ISSN 1392-3196 / e-ISSN 2335-8947
Zemdirbyste-Agriculture, vol. 109, No. 4 (2022), p. 297–304
DOI 10.13080/z-a.2022.109.038

Variation of winter wheat grain yield and its quality in fields with different soil cover

Paulius ASTRAUSKAS, Gediminas STAUGAITIS, Aistė MASEVIČIENĖ, Lina ŽIČKIENĖ

Lithuanian Research Centre for Agriculture and Forestry
Savanorių pr. 287, Kaunas, Lithuania
E-mail: gediminas.staugaitis@lammc.lt

Abstract

The experiment was carried out in 2018–2021 in the Baltic Upland of the Eastern Lithuania, where the soil cover was very different. The objective was to determine the yield and grain quality of winter wheat (*Triticum aestivum* L.) in fields with a different soil cover, their variation and dependence on soil texture and typology. For the experiment, three fields with a different soil cover were selected and 30 observation sites were set up. The results showed that the field with light-textured soils of sand, loamy sand, and sandy loam produced a lower number of productive stems and a lower grain yield of winter wheat compared to the field with heavier-textured soils. The average grain yield in sites, where the sandy loam fraction predominated, was 7.22 t ha^{-1} compared with 5.55 t ha^{-1} for loamy sand and 4.33 t ha^{-1} for loamy sand and sand fractions. The yield and productivity of winter wheat in the experimental field with the heavy-textured subsoil depended on the distribution of soil particles throughout the soil profile. *Eutric Planosol*, where the sand and loamy sand fraction in the top layer, and sandy clay at 60–70 cm depth dominated, produced the highest grain yield of 9.20 t ha^{-1}. The variation in winter wheat yield of the field in the hilly terrain was as much as 2.3 times. Winter wheat yield was higher in *Gleyic Luvisol* and *Eutric Fluvisol* in the lowlands, while yield was lower on the hilltops and slopes, where *Haplic Luvisol* predominated. Winter wheat was less fertile in organic soils in the lowlands due to the intensive growth and lodging of the vegetative part. The content of crude protein in winter wheat grains was influenced by the annual weather conditions and soil properties. In dry years, in the fields, where the lightest-textured loamy sand and sand, sandy loam and sandy clay loam prevailed, the grains were finer and at the same time had a higher level of crude protein.

Keywords: *Triticum aestivum*, productivity, soil type, soil texture.

Introduction

Winter wheat (*Triticum aestivum* L.) is one of the main agricultural crops used for food and feed production (Jonathan et al., 2011; Darguza, Gaile, 2019). Therefore, increasing population and consumption are driving the pursuit of a higher productivity and a high yield quality of these crops (Tkaczyk et al., 2018). In fields with uniform soil cover and similar soil properties, winter wheat productivity is quite similar and allows for the correct planning of intensive technologies (Mažvila et al., 2008; Management…, 2010; Staugaitis, Vaišvila, 2019). However, in Lithuania, for example, there are fields with a very different soil cover, and even more than 50% of the area has a low land productivity score of 37 or lower (Innovative Solutions..., 2015). In such fields, *Haplic Arenosol* makes up a significant part of the area, while in others, where the terrain is rugged, there are many different soil typological units such as *Haplic Luvisol*, *Eutric Gleysol*, *Gleyic Luvisol*, *Eutric Fluvisol*, *Mollic Gleysol*, *Pachiterric Histosol*, etc. Soils with a different texture are also prevalent in the same field and some of them are eroded (Juodis, 2001; The Productivity..., 2011).

In Poland, the productivity of soils for agriculture is closely related to the soil texture (Jadczyszyn et al., 2016), and consequently, the productivity of arable soils correlates strongly with crop yield. Iwańska and Stępień (2019) found that soil productivity had a greater influence on yield compared to weather conditions. Lower yields of winter wheat were mostly produced on soils with a lower productivity (when values did not exceed 70) and with more frequent periods of longer droughts, while higher yields were obtained on soils with a higher productivity (scores of 80 and above), where drought did not occur or occurred for a shorter period of time. Bird and co-authors (2000) also found that soil texture was a very important soil parameter and had a significant impact on crop productivity, as it was directly related to organic matter accumulation in soil and microbial biomass.

The results of the experiments showed that different topography and variability of soil properties

---

Please use the following format when citing the article:
Astrauskas P., Staugaitis G., Masevičienė A., Žičkienė L. 2022. Variation of winter wheat grain yield and its quality in fields with different soil cover. Zemdirbyste-Agriculture, 109 (4): 297–304. https://doi.org/10.13080/z-a.2022.109.038

are important for sustainable management system, crop productivity, and land use planning (Staugaitis, Šumskis, 2011; Juhos et al., 2015; Žičkienė, 2016; Astrauskas, Staugaitis, 2022). Other researchers have found that soil type and its ability to accumulate moisture are very important for the fertility of winter wheat (He et al., 2014). The fact that soil cover and its chemical properties are among the most important factors determining wheat yield is also emphasised by Carew et al. (2009), Bünemann et al. (2018), Wójcik-Gront (2018), and Káš et al. (2019).

The application of intensive technologies is complicated by different soil cover in the same field, and the diverse yield and plant performance of winter wheat require a decision on how to take into account certain soil properties. Therefore, the aim of this study was to investigate the yield and grain quality of winter wheat grown in different fields in the same region, their variation and dependence on different soil cover properties.

Material and methods

Experiment location. The experiment was carried out in the southern part of the Baltic Upland in Eastern Lithuania, in the municipalities of Elektrėnai and Trakai. For the experiment, three fields with a different soil cover in the same region were selected. Drainage was installed in all three fields. In the 1st and 2nd fields, the experiment was carried out in 2018–2020, and in the 3rd field, in 2018–2021.

Cultivation technology. Winter wheat (*Triticum aestivum* L.) cultivar 'Skagen' was grown in the selected fields. In 2018–2019, it was grown after winter rapeseed, in 2019–2020, reseeded for the first year, and in 2020–2021, reseeded for the second year in the 3rd field. Sowing dates for 2018–2019, 2019–2020, and 2020–2021 were 16, 24, and 23 September, respectively, and harvesting dates were 14, 9, and 28 August, respectively.

On 2 August 2018, fresh poultry manure was incorporated into the soil at a rate of 10 t ha^{-1} prior to sowing winter wheat together with $N_{145}P_{109}K_{83}$ kg ha^{-1}. Therefore, the plants were no longer fertilised with phosphorus and potassium mineral fertilisers for three years. In autumn, the winter wheat was also not fertilised with nitrogen (N). During all experimental years, the wheat crop was fertilised with N fertilisers in spring with three applications during the growing season: in 2019 – N_{80} (1 April), N_{35} (10 April), and N_{80} (1 April) at a total rate of N_{195} kg ha^{-1}; in 2020 – N_{80} (27 March), N_{50} (18 April), and N_{55} (17 May) at a total rate of N_{185}; and in 2021 – N_{80} (26 March), N_{45} (9 April), and N_{80} (15 May) at a total rate of N_{205} kg ha^{-1}. The first and third spring N application was carried out with ammonium nitrate (N 34%), and for the second application, ammonium sulphate (N 21%) was used. Foliar fertilisation was used for the winter wheat crop during all years: in 2019 – K-leaf 4.4 (52% K_2O, 56% SO_4), urea 9.7 (46.2% N, 46.2% NH_2), $MgSO_4$ 7.5 kg ha^{-1} (16% MgO, 32% SO_3), on 5 May; in 2020 – Speedfol balance (20-20-20) 5.1 kg ha^{-1} (18% N, 18% P_2O_5, 20% K_2O, 2% MgO, 1.8% SO_3, 0.02% B, 0.004% Cu (EDTA), 0.1% Fe (EDTA), 0.04% Mn (EDTA), 0.001% Mo, 0.06% Zn (EDTA)), on 8 June; $MgSO_4$ 2.0 (16% MgO, 32% SO_3), Universal Bio 2.0 kg ha^{-1} (8.5% N-NH_2, 3.4% P_2O_5, 6.0% K_2O, 0.02% B, 0.1% Cu (EDTA 70%), 0.11% Mn (EDTA 70%), 0.003% Mo), on 29 April; in 2021 – $MgSO_4$ 2.0 kgha^{-1} (16% MgO, 3% SO_3), on 10 April; K-leaf 4.0 kg ha^{-1} (52% K_2O, 56% SO_4), on 20 May. In the stem elongation and booting stages, winter wheat was fertilised with foliar fertilisers. Depending on the occurrence of diseases and pests in the winter wheat crop, plant protection products were applied. Also, during the growing season of winter wheat, growth regulators were used depending on plant condition and development.

Sites and research methods. In the fields, 30 sites were marked with a GPS device to study soil agrochemical properties in the winter wheat crop every spring and grain yield and productivity performance indicators at harvest. The size of the experimental sites was 16 m^2 (4 × 4 m), where pH, humus, available phosphorus (P_2O_5) and potassium (K_2O) were determined in the 0–20 cm soil layer, and mineral nitrogen (N_{min}) and soil texture (sand – 2–0.063 mm, silt – 0.063–0.002 mm, and clay – < 0.002 mm particle size) were determined in the 0–30 and 30–60 cm layers. One soil composite sample was made up of 20 cores from the 0–20 cm layer and 9 cores from the 0–30 and 30–60 cm layers. Soil pH_{KCl} was determined potentiometrically in a 1M KCl extraction at a 1:5 ratio according to standard ISO 10390:2005, P_2O_5 and K_2O by the Egner-Riehm-Domingo (A-L) method, and humus was determined by the dry combustion method according to standard ISO 10694:1995 using a carbon analyser (Analytic Jena AG, Germany) multiplying the resulting organic carbon content by a factor of 1.724. N_{min} – air-dry soil samples were extracted with 1M KCl at a 1:5 ratio using flow injection analysis (FIA) spectrometry according to standard ISO 14265-2:2005. The grain yield from two 0.25 m^2 plots was weighed, and 20 plants were sampled for biometric measurements: number of productive stems, plant height, and 1000-grain weight. The grain yield was expressed in moisture of 14% absolutely clean seed. The 1000-grain weight of winter wheat was determined according to standard ISO 520:2010, and the crude protein in the grain was determined by the Kjeldahl method according to standard ISO 20483:2006.

Meteorological conditions. The autumn of the 2018–2019 winter wheat growing season was dry and warm (Table 1), which resulted in good rooting and vigorous plants by the end of November. The winter was mild, and the plants overwintered well resuming vegetation in the third ten-day period of March. However, very little rainfall from April to mid-June resulted in poor tillering and a prolonged lack of moisture for the winter wheat. Although the air temperature was favourable for the plants afterwards and the soil moisture was sufficient, the dry period resulted in a season that was not favourable for winter wheat in the end, with fewer productive stems and a lower grain yield.

The 2019–2020 season was the warmest in the region with no freeze in winter. In autumn, the plants emerged in a vigorous state, overwintered well, and resumed vegetation in the first days of April. During the spring and summer, the soil moisture was sufficient, and the temperature was favourable during that period, which resulted in good tillering, more productive stems, and larger grains. Therefore, the season was favourable for the growth and yield of winter wheat. The autumn of the 2020–2021 season was warm with a sufficient moisture to allow winter wheat to germinate and take root well. From January onwards, temperature was slightly negative resulting in soil freeze of 6–13 cm by the second ten-day period of March. The winter wheat benefitted from this weather, overwintered well, and resumed growth in early April. April and May were cooler than normal, and the soil moisture was sufficient, so that the plants were able to tiller in the spring and grow vigorously. However, the heat from the second ten-day period of June onwards had

Table 1. Meteorological conditions during the winter wheat growing season (data of Elektrėnai Meteorological Station)

Indicator	Month											
	09	10	11	12	01	02	03	04	05	06	07	08
Monthly average daily temperature °C												
2018–2019	15.2	8.9	2.7	−1.1	−4.2	1.1	3.4	9.2	13.5	21.2	17.3	18.5
2019–2020	13.3	9.6	5.0	2.5	2.2	2.2	3.8	7.0	10.8	19.6	18.1	18.9
2020–2021	15.3	9.8	5.0	0.3	−3.7	−4.9	1.5	6.2	11.4	19.7	22.8	16.4
SCN	13.9	7.8	3.7	0.1	−3.6	−2.1	1.8	8.0	14.0	18.1	18.8	18.5
Monthly precipitation rate mm												
2018–2019	22.0	27.6	12.4	40.5	31.3	20.6	31.3	0.1	10.7	25.5	44.3	56.4
2019–2020	40.5	37.0	32.8	22.3	38.6	39.5	21	6.4	60.1	79.4	54.0	76.8
2020–2021	15.0	45.0	147.9	24.7	57.5	14.6	17.4	29.0	123.1	49.4	36.9	175.7
SCN	45.4	44.8	41.8	44.7	39.6	29.6	27.5	33.1	50.7	51.2	100.4	74.3

SCN – standard climate normal during the 2010–2020 period

a severe effect on the crops during flowering, and the plants on the hilltops began to lose the emerging grains in segments due to the lack of moisture with uneven maturity in the field. The lowland plants looked best.

Soil types. The 1st field was 18.5 ha in size and was dominated by *Haplic Luvisol* and *Haplic Arenosol* (WRB, 2015) that had a light texture of sand, loamy sand, and sandy loam (Table 2) with the predominance of sandy particles (2–0.063 mm) 66–94%. The relief was slightly undulating. In the 0–20 cm layer, the pH ranged from 5.8 to 6.9, the humus content was from 1.1% to 2.0%, and the content P_2O_5 and K_2O was very high: 259–519 and 193–348 mg kg^{-1}, respectively.

The 2nd field, 19.9 ha in size, was dominated by *Haplic Luvisol*, *Eutric Planosol*, and, to a lesser extent, by *Eutric Gleysol*. In the deeper (>60 cm) layer, most of the soils had a heavy texture of clay, silty clay, sandy clay, and sandy clay loam, and in the upper layer, they had a light to moderate texture of sand, loamy sand, sandy loam, sandy loam, and clay loam. The relief was flat. The pH of the soils varied between 5.8 and 6.7 with a high humus content of 2.6–4.7%. The content of P_2O_5 and K_2O was also abundant, 171–1025 and 204–593 mg kg^{-1}, respectively.

The 3rd field was 37.6 ha in area with a hilly relief. The predominant soil was *Haplic Luvisol* with a hilltop to lowland gradient, and the slopes were slightly eroded. The lowest parts of the field were *Gleyic Luvisol*, *Eutric Fluvisol*, *Mollic Gleysol*, *Pachiterric Histosol*, and *Bathiterric Histosol*. The texture was mostly sandy loam with sand particles (2–0.063 mm) ranging from 53% to 76% and peat in the lowest parts of the field. The pH of the mineral soils varied between 5.6 and 7.4 with a higher pH of 7.0 in the eroded areas. The peat pH in this field was 5.6–6.0. The content of humus in the mineral soils varied between 1.3% and 4.2% with the lowest content in the eroded areas and the highest one in *Eutric Fluvisol*. In terms of the organic soils (sites 19, 20, and

Table 2. Soils of the studied fields and their agrochemical characteristics

Site No.	Soil (LTDK-99)	Soil texture[1]	pH_{KCl}	N_{min} 0–60 cm mg kg^{-1}	P_2O_5 mg kg^{-1}	K_2O mg kg^{-1}	Humus %
1st field							
1, 8, 9	*LVh*	LS-SL/LS-SL	6.8	9.9	462	273	1.6
2, 3, 7	*LVh*	LS-SL/LS	6.2	4.5	300	253	1.4
4, 5, 6	*ARh*	LS/S-LS	5.9	4.5	395	264	1.4
		$\bar{x}$/median	6.3/6.2	6.3/5.1	386/411	263/254	1.5/1.4
		min/max	5.8/6.9	2.3/18.6	259/519	193/348	1.1/2.0
		σ/CV%	0.41/6.6	4.83/76.7	99.48/25.8	54.82/20.8	0.32/21.8
2nd field							
13, 14, 15	*GLe*	SL-SCL/SL-SCL	6.1	3.9	245	271	4.4
16, 17	*PLe*	S-LS/SC	6.2	5.5	854	429	2.8
10, 11, 12	*LVh*	CL/SiC	6.1	8.1	377	516	4.0
18	*LVh*	SL/C	6.7	11.4	886	585	3.5
		$\bar{x}$/median	6.2/6.2	6.5/6.0	496/342	422/395	3.8/3.9
		min/max	5.8/6.7	2.4/11.5	171/1025	204/593	2.6/4.7
		σ/CV%	0.29/4.7	3.11/48.1	319.75/64.5	142.26/33.7	0.72/18.7
3rd field							
28, 29, 30	*LVh*	SL/SL	6.7	6.8	342	282	2.1
26, 27	*LVh*[2]	SL/SL	7.0	4.6	156	175	1.7
24, 25	*LVg*	SL/SL	6.7	10.0	147	252.5	1.7
22, 23	*FLe*	SL/SL	5.7	12.4	149	297	3.5
21	*GLm*	M/SL	6.6	47.4	542	399	38.1**
19	*HSs-ph*	U/SL	5.9	56.1	454	527	49.6**
20	*HSs-d*	U/U	5.8	69.5	363	568	54.7**
		$\bar{x}$/median (22–30)	6.5/6.5	8.2/5.03	214/169	255/247	2.2/2.1
		min/max (22–30)	5.6/7.4	2.3/21.6	114/603	148/346	1.3/4.2
		σ/CV% (22–30)	0.57/8.7	6.85/82.9	149.66/69.8	59.08/23.2	0.89/40.1

[1] – topsoil/subsoil; [2] – slighly eroded; *LVh – Haplic Luvisol*, *ARh – Haplic Arenosol*, *GLe – Eutric Gleysol*, *PLe – Eutric Planosol*, *LVg – Gleyic Luvisol*, *FLe – Eutric Fluvisol*, *GLm – Mollic Gleysol*, *HSs-ph – Pachiterric Histosol*, *HSs-d – Bathiterric Histosol*; S – sand, LS – loamy sand, SL – sandy loam, SCL – sandy clay loam, CL – clay loam, SC – sandy clay, SiC – silty clay, C – clay; M – mollic A horizon, umbric horizon (peat), U – peat; ** – organic matter

21), organic matter was found in a content ranging from 38.1% to 54.7%. P_2O_5 content ranged from 114 to 603 mg kg^{-1} with the lowest amount in the *Gleyic Luvisol* and *Eutric Fluvisol* sites and the highest one in the organic soils. Similarly, K_2O content was found in a range of 148–346 mg kg^{-1} and was more abundant in the organic soils as well.

The N_{min} content found in the soil in spring depended on the texture with a two-year median N_{min} amount of 5.1 kg^{-1} in the 0–60 cm light soil layer of the 1st field, 6.0 mg kg^{-1} in the 0–60 cm heavier soil layer of the 2nd field, and as high as 11.4 mg kg^{-1} in the sandy loam/clay layer of the same field. In addition, the lower area soils in the 3rd field with more humus and organic matter also had a significantly higher N_{min} content, e.g., it was 12.4 mg kg^{-1} in *Eutric Fluvisol*, 47.4 mg kg^{-1} in *Mollic Gleysol*, 56.1 mg kg^{-1} in *Pachiterric Histosol*, and 69.5 mg kg^{-1} in *Bathiterric Histosol*.

Statistical analysis. The experimental data were processed using MO Excel. Minimal (min) and maximal (max) values, arithmetic means ($\bar{X}$), medians, and standard deviations (σ) were determined/calculated and are presented in the tables. To estimate the variance of the data, the coefficient of variation (CV) was calculated. Variation of the trait is small when the coefficient of variation does not exceed 10%, medium 10–20%, and high above 20%. The relationship between the variables was assessed using the correlation-regression analysis. For correlation coefficients and ratios and for expression of the relationship between the objects of the research, the program STATISTICA, version 9 (Sakalauskas, 2003; Hill, Levicki, 2005) was used.

Results

Winter wheat performance was influenced by both annual conditions and soil cover. In the dry year of 2019, fewer productive stems formed and grew, and the plant stems were shorter (Table 3). This was due to the very low amount of precipitation that fell from April to mid-June, as a result of which the winter wheat was poorly tillering, felt a lack of moisture for a long time, and formed fewer and less productive stems. In contrast, 2020 was favourable for winter wheat, both in terms of temperature and moisture. The median of productive stems in the 1st field in 2019 was 200 units m^{-2}, while in the favourable year 2020 it was 382 units m^{-2}. The 2nd field demonstrated 340 and 511 units m^{-2}, and the 3rd one showed 283 and 351 units m^{-2}, respectively. In contrast, the highest number of grains per ear was obtained in 2019, which was influenced by the thinner crop that was formed that year. Other physiological aspects of the plant also probably appeared – the plants formed fewer and shorter stems but preserved a higher number of full-fledged grains in the ear.

In the light-textured soils, winter wheat produced significantly fewer productive stems compared to the heavier-textured soils. While the two-year average for the 1st field showed a median of productive stems of 291 units m^{-2}, the median of productive stems in *Haplic Arenosol* was only 264 units m^{-2}, and it was 425 units m^{-2} in the 2nd field. According to the three-year average, the median of productive stems in the 3rd field on a rough terrain was 309 units m^{-2} with minimum and maximum values ranging over a wide range of 184–419 units m^{-2}.

Table 3. Productivity indicators of winter wheat crop

Site No.	Number of productive stems per m^{-2}				Plant height cm				Number of grains per ear, units			
	2019	2020	2021	$\bar{X}$	2019	2020	2021	$\bar{X}$	2019	2020	2021	$\bar{X}$
1st field												
1, 8, 9	291	399	–	345	76	82	–	79	52	42	–	47
2, 3, 7	202	394	–	298	72	76	–	74	46	42	–	44
4, 5, 6	150	378	–	264	59	72	–	66	45	40	–	43
$\bar{x}$/median	214/200	390/382	–	302/291	69/73	77/77	–	73/75	48/47	41/42	–	45/44
min/max	130/322	341/469	–	236/409	48/84	67/84	–	5784	42/57	37/46	–	39/52
σ/CV%	68.9/32	43.5/11	–	56.2/22	11.1/16	5.4/7	–	8.3/1	5.0/11	3.0/7	–	4.0/9
2nd field												
13, 14, 15	345	488	–	416	60	77	–	68	48	45	–	47
16, 17	395	579	–	487	66	82	–	74	52	45	–	48
10, 11, 12	276	498	–	387	67	85	–	76	54	41	–	48
18	370	394	–	382	63	81	–	72	48	49	–	48
$\bar{x}$/median	335/340	501/511	–	428/425	64/64	81/82	–	72/73	51/50	44/43	–	47/47
min/max	254/396	394/588	–	324/492	53/73	74/87	–	63/80	43/57	40/49	–	41/53
σ/CV%	50.7/15	57.8/12	–	54/14	5.5/9	4.4/5	–	4.9/7	4.1/8	3.4/8	–	3.8/8
3rd field												
28, 29, 30	249	342	325	305	60	78	67	68	43	44	38	42
26, 27	317	348	292	319	68	74	63	68	44	44	41	43
24, 25	388	473	289	383	65	74	71	70	46	42	45	44
22, 23	385	497	323	402	67	76	80	74	38	40	38	39
21	250	353	181	261	72	63	74	69	55	43	48	49
19	106	318	188	204	66	79	77	74	46	45	42	44
20	118	288	157	187	69	78	76	74	50	44	44	46
$\bar{x}$/median	283/283	385/351	276/292	315/309	65/67	75/77	71/71	71/71	44/44	43/43	41/41	43/43
min/max	106/396	288/507	157/353	184/419	44/72	63/85	61/80	56/79	35/55	38/47	37/48	36/50
σ/CV%	99.6/35	78.5/20	67.5/25	83.6/27	7.3/11	6.3/8	6.3/9	6.6/9	6.5/15	2.8/7	3.6/9	3.6/10

The lowest number of productive stems (187–261 units m^{-2}) was found in winter wheat growing in hollows and where humus or peat was present (sites 19, 20, and 21). In contrast, in the lower areas of the field with *Gleyic Luvisol* and *Eutric Fluvisol* predominant and the texture being sandy loam, the highest number of productive stems was produced, 383 and 402 units m^{-2}, respectively. In 2020, the relationship between the humus content (%) in the mineral soil and the number of productive stems (units m^{-2}) was confirmed by the correlation (r = 0.590*).

The median for plant height of winter wheat in the fields studied was 64–82 cm for individual years (Table 3). In most of the fields, the plant height varied within the standard square deviation, and the estimated coefficient of variation in the three fields in each year was only 5–16%. The wheat grown in *Haplic Arenosol* had the lowest plant height with a two-year average plant height of 66 cm.

The number of grains per ear, based on several year medians, was 44 in the 1st field, 47 in the 2nd field, and 43 in the 3rd one (Table 3). While the number of grains per ear found in the 1st and 2nd fields varied within the standard deviation, the 3rd field had the lowest number (39) of grains per ear for *Eutric Fluvisol* and the highest number (49) of grains per ear for *Mollic Gleysol*, which was contrary to the density of the plants in the sites of these soils.

Winter wheat grain yield varied considerably depending both on the conditions of the year and on the different soils present in individual fields (Table 4).

In the 1st field, in the dry year 2019, the grain yield median of light-textured soils was 3.82 t ha^{-1}, while the range between the minimum and maximum values at the respective sites was 2.17–7.31 t ha^{-1}, i.e., a max/min difference of 3.4 times. The year 2020 was more favourable for wheat growth. In this field, the grain yield median was significantly higher (6.92), and the range between the minimum and maximum values obtained in the sites was 5.18–8.11 t ha^{-1} resulting in a significantly smaller max/min difference of 1.6 times.

Table 4. Winter wheat grain yield and quality

Site No.	Grain yield t ha^{-1}				Crude protein %				1000-grain weight g			
	2019	2020	2021	$\bar{x}$	2019	2020	2021	$\bar{x}$	2019	2020	2021	$\bar{x}$
1st field												
1, 8, 9	7.09	7.35	–	7.22	15.9	15.3	–	15.6	46.1	41.4	–	43.8
2, 3, 7	3.96	7.14	–	5.55	17.7	16.0	–	16.8	40.0	43.6	–	41.8
4, 5, 6	2.50	6.15	–	4.33	20.3	15.2	–	17.7	37.1	39.3	–	38.2
$\bar{x}$/median	4.52/3.82	6.88/6.92	–	5.70/5.37	17.9/17.8	15.5/15.6	–	16.7/16.7	41.1/40.1	41.4/41.6	–	41.3/40.9
min/max	2.17/7.31	5.18/8.11	–	3.68/7.71	14.3/20.8	13.9/16.7	–	14.1/18.8	34.7/54.0	35.9/47.5	–	35.3/50.8
σ/CV%	2.14/48	0.91/13	–	1.53/30	2.20/12	0.8/6	–	1.5/9	5.9/14	3.4/8	–	4.7/11
2nd field												
13, 14, 15	5.72	9.11	–	7.14	19.7	13.4	–	16.6	34.4	40.3	–	37.4
16, 17	7.43	10.97	–	9.20	17.2	13.4	–	15.3	37.6	40.8	–	39.2
10, 11, 12	5.97	8.71	–	7.34	16.1	13.0	–	14.5	41.8	40.7	–	41.3
18	4.45	7.24	–	5.84	15.4	13.7	–	14.6	40.9	39.1	–	40.0
$\bar{x}$/median	6.04/6.15	9.18/9.16	–	7.61/7.66	17.5/16.9	13.3/13.3	–	15.4/15.1	38.3/38.5	40.4/40.5	–	39.4/39.5
min/max	4.45/7.75	7.24/11.19	–	5.85/9.47	15.4/20.2	12.6/14.0	–	14.0/17.1	32.1/45.5	37.2/43.2	–	34.7/44.4
σ/CV%	1.18/20	1.22/13	–	1.21/16	1.9/11	0.5/4	–	1.2/8	3.90/10	1.7/4	–	2.8/7
3rd field												
28, 29, 30	4.50	7.33	5.68	5.84	18.9	13.6	15.1	15.9	40.8	46.7	39.6	42.4
26, 27	5.89	7.37	5.41	6.22	17.4	12.7	15.5	15.2	42.3	45.6	40.6	42.8
24, 25	7.58	9.54	5.56	7.56	17.2	14.3	16.0	15.8	42.5	46.5	41.4	43.5
22, 23	6.55	9.14	5.50	7.06	19.5	13.1	16.0	16.2	43.8	46.0	38.7	42.8
21	6.75	7.11	3.90	5.92	17.8	13.3	16.2	15.8	51.5	45.6	44.1	47.0
19	2.35	6.03	3.66	4.01	17.3	12.3	16.6	15.4	50.9	43.2	42.1	45.4
20	2.70	5.78	3.04	3.84	16.5	15.0	15.6	15.7	45.9	40.9	42.3	43.0
$\bar{x}$/median	5.45/5.89	7.75/7.63	5.05/5.33	6.08/6.28	18.0/17.5	13.5/13.5	15.7/15.8	15.7/15.6	44.0/43.3	45.5/46.0	40.7/40.8	43.4/43.4
min/max	2.35/8.45	5.78/10.31	3.04/6.34	3.72/8.37	16.5/21.5	11.9/15.0	14.1/16.6	14.2/17.7	40.5/51.5	40.9/48.0	38.6/44.1	40.0/47.9
σ/CV%	1.84/34	1.42/18	1.06/21	1.44/24	1.6/9	1.0/8	0.7/5	1.1/7	3.7/8	2.0/4	1.8/4	2.5/5

The highest grain yield was obtained in this field with a predominant sandy loam and loamy sand fraction to a lesser extent, where the proportions of sand particles (2–0.063 mm) in topsoil/subsoil were 60–75/68–80%. Such sites demonstrated the two-year average yield of 7.22 t ha^{-1}. When the loamy sand fraction was more predominant and sandy loam was less prevalent with sand of 60–80/70–80%, the grain yield was 5.55 t ha^{-1}. On the other hand, the lowest grain yield was obtained in the loamy sand and sand fractions with sand particles of 80–87/87–94% resulting in a grain yield of 4.33 t ha^{-1}. Thus, it can be observed that the yield of winter wheat decreased when the soil contained more sand particles and especially significantly when the soil contained more than 80% sand particles. Tkaczyk and co-authors (2018) found that winter wheat grain yield was positively but not always significantly related to soil texture (in particular, to the content of silt and clay particles). Sandy loam yielded 28.5% more winter wheat compared to loamy sand, while sandy silt yielded 33.6% more compared to loamy sand. The highest grain yield was obtained when the plants were grown in soils with a high content of silt particles. In this case, it was almost 70% higher than that obtained in loamy sand. It was observed that there was no statistical difference in the grain yield between the crops grown in loamy sand, sandy loam, and sandy silt. On the other hand, the effect of silt was significant when comparing the results with the above soil texture groups.

In the 2nd field, where the subsoil was heavy-textured with *Eutric Gleysol* in the lower areas, sandy loam and sandy clay loam, and with 67–74/57–70% sandy particles, the winter wheat yield was 5.70 t ha^{-1}. In contrast, *Eutric Planosol* with sand and loamy sand in the upper layer and sandy clay at a depth of 60–70 cm, and with 80–92/49–51% sand particles (30–46% silt (0.063–0.002 mm) in the subsoil) produced the highest grain yield of 9.20 t ha^{-1}. It was in this soil that the winter wheat germinated, rooted, and established well with the highest number of productive stems and a sufficient moisture for the plants throughout the growing season due to sandy clay found deeper. In this field, in the *Haplic Luvisol* areas of a flat terrain with a heavy texture, where clay loam on silty clay loam prevailed with a slightly lower proportion of clay and only 18–26/4–25% sand, the average two-year yield was 7.34 t ha^{-1}. In contrast, the even heavier clay subsoil (sand-clay-silt 20–51–29%) yielded a lower grain yield of 5.84 t ha^{-1}. The 2nd field produced a higher grain yield than the first one with two-year averages of 5.70 and 7.61 t ha^{-1}, respectively.

In the 3rd field, which was predominantly hilly, the three-year average yield of winter wheat grain was 6.08 t ha^{-1}; however, there was a large variation in yield from one site to another within the same field with a range of 3.72 to 8.37 t ha^{-1} between the minimum and the maximum values, or a 2.3-fold difference. The lowland soils (*Gleyic Luvisol* and *Eutric Fluvisol*) were more fertile with a three-year average grain yield of 7.56 and 7.00 t ha^{-1}, respectively. The hilltops and slopes were less fertile, where *Haplic Luvisol* predominated with an average grain yield of 5.84 and 6.22 t ha^{-1}, respectively. In contrast, the low-lying soils rich in organic matter were less fertile: an average grain yield in *Mollic Gleysol* was 5.92 t ha^{-1}, in *Pachiterric Histosol* 4.01 t ha^{-1}, and in *Bathiterric Histosol* 3.84 t ha^{-1}. The high organic matter content of these soils resulted in a very intensive growth of the vegetative part of winter wheat and increased plant lodging. In addition, the wheat was less vigorous in tillering and formed less productive stems. Studies of other authors (Cox et al., 2003; Cambouris et al., 2006; Juhos et al., 2015) also referred to differences in soil texture and crop yield under different terrain conditions indicating the need for variable rate N application.

No correlation was found between sand particles in soil, agrochemical parameters, and winter wheat grain yield in either year. Only in 2020, a moderate correlation was found between the soil humus content and grain yield ($r = 0.560$; $p \leq 0.05$).

The content of crude protein in winter wheat grain was influenced by the annual weather conditions and soil properties (Table 4). During the dry and warm weather in the second half of spring and early summer in 2019, the crude protein content in grain was higher compared to other experimental years, e.g., the median of crude protein content of winter wheat grain in the 1st field was 17.8% in 2019 and 15.6% in 2020, in the 2nd field 16.9% and 13.3%, respectively, in the 3rd field 17.5% and 13.5%, respectively, and it was 15.8% in 2021.

In the 1st field, dominated by loamy sand and sand (sites 4, 5, and 6), in 2019, the grain were finer due to the drought in April–June, and at the same time had a higher level of crude protein – 20.3%. Similar results were obtained that year in the 2nd field, where the lightest-textured sandy loam and sandy clay loam prevailed, with a crude protein content of 19.7%. The differences in crude protein content between other sites of these fields in that year and in all the grouped sites in 2020 were within the standard deviation. In the 3rd field, although the crude protein content increased in some years in one or other of the sites, the three-year averages were not different from each other.

The 1000-grain weight in the 1st and 2nd fields varied within a range of 34.7–54.0 and 32.1–45.5 g, respectively (Table 4). Among the sites studied, a lower 1000-grain weight was demonstrated by loamy sand and sand soils (sites 4, 5, and 6) in the 1st field and sandy loam and sandy clay loam soils (sites 13, 14, and 15) in the 2nd field. In these sites, the lower grain weight was due to the drought in 2019 and the decrease in grain weight also affected the results of the two-year average. The 1000-grain weight in other sites of these fields varied within the standard deviation. In the 3rd field, organic-rich *Mollic Gleysol* and *Pachiterric Histosol* found in the low-lying areas were less affected by the prevailing drought in 2019 with a 1000-grain weight of 51.5 and 50.9 g, respectively, compared with the field median of 43.3 g. The 1000-grain weight of other sites in the 3rd field varied within the standard deviation. No correlation could be established in either year between soil humus and N_{min} content and between crude protein and 1000-grain weight.

A 12-year study in eastern Canada (Nyiraneza et al., 2012) showed that both N fertilisation and different soil texture and different soil types had a significant effect on spring wheat productivity, and that their interaction was significant not only in terms of total yield but also in terms of grain quality indicators: protein, 1000-grain weight, and chlorophyll index. It is important to note that the response of wheat to N fertilisers and to different soil textures was also strongly influenced by the environmental conditions of individual years, which differed in terms of rainfall, air temperature, and soil moisture content.

Discussion

This study examined the most important soil properties affecting the yield and quality of winter wheat: different texture, prevailing soil typology, and hilly topography. The data obtained showed that due to soil cover variability in the soil zone of the Baltic Upland of Eastern Lithuania the yield of winter wheat could vary considerably from field to field as well as within the same one. The findings are supported by long-term studies conducted by He and co-authors (2014), which found that soil texture was an important factor that influenced the productivity of spring wheat crops. The regression analysis of the data showed that the wheat grown in silty loam was more sensitive to moisture uptake and less drought tolerant compared to the wheat grown in clay soil. When investigating plant productivity in different soil typological units, Pużyńska and co-authors (2021) found that different soil types were also very important for the quantity and quality of yield. A higher plant yield was found in *Stagnic Luvisol*, whereas the total protein content was higher in the plants grown in *Haplic Cambisol*. Žičkienė (2016) found that the yield of different agricultural crops varied depending on topography, soil group, waterlogging, and texture.

In light-textured soils, an important indicator is the proportion of sand particles (sand, loamy sand, and sandy loam) in soil and their distribution in the profile. In the subsoil of a field with a heavy texture, the distribution of soil particles in the soil profile is also very important; however, this is already in a much wider range and has less influence. In contrast, on a hilly terrain, it is important where the soil is located, whether it is on the top of a hill or on a slope or in the lowlands. While the mineral soils in the lowlands – *Gleyic Luvisol* and *Eutric Fluvisol* – were the most fertile for winter wheat, the organic soils in the lowlands – *Mollic Gleysol*, *Pachiterric Histosol*, and *Bathiterric Histosol* – were the least favourable and suitable for growing an optimal yield due to the intensive vegetative part growth and lodging. The study by Juhos and co-authors (2015) also showed that the influence of soil properties on the variability of grain yield depended on the weather conditions of the year and the topographical position. In dry years, soil texture, nutrient content, and salinity deterined yield, while in wet years, limiting factors were lower topographic position, soil organic matter, and nutrient conctent. The highest plant yield and the lowest variance were found in *Chernozem*, the medium yield and medium variance in *Solonetz*, and the lowest yield and highest variance in *Gleysol*. Yield was not significantly affected by drought, as all soil types had a high available water capacity. Other researchers also highlighted that differences in soil texture and topography influenced yield variability at the field spatial scale (Manoli et al., 2015; Hallema et al., 2016; Fang, Su, 2019; Neupane, Guo, 2019; Ayoubi et al., 2021), especially during dry years, when water reserves and water available to the plants were strongly influenced by a local soil texture. For example, Fang and Su (2019) reported that in dryland farming, sandy loam soils showed a more significant decrease in crop productivity and an increase in N leaching losses compared to loamy soils. Similar results were obtained by Roncucci and co-authors (2015), where crop yield was higher in silty clay loam soils compared to sandy loam soils during anomalously dry years in the Mediterranean climate zone. Agronomic experience is also quite rich in examples showing the importance of soil structure in controlling drainage, water redistribution, and soil aeration, which play a direct role in shaping crop productivity (Travlos, Karamanos 2006; Obia et al., 2018).

Depending on the soils and their properties, it is appropriate to map the yield of the crops grown. This would allow more accurate calculation of fertiliser application rates and application limits in the field, and the use of smart fertilising systems accordingly. Peralta and co-authors (2015) found that terrain-specific field-specific N fertiliser management systems were an attractive and intuitive way to increase the efficiency of N fertilisers use to maximise winter wheat productivity, while adjusting fertiliser rates according to soil cover characteristics. The study captured soil spatial variability (terrain, soil texture, and depth), which enabled the application of targeted variable rate N fertilisers on typical *Argiudoll* and *Petrocalcic Paleudoll*, and reduced the risk of pollution due to over-use.

Information on soil typology and texture at 1:10000 scale in Lithuania can be found on the website *www.zis.lt*, and growers can use smart harvesters to obtain data in the yield of crops grown in the field, or use field sites to determine the yield of the crops grown in the field, as was done during current experiment. Research data is also available in scientific and methodological publications (Budňáková, Čermák, 2009; Peralta et al., 2015; Staugaitis, Vaišvila, 2019; Astrauskas, Staugaitis, 2022).

Conclusions

1. The light texture of the soils (sand, loamy sand, and sandy loam) had a negative effect on the number of productive stems and the grain yield of winter wheat. The yield was lower compared to that of heavier-textured soils. The highest grain yield in that field was obtained with sandy loam and, to a lesser extent, loamy sand, i.e., 7.22 t ha^{-1}. The grain yield in the areas with a loamy sand fraction with a smaller proportion of sandy loam was 5.55 t ha^{-1}, while the lowest grain yield was obtained in the areas with loamy sand and sand fractions – 4.33 t ha^{-1}.

2. The yield of winter wheat depended on the distribution of soil particles in the soil profile. In *Eutric Gleysol* with sandy loam and sandy clay loam, and 67–74/57–70% sandy particles, the wheat yield was 5.70 t ha^{-1}. In *Eutric Planasol*, where predominant fractions were sand and loamy sand, in the top layer and sandy clay found at a depth of 60–70 cm with 80–92/49–51% sand particles, respectively, the highest yield obtained was 9.20 t ha^{-1}.

3. The yield of winter wheat was also influenced by field topography. The results of the experiment showed that soil location – on the top of a hill, on a slope, or in the lowlands – was very important. *Gleyic Luvisol* and *Eutric Fluvisol* found in the lowlands gave the highest yield of 7.56 and 7.00 t ha^{-1}. The hilltops and slopes, where *Haplic Luvisol* predominated, were less fertile yielding 5.84 and 6.22 t ha^{-1}, respectively. The winter wheat grown in organic soils in the lowlands was less productive due to the intensive vegetative growth and lodging: the average grain yield was 5.92, 4.01, and 3.84 t ha^{-1} for *Mollic Gleysol*, *Pachiterric Histosol*, and *Bathiterric Histosol*, respectively.

4. The content of crude protein in winter wheat grains was influenced by the annual weather conditions and soil properties. During the dry and warm weather in the second half of spring and early summer in 2019, the crude protein content in grains was higher compared to other experimental years. In dry years, in the fields, where the lightest-textured loamy sand and sand, sandy loam and sandy clay loam prevailed, the grains were finer and at the same time had a higher level of crude protein.

Received 03 07 2022
Accepted 11 09 2022

References

Astrauskas P., Staugaitis G. 2022. Digital technologies determination effectiveness for the productivity of organic winter wheat production in low soil performance indicator. Agriculture, 12 (4): 474. https://doi.org/10.3390/agriculture12040474

Ayoubi S., Sadeghi N., Afshar F. A., Abdi M. R., Zeraatpisheh M., Rodrigo-Comino J. 2021. Impacts of oak deforestation and rainfed cultivation on soil redistribution processes across hillslopes using ^{137}Cs techniques. Forest Ecosystems, 8: 1–14. https://doi.org/10.1186/s40663-021-00311-1

Bird M. I., Veenendaal E. M., Moyo C., Lloy J., Frost P. 2000. Effect of fire and soil texture on soil carbon in a subhumid savanna (Matopos, Zimbabwe). Geoderma, 94: 71–90. https://doi.org/10.1016/S0016-7061(99)00084-1

Budňáková M., Čermák P. 2009. Fertilising recommendation system based on results of agrochemical soil testing. Fertilizers and Fertilization, 37: 149–159. http://nawfert.iung.pulawy.pl/zeszyty/pelne/37%202009.pdf

Bünemann E. K., Bongiorno G., Bai Z., Creamer R. E., De Deyn G., de Goede R., Fleskens L., Geissen V., Kuyper T. W., Mäder P., Pulleman M., Sukkel W., van Groenigen J. W., Brussaard L. 2018. Soil quality – A critical review. Soil Biology and Biochemistry, 120: 105–125. https://doi.org/10.1016/j.soilbio.2018.01.030

Cambouris A. N., Nolin M. C., Zebarth B. J., Laverdière M. R. 2006. Soil management zones delineated by electrical conductivity to characterize spatial and temporal variations in potato yield and in soil properties. American Journal of Potato Research, 83: 381–395. https://doi.org/10.1007/BF02872015

Carew R., Smith E. G., Grant C. 2009. Factors influencing wheat yield and variability: Evidence from Manitoba, Canada. Journal of Agricultural and Applied Economics, 41 (3): 625–639. https://doi.org/10.1017/S1074070800003114

Cox M. S., Gerard P. D., Wardlaw M. C., Abshire M. J. 2003. Variability of selected soil properties and their relationships with soybean yield. Soil Science Society of America Journal, 67: 1296–1302. https://doi.org/10.2136/sssaj2003.1296

Darguza M., Gaile Z. 2019. Yield and quality of winter wheat, depending on crop rotation and soil tillage. Research for Rural Development, 2: 29–35. https://doi.org/10.22616/rrd.25.2019.045

Fang J., Su Y. 2019. Effects of soils and irrigation volume on maize yield, irrigation water productivity, and nitrogen uptake. Scientific Reports, 9: 7740. https://doi.org/10.1038/s41598-019-41447-z

Hallema D. W., Moussa R., Sun G., McNulty S. G. 2016. Surface storm flow prediction on hillslopes based on topography and hydrologic connectivity. Ecological Processes, 5: 13. https://doi.org/10.1186/s13717-016-0057-1

He H., Hou L., Wang H., Kelin Hu K., McConkey B. 2014. A modelling approach to evaluate the long-term effect of soil texture on spring wheat productivity under a rain-fed condition. Scientific Reports, 4: 5736. https://doi.org/10.1038/srep05736

Hill T., Levicki P. 2005. Statistics methods and applications (1st ed.). StatSoft Inc., 800 p.

Innovative Solutions of Soil and Agrochemistry Science. 2015 / compiled by Staugaitis G. and Vaišvila Z. Lithuanian Research Centre for Agriculture and Forestry, 320 p. (in Lithuanian).

Iwańska M., Stępień M. 2019. The effect of soil and weather conditions on yields of winter wheat in multi-environmental trials. Biometrical Letters, 56 (2): 263–279. https://doi.org/10.2478/bile-2019-0016

Jadczyszyn J., Niedźwiecki J., Debaene G. 2016. Analysis of agronomic categories in different soil texture classification systems. Polish Journal of Soil Science, 49 (1): 61–72. https://doi.org/10.17951/pjss.2016.49.1.61

Jonathan A., Ramankutty N., Brauman K. A., Cassidy S. E., Gerber J. S., Johnston M., Mueller N. D., O'Connell C., Ray D. K., West P. C., Balzer C., Bennett E., Monfreda C., Polasky S. M., Carpenter S. R., Hill J., Rockström J., Sheehan J., Siebert S., Tilman D., Zaks D. P. M. 2011. Solutions for a cultivated planet. Nature, 478: 337–342. https://doi.org/10.1038/nature10452

Juhos K., Szabó S., Ladányi M. 2015. Influence of soil properties on crop yield: a multivariate statistical approach. International Agrophysics, 29 (4): 433–440. https://doi.org/10.1515/intag-2015-0049

Juodis J. 2001. Soil regions. Lithuanian Soil: monograph, p. 699–707 (in Lithuanian).

Káš M., Mühlbachova G., Kusá H. 2019. Winter wheat yields under different soil-climatic conditions in a long-term field trial. Plant, Soil and Environment, 65 (1): 27–34. https://doi.org/10.17221/606/2018-PSE

Management of Agroecosystem Components. Results of long-term agrochemical experiments. 2010 / compiled by Tripolskaja L. et al. Lithuanian Research Centre for Agriculture and Forestry, 568 p. (in Lithuanian).

Manoli G., Bonetti S., Scudiero E., Morari F., Putti M., Teatini P. 2015. Modelling soil–plant dynamics: Assessing simulation accuracy by comparison with spatially distributed crop yield measurements. Vadose Zone Journal, 14 (12): 1–13. https://doi.org/10.2136/vzj2015.05.0069

Mažvila J., Staugaitis G., Adomaitis T., Arbačiauskas J., Vaišvila Z., Šumskis D. 2008. Agrochemical properties of Lithuanian soils and their changes after regaining independence. Žemės ūkio mokslai, 15 (3): 13–21.

Neupane J., Guo W. 2019. Agronomic basis and strategies for precision water management: A review. Agronomy, 9 (2): 87. https://doi.org/10.3390/agronomy9020087

Nyiraneza J., Cambouris A. N., Ziadi N., Tremblay N., Nolin M. C. 2012. Spring wheat yield and quality related to soil texture and nitrogen fertilization. Agronomy Journal, 104 (3): 589–599. https://doi.org/10.2134/agronj2011.0342

Obia A., Mulder J., Hale S. E., Nurida N. L., Cornelissen G. 2018. The potential of biochar in improving drainage, aeration and maize yields in heavy clay soils. PLoS ONE, 13 (5): e0196794. https://doi.org/10.1371/journal.pone.0196794

Peralta N. R., Costa J. L., Balzarini M., Franco M. C., Córdoba M., Bullock D. 2015. Delineation of management zones to improve nitrogen management of wheat. Computers and Electronics in Agriculture, 110: 103–113. https://doi.org/10.1016/j.compag.2014.10.017

Pużyńska K., Pużyński S., Synowiec A., Bocianowski J., Lepiarczyk A. 2021. Grain yield and total protein content of organically grown oats–vetch mixtures depending on soil type and oats' cultivar. Agriculture, 11 (1): 79. https://doi.org/10.3390/agriculture11010079

Roncucci N., Nassi O., di Nasso N., Bonari E., Ragaglini G. 2015. Influence of soil texture and crop management on the productivity of miscanthus (*Miscanthus* × *giganteus* Greef et Deu.) in the Mediterranean. GCB Bioenergy, 7: 998–1008. https://doi.org/10.1

Sakalauskas V. 2003. Duomenų analizė su STATISTICA. Vilnius, 236 p. (in Lithuanian).

Staugaitis G., Šumskis D. 2011. Spatial variability of pH as influenced by different soil sampling methods and geostatistical techniques. Zemdirbyste-Agriculture, 98 (3): 323–333.

Staugaitis G., Vaišvila Z. 2019. Soil Agrochemical Research. Lithuanian Research Centre for Agriculture and Forestry, 111 p. (in Lithuanian).

The Productivity of Lithuania's Land. 2011 / compiled by Mažvila J. Lithuanian Research Centre for Agriculture and Forestry, 280 p. (in Lithuanian).

Tkaczyk P., Bednarek W., Dresler S., Krzyszczak J. 2018. The effect of some soil physicochemical properties and nitrogen fertilisation on winter wheat yield. Acta Agrophysica, 25 (1): 107–116. https://doi.org/10.31545/aagr0009

Travlos I. S., Karamanos A. J. 2006. Effects of soil texture on vegetative growth of tropical legume marama bean (*Tylosema esculentum*). Journal of Agronomy, 5: 609–612. https://doi.org/10.3923/ja.2006.609.612

Wójcik-Gront E. 2018. Variables influencing yield-scaled Global Warming Potential and yield of winter wheat production. Field Crops Research, 227: 19–29. https://doi.org/10.1016/j.fcr.2018.07.015

WRB. 2015. World reference base for soil resources. World Soil Resources Reports No. 106. FAO.

Žičkienė L. 2016. Mineral nitrogen fluxes in different soils: doctoral dissertation. Aleksandras Stulginskis University, Lithuanian Research Centre for Agriculture and Forestry, 111 p. (in Lithuanian).

Žieminių kviečių grūdų derliaus ir jo kokybės variacija įvairios dirvožemio dangos laukuose

P. Astrauskas, G. Staugaitis, A. Masevičienė, L. Žičkienė

Lietuvos agrarinių ir miškų mokslų centras

Santrauka

Tyrimas atliktas 2018–2021 m. Rytų Lietuvos Baltijos aukštumose, kurių dirvožemio danga yra labai įvairi. Tikslas – nustatyti skirtingos dirvožemio dangos laukuose žieminių kviečių derlingumą ir grūdų kokybę, jų variaciją bei priklausomumą nuo dirvožemio granuliometrinės sudėties ir tipologijos. Eksperimentui parinkti trys skirtingos dirvožemio dangos laukai, kuriuose buvo įrengta 30 stebėjimo aikštelių. Tyrimo rezultatai parodė, kad lengvos granuliometrinės sudėties dirvožemio lauke, kuriame vyravo smėlis, rišlus smėlis ir priesmėlis, žieminių kviečių produktyvių stiebų skaičius ir grūdų derlius gautas mažesnis nei sunkesnės granuliometrinės sudėties lauke. Laukeliuose, kuriuose vyravo priesmėlio frakcija, grūdų vidutinis derlingumas siekė 7,22 t ha^{-1}, rišlaus smėlio – 5,55 t ha^{-1}, rišlaus smėlio ir smėlio frakcijos – 4,33 t ha^{-1}. Lauke, kurio podirvio granuliomerinė sudėtis sunki, žieminių kviečių grūdų derlius ir produktyvumo elementai priklausė nuo dirvožemio granuliometrinės sudėties dalelių pasiskirstymo visame dirvožemio profilyje. Didžiausias grūdų derlius – 9,20 t ha^{-1} – gautas pasotintame palvažemyje, kurio viršutiniame sluoksnyje vyravo smėlio ir rišlaus smėlio frakcija, o nuo 60–70 cm gylio – smėlingas molis. Kalvoto reljefo lauke žieminių kviečių derlingumas įvairavo net 2,3 karto. Derlingesni žieminiai kviečiai buvo žemumose esančiuose glėjiškuose išplautžemiuose ir pasotintuose salpžemiuose, mažiau derlingi – kalvų viršūnėse ir šlaituose, kuriuose vyravo paprastieji išplautžemiai. Žemumose esančiuose organiniuose dirvožemiuose žieminiai kviečiai dėl intensyvaus vegetatyvinės dalies augimo ir išgulimo buvo mažiau derlingi. Žalių baltymų koncentracijai žieminių kviečių grūduose turėjo įtakos metų sąlygos ir dirvožemio savybės. Sausesniais ir šiltesniais metais laukuose, kuriuose vyravo lengvesnės granuliometrinės sudėties dirvožemiai, grūdai buvo smulkesni ir kartu juose nustatytas didesnis kiekis žalių baltymų.

Reikšminiai žodžiai: žieminiai kviečiai, grūdų derlius, dirvožemio tipas, dirvožemio granuliometrinė sudėtis.