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EFFECT OF NITROGEN FERTILISATION AND MICROBIAL PREPARATIONS ON QUALITY AND STORAGE LOSSES IN EDIBLE POTATO

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Abstract. The effect of nitrogen fertilisation and microbial preparations on the content of dry matter, starch, total protein and nitrates (V), raw potato tuber flesh tendency to darkening and the size of edible potato tuber storage losses was assessed in field experiments. The experimental factors were nitrogen fertilisation levels: 0, 60, 120 and 180 kg N ha^{-1} and preparations: BactoFil B 10, Effective Microorganisms EM and UGmax soil fertiliser. The level of nitrogen fertilisation and application of microbial preparations had a significant effect on shaping the chemical composition and storage durability of potato tubers, however no influence of these factors was noted for the intensity of raw tuber flesh darkening. Increase in nitrogen fertilisation level was accompanied by a decrease in the content of dry matter and starch, whereas total protein and nitrate contents were increasing. Moreover, nitrogen fertilisation caused a significant increase in natural depletion in tubers during a 6-month storage period. The influence of microbial preparations on the tuber chemical composition was different than nitrogen fertilisation effect. Application of BactoFil B 10 preparation favoured accumulation of dry matter and starch in tubers, application of Effective Microorganisms EM preparation contributed to an increase in starch and nitrate content, whereas after using UGmax soil fertiliser a significantly lower total protein content was registered than in the case of the control.

Keywords: potato, quality of tubers, microbial preparations, nitrogen fertilisation, storage losses

INTRODUCTION

Potato is the basic food for people in many countries of the world. It has better nutritive value and protein content than cereal grain. Potato tubers meant for consumption and processing for food purposes should have certain morphological and internal features which determine their quality. The most important inner characteristics determining edible potato tuber quality comprise: the content of dry matter, starch, protein, nitrates (V), reducing sugars and total sugars and vitamins, as well as raw and cooked tuber flesh tendency to darkening (Jarych-Szyszka 2006, Lisińska 2006, Sawicka *et al*. 2006, Pal *et al*. 2008, Murnice *et al*. 2011). Despite many-year assessments conducted at the stage of breeding, the values of some features can be verified only under production conditions (Bombik *et al*. 2003, Zimnoch-Guzowska and Flis 2006). The content of dry matter and starch in potato tubers is a cultivar feature and more or less modified by the effect of environmental factors (Bombik *et al*. 2003, Sawicka *et al*. 2011, Kołodziejczyk 2013). Nitrogen fertilisation plays a crucial role in shaping the content of dry matter and starch in potato tubers. A negative effect of high nitrogen doses on accumulation of dry matter and starch in tubers was observed by, among others, Porter *et al*. (1999), Blecharczyk and Małecka (2000), Sądej *et al*. (2004), Blecharczyk *et al*. (2008), Jabłoński (2008) and Eremeev *et al*. (2009). A stable level of dry matter and starch in tubers of various early potato varieties, under conditions of both low and high nitrogen fertilisation, was demonstrated by Bártowa *et al*. (2009). On the other hand, Wszelaczyńska *et al*. (2007) noted that the content of dry matter and starch in tubers increases only to a certain determined level of fertilisation with this component. Nitrogen is a microelement which plays an important role also in the accumulation protein and non-protein nitrogen compounds in potato tubers. Increasing nitrogen doses cause an almost linear increase in the content of total protein, total exogenous amino acids and nitrates (V) (Wyszkowski 1996, Leszczyński 2002, Bélanger 2003, Stankiewicz *et al*. 2008). An undesired feature of raw and cooked tubers is their flesh darkening, although it does not affect either the taste or the nutritional value of potatoes. Genetic and environmental factors have a marked influence on these features (Leja 1989, Eldrege *et al*. 1996, Leszczyński 2002, Sawicka *et al*. 2006).

Potato tubers are stored for a period of several months. Their suitability for long-term storage is determined genetically. However, the level of natural and waste losses during storage depends both on storage conditions and on agrotechnical measures. Wojdyła *et al*. (2009) registered a significant effect of nitrogen fertilisation on the level of storage losses, whereas Zgórska and Grudzińska (2012) revealed a dependency of potato tuber quality on temperature during storage.

The investigations presented here aimed at an assessment of the effect of nitrogen fertilisation and microbial preparations on the content of dry matter, starch, protein and nitrates (V), the tendency for raw tuber flesh darkening, and the level of loss during 6-month storage of potato tubers.

MATERIAL AND METHODS

Field experiments were conducted in 2006-2008 at an Experimental Station of the University of Agriculture in Krakow (50°07′N, 20°05′E, 271 m a.s.l.) on Luvic Chernozem with particle size distribution of ordinary silt. The soil arable layer revealed slightly acidic pH, was medium abundant in potassium and highly abundant in phosphorus and magnesium. The factors of the experiment were nitrogen fertilisation levels: 0, 60, 120 and 180 kg ha^{-1} and microbial preparations improving soil properties: BactoFil B 10 (3 l ha^{-1}), Effective Microorganisms EM (3 l ha^{-1}) and UGmax Soil fertilizer (0.9 l ha^{-1}), applied to the soil after the previous crop harvest and prior to spring soil cultivation. Further in the paper the fertiliser treatments will be described as N_0, N_{60}, N_{120} and N_{180}, whereas the microbial preparations as B, EM and UGmax, respectively. Characteristics of the microbial preparations and the methodology were presented in detail in an earlier paper by Kołodziejczyk (2014).

The content of dry matter in potato tubers was determined by means of the oven-dry method (at 105°C), that of starch on Reimann's balance, total protein by the Kjeldahl method, N x 6.25, and nitrate content by a potentiometric method. Assessment of raw tubers tendency to darkening after 10 minutes, 1 and 4 hours from cutting was conducted on 9° scale, where 9 means no darkening and 1 the strongest darkening. 10 kg tuber samples were stored for 6 months at 4-6°C and relative humidity 90%. After the storage period the level of natural losses and caused by evaporation, respiration and shoot development was determined.

The research results obtained were subjected to statistical assessment by means of ANOVA. Honestly significant differences (HSD) for the studied traits were verified using the Tukey's test at significance level $\alpha = 0.05$.

The potato vegetation period in 2006, classified as quite dry, was characterised by the lowest amount of precipitation for the three-year period of investigations (297 mm). A considerable rainfall deficit occurred in July. In 2007 the precipitation total from April to September was 541 mm, and it was higher that the multiannual average by 24%. Excessive precipitation amounts were registered in August and September. The vegetation period in 2008 was characterised by an irregular precipitation pattern. Rainfall deficits occurred from April to June and in August, whereas excesses in July and September. The precipitation total from April to September was 387 mm.

RESULTS AND DISCUSSION

Nitrogen fertilisation significantly diversified the content of dry matter and starch in potato tubers (Tab. 1). The highest concentrations of these components were noted in tubers from the non-fertilised treatments – N_0. Application of 60 kg N ha^{-1} caused a marked decrease in dry matter content in tubers. A decline in starch content happened after the application of 120 kg N ha^{-1}. The lowest concentrations of dry matter and starch were noted in potato tubers fertilised with 180 kg N ha^{-1}. Pińska *et al.* (2009) obtained different results. Those authors reported an increase in dry matter and starch concentrations in potato tubers as a result of increasing nitrogen level to 80 kg N ha^{-1} and a slight decline in these components content at 120 kg N ha^{-1}. The results obtained in this study are consistent with those reported by Ereemev *et al.* (2007) who demonstrated an unfavourable effect of nitrogen fertilisation on starch accumulation in potato tubers. In the research of the above mentioned authors the difference in starch content in tubers between the non-fertilised object and the fertiliser treatment with 150 kg N ha^{-1} was 3.1%. The contents of dry matter and starch in tubers were also markedly affected by microbial preparations. Application of B preparation contributed to an increase in dry matter and starch content, whereas after the application of EM preparation starch content in tubers was significantly higher than in the control. There are a few reports in the literature of the subject on the influence of microbial preparations on the chemical composition of potato tubers. In the research by Trawczyński and Bogdanowicz (2007) the application of UG preparation caused an increased concentration of dry matter, however it had no significant effect on starch concentration in potato tubers. On the other hand, Maciejewski *et al.* (2007) demonstrated that Asahi SL and Atonik SL biostimulants had no effect on dry matter content in tubers or on the properties of potato starch. The study presented here revealed an interactive effect of the experimental factors on starch accumulation in tubers. B preparation used for potato cultivation alleviated the unfavourable effect of nitrogen fertilisation on starch concentration in tubers (Fig. 1). The effect was particularly pronounced in N_{60} and N_{120} fertiliser treatments. The content of dry matter and starch in tubers depended also on the weather conditions during potato plant vegetation. The highest content of these components was registered in tubers harvested respectively in the years 2006 and 2008, characterised by deficient rainfall in the July-August period. Excessive amounts of rainfall in August and September, 2007, unfavourably influenced the accumulation of both dry matter and starch in tubers. Research conducted by Bártowa *et al.* (2009) also revealed an unfavourable effect of excessive rainfall in July and August on dry matter accumulation in potato tubers.

Table 1. Mean squares and statistical significance for years, microbial preparations and N rate

Factor	df	Dry matter	Starch	Total protein	Nitrates (V)	Darkening of raw tuber flesh after:			Storage losses
						10 min.	1 h	4 h	
Years [Y]	2	4216.7 *	145.7 *	21.1 *	6487.0 *	0.05	1.02 *	1.28	82.69 *
Error	6	44.3	11.0	0.4	31.5	0.02	0.17	0.33	0.44
Microbial preparations [P]	3	325.9 *	159.0 *	3.2 *	129.6 *	0.04	0.04	0.16	2.25 *
Y x P	6	459.5 *	131.1 *	2.6 *	242.1 *	0.06 *	0.08	0.18	1.58 *
Error	27	45.0	14.0	0.4	19.0	0.02	0.06	0.23	0.24
N rates [N]	3	1596.1 *	303.1 *	97.4 *	6860.9 *	0.00	0.00	0.63	4.00 *
Y x N	6	28.9	30.1	10.0 *	523.0 *	0.01	0.10	0.67	0.60 *
P x N	9	46.6	16.8	4.0 *	128.9 *	0.01	0.04	0.58	0.10
Y x P x N	18	51.0	11.1	1.3 *	244.1 *	0.01	0.11 *	0.62	0.19
Error	108	49.7	14.3	0.5	34.5	0.01	0.05	0.50	0.16

*significance level $\alpha = 0.05$

Nitrogen fertilisation positively affected total protein accumulation in potato tubers. A significant increase in this component quantity started from the fertilisation dose of 120 kg N ha^{-1} (Tab. 2). Systematic growth of protein content with growing nitrogen dose was observed also by Stankiewicz *et al*. (2008) and Bártowa *et al*. (2009), whereas Zahibi-e-Mahmoodabad *et al*. (2011) obtained different results. Those authors demonstrated that nitrogen fertilisation with 200 kg N ha^{-1} had no significant effect on protein accumulation in potato tubers. In the presented experiment nitrate concentration in tubers was increasing with growing nitrogen dose. A marked increase in this nitrogen form was registered up to the fertilisation level 180 kg N ha^{-1}, however even in these fertiliser treatments nitrate content was several times lower than the permissible standard (200 mg NO_3 kg^{-1} of fresh tuber mass). The microbial preparations tested in the experiment had lesser influence than fertilisation on protein accumulation and nitrate concentration in tubers. Decreased total protein concentration in tubers was noted following the application of UGmax preparation, whereas higher nitrate accumulation after the application of EM preparation (Tab. 2). The research also demonstrated an interactive effect of the experimental factors on protein and nitrate concentrations in potato tubers (Fig. 2). Application of the microbial preparations in the treatments which did not receive nitrogen contributed to a significant decrease in total protein content but an increase in nitrate concentration in tubers, following the application of B and EM preparations. No such relationship was observed in the nitrogen treatments. It may evidence a periodical immobilisation and release of mineral nitrogen by microorganisms in soil. Trawczyński and Bogdanowicz (2007) obtained different results, since they revealed no marked effect of UG preparation on total protein and nitrate content in potato tubers. The weather conditions during potato vegetation had a significant effect on nitrogen uptake and concentration in plants. The highest concentrations of total protein but the lowest content of nitrates (V) were noted in tubers harvested in 2006, characterised by the lowest precipitation total over the three year period of research. On the other hand, potato plants which had the highest concentrations of nitrates (V) but the lowest amount of protein in tubers were harvested in 2008, characterised by precipitation amount close to multiannual average but unevenly distributed.

Table 2. Content of dry matter, starch, total protein and nitrates (V) in fresh mass of tubers, and tendency of raw flesh to darkening

Factor	Dry matter	Starch	Total protein	Nitrates	Darkening of raw tubers after:		
					10 min.	1 h	4 h
	g kg^{-1}			mg NO_3 kg^{-1}	scale 9°		
Microbial preparation							
control	211.4^{b}	141.7^{c}	21.4^{a}	52.5^{b}	8.9^{a}	8.4^{a}	8.2^{a}
B	216.9^{a}	146.1^{a}	21.3^{a}	53.2^{b}	8.8^{a}	8.5^{a}	8.1^{a}
EM	212.6^{b}	144.2^{ab}	21.2^{ab}	56.3^{a}	8.8^{a}	8.4^{a}	8.1^{a}
UGmax	211.4^{b}	143.6^{bc}	20.8^{b}	54.4^{ab}	8.8^{a}	8.4^{a}	8.1^{a}
N rate (kg ha^{-1})							
N_0	219.9^{a}	146.3^{a}	19.1^{c}	39.0^{d}	8.8^{a}	8.4^{a}	8.0^{a}
N_{60}	214.5^{b}	145.4^{a}	21.4^{b}	50.7^{c}	8.8^{a}	8.4^{a}	8.1^{a}
N_{120}	212.1^{b}	143.3^{b}	22.0^{a}	60.1^{b}	8.8^{a}	8.4^{a}	8.1^{a}
N_{180}	205.9^{c}	140.7^{c}	22.3^{a}	66.5^{a}	8.8^{a}	8.4^{a}	8.2^{a}
Year							
2006	222.5^{a}	143.6^{b}	21.8^{a}	48.3^{b}	8.9^{a}	8.5^{a}	8.2^{a}
2007	208.4^{b}	142.6^{b}	21.1^{b}	48.2^{b}	8.8^{a}	8.3^{b}	8.0^{a}
2008	208.4^{b}	145.6^{a}	20.7^{c}	65.7^{a}	8.8^{a}	8.5^{a}	8.2^{a}

Values in the columns followed by the same letters do not differ at 5% level of significance

According to Leszczyński (2002), high level of nitrogen fertilisation is one of the main causes of raw and cooked tuber flesh darkening. In the opinion of Sawicka (2000), a safe nitrogen dose in potato cultivation, considering tuber quality, is 100 kg N ha^{-1}. Also pesticides may be responsible for the intensity of raw and cooked tuber flesh darkening (Sawicka *et al*. 2006). The authors' own investigations did not reveal any significant effect of either nitrogen fertilisation level or the application of the microbial preparations on raw potato flesh darkening (Tabs 1 and 2).

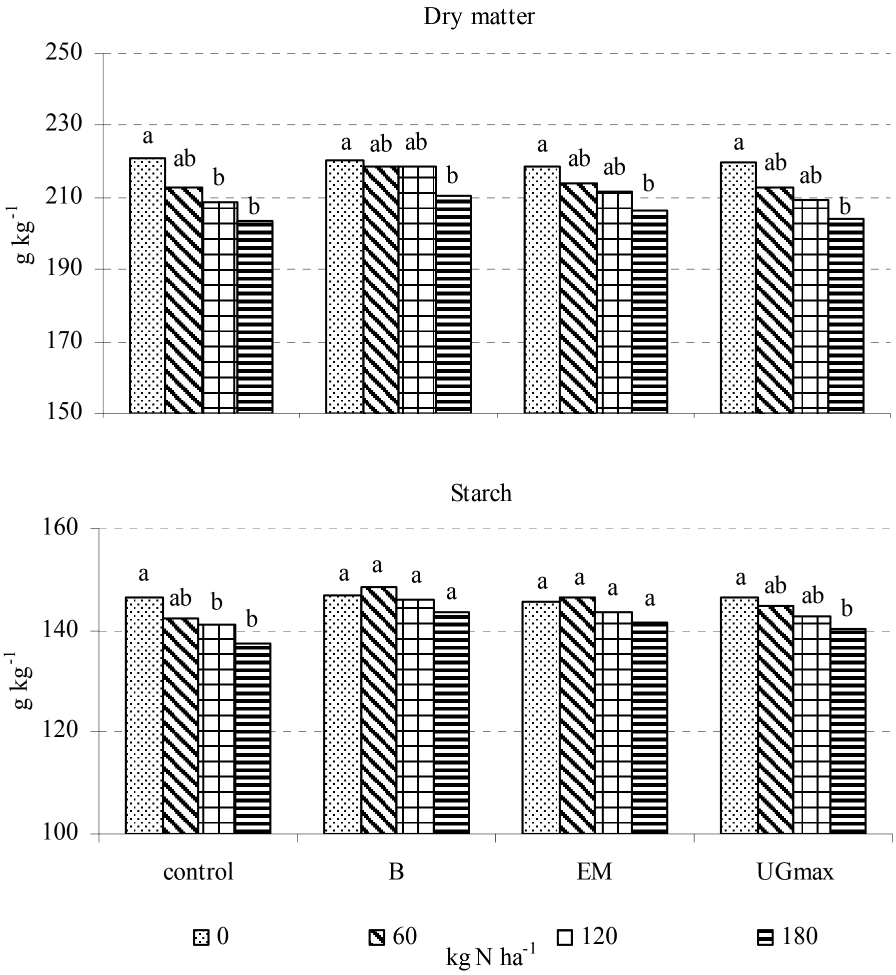

Fig. 1. Dry matter and starch content in potato tubers depending on the application rate of nitrogen and microbial preparations (values marked by the same letter do not differ significantly at $\alpha = 0.05$, Tukey's test)

Storage losses still pose an unsolved problem in agronomic production. Losses during potato tuber storage are caused by evaporation, respiration and shoot development, as well as by fungal and bacterial diseases. Beside the quantitative losses during storage, also changes of properties and chemical composition of tubers occur (Kaaber *et al*. 2001, Murnice *et al*. 2011).

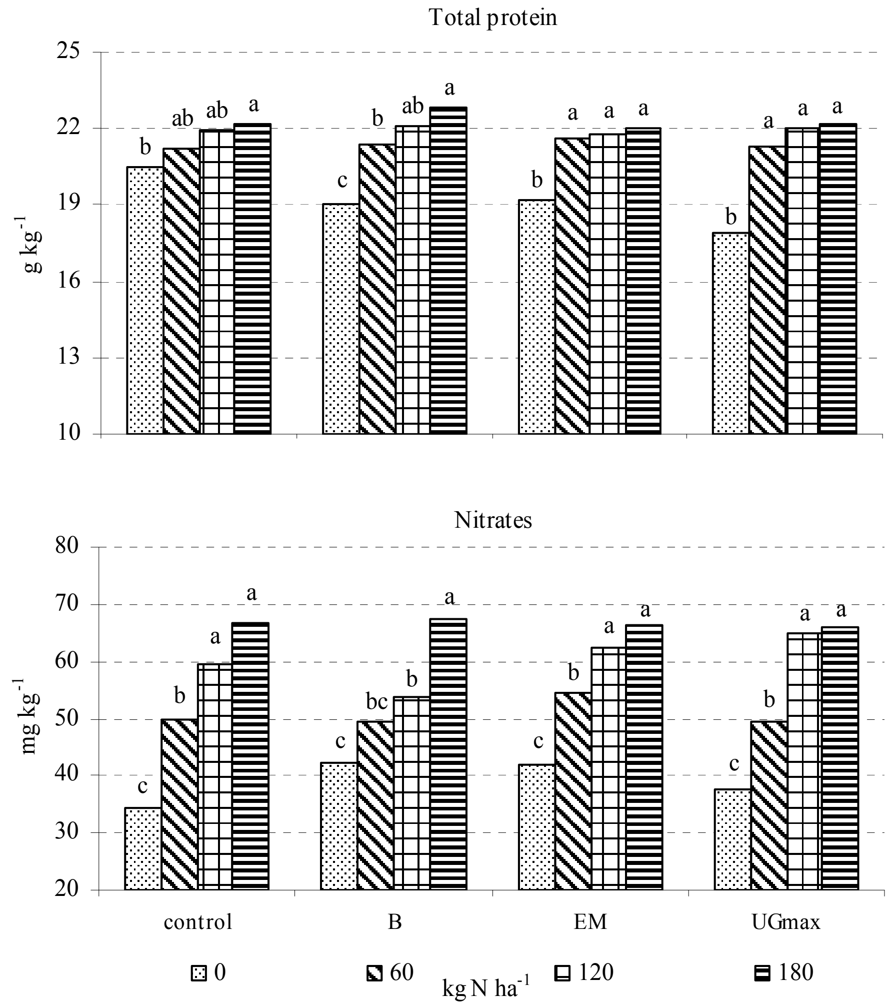

Fig. 2. Total protein content and nitrate content in potato tubers depending on the application rate of nitrogen and microbial preparations (values marked by the same letter do not differ significantly at α = 0.05, Tukey's test)

The amount of losses during storage is determined by cultivar properties and storage conditions, but also by agrotechnical measures. In the presented experiment the amount of natural losses depended on the level of nitrogen fertilisation, application of microbial preparations and weather conditions during the plants vegetation (Fig. 3). The highest mass losses after 6 months of storage were noted in potato tubers fertilised with 180 kg N ha^{-1}, whereas the lowest in tubers from the treatment which did not receive nitrogen.

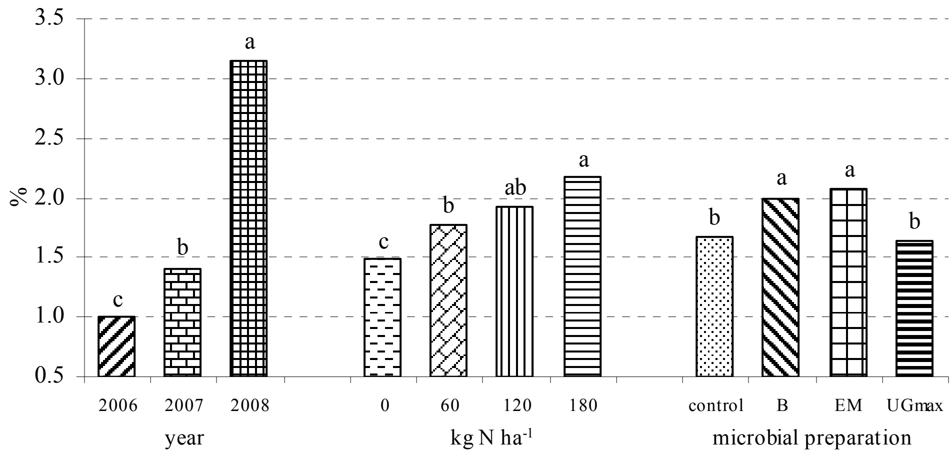

Fig. 3. Storage losses of potato tubers depending on year, application rate of nitrogen and microbial preparations (values marked by the same letter do not differ significantly at $\alpha = 0.05$, Tukey's test)

Wojdyła *et al.* (2009) obtained different results. They registered the highest natural losses (9.8%) after the application of 120 kg N ha^{-1}, significantly lower (9.2%) on the N non-fertilised objects, and the lowest (8.7%) after the application of moderate nitrogen fertilisation with 40 and 80 kg N ha^{-1}. Microbial preparations applied before and during potato vegetation had a negative effect on tuber storage stability. Application of B and EM preparations caused an increase in natural losses in tubers during storage. Storage stability of tubers was markedly affected by the weather conditions during vegetation. Tubers harvested in 2006, characterised by the lowest precipitation amount during vegetation over the entire experimental period, were in the best condition after storage. On the other hand, tubers gathered in 2008, when precipitation total was close to the multiannual average but unevenly distributed, were the worst keeping. The research results obtained are compatible with the reports of Gąsiorowska and Zarzecka (2002) and Wojdyła *et al.* (2009) who also observed that dry and warm weather, particularly in the final period of potato vegetation, favours good storage of tubers.

CONCLUSIONS

Nitrogen fertilisation of potatoes has a significant effect on the chemical composition and storage stability of tubers. With increasing level of nitrogen fertilisation the content of dry matter and starch was decreasing, whereas total protein and nitrates (V) concentrations were increasing. The highest concentration of nitrate in tubers was registered in treatments receiving 180 kg N ha^{-1}, but it was several-fold lower than the permissible content of this nitrogen form in fresh tuber mass. Moreover, nitrogen fertilisation led to an increase in natural losses in tubers during storage. The effect of microbial preparations on chemical composition of tubers and on the amount of storage losses was different than the effect of nitrogen fertilisation. The application of B preparation favoured the accumulation of dry matter and starch in tubers, the application of EM preparation contributed to an increase in starch and nitrate content, whereas total protein concentration significantly lower than in the control was noted following the application of UGmax preparation.

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WPŁYW NAWOŻENIA AZOTEM I PREPARATÓW MIKROBIOLOGICZNYCH NA KSZTAŁTOWANIE SIĘ JAKOŚCI ORAZ STRAT PRZECHOWALNICZYCH ZIEMNIAKA JADALNEGO

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Streszczenie. W badaniach polowych oceniano wpływ nawożenia azotowego oraz preparatów mikrobiologicznych na kształtowanie się zawartości suchej masy, skrobi, białka ogółem i azotanów, skłonności do ciemnienia miąższu bulw surowych oraz wielkości strat przechowalniczych bulw ziemniaka jadalnego. Czynnikami doświadczenia były poziomy nawożenia azotem: 0, 60, 120 i 180 kg $N \cdot ha^{-1}$ oraz preparaty: BactoFil B 10, Efektywne Mikroorganizmy EM oraz Użyźniacz Glebowy UGmax. Poziom nawożenia azotowego oraz aplikacja preparatów mikrobiologicznych miały istotny wpływ na kształtowanie się składu chemicznego i trwałość przechowalniczą bulw ziemniaka, nie stwierdzono natomiast wpływu tych czynników na intensywność ciemnienia miąższu bulw surowych. Wraz ze wzrostem poziomu nawożenia azotowego zmniejszała się zawartość suchej masy i skrobi, a zwiększała ilość białka ogółem i azotanów. Nawożenie azotowe powodowało ponadto istotne zwiększenie ubytków naturalnych bulw w czasie 6 miesięcznego okresu przechowywania. Wpływ preparatów mikrobiologicznych na kształtowanie się składu chemicznego bulw był odmienny niż nawożenia azotowego. Aplikacja preparatu BactoFil B 10 sprzyjała gromadzeniu suchej masy i skrobi w bulwach, zastosowanie preparatu Efektywne Mikroorganizmy EM przyczyniło się do zwiększenia zawartości skrobi i azotanów, natomiast po zastosowaniu preparatu Użyźniacz Glebowy UGmax stwierdzono istotnie mniejszą niż w obiekcie kontrolnym zawartość białka ogółem.

Słowa kluczowe: ziemniak, jakość bulw, preparaty mikrobiologiczne, nawożenie azotem, straty przechowalnicze