Fragm. Agron. 35(4) 2018, 17–28
DOI: 10.26374/fa.2018.35.39

AN EFFECT OF BIOLOGICAL, CHEMICAL AND INTEGRATED POTATO PROTECTION AGAINST *PHYTOPHTHORA INFESTANS* (MONT.) DE BARY ON THE QUALITY OF TUBERS

Marek Kołodziejczyk[1]

Department of Crop Production, University of Agriculture in Krakow,
Al. Mickiewicza 21, 31-120 Krakow

Abstract. Potato protection against late blight is an essential element of agrotechnics in all production systems. In order to ensure food safety and to care for the natural environment, the aim is to reduce chemical plant protection products and promote alternative methods, including biological methods. Therefore, the study was conducted in the years 2012–2014 in order to determine an effect of chemical (Ridomil Gold MZ 68 WP and Infinito 687.5 SC, Flowbrix 380 SC), biological (Polyversum WP, Timorex Gold 24 EC, Biosept Avtive 33 SL) and integrated protection (alternately biopreparations and Flowbrix 380 SC) on the quality of potato tubers. The early cultivar Vineta and moderately early Red Fantasy were examined. The results of the study indicate a slight influence of the method of plants protecting against *P. infestans* on dry matter accumulation, including starch, in potato tubers. A decrease in the value of these features was found only in one year of the study on objects protected by *P. oligandrum* fungus spores, and in the case of dry matter also after using Ridomil Gold MZ 68 WG and Infinito 687.5 SC fungicides. The application of chemical fungicides and individually biopreparations Timorex Gold 24 EC and Biosept Avtive 33 SL had a beneficial effect on total protein accumulation, however, this effect was modified by weather conditions during the growing season as well as cultivar properties. The tuber quality deteriorated as a result of an increased accumulation of nitrates on objects protected by Ridomil Gold 72 WP and Infinito 687.5 SC as well as Biosept Avtive 33 SL, and as a result of stronger darkening of tubers raw flesh after an application of Ridomil Gold MZ 68 WG and Infinito 687.5 SC fungicides, Timorex Gold 24 EC and alternately Flowbrix 380 SC / Timorex Gold 24 EC.

Key words: late blight, fungicides, biological protection, cultivar, quality of tubers

INTRODUCTION

The prevalence of *Phytophthora infestans* and continuous changes and the formation of physiological varieties (resistant among others to metalaxyl, oomycete-specific fungicide), as well as the easy and rapid spread make protecting the potato against late blight very difficult [Andrivon 1996, Hermansen et al. 2000, Matson et al. 2015]. In conditions conducive to the development of *P. infestans*, even intensive chemical treatments do not completely protect the plants from potential crops reduction [Cwalina-Ambroziak et al. 2015]. Effective protection against the strong infective pressure of *P. infestans* is provided by integrated protection using cultivars of high resistance to late blight [Aav 2016, Chmielarz et al. 2014, Kapsa 2007, Michalska et al. 2011]. Unfortunately, both in Poland and in the world, the majority of widely cultivated varieties of potato are susceptible to late blight [Forbes 2012]. Clear deficiency of highly resistant cultivars is visible in the cultivation of edible potato, especially in the group of

[1] *Corresponding address* – Adres do korespondencji: mkolodziejczyk@ur.krakow.pl

cultivars with short vegetation, which registration is carried out primarily on the basis of the size and quality of tuber yields [Nowacki et al. 2017]. Most cultivars with an increased resistance belong to the group of late starch varieties, the usefulness of which in organic production is limited due to the long growing season and the low level of culinary values [Pilch 2007, Pilch et al. 2015]. An alternative to copper preparations, commonly used in organic production but gradually withdrawn from use due to the strong toxicity of this element, is the use of *P. infestans* antagonists [Benhamou et al. 2012, Cwalina-Amroziak 2012, El-Mougy et al. 2012, Gupta et al. 2004, Jindal et al. 1988, Shanthiyaa et al. 2013, Stephan et al. 2005]. Moreover, also plant extracts are environmentally friendly, and effective in controlling the development of *P. infestans* [Stephan et al. 2005, Wang et al. 2007, Abayhne and Chauhan 2016].

The crop protecting function of fungicides and insecticides is primarily related to preserving possibly the largest assimilation surface of plants until the end of their vegetation. The studies of Kołodziejczyk [2012] and Kołodziejczyk and Szmigiel [2012] show that the reduction of the assimilation area of potato plants leads not only to a significant reduction in yield but also to the modification of chemical composition conditioning the quality of tubers. The shortening of potato vegetation period resulting from improper agrotechnics, the harvest before full maturity of the tubers or the occurrence of pests and disease infections results in the reduction of the dry matter and starch content as well as an increased protein and nitrate concentration in tubers [Kołodziejczyk and Szmigiel 2012, Wierzbicka et al. 2008].

An effectiveness of potato protection against *P. infestans* presented in the literature on the subject most often refers to the size of the tuber yield, i.e., a feature significant from the producer's point of view. The quality of tubers is the most important for consumers, and it is determined, inter alia, by their chemical composition. Therefore, the aim of the study was to determine an effect of biopreparations and synthetic fungicides used in the protection of potato against late blight on the formation of dry matter, starch, protein, nitrates and the tendency of raw tubers flesh darkening.

MATERIAL AND METHODS

The study was carried out in the years 2012–2014 at the Experimental Station in Prusy (50°07′ N and 20°05′ E) belonging to the University of Agriculture in Krakow. A two-factor field experiment was established in a randomized block system in 4 replications on degraded Chernozem soil (*CWt*) classified as very good wheat complex and 1st bonitation class. The experimental factors were as follows: the cultivar and method of potato protecting against late blight. The evaluation included the early cultivar Vineta (resistance to late blight of potato: 2 on a scale of 1–9) and moderately early Red Fantasy (resistance to late blight 3 on a scale of 1-9). Protection variants included: 1) control plot – without protection; 2) Ridomil Gold MZ 68 WG (1 x 2 kg·ha^{-1}) and Infinito 687.5 SC (1 x 1,6 l·ha^{-1}); 3) Flowbrix 380 SC (4 x 1,6 l·ha^{-1}); 4) Polyversum WP (tubers treatment 10 g·kg^{-1} and 4 x plants spraying 0.05%); 5) Polyversum WP (tubers treatment 10 g·kg^{-1}) and Flowbrix 380 SC (4 x 1.6 l·ha^{-1}); 6) Timorex Gold 24 EC (4 x 1.5 l·ha^{-1}); 7) Biosept Active 33 SL (4 x 1.5 l·ha^{-1}); 8) alternately: Flowbrix 380 SC (2 x 1.6 l·ha^{-1}) and Timorex Gold 24 EC (2 x 1.5 l·ha^{-1}); 9) Flowbrix 380 SC (2 x 1.6 l·ha^{-1}) and Biosept Active 33 SL (2 x 1.5 l·ha^{-1}) and 10) Timorex Gold 24 EC (2 x 1.5 l·ha^{-1}) and Biosept Active 33 SL (2 x 1.5 l·ha^{-1}). The first treatment was performed after the disease symptoms were found on the aboveground part of plants, i.e., in the 2-3rd decade of June. Ridomil Gold MZ 68 WG and Infinito 687.5 SC fungicides were applied with a 2-week interval, while the other preparations at weekly intervals. Treatment of tubers with Polyversum WP was carried out immediately before planting.

The previous crop for potato was winter wheat. Following the wheat harvest, crushed straw was plowed and a catch crop (white mustard) was sown. In spring, mineral fertilizers were applied in the following doses: 150 kg N, 60 kg P_2O and 180 kg $K_2O \cdot ha^{-1}$. Potato tubers were planted at 75 x 35 cm spacing in the second week of April. The harvesting plot area was 18 m^2. Weeds were limited by a mechanical and chemical method including 2 times spreading and application of Linurex 500 SC (linuron 1000 g a.i.$\cdot$ha^{-1}) and Targa Super 05 EC herbicides (quizalofop-p-ethyl 75 g a.i.$\cdot$ha^{-1}). The Actara 25 WG (thiamethoxam 20 g a.i.$\cdot$ha^{-1}) insecticide was used against the potato beetle. The potato harvest was made in the 3rd decade of September.

Before harvest, tubers from 10 randomly selected potato plants (about 10 kg) were taken from each plot. Dry matter content (dried-weight method), starch (Reimann method, hydrostatic scales), total protein (Kiejdahl method, N x 6.25) and nitrates (V) content (potentiometric method) and the tendency of raw tubers flesh to darken were determined in the tubers after 4 hours from cutting (according to 9^o inverted Danish scale, where 9 means unchanged, and 1 - strongest darkening). The results were subjected to statistical evaluation using an analysis of variance. Highly significant differences (*HSD*) for the investigated features were verified Tukey's test at a significance level of $p < 0.05$.

The characteristics of the precipitation-thermal conditions during potato vegetation are presented in Fig. 1. The potato vegetation period in 2012 was characterized by the least amount of rainfall, and concurrently the highest air temperature in the three-year research cycle. Significant shortages of precipitation were recorded in May and August, while excessive amount in June. In 2013, the amount of rainfall was close to the long-term average, but their distribution

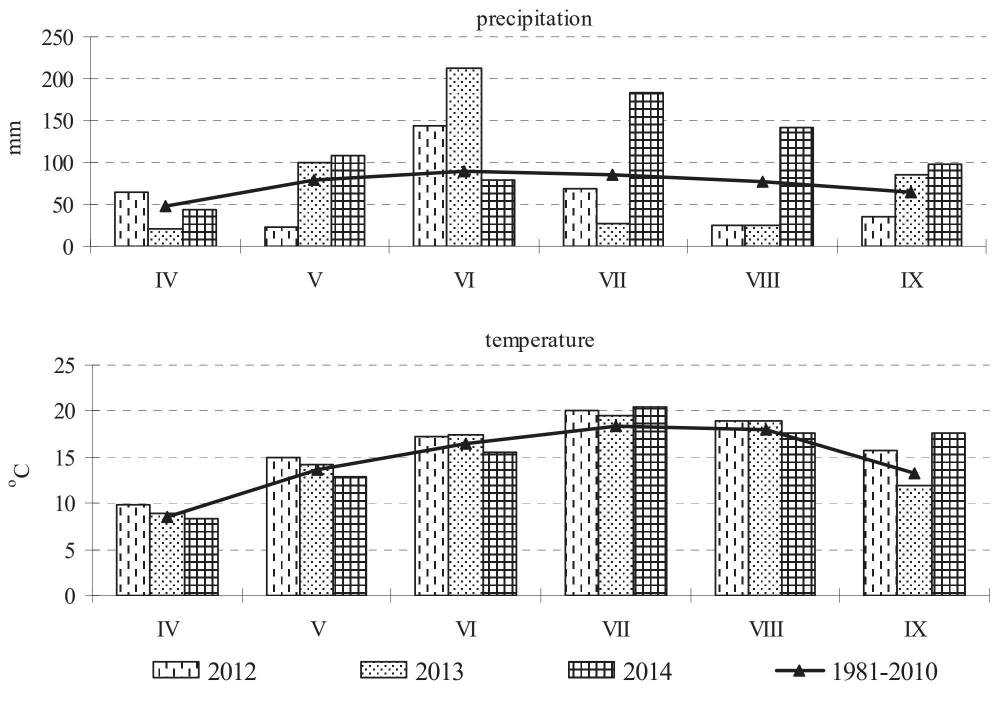


Fig. 1. Weather conditions during the growing season of potato in 2012–2014

was uneven. June was extremely humid (213 mm), while the amount of precipitation in April, July and August accounted for 42, 32 and 34% of the average of the long-term sum of rainfall, respectively. The potato vegetation in 2014 was under conditions of excessive rainfall, especially in July and August, which favored the development of *P. infestans*.

RESULTS AND DISCUSSION

Analysis of dry matter content, including starch, in potato tubers showed significant variation within the genotype, the method of protection against *P. infestans*, the weather conditions in years and the interaction of the study year and the variant of protection (Table 1).

Table 1. Significance of differences for individual sources of variation

Variance source	Content of:				Darkening of raw tuber flesh
	dry mater	starch	total protein	nitrates (V)	
Protection (A)	*	***	***	***	***
Cultivar (B)	*	***	***	***	***
Year (C)	***	***	***	***	
AxB			***	***	*
AxC	***	***	***	***	
BxC			***	***	***
AxBxC	***	***	***	***	**

Significant effects at p<0.05 (*), p<0.01 (**) and p<0.001 (***). Blank values indicate no significant (p>0.05)

Higher content of both dry matter and starch was found for moderately early potato cultivar - Red Fantasy (Table 2). Weather conditions prevailing during the potato vegetation period in 2012 were conducive to the accumulation of dry matter in tubers, while in 2013, the concentration of starch. Excessive rainfall in July and August 2014 had an unfavorable effect on the content of both dry matter and starch. A similar relationship was demonstrated by Rymuza et al. [2015] and Trawczyński [2016]. According to Sawicka et al. [2011], starch content is one of the most stable characteristics of potato and is determined by cultivar properties and weather conditions, as well as mutual interaction of these factors. The interaction of years and cultivars was not demonstrated in the study conducted, which proves that both cultivars showed the same reaction to the growing conditions in particular years. The method of potato protecting against late blight slightly differentiated the content of dry matter and starch in tubers. Significant reduction in the value of these features in relation to the control was found only in 2012 on plots protected by *P. oligandrum* spores, and in dry matter also after chemical protection with Ridomil Gold MZ 68 WG and Infinito 687.5 SC fungicides (Fig. 2A and 2B). Thus, the obtained results are not confirmed in the opinion of Apel et al. [2002] and Vos and Groenwold [1999], who believe that the potential for photosynthesis can be more fully utilized by plants in conditions of protected

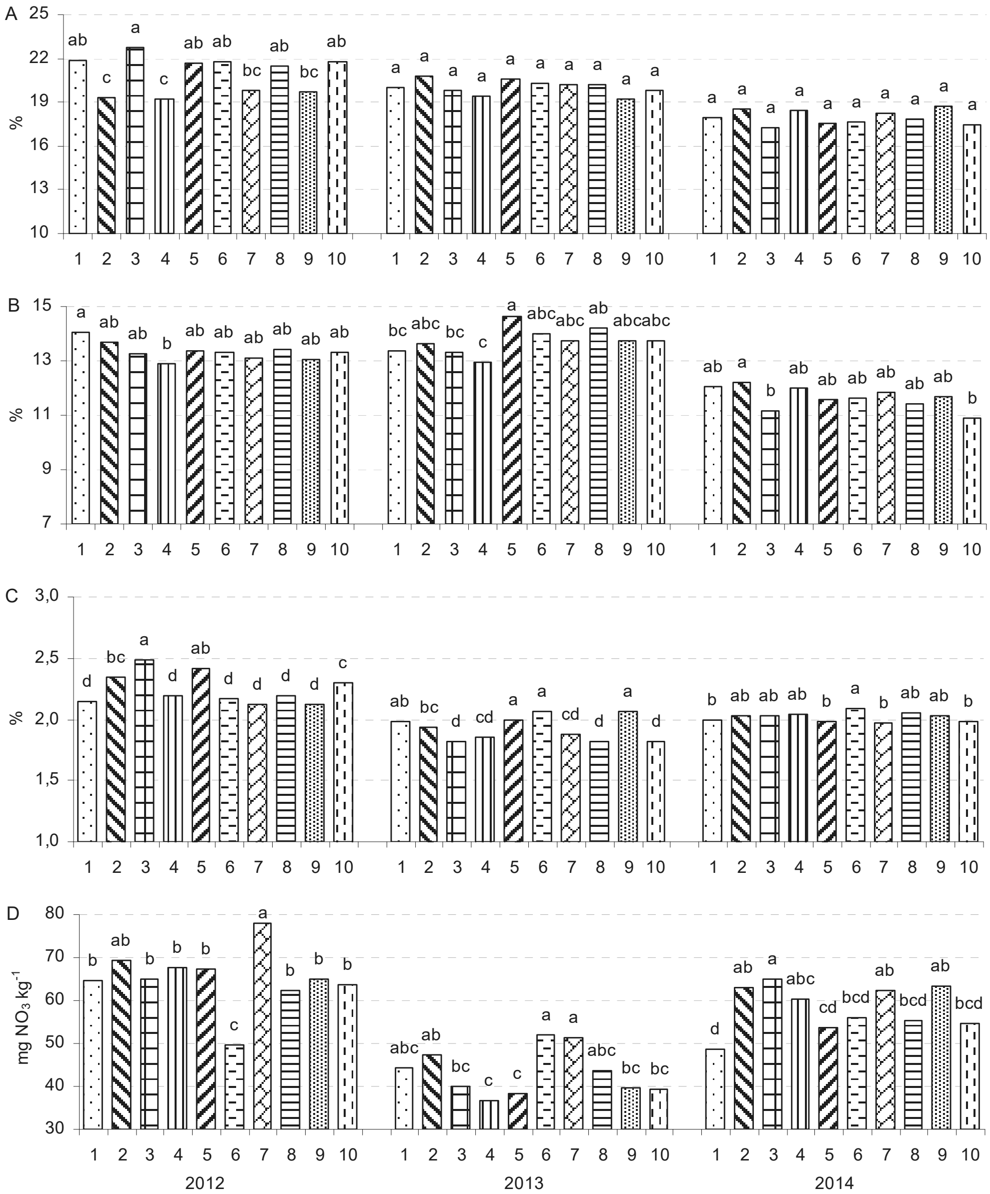
Table 2. Chemical composition of tubers and darkening of raw tuber flesh

Factor	Content of:				Darkening of raw tuber flesh
	dry matter	starch	protein	nitrates(V)	
	(%)			(mg $NO_3 \cdot kg^{-1}$)	(9^o scale)
Variant of protection					
Control	19.9 a	13.2 a	2.04 cd	54.8 b	8.6 a
Ridomil Gold MZ 68 WG and Infinito 687.5 SC	19.5 ab	13.2 a	2.10 ab	62.3 a	8.3 c
Flowbrix 380 SC	19.9 a	12.8 ab	2.11 ab	59.1 ab	8.5 ab
Polyversum WP	19.0 b	12.5 b	2.03 cd	57.0 b	8.6 a
Polyversum WP and Flowbrix 380 SC	19.2 ab	12.8 ab	2.07 bc	55.2 b	8.5 ab
Timorex Gold 24 EC	19.9 a	13.2 a	2.13 a	54.7 b	8.4 bc
Biosept Avtive 33 SL	19.9 a	13.0 ab	2.11 ab	66.5 a	8.5 ab
Flowbrix 380 SC/Timorex Gold 24 EC	19.8 ab	13.0 ab	2.02 cd	58.3 ab	8.4 bc
Flowbrix 380 SC/Biosept Active 33 SL	19.4 ab	12.9 ab	1.99 d	56.0 b	8.5 ab
Timorex Gold 24 EC/Biosept Active 33 SL	19.7 ab	12.8 ab	2.03 cd	54.7 b	8.5 ab
Cultivar					
Vineta	19.4 b	12.4 a	2.11 a	61.6 a	8.6 a
Red Fantasy	19.8 a	13.4 b	2.02 b	54.1 b	8.4 b
Year					
2012	20.9 a	13.4 a	2.25 a	67.9 a	8.4 a
2013	20.0 b	13.7 a	1.92 c	45.0 c	8.5 a
2014	18.0 c	11.7 b	2.02 b	60.6 b	8.5 a

Different letters indicate significant differences between means ($p<0.05$)

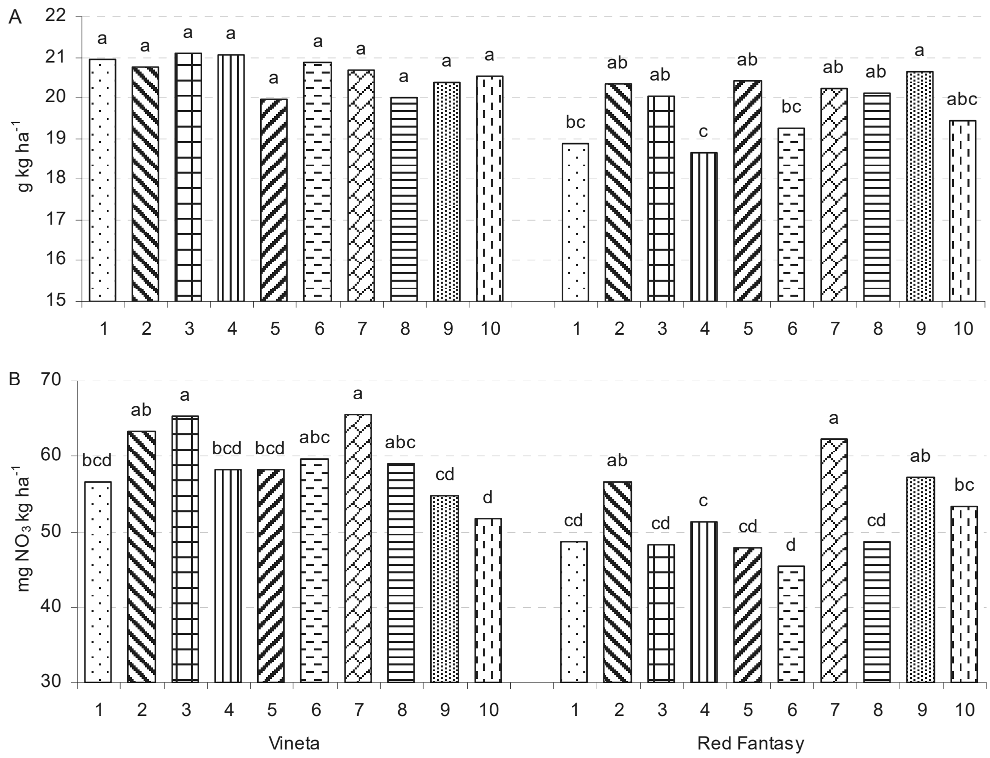
cultivation. No significant differences in the content of dry matter and starch in potato tubers cultivated in an organic and conventional systems were demonstrated by Hamouz et al. [2005] and Tein [2015].

The beneficial effect of potato protection against late blight on total protein accumulation in tubers was found on chemically protected objects and after individual application of biopreparations Timorex Gold 24 EC and Biosept Avtive 33 SL (Table 2). The study conducted showed a varied reaction of potato plants on the way of protection in particular periods of vegetation in the field of protein accumulation (Fig. 2C). In 2012, with the least amount of rainfall, an increase in protein content in tubers was found on plots protected by fungicides Ridomil Gold MZ 68 WG and Infinito 687.5 SC, Flowbrix 380 SC and Polyversum WP as well as Flowbrix 380 SC. In 2013, however, the content of this component was reduced after individual using of Flowbrix 380 SC and Polyversum WP, and alternately Flowbrix 380 SC/Timorex Gold 24 EC as well as Timorex Gold 24 EC / Biosept Active 33 SL. In turn, in 2014, characterized by the highest amount of rainfall in the three-year research cycle, the protein content higher than in the control plot was only found on the plots protected by biopreparation Timorex Gold 24 EC.



Different letters indicate significant differences between means ($p<0.05$)

Fig. 2. The content of dry matter (A), starch (B), protein (C) and nitrates (D) in the aspect of interaction year x variant of protection: 1 – control, 2 – Ridomil Gold MZ 68 WG and Infinito 687,5 SC, 3 – Flowbrix 380 SC, 4 – Polyversum WP, 5 – Polyversum WP and Flowbrix 380 SC, 6 – Timorex Gold 24 EC, 7 – Biosept Active 33 SL, 8 – Flowbrix 380 SC/Timorex Gold 24 EC, 9 – Flowbrix 380 SC/Biosept Active 33 SL, 10 – Timorex Gold 24 EC/Biosept Active 33 SL



Different letters indicate significant differences between means ($p<0.05$)

Fig. 3. The content of protein (A) and nitrates (B) in the aspect of interaction cultivar x wariant of protection: 1 – control, 2 – Ridomil Gold MZ 68 WG and Infinito 687,5 SC, 3 – Flowbrix 380 SC, 4 – Polyversum WP, 5 – Polyversum WP and Flowbrix 380 SC, 6 – Timorex Gold 24 EC, 7 – Biosept Active 33 SL, 8 – Flowbrix 380 SC/Timorex Gold 24 EC, 9 – Flowbrix 380 SC/Biosept Active 33 SL, 10 – Timorex Gold 24 EC/Biosept Active 33 SL

In the study of Sawicka and Kuś [2002], the highest concentration of protein in potato tubers cultivated in the organic system was demonstrated in a wet and warm year, while in integrated production in conditions of a significant shortage of precipitation. In general, a small amount of rainfall in 2012, and especially in the final potato vegetation period, favored the accumulation of protein in tubers. In turn, a large amount of rainfall in September 2013 was probably the reason for a significant reduction in protein content in tubers of moderately early potato cultivar Red Fantasy, in contrast to the Vineta variety, which ended vegetation earlier (Table 3). It can be concluded from the study by Kolodziejczyk [2013] that the protein content in potato tubers is a feature of high stability, however, like other qualitative characteristics, it is subject to modification by habitat factors. The author showed that the main source of variation is the interaction of cultivars and years (51% of total variability) and environmental variability (39%). In the study conducted, the higher total protein content was demonstrated for the early Vineta potato cultivar, in the case of which, however, there was no differentiated reaction to the method of protection against *P. infestans* (Fig. 3A). All variants of protection with the exception of Polyversum WP

Table 3. Chemical composition of tubers depending on the year and cultivar

Year	Dry matter		Starch		Protein		Nitrates(V)	
	(%)						(mg $NO_3 \cdot kg^{-1}$)	
	Vineta	Red Fantasy	Vineta	Red Fantasy	Vineta	Red Fantasy	Vineta	Red Fantasy
2012	20.8 a	21.0 a	12.8 a	13.9 b	2.28 a	2.22 a	69.9 b	66.9 a
2013	19.7 b	20.3 b	13.3 a	14.1 a	2.02 b	1.83 c	40.9 c	49.1 b
2014	17.8 c	18.1 c	11.1 b	12.2 c	2.02 b	2.01 b	74.1 a	47.2 b

Different letters indicate significant differences between means ($p<0.05$)

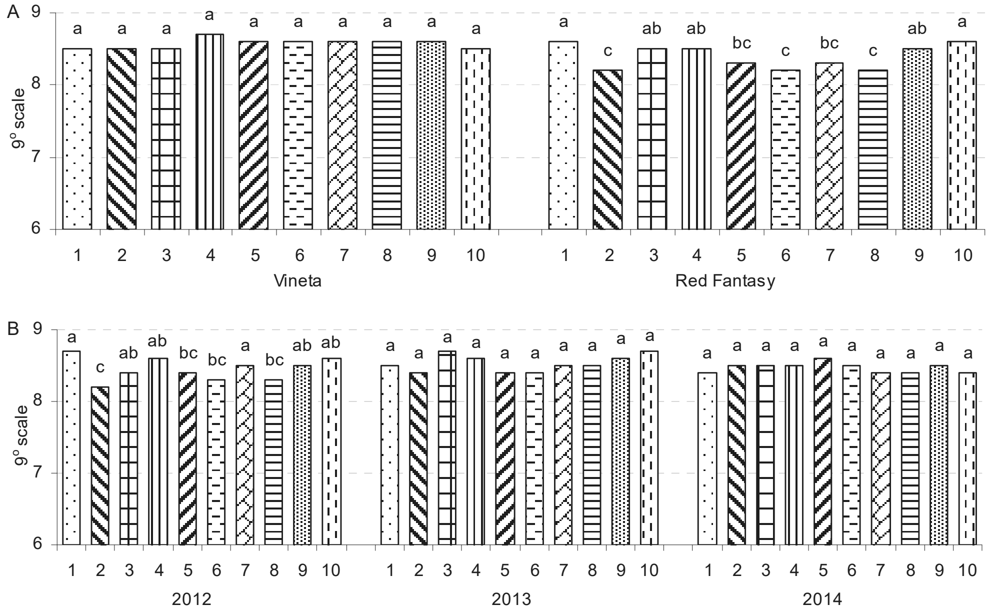
had a beneficial effect on protein accumulation in Red Fantasy cultivar tubers, but a significant increase in the content of this component compared to control was found only after alternating application of copper preparation and Biosept Avtive 33 SL.

Nitrates (V) are characterized by relatively low harmfulness to humans, but about 5%, and in individual cases even 20% of these compounds are reduced to toxic nitrites (III). The high consumption of tubers makes them a significant source (27-30%) of the daily intake of nitrates (V) [Wadas et al. 2012]. The ability to accumulate nitrates in potato tubers is determined by cultivar properties, climatic and soil conditions, and agrotechnics. In the study conducted, cultivar, form of protection, weather conditions and the interaction of these factors had a differentiating effect on this nitrogen form concentration (Table 1). An increased content of nitrates was found in potato tubers protected with fungicides Ridomil Gold 72 WP and Infinito 687.5 SC as well as Biosept Avtive 33 SL (Table 2). The study also showed a differentiated reaction of cultivars in the case of the above-mentioned preparations as well as copper fungicide (Fig. 3B).

Also Wichrowska and Wojdyła [2011] indicate the relationship between the use of plant protection products (herbicides) and the content of nitrates(V) in potato tubers. Increased concentration of nitrates was recorded in 2012 after the use of grapefruit extract and in most plants protected against *P. infestans* in 2014 (Fig. 2D). Irrespective of the protection variant, the highest content of nitrates was noted in the tubers collected in 2012, in which there were shortages of precipitation, especially in August and September (Table 2).

The content of these components was higher in the potato tubers of the Vineta cultivar, which is confirmed in the long-term study of Grudzińska and Zgórska [2008]. The authors showed that the highest amount of nitrates is accumulated by very early and early potatoes (over 200 mg $NO_3 \cdot kg^{-1}$), while the moderately early ones contain even half less that amount.

One of the important features of culinary quality of potato tubers is flesh tendency to enzymatic darkening. Zgórska [2013] states that potatoes intended for direct consumption should have low darkening of the raw flesh (above 6.5 in 9^o scale). In the analyzed experiment, potato tubers were characterized by very low darkening of the raw flesh (8.3-8.6). The protection of the potato against late blight carried out on the basis of Ridomil Gold MZ 68 WG and Infinito 687.5 SC fungicides, Timorex Gold 24 EC and alternately Flowbrix 380 SC / Timorex Gold 24 EC had an adverse effect on this feature value. The tubers of Red Fantasy potato were characterized by stronger darkening flesh. Moreover, a differentiated reaction of cultivars to the applied protection was found. In the case of early potato, there were no significant differences between the individual protection variants, whereas in the moderately early variety, the tuber showed a significantly darker color in 5 plots compared to the control plot (Fig. 4A). An effect of protec-



Different letters indicate significant differences between means (p<0.05)

Fig. 4. The darkening of raw tuber flesh in the aspect of interaction cultivar x variant of protection (A) and year x variant of protection (B): 1 – control, 2 – Ridomil Gold MZ 68 WG and Infinito 687,5 SC, 3 – Flowbrix 380 SC, 4 – Polyversum WP, 5 – Polyversum WP and Flowbrix 380 SC, 6 – Timorex Gold 24 EC, 7 – Biosept Active 33 SL, 8 – Flowbrix 380 SC/Timorex Gold 24 EC, 9 – Flowbrix 380 SC/Biosept Active 33 SL, 10 – Timorex Gold 24 EC/Biosept Active 33 SL

tion on the tendency of raw tubers flesh to darken was noted only in the first year of the study, i.e., in the conditions of low precipitation and concurrently higher than the average air temperature in July, August and September (Fig. 4B).

CONCLUSIONS

The results of the study obtained in three seasons differing in weather conditions, indicate a small effect of the method of plants protecting against late blight on the accumulation of dry matter, including starch, in potato tubers. It was found that these values were reduced on plots protected with *P. oligandrum* spores, and in the case of dry matter also after an application of Ridomil Gold MZ 68 WG and Infinito 687.5 SC fungicides only in 2012 characterized by the lowest amount of precipitation in the examined cycle, i.e., theoretically no conducive to the development of *P. infestans*. The significant impact of potato protection on total protein accumulation in tubers was found after the use of chemical fungicides and individually biopreparations Timorex Gold 24 EC and Biosept Avtive 33 SL, the effect of which was modified by weather conditions and cultivar properties. The study conducted demonstrated an increased accumulation of nitrates in potato tubers protected with fungicides Ridomil Gold 72 WP and Infinito 687.5 SC as well as Biosept Avtive 33 SL. The quality of tubers deteriorated also due to stronger enzymatic darkening after an application of Ridomil Gold MZ 68 WG and Infinito 687.5 SC, Timorex Gold 24 EC and alternately Flowbrix 380 SC/Timorex Gold 24 EC.

REFERENCES

Aav A. 2016. Phenotypic characterisation of potato late blight pathogen *Phytophthora infestans* in Baltic Countries. A Thesis submitted for the degree of Doctor of Philosophy in Agriculture. Est. Univ. Life Sci., Tartu, pp. 126.

Abayhne M.A., Chauhan N.M. 2016. Antifungal activity of various medicinal plants against late blight of potato from Ethiopia. J. Scient. Res. Rep. 12(5): 1–9.

Andrivon D. 1996. The origin of *Phytophthora infestans* populations present in Europe in the 1840: a critical review of historical and scientific evidence. Plant Pathol. 45: 1027–1035.

Apel H., Paudyal M.S., Richter O. 2002. Population dynamics and treatment strategies of *Phytophthora infestans* (late blight) in the Mid-Hills of Nepal. Landschaftsökol. Umweltforsch. 38: 1–12.

Benhamou N., Le Floch G., Vallance J., Gerbore J., Grizard D., Rey P. 2012. *Pythium oligandrum*: an example of opportunistic success. Microbiology 158 (11): 2679–2694.

Chmielarz M., Sobkowiak S., Dębski K., Cooke D.E.L., Brurberg M.B., Śliwka J. 2014. Diversity of *Phytophthora infestans* from Poland. Plant Pathol. 63: 203–211.

Cwalina-Ambroziak B. 2012. Skuteczność biologicznej i chemicznej ochrony roślin ziemniaka przed zarazą (*Phytophthora infestans* /Mont./ de Bary) i alternariozą (*Alternaria* spp.). Pol. J. Agron. 11: 3–9.

Cwalina-Ambroziak B., Damszel M.M., Głosek-Sobieraj M. 2015. The effect of biological and chemical control agents on the health status of the very early potato cultivar Rosara. J. Plant Prot. Res. 50: 389–395.

El-Mougy N.S., Abdel-Kader M.M., Aly D.E.H. 2012. Application of plant resistance inducers for controlling early and late blights of tomato under plastic houses conditions. J. App. Sci. Res. 8(7): 3406–3414.

Forbes G.A. 2012. Using host resistance to manage potato late blight with particular reference to developing countries. Potato Res. 55: 205–216.

Grudzinska M., Zgórska K. 2008. Wpływ warunków meteorologicznych na zawartość azotanów (V) w bulwach ziemniaka. Żywność. Nauka. Technologia. Jakość 5(6): 98–106.

Gupta H., Singh B.P., Mohan J. 2004. Bio-control of late blight of potato. Potato J. 31(1–2): 39–42.

Hamouz K., Lachman J., Dvořák P., Pivec V. 2005. The effect of ecological growing on the potatoes yield and quality. Plant Soil Environ. 51: 397–402.

Hermansen A., Hannukkala A., Naerstad R.H., Brurberg M.B. 2000. Variation in populations of *Phytophthora infestans* in Finland and Norway: mating type, metalaxyl resistance and virulence phenotype. Plant Pathol. 49(1): 11–22.

Jindal K.K., Sindh H., Meeta M. 1988. Biological control of *Phytophtora infestans* on potato. Indian J. Plant Pathol. 6: 59–62.

Kapsa J. 2007. Effect of climatic conditions on infection pressure of *Phytophthora infestans* and harmfulness of the pathogen to potato crops. J. Plant Prot. Res. 47: 357–366.

Kołodziejczyk M. 2012. Wpływ stopnia oraz terminu symulowanej redukcji powierzchni asymilacyjnej roślin na plonowanie ziemniaka jadalnego. Fragm. Agron. 29(3): 81–87.

Kołodziejczyk M. 2013. Fenotypowa zmienność plonowania, składu chemicznego oraz wybranych cech jakości bulw średnio późnych i późnych odmian ziemniaka jadalnego. Acta Agrophys. 20(3): 411–422.

Kołodziejczyk M., Szmigiel A. 2012. Skład chemiczny oraz wybrane parametry jakości bulw ziemniaka w zależności od terminu i stopnia redukcji powierzchni asymilacyjnej roślin. Fragm. Agron. 29(3): 88–94.

Matson M.EH., Small I.M., Fry W.E., Judelson H.S. 2015. Metalaxyl resistance in *Phytophthora infestans*: Assessing role of RPA190 gene and diversity within clonal lineages. Phytopathology 105(12): 1594–1600.

Michalska A.M., Zimnoch-Guzowska E., Sobkowiak S., Plich J. 2011. Resistance of potato to stem infection by *Phytophthora infestans* and a comparison to detached leaflet and field resistance assessments. Am. J. Pot. Res. 88: 367–373.

Nowacki W., Boguszewska D., Czerko Z., Goliszewski W., Grudzińska M., Jankowska J., Lutomierska B., Pietraszko M., Trawczyński C., Wierzbicka A., Zarzyńska K., Michalak K. 2017. Charakterystyka Krajowego Rejestru Odmian IHAR-PIB Jadwisin, Ed. XX, pp. 42.

Pilch J., Tatarowska B., Flis B. 2015. Ocena wybranych polskich odmian i klonów hodowlanych ziemniaka pod względem poziomu odporności na *Phytophthora infestans* oraz przydatności do upraw ekologicznych. Prog. Plant Prot. 55(4): 452–457.

Plich J. 2007. Odporność roślin ziemniaka na *Phytophthora infestans* i jej związek z wczesnością odmian – przegląd literatury. Biul. IHAR 246: 61–71.

Rymuza K., Radzka E., Lenartowicz T. 2015. The effect of environmental conditions on starch content in the tubers of medium-early potato cultivars. Acta Agrophys. 22(3): 279–289.

Sawicka B., Kuś J. 2002. Variability chemical composition of potato tubers using ecological and integrated production system. Zesz. Probl. Post. Nauk Rol. 489: 273–282.

Sawicka B., Michałek W., Pszczółkowski P. 2011. Determinants of yield potential of medium-late and late potato cultivars in central-eastern Poland. Biul. IHAR 259: 219–228.

Shanthiyaa V., Saravanakumar D., Rajendran L., Karthikeyan G., Prabakar K., Raguchander T. 2013. Use of *Chaetomium globosum* for biocontrol of potato late blight disease. Crop Prot. 52: 33–38.

Stephan D., Schmitt A., Martins Carvalho S., Seddon B., Koch E. 2005. Evaluation of biocontrol preparations and plant extracts for the control of *Phytophthora infestans* on potato. Europ. J. Plant Pathol. 112: 235–246.

Tein B. 2015. The effect of different farming systems on potato tuber yield and quality. PhD, Est. Univ. Life Sci., pp. 180.

Trawczyński C. 2016. Wpływ odmiany i warunków pogodowych okresu wegetacji na zawartość wybranych składników odżywczych i antyżywieniowych w bulwach ziemniaka. Acta Agrophys. 23(1): 119–128.

Vos J., Groenwold J. 1999. Water relations of potato leaves. I. Diurnal changes, gradients in the canopy, and effects of leaf-insertion number, cultivar and drought. Ann. Bot. 62: 363–371.

Wadas W., Łęczycka T., Borysiak-Marciniak I. 2012. Effect of fertilization with multinutrient complex fertilizers on tuber quality of very early potato cultivars. Acta Sci. Pol., Hortorum Cultus 1(3): 27–41.

Wang S., Hu T., Zhang F., Forrer H.R., Cao K. 2007. Screening for plant extracts to control potato late blight. Front. Agric. China 1: 43–46.

Wichrowska D., Wojdyła T. 2011. Wpływ herbicydów na zmiany zawartości azotanów (V) w bulwach ziemniaka po zbiorach i przechowywaniu. Zesz. Nauk. UE Poznań 206: 27–36.

Wierzbicka A., Mazurczyk W., Wroniak J. 2008. Wpływ nawożenia azotem i terminu zbioru na plon i wybrane cechy jakości bulw wczesnych odmian ziemniaka. Zesz. Probl. Post. Nauk Rol. 530: 207–216.

Zgórska K. 2013. Wykorzystanie ziemniaka do celów spożywczych i przemysłowych. Inż. Przetw. Spoż. 3(7): 5–9.

M. Kołodziejczyk

WPŁYW BIOLOGICZNEJ, CHEMICZNEJ I INTEGROWANEJ OCHRONY ZIEMNIAKA PRZED *PHYTOPHTORA INFESTANS* (MONT.) DE BARY NA JAKOŚĆ BULW

Synopsis. Ochrona ziemniaka przed zarazą jest niezbędnym elementem agrotechniki we wszystkich systemach produkcji. W celu zapewnienia bezpieczeństwa żywności oraz w trosce o środowisko przyrodnicze dąży się do ograniczenia chemicznych środków ochrony roślin a promuje metody alternatywne, w tym metodę biologiczną. Dlatego w latach 2012-2014 przeprowadzono badania, których celem określenie wpływu ochrony chemicznej (Ridomil Gold MZ 68 WP i Infinito 687.5 SC, Flowbrix 380 SC), biologicznej (Polyversum WP, Timorex Gold 24 EC, Biosept Avtive 33 SL) oraz integrowanej (przemiennie biopreparaty i Flowbrix 380 SC) na kształtowanie się jakości bulw ziemniaka jadalnego. Ocenie poddano wczesną odmianę Vineta oraz średnio wczesną Red Fantasy. Wyniki badań, wskazują na niewielki wpływ sposobu ochrony roślin przed *P. infestans* na gromadzenie suchej masy, w tym skrobi w bulwach ziemniaka. Stwierdzono zmniejszenie wartości tych cech tylko w jednym roku badań na obiektach chronionych zarodnikami grzyba *P. oligandrum*, a w przypadku suchej masy również po zastosowaniu fungicydów Ridomil Gold MZ 68 WG i Infinito 687,5 SC. Aplikacja fungicydów chemicznych oraz indywidualnie biopreparatów Timorex Gold 24 EC i Biosept Avtive 33 SL miała korzystny wpływ na gromadzenie białka ogółem, jednak wpływ ten modyfikowany był warunkami pogodowymi w okresie wegetacji a także właściwościami odmianowymi. Stwierdzono pogorszenie się jakość bulw w efekcie zwiększonej kumulacji azotanów na obiektach chronionych preparatami Ridomil Gold 72 WP i Infinito 687.5 SC oraz Biosept Avtive 33 SL, a także w wyniku silniejszego ciemnienia miąższu surowego bulw po zastosowaniu fungicydów Ridomil Gold MZ 68 WG i Infinito 687.5 SC, Timorex Gold 24 EC oraz przemiennie Flowbrix 380 SC/Timorex Gold 24 EC.

Słowa kluczowe: zaraza ziemniaka, fungicydy, ochrona biologiczna, odmiana, jakość bulw

Accepted for print – Zaakceptowano do druku: 6.11.2018

For citation – Do cytowania:
Kołodziejczyk M. 2018. An effect of biological, chemical and integrated potato protection against *Phytophthora infestans* (Mont.) de Bary on the quality of tubers**.** Fragm. Agron. 35(4): 17–28.