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POTATOES REACTION ON PRP SOL FERTILISATION

Summary

In the paper reaction of potatoes on PRP SOL fertilization was investigated. Experiments on the assessment of potato variety Satina response to the use of PRP SOL were conducted in 2007-2011 in the field in Złotniki belonging to the Experimental Station Gorzyń, Department of Agronomy, University of Life Sciences in Poznań. The trial was established as one factor, in random block design, in four replications. In the cultivation of potatoes, phosphorus-potassium fertilizers can be replaced by fertilizer PRP SOL, as indicated by no significant differences in tuber yields obtained in tested technologies and yield increase trends occurred in four of the five years of research. The leaves of plants fertilized with PRP SOL characterized in each year of the study a higher greenness index, expressed in SPAD unites, which indicates a better nutritional status of plants. The use of PRP SOL fertilizer can be especially useful for potato seed production, because after using it increases the fraction of potato seed in tuber yield.
Key words*: potatoes; fertilizers; fertilization; yields; field experimentation*

REAKCJA ZIEMNIAKÓW NA NAWOŻENIE PRP SOL

Streszczenie

W pracy przedstawiono reakcję ziemniaków na stosowanie PRP SOL. Doświadczenia nad oceną reakcji ziemniaków odmiany Satina na stosowanie PRP SOL prowadzono w latach 2007-2011 na polu w Złotnikach należącym do Zakładu Doświadczalno-Dydaktycznego Gorzyń, Katedry Agronomii, Uniwersytetu Przyrodniczego w Poznaniu. Współrzędne GPS prowadzonego doświadczenia: N 52029, 193 E0160569. Doświadczenie zostało założone jako jednoczynnikowe, metodą losowanych bloków, w czterech powtórzeniach polowych. W uprawie ziemniaków można zastąpić nawozy fosforowo-potasowe nawozem PRP SOL, na co wskazuje brak istotnych różnic w plonach kłębów uzyskanych w porównywanych technologiach nawożenia oraz wystąpienie tendencji wzrostu plonów w czterech spośród pięciu lat prowadzenia badań. Liście roślin nawożonych PRP SOL charakteryzował w każdym roku badań wyższy wskaźnik zieloności, wyrażony w jednostkach SPAD, co świadczy o lepszym stanie odżywienia roślin. Stosowanie nawozu PRP SOL może być szczególnie przydatne do upraw nasiennych, gdyż po jego zastosowaniu wzrasta udział frakcji sadzeniaków w plonie kłębów.
Słowa kluczowe*: ziemniaki; nawozy; nawożenie; plony; badania polowe*

1. Introduction

Among the few fertilizers approved for use in organic farming systems, there is PRP SOL, which can be used for all agricultural crops in annual doses ranging 150-300 kg·ha-1.

It is a balanced blend of granulated minerals produced on the basis of liming materials, which in its composition contains 32% CaO, 8% MgO, and 3.5% sodium (Na) and 3-5% of the prefixes, which introduced into the soil 48 trace elements needed for proper growth and development of plants [13].

In agriculture, for years research is done to find alternative ways to supply the needs of plants for nutrients, which would allow preserving the fertility and yielding possibilities of soil, also in conditions of limited use of fertilizers [9, 14].

PRP SOL fertilization technology assumes that in soil there are large stocks of nutrients, including phosphorus and potassium. Depending on the type of soil phosphorus content ranges from 300 to 6 000 kg P·ha^{-1}, and potassium from 300 to 60 000 kg C ·ha^{-1} [21], but more than 90% of this element in soil is in a form unavailable for crops [12]. Most of the soil phosphorus is in the form unavailable to plants as phosphates $FePO_4$ and $AlPO_4$, and potassium is blocked in clay minerals. Introduction to soil PRP SOL unlocks and provides plants with these elements [10]. According to the manufacturer, Roland Procedes Pigeon from France, PRP SOL is used to fertilize the soil, not plants. This fertilizer improves soil structure, activates the microbial life in soil, resulting in a gradual release of large amounts of components previously unavailable to plants [16]. The company also ensures that the application of PRP SOL achieved improved air-water relationships in soil. The use of soil fertilizers is complementary to the proper crop management, and their effects are faster noticeable usually on degraded soils [1].

The potato is "potassiumphile" plant because of the special role of potassium in the synthesis of starch and protein. Optimally supplied in potassium plants grow well, are fertile and lush, leafy well, resistant to drought and diseases. They produce high tuber yield of good consumer and industrial quality [9, 26]. Optimal supply in potassium plays an important role in the synthesis of starch in tubers.

Application for the cultivation of potatoes only manure or other organic fertilizers are not sufficient because these fertilizers contain too little phosphorus in relation to the requirements of the plant, and potato has very little ability to use phosphorus from sparingly soluble compounds. Hence it is advisable to use each time in the cultivation of potatoes compound fertilizers containing superphosphate in granular form [26]. These fertilizers are not permitted in organic farming. Phosphorus in the plant is involved in various processes that contribute to the metabolism and reproduction. Is an essential component of energetic compounds, part of the nucleic acids, nucleotides, activates enzymes, is part of the structure of cells and their organelles and reserve substances. Underestimated is the effect of phosphorus on yield and quality. The pants rich in phosphorus show greater tolerance to stress caused by low temperature and water deficient [9].

Potato-growing area in organic farms in Poland increased to about 2000 ha in 2010, previously it was about 1500 ha [25]. In the domestic and foreign references there is no information about the reaction of potatoes to fertilizer PRP SOL, approved for use on organic farms. It is therefore important from a cognitive and utilitarian point of view to make such research in Poland.

The aim of this study was to evaluate the usefulness of PRP SOL in the cultivation of potatoes.

The research hypothesis assumes that the PRP SOL can replace traditional phosphorus-potassium fertilization, not permitted in organic farming system. Furthermore, it was assumed that the obtained yields are similar in terms of quantity and quality compared with those obtained from using traditional fertilizing plants.

2. Materials and methods

Experiments on the assessment of potato variety Satina response to the use of PRP SOL were conducted in 2007-2011 in the field in Złotniki belonging to the Experimental Station Gorzyń, Department of Agronomy, University of Life Sciences in Poznań. GPS coordinates of the experiments: N 52029,193 E 01605,69. The trial was established as one factor, in random block design, in four replications. The soil of experimental fields, in accordance with current WRB [2003] soil systematics [21, 24], was classified as luvisols.

The evaluation of the experimental field soil can be divided into classes IVa and, according to agricultural suitability into complex 4 (very good rye). Potatoes grown in the five-year rotation, where maize for grain was always forecrop and straw was plowed after grinding, providing a source of organic matter. The size of plots to harvest was 64 m^2. Control object was fertilized using 80 kg/ha of phosphorus in the autumn (triple superphosphate), 120 kg/ha of potassium (potassium salt) and 130 kg/ha of nitrogen (ammonium nitrate) in the spring (Table 1). Objects treated with PRP SOL were not fertilized with phosphorus and potassium. All tillage treatments were performed in accordance with good agricultural practice.

Soil compaction in the experiments was assessed using a hand penetrometer Eijkelkamp and in 2010 and 2011 by penetrometer Eijkelkamp Penetrologger SN. Leaf area index (LAI) was determined by Sunscom Cangoy Analysis System type SS1 gauge, the nutritional status of plants, expressed in units SPAD by N-Tester Hydro gauge, hectoliter weight and grain moisture by electronic moisture and density meter of seeds with built-in electronic scales, the protein content in dry matter by Kjeldahl method using Kjeltec Foss TM 2200 device. The starch content in tubers was determined by Reimann-Parow scale gauge.

Table 1. Fertilization of experimental objects – dose PRP SOL, phosphorus, potassium and nitrogen (kg·ha^{-1})

Tab. 1. Nawożenie obiektów doświadczalnych – dawki PRP SOL, fosforu, potasu oraz azotu (kg·ha^{-1})

Species / Gatunek	*Object* / Obiekt	PRP SOL	P*	K*	N*
Potato /Ziemniaki	*Control* /Kontrola	0	80	120	130
	PRP SOL	260	0	0	130

** potassium salt 60%, triple superphosphate, ammonium nitrate*

*sól potasowa 60% , superfosfat potrójny, saletra amonowa

3. Results and discussion

The potato is one of the most efficient plants in converting solar energy into food for humans in terms of both quality and quantity of yield obtained [20]. The length of growing period of potato tubers depends on the stage of photosynthetic active leaves of the plant [19].

Leaf area index (LAI) is a fundamental parameter of canopy structure [5]. Frequently it is referred to the ratio of the canopy assimilatory organs, mainly leaves, to the ground surface [8].

LAI index values obtained between 2010 and 2011, were comparable to those obtained by Kołodziejczyk et al. [11], but much higher in 2009, although the measurements were made at similar stages of flowering plants. Potato fertilization with the use of PRP SOL led to the forming of plants usually characterized by a tendency to produce leafy plants better than the control site (Table 2). Leaf area index (LAI) in PRP SOL technology of fertilization was on average for the three years of research, higher by 0,2 compared when using traditional fertilization with phosphorus and potassium, and in studies of this characteristic difference values ranged from -0,4 in 2011, the year of exceptionally dry spring to 0,8 in 2009. These differences, however, was not confirmed statistically. Also in studies on wheat and barley crops has not been proven response to fertilization with PRP SOL, expressed by the values of LAI. Both species showed a slight tendency to reduce the surface of leaves produced per 1m^2 [22]. Fertilization with PRP SOL in each of the years of research had a positive impact on nutritional status of potato plants, expressed in units SPAD, as measured during the beginning of flowering (BBCH 61-63) (Table 3). Also in studies with winter wheat and spring barley fertilization with PRP SOL positively affect the state of green leaves of both species, measured in flowering plants [22]. The intensity of the reaction of potato plants in this respect was different between SPAD units and the increase due to the use of PRP SOL ranged from 14,0 in the dry year 2011 to 55,2 in 2010. In each year of the study and synthesis in terms of years, the differences relative to the control have been proven statistically. SPAD readings were comparable with those of Matysiak et al. [17] studies on the reaction of potatoes in the use of Asahi SL biostimulator containing nitrophenols. In our own studies, as well as this herewith quoted the results were different in different years. Positive response of potato plants to use the PRP SOL was confirmed by harvested tuber yields (Table 4). In four out of five years of research it was observed the trend towards higher yields of crops grown in the technology of PRP SOL, while in 2011, characterized by a three-month drought (Fig. 1) during the spring, the plants have responded to the fertilizer on the contrary, a slight decrease in yield, 4 dt·ha^{-1} (-0,7%). The largest yield increase of tubers of 47 dt·ha^{-1} (7,3%) occurred in 2009, characterized by a very good supply of plants in water from the beginning of vegetation until the end of July, but these differences are not statistically confirmed (Fig. 1). Also positive, confirmed statistically was the effect of PRP SOL on wheat yield, which increased in average for the four years by 3,7%. In case of spring barley there was the lack of such a reaction observed, the yield irrelevant to decline by 0,18% - Sulewska et al. [22]. Strong reaction of potato on the course of weather conditions showed earlier Ciećko et al. [3], obtaining 50% yield of tubers decrease as a result of drought during the growing season.

No significant differences in the yield of potatoes grown using PRP SOL and using phosphorus-potassium fertilizer indicates good and comparable nutritional status of plants grown in this fertilizer as compared to standard phosphorus-potassium fertilization. According to various observations the contribution of individual fractions of tubers in the yield of potatoes depends on fertilization and for example in studies of Dmowski et al. [6] together with the improvement of nutritional status of plants it was shown the increase the participation of tubers with a diameter over 6 cm.

Table. 2. Leaf area index (LAI)
Tab. 2. Indeks powierzchni liści (LAI)

Specification /Wyszczególnienie	*Year* / Rok			*Average* / Średnio
	2009	2010	2011	
Control / Kontrola	3,8	1,3	2,7	2,6
PRP-SOL	4,6	1,5	2,3	2,8
Difference /Różnica	0,8	0,2	-0,4	0,2
LSD $_{(0.05)}$ / NIR $_{(0,05)}$	n.s.	n.s.	n.s.	n.s.

n.s. – *not significant differences* - różnice nieistotne

Table 3. Nitrogen nutritional status (SPAD) – beginning of flowering (BBCH 61-63)
Tab. 3. Stan odżywienia roślin azotem (SPAD) – początek kwitnienia (BBCH 61-63)

Specification /Wyszczególnienie	*Year* / Rok				*Average* /Średnio
	2008	2009	2010	2011	
Control / Kontrola	633,5	491,8	544,8	641,5	577,9
PRP-SOL	667,5	517,8	600,0	655,5	610,2
Difference /Różnica	34,0	26,0	55,2	14,0	32,3
LSD $_{(0.05)}$ / NIR $_{(0,05)}$	26,07	19,41	49,04	11,21	29,82

Table 4. Yield of potato tubers (dt·ha^{-1})
Tab. 4. Plon kłębów (dt·ha^{-1})

Specification /Wyszczególnienie	*Year* / Rok					*Average* /Średnio
	2007	2008	2009	2010	2011	
Control / Kontrola	451,6	116,8	644,7	478,6	592	456,7
PRP-SOL	479,1	124,9	691,7	479,1	588	472,6
LSD $_{(0.05)}$ / NIR $_{(0,05)}$	r.n.	r.n.	r.n.	r.n.	r.n.	r.n.

n.s. – *not significant differences* - różnice nieistotne

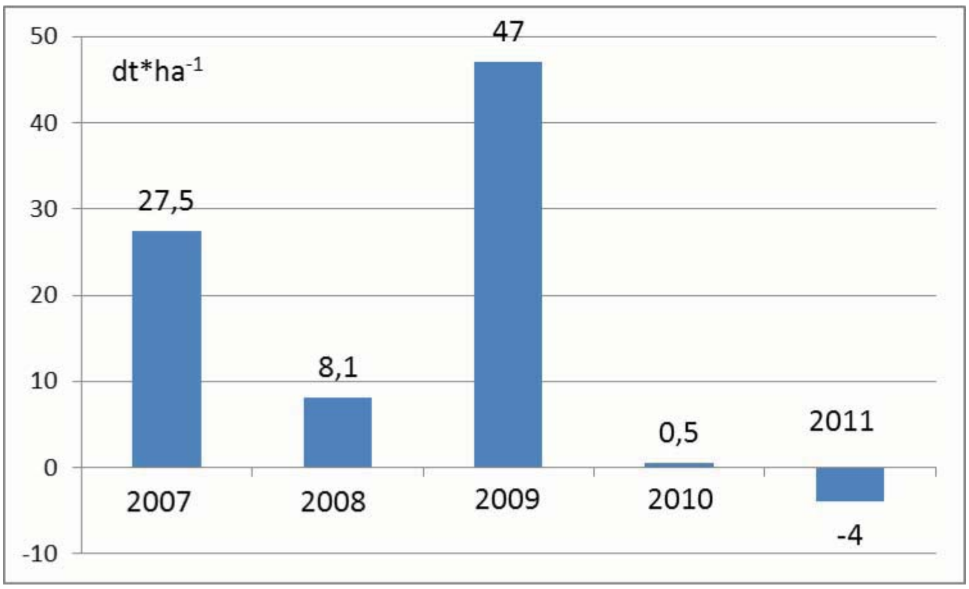

Fig. 1. The difference in potato tubers yields after PRP SOL application compared with the control
Rys. 1. Różnica w plonach kłębów po zastosowaniu PRP SOL w porównaniu z kontrolą

The use of PRP SOL slightly increased the variability of yields in years, as indicated by the higher value of the coefficient of variation (Table 5). The smaller yield stability in the years however was followed by a favorable increase in both the minimum and maximum yield of tubers.

The use of fertilizer PRP SOL caused a tendency to change the structure of tubers yield of potatoes (Table 6 and 7). Increased participation in the mass fraction of tubers with a diameter below 6 cm and below 4 cm in the assessment carried out for the number of tubers, and declining participation of tubers over 6 cm in diameter. Obtaining such a trend in the five years of research, concludes to identify the usefulness of this fertilizer for the production of seed potatoes.

Fertilization is a crop management procedure significantly affecting the quality of the potato yield. Intensifying plant physiological processes, it affects the chemical composition of tubers. This is particularly the case for the use of one-nutrient fertilization or improper ratio of the ingredients used [15].

The effect of fertilizer on the dry matter content in tubers was different in the years of study (Table 7). In summary, the application of PRP SOL caused a trend towards greater by 0.3 points % concentration of dry matter (Table 8). Also in the study of Dmowski et al. [6], this feature is not independent on applied fertilizer, but was associated with a row spacing and weather conditions in particular years. Also, the starch content in tubers was not affected significantly by the use of PRP SOL (Table 9). The difference between values of this parameter in the years ranged from -0.3 ponits % (2010) to 0.3 points % (2007) compared to standard fertilization.

Table 5. Statistical characteristics of potato tubers yield (dt·ha^{-1})
Tab. 5. Charakterystyki statystyczne plonu kłębów (dt·ha^{-1})

Specification /Wyszczególnienie	*Values* / Wartości		*Standard deviation* /Odchylenie standardowe *SD*	*Coefficient of Variation* Współczynnik zmienności *CV%*
	Minimum /Minimalna	*Maximum* /Maksymalna		
Control / Kontrola	116,8	644,7	206,0	45,09
PRP-SOL	124,9	691,7	213,5	45,18

Table 6. Structure of potato tuber yield in the mass – (2007-201)
Tab. 6. Struktura plonu kłębów w masie – (2007-2011)

Specification /Wyszczególnienie	*% Fractions participation* / % Udział frakcji			
	<3 cm	3-4 cm	4-6 cm	>6 cm
Control / Kontrola	1,7	5,0	47,6	45,7
PRP-SOL	2,3	5,4	48,5	43,8
Difference /Różnica	0,6	0,4	0,9	-1,9
LSD $_{(0.05)}$ / NIR $_{(0,05)}$	r.n.	r.n.	r.n.	r.n.

n.s. – *not significant differences* - różnice nieistotne

Table 7. The structure of potato tubers yield in the number – (2007-2011)
Tab. 7. Struktura plonu kłębów w liczbie – (2007-2011)

Specification Wyszczególnienie	*% Fractions participation* / % Udział frakcji			
	<3 cm	3-4 cm	4-6 cm	>6cm
Control / Kontrola	8,2	12,3	53,6	25,9
PRP-SOL	8,6	14,3	52,6	24,5
Difference /Różnica	0,4	2,0	-1,0	-1,4
LSD $_{(0.05)}$ / NIR $_{(0,05)}$	r.n.	r.n.	r.n.	r.n.

n.s. – *not significant differences* - różnice nieistotne

Table 8. Dry matter content in potato tubers (%)
Tab. 8. Zawartość suchej masy w kłębach (%)

Specification /Wyszczególnienie	*Year* / Rok					*Average* /Średnio
	2007	2008	2009	2010	2011	
Control / Kontrola	20,8	20,7	16,3	19,9	17,3	19,0
PRP-SOL	19,0	21,7	17,1	19,4	19,3	19,3
Difference /Różnica	-1,8	1,0	0,8	-0,5	2,0	0,3
LSD $_{(0.05)}$ / NIR $_{(0,05)}$	0,92	r.n.	r.n.	r.n.	r.n.	r.n.

n.s. – *not significant differences* - różnice nieistotne

Table 9. Starch content in potato tubers (%)
Tab. 9. Zawartość skrobi w kłębach (%)

Specification /Wyszczególnienie	*Year* / Rok					*Average* /Średnio
	2007	2008	2009	2010	2011	
Control / Kontrola	11,8	12,0	9,7	11,5	12,5	11,5
PRP-SOL	12,1	11,8	9,8	11,2	12,4	11,5
Difference /Różnica	0,3	-02	0,1	-0,3	-0,1	0,0
LSD $_{(0.05)}$ / NIR $_{(0,05)}$	r.n.	r.n.	r.n.	r.n.	r.n.	r.n.

n.s. – *not significant differences* - różnice nieistotne

Table 10. Starch yield (dt·ha⁻¹)
Tab. 10. Plon skrobi (dt·ha⁻¹)

Specification /Wyszczególnienie	*Year* / Rok					*Average* /Średnio
	2007	2008	2009	2010	2011	
Control / Kontrola	53,3	14,0	62,5	55,0	74,0	51,8
PRP-SOL	58,0	14,7	67,8	53,7	72,9	53,4
Difference /Różnica	4,7	0,7	5,3	-1,3	-1,1	1,6
LSD $_{(0.05)}$ / NIR $_{(0,05)}$	1,79	r.n.	4,25	r.n.	r.n.	r.n.

n.s. – *not significant differences* - różnice nieistotne

Table 11. Statistical characteristics of starch yield (dt·ha⁻¹)
Tab. 11. Charakterystyki statystyczne plonu skrobi (dt·ha⁻¹)

Specification /Wyszczególnienie	*Values* / Wartości		Standard deviation /Odchylenie standardowe *SD*	Coefficient of Variation /Współczynnik zmienności *CV%*
	Minimum /Minimalna	*Maximum* /Maksymalna		
Control / Kontrola	14,0	74,0	22,6	43,72
PRP-SOL	14,7	72,9	23,0	42,96

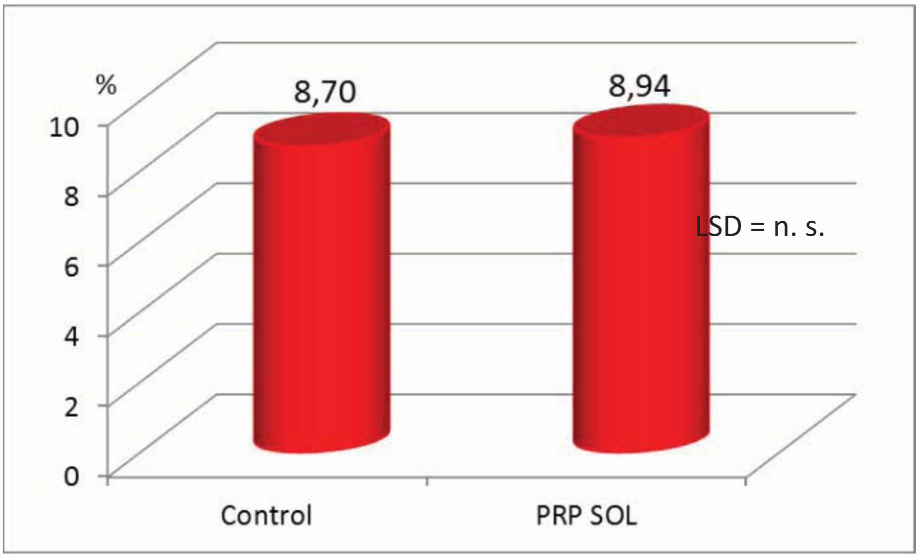

Fig. 2. Protein content in potato tubers (%)
Rys. 2. Zawartość białka w kłębach (%)

In studies of Dmowski et al. [6], the starch content in tubers varied depending on the level of fertilization from 15,5% to 15,9% and was higher than in reported study on control objects as well as fertilized with PRP SOL. The concentration of starch to a large extent is related with the variety and weather conditions during the growing period of potatoes, which may explain these differences. Ciećko et al. [4] showed that the starch content corresponds inversely to the amount of rainfall, and fertilization did not cause a significant change in the concentration of this component.
The yield of starch in three of the five years of research does not depend significantly on the type of fertilizer (Table 10). In general, the yield of starch is more associated with total yield of potato tubers than the concentration of this component in the tubers. In 2007 and 2009, years with very good moisture conditions (Fig. 2), after application of PRP SOL achieved a significant increase in yield of starch. Declines of this yield in any of the years were not statistically significant.

The use of PRP SOL somewhat stabilized starch yield obtained in the years of research, as evidenced by the lower value of the coefficient of variation (Table 11). Fertilizer caused an increase in the minimum yield of starch, but at the same time decrease the maximum value.

The protein content in tubers obtained after application of PRP SOL increased by 0.24 points %, but this difference was not confirmed statistically (Fig. 2). On the other hand, in previous studies of Sulewska et al. [22] on winter wheat and spring barley, it has been shown that the use of PRP SOL results in a significant increase in the concentration of protein in wheat grain and such a trend in grain of spring barley was ales observed.

As well-known potato is a "potassiumphile" plant because of the special role of potassium in the synthesis of starch and protein [26]. No significant differences in starch and protein content in tubers of potatoes grown in the compared technologies fertilization proves a good supply of potassium and phosphorus-fertilized plants traditionally and by the PRP SOL. Birch et al. [2] showed that the stimulating effect of potassium on starch in potatoes is in terms of optimal doses, whereas higher doses cause its inhibition. The studies of Mazur and Frieske [18] showed that fertilization positively affected the percentage of starch in tubers. The application of PRP SOL to increasing doses of compost at the Crooked-Gawrońska studies [14] led to increased levels of starch and fat in the tested plants, including starch content in the potato tuber yield.

4. Conclusions

1. In the cultivation of potatoes, phosphorus-potassium fertilizers can be replaced by fertilizer PRP SOL, as indicated by no significant differences in tuber yields obtained in tested technologies and yield increase trends occurred in four of the five years of research.
2. The leaves of plants fertilized with PRP SOL characterized in each year of the study a higher greenness index, expressed in SPAD unites, which indicates a better nutritional status of plants.
3. The use of PRP SOL fertilizer can be especially useful for potato seed production, because after using it increases the fraction of potato seed in tuber yield.

5. References

[1] Biernacki J.: Ulepszacze glebowe: duża oferta i możliwości. Top Agrar, 2010, 7: 72-75.

[2] Birch J.A., Devine J.R., Holmes M.R.J., Whiteor J.D.: Field experiments on on the fertilizer requirements of main crop potatoes. J.Agric.Sci., 1993, 69(1): 13-24.

[3] Ciećko Z., Żołnowski A., Wyszkowski M.: Plonowanie i zawartość skrobi w bulwach ziemniaka w zależności od nawożenia NPK. The effect of NPK fertilization on tuber yield and starch content in potato tubers ANNALES UNIVERSITATIS MARIAE CURIE-SKŁODOWSKA LUBLIN – POLONIA SECTIO E, 2004, 59(1): 399-406.

[4] Ciećko Z., Krajewski W., Wyszkowski M., Żołnowski A.: Wpływ nawożenia fosforem na plonowanie, zawartość skrobi i witaminy C w bulwach ziemniaka. Prac. Nauk. AE we Wrocławiu, 2004, 1017: 120-132.

[5] Czerednik A., Nalborczyk E.: Współczynnik wykorzystania napromieniowania fotosyntetycznie aktywnego (RUE) – nowy wskaźnik fotosyntetycznej produktywności roślin w łanie. Biul. IHAR, 2000, 215: 13-22.

[6] Dmowski Z., Nowak L. Kruhlak A.: Wpływ deszczowania, gęstości sadzenia i zróżnicowanego nawożenia mineralnego na wysokość i jakość plonu ziemniaka. Zesz. Probl. Post. Nauk Rol., 2002, 489: 239-247.

[7] Gleboznawstwo. Pod red. B. Dobrzańskiego i S. Zawadzkiego. PWRiL, 1981: 368 ss.

[8] Gregorczyk A., Piech M.: Porównanie dynamiki wzrostu owsa nieoplewionego z oplewionym. Biul. IHAR, 2000, 215: 201-208.

[9] Grzebisz W.: Nawożenie roślin uprawnych. PWRiL, 2008, ss. 234.

[10] Hüttl R.F., Fischer Th.: Ekspertyza dotycząca działania produktu „PRP Boden” (podłoże PRP) na uprawy polowe. Politechnika Brandenburska, Cottbus, 2004: 1-7.

[11] Kołodziejczyk M., Ropek D., Szmigiel A.: Kształtowanie się powierzchni asymilacyjnej roślin ziemniaka oraz składu chemicznego bulw w zależności od metody zwalczania stonki ziemniaczanej. Prog. in Plant Prot./Post. w Ochr. Roślin, 2010, 50(1): 477-481.

[12] Krzywy E.: Żywienie roślin. Wyd. Akademia Rolnicza w Szczecinie, 2007, ss. 178.

[13] Krzywy E.: Ocena wpływu substancji czynnej PRP na kształtowanie żyzności i urodzajności gleb. w: Dla rolnictwa czystego i produktywnego. PRP Polska, Warszawa, 2008: 31-32.

[14] Krzywy-Gawrońska E.: Badania wpływu kompostu z komunalnego osadu ściekowego i substancji czynnej PRP SOL na żyzność i urodzajność gleby. Wyd. ZUT Szczecin, 2009, ss. 96.

[15] Leszczyński W.: Zależność jakości ziemniaka od stosowania w uprawie nawozów i pestycydów. The influence of fertilizer and pesticide use on potato quality. Zesz. Probl. Post. Nauk Rol., 2002, 489: 65-72.

[16] Lipski S.: Żywienie roślin czy nawożenie gleby? W: Dla rolnictwa czystego i produktywnego. PRP Polska, Warszawa, 2008, 1: 3-6.

[17] Matysiak K., Adamczewski K., Kaczmarek S.: Wpływ biostymulatora Asahi SL na plonowanie i wybrane cechy ilościowe i jakościowe niektórych roślin rolniczych uprawianych w warunkach Wielkopolski. Progr. in Plant. Prot./Post. w ochr. Roślin, 2011, 51(4): 1849 - 1857.

[18] Mazur T., Frieske J.: Wpływ nawożenia obornikiem oraz wapniem, magnezem i mikroelementami na plon i skład chemiczny sześciu odmian ziemniaka. Influence of farm manure, calcium, magnesium and mikronutrients applied to soil on yield and quality of six potatoe cultivars. Zesz. Nauk. ART w Olsztynie, Rolnictwo, 1984, 40: 65-77.

[19] Milthrope F.L., Moorby J.: Wstęp do fizjologii plonowania roślin. Warszawa: PWRiL, 1979.

[20] Niederhauser J.S.: International cooperation and the role of potato in feeding the world. Am. Potato J., 1993, 70: 385-403.

[21] Praca zbiorowa pod red. J. Marcinka i J. Komisarek. Roczniki Gleboznawcze, 2011, Wydanie 5, LXII (3), Warszawa, ss.193.

[22] Sulewska H., Koziara W., Panasiewicz K., Niewiadomska A.: Reakcja pszenicy ozimej i jęczmienia jarego na nawożenie PRP SOL. J. Res. and Applic. Agric. Engng, 2011, 56(4): 129-133.

[23] Walter H.: Strefy roślinności a klimat, 1976: 26-31.

[24] WRB: Klasyfikacja zasobów glebowych świata. Polish Soil Science Society, Toruń, ss. 106, 2003.

[25] www.piagro.pl/artykuly-rolnicze/produkcja-roslinna/warzywa/ekologiczna-uprawa-ziemniaka

[26] www.ppr.pl/artykul-wplyw-nawozenia-ziemniaka-na-wielkosc-i-jakosc-plo-86252-dzial-2203.php