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THE EFFECT OF APPLICATION OF BIOPREPARATIONS AND FUNGICIDES ON THE YIELD AND SELECTED PARAMETERS OF SEED VALUE OF SEED POTATOES

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A b s t r a c t. The study presented in this paper is based on the results of a field experiment conducted in the years 2014-2016 at the Research Station for Cultivar Testing COBORU at Uhnin (51°34', 23°02'E), on a slightly acidic grey-brown podzolic soil. The experiment was performed with the random sub-block method, in a split-plot related system, in three replicates. The first-order experimental factor were potato cultivars (Vineta and Satina), and the second-order factor were six variants of potato plant protection: A – with the use of fungicides against potato blight, variants B, C, D, E – with the application of effective microorganisms, and variant F – without the application of fungicides and effective microorganisms, as the control treatment. Organic and mineral fertilisation for potato cultivation was at a constant level (20 t ha^{-1} white mustard for ploughing-over and 90 kg N, 39.3 kg P, 112.0 kg K ha^{-1}). The experiment was conducted in conformance of the methodology of estimation of economic value of crop plants cultivars in force at COBORU (Research Centre For Cultivar Testing) stations. The scope of the study comprised the estimation of the effect of application of fungicides, EM (Effective Microorganisms) and herbal extracts on the yield and on the quality parameters of seed potatoes. The protection variant with the use of fungicides contributed significantly to a decrease in the yield of seed potatoes, relative to the control treatment. All plant protection variants caused a significant increase in the numbers and multiplication factor of seed potatoes, relative to the control treatment. The genetic traits of the cultivars had a significant impact on the yield and number of seed potatoes, but they did not differentiate the average mass of seed potatoes and the values of the multiplication factor. The weather and soil conditions in the years of the study significantly determined the evaluated parameters.

K e y w o r d s: effective microorganisms, plant extracts, fungicides, cultivars, yield, seed value

INTRODUCTION

The condition for obtaining high and stable yields of potato, with good tuber health status, is to use high quality seed potato material (Struik and Wiersema 1999, Liefrink 2005, Biswas *et al.* 2015). The process of seed potato production is burdened with high capital and labour expenditure (mineral fertilisers, herbicides, insecticides, fungicides, growth regulators) for protection against pathogens and pests. In many countries there is a trend toward a limitation of chemisation of agriculture and restoration of biodiversity in nature, as excessive use of synthetic fertilisers causes a threat to the ecology and to human health, and a deterioration of the health status of the soil with resultant drops in crop yields. In these circumstances organic sources play a significant role in the improvement of soil fertility and of the productivity of cultivations. Biological fertilisers, such as *Azotobacter*, *Phosphobacteria* and *Bacillus*, are accepted to be the cheapest fertiliser components for the improvement of soil fertility and for optimal plant production. However, their effect depends on the kind of cultivation, on the soil, and on the environmental conditions (Singh 2001, Singh *et al.* 2017). Those authors suggest that the capacity of *Azotobacter* and *Fosfobacter* for proliferation in the rhizosphere of cultivations causes enhanced nutrients availability for plants, thanks to which there is an increase in the number of tubers produced by plants, and the size of the tubers is modified. Singh *et al.* (2017) applied various bio-fertilisers individually, or in combination with others, in the form of spraying of seed potatoes, and also of the soil and leaves, and demonstrated that they had a stimulating effect on the germination and on the multiplication factor of potato. In recent years, in the world (Japan, India, Western Europe, USA, Brazil) and in Poland, microbiological preparations called Effective Microorganisms (EM) are gaining notable popularity (Boligłowa 2005, Zydlik and Zydlik 2013, Kołodziejczyk 2014a, 2014b, Paśmionka and Kotarba 2015, Szewczuk *et al.* 2016). They are a mixture of naturally occurring microorganisms, mainly lactic acid bacteria (*Lactobacillus casei*, *Streptococcus lactis*), photosynthesising bacteria (*Rhodopseudomonas palustrus*, *Rhodobacter spae*), yeasts (*Saccharomyces albus*, *Candida utilis*), actinomycetes (*Streptomyces albus*, *S. griseus*) and mould fungi (*Aspergillus oryzae*, *Mucor hiemalis*) (Higa 1998, Valarini *et al.* 2003, Martyniuk and Księżak 2011, Jurkowski and Błaszczyk 2012). There are positive opinions on the positive effect of EM preparations on the vegetative growth of plants, improvement of their overall status, which contributes to their greater resistance to diseases and pests and inhibits the growth of pathogens in the environment (Higa 1998, Stewart and Daly 1999, Hoshino *et al.* 2002, Kaczmarek *et al.* 2008, Janas 2009, Pszczółkowski and Sawicka 2018). Studies by Boligłowa *et al.* (2004) and Boligłowy (2005) on EM and herbal extracts suggest that they can successfully replace fungicides in potato production and lead to a reduction or total elimination of the use of plant protection agents in potato pest and diseases control. Hence the urgent need for an estimation of the effect of application of EM and herbal extracts on seed potato efficiency, their number per area unit, multiplication factor, and seed value. The research hypothesis assumes that the application of EM and herbal extracts, both in the form of seed dressing and on plants during their vegetation, can help control potato diseases and allow to obtain healthier seed material. Therefore, the objective of the study was to determine the effect of effective microorganisms (EM) and herbal extracts on the efficiency and selected quality parameters of seed potatoes, in comparison with conventional plant protection with the use of fungicides, and with a control treatment, with no such application.

MATERIAL AND METHOD

The field experiment was conducted in the years 2014-2016, at the Research Station for Cultivar Testing at Uhnin (51°34',23°02'E), on a slightly acidic grey-brown podzolic soil. The experiment was performed with the random sub-block method, in a split-plot related system, in three replicates, in conformance with the COBORU methodology of studies on the economic value of crop plants cultivars (CEV) (Lenartowicz 2013). The first-order experimental factor were potato cultivars (Vineta and Satina), and the second-order factor were six variants of potato protection: 4 variants with effective microorganisms (EM) and protective treatments against potato blight a standard treatment with fungicide protection against *Phytopthora infestans*, and a control treatment without fungicides and effective microorganisms, with potato tubers spraying with clean water prior to planting.

The following variants were used:

Variant A (standard): three treatments with protection against potato blight. Application, i.e. times and doses, in conformance with the recommendations of IOR-PIB (Tab. 1).

Variant B – prior to planting, tubers were primed in a water solution of EmFarma^{TM} (1 dm EmFarma^{TM} 10 dm of water ha^{-1}) for 5 minutes. In the course of vegetation also 3 treatments were applied with the preparations EmFarma Plus^{TM} (12 dm^{-1}) + Ema5^{TM} (2 dm^{-1}) in 400 dm of water ha^{-1}.

Variant C – prior to planting, tubers were primed in a water solution of EmFarma^{TM} with an extract from tansy and yarrow (1 dm of EmFarmaTM 10 dm of water ha^{-1}) for 5 minutes. In the course of vegetation 3 treatments were applied with the preparations EmFarma Plus^{TM} (at dose of 12 dm^{-1}) and Ema5^{TM} (2 dm^{-1}) in 400 dm of water ha^{-1}.

Variant D − prior to planting, tubers were primed in a water solution of EmFarma™ (1 dm 10 dm of water ha^{-1}) for 5 minutes. In the course of potato vegetation, 8-10 treatments were applied, in relation to the cultivar and to the meteorological conditions during vegetation, with the preparations EmFarma Plus™ (at 10 dm^{-1}) and Ema5™ (1 dm^{-1}), every third treatment, in 400 dm of water ha^{-1}.

Variant E – prior to planting, tubers were primed in a water solution of EmFarma™ with an extract from vetiver and yarrow (1 dm 10 dm of water ha^{-1}) for 5 minutes. In the course of potato vegetation, spraying with the preparations EmFarma Plus™ (10 dm^{-1}) and Ema5™ (1 dm^{-1}) was applied, at every third treatment, on 400 dm of water ha^{-1}. During potato vegetation from 8 to 10 treatments were applied, depending on the cultivar and on the meteorological conditions.

Variant F – prior to planting, potato tubers were soaked in clean water for 5 minutes. In the course of vegetation no protective treatments and no fertilisation were applied. This was the control treatment.

In variants B and C the first treatment was performed in phase 19 BBCH, the second – 2 weeks after the first, and the third – in phase 65 BBCH (full flowering of potato). In protection variants D and E – the first treatment was applied in phase 19 BBCH, and subsequent ones at every 7 days until the beginning of plant ripening.

Table 1. Doses and times of application of fungicides in the standard technology, 2014-2016

Years	Application time	Trade name of fungicide/active substance	Dose of fungicide (dm or kg ha^{-1})
2014	16.06.2014	Infinito 687,5 SC − propamocarb hydrochloride, fluopicolide	1.6 dm
	27.06.2014	Ridomil Gold MZ 67,8 WG − mancozeb metalaxyl M	2.0 kg
	11.07.2014	Infinito 687,5 SC − propamocarb hydrochloride, fluopicolide	1.6 dm
2015	02.07.2015	Infinito 687,5 S.C. − propamocarb hydrochloride, fluopicolide	1.6 dm
	15.07.2015	Ridomil Gold MZ 67,8 WG − mancozeb metalaxyl M	2.0 kg
	27.07.2015	Infinito 687,5 SC − propamocarb hydrochloride, fluopicolide	1.6 dm
2016	22.06.2016	Infinito 687,5 SC − propamocarb hydrochloride, fluopicolide	1.6 dm
	05.07.2016	Ridomil Gold MZ 67,8 WG − mancozeb metalaxyl M	2.0 kg
	20.07.2016	Infinito 687,5 S.C. − propamocarb hydrochloride, fluopicolide	1.6 dm

Source: own study

Winter triticale was the preceding crop for potato. In the experiment a constant level of NPK fertilisation was applied, determined in relation to soil fertility, at 90 kg N, 39.3 kg P, 112.0 kg K ha^{-1}. In addition, in autumn a catch crop of mustard was ploughed over, in the amount of 20 t ha^{-1}. Tubers of health class C/A were planted in the third decade of April, at spacing of 67.5 x 37 cm. The harvest area of the plots was 15 m^2. Cultivation and plant protection treatments against Colorado beetle were performed in conformance with agricultural practice and recommendations of IOR-PIB. Tuber harvest was made in phase 99 BBCH. In the course of the harvest, representative samples were collected from each plot for analyses to determine the tuber yield, its structure, and the efficiency of seed potatoes and the multiplication factor. Yield structure was determined on the basis of tuber diameter fractions <4, 4-5, 5-6, >6 cm. The yield of seed potatoes was adopted as that of tubers with diameters of 4-6 cm, excluding tubers with pest or strong mechanical damage (Lenartowicz 2013).

The field experiment was conducted at the Research Station Uhnin, on a grey-brown podzolic soil with sandy-loamy particle size distribution (WBR 2014) and lightly acidic reaction (pH 5.8-6.4 in 1 n KCl). The soil was characterised by humus content at the level of 0.94% to 1.06%, very high content of available phosphorus, medium content of potassium, and low to very high content of available magnesium, depending on the year of the study (Tab. 2).

Table 2. Conditions of field experiment, abundance of available phosphorus, potassium and magnesium and pH of the soil and the content of humus (2014-2016)

Years	Content of available forms (mg 100 g^{-1} in dry matter of soil)			pH (1M KCl)	Humus (% ADM)
	P_2O_5	K_2O	Mg		
2014	22.8	15.8	3.4	6.4	1.03
2015	20.1	13.1	7.8	5.9	0.94
2016	18.9	10.9	7.0	5.8	1.06
Mean	20.6	13.3	6.1	6.0	1.01

The meteorological conditions in the years of the study were varied. The year 2014 can be classified as wet year, 2015 was one of the least favourable years, with a high rainfall deficit in the period of June-August, decisive for yield accumulation, while 2016 was an average year, both in terms of temperature and rainfalls (Tab. 3). The Sielianinov hydrothermal coefficient was applied for the estimation of thermal and pluviometric conditions of the meteorological station at Uhnin in 3 periods of potato vegetation, while the humidity characteristics of those months were determined after Skowera *et al.* (2014). The coefficient allows the determination of the effect of temperatures on the hydrothermal conditions. In the study a considerable variation of hydrothermal conditions was noted in the particular years. In April and May, in all the years of the study, the hydrothermal coefficient varied from 1.7 to 2.4, which means optimum conditions in the period of germination, formation of shoots, development of leaves and lateral shoots on the main shoot of potato. In the period of June-August, i.e. during flowering, tuber formation and yield accumulation, fruit development and ripening, the values of the hydrothermal coefficient were not always optimal. The highest value of the hydrothermal coefficient was calculated in 2014, in May – 3.1 (an extremely humid month). The lowest values of that coefficient were noted in 2015, in the period of intensive yield accumulation by potato, with values varying from 0.9 (dry) in June to 0.1 (extremely dry) in August. The year 2016 was defined by the hydrothermal coefficient as an optimal year, with values of the coefficient varying from 0.7 (dry) to 1.8 (rather humid) (Tab. 3).

Table 3. Rainfalls, air temperature and the Sielianinov hydrothermal coefficient (k) during the growing season of potato, according to the meteorological station in Uhnin in 2014-2016

Month	Rainfall (mm)			Air temperature (°C)			Sielianinov's hydrothermal coefficient*		
	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	–	–	–	–	–	–

* Skowera *et al.* 2014; Ranges of values of this index were classified as follows: extremely dry – $\leq$ k 0.4; very dry – 0.7 $\leq$ k < 0.4; dry – 1.0 $\leq$ k < 0.7; rather dry – 1.3 $\leq$ k < 1.0; optimal – 1.6 $\leq$ k < 1.3; rather humid – 2.0 $\leq$ k < 1.6; wet – 2.5 $\leq$ k < 2.0; very humid – 3.0 $\leq$ k < 2.5; extremely humid – 3.0 > k

Statistical calculations were based on a model of three-factorial analysis of variance (ANOVA) and multiple Tukey's t-tests, at significance level of 0.05. The multiple comparison tests allowed detailed analyses of comparisons of mean values, through the identification of statistically homogeneous groups of means (homogeneous groups) and determination of statistically significant differences of means that, in the case of Tukey's tests, are denoted as HSD (Tukey's Honest Significant Difference) (SAS 9.2 2008).

RESULTS

The triple application of fungicides in the standard variant (A) caused a significant decrease of yield of seed potatoes, relative to the control treatment (F), and to variants (B) and (C), where tubers, prior to planting, were primed with a solution of EmFarmaTM and an extract from vetiver and yarrow, and during potato growing period 3 treatments with the preparation EmFarma Plus^{TM} were applied. In the remaining variants of the experiment the differences in the values of that parameter were not significant. Protection variants (D) and (E) proved to be homogeneous with regard to the values of that parameter. Of the two analysed cultivars, a significantly higher yield of seed potatoes was characteristic of Satina (Tab. 4).

Table 4. Impact of cultivation variants, cultivars and years on the seed yield and its parameters

Experimental factors		Yield of seed potatoes (t ha^{-1})	Number of seed potatoes (thousands pcs. ha^{-1})	Weight of seed potatoes (g)	Multiplication factor
Protection variants*	A	41.2	231.85	66.4	8.5
	B	43.5	230.27	66.8	8.4
	C	44.9	245.12	65.7	9.3
	D	41.8	243.00	65.7	9.2
	E	42.5	236.44	66.7	8.9
	F	45.9	214.67	67.2	8.0
	$HSD_{0.05}$	1.3	6.93	1.2	0.3
Cultivars	Vineta	40.8	219.82	66.0	8.4
	Satina	45.7	247.27	67.1	8.8
	$HSD_{0.05}$	2.6	13.87	2.4	0.5
Years	2014	48.8	192.35	63.7	7.6
	2015	35.7	256.48	64.7	9.9
	2016	45.5	251.87	70.5	8.8
	Mean	43.3	233.57	66.3	8.8
	$HSD_{0.05}$	3.8	20.57	3.6	0.8

*A – standard: 3 treatments with protection against potato late blight; B – pre-planting tubers were treated with EmFarmaTM + Ema5TM in aqueous solution during vegetation 3 treatments; C – tubers for planting were treated in EmFarmaTM aqueous solution with a tansy and yarrow extract and in the vegetation period of potato 3 treatments were applied: EmFarma PlusTM and Ema5TM; D – tubers were treated with aqueous solution of EmFarmaTM before planting, and during the vegetation of potato 8-10 treatments were made: EmFarma PlusTM and Ema5TM, every third treatment; E – tubers were treated with aqueous solution of EmFarmaTM with tansy and yarrow extract and during potato vegetation 8-10 treatments were applied: EmFarma PlusTM and Ema5TM, every third treatment; F– potato tubers prior to planting were soaked in clean water (control treatment)

The effect of the protection variants on the level of yield of seed potatoes was dependent on the response of the tested potato cultivars. In the case of cv. Satina, the triple application of fungicides (A) and protection variants (B) and (D) caused a significant reduction of the value of that parameter, relative to the control treatment (F) and to protection variants (E) and (C) in which EM and herbal extracts were applied. In the case of cv. Vineta, the application of fungicides in variants (A), (D) and (E), where tubers were primed pre-planting with a water solution of EmFarmaTM and a tansy and yarrow extract, and during potato vegetation 8-10 treatments with the preparations EmFarma Plus^{TM} and Ema5^{TM} were applied, every third treatment, contributed to a significant decrease of seed potato yield, relative to the control treatment and protection variants (B) and (C). Protection variants (D) and (E) proved to be homogeneous with regard to the value of that parameter (Tab. 5).

Table 5. Influence of protection variants, cultivars and years on the yield of seed potato (t ha^{-1})

Protection variants*	Cultivars		Years		
	Vineta	Satina	2014	2015	2016
A	38.6	43.8	45.6	32.0	46.2
B	42.9	44.0	51.0	34.1	45.4
C	42.4	47.3	50.6	37.7	46.4
D	39.7	44.0	48.1	34.4	44.1
E	37.5	47.5	48.4	34.7	44.6
F	43.8	47.9	49.4	41.8	46.4
$HSD_{0.05}$	2.6			3.8	

RSD – relative standard deviation (%) 8.5; * explanations as in Table 4

The weather conditions in the vegetation periods had also a significant impact on the yield of seed potatoes. The highest yield was obtained in the humid year 2014, and the lowest in 2015, a year with a notable rainfall deficit in the period of July-August (Tab. 4). Also significant was the interaction between the protection levels applied and the atmospheric conditions in the years of the study (Tab. 5). In the most humid year, 2014, the triple application of fungicides in variant (A) contributed to a significant decrease of the yield of seed potatoes, relative to the control treatment and to protection variants (B) and (C), where EM and the herbal extracts were applied. Protection variants (D) and (E) proved to be homogeneous with regard to the yield of seed potatoes. In 2015, a year with significant rainfall deficit in the period of yield accumulation, a significant decrease of the yield of seed potatoes under the effect of all the protection variants applied was noted, relative to the control treatment (F), the highest decrease being observed in variant (A), with the triple application of fungicides. In 2016, a year with average rainfall totals and air temperature, the protection variants did not have any significant impact on the value of that parameter (Tab. 5).

The number of seed potatoes from a unit of area was related to the protection variant. All of the protection variants, both those with fungicides and those with the application of EM and herbal extracts, contributed to a significant increase in the number of seed potatoes, relative to the control treatment. Protection variants (A), (B) and (E), as well as (C) and (D), proved to be homogeneous with regard to the value of that parameter (Tab. 4). Out of the two analysed cultivars, cv. Satina produced a significantly higher number of seed potatoes (Table 4).

The analysed cultivars were characterised by diverse responses to the protection variants applied. In the case of cv. Vineta, a significant increase in the number of seed potatoes was noted under the effect of cultivation in technologies (C), (D) and (E), with the application of EM and the herbal extracts, relative to the control treatment (F) and variant (A), with triple application of fungicides, and variant (B), with triple application of treatments with the use of the preparations EmFarma Plus^{TM} and Ema5^{TM}. Cultivar Satina produced the largest number of seed potatoes under the effect of triple application of fungicides in the standard variant (A), and the lowest – in the control treatment (F), while protection variants (A), (B), (C) and (D), as well as (E) and (F), proved to be homogeneous with regard to the value of that parameter (Tab. 6).

Table 6. Influence of protection variants, cultivars and years on the numbers of seed potatoes (thousands of pieces ha^{-1})

Protection variants*	Cultivars		Years		
	Vineta	Satina	2014	2015	2016
A	201.93	261.79	175.35	263.56	256.67
B	206.01	254.53	199.02	234.89	256.89
C	234.60	255.64	203.36	276.22	255.78
D	235.40	250.60	198.35	292.45	238.20
E	236.86	235.86	202.36	247.51	259.61
F	204.14	225.19	175.68	224.22	244.09
$HSD_{0.05}$	13.87			205.70	

RSD – relative standard deviation (%) 8.6%; *explanations as in Table 4

The weather conditions in the years of the study determined the number of seed potatoes on a unit of area. The largest number of seed potatoes was obtained in 2015, a year with dry July and August, and the lowest in 2014, a year with excessive rainfalls in May, June and August (Tab. 3).

The interaction of the protection variants with the weather conditions in the year of the study was also important for tuber production and the size of seed potatoes (Tab. 6). In 2014, a year with a notable excess of rainfalls, significantly the largest number of seed potatoes with sizes characteristic of seed potatoes was noted in protection variants (C) and (E), where tubers were primes with EM and the tansy and yarrow extracts prior to planting, and during potato vegetation 8-10 treatments with the preparations EmFarma Plus^{TM} and Ema5^{TM} were applied, at every third treatment. In the driest year, 2015, protection variants (A), (C), (D) and (E) contributed significantly to an increase in the number of seed potatoes, relative to the control treatment. The largest number of tubers with the size of seed potato was obtained in variant (D), in which EM and herbal extracts were applied. In 2016, a year with average weather conditions, the protection variants did not have any significant impact on the value of that parameter, relative to the control treatment (Tab. 6).

The protection variants significantly modified the weight of a single seed potato (Tab. 4). Protection variant (C), where prior to planting tubers were primed with a water solution of EmFarmaTM with a ransy and yarrow extract, and during potato vegetation three treatments with EmFarma Plus^{TM} and Ema5^{TM} were applied, and variant (D), in which prior to planting tubers were primed with a water solution of EmFarma^{TM}, and during potato vegetation 8-10 treatments with the preparations EmFarma Plus^{TM} and Ema5^{TM} were applied, but every third treatment, contributed to a significant decrease in the weight of a single seed potato, compared to the control treatment (F). Protection variants (C) and (D), (A), (B) and (E), as well as (E) and (F), were homogeneous in regard to the value of that parameter (Tab. 7).

The analysed cultivars did not differ significantly in the mean weight of tubers with the size of seed potatoes (Tab. 7). Whereas, the response of the cultivars to the protection variants proved to be significant (Tab. 7). Cultivar Vineta, under the effect of variant (B), where tubers were primed prior to sowing with a water solution of EmFarma^{TM} and during vegetation 3 treatments with EmFarma Plus^{TM} and Ema5^{TM} were applied, produced the largest weight of an average seed potato, relative to the protection variants (A) and (D). Protection variants (E) and (F) proved to be homogeneous with regard to the value of that parameter. In the case of cv. Satina, the triple application of fungicides in variant (A) contributed to the production of seed potatoes with significantly greater weight, relative to variant (B). The remaining protection variants, (A), (C), (D), (E) and (F), were homogeneous with regard to the value of that parameter (Tab. 7).

Table 7. Influence of protection variants, cultivars and years on the weight of one seed potato (g)

Protection variants*	Cultivars		Years		
	Vineta	Satina	2014	2015	2016
A	65.7	68.6	68.3	62.3	67.1
B	68.3	65.8	65.3	66.9	67.5
C	65.3	66.7	61.2	62.9	72.5
D	64.6	66.8	60.0	64.1	73.0
E	66.0	67.3	61.6	67.9	70.5
F	66.0	67.5	65.9	63.8	72.7
$HSD_{0.05}$	2.4			3.6	

RSD – 5.2%; * explanations as in Table 4

Atmospheric conditions in the years of the study significantly determined the weight of a single seed potato (Tab. 7). The highest weight of a single tuber (70.5 g) was obtained in 2016, a year with average weather conditions, and the lowest (63.7 g) in 2014, a year with a considerable excess of rainfalls in the months that determine the accumulation of yield (Tab. 4).

There was a significant interaction between the protection variants and the weather conditions in the years of the study (Tab. 7). In the most humid year, 2014, in protection variants (C), (D) and (E) a significant decrease of the weight of a single seed potato was observed, relative to the control treatment. Protection variants (A), (B) and (F) proved to be homogeneous with regard to the value of that parameter. In 2015, a year with a considerable deficit of rainfalls in the period of the most intensive yield accumulation, a significantly higher weight of a single seed potato was obtained in protection variant (E), where tubers were primed prior to planting with a water solution of EmFarma^{TM} with a tansy and yarrow extract, and during potato vegetation spraying with the preparations EmFarma Plus^{TM} (8 to

10 treatments) and Ema5^{TM} was applied, every third treatment, in relation to the control treatment (F). The remaining variants were homogeneous with regard to the value of that parameter. In 2016, a year with average weather conditions, a significant decrease of the weight of the average seed potato was noted in protection variants (A) and (B), relative to the control treatment. The remaining variants were homogeneous with regard to the value of that parameter (Tab. 7).

The protection variants significantly modified the seed potato multiplication factor (Tab. 4). Its highest value was obtained in variant (C), were tubers were primed pre-planting with a water solution of EmFarma^{TM} with a tansy and yarrow extract and during vegetation 3 treatments with EmFarma Plus^{TM} and Ema5^{TM} were applied, and the lowest – in the control treatment. It should be noted that in variants (A) and (B), (C) and (D), and (E) and (D) the values of that factor were homogeneous (Tab. 4).

With regard to the multiplication factor, the response of the cultivars to the protection variants was varied. In the case of cv. Vineta, the application of EM and the herbal extracts in the protection variants (D), (C) and (E) contributed to the obtainment of a significantly higher multiplication factor, relative to the control treatment (F), and to the protection variants with the use of fungicides (A), and to variant (B), where prior to planting tubers were primed with a water solution of EmFarma^{TM} and during vegetation 3 treatments with water solution of EmFarma Plus^{TM} and Ema5^{TM} were applied. In the case of cv. Satina, all protection variants with the use of fungicides, EM preparations and herbal extracts contributed to a significant increase of the multiplication factor, relative to the control treatment (F). It should also be noted that variants (A), (B) and (E), as well as (C) and (D), were homogeneous with regard to the value of that parameter (Tab. 8).

Table 8. Influence of protection variants, cultivars and years on seed potato multiplication factor

Protection variants*	Cultivars		Years		
	Vineta	Satina	2014	2015	2016
A	7.8	8.7	6.5	10.0	9.5
B	7.6	8.6	7.7	9.3	8.9
C	9.0	9.3	8.3	10.9	8.8
D	9.1	9.2	8.3	11.0	8.5
E	8.9	8.8	8.2	9.4	9.0
F	7.7	8.0	6.7	8.9	8.5
$HSD_{0.05}$	0.5			0.8	

RSD (%) 8.8%; * explanations as in Table 4

The meteorological conditions in the years of the study significantly modified the value of the multiplication factor. The highest value was obtained in 2015, a year with a considerable rainfall deficit, and the lowest in 2014, a year with excessive rainfalls (Tab. 8).

A significant interaction was noted between the meteorological conditions in the years of the study and the protection variants (Tab. 8). In the humid year 2014 all the protection variants with th use of EM and herbal extracts had a significant effect on the value of the multiplication factor, relative to the control treatment and to variant (A), in which fungicides were applied three times. In 2015, a year with dry July and August, significantly higher values of the multiplication factor were obtained in protection variants (D), (C) and (A), relative to the control treatment (F). Protection variants (B), (E) and (F) proved to be homogeneous in this respect. In 2016, an optimal year in terms of rainfalls and air temperature, the highest multiplication factor was obtained in the variant with triple application of fungicides, compared to the control treatment. The remaining protection variants were homogeneous with regard to the value of that parameter (Tab. 8).

The coefficient of variation (CV or RSD), which is a measure of random variability, was very low to low and varied from 5.2 to 8.8%. This means that the results obtained are credible and can be treated with a high confidence (Tab. 5-8).

DISCUSSION

The plant protection variants with the use of EM and herbal extracts, applied in the experiment, contributed to a decrease in the yield of seed potatoes, relative to the control treatment. The exception was the protection variant with pre-planting tuber priming with a water solution of EmFarma^{TM} with extract from tansy and yarrow and with the application, during potato vegetation, of 3 treatments with the preparations EmFarma Plus^{TM} and Ema5^{TM}. Whereas, research by Martyniuk (2010), and by Martyniuk and Księżak (2011), indicate a small effect of EM on the yields of plants. A different opinion is presented by Szewczuk *et al.* (2016). In this study, all the variants of plant protection with the use of EM and herbal extracts contributed to a significant increase of the number of seed potatoes and of the value of the multiplication factor, relative to the control treatment. The literature does not provide any data on this subject. One can only suppose that the cause of this is the variation of tuber yield structure.

The protection variants with pre-planting priming of tubers in a water solution of EmFarma^{TM} with a tansy and yarrow extract, and 3 treatments with EmFarma Plus^{TM} and Ema5^{TM} during vegetation, and with pre-planting priming of tubers in a water solution of EmFarma^{TM} and the application of 8-10 treatments with the preparations EmFarma Plus^{TM} and Ema5^{TM} during potato vegetation, at every third treatment, caused a decrease of the weight of the average seed potato, relative to the control treatment. The advocates of the microbiological preparations (Boligłowa 2005, Kołodziejczyk 2014a, 2014b, Szewczuk *et al.* 2016) indicate their favourable effect on the yields and health status of plants, and on the physicochemical and microbiological properties of soil. Zydlik and Zydlik (2013) observed a significant increase in the activity of dehydrogenase and protease under the effect of three microbiological preparations, but those did not have any significant effect on soil pH. Martyniuk (2011) maintains that EM preparations applied to the soil, or in the form of spraying during vegetation, do not cause any significant increase of yields of crop plants and have no significant effect on the microbiological and biochemical properties of soil.

The genetic properties of the analysed potato cultivars had a significant effect on the yield of seed potatoes and their number per unit of area, which is supported also in studies by numerous authors (Striuk and Wiersema 1999, Liefrink 2005, Pszczółkowski and Sawicka 2018). Whereas, the varietal traits did not cause any significant effect on the weight of the average seed potato and on the multiplication factor of potato. This can be attributed to the high genetic stability of the tested cultivars, that do not succumb to modification through the application of fungicides, or EM and herbal extracts.

For achieving high yields of potato tubers, the use of pesticides in the cultivation is not without importance, as observed by many authors (Boligłowa *et al.* 2004, Wszelaczyńska *et al.* 2007, Zydlik and Zydlik 2013) who at the same time emphasise their ambiguous effect on the quality characteristics of the yield. The triple application of fungicides in this experiment, in the standard technology, contributed to a significant decrease of the yield of seed potatoes and to an increase of their numbers per unit of area, relative to the control treatment. This may result from the stress for plants, caused by the application of fungicides in unfavourable atmospheric conditions (Pacholak and Zydlik 2004). Wojcieszyńska and Wilczek (2006) report, on the other hand, that in potato infected with spores of *Phytopthora infestans,* between the healthy and the infected tissue a blue fluorescent zone is formed, that is a barrier between those two types of tissue. Comparison of phenolic compounds in the healthy tissue and the fluorescent tissue indicates that in that area there takes place intensive synthesis of two phenolic compounds: fluorescent scopolin and chlorogenic acid. Therefore, the use of fungicides alone, without the protective barrier of herbal extracts, may be conducive to the formation of spores of *Phytopthora infestans*, and thus cause a reduction of potato yields. According to Derda *et al.* (2012), Kurkin *et al.* (2011) and Vitalini *et al.* (2011), extracts from yarrow and tansy have an inhibiting effect on the pathogenic and non-pathogenic strains of *P. infestans.*

Meteorological conditions during vegetation had a significant impact on the parameters in question. The highest yield of seed potatoes, and at the same time their lowest number per unit of area, the highest weight and multiplication factor, were obtained in a rather humid year. Whereas, in years with considerable rainfall deficit in the period of July-August, the lowest yield of seed potatoes was obtained, but also their highest number and the highest multiplication factor. In the opinion of Zydlik and Zydlik (2013), this results from different levels of soil respiratory activity during the period of vegetation and from the effect of climatic factors, as at a time of air temperature increase there is also an intensification of the activity of soil microorganisms, accelerating the emission of CO_2. Another important factor is the soil moisture. Both in years with low and with very high moisture, soil activity decreases, and that in turn affects plants and their respiratory activity (Pacholak and Zydlik 2004). Low soil moisture does not ensure sufficient access of microorganisms to water, and at excessive soil moisture the access to oxygen is insufficient. In 2014 the mean monthly temperature in September was lower than the multi-year average. In combination with a high level of soil moisture, it could have created less favourable atmospheric conditions for the growth of soil microorganisms in autumn, and that in turn could have caused lower respiratory activity of soil during the spring-summer period.

The application of the EM technology is aimed primarily at improving the quality of the environment. It provides the possibility of reducing the use of chemical agents in agriculture, improves soil quality and enhances the yields of crop plants. Due to the progressing degradation of the environment, there is increased risk of neoplastic diseases, and hence the urgent need for the substitution of the use of chemical agents with effective biopreparations with a multi-directional spectrum of activity. However, the effectiveness of EM preparations depends on both biotic and abiotic factors, the most important of which are the responses of specific crop plant species and cultivars to those preparations, and the degree of degradation of soils.

CONCLUSIONS

1. The protection variants with the use of microbiological preparations and herbal extracts (tansy and yarrow) contributed to a significant:

– decrease of the yield of seed potatoes, but an increase of their number of unit of area and of the value of the multiplication factors, relative to the control treatment;

– decrease of the mean weight of seed potatoes in variants were tubers, prior to planting, were primed with water solution of EmFarma^{TM} with a tansy and yarrow extract, and during vegetation 3 treatments were applied with the preparations EmFarma Plus^{TM} and Ema5^{TM}, and in the variant where tubers, prior to planting, were primed with water solution of EmFarma^{TM}, a during potato vegetation 8-10 treatments were applied, depending on the cultivar and on the meteorological conditions, using the preparations EmFarma Plus^{TM} and Ema5^{TM} (every third treatment), relative to the control treatment.

2. The triple application of fungicides caused a decrease of the yield of seed potatoes, in relation to the control treatment and to the protection variants with the use of EM and herbal extracts.

3. The medium early cultivar Satina gave higher yields of seed potatoes and their larger number per unit of area, and thus it can ensure greater advances in potato seed production than the early cultivar Vineta.

4. Years with unfavourable weather conditions for potato vegetation, with a high deficit of rainfalls, did not create beneficial conditions for the production of a high yield of seed potatoes, but allowed their higher numbers per unit of area and higher values of the multiplication factor. Optimum rainfall-air temperature conditions during potato vegetation did not differentiate the parameters of seed potatoes.

5. Potential possibilities of the application of EM preparations and herbal extracts can be found in organic systems of potato cultivation, where there is practically no possibility of potato blight control with the use of systemic fungicides.

REFERENCES

Biswas S.K., Shankar U., Kumar S., Kumar A., Kumar W., Lal K., 2015. Impact of bio-fertilizers for the management of spot blotch disease and growth and yield contributing parameters of wheat. J. Pure Appl. Microbiol., 9(4), 3025-3030.

Boligłowa E., 2005. Protecting potato against diseases and pests using Effective Microorganisms (EM) with herbs. Selected ecological issues in modern agriculture (in Polish). In: Wybrane zagadnienia ekologiczne we współczesnym rolnictwie (Ed. Z. Zbytek). PIMR, Poznań, 165-170.

Boligłowa E., Gleń K., Pisulewski P., 2004. The effect of herbicides on the yield and some quality characteristics of potato tubers (in Polish). Zeszyty Problemowe Postępów Nauk Rolniczych, 500, 391-397.

Derda M., Hadaś E., Thiem B., Wojt W. J., Wojtkowiak-Giera A., Cholewiński M., Skrzypczak Ł., 2012. *Tanacetum vulgare* L. as a plant with potential medicinal properties in *Acanthamoeba* keratitis (in Polish). Nowiny Lekarskie, 81, 6, 620-625.

Higa T., 1998. Effective Microorganisms, concept and recent advances in technology. Proceedings of the Conference on Effective Microorganisms for a sustainable agriculture and environment. 4th International Conference on Kyusei Nature Farming, Bellingham-Washington USA, 247-248.

Hoshino Y., Satou N., Higa T., 2002. Remediation and preservation of natural ecosystems through application of effective microorganisms (EM): Proceedings of 7th International Conference on Kyusei Natural Farming. New Zealand, 129-137.

Janas R., 2009. Possibilities of using Effective Microorganisms in organic production systems of cultivated crops (in Polish). Problemy Inżynierii Rolniczej, (17)3, 111-119.

Jurkowski M., Błaszczyk M., 2012. Physiology and biochemistry of lactic acid bacteria (in Polish). Kosmos, Problemy Nauk Biologicznych, 61(3), 493-504.

Kaczmarek Z., Wolna-Murawka A., Jakubs M., 2008. Changes of the number of selected microorganism groups and enzymatic activity in the soil inoculated with effective microorganism (EM). J. Res. Appl. Agric. Eng., 53 (3), 122-127.

Kołodziejczyk M., 2014b. Effect of nitrogen fertilization and microbial preparations on potato yielding. Plant Soil Environ., 60(8), 379-386, doi:10.17221/7565-PSE

Kołodziejczyk M. 2014a. Effectiveness of nitrogen fertilization and application of microbial preparations in potato cultivation. Turk. J. Agric. For., 38: 299-310, doi:10.3906/tar-1305-105

Kurkina A.V., Khusainova A.I., Daeva E.D. *et al.* (2011) Flavonoids from Tanacetum vulgare flowers. Chem. Nat. Comp., 47(2), 284-285, doi:10.1007/s10600-011-9906-4

Lenartowicz T., 2013. Methodology for the study of the economic value of varieties (WGO). Potato (in Polish). COBORU Publishing House, Słupia Wielka

Liefrink S. R., 2005. Inspection of Dutch seed potatoes, the importance of certified seed potatoes. NIVAP Netherlands publisher, 36.

Martyniuk S., 2010. Production of microbial preparations: symbiotic bacteria of legumes as an example. J. Res. Appl. Agric. Eng., 55(4), 20-23.

Martyniuk S., 2011. Effective and ineffective microbiological preparations used in plant protection and cultivation, and reliable and unreliable methods of their estimation (in Polish). Post. Mikrobiol., 50,4, 321-328.

Martyniuk S., Księżak J., 2011. Evaluation of pseudo-microbial biopreparations used in crop production (in Polish). Polish Journal of Agronomy, 6, 27-33.

Pacholak E., Zydlik Z., 2004. Effect of soil locality on the growth of strawberry plants grown in rhizoboxes. Sodininkystė ir Daržininkystė, 23 (2), 388-394.

Paśmionka I., Kotarba K., 2015. Possible application of effective microorganisms in environmental protection (in Polish). Kosmos, Problemy Nauk Biologicznych, 64(1), 173-184.

Pszczółkowski P., Sawicka B., 2018. The effect of using fungicides, microbiological preparations and herbal extracts on shaping of potato yield (in Polish). Fragm. Agron., 35(1), 81-93.

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

Singh K., 2001. Response of potato (*Solanum tuberosum*) to biofertilizer and nitrogen under North-Eastern hill conditions. Indian Journal Agronomy, 46, 375-379.

Singh M., Biswas S.K., Nagar D., Lal K., Singh J., 2017. Impact of bio-fertilizer on growth parameters and yield of potato. Int. J. Curr. Microbiol. Appl. Sci., 6(5), 1717-1724.

Skowera B., Kopcińska J., Kopeć B., 2014. Changes in thermal and precipitation conditions in Poland in 1971-2010. Ann. Warsaw Univ. of Life Sci. SGGW, Land Reclam., 46(2), 153-162, doi:. 10.2478/sggw-2014-0013

Stewart D. P. C., Daly M. J., 1999. Influence of "effective microorganisms" (EM) on vegetable production and carbon mineralization – a preliminary investigation. J. Sustain. Agr., 14 (2), 3-15.

Struik P.C., Wiersema S.G., 1999. Seed potato technology. Wageningen University Press.

Szewczuk Cz., Sugier D., Baran S., Bielińska E.J., Gruszczyk M., 2016. The impact of fertilizing agents and different doses of fertilizers on selected soil chemical properties as well as the yield and quality traits of potato tubers (in Polish). Annales UMCS E Agricultura, 71(2), 65-79.

Torrance, L. 1992. Developments in methodology of plant virus detection. Neth. J. Plant. Pathol., 98 Suppl., 2, 21-28.

Valarini P.J., Alvarez M.C.D., Gasco J.M., Guerrero F., Tokeshi H., 2003. Assessment of soil properties by organic matter and EM – microorganism's incorporation. R. Bras. Ci. Solo, 27, 519-525, doi:10.1590/S0100-06832003000300013

Vitalini S., Beretta G., Iriti M., Orsenigo S., Basilico N., Dall'Acqua S., Iorizzi M., Fico G., 2011. Phenolic compounds from *Achillea millefolium* L. and their bioactivity. Acta Biochim. Pol., 58(2), 203-207.

Wojcieszyńska D., Wilczek A., 2006. Phenolic compounds of natural origin. Sci. Technol., 6-12. Retrieved 11.04.2018 from https://www.kiosk24.pl/download.html

WRB, 2015. World reference base for soil resources 2014. International soil classification system for naming soils and creating legends for soil maps. Retrieved 20.04.2018 from http://www.fao.org/3/i3794en/I3794en.pdf

Wszelaczyńska E., Wichrowska D., Pińska M., Rogozińska I., 2007. Evaluation of enzymatic browning degree of edible potato tubers induced by herbicides, mechanical damages and storage by means of instrumental and sensory methods. Pol. J. Food Nutr. Sci., 57(3A), 163-166.

Zydlik Z., Zydlik P., 2013. The effect of microbiological products on soil properties in the conditions of replant disease. Zemdirbyste-Agriculture, 100(1), 19-24, doi: 10.13080/z-a.2013.100.003

WPŁYW APLIKACJI BIOPREPARATÓW I FUNGICYDÓW NA PLON I WYBRANE PARAMETRY WARTOŚCI NASIENNEJ SADZENIAKÓW ZIEMNIAKA

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Streszczenie. Wyniki badań oparto na doświadczeniu polowym przeprowadzonym w latach 2014-2016, w Zakładzie Doświadczalnym Oceny Odmian w Uhninie (51°34',23°02'E), na glebie płowej, lekko kwaśnej. Eksperyment wykonano metodą podbloków losowanych, w układzie zależnym, split-plot, w trzech powtórzeniach. Czynnikiem I rzędu były odmiany ziemniaka (Vineta i Satina), zaś czynnik II rzędu stanowiło sześć wariantów ochrony ziemniaka: A – z zastosowaniem fungicydów do zwalczania zarazy ziemniaka, warianty: B, C, D, E – z aplikacją efektywnych mikroorganizmów oraz wariant F – bez stosowania fungicydów i efektywnych mikroorganizmów, jako obiekt kontrolny. Nawożenie organiczne i mineralne pod ziemniak było na jednakowym poziomie (20 $t \cdot ha^{-1}$ gorczycy białej na przyoranie oraz 90 kg N, 39,3 kg P, 112,0 kg $K \cdot ha^{-1}$). Doświadczenie przeprowadzono zgodnie z obowiązującą w stacjach COBORU metodyką badania wartości gospodarczej odmian roślin uprawnych. Zakres badań obejmował ocenę wpływu aplikacji fungicydów i EM (Effective Microorganisms) i wyciągów z ziół na plon oraz parametry jakości sadzeniaków. Wariant ochrony z aplikacją fungicydów przyczynił się istotnie do spadku plonu sadzeniaków, w stosunku do obiekt kontrolnego. Wszystkie warianty ochrony istotnie zwiększyły liczbę oraz współczynnik rozmnożenia sadzeniaków, w stosunku do obiektu kontrolnego. Właściwości genetyczne odmian wywarły istotny wpływ na plon i liczbę sadzeniaków, natomiast nie różnicowały ich przeciętnej masy i współczynnika rozmnożenia. Warunki meteorologiczne i glebowe w latach badań istotnie determinowały oceniane cechy.

Słowa kluczowe: efektywne mikroorganizmy, wyciągi roślinne, fungicydy, odmiany, plon, wartość nasienna