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Response of spring barley root and soil physical properties to changes under cover crop and different tillage

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Abstract

Cover cropping is a successful soil conservation technique, but it has limitations and must be recognised as part of a well-planned integrated farming system. Environmental conditions, soil type, crop, and tillage method are factors that should be taken into consideration before building cover crops into the farming system. The aim of this study was to explore the effect of cover crop management under different tillage practices on the spring barley (*Hordeum vulgare* L.) root growth and the interaction with soil hydrophysical properties. The experiment was conducted in Central Lithuania in *Endocalcari-Epihypogleyic Cambisol*, a loam texture soil. The split-plot experiment was conducted: tillage – ploughing, harrowing, and direct drilling, as subplot, and cover crop – with cover crop and without cover crop, as main plot. A significantly higher total porosity and microporosity of topsoil was identified in ploughing, and direct drilling resulted in a significantly higher soil bulk density, lower total porosity and microporosity, but did not change meso- and microporosity. The establishment of cover crop has resulted in a significantly higher soil microporosity and lower mesoporosity as well as tended to decrease the soil bulk density and to increase the root diameter and volume for all tillage treatments in a 5–20 cm layer. The root length and root volume of spring barley positively correlated with the soil total porosity, whereas the correlation of root parameters with the bulk density was negative. The influence of the cover crop and tillage interaction was significant for the soil bulk density and root diameter.

Keywords: deep ploughing, shallow harrowing, direct drilling, cover crop management, root growth.

Introduction

Understanding the effects of cover crops (CC) and tillage on soil properties is important for determining soil productivity. Soil and crop management practices such as tillage and CC influence soil physical properties like the bulk density, water content, pore size distribution, and water infiltration, and these turns influence the plant root growth and crop production.

Plant roots are central to the function of natural and agricultural ecosystems by driving plant acquisition of soil resources. Root characteristics like length, diameter, and volume are critical to measure to understand plant and soil functions (Seethepalli et al., 2021). Crops with optimised root traits are considered an important determinant of future food security that improves farm productivity and sustainability (Lynch, 2015). However, the root growth and development of agriculture crops depend on the plant species, soil texture, and agronomic practices.

Cereals, including barley (*Hordeum vulgare* L.), have a typical fibrous root system. This root type develops lateral roots and root hairs, which are major components for nutrient and water absorption (Robinson et al., 2018).

Effects of tillage on soil properties and root growth have been studied worldwide, but the results have been inconsistent (Shi et al., 2012; Li et al., 2015; Säle et al., 2015). The long-term effect of direct drilling change soil physical properties and moisture by increasing soil bulk density and penetration resistance (Feizienė, Kadžienė, 2008; Velykis, Satkus, 2018). Higher bulk density affects the root growth (Kadziene et al., 2011). Ploughing breaks down crop residues and incorporates them into the soil improving aeration and facilitating the breakdown of organic material and the release of nutrients. Also, it reduces bulk density and positively affects water infiltration as well as root growth and development (Dozier et al., 2017).

Integration of CC in crop management is a practice in conservation agriculture (Lal, 2015; Kadziene et al., 2020), because it has multifunctional properties that enhance soil carbon concentration and total porosity (Blanco-Canqui et al., 2015; Frasier et al., 2016; Carver

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et al., 2017) and, also, help to reduce soil bulk density (Blanco-Canqui et al., 2015). Therefore, CC usage as a part of the farming system affects soil properties. Haruna et al. (2018a) reported that CC increased macroporosity by 24%, and this increased the soil saturated hydraulic conductivity. Furthermore, Haruna et al. (2018b) found that CC management increased water infiltration parameters. According to Hudek et al. (2021), CC significantly increased aggregate stability and microporosity. However, the impact of CC on soil physical properties is inconsistent (Zaibon et al., 2016; Haruna et al., 2018a; Çerçioğlu et al., 2019), and some studies have shown no effect of cover crops on soil properties.

The ambiguities in these findings suggest that more studies are needed to improve our understanding how tillage, cover crops, and the interactions between these management practices affect soil physical properties. We hypothesise that tillage and cover crop may significantly affect soil physical properties and plant root characteristics. Therefore, the objective of this study was to assess the combined effects of tillage and cover crop on the soil physical properties and the influence on the plant root growth.

Material and methods

Site description and experimental design. The experiment was a long-term tillage and cover crop experiment (established in 2012 in autumn) performed in Lithuania Research Centre for Agriculture and Forestry (55°23′50″ N, 23°51′40″ E), Kėdainiai district, Central Lithuania in 2019. The weather conditions of spring barley growing season were close to the long-term. The mean air temperature was 13.5°C, and the total amount of rainfall was 293.0 mm. The soil was classified as *Endocalcari-Epihypogleyic Cambisol* of a loam texture according to the World Reference Base (WRB, 2015). The soil texture and agrochemical soil characteristics are presented in Table 1.

Table 1. Soil site characteristics

Soil texture	0–20 cm	
Sand %	47.4 ± 1.9	
Clay %	18.6 ± 2.6	
Silt %	34.1 ± 2.8	
Soil agrochemical parameters	**0–10 cm**	**10–20 cm**
pH_{KCl}	7.0 ± 0.26	7.0± 0.24
P_2O_5 mg kg^{-1}	256 ± 30.30	201 ± 36.28
K_2O mg kg^{-1}	272 ± 43.97	228 ± 42.22
Total N %	0.152 ± 0.02	0.146 ± 0.02
Humus %	2.21 ± 0.27	2.11 ± 0.36

± standard error

The field experiment was a split-plot design in four replications. Experimental plots without (NC) and with (CC) cover crop were a main plot, and deep ploughing (DP), shallow harrowing (SH), and direct drilling (DD) were a subplot (Table 2). Assessments and analyses were proceeded in a sample collected from the subplots of 4 × 9 m (36 m^2).

Table 2. Experimental design

Tillage treatment (subplot)	Abbreviation
Deep ploughing, 22–24 cm	DP
Shallow harrowing, 8–10 cm	SH
Direct drilling	DD
Cover crop (main)	
Without cover crop	NC
With cover crop	CC

The crop sequence was as follows: spring wheat (2013) → spring barley (2014) → field pea (2015) → winter wheat (2016) → winter oilseed rape (2017) → spring wheat (2018) → spring barley (2019). CC seeds were spread out using a fertiliser spreader: white mustard (*Sinapis alba* L.) approximately three weeks before the planned harvest of spring wheat in 2013 and 2018, spring barley (*Hordeum vulgare* L.) in 2014 and 2019, and white clover (*Trifolium repens* L.) in 2017 in spring at the beginning of vegetation of winter oilseed rape.

CC was chopped and spread on the subplots using the chopping machine just before the autumn tillage at mid-end October. The same procedure was also done for the NC plots for weed destruction to simplify the tillage.

Soil sampling and analysis. Soil hydrophysical properties were determined by a laboratory sorption method. Undisturbed soil samples were taken with steel cylinders (diameter 5 cm, volume 100 cm^3) from 5–10 and 15–20 cm layers from four replications when the soil moisture content was close to the field capacity. To determine the soil water potential, a synthetic sand box system from 0 to −100 hPa, a sand-kaolin box from −100 to −490 hPa, and a membrane apparatus from −98 to −15500 hPa were used (Klute, 1986). The laboratory experiment results obtained by that method were used to calculate the total soil porosity, soil pore size distribution, field moisture, and plant available moisture content in the soil.

Soil monoliths for root investigation were taken from the spring barley stand at the crop flowering (BBCH 63–65) stage at three replications from 0–10 and 10–20 cm soil depths. For collecting soil cores, a custom-made steel frame (10 × 10 × 10 cm) sharpened at the outside of the cutting edge was used (Lapinskienė, 1993). To prevent root degradation, the samples were placed in plastic bags and transported to the laboratory to store under deep freezing conditions (−20°C). Before scanning the roots, the samples were carefully washed with water using 500 and 250 µm sieves. Roots were cut with scissors into about 2 cm segments, and a "neutral red" solution was added. The roots were stored in the refrigerator at 2–6°C temperature for 24 h. The colour was rinsed out in a sieve (53–125 µm) with demineralised water. For scanning, the coloured roots were placed in a transparent tray in a thin layer of distilled water, spread out evenly with as little overlapping of roots as possible. The image analysis of the roots was done with the software WinRHIZO (Bouma et al., 2000).

Statistical analysis. Calculating means and standard errors, the averages were calculated. To assess the statistical significance of differences between the mean values, the software package SAS, version 7.1 (SAS Inc., USA) using Duncan's multiple range test at the probability level of $P < 0.05$ was applied. Correlation-regression analysis was also implemented. To construct error bars, the standard error values were used.

Results and discussion

The deep ploughing (DP) with (CC) and without (NC) cover crop in the arable layer down to 20 cm significantly increased the total porosity and macroporosity (Table 3). The direct drilling (DD) contributed to a significantly lower total porosity and macroporosity but did not change the meso- and microporosity compared to DP. A significantly higher total porosity was in the 5–10 cm soil depth for all tillage treatments in NC and with CC. The CC significantly increased soil micropores and decreased mesopores under DP, shallow harrowing (SH), and DD in both depths. The influence of the cover crop and tillage handling interaction was significant for the total and mesoporosity.

Table 3. The influence of cover crop management, soil depth, and different tillage on the soil pore size distribution and the total porosity (TP) ± standard error

Factor			Soil pores m^3 m^{-3}			Total porosity m^3 m^{-3}
cover crop (A)	soil depth (B)	tillage treatment (C)	micro- <0.2 µm	meso- 0.2–30 µm	macro- >30 µm	
Data averaged across cover crop management at 5–20 cm depth						
NC			0.100 ± 0.01 b	0.185 ± 0.02 a	0.115 ± 0.02 a	0.400 ± 0.03 a
CC			0.109 ± 0.01 a	0.166 ± 0.01 b	0.127 ± 0.04 a	0.402 ± 0.04 a
Data averaged across cover crop management and tillage						
	5–10 cm		0.104 ± 0.01 a	0.180 ± 0.02 a	0.125 ± 0.03 a	0.412 ± 0.03 a
	15–20 cm		0.105 ± 0.01 a	0.170 ± 0.01 a	0.117 ± 0.03 a	0.389 ± 0.03 b
Data averaged across tillage at 5–20 cm depth						
		DP	0.105 ± 0.01 a	0.179 ± 0.01 a	0.137 ± 0.04 a	0.420 ± 0.03 a
		SH	0.106 ± 0.01 a	0.178 ± 0.02 a	0.118 ± 0.02 ab	0.402 ± 0.03 ab
		DD	0.103 ± 0.01 a	0.169 ± 0.01 a	0.109 ± 0.03 b	0.380 ± 0.03 b
Influence and interactions						
A			**	**	ns	ns
B			ns	ns	ns	**
C			ns	ns	**	**
A × B			*	**	ns	ns
A × C			ns	**	ns	*
B × C			ns	**	ns	ns
A × B × C			ns	**	ns	*

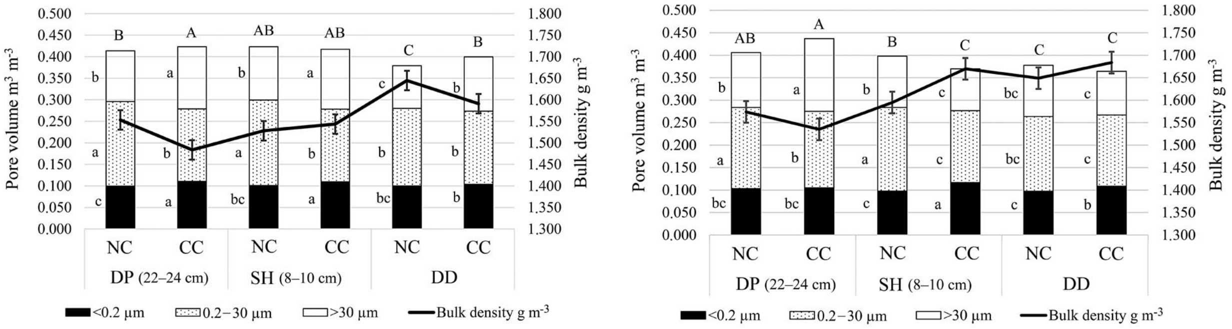
Note. Data followed by the same letters within an individual pore class are not significantly different at $P < 0.05$; * and ** – the level of statistical significance at $P < 0.05$ and $P < 0.01$, respectively, ns – not significant.

To ensure soil water availability during the crop vegetation period is of great importance under changing climate conditions. Employing management practices that improve soil water dynamics such as increased storage is one approach to mitigate the impacts of increased rainfall variability on a field (Basche et al., 2016).

In the 5–10 cm soil layer, there was a significant difference in the total porosity between DP and DD (Figure). A lower total porosity was a result of DD in NC and CC compared to DP and SH. The significantly higher volume of macropores (>30 µm) and the total porosity were found in DP and SH soil with CC. The volume of mesopores (0.2–30 µm) was significantly higher under DP and SH in NC. The soil microporosity tended to increase under DP, SH, and DD with CC. In the 15–20 cm soil layer, the significantly higher total porosity was found under DP with NC and CC. The volume of macropores was significantly higher under DP with CC, and a significantly higher volume of mesopores was found under DP and SH in NC. The application of CC increased the soil macroporosity at DP and tended to decrease the mesoroporosity under DP, SH, and DD.

Research findings suggest that the soil bulk density depends on the soil pore size distribution (Laclau, Laclau, 2009; Lima et al., 2022). Volungevicius et al. (2018) reported that ploughless tillage significant increase soil bulk density and caused a decrease in total porosity, water capacity and plant available water compared with other land uses.

In the topsoil (5–10 cm) layer, a significantly higher soil bulk density was determined under DD in NC. Under DP and DD with CC, the soil bulk density was lower than in NC. In the 5–20 cm soil layer, a significantly higher bulk density was determined under



5–10 cm depth

15–20 cm depth

Note. Explanation in Table 2; lower case letters indicate significant differences for the soil fractions and upper-case letters show significant differences ($P \leq 0.05$) for the total porosity.

Figure. Soil pore size distribution and bulk density after different tillage intensities and cover crops

DH and DD with CC. Under DP, the soil with CC tended to decrease the bulk density (Figure).

The growth and development of roots of agricultural crops depend on the plant species, soil texture, bulk density, total porosity, and agronomic practices, i.e., tillage and fertilisation method. Munkholm et al. (2008) reported about limitations on root growth when using soil management conservation techniques such as minimum tillage. Studies of Bécel et al. (2012) highlighted the effect of bulk density on the development of the root system often linking compaction to restricted root growth.

Table 4. The influence of cover crop management, soil depth, and different tillage treatments on the plant root parameters and the bulk density (± standard error)

Factor			Plant root parameter			Bulk density $g\ m^{-3}$
cover crop (A)	soil depth (B)	tillage treatment (C)	length $km\ m^{-3}$	diameter mm	volume cm^3	
Data averaged across tillage at 0–20 cm depth						
NC			98.43 ± 6.0 a	0.31 ± 0.04 a	0.64 ± 0.29 a	1.59 ± 0.07 a
CC			97.99 ± 7.6 a	0.33 ± 0.04 a	0.85 ± 0.69 a	1.58 ± 0.10 a
Data averaged across cover crop management and tillage						
	0–10 cm		100.37 ± 4.8 a	0.33 ± 0.04 a	1.03 ± 0.63 a	1.55 ± 0.08 b
	10–20 cm		96.05 ± 7.8 a	0.31 ± 0.03 b	0.46 ± 0.12 b	1.62 ± 0.07 a
Data averaged across cover crop management at 0–20 cm depth						
		DP	99.78 ± 5.4 a	0.31 ± 0.03 b	0.71 ± 0.41 a	1.54 ± 0.07 b
		SH	97.45 ± 8.7 a	0.31 ± 0.03 b	0.70 ± 0.42 a	1.58 ± 0.08 ab
		DD	97.40 ± 6.0 a	0.35 ± 0.04 a	0.84 ± 0.74 a	1.64 ± 0.07 a
Influence and interactions						
A			ns	ns	ns	ns
B			ns	**	**	**
C			ns	**	ns	**
A × B			ns	ns	**	ns
A × C			ns	*	ns	*
B × C			ns	*	*	ns
A × B × C			ns	*	ns	*

Note. Data followed by the same letters within an individual pore class are not significantly different at $P < 0.05$; * and ** – significant at $P < 0.05$ and $P < 0.01$, respectively; ns – not significant.

The spring barley root characteristics under DP, SH, and DD with CC and in NC in two (0–10 and 10–20 cm) soil depths are presented in Table 4. The soil bulk density in the upper profile under DD (1.64 g m^{-3}) was higher than that under DH (1.58 g m^{-3}) and DP (1.54 g m^{-3}) tillage leading to a decrease in the root length but the root diameter was significantly higher under DD (0.35 mm) than DP (0.31 mm) and DH (0.31 mm). The application of CC tended to decrease the soil bulk density and increase the root diameter and volume for DP, SH, and DD in a 0–20 cm depth. The influence of the cover crop and tillage handling interaction was significant for the soil bulk density and the root diameter.

The root development of spring barley depended on the soil and crop management practices. The experimental data showed that the root length of spring barley positively correlated with the total soil porosity ($r = 0.38$, $P < 0.05$), while the correlation with the bulk density ($r = -0.38$, $P < 0.05$) was negative (Table 5). The root volume positively correlated with the soil macroporosity ($r = 0.40$, $P < 0.05$) and the total porosity ($r = 0.41$, $P < 0.05$), and the correlation with the bulk density ($r = -0.41$, $P < 0.05$) was negative.

Hudek et al. (2021) also reported that the total root length and root surface area had a significant effect on soil microporosity. Bodner et al. (2014) found that greater root density significantly increased the micropore volume by cover crops, but in the meantime reduced the volume of larger pores. The results of several studies (Chen, Weil, 2011; Correa et al., 2019; Ren el al., 2019) showed that roots with an increased diameter can penetrate through compacted soil and are able to alleviate soil compaction. On the other hand, the increased root diameter could increase soil densification (Kolb et al., 2017) negatively impacting porosity, which decreases the

Table 5. The relationship of root length, diameter, and volume of spring barley with the soil pore size distribution, total porosity, and bulk density

Properties	RL	RD	RV	Micro	Meso	Macro	TP	BD
RL	1.00							
RD	–0.05	1.00						
RV	0.43**	0.17	1.00					
Micro	0.09	–0.04	–0.21	1.00				
Meso	0.16	–0.27	0.13	–0.41*	1.00			
Macro	0.19	–0.21	0.40*	–0.31	–0.001	1.00		
TP	0.38*	–0.31	0.41*	–0.12	0.42*	0.76**	1.00	
BD	–0.38*	0.31	–0.41*	0.12	–0.42*	–0.76**	–1.00**	1.00

RL – root length (km m^{-3}), RD – root diameter (mm), RV – root volume (cm^3); soil pores (m^3 m^{-3}): Micro – micropores, Meso – mesopores, Macro – macropores; TP – total porosity (m^3 m^{-3}), BD – bulk density (g m^{-3}); * and ** – significant at $p < 0.05$ and $p < 0.01$, respectively

water conductivity and water holding capacity of the soil (Tubeileh et al., 2003).

A positive correlation was revealed between the meso-, microporosity, and total porosity. Meso- and macroporosity relationships with the soil bulk density were negative.

Conclusions

1. The deep ploughing (DP) resulted in significantly higher total porosity and microporosity with (CC) and without (NC) cover crop in a 0–20 cm layer, and the direct drill (DD) contributed to significantly higher soil bulk density, lower total porosity and microporosity, but did not change the meso- and microporosity. It resulted in a decrease of the root length, but the root diameter was significantly higher.

2. The cover crop (CC) management resulted in a significantly higher amount of soil micropores and a lower amount of mesopores for all tillage treatments in both depths. The application of CC tended to decrease the soil bulk density and to increase the root diameter and volume for all tillage treatments in a 0–20 cm depth.

3. The root length and volume of spring barley positively correlated with the soil total porosity, whereas the correlation of root parameters with the bulk density was negative. The influence of the cover crop and tillage interaction was significant for the soil bulk density and the root diameter.

4. The study results suggest that CC management is an important tool for the improvement of soil physical parameters, especially when reduced tillage technologies are applied.

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References

Basche A. D., Kaspar T. C., Archontoulis S. A., Jaynes D. B., Sauer T. J., Parkin T. B., Miguez F. E. 2016. Soil water improvements with the long-term use of a winter rye cover crop. Agricultural Water Management, 172: 40–50. https://doi.org/10.1016/j.agwat.2016.04.006

Bécel C., Vercambre G., Pagès L. 2012. Soil penetration resistance, a suitable soil property to account for variations in root elongation and branching. Plant and Soil, 353: 169–180. https://doi.org/10.1007/s11104-011-1020-7

Blanco-Canqui H., Shaver T. M., Lindquist J. L., Shapiro C. A., Elmore R. W., Francis C. A., Hergert G. W. 2015. Cover crops and ecosystem services: Insights from studies in temperate soils. Agronomy Journal, 107 (6): 2449–2474. https://doi.org/10.2134/agronj15.0086

Bodner G., Leitner D., Kaul H. P. 2014. Coarse and fine root plants affect pore size distributions differently. Plant and Soil, 380: 133–151. https://doi.org/10.1007/s11104-014-2079-8

Bouma T. J., Nielsen K. L., Koutstaal K. 2000. Sample preparation and scanning protocol for computerized analysis of root length and diameter. Plant and Soil, 218: 185–196. https://doi.org/10.1023/A:1014905104017

Carver R. E., Nelson N. O., Abel D. S., Roozeboom K., Kluitenberg G. J., Tomlinson P. J., Williams J. R. 2017. Impact of cover crops and phosphorus fertilizer management on nutrient cycling in no-tillage corn-soybean rotation. Kansas Agricultural Experiment Station Research Reports, 3 (3). https://doi.org/10.4148/2378-5977.1396

Çerçioğlu M., Anderson S. H., Udawatta R. P., Alagele S. 2019. Effect of cover crop management on soil hydraulic properties. Geoderma, 343: 247–253. https://doi.org/10.1016/j.geoderma.2019.02.027

Chen G., Weil R. R. 2011. Root growth and yield of maize as affected by soil compaction and cover crops. Soil and Tillage Research, 117: 17–27. https://doi.org/10.1016/j.still.2011.08.001

Correa J., Postma J. A., Watt M., Wojciechowski T. 2019. Soil compaction and the architectural plasticity of root systems. Journal of Experimental Botany, 70 (21): 6019–6034. https://doi.org/10.1093/jxb/erz383

Dozier I. A., Behnke G. D., Davis A. S., Nafziger E. D., Villamil M. B. 2017. Tillage and cover cropping effects on soil properties and crop production in Illinois. Agronomy, Soils and Environmental Quality, 109: 1261–1270. https://doi.org/10.2134/agronj2016.10.0613

Feizienė D., Kadžienė G. 2008. The influence of soil organic carbon, moisture, and temperature on soil surface CO_2 emission in the 10th year of different tillage-fertilisation management. Zemdirbyste-Agriculture, 95 (4): 29–45.

Frasier I., Quiroga A., Noellemeyer E. 2016. Effect of different cover crops on C and N cycling in sorghum NT systems. Science of the Total Environment, 562: 628–639. https://doi.org/10.1016/j.scitotenv.2016.04.058

Haruna S. I., Anderson S. H., Nkongolo N. V., Zaibon S. 2018 (a). Soil hydraulic properties: Influence of tillage and cover crops. Pedosphere, 28 (3): 430–442. https://doi.org/10.1016/S1002-0160(17)60387-4

Haruna S. I., Nkongolo N. V., Anderson S. H., Eivazi F., Zaibon S. 2018 (b). *In situ* infiltration influenced by cover crop and tillage management. Journal of Soil Water Conservation, 73 (2): 164–172. https://doi.org/10.2489/jswc.73.2.164

Hudek C., Putinica C., Otten W., De Baets S. 2021. Functional root trait-based classification of cover crops to improve soil physical properties. European Journal of Soil Science, 73 (1): e13147. https://doi.org/10.1111/ejss.13147

Kadziene G., Munkholm L. J., Mutegi J. K. 2011. Root growth conditions in the topsoil as affected by tillage intensity. Geoderma, 166 (1): 66–73. https://doi.org/10.1016/j.geoderma.2011.07.013

Kadziene G., Suproniene S., Auskalniene O., Pranaitiene S., Svegzda P., Versuliene A., Ceseviciene J., Janusauskaite D., Feiza V. 2020. Tillage and cover crop influence on weed pressure and *Fusarium* infection in spring cereals. Crop Protection, 127: 104966. https://doi.org/10.1016/j.cropro.2019.104966

Klute A. 1986. Water retention: laboratory methods. Methods of Soil Analysis: Part 1 Physical and Mineralogical Methods, 5.1 (2nd ed.). SSSA Book Series, chapter 26.

Kolb E., Legué V., Bogeat-Triboulot M. B. 2017. Physical root–soil interactions. Physical Biology, 14 (6): 065004. https://doi.org/10.1088/1478-3975/aa90dd

Laclau P. B., Laclau J. P. 2009. Growth of the whole root system for a plant crop of sugarcane under rainfed and irrigated environments in Brazil. Field Crops Research, 114 (3): 351–360. https://doi.org/10.1016/j.fcr.2009.09.004

Lal R. 2015. Restoring soil quality to mitigate soil degradation. Sustainability, 7 (5): 5875–5895. https://doi.org/10.3390/su7055875

Lapinskienė N. 1993. Ecomorphological, quantitative and phytoestimational assessment of the underground organs of the herbal communities of the ecosystems of Lithuania: a reference to the habilitation work of the natural sciences [Lietuvos agrolandšafto ekosistemų žolinių bendrijų požeminių organų ekomorfologinis, kiekybinis ir fitocenotinis įvertinimas] (in Lithuanian). Vilnius, 45 p.

Li S. W., Jiang X. J., Wang X. L., Wright A. L. 2015. Tillage effects on soil nitrification and the dynamic changes in nitrifying microorganisms in a subtropical rice-based ecosystem: A long-term field study. Soil and Tillage Research, 150: 132–138. https://doi.org/10.1016/j.still.2015.02.005

Lima de R. P., Rolim M. M., Toledo M. P. S., Tormena C. A., Silva da A. R., Silva e I. A. C., Pedrosa E. M. R. 2022. Texture and degree of compactness effect on the pore size distribution in weathered tropical soils. Soil and Tillage Research, 215: 105215. https://doi.org/10.1016/j.still.2021.105215

Lynch J. P. 2015. Root phenes that reduce the metabolic costs of soil exploration: opportunities for 21st century agriculture. Plant, Cell and Environment, 38: 1775–1784. https://doi.org/10.1111/pce.12451

Munkholm L. J., Hansen E. M., Olesen J. E. 2008. The effect of tillage intensity on soil structure and winter wheat root/shoot growth. Soil Use Management, 24: 392–400. https://doi.org/10.1111/j.1475-2743.2008. 00179.x

Ren L., Nest T. V., Ruysschaert G., D'Hose T., Cornelis W. M. 2019. Short-term effects of cover crops and tillage methods on soil physical properties and maize growth in a sandy loam soil. Soil and Tillage Research, 192: 76–86. https://doi.org/10.1016/j.still.2019.04.026

Robinson H., Kelly A., Fox G., Franckowiak J., Borrell A., Hickey L. 2018. Root architectural traits and yield: Exploring the relationship in barley breeding trials. Euphytica, 214: 151. https://doi.org/10.1007/s10681-018-2219-y

Säle V., Aguilera P., Laczko E., Mäder P., Berner A., Zihlmann U., Oehl F. 2015. Impact of conservation tillage and organic farming on the diversity of arbuscular mycorrhizal fungi. Soil Biology and Biochemistry, 84: 38–52. https://doi.org/10.1016/j.soilbio.2015.02.005

Seethepalli A., Dhakal K., Griffiths M., Guo H., Freschet G. T., York L. M. 2021. RhizoVision Explorer: open-source software for root image analysis and measurement standardization. AoBP Plants, 13 (6): plab056. https://doi.org/10.1093/aobpla/plab056

Shi X. H., Yang X. M., Drury C. F., Reynolds W. D., McLaughlin N. B., Zhang X. P. 2012. Impact of ridge tillage on soil organic carbon and selected physical properties of a clay loam in southwestern Ontario. Soil and Tillage Research, 120: 1–7. https://doi.org/10.1016/j.still.2012.01.003

Tubeileh A., Groleau-Renaud V., Plantureux S., Guckert A. 2003. Effect of soil compaction on photosynthesis and carbon partitioning within a maize–soil system. Soil and Tillage Research, 71 (2): 151–161. https://doi.org/10.1016/S0167-1987(03)00061-8

Velykis A., Satkus A. 2018. The impact of tillage, Ca-amendment and cover crop on the physical state of clay loam soil. Zemdirbyste-Agriculture, 105 (1): 3–10. https://doi.org/10.13080/z-a.2018.105.001

Volungevicius J., Amaleviciute K., Feiziene D., Feiza V., Slepetiene A., Liaudanskiene I, Versuliene A., Vaisvalavicius R. 2018. The effects of agrogenic transformation on soil profile morphology, organic carbon and physico-chemical properties in *Retisols* of Western Lithuania. Archives of Agronomy and Soil Science, 64 (13): 1910–1923. https://doi.org/10.1080/03650340.2018.1467006

WRB. 2015. World Reference Base for Soil Resources. World Soil Resources Reports No. 106. FAO. https://doi.org/10.1007/springerreference_76722

Zaibon S., Anderson S. H., Kitchen N. R., Haruna S. I. 2016. Hydraulic properties affected by topsoil thickness in switchgrass and corn–soybean cropping systems. Soil Science Society of America Journal, 80 (5): 1365–1376. https://doi.org/10.2136/sssaj2016.04.0111

Tarpinių pasėlių ir skirtingų žemės dirbimo būdų įtaka vasarinių miežių šaknų augimui ir dirvožemio fizikinėms savybėms

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Santrauka

Tarpinių pasėlių auginimas yra gera tausojamoji dirvožemio naudojimo praktika ir gali būti integruota į ūkininkavimo sistemą. Pasirenkant planuojamų auginti tarpinių pasėlių rūšį, reikia atsižvelgti į aplinkos sąlygas, dirvožemio tipą, auginamų pagrindinių augalų rūšį ir taikomą auginimo technologiją. Tyrimas atliktas siekiant ištirti žemės dirbimo ir auginamų tarpinių pasėlių poveikį vasarinių miežių šaknų formavimuisi ir dirvožemio fizikinėms savybėms. Ilgalaikis eksperimentas įrengtas Vidurio Lietuvoje, dirvožemis – giliau karbonatingas sekliai glėjiškas rudžemis, priemolis. Lauko eksperimentas atliktas skaidytų laukelių metodu, keturiais pakartojimais. Tyrimo schemą sudarė du tarpinių pasėlių variantai (be ir su tarpiniu pasėliu) ir trys žemės dirbimo variantai (javai auginti po arimo, skutimo ir taikant tiesioginę sėją). Tarpinių pasėlių ir žemės dirbimo sąveika buvo reikšminga dirvožemio tankiui ir vasarinių miežių šaknų skersmeniui. Arimo variante nustatytas esmingai didesnis dirvožemio bendras poringumas ir mikroporų kiekis visame (0–20 cm) armens sluoksnyje, o tiesioginės sėjos taikymas esmingai didino dirvožemio tankį ir mažino bendrą poringumą bei mikroporų kiekį. Mezo- ir mikroporų kiekis taikant arimą, skutimą ir tiesioginę sėją nepakito. Tarpinių pasėlių auginimas esmingai didino dirvožemio mikroporų ir mažino mezoporų kiekį. Visuose tirtuose žemės dirbimo variantuose tarpinių pasėlių auginimas turėjo įtakos dirvožemio tankio mažėjimui ir didesniam šaknų skersmeniui 0–20 cm sluoksnyje. Vasarinių miežių šaknų ilgis ir tūris teigiamai koreliavo su bendru dirvožemio poringumu, o šaknų parametrų koreliacija su dirvožemio tankiu buvo neigiama.

Reikšminiai žodžiai: arimas, skutimas, tiesioginė sėja, tarpiniai augalai, šaknų augimas.