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Mineral nitrogen in Lithuanian soils

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Studies were conducted in different regions of Lithuania, in soils of varying granulometric texture and occupied by different plants (winter and spring cereals, row crops, meadows and pasturelands, etc.), in spring and autumn, at a depth of 0–30, 30–60 and 60–90 cm and on 20 × 20 m plots. Besides, studies of mineral nitrogen were conducted also in a long-term field trial (38 years), applying different rates of NPK fertilizers. Based on mean monitoring data in the spring of 2005–2008, the content of mineral nitrogen ($NO_3 + NH_4$) at a depth of 0–60 cm varied from 50.2 to 62.6 kg ha^{-1} (mean, 55.7 kg ha^{-1}) and depended on the intensity of agricultural activities, soil genesis and granulometric texture, amount of precipitation (r = 0.70; t = 2.91) and in individual years also on air temperature. The highest content of mineral nitrogen was found in 2005, while the lowest in 2007 and 2008. In a deeper 60–90 cm layer, the N_{min} level was 11.6–25.5 kg ha^{-1} (mean, 19.4).

In a long-term trial, under different rates of NPK fertilizers, the content of mineral nitrogen in spring at a depth of 0–60 cm depended on the rate of nitrogen fertilizers and their ratio with phosphorus and potassium, as well as on meteorological conditions in the autumn–spring period. In unfertilized plots, it comprised on average 41.5 kg ha^{-1}, in plots fertilized every year with the mean $N_{90}P_{90}K_{90}$ rates – 53.1 kg ha^{-1}, while in plots fertilized with N_{180} $P_{90}K_{90}$ – 58.7 kg ha^{-1}. The content of mineral nitrogen at a depth of 0–60 cm in autumn versus spring in plots fertilized at average rates of N_{90} and high rates of N_{180} increased (respectively by 5.2 and 21.1 kg ha^{-1}), and in unfertilized plots decreased (on average by 7.7 kg ha^{-1}). In spring, before the next fertilization applying N_{90} and N_{180} rates, N_{min} decreased, while in the soil of unfertilized plots it remained almost unchanged.

Key words: soil regions, soils, N_{min}, rates and ratios of fertilizers

INTRODUCTION

Under intensified agricultural production, together with synthetic fertilizers, manure, and plant and seed residues, the soil receives ever more nitrogen (Freney, 2005; Erisman, Domburg, de Vries et al., 2005; Smil, 1999). Unfortunately, the application of nitrogen fertilizers is usually inefficient.

Growing cereals, the mean efficiency of the application of nitrogen fertilizers comprises only 33% (Raun, Johnson, 1999). Insufficiently efficient application of nitrogen fertilizers may result in the leaching of nitrates into groundwater, contamination of rivers and other water bodies (Bergström, Brink, 1986; Galloway, 2005, Goulding, 2005, Jensen, Haugagard–Nielsen, 2003).

The guidelines on nitrates of 1991 (91/676EEC) oblige all countries to protect water against contamination by nitrates from agricultural sources (Directive..., 1999). Therefore, many countries pay an ever greater attention to the studies of nitrogen.

Swedish scientists have ascertained that 54% of nitrogen compounds get into the Baltic Sea due to human activities. The leaching of nitrogen, phosphorus and potassium compounds due to increased agricultural production in Sweden and Finland has significantly augmented from 1950 to 1980 (Granstedt, 2000).

An increasing number of farmers in Lithuania, seeking to obtain higher yields of crops, apply rather high rates of nitrogen fertilizers, which not always correspond to the needs of plants and the resources of this element in the soil. When fertilizers are applied inefficiently, the threat of environmental pollution arises, meanwhile, environmental requirements have increased since Lithuania became an EU member.

Much attention in agriculture worldwide is devoted to the application of nitrogen fertilizer efficiency improvement measures (Freney, 2005). Among other measures, it is suggested to reduce the losses of plant nutrients, seeking for a more uniform intensity of agricultural production among different regions of the country (Granstedt, 2000).

The efficiency of nitrogen application in agriculture is often assessed according to the accumulation of nitrogen residues in the soil. This is mineral nitrogen, which accumulates in the soil during the vegetative period, and a high amount of which may be leached into groundwater during the autumn–winter–spring period (Malhi, Brandt, 2004; Sheperd, Sylvester-Bradley, 1996; Staugaitis ir kt., 2007). The unleached residual nitrogen in spring may be used by plants of the current year. Thus, nitrogen content may be estimated by direct studies of the soil, applying mathematical models or using both methods at the same time.

The best method is direct soil sampling in the field. Meanwhile, mathematical models are better suited to estimate the amount of residual nitrogen, its forecasting on a regional or country scale, when the data base of studies on mineral nitrogen is available (Hartkamp et al., 1999; Probert et al., 1998).

The aim of the studies was to ascertain the content of mineral nitrogen ($N\text{-}NO_3$+$N\text{-}NH_4$) and its changeability in different Lithuanian soils at a depth of 0–30, 30–60, 60–90 cm layers in spring and autumn, to investigate the impact of long-term application of NPK fertilizers at different rates on its accumulation in the soil.

MATERIALS AND METHODS

The studies were conducted in different Lithuanian soils of various granulometric texture and occupied by different plants (winter and spring cereals, row crops, meadows and pastures, etc.), in spring – in the last ten days of April (before nitrogen fertilization) and in autumn – in the first ten days of October – after the harvesting in 0–30, 30–60 and 60–90 cm layers, in 20 × 20 m size plots. Every year (2005–2008), 600–800 soil samples were taken. Besides, studies of mineral nitrogen were conducted also in a field trial in which different rates of NPK fertilizers were applied.

$N\text{-}NO_3$ was ascertained by the colorimetric method, using hydrazinesulfate and sulfanilamide, and $N\text{-}NH_4$ by the colorimetric method, using natrium phenolate and natrium hypochlorite. P and K fertilizer rates are presented as oxides (P_2O_5, K_2O).

Meteorological conditions varied in different years of studies (Fig. 1). The most favourable conditions for the leaching of mineral nitrogen in winter, especially in West Lithuania, were observed in the autumn and winter of 2006–2007. Here, the amount of precipitation in November and January comprised 105 and 138 mm, respectively. The average daily air temperature in winter months of the mentioned years was above zero. Besides, in all study years, air temperature in autumn was higher than in spring, which influenced the mineralization of organic matter and accumulation of mineral nitrogen in the soil.

The statistical validity of the data was assessed according to LSD_{05} and correlation analysis, applying ANOVA and STAT computer programs (Tarakanovas, Raudonius, 2003). The

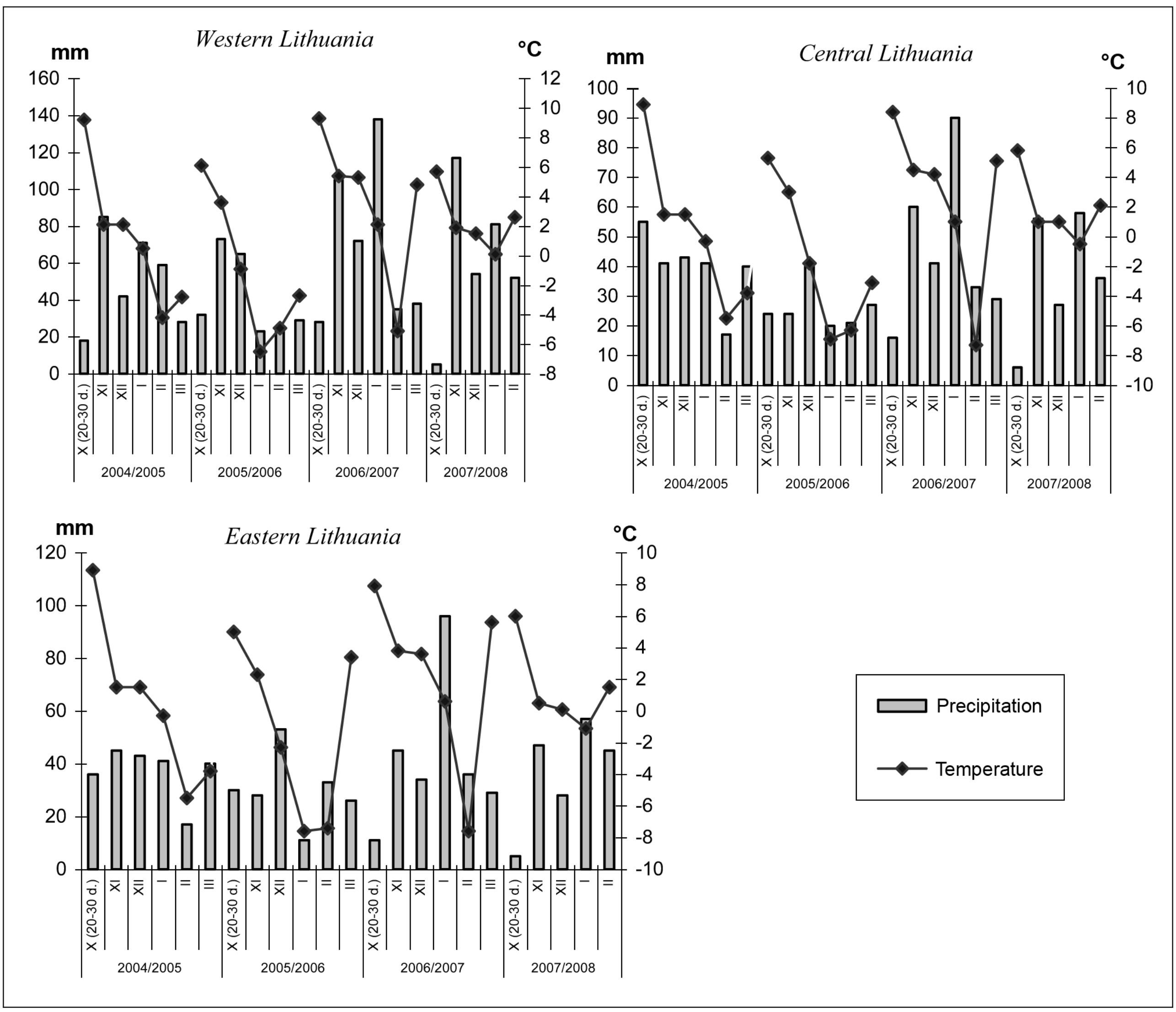

Fig. 1. Meteorological conditions in Lithuania, 2004–2008

dependence of soil mineral nitrogen in spring on precipitation in the late autumn–winter period was calculated using the linear equation $y = a + bx$.

RESULTS AND DISCUSSION

In plant nutrition, the most important is mineral nitrogen found at a depth of 0–60 cm in a soil layer (Vai vila, 1996). Its amount in the soils of the country in the spring of 2005–2008 ranged from 50.2 to 62.6 kg ha^{-1} (mean, 55.7 kg ha^{-1}) and depended on the amount of precipitation (y = 71.01–0.073x; r = 0.70; t = 2.91), while in individual years also on air temperature. Based on mean study data of 4 years, N_{min} at a depth of 0–30 cm comprised 35.1 kg ha^{-1} (46.6% of the total amount in a 0–90 cm deep layer), at a depth of 30–60 cm – 20.8 kg ha^{-1} (27.6%), and at 60–90 cm – 19.4 kg ha^{-1} (25.8%). The highest content of soil mineral nitrogen in spring was found in 2005, while the lowest in 2007 and 2008 (Fig. 2).

It was influenced by meteorological conditions in different years (Fig. 1). The most favourable conditions for the leaching of mineral nitrogen from the soil in winter, especially in West Lithuania, occurred in the autumn and winter of 2006–2007 and 2007–2008. The amount of precipitation here in November and January 2006–2007 comprised 105 and 138 mm, respectively. The winter of 2008 was warm, the ground was frozen for a short time and shallowly, thus providing favourable conditions for the migration of available nitrogen compounds into deeper soil layers and its leaching into groundwater. Therefore, high amounts of mineral nitrogen, especially in the Lowland of Central Lithuania, were detected in the mentioned year in deeper 30–60 and 60–90 cm soil layers, while in West Lithuania it leached into still deeper layers.

In 2007 and 2008, a very low content of nitrogen was found in about 25%, low in 52%, moderate in 17%, high and very high only in 6% of the country's farmlands, its average amount in a 0–60 cm layer comprising 50.3 kg ha^{-1}. The lowest nitrogen levels were found in the areas of perennial grasses and pastures – 41.6 kg ha^{-1} (2007), because the vegetation of grasses continued over a long and warm autumn, consuming mineral nitrogen present in the soil. Low amounts of mineral nitrogen after a winter period were found in the areas of winter crops, slightly more in the areas of former row crops, especially those fertilized with manure. As in earlier years, high amounts of mineral nitrogen were detected mostly in fields of companies possessing large cattle-breeding complexes.

Due to an uneven ground cover, farming intensity and climatic conditions, the content of mineral nitrogen in different areas and regions differs.

In **East Lithuania**, where the soils are less cultured, lighter granulometric texture prevails, from which mineral nitrogen is leached faster and the amount of nitrogen in the 0–60 cm layer was lower: in spring 2005–2008 – 44.4 to 54.2 kg ha^{-1} (mean, 49.7 kg ha^{-1}) (Table 1).

In slightly heavier soils of Rokiškis, Zarasai, Utena, Ignalina, Molėtai, Švenčionys districts, the level of mineral nitrogen in 2008 was higher than in 2007 (40–50 kg ha^{-1}), however, it was very low in soils of a very light granulometric texture, found in Southeastern Lithuania, i.e. Varėna, Trakai, Šalčininkai, Vilnius districts. Here, the level of mineral nitrogen at a depth of 0–60 cm failed to reach even 30 kg ha^{-1} (Fig. 3).

In East Lithuania, lower amounts were found also at different depths: 0–30 cm – 31.1 kg ha^{-1}, 30–60 cm – 18.6, while at 60–90 cm – 15.4 kg ha^{-1}. However, the level of N_{min} in individual years at a depth of 0–30 cm fluctuated not much – from 28.7

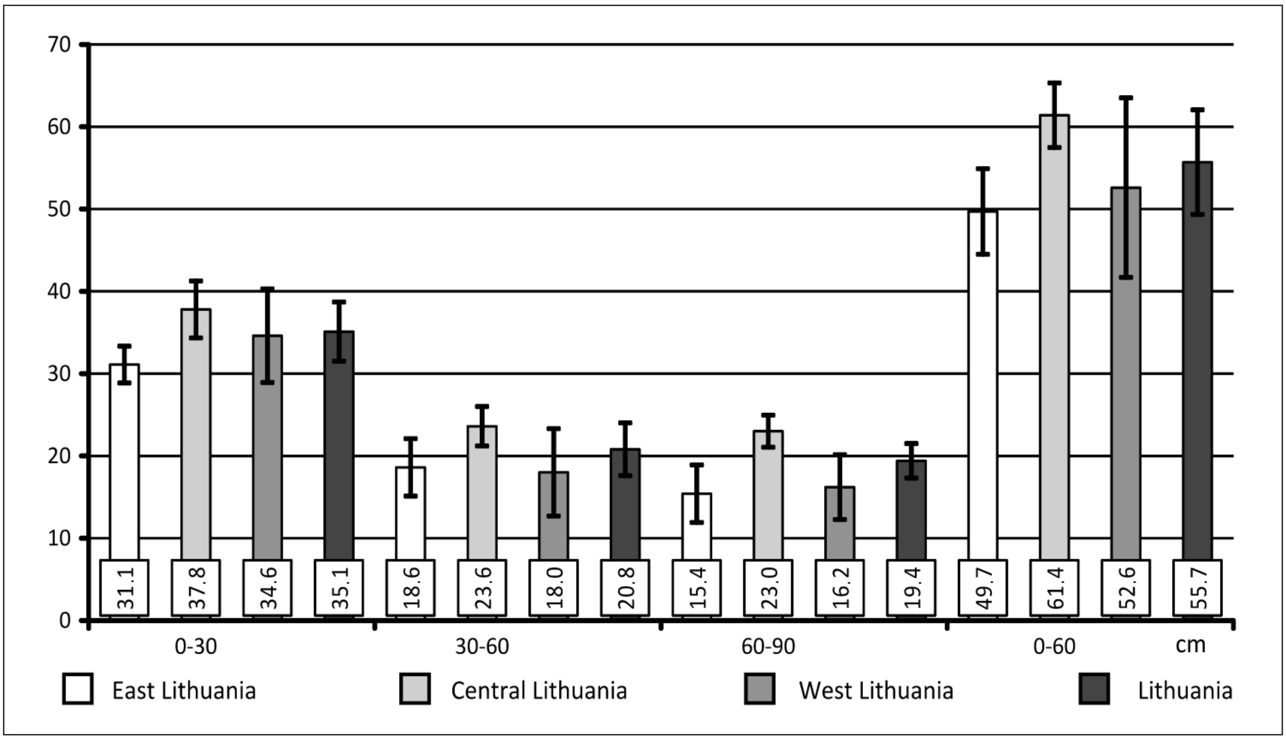

Fig. 2. Soil mineral nitrogen content in spring in various regions of Lithuania, 2005–2008

Table 1. **Content of mineral nitrogen in soil in spring and autumn**

Depth, cm	2005	2006	2007	2008
	Mineral nitrogen content in soil kg ha^{-1} – spring / autumn			
East Lithuania				
0–30	33.9 / 33.3	31.8 / 25.9	28.7 / 29.4	30.1 /
30–60	20.3 / 17.9	22.3 / 15.8	17.4 / 12.2	14.3 /
60–90	18.2 / 16.8	18.5 / 11.9	13.2 / 9.3	11.6 /
0–60	54.2 / 51.2	54.2 / 41.8	46.1 / 41.7	44.4 /
West Lithuania				
0–30	41.8 / 37.2	35.9 / 29.4	32.3 / 30.6	28.4 /
30–60	22.7 / 20.8	22.4 / 24.8	14.0 / 16.0	12.8 /
60–90	19.5 / 16.3	19.4 / 17.1	14.2 / 12.6	11.6 /
0–60	64.5 / 58.0	58.4 / 54.2	45.0 / 46.6	41.2 /
Central Lithuania				
0–30	42.3 / 41.3	36.7 / 39.7	34.0 / 43.3	38.0 /
30–60	22.6 / 24.1	27.2 / 27.4	22.3 / 20.6	22.3 /
60–90	23.3 / 23.0	22.2 / 21.1	25.5 / 17.8	20.9 /
0–60	64.9 / 65.4	64.0 / 67.2	56.4 / 63.9	60.3 /
Lithuania				
0–30	40.2 / 37.0	35.1 / 32.7	32.2 / 35.6	33.0 /
30–60	22.4 / 21.2	24.4 / 23.3	19.0 / 16.8	17.3 /
60–90	20.5 / 19.8	20.3 / 17.6	20.4 / 14.0	16.2 /
0–60	62.6 / 58.2	59.5 / 56.1	50.9 / 52.4	50.3 /

to 33.9 kg ha^{-1}, while at a depth of 30–60 and 60–90 cm it fluctuated slightly more – within 14.3– 22.3 and 11.6–18.5 kg ha^{-1}, respectively.

In soils of **Central Lithuania**, which are more fertile than soils of Eastern and Western Lithuania, the average amount of mineral nitrogen over 4 years in spring at a depth of 0–60 cm comprised 61.4 kg ha^{-1} or by 11.7 kg ha^{-1} more than in East Lithuania. Higher amounts of nitrogen were also found in different soil layers, however, the distribution of its relative amount was similar to that of East Lithuania. Due to a more uniform ground cover, the amount of mineral nitrogen in deeper layers (30–60 and 60–90 cm) in separate years varied less than in East Lithuania. Its average amount in 0–60 cm deep soils in the spring of 2008 comprised 60.3 kg ha^{-1} (Table 1). As in earlier years, a higher content of mineral nitrogen was determined in the Lowland of Central Lithuania – in Kėdainiai, Joniškis, Pakruojis, Panevėžys, Pasvalys and in most areas of Akmenė, Biržai, Šiauliai districts (Fig. 3).

Soils of **West Lithuania**, according to the data of 4 years, in spring at a depth of 0–60 cm contained 52.6 kg ha^{-1} of mineral nitrogen, while in 2007 and 2008 this value equalled 45.3 and 41.2 kg ha^{-1}. Besides, in the winter–spring period when precipitation is more abundant, the content of mineral nitrogen in different years varied considerably not only in the deeper but also in the upper (0–30 cm) soil layer. In 2007, a lower level of mineral nitrogen was recorded due to a more abundant precipitation in autumn and winter (precipitation was 1.7 times more abundant than in Central and East Lithuania) (Table 1).

In earlier years, the content of mineral nitrogen at a depth of 0–60 cm in soils of Kretinga, Klaipėda and Šilutė districts located in the Littoral and Nemunas Delta Plain and the Western Žemaitija Plateau was higher, but in 2008 rached only 30–40 kg ha^{-1}. Similar levels of mineral nitrogen were ascertained also in Žemaitija (the Western Kuršas Upland) and in the Western Žemaitija Plateau – Tauragė, Šilalė, Plungė, Skuodas, Telšiai, Mažeikiai and in the western part of Kelmė districts (Fig. 3).

Studying the influence of soil management on its ecological condition, it is important to determine changes in the content of mineral nitrogen following the winter period, because its level in spring at a depth of 60–90 cm, as compared to autumn, differs from year to year.

Changes of mineral nitrogen. In East Lithuania, the amount of mineral nitrogen at a depth of 60–90 cm in spring, as compared to autumn, changed but slightly. The amount of mineral nitrogen in the surface (0–30 cm) layer after winter was found to remain almost unchanged. Meanwhile, in Central Lithuania where farming is more intensive, the content of mineral nitrogen in the surface layer, following the winters of 2005, 2006 and 2007, decreased by 4.6, 5.7 and 5.3 kg ha^{-1}. The nitrogen unused by plants migrated from this layer to deeper layers and accumulated at a depth of 30–60 or 60–90 cm and deeper (Table 1).

In West Lithuania, due to more abundant precipitation, mineral nitrogen migrated to deeper soil layers more intensively. Following the warm winter of 2006/2007, the content of mineral nitrogen at a depth of 30–60 and 60–90 cm decreased by 10.8 and 2.9 kg ha^{-1}, respectively. Meanwhile, over the winter of 2005/2006 with less abundant precipitation, the migration of mineral nitrogen was less intensive – it leached only to a depth of 60–90 cm.

In a long-term trial (since 1971), having applied different rates of NPK fertilizers, the content of mineral nitrogen in spring at a depth of 0–60 cm depended on the rate of nitrogen fertilizers and their ratios with phosphorus and potassium, as well as on meteorological conditions in autumn and spring. In unfertilized plots it comprised on an average 41.5 kg ha^{-1}, in plots annually fertilized with average $N_{90}P_{90}K_{90}$ rates 53.1kg ha^{-1}, and in fertilized with N_{180} $P_{90}K_{90}$ 58.6 kg ha^{-1} (Fig. 4).

On applying average N_{90} rates on the background of $P_{90}K_{90}$, the content of mineral nitrogen at a depth of 0–60 cm was higher (11.6 kg ha^{-1}) than in unfertilized plots. Although with the application of the same rate of nitrogen fertilizers without phosphorus and potassium fertilizers the content of nitrogen increased to 14.2 kg ha^{-1}, however, at a depth of 60–90 cm it was by 8.6 kg ha^{-1} higher. It shows that following the winter period, a greater part of nitrogen was leached from the soil, while the remaining amount will be available to plants in the next year (Table 2).

Studies conducted in England have also confirmed that the content of mineral nitrogen at a depth of 90 cm depends on fertilization, while its changes in autumn by 70% depended on the rate of applied nitrogen fertilizers and the amount of organic matter in the arable layer. The nitrogen that had accumulated in autumn failed to be fully leached from the soil, thus, it should be taken into account when preparing fertilization recommendations for the following year (Sheperd, Sylvester-Bradley, 1996).

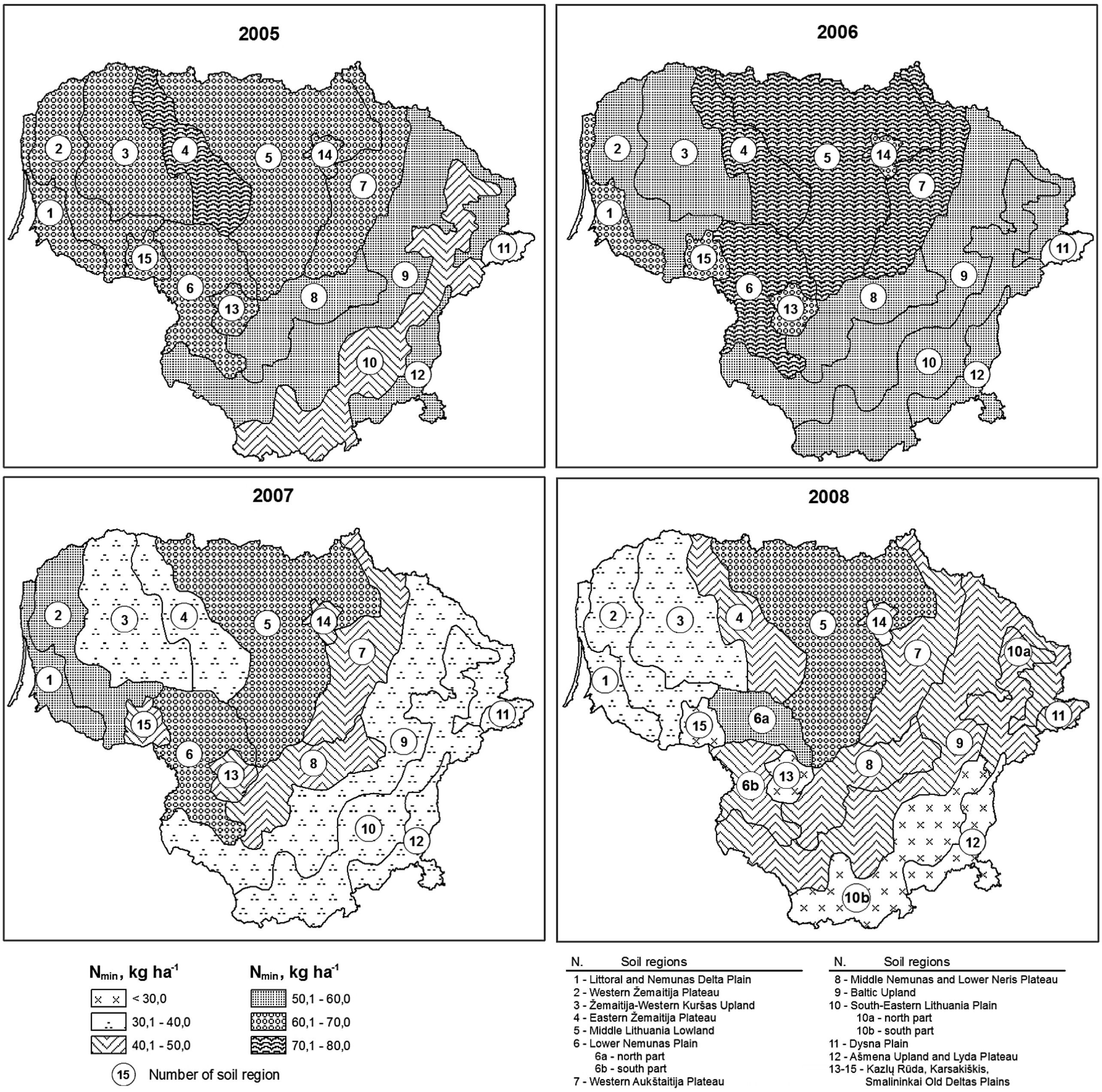

Fig. 3. Mineral nitrogen (N_{min}) in Lithuanian soil regions (spring, 0–60 cm, kg ha^{-1})

In the unfertilized plots of our trial, due to consumption by plants, the content of mineral nitrogen in the soil in autumn as compared to spring decreased by 9.7 kg ha^{-1} (Fig. 5). On applying the average rates of nitrogen (90 kg ha^{-1}), the content of nitrogen in the 60–90 cm deep layer increased not much – by 8.4 kg ha^{-1}. However, when high rates of nitrogen (180 kg ha^{-1}) were applied in spring, its level in the layers in autumn, as compared to spring, increased significantly – by 29.1 kg ha^{-1}. It increases environmental pollution, because the nitrogen unused by plants migrates to deeper soil layers.

The results of the study are in agreement with the data obtained in England: applying optimal rates of nitrogen fertilizers, only a small and unreliable tendency of nitrogen increment in the soil was observed, however, when the rates of nitrogen fertilizers were increased above optimal, the amount of nitrates in the soil augmented reliably (Chaney, 1990). According to studies in Sweden, residual nitrogen accumulated after harvesting in the soil only upon applying high rates (N_{200}) of nitrogen fertilizers, while in unfertilized plots and those fertilized with N_{100} the content of mineral nitrogen reached respectively 45 and 70 kg ha^{-1} (Bergstrëm, Brink, 1986).

From the environmental viewpoint, it is especially important to assess changes of nitrogen content in soil after winter. For a long time – since 1971 – the content of nitrogen in the soil of unfertilized plots in spring, as compared to autumn, altered insignificantly (Fig. 6). Meanwhile, applying average rates (90 kg ha^{-1}) of nitrogen fertilizers, the amount of nitrogen in the 60–90 cm soil layer over winter decreased on an average by 8.2 kg ha^{-1}.

However, applying high rates (180 kg ha^{-1}) of nitrogen fertilizers, the content of mineral nitrogen in the ecologically most sensitive 60–90 cm deep layer over winter decreased even

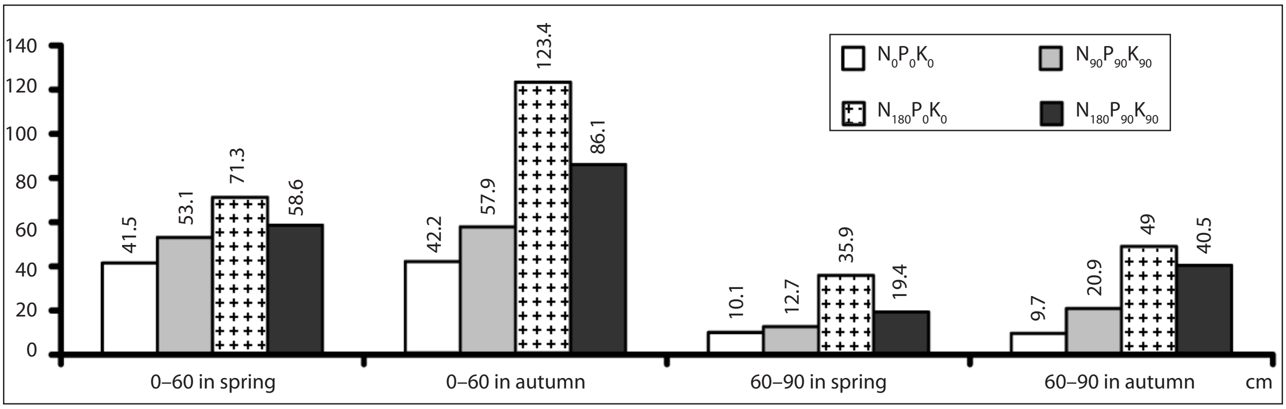

Fig. 4. Effect of long-term fertilization on mineral nitrogen content in soil, 2005–2008

Table 2. **Effect of long-term fertilization on mineral nitrogen content in soil Skėmiai, 2005–2008**

Years of research	Fertilization rates, kg ha^{-1}			Depth, cm		
				0–30	30–60	60–90
	N	P	K	N_{min} kg ha^{-1} in spring / in autumn		
2005	0	0	0	/ 37.9	/ 17.4	/ 13.3
	0	90	90	/ 32.7	/ 17.9	/ 15.1
	90	0	0	/ 56.3	/ 22.3	/ 15.7
	90	0	90	/ 43.5	/ 17.2	/ 15.8
	90	90	0	/ 38.2	/ 17.7	/ 17.0
	90	90	90	/ 58.8	/ 21.6	/ 17.2
	180	0	0	/ 54.2	/ 48.7	/ 28.8
	180	90	90	/ 58.7	/ 32.9	/ 18.1
	180	0	180	/ 65.4	/ 33.5	/ 25.6
	180	180	0	/ 59.8	/ 35.7	/ 24.9
	180	180	180	/ 46.8	/ 35.6	/ 19.1
2006	0	0	0	40.5 / 23.9	25.1 / 15.4	14.9 / 9.0
	0	90	90	38.2 / 23.7	26.6 / 13.8	15.6 / 14.9
	90	0	0	40.9 / 44.2	42.3 / 51.2	25.3 / 35.2
	90	0	90	39.2 / 48.6	37.3 / 105.1	18.6 / 48.0
	90	90	0	43.9 / 23.1	29.2 / 45.9	21.9 / 29.0
	90	90	90	46.3 / 28.1	43.9 / 24.1	20.1 / 35.1
	180	0	0	53.5 / 36.7	60.2 / 168.8	38.8 / 78.9
	180	90	90	51.0 / 25.2	42.2 / 71.5	25.9 / 76.9
	180	0	180	63.9 / 87.8	56.2 / 138.6	33.5 / 58.2
	180	180	0	53.4 / 27.1	60.8 / 72.2	28.7 / 34.4
	180	180	180	49.6 / 24.6	53.4 / 53.4	21.1 / 47.0

Table 2 (continued)

Years of research	Fertilization rates, kg ha^{-1}			Depth, cm		
				0–30	30–60	60–90
	N	P	K	N_{min} kg ha^{-1} in spring / in autumn		
2007	0	0	0	15.9 / 23.8	9.1 / 8.2	5.3 / 6.8
	0	90	90	15.0 / 20.2	9.6 / 8.0	6.9 / 7.8
	90	0	0	17.0 / 28.2	13.1 / 14.2	17.9 / 15.4
	90	0	90	14.8 / 23.8	10.6 / 15.2	14.1 / 10.3
	90	90	0	13.5 / 24.4	10.5 / 13.4	6.9 / 11.6
	90	90	90	19.0 / 29.4	11.5 / 11.6	8.7 / 10.4
	180	0	0	21.1 / 26.6	16.5 / 35.2	35.1 / 39.2
	180	90	90	15.7 / 36.8	15.8 / 33.2	19.4 / 26.6
	180	0	180	14.1 / 35.2	20.5 / 28.2	61.4 / 38.0
	180	180	0	19.1 / 35.7	19.7 / 33.8	28.5 / 24.0
	180	180	180	16.8 / 24.4	12.5 / 36.4	19.7 / 24.6
2008	0	0	0	24.5 /	9.4 /	10.0 /
	0	90	90	20.2 /	9.6 /	3.6 /
	90	0	0	32.2 /	21.6 /	13.0 /
	90	0	90	25.9 /	10.0 /	9.2 /
	90	90	0	22.8 /	11.4 /	7.0 /
	90	90	90	26.2 /	12.4 /	9.4 /
	180	0	0	37.8 /	24.7 /	33.7 /
	180	90	90	34.0 /	17.2 /	12.9 /
	180	0	180	33.5 /	21.9 /	21.5 /
	180	180	0	26.8 /	27.6 /	24.0 /
	180	180	180	51.2 /	28.2 /	14.2 /
			LSD_{05}	5.16/6.46	4.01/6.92	3.10 / 4.67

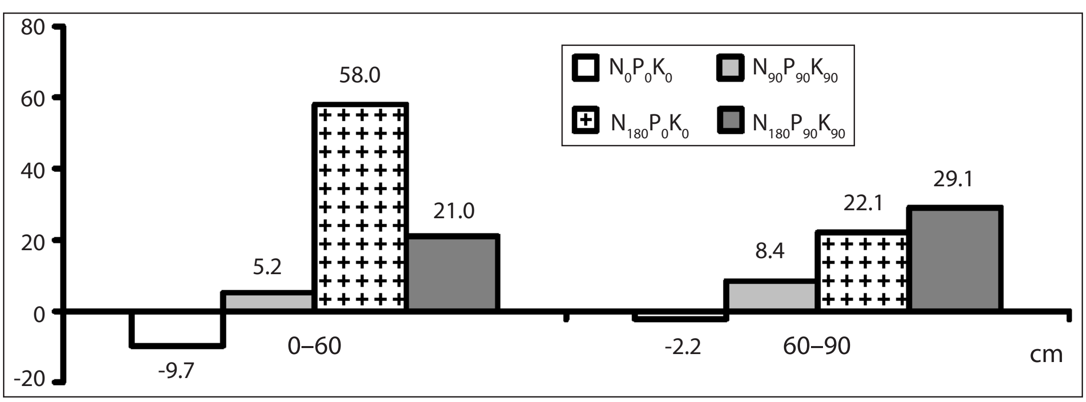

Fig. 5. Effect of fertilization on N_{min} changes in soil after summer season, 2005–2008

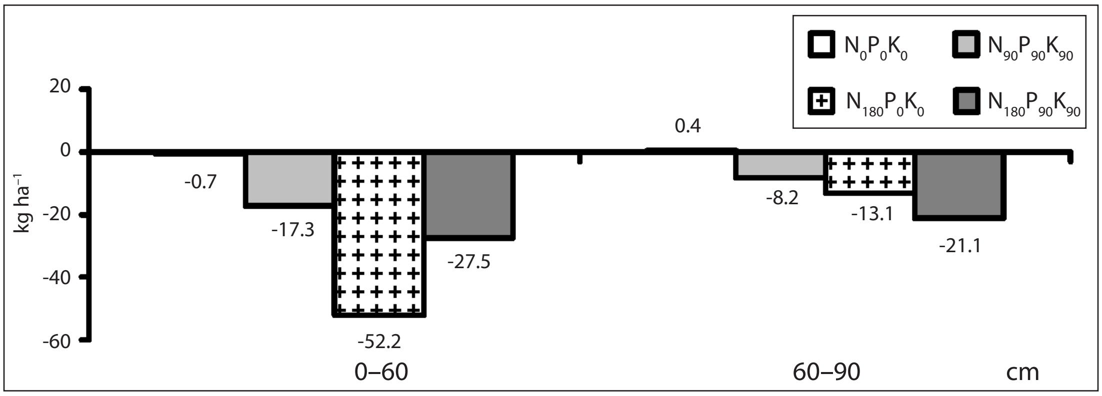

Fig. 6. Effect of fertilization on N_{min} changes in soil after winter season, 2006–2008

by 21.1 and in the 0–60 cm layer – by 27.5 kg ha^{-1}. Therefore, application of higher than 90 kg ha^{-1} rates of nitrogen is risky, as part of the nitrogen migrates deeper and contaminates the environment.

Seeking to reduce environmental pollution by nitrogen compounds and to improve the efficiency of fertilization in the following year, it is necssary to take into account the content of nitrogen that is present in the soil in spring (Yang, Jong, Huffman et al., 2004). Data of our studies show that the content of mineral nitrogen in soil was influenced not only by the application of nitrogen on the background of PK fertilizers, but also by precipitation, air temperature and soil freezing. On applying $N_{90}P_{90}K_{90}$ rates of fertilizers, due to different meteorological conditions, the content of nitrogen in soil differed (Table 2). This shows that the monitoring of nitrogen levels in soil requires precise meteorological data of each year (amount of precipitation, air temperature, soil freezing depth). Upon compiling more data on the content of mineral nitrogen in Lithuanian soils and upon relating them to the meteorological data in individual periods, it would be possible to forecast its levels in the course of years without additional N_{min} studies.

CONCLUSIONS

1. According to the mean data of 2005–2008, the amount of mineral nitrogen (NO_3 + NH_4) in the 0–60 cm soil layer varied from 50.2 to 62.6 kg ha^{-1} (mean, 55.7 kg ha^{-1}) and depended on the intensity of farming, soil granulometric texture, amount of precipitation and air temperature. The highest amounts were found in 2005, while the lowest – in 2007 and 2008.

2. The highest N_{min} levels (46.6% of the total content in the 0–90 cm layer) were found at a depth of 0–30 cm, and they were lower at a depth of 30–60 cm (27.6%) and 60–90 cm (25.8%).

3. In 2007 and 2008, very low levels of nitrogen were found in 25%, low in 52%, moderate in 17%, high and very high only in 6% of the country's farmlands, its average content in the 0–60 cm layer being 50.3 kg ha^{-1}.

4. In the soils of Central Lithuania, which are more fertile than soils of Eastern and Western Lithuania, the levels of mineral nitrogen at a depth of 0–60 cm were highest and on the average over 4 years comprised 61.4 kg ha^{-1}; they were lower in West Lithuania (52.6 kg ha^{-1}) and in East Lithuania (49.7 kg ha^{-1}).

5. In a long-term trial (38 years), under different rates of NPK fertilizers, the content of mineral nitrogen in spring at a depth of 0–60 cm depended on the rate of nitrogen fertilizers and their combination with phosphorus and potassium, as well as on meteorological conditions in the autumn–spring period. In unfertilized plots it comprised on the average 41.5 kg ha^{-1}, in plots fertilized every year with $N_{90}P_{90}K_{90}$ 53.1 kg ha^{-1}, and in plots fertilized with $N_{180}P_{90}K_{90}$ – 58.7 kg ha^{-1}.

6. The content of mineral nitrogen at a depth of 0–60 cm fertilized at average rates of $N_{90}P_{90}K_{90}$ and high rates of $N_{180}P_{90}K_{90}$ in autumn increased (respectively by 5.2 and 21.1 kg ha^{-1}) as compared to spring, and in the soil of unfertilized plots decreased (by 7.1 kg ha^{-1}). In the spring before the next fertilization applying N_{90} and N_{180} rates, N_{min} decreased and in the soil of unfertilized plots remained almost unchanged.

7. With high rates (180 kg ha^{-1}) of nitrogen fertilizers applied in spring and unused by plants in summer, under unfavourable conditions in autumn–winter, considerable amounts of nitrogen migrates into deeper soil layers and contaminate the environment.

8. To implement the monitoring of nitrogen research in the soil, it is necessary to have meteorological data on precipitation, air temperature and soil freezing depth of each year. Upon compiling more data on the levels of mineral nitrogen in Lithuanian soils, and having related them to the meteorological data of different periods, it could be possible to forecast its levels in the run of years without additional investigations.

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MINERALINIS AZOTAS LIETUVOS DIRVOŽEMIUOSE

Santrauka

Tyrimai daryti įvairiuose Lietuvos dirvožemių rajonuose, skirtingos granuliometrinės sudėties plotuose su įvairiais augalais (žiemkenčiais, vasarojumi, kaupiamaisiais, pievomis, ganyklomis ir kt.) pavasarį ir rudenį 0–30, 30–60 ir 60–90 cm sluoksniuose, 20 × 20 m aikštelėse. Be to, mineralinio azoto tyrimai atlikti ir skirtingai NPK trąšomis kasmet (38 m.) tręštame dirvožemyje. Vidutiniais 2005–2008 m. pavasarį šalyje atliktos stebėsenos duomenimis, mineralinio azoto (NO_3 + NH_4) kiekis 0–60 cm sluoksnyje įvairavo nuo 50,2 iki 62,6 kg ha^{-1} (vidutiniškai 55,7 kg ha^{-1}) ir priklausė nuo žemės ūkio gamybos intensyvumo, dirvožemio genezės, granuliometrinės sudėties ir kritulių kiekio (r = 0,70; t = 2,91), o atskirais metais ir nuo oro temperatūros. Daugiausiai jo aptikta 2005 m., o mažiausiai – 2007 ir 2008 m. Dirvožemio 60–90 cm sluoksnyje azoto nustatyta nuo 11,6 iki 25,5 (vidutiniškai 19,4 kg ha^{-1}).

Ilgalaikiame bandyme augalus įvairiai patręšus NPK, mineralinio azoto kiekis pavasarį 0–60 cm dirvožemio sluoksnyje priklausė nuo azoto trąšų normų ir jų derinių su fosforu ir kaliu bei meteorologinių sąlygų rudenį–pavasarį. Netręšus jo nustatyta vidutiniškai 41,5 kg ha^{-1}, kasmet patręšus vidutiniškai $N_{90}P_{90}K_{90}$ – 53,1 kg ha^{-1}, o patręšus $N_{180}P_{180}K_{180}$ – 58,7 kg ha^{-1}. Mineralinio azoto kiekis 0–60 cm sluoksnyje rudenį, palyginti su pavasariu, netręštų bandymo laukelių dirvožemyje sumažėjo 7,7 kg ha^{-1}, o tręšiant vidutiniškai (N_{90}) ir gausiai (N_{180}) – padidėjo atitinkamai 5,2 ir 21,1 kg ha^{-1}. Pavasarį, prieš eilinį tręšimą N_{90} ir N_{180}, mineralinio azoto kiekis dirvožemyje sumažėjo, o netręšus – mažai pasikeitė.

Raktažodžiai: dirvožemio rajonai, dirvožemiai, N_{min}, trąšų normos ir jų deriniai