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INVESTIGATION OF THE NITROGEN AND PHOSPHORUS CONTENT IN ARABLE AGRICULTURAL LAND IN SERBIA

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Abstract: The aim of this work was to determine the nitrogen and phosphorus content in arable agricultural land on farms in the Republic of Serbia. The sampling of soils was carried out in 2020 with the recording of GPS coordinates and entering the obtained results into the software platform. The analysis of the nitrogen content (N) was determined by the Kotzman method and calculated from the humus on a sample of 30,957 plots, with an area of 19,629.24 ha. The phosphorus content (P_2O_5) was determined by extraction, whereby the easily soluble part of the phosphorus was transferred into a solution and colorimetrically determined in the resulting extract, on a sample of 28,944 plots with an area of 18,459.96 ha. The results obtained show that 64.59% of the area, i.e., 12,678.81 ha, had a good nitrogen content (0.2–0.1%). A very high phosphorus content (400.1–500.0 mg kg^{-1} of the area) was found on 27.68% of the area, which is 5,108.92 ha. On 15.34% of the plots where a harmful value was found, additional analyses should be carried out to determine the cause of such a high phosphorus content in the soil. Based on data on the content of total nitrogen and readily available phosphorus in the soil, the type and amount of fertilizer can be adequately selected, which can lead to a reduction in ecosystem pollution. The results in this study represent the basis for soil management, biodiversity protection and optimal planning of cultivation of arable, vegetable and fruit crops. The obtained results can help agricultural producers and other entities to increase the competitiveness of their production.

Key words: soil, nitrogen and phosphorus content, GPS coordinates, resource conservation.

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Introduction

Soil is one of the most important natural resources of any country. As a basic means of agricultural production, its economic importance is determined by fertility, which represents the ability of the soil to provide the necessary nutrients, water, air, heat and other factors during the growing season. An important measure to preserve this resource is the control of soil fertility, which also plays a role in the proper use and reduction of the negative effects of uncontrolled fertilizer application, development and planning of agricultural production based on the principles of sustainable development and environmental protection.

The concept of a new generation of agricultural production requires soil protection and product quality improvement. For this reason, it is important to know the content of nitrogen and phosphorus and other macro and micro elements. Soil protection also significantly contributes to the preservation of agroecology (Ikanović and Popović, 2020). Moreover, the correct use of fertilizers is one of the most important factors because they contain necessary elements whose application (directly or indirectly) improves plant nutrition.

Fertilizers are any material of 1) natural or 2) synthetic origin (Manojlović and Čabilovski, 2019). Organic fertilizers are obtained from natural sources (livestock and poultry droppings, plant residues, biogas residues and agricultural by-products), while inorganic fertilizers are obtained from mineral deposits or produced from synthetic compounds.

Optimal and balanced nitrogen nutrition is important as a building block of plants (Bojović et al., 2014; 2022; Janković et al., 2021; Nožinić et al., 2022). Insufficient amounts negatively affect the yield and quality, and the first signs appear in older leaves, the formation and setting of fruits are reduced, the root system is longer, more elongated and less branched in the search for nutrients (Đekić et al., 2016; Popović et al., 2011; 2013; 2017; 2019; 2020; 2022; Lakić et al., 2018; 2020).

Plants take up nitrogen from the soil in the form of nitrate and ammonium ions, whereas legumes in symbiosis with nitrogen fixers can use elemental nitrogen from the atmosphere, transforming it into a form available for plants. It depends on soil fertility, plowed crop residues, organic matter content, preceding crops and nitrogen fertilization, yields, basic fertilization and climatic factors. It also depends on the type of soil, its use, temperature, humidity and water content in the soil. Due to its high mobility in soil, nitrogen can be lost very easily, mostly through evaporation and leaching. Some of the most important parameters that lead to nitrogen depletion from the soil are the form of nitrogen, soil properties, the timing of fertilizer application, improper fertilizer application and other factors (Simić et al., 2020).

Increased nitrogen efficiency can be achieved by applying appropriate fertilizers at the optimal time (Janković et al., 2020a). The needs of plants for nitrogen are different, and harmful consequences can arise from both nitrogen deficiency and nitrogen excess. An excess of nitrogen can cause more problems than a slight deficiency. Due to the excess of nitrogen, plants are less resistant to various stressful conditions. Large amounts of nitrogen can result in bad taste of fruits, but more importantly, those fruits are less safe for human health (Glamočlija et al., 2015; Ikanović et al., 2020). Large amounts of nitrogen in the soil can have a detrimental effect in the case of leaching, contaminating groundwater and disrupting biodiversity.

Phosphorus is a necessary element for the development of generative organs, plant growth, and cell division, better rooting of plants, seed and fruit development, early fruit ripening, and for increased plant resistance to diseases. The lack of phosphorus slows down the growth of the plant, the formation of fruit and leaf buds. Such leaves are initially dark green, and later they turn red purple. An excess of phosphorus rarely occurs, but when it does, it causes a reduced growth of plants, with dark brown spots on the leaves (Glamočlija et al., 2015). Phosphorus is a non-renewable resource, and modern research focuses on a more efficient use of phosphorus fertilizers, its recycling and the use of alternative sources (Dawson and Hilton 2011). The amount of remaining fossil phosphate resources in the world is uncertain, but practically finite. Thus, fossil P resources may become depleted by ongoing mining. Despite calls for resource conservation, fossil P resources are being depleted at an increasing rate. More than 90% of current phosphorus resources are still used as fertilizer in agriculture (Reijnders, 2014). Therefore, increasing the efficiency of using phosphorus from fertilizers and, accordingly, reducing the pressure on the environment, and decreasing the demand for fossil phosphorus is a primary goal. The mobility of phosphorus in the soil is limited and therefore the roots of plants can only take up phosphorus from their immediate environment (Glamočlija et al., 2015). Plants absorb a certain amount of phosphorus that they need at that moment, and the rest remains in the soil. Phosphorus ions that have not been adopted by the plants remain free and unstable in the soil and as such can quickly bind to manganese, iron and calcium ions, all depending on the pH value of the soil (Janković et al., 2020b). These reactions create insoluble compounds in the soil and thus phosphorus becomes unavailable to the plants. The leaching of phosphorus originating from mineral fertilizers and manure from the soil is the cause of water quality degradation and damage to biodiversity.

The aim of this study was to determine the content of nitrogen and phosphorus in arable agricultural land on farmers' plots.

Material and Methods

The soil samples for the determination of the nitrogen content were taken from 30,957 farm plots, comprising the area of 19,629.24 ha, and those for the phosphorus content from 28,944 plots, comprising the area of 18,459.96 ha.

The samples were taken from arable agricultural areas after the harvest of arable and vegetable crops (maize, wheat, alfalfa, clover, peppers, tomatoes, potatoes).

An Android application was used to record the GPS coordinates on the Android6+ operating system. It recorded the location coordinates, date and time, the cadastral municipality number and the plot number. The data were then automatically sent to the software. The data on the sampler, the soil class, the sampling depth and the preceding crop were also recorded in the software. The samples were prepared and delivered to accredited laboratories (SRPS ISO/IEC 17025 standard).

The nitrogen content (Table 1) was determined from the humus (Aksentijević et al., 2017; Džamić et al., 1996), and the readily available phosphorus (Table 2) according to the AL method of Egner and Riehm, 1960.

Table 1. Total nitrogen content (%) (calculated from humus).

Soil nitrogen	Of limited capability	Very poor	Poor	Medium secured	Well provided	Rich	Very rich
% Nitrogen	<0.02	0.03–0.02	0.06–0.03	0.1–0.06	0.2–0.1	0.3–0.2	>0.3

Table 2. The content of easily accessible phosphorus (P_2O_5) according to the AL method of Egner and Riehm.

Phosphorus in the soil	Very low	Low	Medium	Optimal	High	Very high	Harmful
P_2O_5 mg kg^{-1}	<50.0	50.1–100.0	100.1–150.0	150.1–250.0	250.1–400.0	400.1–500.0	>500.1

Statistical analyses: Statistical tests were carried out by the statistical package and descriptive statistics and presented in tabular and graphical form.

Results and Discussion

The study covered large areas of agricultural land of individual farmers. Modern methodologies and technologies were used to obtain the results presented in the study. The application of digital technologies, in addition to monitoring functions, is an important tool in plant nutrition management, providing the necessary information on the nutritional status of the soil.

In the arable layer of cultivated soils, the content of total nitrogen is usually between 0.1 and 0.2%. Most of it (over 90%) is contained in organic compounds of the soil, while it is only a few percent in the inorganic form (mineral $NH4^+$, $NO2^-$, $NO3^-$), which is mostly taken up by the plants. Considering that it is not possible to precisely assess the supply of these nutrients in the crop based on the total amount of nitrogen in the soil, the value of this analysis is a useful indicator, especially when analyzing smaller agroecological units, on a farm and on the same type of soil.

The results of the N content on a sample of 30,957 plots comprising the area of 19,629.24 ha show that 64.59%, i.e., 12,678,81 ha, had a good level of nitrogen availability (0.2%–0.1%), calculated based on the humus content. Moreover, 23.39% of the examined plots, i.e., 4,590.34 ha, were rich in nitrogen (0.3%–0.2%), 7.73% of the examined areas, i.e., 1,518.26 ha had medium nitrogen levels (0.1%–0.06%), while 3.23% of the examined areas, i.e., 634.07 ha were very rich in nitrogen (> 0.3%). A poor nitrogen content was found on 0.81% of the surveyed plots, i.e., 159.01 ha, (0.06%–0.03%) and a very poor nitrogen content (0.03%–0.02%) on 0.14% of the examined plots, i.e., 28.31 ha. Furthermore, 0.10% of the examined plots, i.e., 20.54 ha, had a limited ability to provide nitrogen (<0.02%) (Table 3, Figure 1).

This indicates that on the examined farm plots, the largest percentage of plots, 64.59%, were well supplied with nitrogen, so farmers in these areas should use formulations with an appropriate nitrogen content when choosing fertilizer.

Table 3. Total nitrogen content (%).

Plot number	Area of analyzed plots (ha)	Nitrogen content from humus (%)	Nitrogen content in the total area (%)
PNo 1	634.07	> 0.3	3.23
PNo 2	4,590.34	0.3–0.2	23.39
PNo 3	12,678.81	0.2–0.1	64.59
PNo 4	1,518.26	0.1–0.06	7.73
PNo 5	159.01	0.06–0.03	0.81
PNo 6	28.31	0.03–0.02	0.14
PNo 7	20.54	< 0.02	0.10
Total	19,629.34	-	100
IV	-	-	64.49
Std. dev.	-	-	23.75

Phosphorus is a non-metal, usually found in the five-valent form in nature. Due to its reactivity, it is not available in free form, but as part of numerous organic and non-organic compounds. It originates from about 170 minerals (apatite, phosphorite, vivianite, amblygonite, monazite, wavellite, triplite), with apatite and phosphorite accounting for the largest proportion of around 90% (Gudžić, 2015). Delgado and Torrent (1997) emphasize the importance of having the balance between the optimal phosphorus content in the soil for agricultural production and ecological and economic security, in which phosphorus fertilizers play a significant role.

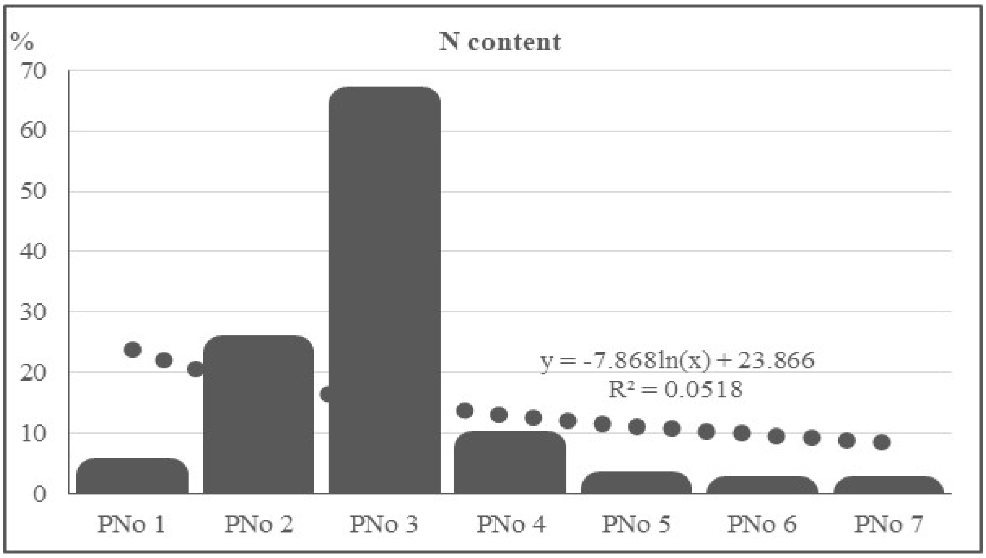

Figure 1. Nitrogen content (%) in the investigated soils in Serbia.

The phosphorus content was determined on a sample of 28,944 plots, comprising the area of 18,459.96 ha.

A very high phosphorus content (400.1–500.0 mg kg-1) was found on 27.68% of the examined plots, i.e., on 5,108.92 ha. On 18.22% of the plots, i.e., on 3,363.25 ha, an average and optimal phosphorus content was detected (100.1–250.0 mg kg^{-1}). A high phosphorus content (250.1–400.0 mg kg-1) was found on 17.37% of the surveyed plots, i.e., on 3,206.59 ha. Moreover, a low phosphorus content was determined (50.1–100 mg kg-1) on 17.25% of the plots, i.e., on 3.183,53 ha. A harmful phosphorus content (>500.0 mg kg^{-1}) was detected on 15.34% of the plots, i.e., 2,832.5 ha. Finally, 4.15% of the plots, i.e., 765.17 ha, were found to have a very low level of phosphorus (< 50.0 mg kg^{-1}) (Table 4, Figure 2).

The result shows that the agricultural soils on the largest percentage of plots (27.78%) had a very high phosphorus content, so farmers in these areas should pay special attention and choose fertilizer formulations without phosphorus or with a lower phosphorus content. Moreover, additional analyses should be carried out on

15.34% of the plots with harmful content in order to determine the cause of such a high phosphorus content in the soil.

Table 4. Content of readily available phosphorus (P_2O_5).

Plot number	Plot area (ha)	Content of readily available phosphorus P_2O_5 (mg kg^{-1})	Content of P_2O_5 in the total analyzed area (%)
PNo 1	765.17	< 50.0	4.15
PNo 2	3,183.53	50.1–100.0	17.25
PNo 3	3,363.25	100.1–250.0	18.22
PNo 4	3,206.59	250.1–400.0	17.37
PNo 5	5,108.92	400.1–500.0	27.68
PNo 6	2,832.5	>500.1	15.34
Total	18,459.96	-	100
IV	-	-	23.53
Std. dev.	-	-	7.52

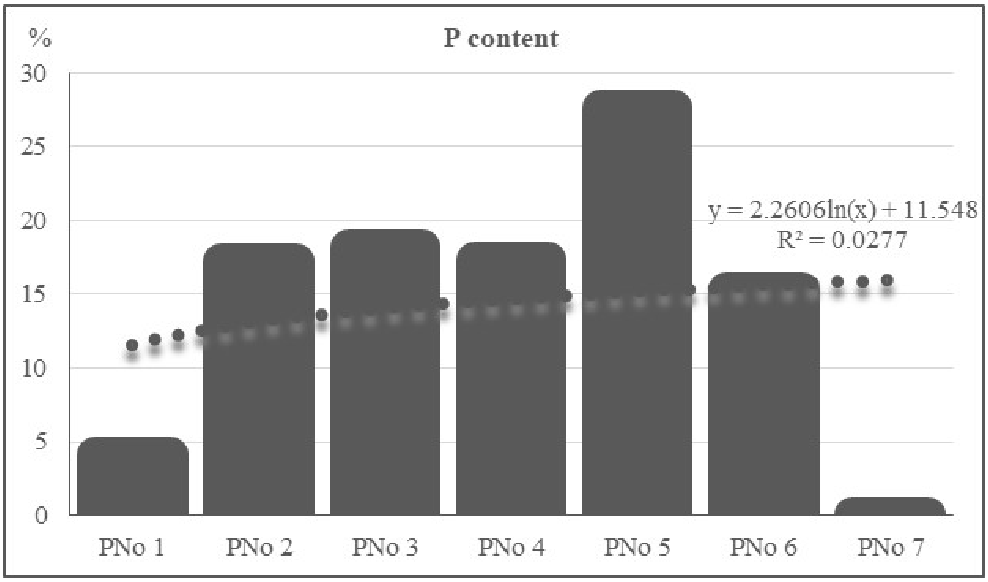

Figure 2. Phosphorus content (mg kg^{-1}) in the examined soils in Serbia.

Conclusion

Based on the obtained results, the following conclusions can be drawn:

The largest percentage of the examined farm plots, 64.59%, were well supplied with nitrogen, and farmers should choose fertilizer formulations with a correspondingly lower nitrogen content.

When it comes to phosphorus, the largest percentage of plots (27.78%) had a very high phosphorus content. On these areas, farmers should pay special attention and use formulations without phosphorus or with a lower phosphorus content when choosing fertilizers.

As for 15.34% of the plots on which harmful phosphorus levels were detected, some additional analyses should be done to determine the reason for such high phosphorus levels in the soil.

The obtained results can enable the optimal application of fertilizers as a prerequisite for the production of healthy and safe food for humans and animals, adaptation to climate change and environmental protection. The aforementioned is a basis for the sustainable development of farmers, the strengthening of environmental awareness and the preservation of biodiversity.

The obtained results can help farmers and other subjects engaged in agricultural production receive the right piece of affordable advice and therefore increase the competitiveness of their production.

Based on the data on the content of total nitrogen and readily available phosphorus in the soil, the type and amount of fertilizer can be adequately selected, which can lead to a reduction in nitrate and phosphate leaching and pollution of ecosystems.

The obtained results can contribute to the development and planning of agricultural production based on the principles of sustainable development and reducing the negative effects of uncontrolled fertilizer application.

The results represent the starting point for the introduction of good practices: rational land management, biodiversity protection, designing appropriate land use systems, improving soil quality, correct application of fertilizers and planning the cultivation of arable, vegetable and fruit crops.

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SADRŽAJ AZOTA I FOSFORA U OBRADIVOM POLJOPRIVREDNOM ZEMLJIŠTU SRBIJE

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R e z i m e

Cilj ovog rada bio je da se utvrdi sadržaj azota i fosfora na obradivom poljoprivrednom zemljištu u Republici Srbiji na poljoprivrednim gazdinstvima. Uzorkovanje zemljišta sprovedeno je u 2020. godini uz evidentiranja GPS kordinata i evidencije dobijenih rezultata u softverskoj platformi. Analiza sadržaja azota (N) određena je metodom Kotzman i izračunata iz humusa, na uzorku od 30.957 parcela, površine 19.629,24 ha. Sadržaj fosfora (P_2O_5) određen je ekstrakcijom, prevođenjem lako rastvorljivog dela fosfora u rastvor i kolorimetrijski određen u dobijenom ekstraktu, na uzorku od 28.944 parcele površine 18.459,96 ha. Dobijeni rezultati su pokazali da 64,59% površina, odnosno 12.678,81 ha, ima dobar nivo azota (0,2–0,1%). Na 27,68% površina, što iznosi 5.108,92 ha, utvrđen je veoma visok nivo fosfora (400,1–500,0 mg kg^{-1} zemljišta). Na površinama od 15,34% na kojima je utvrđen štetni sadržaj potrebno je uraditi dodatne analize kako bi se utvrdio uzrok tako visokog sadržaja fosfora u zemljištu. Na osnovu podataka o sadržaju ukupnog azota i lako dostupnog fosfora u zemljištu, može se adekvatno odabrati vrsta i količina đubriva, što može dovesti do smanjenja zagađenja ekosistema. Rezultati u ovoj studiji predstavljaju osnovu za upravljanje zemljištem, zaštitu biodiverziteta i optimalno planiranje gajenja ratarskih, povrtarskih i voćarskih kultura. Dobijeni rezultati mogu pomoći poljoprivrednim proizvođačima i drugim subjektima da povećaju konkurentnost svoje proizvodnje.

Ključne reči: zemljište, sadržaj azota i fosfora, GPS kordinate, očuvanje resursa.

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