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Effect of biopreparates on the dry matter, starching and vitamin C in potato tubers

Wpływ biopreparatów na zawartość i plon suchej masy, skrobi oraz witaminy C
w bulwach ziemniaka

Summary. The research was aimed at assessing the impact of growing technology with microbiological application and herbal extracts on dry matter content, starch and yields, as well as vitamin C content in two potato cultivars, as compared to traditional fungicide-based and pest control technology, and to the variant without using bio-preparations and fungicides. The results of the study were based on the field experiment conducted in 2014–2016 at in Uhnin (51°34'N, 23°02'E), slightly acidic soil. The experiment was performed by means of randomized blocks method, in dependent split-plot pattern, in three replicates. The 1st order factor was the potato cultivars (‘Vineta’ and ‘Satina’), while the 2nd order factor was six crop technologies. Organic and mineral fertilization of potato was uniform. The applied cultivation techniques using microbiological preparations, herbal extracts and fungicide applications contributed to a significant increase in the dry matter content, vitamin C, while did not significant influence on dry matter yield. Reaction of cultivars towards the bio-preparations used has varied.

Key words: effective microorganisms, plant extracts, productivity, chemical compositions

INTRODUCTION

The uniqueness of the microorganisms and their enormous biosynthetic capacity due to their specific set of environmental conditions, have contributed to help in solving particularly difficult problems in the natural sciences. Proper use of native microorganisms for economic, social and environmental benefits is attractive and sets the spectacular evolution of research from traditional technology through modern technologies to provide an effective way to protect the environment and new ways to monitor it [Siti Aminah et al. 2016]. Effective microorganisms, as one of the products used in plant cultivation, is a natural liquid concentrate containing beneficial microorganisms such as: photosynthetic bacteria, lactic acid bacteria, propionic acid bacteria, *Azotobacter*, *Pseudomonas*, yeast, actinides, as well as some macro- and microelements [Sreenivasan 2013]. The photosynthetic bacteria, such as *Rhodopseudomonas palustris* and *Rhodobacter sphaeroides*, specialize in the production of amino acids, the nitrogen bonding of air and the conversion of toxic gases. In turn, lactic bacteria, e.g., *Lactobacillus plantarum*, *L. casei*, *Streptococcus lactis* – accelerate decomposition and fermentation of organic matter and may also reduce the activity of pathogens. *Actinomycetes* such as *Streptomyces albus* and *S. griseus* produce an antibacterial substance. Fermented fungi, e.g., *Aspergillus oryzae*, *Mucor hiemalis* help in the decomposition of organic matter, participate in the synthesis of amino acids and glucose from carbohydrates and control odor [Sreenivasan 2013, Mbouobda et al. 2014, Siti Aminah et al. 2016]. Technology of using effective microorganisms is natural and environmentally friendly. Effective microorganisms (EM) have already been used in the cultivation of many agricultural plant species, contributing to increased plant's bioavailability of hardly-available elements, improved soil humus conditions, increased plant biomass, improving their quality, and increased plant resistance to diseases and pests [Sreenivasan 2013, Kołodziejczyk 2014, Kowalska 2016, Siti Aminah et al. 2016]. Their effectiveness depends on many factors, mainly on the reactions of particular species, cultivars and the date and form of applying the bio-preparations to plants [Kołodziejczyk 2014, Siti Aminah et al. 2016]. However, it is important not only the quantitative effect of the application of effective microorganisms, but primarily the impact on the crop quality. Hence, the undertaken research was aimed at assessing the influence of the cultivation applying microbiological bio-preparations and herbal extracts on dry matter content, starch and yield as well as vitamin C concentration in potato tubers as compared to traditional fungicide technology protecting against *Phytophthora infestans* and control without the use of bio-preparations and fungicides.

MATERIAL AND METHODS

The field study was carried out in 2014–2016, at the Experimental Station for Cultivar Assessment Institute in Uhnin (51°34'N, 23°02'E), Poland on *Luvisol*, slightly acidic soil. The experiment was performed by means of randomized blocks method, in dependent split-plot pattern, in three replicates. The first-order factors were potato cultivars 'Vineta' (early) and 'Satina' (medium early), and the second factor was six cultivation technologies: four technologies using biopreparations (effective EM microorganisms) and herbal extracts and one object with three applications of fungicides to protection against *Phytophthora infestans* and control object without the use of any biological preparations or fungicides, with spraying potato tubers with clean water before planting. The following technologies were used:

Technology A (standard): three treatments with protection against potato blight (without any other treatments). Their application i.e. terms and doses were in accordance with Institute of Plant Protection – National Research Institute (IOR-PIB) [Wójtowicz and Mrówczyński 2013] recommendation: the preparation Infinito 687.5 SC contains propamocarb hydrochloride (625 $g \cdot l^{-1}$) and fluopicolide (62.5 $g \cdot l^{-1}$), Ridomil Gold MZ 67,8 WG contains: metalaxyl-M (38.8 $g \cdot kg^{-1}$) and mancozeb (640 $g \cdot kg^{-1}$).

Technology B: before setting, tubers were coated in water solution of EmFarma^{TM} (1 L EmFarma^{TM}. 10 l water). The coating time was 5 min. During vegetation, also 3 treatments with EmFarma Plus^{TM} (12 l) + Ema5^{TM} (2 l) in 400 $l \cdot ha^{-1}$ water were applied. The first treatment was made at BBCH 19, second – two weeks later, third – at BBCH 65 (full flowering).

Technology C: before setting, tubers were coated in water solution of EmFarma^{TM} along with tansy and yarrow extract (1 l preparation 10 l water) for 5 min. During vegetation, also 3 treatments with EmFarma Plus^{TM} (at the rate of 12 l) and Ema5^{TM} (2 l) in 400 $l \cdot ha^{-1}$ water were applied. The first treatment was made at BBCH 19, second – two weeks later, third – at BBCH 65 (full flowering).

Technology D: before setting, tubers were coated in water solution of EmFarma^{TM} (1 l on 10 l water) for 5 min. During potato vegetation, 8–10 treatments were performed depending on the cultivar and weather conditions during vegetation using preparations: EmFarma Plus^{TM} (10 l each) and Ema5^{TM} (1 l), every third treatment, in 400 $l \cdot ha^{-1}$ water. The first treatment was applied at BBCH 19, while subsequent every 7 days till BBCH 91 (beginning of maturity).

Technology E: before setting, tubers were coated in water solution of EmFarma^{TM} along with tansy and yarrow extract (1 l on 10 l water) for 5 min. During potato vegetation, spraying was made using preparations: EmFarma Plus^{TM} (10 L) and Ema5^{TM} (1 l), every third treatment, in 400 $l \cdot ha^{-1}$ water. The first treatment was applied at BBCH 19, while subsequent every 7 days till BBCH 91 (beginning of maturity). During potato vegetation, 8–10 treatments were performed depending on the cultivar and weather conditions during vegetation.

Technology F: before setting, potato tubers were soaked in clean water for 5 min. No protection treatments or fertilization was used during vegetation. That combination made up a control.

Winter triticale was the potato forecrop. In the experiment, constant fertilization of NPK was applied: 90 kg $N \cdot ha^{-1}$, 39.3 P and 112.0 kg $K \cdot ha^{-1}$ In addition, the mustard was ploughed in the fall at amount of 20 $Mg \cdot ha^{-1}$. Tubers were planted in the third decade of April at a spacing of 67.5 × 37 cm. Seed potato material was made up of tubers in CA class. Plot area for harvesting was 15 m^2. Agronomic treatments and plant protection treatments against Colorado potato beetle were conducted using ecological preparations according to Institute of Plant Protection – National Research Institute recommendations. Tuber harvest was performed at full physiological maturity, i.e. at 99 BBCH phase. At harvest time, representative samples for testing were taken from each plot to determine the content of starch, dry matter and vitamin C. The content of test components in fresh tuber mass was determined by the following methods: starch – polarimetric, dry matter – dry weight method, vitamin C – Tillman's method [AOAC 2016].

The results obtained were statistically processed. Statistical calculations were based on a three-factor variance analysis (ANOVA) and multiple t-Tukey tests, with significance levels $p = 0.05$. In addition, for each trait, the coefficient of variation (CV) and the relative standard deviation (RSD) was calculated [SAS 2008].

Meteorological conditions in the years of research were varied. Based on the amount of precipitation and air temperature, Sielianinov's hydrothermal coefficient was determined, which is a measure of the precipitation effect in a given month. According to this factor, 2014 can be counted as wet and 2016 – as average. The least favourable rainfall distribution was recorded in 2015 (Tab. 1).

Table 1. Rainfall, air temperature and the hydrothermal coefficient of Sielianinov, during the growing season of potato, according to the meteorological station in Uhnin, 2014–2016

Month	Rainfall (mm)			Air temperature (°C)			Hydrothermal coefficient of Sielianinov*		
	2014	2015	2016	2014	2015	2016	2014	2015	2016
April	43.0	61.8	47.1	11.1	8.8	10.0	1.3	2.3	1.6
May	141.4	120.3	46.3	14.7	12.8	15.3	3.1	3.0	1.0
June	85.2	46.7	87.3	15.9	16.7	19.1	1.8	0.9	1.5
July	69.7	45.2	114.1	21.1	19.4	20.5	1.1	0.8	1.8
August	95.8	6.1	41.0	19.2	21.4	19.5	1.6	0.1	0.7
September	19.6	130.2	11.8	14.6	15.5	15.5	0.4	2.8	0.3
Total	454.7	410.3	347.6	–	–	–	–	–	–

*Ranges of values of Sielianinov index were classified according to Skowera et al. [2014]

Table 2. Physical and chemical properties of soil in Uhnin (2014–2016)

Year	Content of assimilable macronutrients (mg·100 g^{-1} soil)			Humus content (%)	pH KCL (1 mol dm^{-3})	Content of microelements (mg·kg^{-1} soil)				
	P_2O_5	K_2O	Mg			Cu	Mn	Zn	Fe	B
2014	20.1	13.1	7.8	1.34	5.92	7.51	318	40.1	3876	7.24
2015	18.9	10.9	7.0	1.06	5.77	4.92	337	56.7	3697	5.28
2016	24.0	11.8	6.3	1.03	6.60	8.99	166	41.1	3801	6.04
Average	21.0	11.9	7.03	1.02	6.09	7.02	274	46.0	3791	6.17

Source: Own results, which made in the Laboratory Central of Agro-Ecological (CLA), the University of Life Science in Lublin

The field experiment in Uhnin was carried out on sandy loam soil type. According to percentage content of sand, silt and loam fraction, this is a granulometric subgroup – clay sand (light soil). The fraction of sand was 67%, the dust fraction was 30.7% and the loam was 2.3%. This proportion of individual fractions corresponds to the composition of clayey dust [WRB 2014]. In terms of agricultural suitability, these soils belong to slightly acidic good rye complex. This soil is classified to agronomic category as light mineral [Kaczmarek et al. 2013]. The content of assimilable components in soil was as follow: phosphorus and magnesium very high (21.0 mg P_2O·100 g^{-1} soil, 7.03 mg MgO·100 g^{-1} soil), medium in potassium (11.9 mg K_2O·100 g^{-1} soil), in copper medium

(7.02 mg Cu·kg^{-1} of soil), in manganese, iron and zinc also medium and was respectively 274 mg Mn·kg^{-1} of soil, 3791 mg Fe·kg^{-1} of soil, and zinc the average was 46 mg Zn·kg^{-1} of soil. In case of boron, the average was high, about 6.17 B·kg^{-1} of soil. The average acidity of the soil, in a solution of KCl, in 2014 and 2015 was 5.92–5.77 pH; these values allowed the classification of the experimental soil as slightly acidic soil, while in 2016 had 6.6 pH. The humus content in the arable layer was low and formed at 1.06–1.34% (Tab. 2).

RESULTS

The applied crop technologies significantly affected the dry matter content in tubers. The highest dry matter content in tubers was obtained in the technology D with treatment using EmFarma^{TM} water solution and with EmFarma Plus^{TM} and Ema5^{TM} from BBCH 19 to 91, as compared to control and other technologies. The smallest amount was obtained in the technology B, where tubers were planted in EmFarma^{TM} aqueous solution before planting and 3 treatments were applied with EmFarma Plus^{TM} + Ema5^{TM} during vegetation. Dry matter content was found to be homogeneous between technology C, where 3 treatments were used: EmFarma Plus^{TM} and Ema5^{TM} *vs* control (F) (Tab. 3).

Table 3. The effect of cultivation technology, cultivars and years on the content and yield of dry mass of potato tubers

Experimental factors		The dry mass content of tubers (%)				Yield of dry mass of tubers (Mg·ha^{-1})			
		2014	2015	2016	Mean	2014	2015	2016	Mean
Cultivation technologies	A	22.8	21.4	22.9	22.4 c	13.2	7.6	11.6	10.8 a
	B	23.2	19.6	21.7	21.5 e	14.1	7.5	11.2	10.9 a
	C	21.4	22.0	22.9	22.1 d	12.4	8.9	11.7	11.0 a
	D	23.3	22.3	24.1	23.2 a	13.9	8.3	11.6	11.3 a
	E	23.4	22.3	22.6	22.8 b	13.0	8.7	11.0	10.9 a
	F	22.9	21.1	21.5	21.8 d	14.0	9.8	10.7	11.5 a
$LSD_{0.05}$		0.5		0.3		ns*		ns	
Cultivars	'Vineta'	21.2	20.1	21.3	20.9 b	12.2	7.9	9.6	9.9 b
	'Satina'	24.5	22.8	24.0	23.7 a	14.6	9.0	13.0	12.2 a
$LSD_{0.05}$		0.3		0.1		1.1		0.4	
Mean		22.8 a	21.4 c	22.6 b	22.3	13.4 a	8.5 c	11.3 b	11.1
$LSD_{0.05}$		0.1				0.6			
CV (%)		1.2				10.0			

*ns – not significant at $p = 0.05$

On average, the significant higher content of dry matter was found in the medium early cultivar 'Satina' than in the early 'Vineta' (Tab. 3).

Meteorological conditions during the study years significantly determined the dry matter content in potato tubers. Most of the dry matter was produced by tubers in 2014, when optimal supply of potato plants to water was available, while at least in 2015, when there was a significant precipitation deficit during the most intensive harvest. The effect of cultivation technology was dependent on meteorological conditions in the years of research. The response of cultivars to meteorological conditions in the years of research proved to be diverse. The cultivar ‘Satina’ accumulated the most dry matter in 2014, the optimum year in terms of water supply, while the ‘Vineta’ – in 2016, when heavy rainfall occurred in July–August, while beneficial air temperatures promoting the dry mass accumulation (Tab. 3).

The yield of dry matter obtained in the experiment was on average 11.1 $Mg \cdot ha^{-1}$, which can be considered as high. Cultivation technologies did not affect this feature. However, the genetic effects of the cultivars studied and the meteorological conditions in the years of research were significant. Medium early cultivar ‘Satina’ produced significantly higher yields than the early ‘Vineta’.

Starch content was on average 14.0% in fresh weight of tubers (Tab. 4). Crop technologies have significantly influenced on the concentration of this component. The highest content of starch in tubers was obtained in technology A, in which only potato fungicides were applied. The technology D was homogeneous in this regard, where the tubers were treated with aqueous EmFarma™ before planting, and during the vegetation period 8–10 treatments were made with EmFarma Plus™ and Ema5™, every third treatment as well as the technology F (control). Significantly lower starch content in tubers was obtained in the technologies B and C, which proved to be homogeneous in terms of this feature value. The lowest concentration of starch in tubers was recorded in technology E, where most bio-preparations were applied.

Table 4. The effect of cultivation technology, cultivars and years on the content and yield of starch of potato tubers

Experimental factors		Starch content (%)				Starch yield ($Mg \cdot ha^{-1}$)			
		2014	2015	2016	Mean	2014	2015	2016	Mean
Cultivation technologies	A	14.1	14.1	14.4	14.2 a	8.13	4.99	7.30	6.81
	B	14.4	13.6	13.8	13.9 b	8.73	5.19	7.12	7.02
	C	13.5	14.3	13.8	13.9 b	7.79	5.82	7.00	6.87
	D	13.9	14.3	13.8	14.1 a	8.28	5.30	6.70	6.76
	E	13.4	14.3	14.0	13.7 c	7.41	5.48	6.49	6.46 b
	F	13.6	14.5	14.3	14.1 a	8.23	6.73	7.14	7.37 a
$LSD_{0.05}$		0.4			0.2	ns			0.70
Cultivars	Vineta	14.3	14.0	13.7	14.0 a	8.27	5.48	6.20	6.65 b
	Satina	13.2	14.3	14.3	13.9 a	7.93	5.69	7.72	7.11 a
$LSD_{0.05}$		0.2			ns	0.70			0.28
Mean		13.8 c	14.2 a	14.0 b	14.0	8.10 a	5.58 c	6.96 b	6.88
$LSD_{0.05}$		0.1				0.40			
CV (%)		1.4				10.4			

ns – not significant at $p = 0.05$

The studied cultivars did not modify the value of this feature, while the meteorological conditions in the years of research significantly determined the starch content in potato tubers. Most of the starch was accumulated by tubers in 2015, which have experienced a significant shortage of rainfall in June–August, while at the same time, very high air temperatures exceeding the long-term average, occurred. The lowest amount of this component was produced by tubers in the optimum, in terms of precipitation, 2014 (Tab. 4).

The effect of growing technology, in the form of starch accumulation in tubers, was dependent on meteorological conditions during the study years. The technologies B, C, D and E using effective microorganisms and control (technology F) have shown significant responses to vegetation conditions. In technology B with a 3-fold introduction of microbiological formulations, the highest starch content was recorded in the first, optimal in terms of precipitation and temperature, year of study, whereas in the remaining years, the starch content was homogeneous. In technologies C, D, E and F, the highest starch content was obtained in dry 2015 (Tab. 4).

The highest content of vitamin C in tubers was obtained in technology E, with the treatment of tubers with aqueous solution of EmFarma^{TM} with tansy and yarrow extract, and during the potato vegetation when 8–10 treatments were used: EmFarma Plus^{TM} and Ema5^{TM}, every third treatment, whilst the smallest in the control object with no tuber treatment using bio-preparations. Technologies C, D, A and B proved to be homogeneous in terms of this feature value (Tab. 5).

The interaction of cropping technology and meteorological conditions has been found in the research years. In technology A, significantly higher vitamin C content was obtained in dry 2015, and lowest in 2014, optimal in terms of precipitation conditions (Tab. 5).

Table 5. Influence of cultivation technology, cultivars and years on vitamin C content (mg·kg^{-1})

Experimental factors		2014	2015	2016	Mean
Cultivation technologies	A	10.3	16.9	16.4	14.5 cb
	B	17.4	13.1	18.4	16.3 b
	C	11.6	14.1	15.5	13.7 c
	D	10.4	13.9	14.6	13.0 c
	E	18.5	16.6	21.2	18.8 a
	F	11.1	9.0	12.2	10.8 d
$LSD_{0.05}$		4.6			2.1
Cultivars	‘Vineta’	9.1	12.1	12.8	11.3 b
	‘Satina’	17.3	15.8	20.0	17.7 a
$LSD_{0.05}$		2.1			0.8
Mean		13.2 b	13.9 b	16.4 a	14.5
$LSD_{0.05}$		1.2			
CV(%)		15.1			

On average, the medium early cultivar ‘Satina’ had significantly more vitamin C than early ‘Vineta’; both of them accumulated the largest amounts in 2016, with periodic excess and deficiency of precipitation (Tab. 4).

The variability coefficient CV (%), which is a measure of random variation, was low in the analyzed studies and ranged from 1.2% to 15.1%. This means that the results are reliable (Tabs 3–5).

DISCUSSION

Studies have shown that the use of bio-preparations in potato cultivation has contributed to increased dry matter and vitamin C content in tubers, but at the same time, to the decrease in the content and yield of starch. Kowalska [2016] did not show significant effect on starch content in potato tubers, but demonstrated that EM Farma Plus and UG--max in combined treatments (applied to soil before planting and 4 times as foliar treatment during vegetation period) significantly contributed to the increase of potato yields and the participation of commercial tubers fractions. In opinion of Allahverdiyev et al. [2011], Kołodziejczyk [2014] and Kowalska [2016], addition of microbiological preparations to soil is a way to speed up the process of restoring the biological balance in the soil. According to Xiao et al. [2008] these microorganisms may enrich the soil with nitrogen (nitrogen binding) and increase the pool of bioavailable forms P and K from soil minerals or by reducing the reversion of these elements introduced with mineral fertilizer. It is particularly important in the organic farming system. The use of microorganisms as well as plant extracts can be one of the agricultural practices in plant protection, especially in ecological farming systems. In opinion of Jamiołkowska [2011] and Jarienė et al. [2014] natural products such as plant extracts are increasingly used to protect plants against pathogens. The genetic traits of cultivars tested modified all studied characteristics. The effect of cultivars on yield of dry matter, starch and vitamin C is confirmed by many authors [Hamouz et al. 2009, Kołodziejczyk 2014, Kowalska 2016]. In studies carried out in two technologies (C and E), extracts of tansy and yarrow plants were used to protect seedlings from diseases. Studies upon the use of plant extracts indicate a new way to combat plant diseases [Javaid 2011]. These extracts have been found to be safe, non-toxic to humans but effective against plant pathogens. Chemical composition of potato tubers tested was also dependent on the meteorological conditions in the years of study. The highest content and yield of dry matter and starch were obtained in years with optimum and well-distributed rainfall, while the highest starch content was recorded in dry and sunny years. Such a response to the weather is confirmed by many authors [Hamouz et al. 2009, Khayatnezhad et al. 2011]. The use of natural, biological means in growing crops can contribute to the production of high quality food in an agrophytocoenose-friendly system. According to Kaczmarek et al. [2008], Sharma et al. [2014] and Siti Aminah et al. [2016], effective microorganisms can clean the environment, while reducing the amount of waste dumped into landfills, provided they are properly applied.

CONCLUSIONS

Application of bio-preparations in potato cultivation contributed to the increase in dry matter and vitamin C content in tubers, but also to the decrease in starch contents, except for the technology of tubers soaking before planting and 8–10 times effective microorganisms (EM) treatments during vegetation.

Growing technology applying tuber soaking in EmFarma^{TM} aqueous solution with the tansy and yarrow extract prior to planting, and the application of EmFarma Plus^{TM} and Ema5^{TM}, every 7 days, starting from BBCH 19 to 91, during potato vegetation, contributed to a significant increase in vitamin C content. Technology D with tuber treatment prior to planting with EmFarma^{TM} aqueous solution and 8–10 treatments with EmFarma Plus^{TM} and Ema5^{TM}, resulted in the highest increase in tuber dry mass as compared to the control.

Medium early cultivar 'Satina' appeared to be the cultivar with higher potential of accumulating the nutrients in tubers than 'Vineta'.

REFERENCES

Allahverdiyev S.R., Kırdar E., Gunduz G., Kadimaliyev D., Revin V., Filonenko V., Rasulova D.A., Abbasova Z.I., Gani-Zade S.I., Zeynalova E.M., 2011. Effective microorganisms (EM) technology in plants. Technology 14(4), 103–106.

AOAC, 2016. Official methods of analysis of AOAC International. Ed. 20.

Hamouz K., Lachman J., Dvořák P., Orsák M., Hejtmánková K., Čížek M., 2009. Effect of selected factors on the content of ascorbic acid in potatoes with different tuber flesh colour. Plant Soil Environ. 55, 281–287.

Jamiołkowska A., 2011. Laboratory effect of azoxystrobin (Amistar 250 SC) and grapefruit extract (Biosept 33 SL) on growth of fungi colonizing *Zucchini* plants. Acta Sci.Pol. Hortorum Cultus 10(2), 245–257.

Jarienė E., Danilčenko H., Vaitkevičienė N., Kita A., 2014. Effects of biodynamic preparations on the growth and yield parameters of potatoes with coloured flesh. Short Communication. Biuletyn IHAR 272, 73–79.

Javaid A., 2011. Effects of biofertilizers combined with different soil amendments on potted rice plants. Chil. J. Agric. Res. 71(1), 157–163.

Kaczmarek Z., Owczarzak W., Mocek A., Gajewski P., 2013. The Influence of Various Means of Tillage Simplified Modification on Selected Physical and Water Properties of the Arable-Humus Horizon in a Mineral Soil. Pol. J. Soil Sci. 46(1), 51–59.

Kaczmarek Z., Jakubus M., Grzelak M., Mrugalska L., 2008. Impact of the addition of various doses of effective microorganisms to arable-humus horizons of mineral soils on their physical and water properties. J. Res. Appl. Agric. Eng. 53, 118–121.

Khayatnezhad M., Shahriari R., Gholamin R., Jamaati-e-Somarin S., Zabihi-e-Mahmoodabad R., 2011. Correlation and path analysis between yield and yield components in potato (*Solanum tuberosum* L.). Middle East J. Sci. Res. 7, 17–21.

Kołodziejczyk M., 2014. Effect of nitrogen fertilization and microbial preparations on potato yielding. Plant Soil Environ. 60(8), 379–386.

Kowalska J., 2016. Wpływ nawożenia oraz biostymulatorów mikrobiologicznych na zdrowotność i plonowanie ziemniaka w systemie ekologicznym [Effect of fertilization and microbiological bio-stimulators on healthiness and yield of organic potato]. Progr. Plant Prot. 56(2), 230–235, https://doi.org/10.14199/ppp-2016-039

Mbouobda H.D., Fotso F.O.T.S.O., Djeuani C.A., Baliga M.O., Omokolo D.N., 2014. Comparative evaluation of enzyme activities and phenol content of Irish potato (*Solanum tuberosum*) grown under EM and IMO manures Bokashi. Int. J. Biol. Chem. Sci. 8 (1), 157–166.

Wójtowicz A., Mrówczyński M. (red.), 2013. Metodyka integrowanej ochrony ziemniaka dla producentów [Methodology of integrated potato protection for producers]. IOR-PIB, Poznań, pp. 68, https://www.ior.poznan.pl/plik,1745,metodyka-integrowanej-ochrony-ziemniaka-dla-producentow-pdf.pdf

SAS Institute Inc., 2008. SAS/STAT®9.2 User's Guide. SAS Institute Inc., Cary, NC.

Sharma A., Sharma R., Arora A., Shah R., Singh A., Pranaw K., Nain L., 2014. Insights into rapid composting of paddy straw augmented with efficient microorganism consortium. Int. J. Recycl. Org. Waste Agric. 3(2), 1–9.

Siti Aminah A.M., Ismail S.N.S., Praveena S.M., 2016. Application of effective microorganism (EM) in food waste composting: a review. Asia Pac. Environ. Occup. Health J. 2(2), 37–47.

Skowera B., Kopcińska J., Kopeć B., 2014. Changes in thermal and precipitation conditions in Poland in 1971–2010. Ann. Warsaw Univ. Life Sci. SGGW, Land Reclam. 46(2), 153–162.

Sreenivasan E., 2013. Evaluation of effective microorganisms technology in industrial wood waste management. Int. J. Adv. Engin. Technol. 21/22, 1–2.

WRB 2014. World reference database for soil resources. World Soil Resources Reports, No. 106. FAO, Rome, 192 pp.

Xiao C.O., Chi R.A., Huang X.H., Zhang W.X., Qiu G.Z., Wang D.Z., 2008. Optimization for rock phosphate solubilization by phosphate-solubilizing fungi isolated from phosphate mines. Ecol. Engin. 33, 187–193.

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Streszczenie. Praca miała na celu ocenę wpływu technologii uprawy z aplikacją preparatów mikrobiologicznych, wyciągów z ziół na zawartość suchej masy, skrobi i ich plon oraz zawartość witaminy C w dwu odmianach ziemniaka, w porównaniu z tradycyjną technologią z użyciem fungicydów w ochronie przed zarazą oraz obiektem kontrolnym, bez stosowania biopreparatów i fungicydów. Wyniki badań oparto na doświadczeniu polowym przeprowadzonym w latach 2014–2016, w Uhninie (51°34'N, 23°02'E), na glebie lekko kwaśnej. Eksperyment wykonano metodą bloków losowanych, w układzie zależnym, split-plot, w trzech powtórzeniach. Czynnikiem I rzędu były odmiany ziemniaka ('Vineta' i 'Satina'), zaś czynnik II rzędu stanowiło sześć technologii uprawy. Nawożenie organiczne i mineralne pod ziemniak było na jednakowym poziomie. Zastosowane technologie uprawy z użyciem preparatów mikrobiologicznych, wyciągów z ziół, jak i aplikacją fungicydów przyczyniły się do istotnego zwiększenia zawartości suchej masy, witaminy C, nie wywarły zaś istotnego wpływu na plon suchej masy. Reakcja odmian na stosowanie biopreparatów okazała się zróżnicowana.

Słowa kluczowe: efektywne mikroorganizmy, wyciągi roślinne, produktywność, skład chemiczny

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