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The content of mineral nitrogen in *Histosols* and its relationship with soil organic matter

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Abstract

The aim of the research was to investigate the content of mineral nitrogen (N_{min}) at the 0–30, 30–60 and 60–90 cm layers of *Histosols* and their relationship with soil organic matter (SOM). The experiment was conducted in natural or cultivated perennial meadows of Lithuania in 2016–2018. Every year in November, 21 sites were installed and N_{min} was analysed. The studies showed that the content of N_{min} in *Histosols* were significantly higher compared to those in mineral soils, and they widely ranged in the air-dried soil samples at different depths as follows: 37.5 to 128.2 mg kg^{-1} at 0–30 cm, 22.9 to 143.4 mg kg^{-1} at 30–60 cm and 5.2 to 85.3 mg kg^{-1} at 60–90 cm. N_{min} content at the 0–30 and 30–60 cm layers were lower in *Bathiterric Histosol* and *Bathifibric-Fibric Histosol* compared to those in *Pachiterric Histosol* and *Pachiterri-Fibric Histosol*. In addition, the content of N_{min} in *Histosols* depended on the peat layer thickness. At the 60–90 cm layer of *Pachiterric Histosol* and *Pachiterri-Fibric Histosol*, mineral soil was already present in many of the profiles, and SOM was lower, therefore, N_{min} content was lower as well. The content of N_{min} (y, mg kg^{-1}) in *Histosols* was strongly dependent on the content of SOM in the soil (x, %). This dependence at the 0–30 cm layer is expressed by the equations: $y = -0.02x^2 + 2.72x - 6.41$ ($r = 0.87^*$), at 30–60 cm layer – $y = -0.01x^2 + 2.2x + 0.31$ ($r = 0.87^*$), and at 60–90 cm layer – $y = 0.78x + 7.82$ ($r = 0.92^{**}$). At the 0–30 cm *Histosols* layer, the average ratio of carbon-to-nitrogen (C:N) was 18, and a very strong correlation was obtained between the ratio of C:N and N_{min} content. At the 30–60 cm layer the ratio of C:N averaged 27, resulting in a weak correlation, leading to a higher impact of SOM concentration on N_{min} content. At the 60–90 cm layer, in the shallow peat soils mineral horizon dominated, resulting in a high variation of the ratio of C:N from 4 to 34 and there was no correlation between the ratio of C:N and N_{min} content.

Key words: *Histosols*, mineral nitrogen, soil organic carbon.

Introduction

The content of mineral nitrogen (N_{min}) in the soil allows us to estimate the stocks of nitrogen readily available to plants, therefore, it is used to calculate the required nitrogen fertiliser rates, estimate available nitrogen leaching and assess how nitrates move down the soil profile, etc. (Robertson, Vitousek, 2009; Shcherbak et al., 2014; Rezanezhad et al., 2016). Considering soil texture, N_{min} scales of assessment in mineral soils are developed (Staugaitis et al., 2007; Arbačiauskas et al., 2014). Optimal terms of soil sampling for N_{min} analyses are determined in different countries according to climatic conditions, the depths from which samples are taken for different agricultural crops and other methodological requirements (Staugaitis et al., 2014; Zhang et al., 2015; Arbačauskas et al., 2018). Most of these studies are conducted early in spring and autumn, less often in summer, as due to intense mineralisation of plant residues and organic matter in the soil, the content of N_{min} significantly increases (Aurangojeb et al., 2017; Friesen, Cattani, 2017; Tripolskaja et al., 2017). This increase mainly occurs in the upper 0–30 cm soil layer (Deng et al., 2016; Wasiu et al., 2018).

It has been documented that the content of N_{min} in the soil depends on the content of soil organic matter (SOM) (Zang et al., 2000; Ruehlmann, Körschens, 2009; Parvage et al., 2015). However, SOM differs in quality and therefore affects the content of N_{min} (Sommer et al., 2004; Dawson et al., 2008; Wang et al 2015; Wei et al., 2017). As mineralisation of peaty soil increases, the size of organic particles decreases, thus reducing the pores and increasing dry soil mass per unit volume (Castillo, Writ, 2008; Volungevičius et al., 2015; Rezanezhad et al., 2016). This results in a change of soil bulk density, which affects chemical, biological and hydrological properties of peaty soil and thus the content of available nitrogen (Johnston et al., 2001; Chambers et al., 2010; Truong, Marschner, 2018). SOM mineralisation in *Histosols* takes place more intensively in the upper layer, and this process is influenced by many factors, including the degree of peat fragmentation, soil moisture, temperature, plants grown, stocks of plant residues left (Burri et al., 2018; Vasilevich et al., 2018).

N_{min} is significantly higher in soils with high SOM, such as *Gleysols* and especially *Histosols*

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(Vasilevich et al., 2018). Due to this reason, N_{min} assessment scales used for mineral soils are not suitable for these soils (Steffens et al., 2014; Norberg et al., 2016), and there is not enough research to develop them. There is also a lack of research on N_{min} variations in *Histosols* with different thickness of peat layers. Therefore, the aim of this research was to investigate the content of N_{min} in *Histosols*, and to assess how the content of N_{min} varies at different depths and depends on the content of SOM.

Materials and methods

The experiment was conducted in Varėna, Ukmergė and Raseiniai municipalities in southern and central Lithuania in 2016–2018. Twenty one sites with an area of 100 m^2 (10 × 10 m) were installed in natural or cultivated perennial meadows, where grass was cut or grazed. The selected sites were marked with a GPS device and soil samples were taken from the same locations for analysis. At each site, a composite soil sample was taken from 5–6 spots using a soil probe. Soil samples were taken in the autumn (20–30 of November) from the 0–30, 30–60 and 60–90 cm soil layers. The soil code (according to WRB, 2014), coordinates of the experimental site, soil profile and its bulk density are presented in Table 1. *Histosol* horizon by type is divided into: low peat soils 0–30 cm (O-Hs-H_3 or Hs-H_3), 30–60 cm (H_2) and 60–90 cm (2Ckr-2Cr or 2Cr), and deep peat soils 0–30 cm (O-Hs-H_3 or Hs-H_3), 30–60 cm (H_2) and 60–90 cm (H_2).

Soil samples collected for mineral nitrogen (N_{min}) analyses were stored in thermal boxes at 0–+3°C during transportation. The moisture of soil samples was determined according to gravimetric method (ISO 11465:1993. Soil quality - Determination of dry matter and water content on a mass basis) by drying the soil at 105°C to a constant weight. Mineral nitrogen (N-NO_3 and N-NH_4) in dried soil samples was determined after extraction with 1 M KCl (1:5 ratio) according to ISO 14256-2005 (Determination of nitrate, nitrite and ammonium in field-moist soils by extraction with potassium chloride solution). Nitrate and ammonium nitrogen content was determined using the FIAstar 5000 Analyser (Foss Analytical A/S, Denmark). Soil organic matter (SOM) was measured by elementary analysis according to ISO 10694:1995 (Determination of organic and total carbon after dry combustion), and the bulk density – according to EN 13040:2008 (Sample preparation for chemical and physical tests, determination of dry matter concentration). Undisturbed core samples for determination of soil bulk density and total porosity were collected using stainless steel rings (100 cm^3 volumes) in four replications. Bulk density and total porosity were calculated from undisturbed soil samples. Soil organic carbon (SOC) content was determined by the Tyurin method modified by Nikitin (1999) with a spectrophotometric measure procedure at the wavelength of 590 nm and glucose as a standard. Soil total nitrogen (N) was determined by the Kjeldhal method with a photometric measure procedure at the wavelength of 655 nm.

Table 1. Coordinates, soil profiles and bulk density of the research sites

Site No.	Soil code according to FAO	Coordinates	Soil profile	Bulk density Mg m^{-3}		
				0–30 cm	30–60 cm	60–90 cm
1.	*ARg-p-w-eu*	52°81′88 N, 60°10′19 E	Ah-Bg-Cg	1.35 ± 0.05	1.4 ± 0.03	1.5 ± 0.02
2.	*ARg-p-w-eu*	37°13′74 N, 61°14′42 E	Ah-Bg-Cg	1.44 ± 0.03	1.4 ± 0.05	1.5 ± 0.03
3.	*Glu-ha*	52°87′89 N, 61°11′97 E	Ah-Bg-Cg	1.28 ± 0.03	1.3 ± 0.02	1.4 ± 0.02
4.	*HSf-s-ph*	41°06′82 N, 61°41′22 E	O-Hs-H_3-H_2-Cr	0.85 ± 0.07	0.8 ± 0.07	1.5 ± 0.07
5.	*HSs-ph*	52°86′19 N, 60°10′51 E	O-Hs-H_3-H_2-2Cr	0.91 ± 0.11	1.0 ± 0.11	1.3 ± 0.11
6.	*HSf-s-d*	42°97′80 N, 61°41′15 E	O-Hs-H_3-H_2	0.83 ± 0.09	0.5 ± 0.09	0.5 ± 0.09
7.	*HSs-d*	37°32′22 N, 61°13′30 E	Hs-H_3-H_2	0.97 ± 0.08	0.9 ± 0.08	0.8 ± 0.08
8.	*HSf-s-ph*	41°06′75 N, 61°41′18 E	Hs-H_3-H_2-2Ckr-2Cr	0.92 ± 0.06	1.1 ± 0.06	1.5 ± 0.06
9.	*HSs-d*	37°25′01 N, 61°13′67 E	Hs-H_3-H_2	0.71 ± 0.09	0.7 ± 0.09	0.6 ± 0.09
10.	*HSf-s-ph*	54°02′59 N, 61°26′36 E	O-Hs-H_3-H_2-2Cr	0.94 ± 0.08	0.8 ± 0.08	1.3 ± 0.08
11.	*HSs-ph*	52°28′49 N, 60°11′71 E	O-Hs-H_3-H_2-2Cr	0.73 ± 0.07	0.6 ± 0.07	1.2 ± 0.07
12.	*HSs-d*	52°86′37 N, 60°10′53 E	Hs-H_3-H_2	0.82 ± 0.07	0.8 ± 0.07	0.8 ± 0.07
13.	*HSf-s-d*	51°29′56 N, 60°61′35 E	Hs-H_3-H_2	0.93 ± 0.08	0.7 ± 0.08	0.6 ± 0.08
14.	*HSs-ph*	52°86′69 N, 61°10′51 E	Hs-H_3-H_2-2Ckr-2Cr	0.93 ± 0.11	0.9 ± 0.11	1.6 ± 0.11
15.	*HSf-s-d*	51°29′54 N, 60°61′33 E	Hs-H_3-H_2	0.81 ± 0.12	0.7 ± 0.12	0.6 ± 0.12
16.	*HSf-s-d*	55°41′47 N, 60°36′39 E	O-Hs-H_3-H_2	0.87 ± 0.07	0.9 ± 0.09	0.9 ± 0.07
17.	*HSf-s-ph*	54°06′54 N, 61°26′69 E	Hs-H_3-H_2-2Cr	0.81 ± 0.07	0.8 ± 0.11	1.4 ± 0.07
18.	*HSs-d*	52°82′67 N, 61°11′71 E	Hs-H_3-H_2	0.76 ± 0.08	0.6 ± 0.12	0.7 ± 0.08
19.	*HSs-ph*	55°50′95 N, 60°32′23 E	O-Hs-H_3-H_2-2Cr	0.91 ± 0.11	0.8 ± 0.11	1.2 ± 0.11
20.	*HSs-ph*	55°64′69 N, 60°33′22 E	Hs-H_3-H_2-2Ckr-2Cr	0.74 ± 0.07	0.7 ± 0.12	1.1 ± 0.14
21.	*HSf-s-ph*	52°28′49 N, 60°11′33 E	Hs-H_3-H_2-2Cr	0.93 ± 0.12	0.7 ± 0.09	1.1 ± 0.13

ARg-p-w-eu – Eutri-Epihypogleyic Arenosol, *Glu-ha – Hapli-Umbric Geysol*, *HSs-d – Bathiterric Histosol* (low moor deep peat soils ≥100 cm), *HSs-ph – Pachiterric Histosol* (low moor shallow peat soils 40–100 cm), *HSf-s-d – Bathifibric-Fibric Histosol (*high moor deep peat soils ≥100 cm), *HSf-s-ph – Pachiterri-Fibric Histosol* (high moor shallow peat soils 50–100 cm); A – decomposition organic material is taking place, h – humic horizon, Bg – mineral surface horizon, O – turtle horizon, Hs – mineralized peat, H_3 – severely decomposed peat, H_2 – moderately decomposed peat, Cg – underground rock horizon, 2Ckr – soil of organic origin, 2Cr – deposited sediments from which soil formed, parent material; ± – standard deviation of the mean

Meteorological conditions. Research objects in the territory of Lithuania are located in the south-eastern part of the Baltic Sea, where the climate is maritime-continental, in winter (December–February) the average daily temperature reaches −2–−3°C, in summer (June–August) – 16.0–18.5°C. Monthly precipitation in November–May and September is 38–50 mm, with more abundant – 60–64 mm precipitation in June, August and October, and the wettest month is July – 79 mm. The climate in the area is favourable for grass cultivation. During the experimental period until the second half of November, when soil samples were taken for mineral nitrogen analyses, the meteorological conditions for individual years were different (Fig. 1).

The weather conditions in 2016 were close to multiannual ones; however, in August–November precipitation in the research sites was more abundant compared to multiannual averages: in August, 53–83%, in September – 71–96%, in October 30–46% and in November – 43–85% more. The moisture concentration

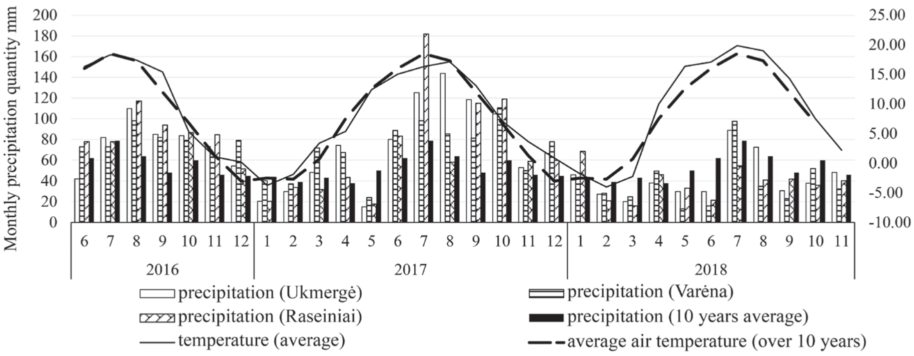

Figure 1. Monthly average daily air temperature and monthly precipitation in 2016–2018

of peat taken for analysis varied between 60–70% during that year. The year 2017 was extremely rainy. During the June–October period, the amount of precipitation exceeded normal by 25–100% for individual months, and in November the lower-lying locations with perennial grasses were covered with water. The soil samples taken for the experiment were wet, especially those taken from more than 60 cm depth. The moisture concentration found in the peat was in the range 80–90%. The year 2018 was dry. The average daily air temperature was 0.7–3.8°C higher than the multiannual average during individual months starting from March. In March–May this difference was +2.5–+3.8°C. During that year, precipitation was lower compared to normal starting from February, and since June plants felt lack of moisture. In that year, grasses were thinner, and the moisture concentration in peat samples ranged from 50% to 60%. Its lowest value (45%) was recorded in the 0–30 cm layer.

The experimental data were evaluated and presented as an arithmetic mean and the mean standard deviation was calculated. The equation $y = ax^2 + bx + c$ was used to calculate the relationship between N_{min} and SOM. The value of the minimum significant difference (*R*) is calculated and the marking ** refers to the statistical significance for R_{01} level and * – statistical significance for R_{05} level. Three-year N_{min} content and SOM concentration data were analysed by a combined analysis of variance (ANOVA) as described by Petersen (1994).

Results and discussion

Having investigated eighteen *Histosols*, the content of N_{min} at various depths was high and varied within a wide range: 37.5–113.0 mg kg^{-1} at the 0–30 cm layer, 48.3–143.4 mg kg^{-1} at 30–60 cm, and 6.3 to 64.9 mg kg^{-1} at 60–90 cm in 2016. In 2017, these variations were 64.7–128.2 mg kg^{-1}, 22.9–109.3 mg kg^{-1} and 9.4–83.3 mg kg^{-1}, respectively; in 2018 they were 43.4–99.7 mg kg^{-1}, 63.6–113.0 mg kg^{-1} and 5.2–85.3 mg kg^{-1}. Thus, the highest content of N_{min} was at the 0–30 and 30–60 cm layers, and at the 60–90 cm layer it was lower in most *Pachiterric Histosol* and *Pachiterri-Fibric Histosol*, where peat ended at the 60–80 cm depth and the mineral soil layer started.

For comparison, in mineral soils – *Eutri-Epihypogleyic Arenosol* – these variations for all the years of the experiment fell within the range of 1.5–3.6 mg kg^{-1} at the 0–30 cm layer, 1.5–3.2 mg kg^{-1} at 30–60 cm layer and 1.4–2.6 mg kg^{-1} at the 60–90 cm layer. N_{min} content in another investigated *Hapli-Umbric Geysol* was significantly higher than that in *Eutri-Epihypogleyic Arenosol*; however, it did not reach the one found in peat and ranged from 8.5 to 20.3 mg kg^{-1} at the 0–30 cm layer, 3.3–23.3 mg kg^{-1} at the 30–60 cm layer and was particularly low at the 60–90 cm layer – 0.8–1.2 mg kg^{-1}, respectively. This influenced higher concentration of SOM at the 0–30 cm and 30–60 cm layers in this soil – 2.91% and 0.87%, respectively, and very low content at the 60–90 cm layer – merely 0.18%.

By grouping the content of N_{min} obtained from the soil profile according to peat types, it was found that at the 0–30 and 30–60 cm layers it was the lowest in *Bathiterric Histosol* (*HSs-d*) and *Bathifibric-Fibric Histosol* (*HSf-s-d*) (Table 2).

Based on three-year data average they were 77.6 ± 11.3 and 74.0 ± 7.61 mg kg^{-1} at the 0–30 cm layer and 66.7 ± 9.18 and 74.8 ± 7.53 mg kg^{-1} at the 30–60 cm layer, respectively. Meanwhile, N_{min} content in *Pachiterric Histosol* (*HSs-ph*) and *Pachiterri-Fibric Histosol* (*HSf-s-ph*) was higher: 80.4 ± 8.40 and 90.1 ± 10.7 mg kg^{-1} at the 0–30 cm layer and 85.8 ± 7.37 and 84.6 ± 10.1 mg kg^{-1} at the 30–60 cm layer, respectively. N_{min} content at the 60–90 cm layer in these soils was lower – 13.5 ± 4.21 and 18.1 ± 4.90 mg kg^{-1}, respectively, whereas in *Bathiterric Histosol* (*HSs-d*) and *Bathifibric-Fibric Histosol* (*HSf-s-d*) it was 59.0 ± 8.14 and 60.8 ± 9.15 mg kg^{-1}, respectively.

The content of N_{min} depended both on the soil type and the content of SOM. The dependence of N_{min} content at the 0–30, 30–60 and 60–90 cm soil layers on the content of SOM is presented in Figure 2. SOM and N_{min} contents at the 0–30 and 30–60 cm layers were similar; therefore, the interdependence of these indicators at these depths varied marginally. The highest N_{min} content slightly above 80 mg kg^{-1} was found when SOM was higher than 60%. Meanwhile, at the 60–90 cm layer in *HSs-ph* and *HSf-s-ph*, the mineral soil layer was located just below the peat layer, which affected the decrease in SOM and N_{min}. Therefore, after analysing all *Histosols* with 60% SOM at this depth it can be stated that the average N_{min} value was 52.7 mg kg^{-1}.

A significant indicator for qualitative assessment of soils with organic matter is the ratio of carbon-to-nitrogen (C:N) (Grandy et al., 2008). If in our experiment in mineral soils – *Eutri-Epihypogleyic Arenosol* and *Hapli-Umbric Geysol* – at 0–30 cm the obtained C:N was respectively 11 and 13, and at 30–60 cm 8 and 20 it was significantly higher in *Histosols* (Table 3), which slows down the mineralization of the peat soils (Tian et al., 2010). At the 30–60 cm layer the average of the C:N in *HSs-ph*, *HSf-S-ph*, *HSf-S-D* and *HSs-D* was 16–20 and at the 30–60 cm, with high SOM content, the ratio was 27–29. Meanwhile, at the 60–90 cm layer *HSs-ph* and *HSf-s-ph* already had a mineral soil in many of the profiles tested, resulting in a significant difference of the C:N with an average of only 4–5, when the *HSf-S-D* and *HSs-D* averaged 26–34.

The relationship between the C:N and N_{min} content in *Histosols* depended on the depth analysed. At the 0–30 cm layer, there was mineralized peat, a very strong correlation (r = 0.99**) was obtained, and the

Table 2. The content of mineral nitrogen (N_{min}) and soil organic matter (SOM) in the soils studied

Site No.	Soil code according to FAO	N_{min} mg kg^{-1}			SOM %		
		0–30 cm	30–60 cm	60–90 cm	0–30 cm	30–60 cm	60–90 cm
1	*ARg-p-w-eu*	2.9 ± 1.09	1.8 ± 0.58	1.2 ± 0.82	1.9 ± 0.11	0.83 ± 0.08	0.11 ± 0.05
2	*ARg-p-w-eu*	2.4 ± 1.32	2.5 ± 0.92	0.8 ± 0.31	3.9 ± 0.21	0.92 ± 0.12	0.26 ± 0.09
3	*Glu*	44.9 ± 2.84	23.3 ± 4.24	1.6 ± 0.82	12.7 ± 0.31	2.77 ± 0.86	1.20 ± 0.68
4	*HSf-s-ph*	63.2 ± 6.41	93.4 ± 8.77	11.7 ± 4.10	32.0 ± 1.62	43.6 ± 1.64	1.04 ± 0.11
5	*HSs-ph*	83.1 ± 11.2	115 ± 9.07	10.5 ± 1.24	54.1 ± 1.87	64.4 ± 0.75	2.83 ±0.38
6	*HSs-d*	61.2 ± 7.22	53.5 ± 10.4	37.2 ± 4.42	37.5 ± 0.40	32.6 ± 2.72	53.6 ± 0.70
7	*HSf-s-d*	63.9 ± 8.82	93.5 ± 8.20	54.6 ± 8.42	78.1 ± 1.11	81.5 ± 0.76	76.0 ± 1.62
8	*HSf-s-ph*	80.6 ± 19.9	86.7 ± 8.81	24.3 ± 2.10	51.5 ± 1.25	50.5 ± 0.40	7.52 ± 0.08
9	*HSf-s-d*	62.9 ± 5.66	90.6 ± 6.62	63.8 ± 8.41	41.6 ± 0.68	74.6 ± 2.12	70.0 ± 0.76
10	*HSf-s-ph*	109 ± 11.2	80.9 ± 9.91	7.47 ± 2.02	58.8 ± 1.26	56.0 ± 1.97	4.24 ± 0.15
11	*HSs-ph*	78.8 ± 8.82	92.3 ± 12.2	11.7 ± 2.31	67.3 ± 0.74	66.9 ± 0.75	1.50 ± 0.07
12	*HSf-s-d*	80.4 ± 5.42	91.5 ± 7.61	68.5 ± 9.44	69.5 ± 0.89	81.4 ± 1.08	73.1 ± 0.82
13	*HSs-d*	75.9 ± 10.4	66.0 ± 9.79	55.3 ± 7.72	44.0 ± 0.80	68.1 ± 0.80	62.2 ± 1.60
14	*HSs-ph*	80.3 ± 12.2	17.1 ± 4.48	17.1 ± 5.16	67.1 ± 2.07	41.8 ± 1.29	3.43 ± 0.12
15	*HSs-d*	86.2 ± 9.91	74.6 ± 9.48	74.6 ± 6.62	65.2 ± 1.78	64.6 ± 1.59	83.5 ± 1.47
16	*HSs-d*	87.2 ± 5.92	69.2 ± 6.47	69.1 ± 7.73	67.6 ± 0.40	65.9 ± 0.71	87.5 ± 0.50
17	*HSf-s-ph*	97.4 ± 12.2	21.3 ± 3.42	21.3 ± 4.40	64.5 ± 1.53	86.6 ± 1.42	31.2 ± 0.78
18	*HSf-s-d*	91.2 ± 9.41	56.1 ± 6.16	56.1 ± 8.61	72.8 ± 0.51	72.1 ± 1.71	52.4 ± 1.23
19	*HSs-ph*	74.4 ± 14.2	71.9 ± 4.97	25.4 ± 10.4	68.9 ± 1.32	64.6 ± 1.15	4.03 ± 0.21
20	*HSs-ph*	85.6 ± 8.82	74.1 ± 7.13	66.3 ± 2.53	54.6 ± 0.58	63.3 ± 1.12	2.11 ±0.33
21	*HSf-s-ph*	99.7 ± 11.8	72.1 ± 5.61	8.71 ± 9.15	77.5 ± 0.61	47.3 ± 0.70	22.1 ± 0.65
				Average			
1, 2	*ARg-p-w-eu*	2.6 ± 0.66	2.2 ± 0.85	1.1 ± 0.22	2.9 ± 0.14	0.87 ± 0.01	0.08 ± 0.01
3	*Glu*	44.9 ± 2.84	23.3 ± 4.24	1.6 ± 0.82	12.8 ±0.09	2.77 ± 0.04	0.12 ± 0.05
4, 8, 10, 17, 21	*HSf-s-ph*	74.1 ± 10.7	84.6 ± 10.1	18.1 ± 4.90	57.4 ± 16.8	58.8 ± 14.8	13.2 ± 0.35
5, 11, 14, 19, 20	*HSs-ph*	80.4 ± 8.40	85.8 ± 7.37	13.5 ± 4.21	62.4 ± 9.92	60.2 ± 10.1	2.78 ± 0.22
6, 13, 15, 16	*HSs-d*	77.6 ± 11.3	66.7 ± 9.18	59.0 ± 8.14	54.5 ± 15.6	57.8 ±14.6	71.7 ± 16.4
7, 9, 12, 18	*HSf-s-d*	90.1 ± 7.61	74.8 ± 7.53	60.8 ± 9.15	65.5 ± 10.7	79.1±7.3	67.9 ± 9.7

Explanations under Table 1

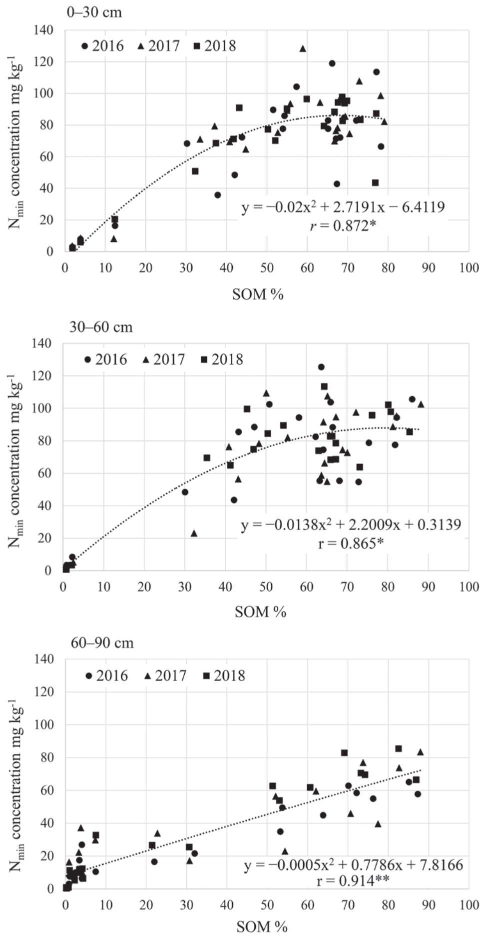

Figure 2. The dependence of mineral nitrogen (N_{min}) content at the 0–30, 30–60 and 60–90 cm soil layers on the concentration of soil organic matter (SOM) (n = 21) in 2016–2018

Table 3. The distribution of carbon-to-nitrogen ratio (C:N) in the studied soils at the 0–30, 30–60 and 60–90 cm layers

Soil code according to FAO	Soil sampling depth		
	0–30 cm	30–60 cm	60–90 cm
	C:N in soil ± SD		
ARg-p-w-eu	11.3 ± 1.15	8.3 ± 0.82	–
Glu	12.8 ± 0.92	19.5 ± 1.15	–
HSs-ph	19.6 ± 3.43	27.2 ± 4.17	4.2 ± 0.84
HSf-s-ph	16.1 ± 3.91	29.3 ± 2.41	5.5 ± 0.59
HSf-s-d	18.7 ± 2.28	28.1 ± 1.43	34.1 ± 4.23
HSs-d	20.3 ± 5.14	25.4 ± 2.16	26.3 ± 2.81

ARg-p-w-eu – Eutri-Epihypogleyic Arenosol, *Glu-ha – Hapli-Umbric Geysol*, *HSs-d – Bathiterric Histosol* (low moor deep peat soils ≥100 cm), *HSs-ph – Pachiterric Histosol* (low moor shallow peat soils 40–100 cm), *HSf-s-d – Bathifibric-Fibric Histosol (*high moor deep peat soils ≥100 cm), *HSf-s-ph – Pachiterri-Fibric Histosol* (high moor shallow peat soils 50–100 cm); SD – standard deviation of the mean

equation y = 1.987x − 6.77. At the 30–60 cm layer, a strong correlation (r = 0.74*) was obtained, and the equation y = 38x − 18.9. In the studied *Histosols*, at the 60–90 cm layers there was either peat or mineral soil layer; therefore, the C:N fluctuated in a wide range – 4–34. There was no correlation (r = 0.29) at this layer.

It should be noted that the content of N_{min} in *Histosols* was significantly higher compared to mineral soils. This is confirmed by the data of other researchers. For example, according to the monitoring data of Latvian researchers, the content of N_{min} at the 0–60 cm layer in mineral soils varied between 25 and 60 kg ha^{-1} (Čermák, Kubík, 2009; Loide et al., 2009); according to Polish researchers: at the 0–30 cm layer – 22.5–112 kg ha^{-1} in spring and 23.5–146 kg ha^{-1} in autumn (Fotyma et al., 2009). The 10-year monitoring data in Lithuania showed that N_{min} content varied from 3.2 to 9.5 mg ha^{-1} at the 0–60 cm layer in mineral soils (Staugaitis et al., 2007).

Results of other studies of natural climate zones are compared (Loch et al., 2009; Wiesler, Armbruster, 2009). High N_{min} content in *Histosols* changes the approach to assessing N_{min} content in these soils, both for individual plants and for samples taken from different depths. Therefore, the existing methodological framework (Rutkowska, Fotyma, 2011) according to which N_{min} sampling from the 0–60 or 0–90 cm layers is conducted and the data obtained evaluated is not appropriate for *Histosols*. Considering that the content of N_{min} was heavily dependent on the content of SOM and C:N in soil, the content of SOM and C:N should be taken into consideration while assessing N_{min} content in *Histosols* and even *Gleysols*.

Conclusions

1. The contents of mineral nitrogen (N_{min}) in *Histosols* were significantly higher compared to those in mineral soils, and widely ranged at different depths as follows: 37.5 to 128.2 mg kg^{-1} at 0–30 cm, 22.9 to 143.4 mg kg^{-1} at 30–60 cm and 5.2 to 85.3 mg kg^{-1} at 60–90 cm.

2. N_{min} content at the 0–30 and 30–60 cm layers was lower in *Bathiterric Histosol* and *Bathifibric-Fibric Histosol*: it was 77.6 ± 11.3 and 74.0 ± 7.61 mg kg^{-1} at the 0–30 cm and 66.7 ± 9.18 and 74.8 ± 7.53 mg kg^{-1} at the 30–60 cm layers, respectively. Meanwhile, N_{min} content in *Pachiterric Histosol* and *Pachiterri-Fibric Histosol* was higher: 80.4 ± 8.40 and 90.1 ± 10.7 mg kg^{-1} at the 0–30 cm and 85.8 ± 7.37 and 84.6 ± 10.1 mg kg^{-1} at the 30–60 cm layers, respectively.

3. The content of N_{min} in *Histosols* depended on the peat layer thickness. At the 60–90 cm layer in *Pachiterric Histosol* and *Pachiterri-Fibric Histosol*, mineral soil was already present in many of the profiles, and soil organic matter (SOM) was lower; therefore, N_{min} content was lower as well – 13.5 ± 4.21 and 18.1 ± 4.90 mg kg^{-1}, respectively, whereas in *Bathiterric Histosol* and *Bathifibric-Fibric Histosol* it was 59.0 ± 8.14 and 60.8 ± 9.15 mg kg^{-1}, respectively.

4. The content of N_{min} (y, mg kg^{-1}) in *Histosols* was strongly dependent on the concentration of SOM in the soil (x, %). At the 0–30 cm layer, this dependence is expressed by the equations $y = -0.02x^2 + 2.72x - 6.41$ ($r = 0.87^*$), at 30–60 cm layer – $y = -0.01x^2 + 2.2x + 0.31$ ($r = 0.87^*$), and at 60–90 cm layer – $y = 0.78x + 7.82$ ($r = 0.92^{**}$).

5. The ratio of carbon-to-nitrogen (C:N) most influenced N_{min} content at the 0–30 cm layer, with a very strong correlation between the C:N and N_{min} content. At the 30–60 cm layer, the correlation between the C:N and N_{min} content was weak, resulting in a significant influence of SOM concentration on N_{min} content. At the 60–90 cm layer, in the shallow peat soils mineral horizon dominated, resulting in a high variation of the C:N from 4 to 34 and there was no correlation between the C:N and N_{min} content.

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Mineralinio azoto kiekis durpžemiuose ir jo sąsajos su dirvožemio organine medžiaga

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Santrauka

Tyrimo tikslas – ištirti mineralinio azoto (N_{min}) koncentracijas durpžemių (*Histosols*) 0–30, 30–60 bei 60–90 cm sluoksniuose ir jo sąsajas su dirvožemio organine medžiaga. Tyrimas atliktas 2016–2018 m. Lietuvoje natūraliose pievose arba jau daug metų naudojamose kultūrinėse pievose. Jose buvo įrengta 21 aikštelė, kuriose kiekvienais metais mineralinis azotas tyrimui imtas lapkričio mėnesį. Tyrimo metu nustatyta, kad N_{min} koncentracija durpžemiuose, lyginant su mineraliniais dirvožemiais, buvo reikšmingai didesnė, o įvairiame gylyje orasausiame dirvožemyje svyravo plačiu intervalu: 0–30 cm sluoksnyje – nuo 37,5 iki 128,2 mg kg^{-1}, 30–60 cm sluoksnyje – nuo 22,9 iki 143,4 mg kg^{-1}, 60–90 cm – nuo 5,2 iki 85,3 mg kg^{-1}. Mineralinio azoto koncentracija 0–30 ir 30–60 cm sluoksniuose buvo mažesnė giliuose žemapelkės durpžemiuose ir giliuose tarpinės pelkės durpžemiuose nei sekliuose aukštapelkės durpžemiuose ir sekliuose tarpinės pelkės durpžemiuose. Be to, N_{min} koncentracija durpžemiuose priklausė nuo durpių sluoksnio gylio. Sekliuose aukštapelkės durpžemiuose ir sekliuose tarpinės pelkės durpžemiuose daugelyje profilių 60–90 cm sluoksnyje mineralinis dirvožemis turėjo mažesnį kiekį organinių medžiagų, todėl jame nustatyta mažesnė N_{min} koncentracija. Durpžemiuose N_{min} koncentracija (y, mg kg^{-1}) priklausė nuo organinių medžiagų koncentracijos dirvožemyje (x, %). Šis priklausomumas 0–30 cm sluoksnyje pavaizduotas lygtimis $y = -0{,}02x^2 + 2{,}72x - 6{,}41$ ($r = 0{,}87^*$), 30–60 cm sluoksnyje – $y = -0{,}01x^2 + 2{,}2x + 0{,}31$ ($r = 0{,}87^*$), 60–90 cm sluoksnyje – $y = 0{,}78x + 7{,}82$ ($r = 0{,}92^{**}$). Durpžemių 0–30 cm sluoksnyje anglies ir azoto santykis (C:N) buvo vidutiniškai 18; nustatytas labai stiprus koreliacinis ryšys tarp C:N ir N_{min} koncentracijos. 30–60 cm sluoksnyje C:N sudarė vidutiniškai 27, nustatytas silpnas koreliacinis ryšys, todėl didesnę įtaką N_{min} koncentracijai turėjo didelė SOM koncentracija. 60–90 cm sluoksnyje sekliuose durpžemiuose vyravo mineralinis horizontas, todėl C:N svyravimas buvo didelis – nuo 4 iki 34, ir nenustatyta koreliacinio ryšio tarp C:N ir N_{min} koncentracijos.

Reikšminiai žodžiai: dirvožemio organinė medžiaga, *Histosols*, mineralinis azotas.