CONTEMPORARY AGRICULTURE / *SAVREMENA POLJOPRIVREDA* 59 (3-4) 278-286, 2010.
UDC: 63(497.1)(051)-"540.2" ISSN 0350-1205

UDC:631.17:546.17:631.41:

MINERAL NITROGEN DYNAMIC IN SOIL OF DIFFERENT FERTILITY AS AFFECTED BY AGRONOMIC PRACTICES*

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SUMMARY: The variability and accessibility of NO_3-N in the soil derives from the complex interaction of mineralization and ecological conditions. The results showed that in unfertilized two–year rotation conditions for mineralization had the most dominant effects on distribution and dynamics of NO_3–N. However, in the fertilized rotation NO_3–N dynamic and distribution was a result of mineral N application, plant assimilation and mineralization. In our agro-ecological conditions year to year NO_3–N variations were extensive. However, without the addition of nitrogen potential NO_3–N released from the mineralization is not sufficient for achievement of high yields. Moreover, fertilization must be based on Soil Fertility Control System.

Key words: *nitrogen, fertilization, crop rotation*

INTRODUCTION

The content and availability of mineral nitrogen (N) in the soil, as well as its dynamics and distribution in the soil profile among other macronutrients could be a critical indicator of high–yield potential for particular production year. The required amount of N needed to achieve economically viable yield differ, since numerous factor are involved in nitrogen balance such as climatic conditions, soil properties, crop variety and production technology (Bogdanovic et al., 1998). The processes of N transformation in soil are complex and comprise a part of the N cycle, which in natural ecosystems is closed. However, in the agro-ecosystems, management of agricultural land leads to disruption of N cycle and removal of N coupled in aboveground biomass therefore external application of N is needed in order to preserve or enhance the productivity of the soil

Original scientific paper / *Originalni naučni rad*
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[*]This study is part of the TR20082 project financially supported by the Ministry of Science of the Republic of Serbia. We express our sincerest gratitude to them for the support.

(Hofman and Van Cleemput, 2004). At the same time, the soil mineralization ability can play an important role in meeting the crop N demand. Though, due to difficult assessment of soil mineralization capacity, that depends on time of sampling and dynamics of NO3–N in the soil, it could result with a rough estimation of readily available N in soil. According to Marinković et al. (2008) good results in agricultural production can be achieved only through a balance between all cultural practices and weather conditions on the one hand and the potential of the growing field and the cultivar/hybrid on the other. Nowadays, growing high–yielding varieties and hybrids could led to increased plant N demand for that reason additional research on mineral nutrition is of great importance to enhance the cropping technology. The reason for this is the fact that the variability of climatic conditions, inadequate cultural practices significantly affects the availability of N from the soil, often reducing availability of the nutrients for plants in conditions of insufficient application of fertilizers (Bogdanovic, 2009). The degree of utilization of mineral fertilizer N seldom exceeds 50% (Rasmussen, and Rhode, 1991) and the most common form of nitrogen loss applied are denitrification, leaching and migration (NO3–N), volatization and gaseous losses of NH3–N by plant organs (Raun et al., 1999). The aim of this study was to determine distribution of NO3–N in soils of contrasting fertility and to evaluate the role of climatic conditions on its dynamic.

MATERIAL AND METHODS

The present study was performed on a long–term crop rotation experiment (LTE) carried out at the Rimski Šančevi Experimental Field of the Institute of Field and Vegetable Crops in Novi Sad (N 45°19`, E 19°50`). The LTE was established on a chernozem soil (subtype: chernozem on loess and loess–like sediments; variety: slightly calcareous) (Milosev, 2000). The study treatments were: a two–year fertilized crop rotation (maize–wheat) (MWF) and a unfertilized two–year crop rotation (maize–wheat) (MW) in 3 year 2007–2009. The treatments are regularly fertilized with mineral nitrogen fertilizers at 120 kg ha^{-1} rate for maize and 100 kg ha^{-1} for winter wheat. Fertilizer with P or K and barnyard manure have been used until 1986, after ward only mineral N was used due to high supply of these nutrients in soil.

Table 1. Content N (%) in Field Crop, and Harvest index
Tabela 1. Sadržaj N (%) u biljkama i žetveni indeks

Cropping system Sistem biljne proizvodnje	Property Svojstvo	Winter wheat Pšenica		Maize Kukuruz	
		Grain Zrno	Straw Slama	Grain Zrno	Straw Slama
Fertilized two-year rotation Đubreno dvopolje	N content (%) Sadržaj N (%)	2*	0.45*	2	1.49
	Harvest index Žetveni indeks	0.45+		0.4§	
Unfertilized two-year rotation Neđubreno dvopolje	N content (%) Sadržaj N (%)	1.7*	0.3*	1.28	0.54
	Harvest index Žetveni indeks	0.48+		0.45§	

[*](Malešević, 1989); [+](Milošev, 2000); [§](Boćanski, 1988)

The prevailing climate in the investigated area is continental, with an average annual precipitation of 611 mm, and annual temperature is 11,1°C. For the calculation of N uptake by crops content of N in wheat and maize grain and straw was either measured or adopted from the literature (Table 1). Soil sampling was conducted in different stages of plant growth from March to October. From November to February NO_3–N content was approximated as 0. Determination of available NO_3–N in soil was conducted according to Scharpf and Wehreman (1975).

RESULTS AND DISSCUSION

For the observed period soil reaction remains alkaline with an increase in pH compared to the obtained results in 1988 (Table 2). The lower pH in fertilized rotation could be attributed to the long–term application of the N–fertilizer. Humus content in the fertilized rotation was preserved by proper crop rotation and rational mineral fertilization with plowing in crop residues. Omitting the application of mineral fertilizer and removal of crop residues for a long period of time (> 41 years for the unfertilized rotation), the productive capacity of the chernozem has changed and the total concentration of humus in the soil was reduced (–0.25%) in relation to the concentration at the time of establishing the experiment. Similar finding for chenozem soil were presented in studies of Jovanovic (1995), Starcevic (1986), Molnar et al. (1999).

Table 2. Soil chemical properties of the investigated treatments
Tabela 2. Hemijska svojstva zemljišta proučavanih sistema biljne proizvodnje

Soil chemical properties Hemijska svojstva zemljišta	Treatments/Tretmani					
	Fertilized two–year rotation Đubreno dvopolje			Unfertilized two–year rotation Neđubreno dvopolje		
	1988	2009	Difference Razlika	1988	2009	Difference Razlika
pH H2O	7.69	8.09	+0.4	7.94	8.27	+0.33
pH KCl	7.21	7.28	+0.7	7.37	7.41	+0.03
CaCO3 (%)	4.68	3.21	-1.47	9.41	12.84	+3.34
Humus (%)	2.57	2.59	+0.02	2.47	2.22	-0.25
Total N (%)	0.17	0.17	0	0.16	0.15	-0.1
C/N	9.67	*	-	8.03	8.58	+0.55
mg P2O5 100 g-1	90.80	67.96	-22.84	6.10	7.37	+1.27
mg K2O 100 g-1	40.7	38.43	-2.27	17.10	16.21	– 1.11

In this study, measured C/N ratio in the soil is slightly wider at the unfertilized rotation compared to fertilized. Readily available phosphorus in fertilized rotation experiment in relation to the unfertilized rotation was significantly higher (Table 2). Similar values for P concentration was found in previous investigation on the same experiment (Šeremešić, 2005). The result was expected after a longer period fertilized with manure until 1991. According to research Bogdanovic et al. (1984) high concentrations of readily available P in soils that are medium or even low provided microelements can cause their lack of plants. Hence the soils with > 50 mg P_2O_5 100 g^{-1} in control systems for soil fertility and use of fertilizers recommended the omission of P fertilization in next 3–4 years.

Readily available potassium in the unfertilized rotation after 42 years of cropping is in the class of soil of optimal availability in this element (table 2). The explanation derives from natural fertility since the prevailing chernozem clay minerals are illit and montmorillonite type which has associated K+, and potential for K release in the soil solution. A very high content of readily available potassium found in the fertilized rotation is a result of long–term application of mineral fertilizers and manure and plowing under a large mass of wheat straw and maize residue.

Table 3. Average uptake of total N in grain and above ground plant remains (kg ha^{-1})
Tabela 3.Prosečno iznošenje N zrnom i ndzemnom masom biljaka (kg ha^{-1})

Cropping system *Sistem proizvodenje*		Grain *Zrno*	Straw *Slama*	Total *Ukupno*
Fertilized Two–year rotation *Đubreno dvopoljw*	Winter wheat *Pšenica*	103.31±23.87	25.38±5.96	128.69
	Maize *Kukuruz*	153.66±45.72	171.78±51.09	325.44
	Total *Ukupno*			454.13
Unfertilized Two–year rotation *Neđubreno dvopolje*	Winter wheat *Pšenica*	17.58±6.61	3.36±1.26	20.94
	Maize *Kukuruz*	31.61±16.77	16.3±8.64	47.91
	Total *Ukupno*			68.85

In the agricultural system N is considerably dynamic and depends on plant–soil interrelation. The amount of total N (kg ha^{-1}) in soils of the two contrasting cropping systems showed considerable difference in quantity of N remain after harvest (Table 3). At the unfertilized two–year crop rotation on the same experiment Bogdanović et al (2008) calculated negative N–balance is soil, and anticipated that new state of equilibrium of N and other biotic element was established. The amount of N remains in the straw of maize (25.38 kg N ha^{-1}) and winter wheat (3.36 kg N ha^{-1}) cannot be considered as an adequate source for the plant nutrition (Table 3). With 120 kg N ha^{-1} application in maize production the considerable amount of N must be provided from soil mineralization. Removal of N in the winter wheat is lesser and could be compensated from soil to some extent. The amount of the total N in the fertilized soil was 6 times higher compared with the unfertilized (454.13 to 68.85). Panković and Malešević (2006) in the 2000–2005 period estimated that removal of N with NS winter wheat cultivars reached 211 kg ha^{-1} (148 grain + 63 straw). In maize production N content in grain and crop residue is strongly influenced by climatic condition and hybrid characteristics. Therefore year–to–year variation can significantly after the N takeout. Starčević at al. (1999), suggest that content and removal of N very in relation to different N fertilization scheme. N content in grain increased respectively with application of higher N doses from 1.15% to 1.51% and in crop residues from 0.45% do 0.67%. Same authors found that removal of the N in maize production with different levels of fertilization fits the quadratic equation with maximum of 153 N ha^{-1} for grain, and 208 N ha^{-1} for crop residue. Similar results for six maize inbred lines were presented by Latković (2009).

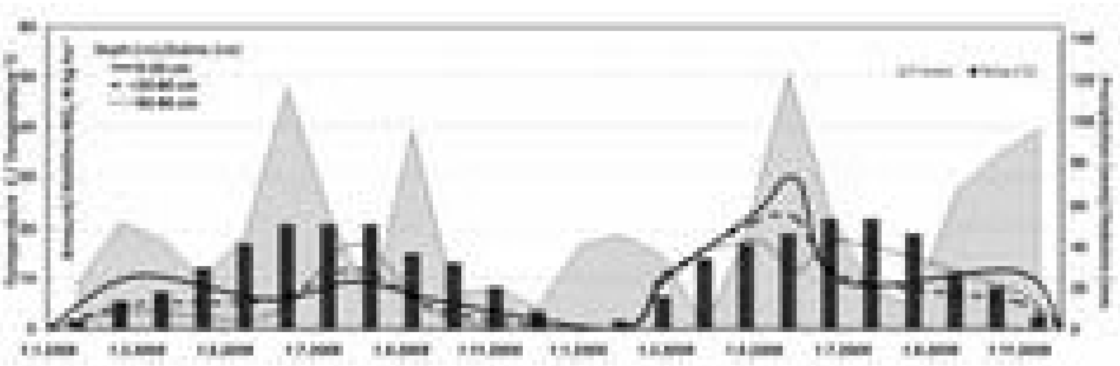

Figure 1. Distribution and dynamics of NO_3–N in different soil layers in unfertilized two–year wheat rotation (kg ha^{-1})

Grafikon 1.Distribucija i dinamika NO_3–N u različitim slojevima zemljišta na neđubrenom dvopolju pšenice (kg ha^{-1})

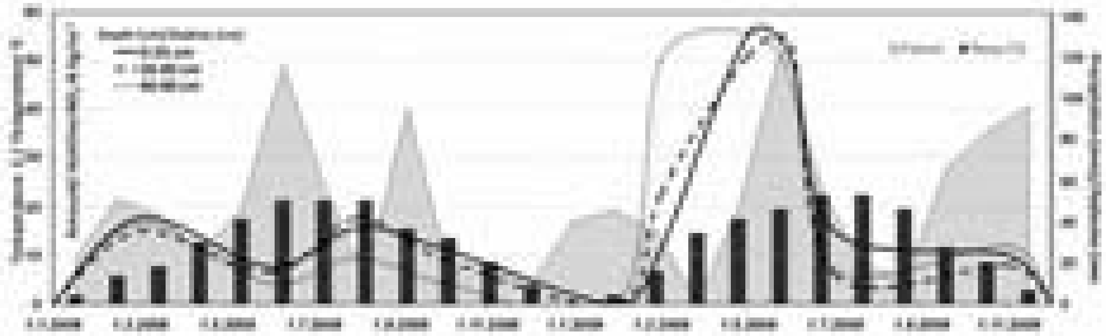

Figure 2. Distribution and dynamics of NO_3–N in different soil layers in the fertilized two–year wheat rotation

Grafikon 2.Distribucija i dinamika NO_3–N u različitim slojevima zemljišta na đubrenom dvopolju pšenice (kg ha^{-1})

Based on the obtained results content of the NO_3 in three depth had a different pattern in the observed cropping system under winter wheat and maize. This could be explained with the differences in dynamics of the microbiological activity in soil and related processes that supply soil with NO_3 (preferably fertilization). During the vegetation of winter wheat, the amount of NO_3–N increase in the March and decrease due to the plant intake and the partial transfer (under the influence of rainfall) (Fig. 1). Malešević et al. (1991) concluded that allocation of nitrate in the soil profile basically depends on soil moisture and that in the "normal" years higher amount of NO_3–N is in the 30–60 cm soil layer. In the unfertilized plots winter wheat plant development was hampered by soil fertility that resulted with shallow root development and intake NO_3 from upper layer. Unlike this in the fertilized treatment higher amount of NO_3 was observed and gradual decline of available nitrate in three depths until harvest (Fig. 2). Stubble tillage after harvest affected the NO_3–N content as a result of N uptake and mineralization of crop residues. In the unfertilized wheat plot in both years higher content of NO_3–N after harvest was found in the 60–90 cm. Subsequently, the amount of NO_3–N in the unfertilized treatment was 20 kg ha^{-1} until winter, whereas content of NO_3–N in 30–90 cm decreased. The application of N in the October at the fertilized plots was followed with higher content of NO_3–N in November before lower temperature occurred.

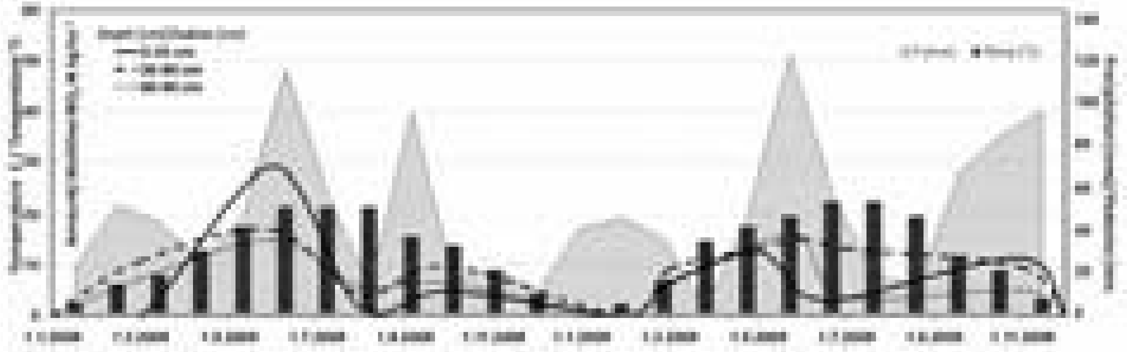

Figure 3. Distribution and dynamics of NO_3–N in different soil layers in the unfertilized two–year maize rotation (kg ha^{-1})
Grafikon 3. Distribucija i dinamika NO_3–N u različitim slojevima zemljišta na neđubrenom dvopolju kukuruza (kg ha^{-1})

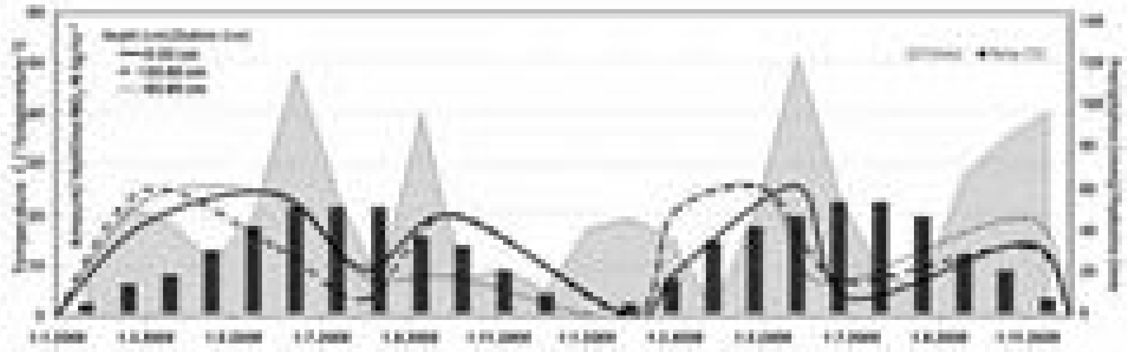

Figure 4. Distribution and dynamics of NO_3–N in different soil layers in the fertilized two–year maize rotation *(kg ha^{-1})*
Grafikon 4.Distribucija i dinamika NO_3–N u različitim slojevima zemljišta na đubrenom dvopolju kukuruza (kg ha^{-1})

In the maize cropping NO_3–N dynamic was influenced by the conditions for mineralization, and the amount of NO_3–N in all layers of the soil increases in May and early June, reached a maximum, then decrease at the begging of July. Similar dynamics of NO_3–N in plow layer after adding N fertilizer under maize crop was found in Ma et al. (1999) study. In the unfertilized plots NO_3–N intake was more pronounced in the 0–30 cm due to shallow root development (Fig. 3). Conversely, for the fertilized maize 30–60 cm soil layer showed higher importance when N nutrition of maize is considered (Fig. 4). Most of the NO_3–N in layer 30–60 cm was recorded earlier during early spring, while in the deepest layer (60–90 cm) achieved the maximum NO_3–N in May. Bundy and Malone (1988) proposed that if > 150 kg N ha^{-1} found in the soil profile (0–90 cm) it is sufficient for attained the high maize yield. In our study the amount of NO_3–N is less than that, and since complex agroecological conditions are involved in its dynamic yield fluctuation is occurred. The intake of NO_3–N by the plants, based on nitrate dynamic in soil is expected to reach maximum in Jun–July. Subsequently, from September (maize harvest) until winter, content of NO_3–N in the unfertilized maize did not exceed 20–30 kg ha^{-1} and 50–60 kg ha^{-1} at the fertilized rotation. Available amounts of NO_3–N in the soil profile had influenced its intake by plants and hence higher yield of grown crops, compared with the unfertilized plots (Yang et al., 2004). Evaluating the nitrate dynamic in soil it is observed that maize have had a higher amount of the accessible NO_3–N compared with winter wheat. This could be explained with N fertilization (100 kg ha^{-1} N for wheat and 120 kg ha^{-1} for maize) in the fertilized plots, but in some years it could be compensated with favorable soil condition for mineralization under winter wheat.

CONCLUSION

Obtained result showed that in the unfertilized two–year rotation conditions for mineralization had the most dominant effects on distribution and dynamics of NO_3–N in soil. However, in the fertilized rotation NO_3–N dynamic and distribution was a result of the mineral N application, plant assimilation and mineralization. Mineralization intensity was higher in April and May. Without addition of nitrogen potential NO_3–N released from the mineralization is not sufficient for achievement of high yields. In our agro-ecological conditions NO_3–N variations were significant, and therefore not predictable. To achieve yield potential of growing crop it is necessary to judiciously apply fertilizer based on the Soil Fertility Control System.

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UTICAJ TEHNOLOGIJE GAJENJA NA DINAMIKU MINERALNOG AZOTA U ZEMLJIŠTU RAZLIČITOG NIVOA PLODNOSTI

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Izvod

Varijabilnost pristupačnog NO_3-N u zemljištu posledica je interakcije mineralizacije i faktora spoljne sredine. Dobijeni rezultati pokazuju da na neđubrenom dvopolju dominatnu ulogu na distribuciju i dinamku NO_3-N imaju uslovi za mineralizaciju. Na đubrenom dvopoljnom plodoredu N-đubrenje i brzina mineralizacije utiču na mobilnost azota i njegovo usvajanje biljkama. U našim agroekološkim uslovima najveća količina mineralnog azota je pristupačna u proleće. Međutim bez dodavanja planiranih količina mineralnih đubriva nije moguće realizovati potencijal prinosa gajanih biljaka. Pored toga neophodno je da se đubrenje obavlja prema principima Sistema kontrole plodnosti zemljišta.

Ključne reči: Azot, đubrenje, plodored

Received / *Primljen*: 28.09.2010.
Accepted / *Prihvaćen*: 07.10.2010.