a few exceptions. Its greatest abundance was noted in newly-harvested tubers in treatment Ad (27.3%) (Fig. 2), and in stored tubers in treatments Ba and Bc (these two treatments were exceptional) (Fig. 3). The interpretation of the obtained results suggests a lower infection rate in treatments with higher levels of nitrogen fertilization. Our data are consistent with the findings of other authors (Davis, 1981; Zarzycka, 1990) who observed higher rates of *C. coccodes* infection in potato plants grown in nitrogen-deficient soil, in comparison with soil fertilized with adequate amounts of nitrogen.

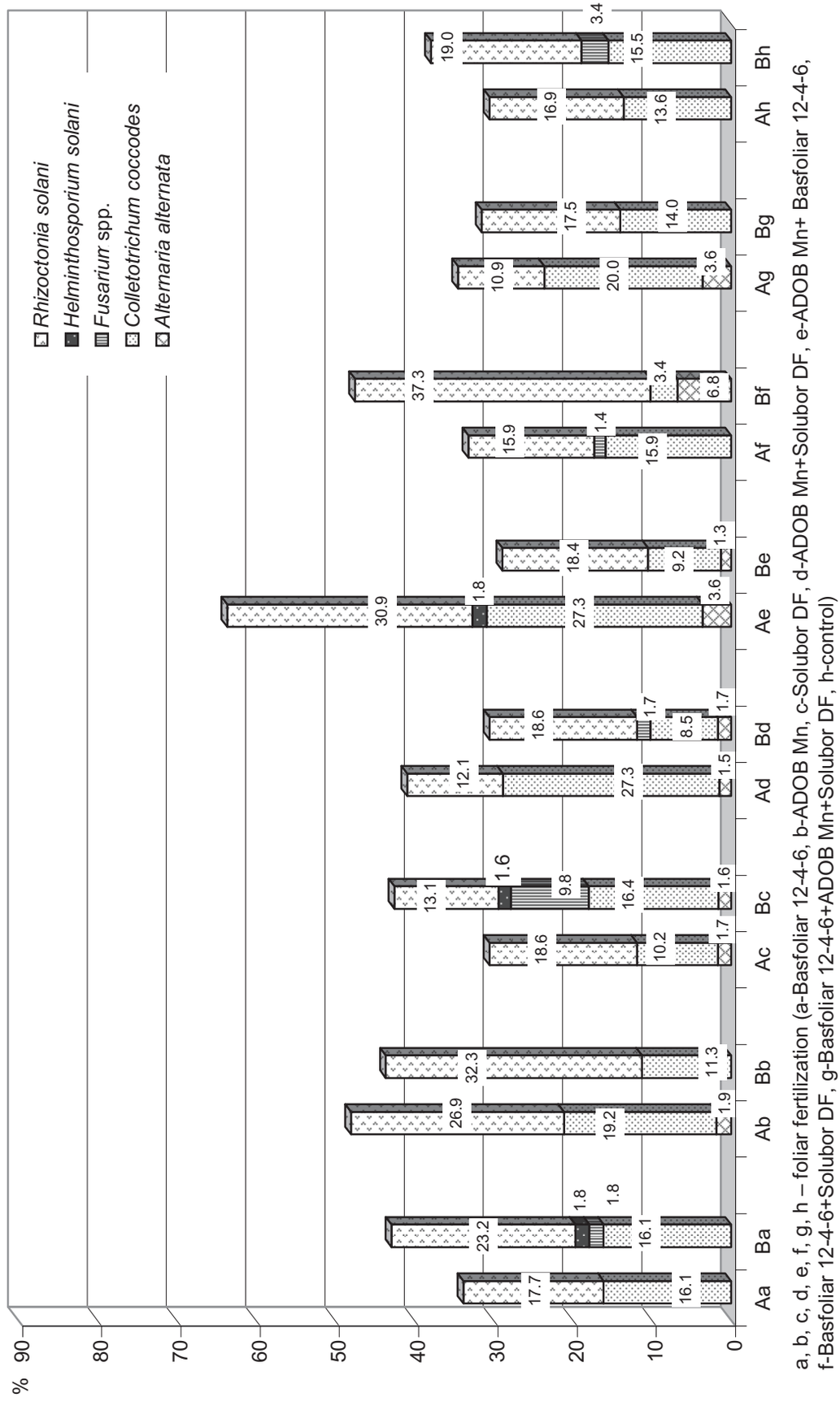

Fig. 2. Pathogens isolated from potato tubers after harvest (mean for investigated period).

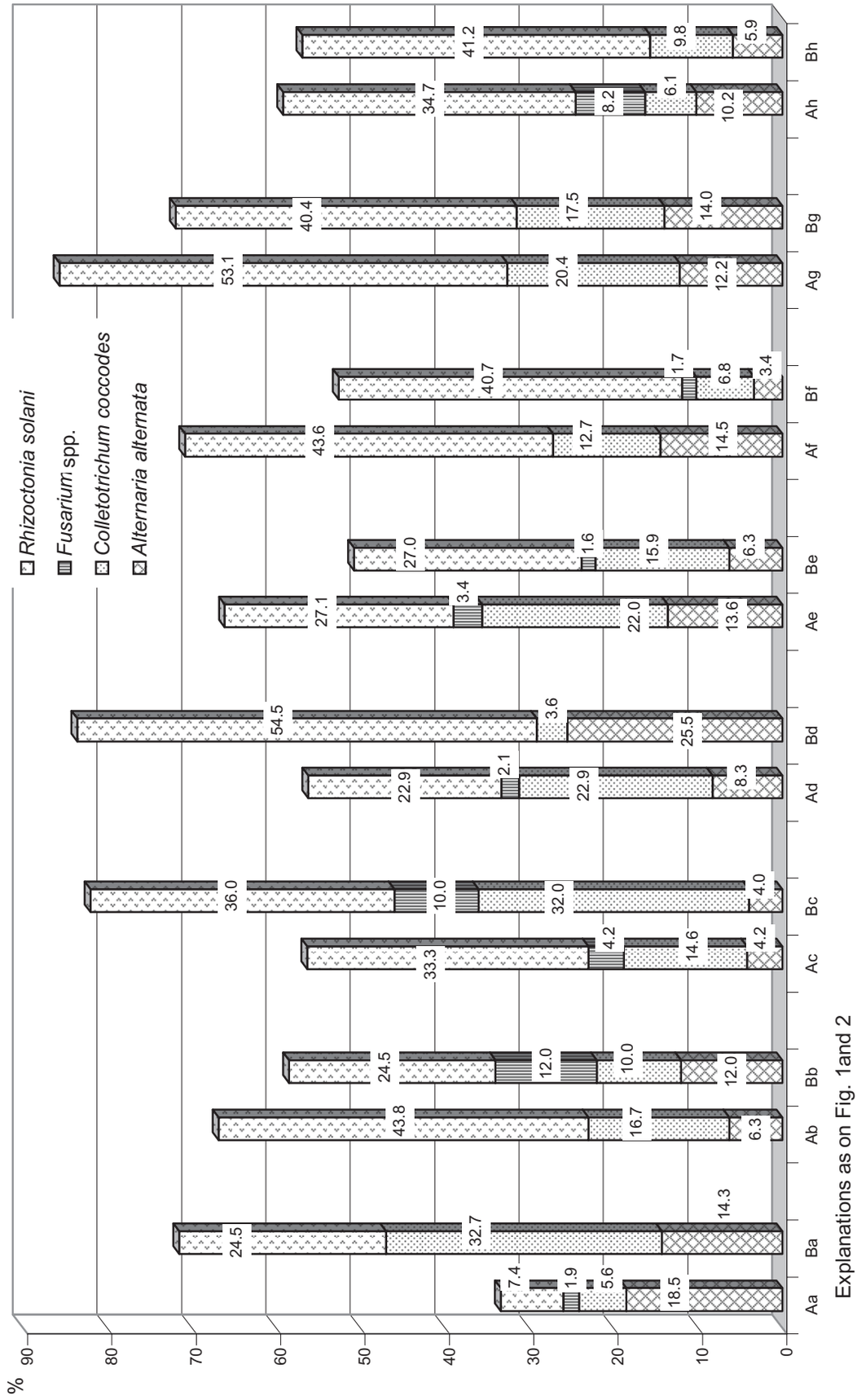

Fig. 3. Pathogens isolated from potato tubers after storage (mean for investigated period).

A different tendency was reported with respect to fungi of the genus *Fusarium*, which more frequently colonized newly-harvested and stored tubers in treatment B (with higher mineral fertilization levels) than in treatment A (with lower fertilization levels). Their greatest abundance (10% to 12%) was noted in stored tubers in treatment B with the foliar fertilizers ADOB Mn and Solubor DF (Fig. 3), and in newly-harvested tubers in the treatment involving the application of Basfoliar 12-4-6 and Solubor DF as well as in the control treatment. According to reference data (Kurzawińska, 1997; Esfahani, 2006; Loiveke, 2006; Peters et al. 2008), among members of the genus *Fusarium* such species as *F. avenaceum, F. culmorum, F. oxysporum, F. sambucinum, F. solani* are most often the causative agents of potato tuber dry-rot. They may penetrate into potato tuber tissues directly or as a result of mechanical damage during harvest (Choroszewski, 1988). Depending on pathogen virulence and cultivar susceptibility, these fungi produce various amounts of mycotoxins dangerous for humans and animals (Schultz et al. 2007).

The species *Alternaria alternata* was not abundant in stored tubers, and it was absent in some treatments, including in the control one. After five-month storage, the highest number of isolates was obtained in treatment Bd (25.5%), and the lowest – in treatments Bc and Bf (around 4%). The impact of NPK fertilization on the occurrence of this fungal species remains ambiguous. Kumar et al. (1983) demonstrated that high rates of mineral fertilizers, including nitrogen, have a negative effect on plant infection by fungi of the genus *Alternaria*. Osowski (2005) pointed to an inhibitory effect of combined Basfoliar 12-4-6 and fungicides treatment on plant infection by the above fungi. Laboratory tests performed by Blachiński et al. (1996), Feng and Zheng (2006) showed an inhibitory effect of potassium on mycelium growth and the germination of *A. solani* conidia.

CONCLUSIONS

1. Pathogens were more frequently isolated from potato tubers after storage than after harvest.
2. Mineral soil fertilization with higher NPK rates contributed to the development of pathogens.
3. The foliar application of mineral fertilizers had varied effects on the occurrence frequency and abundance of the pathogens in fungal communities colonizing potato tubers.

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Wpływ nawożenia mineralnego na grzyby zasiedlające bulwy ziemniaka (*Solanum tuberosum* L.) po zbiorze i po okresie przechowywania

Streszczenie

W pracy przedstawiono wyniki trzyletniego doświadczenia ścisłego w Bałcynach z uprawą późnej odmiany ziemniaka Jasia. Badano wpływ poziomów nawożenia mineralnego: A (N 80 kg × ha^{-1} P 80 kg × ha^{-1} K120 kg × ha^{-1}) i B (N 120 kg × ha^{-1} P 144 kg × ha^{-1} K156 kg × ha^{-1}), a także nawożenia dolistnego (Basfoliar 12-4-6, ADOB Mn i Solubor DF) na skład ilościowy i jakościowy grzybów zasiedlających bulwy ziemniaka. Izolacje grzybów prowadzono bezpośrednio po zbiorze bulw i po 5-miesięcznym okresie przechowywania. Wyrosłe po 7-dniowym okresie inkubacji kolonie grzybów przeszczepiano na skosy agarowe w celu późniejszej identyfikacji mikroskopowej.

Podczas całego okresu badań więcej grzybów chorobotwórczych otrzymano z bulw ziemniaka analizowanych po przechowywaniu niż z bulw po zbiorze,

a największy ich udział zanotowano w 2004 r. Wśród nich najczęściej izolowanym był gatunek *Rhizoctonia solani*, rzadziej *Colletotrichum coccodes* i *Alternaria alternata*. Patogeny z rodzaju *Fusarium* oraz gatunek *Helminthosporium solani* wyosobniano nielicznie. Przeważającą liczebność patogenów w kombinacji z nawożeniem mineralnym doglebowym z niższą dawką NPK zanotowano w 2004 r. w obu terminach po zbiorze i przechowywaniu oraz w 2005 r. po zbiorze. W pozostałych analizowanych terminach patogeny częściej izolowano z bulw w kombinacji z wyższą dawką NPK.

Najwięcej patogenów z bulw po zbiorze uzyskano w kombinacji z zastosowanym nawozem dolistnym ADOB Mn i Basfoliar 12-4-6 łącznie. Po przechowywaniu natomiast patogeny najczęściej kolonizowały bulwy w kombinacji B z nawożeniem dolistnym Solubor DF, Solubor DF i ADOB Mn łącznie oraz w kombinacji A z łącznym stosowaniem nawozów. Liczebność sprawców chorób bulw w pozostałych kombinacjach nawozowych, w tym kontrolnej, kształtowała się na zbliżonym poziomie.