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COMPOSITION OF SOIL SOLUTION AFTER 10 YEARS OF PRP SOL FERTILIZATION BASED ON THE SELECTED CHEMICAL PROPERTIES

Summary

The paper presents the results of the research on the effect of PRP SOL fertilization on the basic chemical properties of soil and composition of soil solution. The soil has been sampled from the level of humus of many years' experiment established on light soil using traditional fertilization (NPK) and PRP SOL fertilizer was used instead of PK fertilization. Nitrogen doses remained the same in both combinations. Collected samples for testing were taken from a depth of 0-20 cm using an automatic soil sampler. In the plots where PRP SOL fertilization was applied, a statistically significant decrease in the content of available forms of potassium and an increase in the amount of available magnesium forms were observed. There was no significant influence of factors used in the experiment on total organic carbon and nitrogen content. Long-term application of PRP SOL fertilization resulted in statistically significant differences in chemical composition of soil solutions. A significant decrease in the concentration of the following components was observed in these plots: K^+, Na^+, PO_4^{3-}, NH_4^+ and the increase in pH value. Modification effect on soil solution chemistry was also caused by the species of cultivated plants.
***Key words**: soil properties, fertilization, soil solution, chemical composition, PRP SOL*

SKŁAD ROZTWORU GLEBOWEGO PO 10-CIO LETNIM OKRESIE NAWOŻENIA PRP SOL NA TLE WYBRANYCH WŁAŚCIWOŚCI CHEMICZNYCH

Streszczenie

W pracy przedstawiono wyniki badań dotyczące wpływu nawożenia PRP SOL na podstawowe właściwości chemiczne gleb oraz skład roztworu glebowego. Przedmiotem badań były próbki glebowe pobrane z poziomu próchnicznego wieloletniego doświadczenia założonego na glebie płowej, na której stosowane było nawożenie tradycyjne (NPK) oraz zamiast nawożenia PK stosowany był nawóz zwany PRP SOL. Dawki azotu pozostały w obu kombinacjach takie same. Próbki powierzchniowe – średnie do badań pobrano z głębokości 0-20 cm za pomocą automatycznego próbnika glebowego. Na poletkach, na których było stosowane nawożenie PRP SOL stwierdzono statystycznie istotny spadek zawartości przyswajalnych form potasu oraz wzrost ilości przyswajalnych form magnezu. Nie stwierdzono istotnego wpływu zastosowanych w doświadczeniu czynników na zawartość węgla organicznego oraz azotu ogółem. Wieloletnie stosowanie nawożenia PRP SOL spowodowało statystycznie istotne różnice w składzie chemicznym roztworów glebowych. Na tych poletkach stwierdzono istotny spadek stężenia następujących składników: K^+, Na^+, PO_4^{3-}, $NH4^+$ oraz wzrost wartości odczynu. Modyfikujący wpływ na chemizm roztworu glebowego wywierał także gatunek uprawianych roślin.
***Słowa kluczowe**: właściwości gleby, nawożenie, roztwór glebowy, skład chemiczny, PRP SOL*

1. Introduction

In the time of intensive activities undertaken for sustainable development, much attention is paid to agriculture as well as to the protection of soils. From a practical point of view it means skillful use of the earth's resources without excessive interference or destruction of its natural resources and, above all, the skillful fertilization of crops to preserve the nutrient content of the soil and its fertility. Such soil may be the basis of sustainable agricultural production [9]. Piwowar [12] draws attention to problems related to ensuring sustainable fertilization in Poland, pointing to the problem of the decrease in organic matter content in our soils, including ecologically managed soils. Cupiał et al. [1] report that there is a real danger of permanent reduction in organic matter and nutrients in ecologically managed soils, largely contributed by the absence of animal production, which is the basis for the supply of organic matter. Approximately 90% of the 265 farms carrying out organic farming surveyed do not produce livestock and do not use fertilizers [1]. The above authors also point out that in all non-livestock farms there is a process of soil degradation due to decrease in nutrients and, in addition, with insufficient application of calcium fertilizers. In the period from 1990 to 2011 there was a drastic reduction of fertilizer lime application from 182.8 to 36.8 kg $CaO\cdot ha^{-1}$ [4], which contributes to the progressive acid degradation of soils [3]. Acidification of soil is particularly harmful to plants, because on the one hand it limits the availability of mineral nutrients and on the other hand facilitates the release of toxic components such as aluminum and manganese or mobile forms of heavy metals from the sorption complex to the soil solution [4, 13]. Half of the area of very acidic and acidic soils contain a low level of phosphorus available for plants. Similarly, the low content of available potassium is recorded mainly in very acidic and acidic soils [4]. Therefore, an important tool to influence the course of biochemical processes of soil is to regulate its acidity. This largely determines the sorption properties of soils, which play an important role as a factor regulating the leaching of nutrients from soil, deciding on the efficiency of fertilization and regulating plant nutrition [7].

Liming is a well-known and effective method of changing the pH of acidic and very acidic soils. Modern calcium-magnesium fertilizers currently available in the market contain calcium and magnesium carbonates in addition to active ingredients. One such fertilizer is PRP SOL manufactured by PRP company. PRP SOL was registered as calcium and magnesium fertilizers (Attachment 18 to the Fertilizer and Fertilization Act from 26.07.2000) and may be used in organic farming in accordance with EU Directive 834/2007 and the "Certificate of Product Qualification" from 05 July 2005, no. NE/33/2005 insured by IUNG-PIB.

As indicated by previous studies, it also improves the biological properties of soil, promotes the development of soil fauna and directly affects the amount of microorganisms, thus contributing to the release chemical elements from clay minerals, especially potassium which are more available to plants [10, 20]. The possibility of using PRP SOL fertilizer to increase soil fertility would be particularly important in the growing number of farms and cultivated areas certified for organic production. Besides, rebuilding the natural fertility of the soil is an urgent challenge for agriculture [6].

Soil solution is the most dynamic part in the three-phase soil system [8, 14]. Its chemical composition gives important information about the degree of anthropogenic effect [16, 17, 19]. The concentration of individual ions can determine the rate of uptake by the plants [8, 15] and the degree of supply of plants to certain nutrients [2, 18].

The purpose of the research was to determine the basic chemical properties and composition of soil solution in soil samples collected from field experiments after 10 years of PRP SOL fertilization, and to indicate if and to what extent the content of available forms of phosphorus and potassium decreased.

2. Material and methods

Field experiments were conducted in Złotniki in the fields of the Experimental and Didactic Department of Gorzyń, Poznan University of Life Sciences. The soils of the experimental field according to the Polish PTG system belong to the typical, while according to WRB, to Luvisol. The soils have been classified into the class IVa of the excellent rye complex. The experiment has been carried out in 2007 – 2016. At that time, two rotations of five-field cycle were carried out: potatoes on manure (30 $t{\cdot}ha^{-1}$), spring barley, winter oilseed rape with plough down of self-sown seeds, spring wheat with after crop (rye with vetch) and maize. The GPS coordinates of the experimental field were as follows: N 52 29.193'; E 016 20.569'.

Annually, 5 single experiments were planned in a randomized block design, in four plot replications. The size of plots for harvesting was 32 m^2. The following factors were taken into account in the experiment:

- control object - mineral fertilization P and K, in doses: 80 kg $P{\cdot}ha^{-1}$ (triple superphosphate 46%) and 120 kg $K{\cdot}ha^{-1}$ (potassium salt 60%),
- PRP SOL object fertilized at 260 $kg{\cdot}ha^{-1}$ under potatoes and 220 $kg{\cdot}ha^{-1}$ before sowing the other species.

Nitrogen fertilization in the form of ammonium nitrate was applied to all experimental plots at the following doses ($kg\ N{\cdot}ha^{-1}$): under potatoes 130, under spring barley 40, under winter rape 120, under winter wheat 100 and under corn 160.

All agrotechnical treatments for each of the tested species were carried out in accordance with the principles of good agricultural practice.

The average soil samples after harvest of the plants, from each plot, randomly from layer 0 - 20 cm, were taken by means of a mechanical soil sampler. Samples were dried at 50^0C, then chopped in a porcelain mortar and sieved through a sieve of mesh size 2 mm.

In the room-dry parts of the soil there were analyzed:

- C and N by elemental analysis by Vario Max device
- Available forms of P and K by Egner-Riehm (DL) method
- Available forms of magnesium by the Sachtschabel method

The soil solution was mixed with 1:1 deionized water. The obtained soil solutions were analyzed for:

- nitrates ($N\text{-}NO_3^-$), phosphates ($P\text{-}PO_4^{3-}$), ammonium ($N\text{-}NH_4^+$) – by colorimetric method,
- Ca^{+2}, Na^+, K^+ by atomic emission spectrometry - ESA, using Varian 220 FS device
- Mg^{+2} by the AAS method on Varian 220 FS device,
- electrolytic conductivity – by conductivity method on Orion devise,
- Cl^- - titrated with $AgNO_3$ in the presence of potassium chromate as an indicator.
- HCO_3^- - titrated with HCl.

The results obtained were statistically calculated using the Statistica 12 software, performing a variance analysis, and homogeneous groups were determined by the Tukey test at significance level $\alpha = 0.05$.

3. Results and discussion

The analyzed soils in terms of soil texture according to the division of PTG were classified into loamy sands. The content of the clay fraction, which influences the physicochemical properties of the soil, was relatively low in value and varied, ranged between 4-5%. The silt content was 16-20% (Table 1). The sand fraction was predominant and its amount in the analyzed soil samples was in the range of 75-79%.

Table 1. Texture of examined soils
Tab. 1. Skład granulometryczny badanych gleb

Percentage share of soil fractions (diameter in mm) *Procentowy udział frakcji ziemistych (średnica w mm)*			
Sand 2-0,05	Silt 0,05-0,002	Clay <0,002	Textural-group *Grupa granulometryczna*
75-79	16-20	4-5	pg

Source: own work / Źródło: opracowanie własne

Long-term application of PRP SOL did not affect significantly the content of organic carbon and total nitrogen compared to control. In PRP SOL soil there was 0.79% C, and 0.071% N, and in control soil - of 0.80% C and 0.072% N. Also, the long-term use of this fertilizer did not significantly affect changes in C:N and its value was 11.1 on plots treated with PRP and 11.2 in control soil samples. The pH of the tested soils ranged from acidic to slightly acidic and the average pH measured in H_2O was 5.47, while for plots after 10 years of PRP SOL fertilization was statistically significantly higher and amounted to 5.68. The pH values measured in the potassium chloride solution were lower compared to those obtained in the water extract and amounted for control 4.86, and for the PRP SOL pH of 5.10. Statistically significant increase in pH of PRP SOL fertilized soil was obtained.

The potassium content after ten years of PRP SOL application allowed us to classify the tested soils as the class with medium content. A statistically significant lower content of this macronutrient was observed in the plots on which the PRP SOL fertilization was applied compared to the control.

The average content of available phosphorus determined in lactic calcium was 67,4 mg P·kg^{-1} (combination with PRP) and 72,8 mg P·kg^{-1} (control), which allowed classification of analyzed soils into soils of high content class in this component. An unconfirmed statistically decrease in the content of this component was observed in soil samples taken from plots applied with PRP SOL.

It has been observed that the fertilizer used in the experiment has a beneficial effect on the content of available forms of magnesium. After more than ten years of PRP SOL application, a statistically significant increase in the content of available Mg forms has been observed. The average content of this nutrient in the samples taken from control plots was 46.0 mg Mg kg^{-1} (III - medium content class) and 57.8 mg Mg kg^{-1} (II high content class) for combination with PRP. By expressing the values of magnesium in the form of content classes, it was found that after 10 years of PRP SOL application, there was an increase in the fertility of these soils in this component compared to the control, from the medium to high content class.

Table 2. Basic chemical properties of soil samples from plots fertilized with PRP SOL and control

Tab. 2. Podstawowe właściwości chemiczne próbek glebowych pobranych z poletkach nawożonych preparatem PRP SOL oraz kontrolnych

Fertilization *Nawożenie*	C	N	C:N	pH		K	P	Mg
	%			H_2O	KCl	mg·kg^{-1}		
PRP	0,79a	0,071a	11,1a	5,68b	5,10b	97,4a	67,4a	57,8b
Control *Kontrola*	0,80a	0,072a	11,2a	5,47a	4,86a	136,5b	72,8a	46,0a

differences between medians marked by the same letters are not ignificant / *wartości oznaczone tymi samymi literami nie różnią się* istotnie

Source: own work / Źródło: opracowanie własne

Table 3. Electrolytic conductivity (EC) and water soluble constituents in soil samples taken from plots fertilized with PRP and control (mg·dm^{-3})

Tab. 3. Przewodnictwo elektrolityczne (EC) oraz stężenie składników rozpuszczalnych w wodzie w próbkach glebowych pobranych z poletek nawożonych PRP oraz kontrolnych (mg·dm^{-3})

Plant *Roślina*	Fertilization *Nawożenie*	EC	K^+	Na^+	Mg^{2+}	Ca^{2+}	P –PO_4^{-3}	NH_4^+	NO_3^-	Cl-	HCO_3^-
		μS·cm^{-1}	mg·dm^{-3}								
PRP	PRP	197,6a	12,8a	3,6b	6,2a	43,1a	2,4a	2,36a	153,3a	13,2a	143,7a
Control *Kontrola*	Control *Kontrola*	209,7a	24,2b	2,6a	5,4a	43,1a	3,3b	3,30b	146,4a	17,3a	132,2a

differences between medians marked by the same letters are not ignificant / *wartości oznaczone tymi samymi literami nie różnią się* istotnie

Source: own work / Źródło: opracowanie własne

Table 4. pH, electrolytic conductivity and concentration of water soluble constituents in soil samples taken from plots with grown winter oil seed rape, fertilized with PRP and control

Tab. 4. Odczyn, przewodnictwo elektrolityczne i stężenie składników rozpuszczalnych w wodzie w próbkach glebowych pobranych z poletek spod uprawy rzepaku nawożonych PRP i kontrolnych

Plant *Roślina*	Fertilization *Nawożenie*	pH		(EC)	K^+	Na^+	Mg^{2+}	Ca^{2+}	P –PO_4^{3-}	NH_4^+	NO_3^-	Cl^-	HCO_3^-
		H_2O	KCl	μS·cm^{-1}	*mg·dm^{-3}*								
Winter oil seed rape Rzepak	PRP	5,30a	4,82a	264,5a	12,8a	3,4a	8,9a	53,9 a	2,1a	2,10a	186,2a	14,77a	181,17a
	Control *Kontrola*	5,31a	4,76a	315,8a	34,1b	3,2a	8,9a	59,7a	3,1b	3,09b	191,1a	28,03a	136,03a

differences between medians marked by the same letters are not ignificant / *wartości oznaczone tymi samymi literami nie różnią się* istotnie

Source: own work / Źródło: opracowanie własne

Table 5. pH, electrolytic conductivity and concentration of water soluble constituents in soil samples taken from plots with grown spring barley fertilized with PRP and control

Tab. 5. Odczyn, przewodnictwo elektrolityczne i stężenie składników rozpuszczalnych w wodzie w próbkach glebowych pobranych z poletek spod uprawy jęczmienia jarego nawożonych PRP i kontrolnych

Plant *Roślina*	Fertilization *Nawożenie*	pH		(EC)	K^+	Na^+	Mg^{2+}	Ca^{2+}	P –PO_4^{3-}	NH_4^+	NO_3^-	Cl^-	HCO_3^-
		H_2O	KCl	μS·cm^{-1}	*mg·dm^{-3}*								
Spring barley *Jęczmień jary*	PRP	5,90a	5,38a	197,3a	22,5a	3,0a	6,4a	42,6a	3,5a	2,10a	186,2a	5,51a	121,90a
	Control *Kontrola*	5,74a	5,13a	213,0a	31,3a	2,7a	5,8a	43,9a	3,9a	3,09b	191,1a	8,68a	98,41a

differences between medians marked by the same letters are not ignificant / *wartości oznaczone tymi samymi literami nie różnią się* istotnie

Source: own work / Źródło: opracowanie własne

Table 3 summarizes the chemical composition of the soil solution of soil samples taken from plots treated with PRP SOL and control. Electrolytic conductivity, which is a parameter correlated with ion concentration, was slightly higher in solutions obtained from control plots (209.7 μS·cm^{-1}), than in PRP SOL soil (197.6 μS·cm^{-1}). These differences, however, turned out to be statistically insignificant.

The studies showed statistically significant influence of PRP SOL fertilization on changes in concentration of K^+, Na^+, P - PO_4^{3-}, NH_4^+. The average water soluble potassium concentration in PRP SOL fertilized plots was 12.8 mg·dm^{-3} and was significantly lower than control at 24.2 mg·dm^{-3}. With the PRP SOL application, the content of 2.6 mg·dm^{-3} sodium increased to 3.6 mg·dm^{-3}. In addition, significant concentrations of phosphate ions from 3.3 mg P -PO_4^{3-}·dm^{-3} to 2.4 mg P -PO_4^{3-}·dm-3 were noted in PRP fertilized plots. A similar significant effect of the factor (PRP) used in the experiment was found for the concentration of ammonium ions in the soil solution. Their average content in PRP-treated soils was 2.36 mg NH_4^+·dm^{-3} and 3.30 mg NH_4^+·dm^{-3} in control soil. PRP SOL application slightly increased concentrations of Mg^{2+}, NO_3^-, HCO_3^-, and Cl^-, but the observed differences were not statistically proved. Concentration of Ca^{2+} ions in water solutions obtained from the fertilized and control soil samples were similar and the average value for both variants was 43.1 mg Ca^{2+}·dm^{-3}.

Table 4 summarizes the results of the chemical composition of water solutions obtained from soil samples taken from rape plots applied with traditional (phosphorus-potassium) fertilizers and PRP SOL fertilizers. There was no statistically significant effect on PRP SOL application in the experiment. Its values pH measured both in water extract and the potassium chloride were relatively low. With respect to pH the analyzed soils were classified as acidic. Water soluble ions obtained from the plots with winter oilseed rape was dominated by nitrate ions. Their concentration for PRP and control soils was 186.2 mg NO_3^-·dm^{-3} and 191.1 mg NO_3^-·dm^{-3} respectively. There was no significant effect of the factors used in the experiment on the content of these ions. On the rape plots after replacement of phosphate-potassium fertilization with PRP SOL application, a statistically significant decrease in concentration in soil solutions of K^+ and PO_4^{3-} as well as ammonium ions was observed. Of the mentioned ions, the largest decrease (almost three times) was obtained for potassium.

Table 5 summarizes the results of the study on the composition of soil solutions obtained from plots with grown spring barley. Based on the presented data it was observed that only in the case of ammonium ion significant lower concentrations were observed in the solutions obtained from PRP plots. At concentrations of K^+, Na^+, Mg^{2+}, Ca^{2+}, P -PO_4^{3-}, NO_3^-, Cl^-, HCO_3^- it was found that there were no statistically significant differences between the concentrations of these components in solutions obtained from soil samples where PRP was applied and control. In turn Sulewska et al. [20], who conducted a similar study on the effect of PRP on the yielding of spring barley, did not find its response to the applied fertilization technology.

Sulewska et al. [20] investigating the effect of replacing phosphate-potassium fertilizers with PRP SOL fertilizer, on the basis of the obtained results showed positive influence of fertilization with PRP SOL on significant increase of winter wheat yield. The average values of composition of soil solution of samples from plots with winter wheat under different fertilization technologies are summarized in Table 6. Analyzing the results of laboratory tests of soil samples collected from wheat plots, it was found that the use of PRP SOL caused significant increase of pH determined in both the KCl and water extracts. The increase in electrolytic conductivity has also been observed, however it has not been confirmed statistically. Concentration of analyzed ions of K^+, PO_4^{3-} and Cl^- in soil samples taken from plots fertilized with PRP SOL was significantly lower than that of control plots. In the case of ions such as Na^+, Mg^{2+}, Ca^{2+} and HCO_3^-, their concentration increased with the application of PRP SOL, but it was not statistically proven.

It is apparent from the literature [20] that the application of PRP SOL fertilization in potato cultivation has a beneficial effect on the yield. The composition of the soil solutions obtained from the soil samples taken from this plant is presented in Table 7. From the figures shown, the fertilizer application resulted in a significant decrease in the concentration of potassium, ammonium and phosphate ions in the soil solutions with the simultaneous growth of sodium ions. Based on the obtained results, relatively low concentration of potassium ions in the soil solutions obtained in soil samples collected from the cultivation of this plant was found. The concentration of these ions was respectively 11.3 mg K·dm^{-3} and PRP 8.6 mg K·dm^{-3}.

From the research conducted by Sulewska et al. [20] concerning the effect of PRP on maize yield, the beneficial effect of PRP SOL application was found to be undoubtedly reflected in the chemical properties of the soil on which it was cultivated. The chemical properties of the soil solutions obtained from the soil samples taken from plots grown with maize are summarized in Table 8. The cultivation of maize, which belongs to plants with long vegetation and high nutrient requirements, resulted in the significant changes in soil chemistry of the soil solutions after application of PRP SOL. On plots after replacing potassium phosphate fertilization with PRP SOL almost threefold decrease in potassium concentration was observed, also a significant decrease of phosphate and ammonium ions, but a significant increase in concentration of calcium, magnesium and nitrate ions.

Table 6. pH, electrolytic conductivity (EC) and concentration of water soluble constituents in soil samples taken plots with grown winter wheat fertilized with PRP and control

Tab. 6. Odczyn, przewodnictwo elektrolityczne ((EC) i stężenie składników rozpuszczalnych w wodzie w próbkach glebowych pobranych z poletek spod uprawy pszenicy ozimej nawożonych PRP i kontrolnych

Plant Roślina	*Fertilization* Nawożenie	pH		*(EC)*	K^+	Na^+	Mg^{2+}	Ca^{2+}	P –PO_4^{3-}	NH_4^+	NO_3^-	Cl^-	HCO_3^-
		H_2O	KCl	μS·cm^{-1}	*mg·dm^{-3}*								
Winter wheat *Pszenica ozima*	PRP	5,87b	5,20b	158,0a	12,8a	3,4b	5,8a	38,8a	2,3a	3,54a	152,4a	7,51a	137,25a
	Control *Kontrola*	5,61a	4,92a	179,8a	23,6b	2,4a	5,1a	38,3a	3,3b	3,89a	160,5a	15,77b	126,88a

differences between medians marked by the same letters are not ignificant / *wartości oznaczone tymi samymi literami nie różnią się* istotnie

Source: own work / Źródło: opracowanie własne

Table 7. pH, electrolytic conductivity (EC) and concentration of water soluble constituents in soil samples taken plots with grown potatoes fertilized with PRP and control

Tab. 7. Odczyn, przewodnictwo elektrolityczne i stężenie składników rozpuszczalnych w wodzie w próbkach glebowych pobranych z poletek spod uprawy ziemniaków nawożonych PRP i kontrolnych

Plant *Roślina*	Fertilization *Nawożenie*	pH		*(EC)*	K^+	Na^+	Mg^{2+}	Ca^{2+}	$P-PO_4^{3-}$	NH_4^+	NO_3^-	Cl^-	HCO_3^-
		H_2O	KCl	$\mu S \cdot cm^{-1}$	*$mg \cdot dm^{-3}$*								
Potatoes *Ziemniaki*	PRP	5,74a	5,06a	171,5a	8,6a	4,0b	4,8a	37,9a	1,8a	1,82a	133,2a	18,52a	117,12a
	Control *Kontrola*	5,39a	4,75a	164,0a	11,3b	2,2a	3,8a	38,4a	2,6b	2,64b	132,8a	11,26a	133,74a

differences between medians marked by the same letters are not ignificant / *wartości oznaczone tymi samymi literami nie różnią się* istotnie

Source: own work / Źródło: opracowanie własne

Table 8. pH, electrolytic conductivity (EC) and concentration of water soluble constituents in soil samples taken *plots with grown maize* fertilized with PRP and control

Tab. 8. Odczyn, przewodnictwo elektrolityczne i stężenie składników rozpuszczalnych w wodzie w próbkach glebowych pobranych z poletek spod uprawy kukurydzy nawożonych PRP i kontrolnych

Plant *Roślina*	Fertilization *Nawożenie*	pH		*(EC)*	K^+	Na^+	Mg^{2+}	Ca^{2+}	$P-PO_4^{3-}$	NH_4^+	NO_3^-	Cl^-	HCO_3^-
		H_2O	KCl	$\mu S \cdot cm^{-1}$	*$mg \cdot dm^{-3}$*								
Maize *Kukurydza*	PRP	5,62a	5,05a	196,8a	7,4a	4,2a	4,9b	42,3b	2,1a	2,07a	161,7b	19,52a	160,97a
	Control *Kontrola*	5,34a	4,74a	176,0a	20,5b	2,8a	3,5a	35,2a	3,5b	3,53b	110,0a	22,78a	165,70a

differences between medians marked by the same letters are not ignificant / *wartości oznaczone tymi samymi literami nie różnią się* istotnie

Source: own work / Źródło: opracowanie własne

4. Conclusions

The obtained results from the conducted studies allow us to formulate the following conclusions:

1. Multiannual application of PRP SOL fertilizer significantly influenced the chemical properties of analyzed soils and resulted in:
- increase in pH,
- decrease in the content of available forms of potassium,
- increased in the content of available forms of magnesium.

2. The average concentration of the analyzed water-soluble ions expressed in mg·dm-3 formed an order of decreasing cations: $Ca^{2+} > K^+ > Mg^{2+} > Na^+ > NH_4^+$ and the anions: $NO_3^- > HCO_3^- > CL^- > PO_4^3$.

3. After replacing the phosphate-potassium fertilization with PRP SOL fertilizer, the soil solution was characterized by a significantly lower concentration of K^+, $PO_4^{3-,}$ NH_4^+ and higher concentration of sodium ions.

4. A significant influence on the chemical composition of soil solutions of the cultivated species was found. Soil solutions obtained from soil samples taken from plots with plants of long vegetation period (potatoes, maize) showed the greatest decrease in concentration of potassium ions.

5. The soil samples collected from plots fertilized with PRP SOL and cultivated with corn, it was found a significant highest decrease in the concentration in soil solution of K^+ PO_4^{3-}, NH_4^+, and increase in the concentration of ions of Mg^{2+}, Ca^{2+}, and NO_3^-.

5. References

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