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The regularities of mineral nitrogen distribution in Lithuania's soils in spring

Gediminas STAUGAITIS, Lina ŽIČKIENĖ, Jonas MAŽVILA, Jonas ARBAČIAUSKAS, Donatas ŠUMSKIS, Aistė MASEVIČIENĖ, Rūta STAUGAITIENĖ

Agrochemical Research Laboratory, Lithuanian Research Centre for Agriculture and Forestry
Savanorių 287, Kaunas, Lithuania
E-mail: agrolab@agrolab.lt

Abstract

The monitoring of mineral nitrogen (N_{min}) concentration in Lithuanian soils was conducted during the period 2005–2014 in 206 test sites of 20 × 20 m size located in 15 different soil regions considering the appropriate geographical units. The soil regions are distinguished from one another by relief, soil type, soil texture, climatic conditions as well as the specialisation and intensity of agricultural activities.

It was found that soil N_{min} concentration in spring differed not only between years, but also between the geographic climatic zones of Lithuania. The most important factors and their interactions affecting the soil N_{min} concentration in spring were crops and pre-crops, soil texture, winter air temperatures and precipitation levels. The lowest N_{min} concentration in 0–60 cm soil layer in spring was recorded in perennial grass fields and pastures, in fields where pre-crops were spring cereals and spring rape, in sandy loam and particularly sand soils, when precipitation levels during the November–March period were high and especially when this level exceeded 250 mm, when predominant winter air temperature was above 0°C. The soil N_{min} concentration tests taking into account the territorial division of Lithuania into 15 soil regions enabled us to assess the long-term fluctuation of this indicator as affected by the local conditions. The accumulated and processed multiannual data can be used as a reference for the assessment of the results of the future tests.

Key words: air temperature, mineral nitrogen, precipitation, soil, soil texture.

Introduction

The optimisation of nitrogen fertilisation is one of the most important tasks in agriculture aiming to avoid the nitrate pollution of environment and to achieve high crop yields (Wiesler, Armbruster, 2009). Soil mineral nitrogen (N_{min}) is an indicator characterising the available amount of nitrogen which is mobile and readily accessible for plants. This form of nitrogen constitutes only 1–5% of the total soil nitrogen (Bednarek, Reszka, 2008). Usually the N_{min} concentration in soil is measured in early spring; based on the obtained results the nitrogen fertilisation rates are calculated. Soil N_{min} concentration is also measured in autumn to know the amount of N_{min} or only nitrates left after the cropping season – before winter (Fotyma et al., 2005; Staugaitis et al., 2009). Soil N_{min} is very mobile due to the fact that large part of it is in nitrate form; therefore it is difficult to precisely forecast the amount of it in soil as well as to foresee its concentration fluxes in the long term (Rutkowska, Fotyma, 2011). Substantial part of large amounts of soil N_{min} recorded in autumn is usually lost until spring; these high levels of nitrate leaching can be decreased using reduced rates of nitrogen fertilisation and growing catch crops (Entz et al., 2001; Zentner et al., 2001; Fan et al., 2010).

N_{min} concentration in soil is affected by a range of different factors: precipitation levels influencing the leaching of nitrates into the deeper soil layers, soil and air temperature influencing the rate of organic matter mineralisation, soil texture and typology, amount of organic matter in soil, crops, amount of plant residues left in field after harvesting, organic and mineral fertilisation rates, etc. (Goulding, 2000; Fotyma et al., 2005; Spiegel et al., 2009; Timbare et al., 2009; Rutkowska, Fotyma, 2011). Plants assimilate soil N_{min} present in the zone of the distribution of their roots, usually not deeper than 60 or 90 cm. The highest concentration of N_{min} is recorded in 0–30 cm layer of soil; the levels of it differ from year to year, yet continue correlating with the concentration of N_{min} available in the deeper layers of soil (Loch et al., 2009).

Effect of N_{min} concentration in soil on the crop productivity is indisputably proved by the multiple experiments conducted in the past (Lazauskas et al., 1995; Staugaitis et al., 2007; Wiesler, Armbruster, 2009), and the measuring of soil N_{min} concentration in spring before application of fertilisers became an inseparable part of nitrogen fertilisation practice in intensive production farms (Staugaitis et al., 2009). Practical experience has shown that due to the large volumes of work to be carried out in a short period of time in spring it is not possible to conduct the N_{min} tests (collect the soil samples) in the majority of farms; therefore the soil N_{min} monitoring systems were introduced by several European Union countries (in Germany – more than 20 years ago, in Czech Republic, Hungary, Poland, Estonia, Latvia and some other countries – 10–15 years ago); the data obtained from these monitoring systems are used for practical, scientific and forecasting purposes (Čermák, Kubík, 2009; Loch et al., 2009; Loide et al., 2009; Timbare et al., 2009; Wiesler, Armbruster, 2009; Rutkowska, Fotyma, 2011). The soil N_{min} monitoring in the aforementioned countries is conducted using different approaches, including sampling methods, as well as taking into account local agro-climatic conditions and plant-growing specifics. The results obtained are used to determine the soil N_{min} concentration in different regions, the amount of it left in soil after different crops and different fertilisation patterns applied, for assessment of the changes taking place during winter, as well as for the balance and leaching calculations (Fotyma et al., 2005; Loide et al., 2009; Wiesler, Armbruster, 2009).

Since 2005 soil N_{min} monitoring has been conducted in Lithuania as well. In this work we reviewed the trends of soil N_{min} concentration changes in different regions of Lithuania for the last 10 years. We also aimed to assess the effect of different climatic conditions and soil properties as well as the crops on the changes in N_{min} concentration in soil.

Materials and methods

In 2005–2014, the mineral nitrogen (N_{min}) concentration in Lithuanian soils in spring was monitored at 206 test sites of 20 × 20 m size located in agricultural lands in 15 different soil regions (Fig. 1). The partition of Lithuanian territory into these regions was based on the covering soil properties – soil type, soil texture, as well as relief and climatic conditions (Juodis, 2001 a).

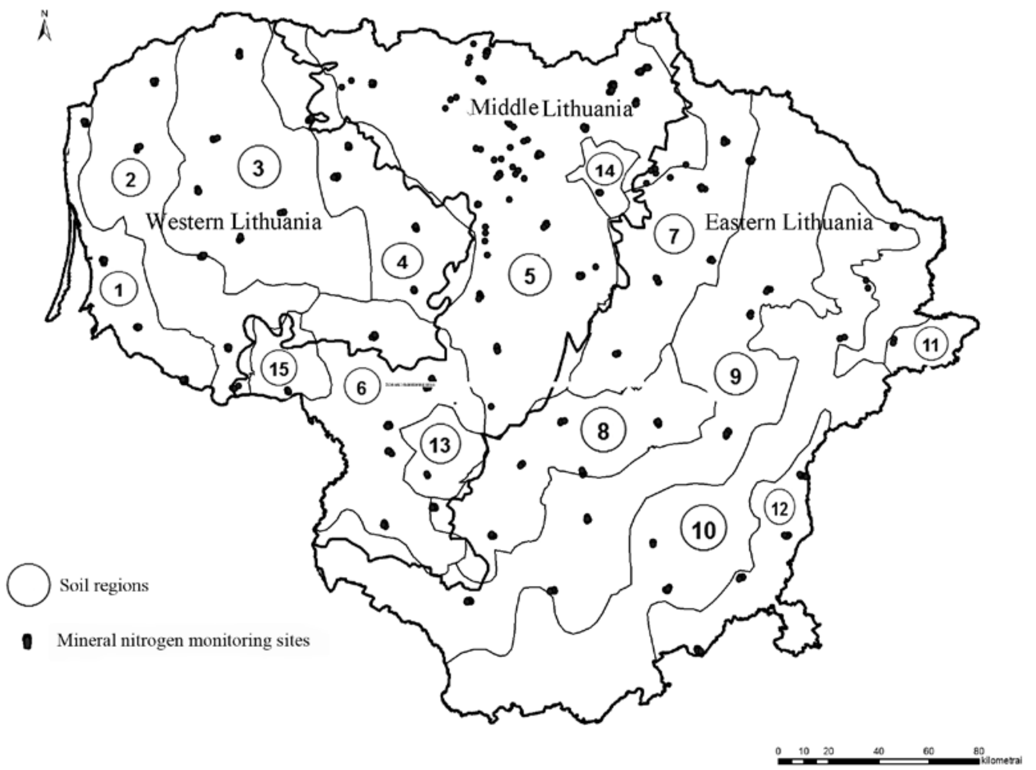


Figure 1. Locations of soil sampling for mineral nitrogen (N_{min}) tests

The main characteristics of an individual soil region are presented in Table 1. The aim of this study was to determine the N_{min} concentration and its changes not only in different soil regions, but also in larger geographical units – Western, Middle and Eastern zones of Lithuania, which differ not only in agro-climatic conditions, but also in the intensity and kinds of agricultural activities.

The climate of Western Lithuania zone is predominantly maritime, annual precipitation rate is 650–900 mm, the average air temperature of the coldest month is −3.0–−3.4°C (in Coastal Lowland −1.9°C), prevailing agricultural activity – average intensive grain producing farms, in strongly rolling landscape areas the agricultural land is mainly occupied with scarcely fertilised perennial grass fields. This zone includes soil regions Nos. 1, 2, 3 and 4, and part of the soil region Nos. 5 and 6.

The climate of Middle Lithuania zone is predominantly transitive from maritime to continental, the landscape is flat, annual precipitation rate is 550–650 mm, the average air temperature of the coldest month is −3.1–−3.6°C. It is the zone of the most intensive agricultural activities, dominated by the intensive plant growing farms producing cereals, oilseed rape, row crops and industrial crops. This zone includes soil regions

Table 1. Characteristics of soil regions

Soil region No.	Dominant landscape type	Prevailing soil types	Prevailing soil texture	Average precipitation (mm) rate during the November–March period in 2005–2014
1	Flat	*Arenosols*, *Gleyic Retisols*, *Fluvisols*	sand, sandy loam	305.4
2	Gently and moderately rolling	*Eutric Retisols*	sandy loam, sandy clay loam, loam	291.4
3	Hilly, rolling	*Eutric Retisols*, *Dystric Retisols*	sandy loam, sandy clay loam, loam	323.4
4	Flat or gently and moderately rolling	*Gleyic Luvisols*, *Eutric Retisols*	sandy loam, sandy clay loam, loam	195.0
5	Flat	*Gleyic Cambisoils*, *Calc(ar)ic Luvisols*, *Gleyic Luvisols*	sandy loam, sandy clay loam, loam	206.5
6	Flat	*Gleyic Cambisols*, *Gleyic Luvisols*	silt loam, silty clay loam	205.6
7	Gently and moderately rolling	*Gleyic Luvisols*	sandy loam, sandy clay loam	205.8
8	Gently and moderately rolling	*Stagnic Luvisols*, *Haplic Luvisols*	sandy clay loam	196.4
9	Moderately and strongly rolling	*Eutric Retisols*	sandy loam, sandy clay loam	207.2
10	Moderately rolling	*Haplic Arenosols*	sand	220.2
11	Flat, gently rolling	*Haplic Luvisols*	silt loam, clay loam	191.8
12	Rolling, hilly	*Dystric Retisols*	sandy loam	247.0
13, 14, 15	Flat	*Gleyic Podzols*, *Haplic Arenosols*	sand	196.4, 199.9, 228.7

Nos. 5, 13, 14 and 15, and the larger part of the soil region No. 6.

The climate of Eastern Lithuania zone is transitive from maritime to continental gradually shifting to continental, the landscape is gently rolling to strongly rolling, light sandy soils, annual precipitation rate is 600–700 mm, the average air temperature of the coldest month is −3.7 – −4.8°C. Snow cover period lasts 90–105 days (in the other two zones – 60–90 days). Low intensity or average-intensive grain farming prevails. Lands of poor soil quality are occupied with scarcely fertilised perennial grass fields. This zone covers soil regions Nos. 7, 8, 9, 10, 11 and 12, and part of the soil region No. 5.

Soil samples for N_{min} concentration tests were collected only from mineral soils and only from the fields used by the cropping farms; these fields were grouped depending on the situation recorded in spring: 1) pre-crops winter cereals (winter wheat, winter rye, winter triticale) and winter rape, 2) present winter cereals and winter rape, 3) pre-crops spring cereals (spring wheat, spring barley, oat) and spring rape, 4) preceding row crops (potato, sugar beet, fodder beet, corn for silage), 5) perennial grasses and pastures. The data obtained from the monitoring plots set in the fields belonging to the large livestock farms were not included in this study. The monitoring plots included in this study were not grouped according to the applied crop fertilisation rates. Every year the monitoring spots were identified using GPS system.

Soil texture in the selected monitoring plots was determined down to 60 cm depth; it differed going through the soil profile, therefore the similar groups of soil texture types were put together and 4 larger units were made: 1) sand (abbr. S), 2) sandy loam (SL), 3) loam (L), 4) clay loam-clay-silt loam (CL-C-SiL).

Soil samples for N_{min} concentration tests were collected in early spring, just when it was possible to enter the fields: from the last days of March till the end of April. Soil samples were collected from 0–30 and 30–60 cm soil layers. One composite soil sample was made of 4–5 subsamples it was then thoroughly mixed, placed into a plastic box or a plastic bag and put into the specially suited cooled bag. These sample-containing bags were brought to the laboratory, where the collected samples were kept in a refrigerator at 1–3°C. The concentration of nitrate and ammonia nitrogen in the tested soil sample was measured in accordance with the national standard GOST 26483-85 (Soils. Preparations of salt extract and determination of its pH by CINAO method); the soil sample was dried, then the 1:2.5 1 M KCl extraction was made. The solution was agitated for 1 hour. Nitrate and ammonia nitrogen concentration in the obtained filtrate was determined using an analyser FIAstar 5000 (Foss Analytical A/S, Denmark). A total of 5840 soil samples were collected during the 10 years of the soil N_{min} monitoring activities.

The data obtained from the soil N_{min} tests were processed using programmes *MS Excel 2010* and *STATISTICA 7* and grouped according to the three country zones, soil regions, crops and pre-crops, soil texture and the year. Minimal and maximal values, arithmetic means, medians, standard deviations, 25% and 75% percentiles were calculated. Correlation and regression analyses were conducted in order to determine the relationship between the amount of precipitation and temperature during winter period and the concentration of N_{min} in soils of different texture. The results obtained were tested for their statistical significance.

Since during the winter period nitrates are often intensively leached into the deeper soil layers, we decided to analyse the obtained data more thoroughly and employed the information obtained from the Lithuanian Hydrometeorological Service; we calculated the average amount of precipitation during November–March period (Table 2).

Table 2. The average air temperature and average precipitation amount during November–March period

Zones of Lithuania	Year									
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Temperature °C										
Eastern	−3.0	−3.6	1.2	0.1	−0.8	−2.8	−3.1	−1.6	−2.2	0.8
Middle	−2.5	−3.1	1.4	0.6	−0.5	−2.8	−3.0	−1.0	−1.9	1.2
Western	−1.9	−2.2	2.6	1.4	0.3	−2.0	−2.2	−0.1	−1.0	1.7
Precipitation mm										
Eastern	180.9	150.0	242.0	239.3	196.8	234.7	233.5	194.3	165.1	211.2
Middle	170.8	132.7	280.6	247.1	218.9	207.7	223.1	177.4	158.4	200.0
Western	250.4	230.2	410.4	385.8	303.0	257.8	317.8	370.0	217.0	275.9

Note. The long term (1991–2003) average air temperature for November–March period in Lithuania is −1.0°C, the long term (1961–1990) average precipitation level for November–March period is 203.7 mm.

Results and discussion

During the ten years of monitoring activities the concentration of N_{min} recorded in 0–60 cm soil layer in spring in three nature-climate zones of Lithuania differed substantially (Fig. 2). In Western Lithuania zone (average intensity of agricultural activities, high precipitation levels) the calculated soil N_{min} concentration ten-year median was 5.38 mg kg^{-1}, 25% and 75% percentiles were 4.35 and 6.87 mg kg^{-1}, respectively. The aforementioned indices calculated for Middle Lithuania zone (most fertile soils, agricultural activities of high intensity) were substantially higher: 6.33, 5.63 and 7.40 mg kg^{-1}, respectively. As for Eastern Lithuania zone (light texture soils prevail), the calculated values of these indices were the lowest ones: 4.95, 4.07 and 6.06 mg kg^{-1}, respectively. Winters of 2007, 2008 and 2014 were mild, soil was frozen only for a short time, while precipitation levels were high and exceeded 200 mm (in Western Lithuania these levels reached even 275–410 mm), which resulted in the lowest recorded N_{min} concentrations in soil.

N_{min} concentration in soils of Western Lithuania zone in spring was very low in the years when winter temperatures were predominantly above 0°C, soil was not frozen or frozen only for a short period of time and the frozen layer was not thick, and the precipitation amount during November–March period was close to 300 mm and more. Such conditions were observed in 2007, 2008, 2009 and 2014. Precipitation levels in Middle Lithuania zone were lower; the influence of mild winters on the soil N_{min} concentration decrease in spring was not so clearly expressed. The span of soil N_{min} values obtained here was much wider, and the recorded maximal N_{min} values were much higher than those found in the other two zones – they varied from 14.3 mg kg^{-1} (2012) to 50.55 mg kg^{-1} (2005) and 50.72 mg kg^{-1} (2008). N_{min} concentration in 0–60 cm layer of soils in Eastern Lithuania zone was not only smallest compared to the rest of Lithuania; the obtained N_{min} concentration values were spread in the quite narrow span. The lowest soil N_{min} concentration in spring was recorded in the years when the average air temperature during November–March period was above 0°C: 2007, 2008 and 2014.

The surface of Lithuania's territory was formed by the several last ice-ages; therefore it is very patchy and diverse in landscape as well as in soil types and soil texture (Juodis, 2001 b). N_{min} concentration in soils of different soil regions differed not only between years, but also between regions – by the calculated ten-year average values (Table 3). N_{min} concentration in the soil region No. 1, located in seacoast area and distinguished by the light-textured soils, was higher than in the soil regions No. 2 and No. 3, where the landscape is transiting from rolling to hilly, the intensity of plant growing activities is lower and the less-fertilised meadows cover the hills. The average N_{min} concentration in the aforementioned soil regions recorded in 0–60 cm soil layer in spring was 6.10, 5.86 and 5.20 mg kg^{-1}, respectively. Precipitation level in this part of the zone is the highest throughout the year, which continued to be so during November–March period also. Extremely low soil N_{min} concentration in this part of the zone was recorded in spring of 2007, 2008 and 2009, when the frozen soil layer was thin and did not last long, and the precipitation amount during November–March period exceeded 300 mm.

Western Lithuanian hills in the soil region No. 4 are gradually replaced by the plains. Soils here are more fertile, the intensity of agricultural activities is higher. Ten-year average N_{min} concentration (5.84 mg kg^{-1}) is higher than that of the hilly soil region No. 3. According to the calculations, the precipitation amounts during November–March period in this soil region and the soil

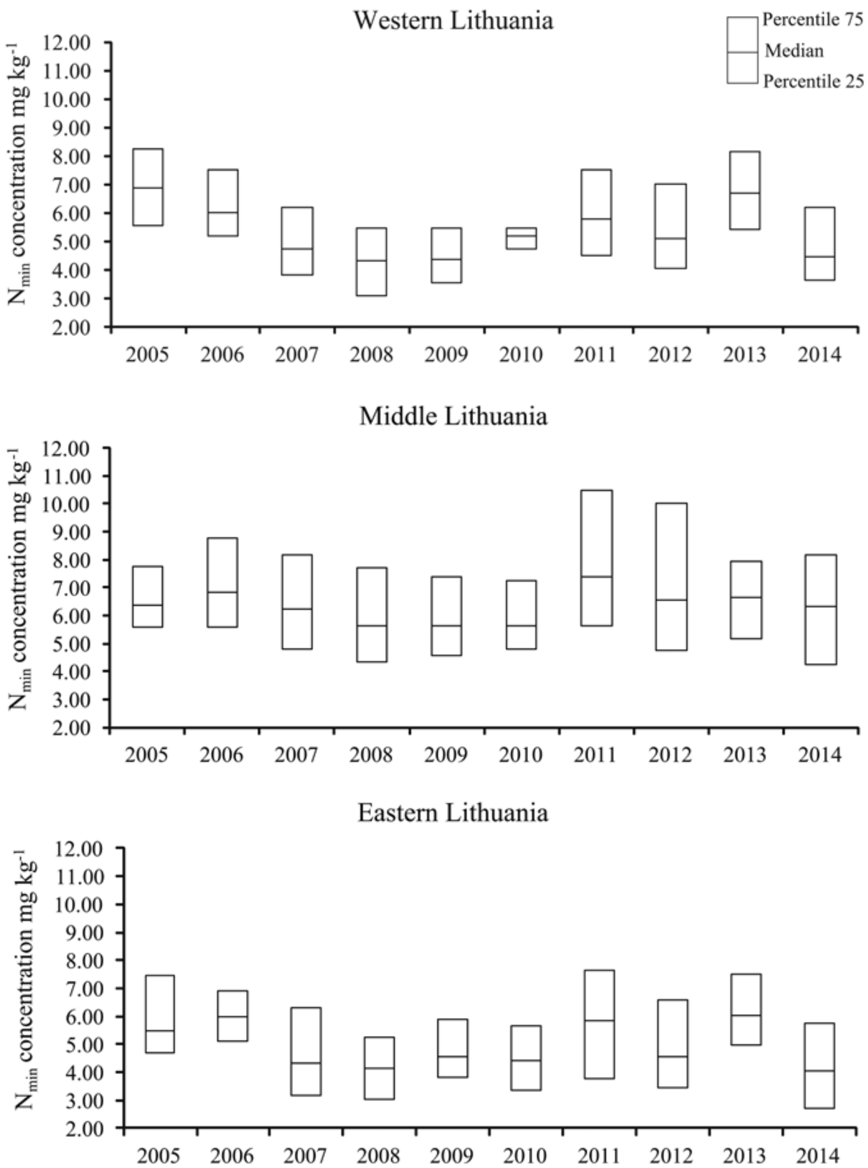


Figure 2. Mineral nitrogen (N_{min}) concentration in 0–60 cm soil layer in spring of 2005–2014

regions located in the Middle and Eastern Lithuania are by 30–50% lower than those recorded in the first three soil regions of Western Lithuania (Table 1); as a result of this, the lesser amounts of nitrates are leached into the deeper layers during winter. The most intensive agricultural activities (both crop production and livestock farming) take place in the soil regions No. 5 and No. 6; the landscape here is predominantly flat, soils are the most fertile here, crop yields are the highest too. Naturally, the N_{min} concentration in 0–60 cm soil layer in these regions recorded in spring was the highest as well – 7.93 and 6.67 mg kg^{-1}, respectively. Substantially higher N_{min} concentration in the soil region No. 5 was recorded in the spring of 2006, 2008, 2011 and 2012 – 8.48, 8.46, 8.73 and 9.54 mg kg^{-1}, respectively.

Moving from the Middle Lithuania zone to the Eastern Lithuania the plains are gradually replaced by the gently and moderately rolling relief, the share of light-textured soils is increasing, *Cambisols* are replaced by *Luvisols*. The ten-year average N_{min} concentration in 0–60 cm layer of soil in spring recorded in the soil regions No. 7 and No. 8 was lower compared to Middle Lithuania – 6.66 and 5.81 mg kg^{-1}, respectively. Landscape in the soil region No. 9 is moderately up to strongly rolling, agricultural land fields are rather small, depressions are most often occupied by natural meadows, and the intensity of cropping activities is quite low. Here the ten-year average N_{min} concentration in 0–60 cm layer of soil in spring was 5.23 mg kg^{-1}, while in the neighbouring soil region No. 10, dominated by the *Arenosols* – only 4.34 mg kg^{-1}. N_{min} concentration in 0–60 cm soil layer in spring recorded in these sandy soils was extremely low in 2008 and 2014 (3.43 and 3.22 mg kg^{-1}, respectively) – the winters in aforementioned years were mild, an average 24 hours' air temperature during November–March period was 0.1°C in 2008 and 0.8°C in 2014, precipitation amount – 239.3 mm and 211.2 mm, respectively. The recorded N_{min} concentration in 0–60 cm soil layer in spring was somewhat higher (compared to the soil region No. 10) in the soil regions No. 11

Table 3. Mineral nitrogen (N_{min}) concentration in 0–60 cm soil layer in spring in different soil regions

Soil region No.	2005	2006	2007	2008	2009
1	7.74 ± 4.81	6.96 ± 1.44	5.19 ± 1.46	4.19 ± 2.23	4.32 ± 1.67
2	7.01 ± 2.43	5.91 ± 1.09	6.36 ± 1.71	4.19 ± 1.11	4.79 ± 1.52
3	6.94 ± 2.27	5.91 ± 2.25	4.11 ± 1.61	4.27 ± 1.49	4.29 ± 1.16
4	7.92 ± 1.98	8.35 ± 4.47	3.99 ± 1.14	5.13 ± 2.06	5.54 ± 1.93
5	7.45 ± 2.61	8.48 ± 3.89	7.92 ± 4.16	8.46 ± 6.70	7.35 ± 2.78
6	6.80 ± 1.75	7.43 ± 2.57	6.69 ± 1.87	5.01 ± 1.49	5.36 ± 1.50
7	7.35 ± 1.83	7.24 ± 2.02	5.80 ± 3.67	5.00 ± 1.60	5.11 ± 1.90
8	6.58 ± 2.20	6.34 ± 1.62	5.14 ± 2.65	5.54 ± 2.46	5.82 ± 1.78
9	7.28 ± 5.17	6.15 ±1.61	4.96 ± 3.44	5.05 ± 2.79	4.60 ± 1.47
10	4.96 ± 1.32	5.72 ± 1.67	3.74 ± 0.93	3.43 ± 1.14	3.74 ± 1.41
11	n.d.	n.d.	n.d.	n.d.	n.d.
12	5.09 ± 1.00	5.59 ± 0.91	3.38±0.80	3.00 ± 0.63	4.45 ± 1.37
13, 14, 15	6.94 ± 5.21	7.11 ± 2.41	4.59±1.40	3.91 ± 1.57	4.19 ± 1.47

Soil region No.	2010	2011	2012	2013	2014	Average
1	n.d.	6.36 ± 1.93	7.75 ± 3.22	6.67 ± 2.17	5.74 ± 2.31	6.10 ± 1.34
2	5.35 ± 0.21	6.87 ± 1.74	5.11 ± 1.96	7.54 ± 2.34	5.46 ± 1.99	5.86 ± 1.07
3	5.24 ± 1.42	6.05 ± 2.67	4.98 ± 1.80	6.49 ± 1.14	3.76 ± 1.30	5.20 ± 1.10
4	6.03 ± 2.00	5.11 ± 2.59	6.11 ± 3.04	5.40 ± 2.79	4.83 ± 1.89	5.84 ± 1.35
5	6.85 ± 2.26	8.73 ± 3.46	9.54 ± 4.47	6.88 ± 2.79	7.60 ± 3.77	7.93 ± 0.87
6	6.70 ± 3.58	9.03 ± 3.47	6.31 ± 3.26	7.50 ± 1.76	5.92 ± 1.79	6.67 ± 1.15
7	6.88 ± 3.01	7.75 ± 3.50	6.59 ± 3.02	8.87 ± 2.46	6.04 ± 1.95	6.66 ± 1.21
8	4.09 ± 1.61	6.07 ± 3.09	6.45 ± 3.45	6.59 ± 2.44	5.45 ± 3.51	5.81 ± 0.79
9	4.19 ± 1.73	5.94 ± 2.21	4.27 ± 1.36	6.60 ± 2.02	3.27 ± 1.06	5.23 ± 1.24
10	4.72 ± 1.91	4.95 ± 2.36	3.89 ± 1.24	5.05 ± 1.62	3.22 ± 1.76	4.34 ± 0.84
11	3.75 ± 0.06	6.62 ± 0.71	5.23 ± 0.73	4.84 ± 0.00	3.58 ± 2.24	4.80 ± 1.23
12	5.03 ± 0.63	3.93 ± 1.53	5.36 ± 0.00	5.34 ± 0.00	4.15 ± 0.11	4.43 ± 0.98
13, 14, 15	4.46 ± 2.46	6.24 ± 1.94	5.86 ± 3.34	6.16 ± 0.86	5.54 ± 3.54	5.50 ± 1.15

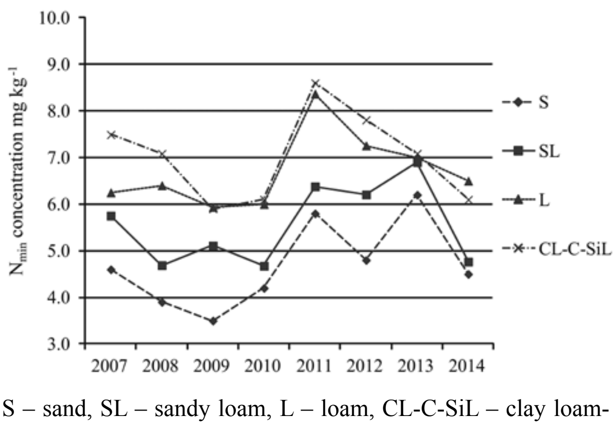
Note. All data are expressed as arithmetic means and mean square deviations; n.d. – data not available.

and No. 12 (4.80 and 4.43 mg kg^{-1}, respectively). Here the plant growing activities are not intensive, but the landscape in the soil region No. 11 is predominantly flat and heavier-textured soils prevail, and the landscape in the soil region No. 12 is rolling and hilly with heavier-textured soils as well.

Soil regions Nos. 13, 14 and 15 are rather small and located in different areas of Lithuania, yet they have one thing in common – they have been formed in the deltas of past rivers. Here a thin layer of sand lays on the heavier-textured and less water-permeable soil layer, therefore these areas are water-logged. At these sites one can find the fields interspacing the forests (Juodis, 2001 b). Agricultural activities are more intensive in the soil region No. 13 and in the part of the soil region No. 14, thus the average N_{min} concentration in 0–60 cm soil layer recorded in spring in the aforementioned three soil regions was 7.0, 5.98 and 3.56 mg kg^{-1}, respectively, and the total average – 5.50 mg kg^{-1}.

The soil N_{min} concentration in spring results obtained from different soil regions are the general outcome of the joint effect of several factors: intensity of agricultural activities, soil properties and climate. The obtained ten-year averages can be used in future as a reference for evaluation of the results of the running year.

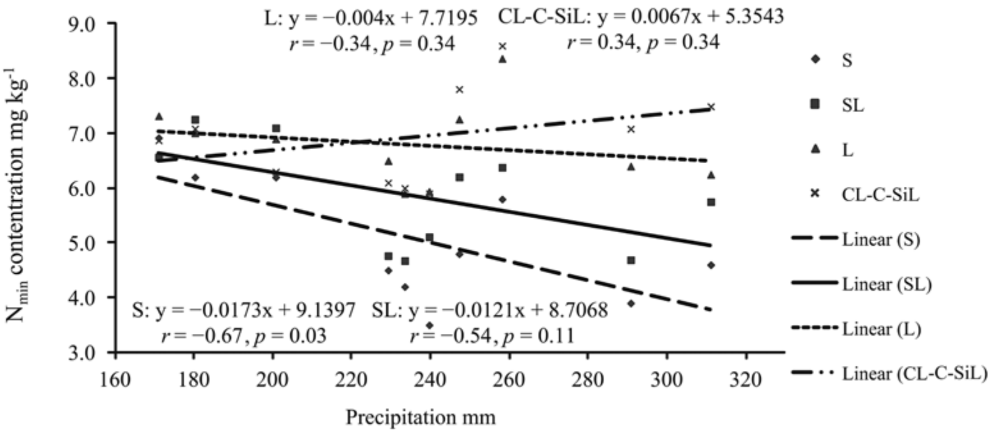
Taken individually, soil texture was found to be the most important factor affecting the N_{min} concentration in 0–60 layer of soil in spring. In 2005–2014, the calculated average N_{min} concentration in 0–60 layer of soil in spring was 5.1 mg kg^{-1} for sand, 5.9 mg kg^{-1} – sandy loam, 6.8 mg kg^{-1} – loam, 6.9 mg kg^{-1} – clay loam, clay and silt loam united into one group. The soil N_{min} concentration recorded in individual years is presented in Figure 3. Leaching of nitrates during the winter period depended strongly on the soil texture, especially in sandy loam and sandy soils. When precipitation levels were 170–310 mm during November–March period the relationship between N_{min} concentration decrease in 0–60 cm soil layer on precipitation levels was significant



S – sand, SL – sandy loam, L – loam, CL-C-SiL – clay loam-clay-silt loam

Figure 3. Mineral nitrogen (N_{min}) concentration in 0–60 cm soil layer in the spring of 2007–2014 as affected by soil texture

and medium strong (r = 0.67, p = 0.03) for sandy soils, and statistically insignificant (r = 0.54, p = 0.11) – for sandy loam soils (Fig. 4). When the precipitation amounts during the November–March period were within the range of 170–310 mm, the relationship between the decrease of N_{min} concentration in 0–60 cm soil layer of sand soils was calculated using the equation $y_S = -0.0173x + 9.1397$; $r = 0.67$, $p = 0.03$, sandy loam soils – $y_{SL} = -0.0121x + 8.7068$; $r = 0.54$, $p = 0.11$ (Fig. 4). The aforementioned relationship was calculated for the heavier textured soils as well, yet it appeared to be statistically insignificant. It must be taken into account that soil N_{min} monitoring sites were set up on farm fields and treated as the rest of the field – there were no conditions which normally would be created if precise scientific research experiments were carried out. This means, that many additional not controlled factors were affecting the results, the depth of soil frost and the duration of it were not always determined

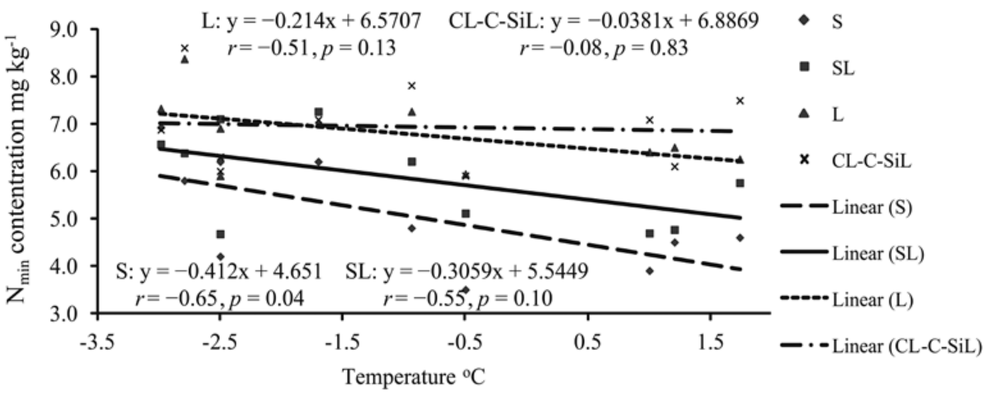


S – sand, SL – sandy loam, L – loam, CL-C-SiL – clay loam-clay-silt loam

Figure 4. Dependence of mineral nitrogen (N_{min}) concentration in 0–60 cm soil layer in spring recorded in soils of different texture on precipitation amount during November–March period

precisely enough. In conclusion, the recorded decrease in N_{min} concentration in 0–60 cm soil layer in spring in sand and sandy loam soils is demonstrative.

As for the November–March average air temperature effect on the N_{min} concentration in soil in spring, first it must be noted that the average air temperature annual values varied from −3.0 to +2.0°C. When prevailing air temperatures were above 0°C, the soil N_{min} concentration decrease recorded in sand soils was statistically significant. The findings were expressed as equations: $y_S = -0.412x + 4.651$; $r = 0.65$, $p = 0.04$, $y_{SL} = -0.3059x + 5.449$; $r = 0.55$, $p = 0.04$ and $y_L = -0.214x + 6.5707$; $r = 0.51$, $p = 0.13$. The influence of positive air temperatures during winter period on N_{min} concentration decrease in spring recorded in the soils of heavier texture – clay loam, clay and silt loam – was not statistically significant (Fig. 5).



S – sand, SL – sandy loam, L – loam, CL-C-SiL – clay loam-clay-silt loam

Figure 5. Dependence of mineral nitrogen (N_{min}) concentration in 0–60 cm soil layer in spring recorded in soils of different texture on average air temperature during November–March period

The crops and pre-crops are very important factors affecting the N_{min} concentration in soil in spring (Fig. 6). According to the average values calculated for the 2011–2014 period, the soils of perennial grasses fields and pastures contained the lowest amounts (5.0 mg kg^{-1}) of N_{min} in 0–60 cm soil layer in spring, soils of the fields where pre-crops were spring cereals and spring rape – 5.4 mg kg^{-1}, soils of winter cereal and rape fields – 7.0 mg kg^{-1}, soils of the fields where pre-crops were winter cereals – 7.1 mg kg^{-1}. The highest average N_{min} concentration in 0–60 cm soil layer in spring was recorded in soils of the fields where row crops

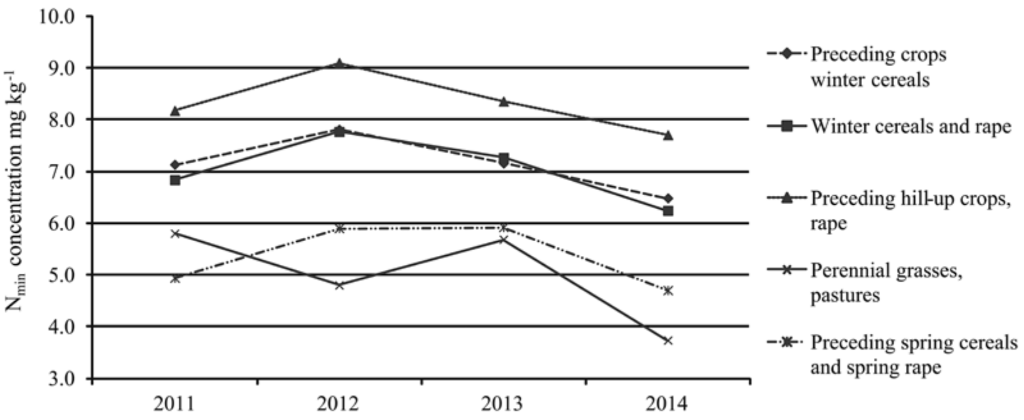


Figure 6. Effect of different crops and pre-crops on mineral nitrogen (N_{min}) concentration in 0–60 cm soil layer in spring of 2011–2014

were preceding – 8.3 mg kg^{-1}. These results show that different crop-dependent growing techniques as well as nitrogen fertilisation rates have a significant effect on the concentration of N_{min} in soil. Only large livestock farms use their perennial grasses fields intensively and apply higher nitrogen fertilisation rates. Major part of pastures and perennial grasses fields in Lithuania is usually treated with low nitrogen fertilisation rates in early spring and after the first grass cut or grazing, therefore the N_{min} concentration recorded in these fields and pastures was the lowest. The highest nitrogen fertilisation rates were applied to winter cereals, winter rape and row crops (part of the latter crops was also treated with organic fertilisers), consequently the N_{min} concentration recorded in these fields was the highest and exceeded that found in soils of pastures and perennial grasses fields by 42% (winter cereals and winter rape) and 66% (row crops).

The results obtained from the ten-year study suggest that soil N_{min} concentration in spring differs substantially between the years, therefore it is important to know the amount of N_{min} available in soil before making the nitrogen fertilisation plans. The data obtained from this long-term monitoring enabled us to identify the most important factors affecting the levels of soil N_{min} concentration in spring and to summarize the effect of peculiar characteristics of different zones of Lithuania on the N_{min} concentration in soil. The determined regularities in the influence of crops and pre-crops, soil texture, precipitation and average air temperature during winter period on the soil N_{min} concentration correspond largely to the results obtained in other countries (Beaudoin et al., 2005; Geypens et al., 2005; Liu et al., 2005; Tong et al., 2005; Wiesler, Armbruster, 2009; Rutkowska, Fotyma, 2011). The obtained results of soil N_{min} tests conducted in spring taking into account the detailed division of Lithuania's territory into 15 soil regions, differing in landscape, climatic conditions, soil type and texture, enabled the assessment of the long-term changes in N_{min} concentration on the level of specific location considering its conditions. The obtained long-term results can be used as a reference for evaluation of results obtained in the running year.

Conclusions

1. The data obtained from the monitoring activities conducted during the 2005–2014 period suggest that mineral nitrogen (N_{min}) concentration in agricultural soils of Lithuania differs not only between the years but also between the geographic climatic zones of Lithuania.

2. The annual value of median for N_{min} concentration in 0–60 cm soil layer in spring in Western zone, characterized by high precipitation levels and average-intensive agricultural activities, varied from 4.35 to 6.87 mg kg^{-1}, the average median value was 5.38 mg kg^{-1}. The respective values were 5.63–7.40 and 6.33 mg kg^{-1} for the Middle zone with most fertile soils and the most intensive agricultural activities, and 4.07–6.06 and 4.95 mg kg^{-1} – for the Eastern zone with predominantly light-textured soils and least intensive agricultural activities.

3. The most significant factors and their interactions influencing the soil N_{min} concentration in spring are crops and pre-crops, soil texture, precipitation and average air temperature during winter period. The lowest concentration of N_{min} in 0–60 cm soil layer in spring was recorded in perennial grasses fields and pastures, in fields where pre-crops were spring cereals and spring rape, in sandy loams and – especially – in sands, also when precipitation rates during November–March period were high (especially when they were higher than 250 mm) and when prevailing air temperatures during winter were above 0°C.

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Mineralinio azoto pasiskirstymo Lietuvos dirvožemiuose dėsningumai pavasarį

G. Staugaitis, L. Žičkienė, J. Mažvila, J. Arbačiauskas, D. Šumskis, A. Masevičienė, R. Staugaitienė

Lietuvos agrarinių ir miškų mokslų centro Agrocheminių tyrimų laboratorija

Santrauka

Lietuvoje 2005–2014 m. žemės ūkio naudmenose įrengtose 20 × 20 m dydžio 206 tyrimų aikštelėse vykdyti mineralinio azoto (N_{min}) kiekio dirvožemyje tyrimai. Tyrimų aikštelės pagal geografinius vienetus buvo išdėstytos 15 Lietuvos dirvožemių rajonų, besiskiriančių dirvožemio dangos ypatumais – reljefu, dirvožemio tipologija, granuliometrine sudėtimi, klimatinėmis sąlygomis, ir pasižyminčiais skirtinga augalininkystės gamybos specializacija bei intensyvumu.

Tyrimų metu nustatyta, kad pavasarį mineralinio azoto kiekis dirvožemyje buvo labai nevienodas ir tam tikrais metais, ir įvairiuose regionuose. Svarbiausi veiksniai ir jų sąveika, pavasarį turinti įtakos N_{min} kiekiui dirvožemyje, buvo auginti augalai ir priešsėliai, dirvožemio granuliometrinė sudėtis, žiemos laikotarpiu iškritusių kritulių kiekis ir oro temperatūra. Pavasarį mažiausias N_{min} kiekis dirvožemio 0–60 cm sluoksnyje nustatytas priesmėliuose ir ypač smėliuose daugiamečių žolių ir ganyklų plotuose po vasarinių javų ir vasarinių rapsų, kai lapkričio–kovo mėnesiais iškrinta daugiau kritulių – ypač daugiau nei 250 mm, o žiemą vyrauja teigiama oro temperatūra. Pavasarį atlikti N_{min} kiekio dirvožemyje tyrimai pagal Lietuvos teritorijos detalų suskirstymą į 15 dirvožemio rajonų leido įvertinti ilgalaikę šio rodiklio kaitą pagal vietovės specifiką, o gauti daugiamečių tyrimų rezultatai galėtų būti panaudoti kaip kontroliniai vertinant būsimų tyrimų rezultatus.

Reikšminiai žodžiai: dirvožemis, granuliometrinė sudėtis, krituliai, mineralinis azotas, oro temperatūra.