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Effect of different methods (conventional and strip-till) of maize cultivation on topsoil moisture and temperature

Vliv různých způsobů (konvenční a strip-till) pěstování kukuřice na vlhkost a teplotu půdy ve svrchní vrstvě

David KABELKA[1,2] (✉), David KINCL[2,3], Pavel FORMÁNEK[2], Petr KONVALINA[1], Vojtěch ŠTROS[2], Antonín KINTL[4], Jan VOPRAVIL[2,3]

[1] Department of Agroecosystems, Faculty of Agriculture and Technology, University of South Bohemia in České Budějovice, Studentská 1668, 370 05 České Budějovice, Czech Republic

[2] Research Institute for Soil and Water Conservation, Žabovřeská 250, 156 00 Prague-Zbraslav, Czech Republic

[3] Department of Land Use and Improvement, Faculty of Environmental Sciences, Czech University of Life Sciences Prague, Kamýcká 1176, 165 00 Prague, Czech Republic

[4] Agricultural Research Ltd., Zahradní 400/1, 664 41, Troubsko, Czech Republic

✉ Corresponding author: dkabelka@fzt.jcu.cz

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ABSTRACT

Soil moisture is an important factor that affects not only crop growth but also a wide range of soil parameters. Nowadays, most crops can be grown in different ways: for example, conventional and conservation techniques. Different cultivation systems also affect soil moisture. For this reason, the main focus of this paper is to compare conventional and strip-till techniques for growing maize (*Zea Mays* L.) in terms of their effect on topsoil moisture. These techniques were chosen primarily because of the significant difference in surface coverage by plant residues. The research was conducted between 2023 and 2024 at two locations in the Czech Republic. Soil moisture at a depth of 15 cm was monitored using moisture sensors with automatic recording throughout the maize growing season. Temperature was also measured in the same way. Due to the changing soil surface cover, the maize growing season was divided into three parts: the initial growth period, the period up to two months after sowing, and the period of full growth. The results show the different effects of the tested techniques on soil moisture, especially in the period shortly after sowing. The strip-till had statistically higher (P=0.05) soil moisture in both years compared to the conventional technique. This confirmed the positive effect on soil water content during the initial growth period of maize. In the remaining two periods, due to the gradual growth of maize and the decomposition of plant residues, the differences between the both techniques decreased. In the case of soil temperature, this is a more stable soil parameter which did not differ statistically between the techniques considered.

Keywords: conservation techniques, soil, soil cover, crop residues, corn, moisture sensor

ABSTRAKT

Vlhkost půdy je důležitým faktorem, který ovlivňuje nejen růst plodin, ale i celou řadu půdních parametrů. V dnešní době je možné většinu zemědělských plodin pěstovat různými způsoby: například konvenční a půdoochranný. Rozdílný technologický způsob pěstování ovlivňuje mimo jiné i půdní vlhkost. Z tohoto důvodu je hlavním předmětem článku porovnání konvenční technologie a technologie strip-till při pěstování kukuřice seté (*Zea Mays* L.) z hlediska jejich vlivu na půdní vlhkost ve svrchní vrstvě půdy. Tyto technologie byly vybrány kvůli výrazné odlišnosti v pokryvnosti povrchu rostlinnými zbytky. Výzkum probíhal v letech 2023-2024 na dvou lokalitách v České Republice. Vlhkost půdy v hloubce 15 cm byla sledována pomocí vlhkostních čidel s automatickým záznamem po celé vegetační období kukuřice seté. Stejným způsobem byla měřena i teplota. Vzhledem k měnící se pokryvnosti povrchu půdy bylo vegetační období kukuřice rozděleno na tři části: období počátečního růstu, období do dvou měsíců od setí, období plného vzrůstu. Z výsledků je patrný rozdílný vliv technologií na půdní vlhkost v období krátce po setí. Technologie strip-till měla v obou letech statisticky vyšší (*P*=0.05) vlhkost ve srovnání s konvenční technologií. Potvrdil se tak pozitivní efekt na obsah vody v půdě v počátečním růstu kukuřice. Ve zbylých dvou obdobích se vlivem postupného růstu rostlin a rozkladem posklizňových zbytků rozdíly mezi technologiemi snižovaly. V případě teploty půdy lze konstatovat, že se jedná o stálejší půdní parametr, který se u posuzovaných technologií statisticky nelišil.

Klíčová slova: ůdoochranné technologie, půda, pokryvnost půdy, rostlinné zbytky, kukuřice, vlhkostní senzor

INTRODUCTION

Soil moisture and soil temperature are very important parameters in terms of crop germination and growth, including yield. Of course, soil water content is influenced by the occurrence and amount of atmospheric precipitation (e.g. Kovacevic et al., 2007; Maitah et al., 2021; Mohammed et al., 2022; Singh et al., 2024). Atmospheric precipitation reaches the crop, where it is further redistributed. The total amount that reaches the soil can vary considerably depending on the crop. For example, in the case of rainfall in maize (*Zea mays* L.), which is the subject of this paper, Nazari et al. (2020) report values for direct raindrop plus leaf runoff ranging from 31%-83%, stem runoff ranging from 15-25%, and interception ranging from 10-20%. Values of rainfall water reaching the soil are, of course, influenced by total volume, rainfall intensity, row spacing, number of plants per unit area, as well as growth stage and leaf orientation, etc. (Zábransky et al., 2013; Brant et al., 2017; Sun et al., 2017). All of the above aspects affect the resulting soil moisture. In addition to soil moisture, soil temperature is also the subject of the paper, which also affects several parameters (Heinze et al., 2017; Onwuka et al., 2018). In plants, for example, it affects germination, emergence time and the onset of other growth stages (Blacklow, 1972). Its increase can lead to higher total leaf area index (Bollero et al., 1996). For some climatic regions and depending on the time of sowing, an increase in soil temperature is associated with higher maize grain yield and total plant biomass (Vâtcă et al., 2021). Some authors also report on a higher effect of temperature than soil water content on maize emergence (Kurtyka et al., 2011; Gaile 2012; Santos et al., 2018). The layer of organic matter on the soil surface then influences the amount of solar radiation, protects the soil from water loss by evaporation and from erosion, and leads to a reduction in surface runoff or soil temperatures, etc. (Nýč et al., 2015; Hůla et al., 2019; Jaskulski 2019; Kabelka et al., 2021).

The use of different tillage techniques (conventional, strip-till, no-till, etc.) can affect soil water content and soil temperature (and other soil characteristics - physical, chemical and biological), and thus on crop germination and growth (Matus et al., 1997; Torabian et al., 2019; Stipešević and Kladivko 2005; Leskovšek 2021; Faligowska et al., 2022). It has been found that deeper soil loosening can lead to drying and temperature changes (e.g. Gałęzewski et al., 2023). According to various authors, the observed differences in terms of soil water content when comparing conventional tillage and soil conservation techniques may also be influenced by the methods of soil water determination (e.g. Gałęzewski et al., 2023).

In this paper, two basic methods of maize cultivation (conventional cultivation, strip-till) are evaluated. In conventional tillage, the soil surface is usually without post-harvest crop residues (Mhlanga et al., 2016) as they are incorporated into the soil (Kämpf et al., 2016). Strip-till is considered a soil conservation technique (Procházková et al., 2020; Różewicz, M., 2022) and combines the advantages of no-till and conventional tillage, where only part of the soil is tilled, and part remains covered with crop residues. This paper aimed to test the following hypotheses:

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1. strip-till will have higher soil moisture at 15 cm soil depth due to higher surface residue coverage;
2. the difference in soil moisture between the techniques will be evident throughout the maize growing season;
3. soil temperature, similar to moisture in strip-till, will be statistically different from conventional cultivation.

MATERIAL AND METHODS

The research was conducted in the Czech Republic in 2023 and 2024 (Figure 1). In 2023, the selected location was in Central Bohemia, and in 2024, the location was in South Bohemia. A more detailed description of the soil parameters at both locations is shown in Table 1.

- Location Central Bohemia – the experimental area is in Central Bohemia. The average annual temperature is 7-8 °C, and the average annual rainfall is approximately 550-650 mm. The altitude of the field is 480-520 meters, and the average slope is 11.6°. Soil type according to WRB (2022) is cambisols.
- Location South Bohemia – the experimental area is in South Bohemia. The average annual temperature is 7-8 °C, and the average annual rainfall is approximately 550-650 mm. The altitude of the field is 440-450 meters, and the average slope is 3.1°. Soil type according to WRB (2022) is stagnosols.

Table 1. Soil conditions at experimental locations

Soil parameter	Central Bohemia	South Bohemia
Texture (USDA*)	Loam	Sandy Loam
pH (KCl)	5.4	5.8
SOC* (%)	0.98	1.16
Bulk density (g/cm^3)	1.44	1.46

*USDA- U.S. Department of Agriculture: texture triangle; SOC-soil organic carbon

In each year, the experimental plots were marked with different variants of maize. All tested variants were located next to each other to ensure the same soil conditions. In total, three sown maize variants were tested in each year and are described below:

- Conventional cultivation: this method is the classical way of cultivating the soil for growing maize. The standard plant spacing for each row is 75 cm. As a rule, tillage is carried out in autumn, supplemented by organic fertilisation. Plant residues are basically absent from the soil surface at the time of sowing.

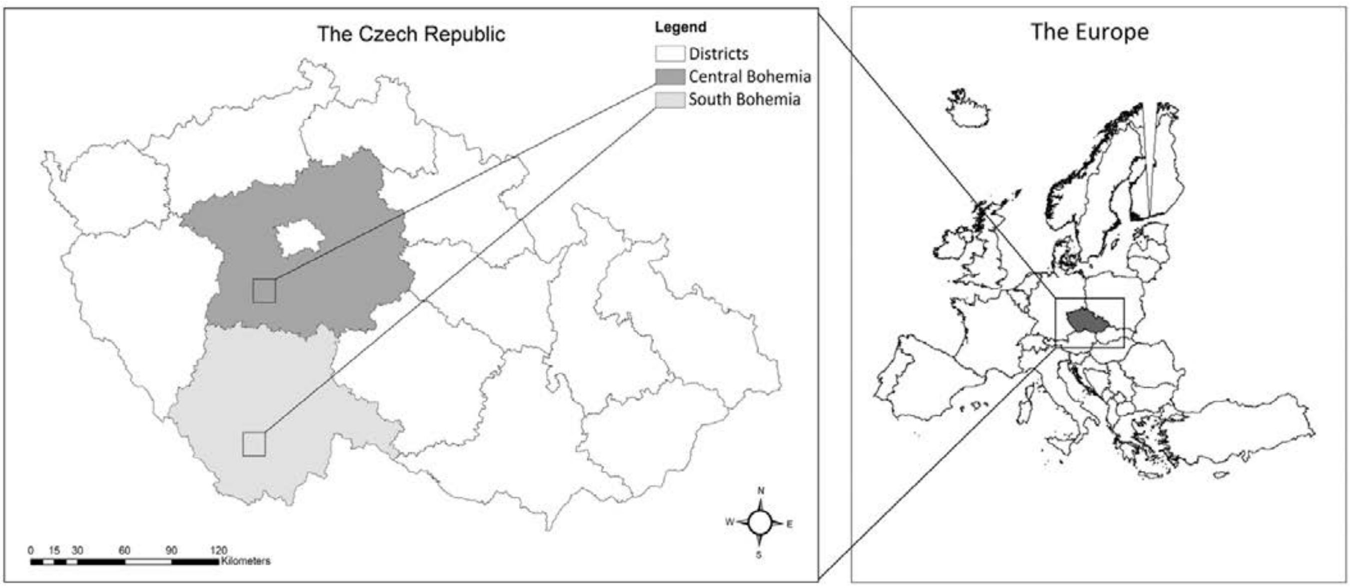

Figure 1. Map of experimental locations in the Czech Republic

– Strip-till: the basic principle is to strip-till the soil in dead plant residues. Only a space of about 25 cm wide is loosened, into which maize is then sown precisely (plant spacing 75 cm). The rest of the surface is not cultivated and is covered with plant residues of different crop species. In both years, two different strip-till variants were tested. In 2023, 1) *Lolium perenne* L., 2) *Trifolium pratense* L. were used for strip-till. In 2024, strip-till was applied to crops of: 1) *Vicia* L. + *Triticosecale* (Witt.) Müntzing, 2) *Secale cereale* L. + *Vicia* L. The strip-till technique is characterized by high surface coverage of plant residues in the spring season.

After marking the experimental plots, the TMS-4 sensors (TOMST, Czech Republic) were set up and checked to avoid possible problems with discharge or lack of memory. This sensor has already been used in a number of papers (Wild et al., 2019; Kopecky et al., 2024; Vopravil et al., 2021; etc.). The TMS-4 dataloggers measure both soil moisture and soil temperature through one moisture sensor and three temperature sensors. Measurements are taken at regular intervals throughout the day. The interval for recording the soil moisture readings was set to every 15 minutes. This was followed by the placement of the sensors in the soil immediately after sowing the maize. The sensors were applied on all three variants in two repetitions to a soil depth of 15 cm. The distance between the two sensors on one variant was 2 meters. In a set interval (15 minutes), the sensors recorded moisture and temperature throughout the maize growing season.

Before the harvest, the TMS-4 sensors were removed from the soil and the data downloaded to the computer, followed by further data processing. There were two TMS-4 sensors per variant. The results from both sensors were averaged so that only one value was worked with. Due to the large number of sensor records, a 3-day interval was chosen for data processing, with the resulting value representing the average moisture content in % (volumetric) for each of the 3 days. Soil temperature, expressed in °C, was processed in the same way.

For data evaluation, the maize growing season was divided into three periods. This step was taken because of the changing parameters on each variant during the season (e.g. residue decomposition in strip-till and the gradual growth of maize plants). The first period represents the period from sowing to approximately one month after sowing. During this period, the maize crops are in the early stages of growth, and the strip-till variants have a significant amount of plant residues on the surface. The second period falls in the growing season from one month after sowing to approximately two months after sowing. The maize has a higher leaf area index, and the plant residues gradually decrease in the strip-till variant. The third period was chosen as two months from sowing to harvest. The maize is fully grown in this period.

The data, divided into three periods, were further statistically evaluated in order to find out the differences between the individual variants. Both soil moisture (%) and temperature (°C) were evaluated. In the case of temperature, the two years (2023, 2024) were additionally compared with each other. For statistical evaluation, the One-Way ANOVA test and Tukey HSD test were chosen at a significance level of P=0.05. This made it possible to determine whether the parameters considered were statistically identical or not.

RESULTS

Soil moisture measured with TMS-4 sensors

Maize: 1st period (from sowing to one month after sowing)

The character of moisture evolution was different in the two evaluated years, as can be clearly seen in Figure 2. The main reason for this is the different climatic conditions due to the air temperature and especially the occurrence of precipitation events in a given year. Precipitation has a major influence on soil moisture. In 2023, precipitation events at the Central Bohemia location were more frequent, which had an impact on soil moisture fluctuations. In 2024 at the South Bohemia location, rainfall was not as frequent and intense. Nevertheless, the same trend was observed at both locations for each technique as described below.

In the first observation period, the average soil moisture values at 15 cm were lowest in the conventional cultivation (see Table 2), which is characterised by low surface cover.

In contrast, the strip-till showed statistically higher moisture content in both years. The main reason for this can be attributed to the surface coverage of plant residues, as these are the basis of this technique. The strip-till was always monitored in two variants (different cover crops). In 2023, there was no statistically significant difference between strip-till (*Trifolium pratense* L.) and strip-till (*Lolium perenne* L.). In 2024, in addition to the statistical difference from the conventional cultivation, there was also a difference between the strip-till variants. The strip-till (*Secale cereale* L. + *Vicia* L.) showed statistically higher moisture content than strip-till (*Vicia* L. + *Triticosecale* (Witt.) Müntzing). The main reason for this was the better quality of the crop residues and the higher surface cover, which was visually evident in the strip-till (vetch+pigeonpea). Hypothesis 1 (higher soil moisture in strip-till) was confirmed in the first period.

Figure 2 also shows that when comparing the differences between conventional cultivation and strip-till, the differences are greatest at the beginning of the period. All lines tend to converge as time progresses. This trend is also clearly visible in Table 2. Throughout the first period, strip-till had a positive effect on soil moisture. Plant residues, by their presence on the surface, prevented evaporation and, at the same time, slowed down surface runoff and promoted water infiltration into the soil when rainfall occurred. This resulted in higher average soil moisture at both locations.

Table 2. Moisture conditions on the tested variants in the first period

Central Bohemia - 2023							South Bohemia - 2024						
Soil moisture (%) - volumetric													
Date	Conventional cultivation		Strip-till: *Trifolium pratense*		Strip-till: *Lolium perenne*		Date	Conventional cultivation		Strip-till: *Vicia + Triticosecale*		Strip-till: *Secale + Vicia*	
	Average	SD	Average	SD	Average	SD		Average	SD	Average	SD	Average	SD
27.5	3.69	0.56	15.76	0.49	13.35	0.54	6.6	16.48	0.26	18.15	0.27	20.74	0.29
30.5	3.28	0.51	14.78	0.48	12.38	0.49	9.6	16.68	0.12	18.63	0.17	20.98	0.21
2.6	2.91	0.52	13.80	0.39	11.73	0.46	12.6	16.48	0.17	18.27	0.16	20.37	0.17
5.6	10.73	8.95	18.19	4.76	17.38	6.22	15.6	16.45	0.26	18.08	0.24	19.79	0.23
8.6	16.60	2.86	21.14	0.58	24.35	0.49	18.6	16.61	0.81	18.09	1.08	19.32	0.41
11.6	20.00	4.96	22.46	1.64	25.22	1.07	21.6	17.08	0.11	18.71	0.18	18.96	0.20
14.6	16.24	1.47	20.36	0.66	24.01	0.54	24.6	17.48	0.15	18.90	0.18	19.03	0.20
17.6	18.67	1.44	20.29	0.98	24.22	0.77	27.6	17.20	0.21	18.37	0.19	18.66	0.24
20.6	19.03	3.04	19.81	1.48	23.74	0.99	30.6	16.83	0.11	17.97	0.13	18.33	0.15
23.6	21.31	1.68	24.10	0.78	24.77	0.49	3.7	16.34	0.20	17.49	0.23	17.76	0.30
26.6	18.43	0.77	22.87	1.08	22.53	1.04	6.7	16.18	0.19	17.11	0.16	17.46	0.22
29.6	16.95	0.36	20.10	0.65	19.12	1.03	x	x	x	x	x	x	x
Average	13.99	2.26	19.47	1.17	20.23	1.18	Average	16.71	0.24	18.16	0.27	19.22	0.24

* SD - standard deviation

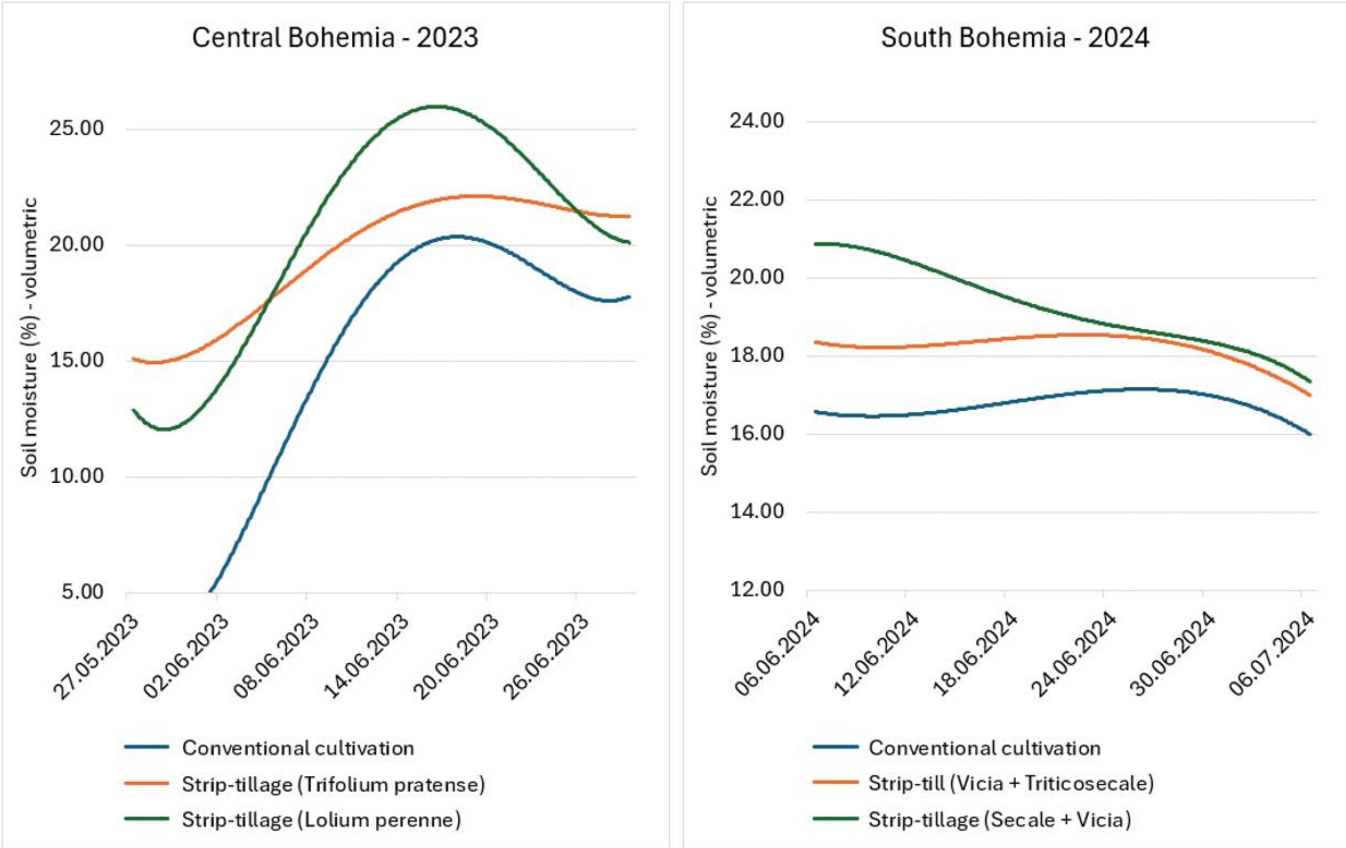

Figure 2. Trend of soil moisture in the experimental plots in the first period (polynomial trend line, fourth degree)

Maize: 2nd period (from the end of the 1st period to two months after sowing)

The beginning of the second period directly follows the end of the first. Again, the lines in the two years under evaluation have a different evolution, which is due, as in the previous case, to the different occurrence and frequency of rainfall. The trend seen in the first period, when the average moisture values were gradually approaching, continued. During the second period, the moisture content of the strip-till was lower than that of the conventional cultivation in a number of cases (Figure 3). This was particularly true for the strip-till (*Lolium perene* L.), where this was also reflected in the statistical evaluation, as this variant is statistically different from the strip-till (*Trifolium pratense* L.). However, the pattern of the trend is the same for both strip-till techniques, as can be clearly seen in Figure 3.

There was no statistical difference between the conventional cultivation and strip-till variants, and therefore, they can be considered identical in the second period (Table 3). One reason for this is the gradual decomposition of the crop residues in strip-till. As a result, the surface cover decreases, and the techniques evaluated gradually become more similar. In addition, conventional cultivation usually leads to partial weeding, which further makes the two farming techniques closer (in terms of surface cover). Another reason is the gradual growth of maize plants. This has the impact of reducing the surface cover effect. While surface cover is a key factor in the period shortly after sowing, once the maize plants are more mature, they are able to intercept any rainfall with their leaves and limit the impact of sunlight. This reduces the effect of remaining crop residues in strip-till techniques.

Table 3. Moisture conditions on the tested variants in the second period

	Central Bohemia - 2023							South Bohemia - 2024					
	Soil moisture (%) - volumetric												
Date	Conventional cultivation		Strip-till: *Trifolium pratense*		Strip-till: *Lolium perenne*		Date	Conventional cultivation		Strip-till: *Vicia + Triticosecale*		Strip-till: *Secale + Vicia*	
	Average	SD	Average	SD	Average	SD		Average	SD	Average	SD	Average	SD
2.7	16.37	0.35	18.55	0.65	16.91	1.05	9.7	16.39	0.82	17.13	0.90	17.47	1.21
5.7	15.69	0.17	16.88	0.50	14.50	0.50	12.7	16.27	0.58	17.19	1.98	17.55	2.22
8.7	15.12	0.41	15.16	0.73	12.40	1.01	15.7	19.21	0.18	22.52	0.18	23.01	0.26
11.7	16.15	4.69	14.62	3.35	10.27	0.66	18.7	18.37	0.76	20.48	0.48	20.04	0.47
14.7	18.43	2.85	20.96	0.71	20.11	4.97	21.7	17.83	0.66	19.71	0.20	19.02	0.92
17.7	18.57	3.52	21.59	2.05	20.82	2.48	24.7	18.14	0.22	19.85	0.19	18.63	0.43
20.7	15.08	0.73	18.87	0.93	17.08	1.34	27.7	17.13	0.25	19.22	0.34	17.11	0.39
23.7	13.57	0.42	16.34	0.79	13.62	1.03	30.7	16.47	0.16	18.41	0.22	16.21	0.18
26.7	12.92	0.14	15.29	0.10	12.53	0.39	2.8	15.60	0.11	17.22	0.07	15.07	0.14
29.7	15.36	2.06	16.19	0.61	12.71	0.33	5.8	15.60	0.14	17.00	0.11	14.97	0.18
1.8	16.30	0.89	16.89	0.23	12.81	0.42	8.8	15.53	0.15	16.82	0.15	14.81	0.18
4.8	15.41	0.47	16.78	0.50	12.41	0.45	x	x	x	x	x	x	x
Average	15.75	1.39	17.34	0.93	14.68	1.22	Average	16.96	0.37	18.69	0.44	17.63	0.60

* SD - standard deviation

Figure 3 shows that when heavier rainfall occurs, strip-till can still slow surface runoff more effectively and promote infiltration of water into the soil. Higher water infiltration results in higher soil moisture. In 2023, this condition is well evident around the time of July 12th, when a higher rainfall event occurred. Shortly after this precipitation event, a significant increase in soil moisture occurred specifically for strip-till, while this increase was less noticeable for conventional cultivation.

A similar situation occurred in 2024, also in the first half of July. The main reason can again be observed in the plant residues on the surface. Although there is a gradual loss of these due to decomposition, they were still present on the soil surface during this period. By the end of the second period, this statement may no longer be true, as there are not many plant residues on the surface. This was confirmed on 26 July 2023, when a more significant rainfall event occurred, and soil moisture in conventional cultivation was higher than strip-till (*Lolium perenne* L.) but lower than strip-till (*Trifolium pratense* L.).

At the end of the second period, in both years, one strip-till technology showed higher average values than conventional cultivation, and the other strip-till technique showed lower values. This is due to the above findings, where both techniques (conventional cultivation, strip-till) become more and more similar as time passes, and different results may occur compared to the first period evaluated. On the basis of the results, hypothesis 2 cannot be confirmed as statistical significance was not confirmed in the second period.

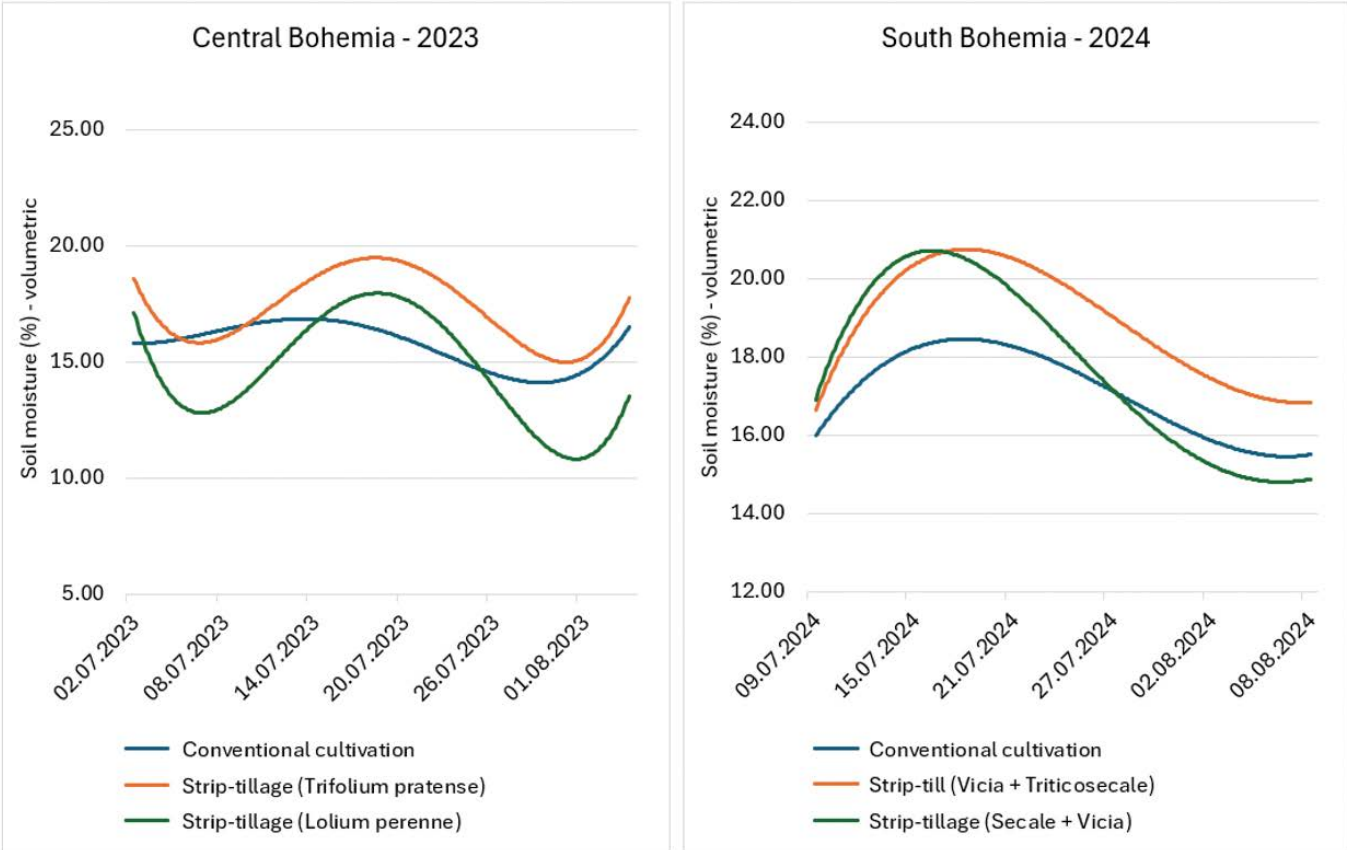

Figure 3. Trend of soil moisture in the experimental plots in the second period (polynomial trend line, fourth degree)

Maize - 3rd season (from the end of the 2nd season to harvest)

The Central Bohemia location received more significant precipitation in 2023 than the South Bohemia location in 2024, where soil moisture trends were downward (Table 4). There were some significant differences in the statistical evaluation (Table 5). In both years, the situation was essentially the same. Conventional cultivation was statistically identical with one strip-till technique each time (*Trifolium pratense* L. 2023; *Secale cereale* L. + *Vicia* L. 2024). A statistically significant difference was found for the other strip-till variant (*Lolium perenne* L. 2023; *Vicia* L. + *Triticosecale* (Witt.) Müntzing 2024). Generalizing the results only to conventional cultivation and strip-till (regardless of cover crop type), it can be concluded that these two techniques are identical during the full growth period of maize. A very important aspect of strip-till in this evaluation is the rate of decomposition of plant residues depending on the type of crop used. Similarly, the effect of weeding must be considered for both conventional cultivation and strip-till. These aspects must be considered individually as they can significantly affect the results in a given year. It may be the case that conventional cultivation achieves better results than strip-till in this period (Figure 4).

Soil temperature from TMS-4 sensors

Soil temperature is generally a more stable parameter. Therefore, one of the aims was to compare whether the soil temperature at 15 cm was statistically the same in both years. The results presented in Figure 5 show the temperature evolution over the growing seasons. Figure 5 shows the temperature changes over the growing seasons. From the results in Table 6, it is clear that the soil temperature trends are statistically significantly different in 2023 and 2024 (*P*=2.51E-09).

Table 4. Moisture conditions on the tested variants in the third period

Central Bohemia - 2023							South Bohemia - 2024						
Soil moisture (%) - volumetric													
Date	Conventional cultivation		Strip-till: *Trifolium pratense*		Strip-till: *Lolium perenne*		Date	Conventional cultivation		Strip-till: *Vicia + Triticosecale*		Strip-till: *Secale + Vicia*	
	Average	SD	Average	SD	Average	SD		Average	SD	Average	SD	Average	SD
7.8	22.23	2.69	21.46	1.61	15.11	0.70	11.8	15.54	0.21	16.73	0.30	14.85	0.23
10.8	24.24	2.04	23.40	0.88	16.14	0.43	14.8	15.12	0.14	15.96	0.11	14.45	0.14
13.8	18.44	1.30	22.10	0.43	14.20	0.75	17.8	14.61	0.16	15.21	0.12	14.04	0.15
16.8	14.88	0.61	19.60	0.92	12.08	0.58	20.8	14.70	0.13	15.28	0.11	14.12	0.18
19.8	13.09	0.52	17.06	0.73	10.40	0.54	23.8	14.78	0.16	15.34	0.08	14.29	0.14
22.8	11.87	0.36	15.04	0.57	8.92	0.51	26.8	14.59	0.20	15.11	0.15	14.01	0.26
25.8	11.11	0.26	13.53	0.36	7.62	0.35	29.8	14.74	0.16	15.18	0.11	14.22	0.16
28.8	18.46	6.83	16.84	2.95	9.22	1.68	1.9	14.44	0.17	14.87	0.11	13.94	0.19
31.8	25.13	0.35	21.16	0.26	11.77	0.23	4.9	14.20	0.14	14.68	0.10	13.83	0.17
3.9	23.19	0.73	20.81	0.52	11.30	0.39	7.9	13.86	0.15	14.44	0.06	13.67	0.28
6.9	21.64	0.42	19.61	0.24	10.52	0.41	10.9	13.73	0.16	14.39	0.10	13.83	0.12
Average	18.57	1.46	19.15	0.86	11.57	0.60	Average	14.57	0.16	15.20	0.12	14.11	0.18

* SD - standard deviation

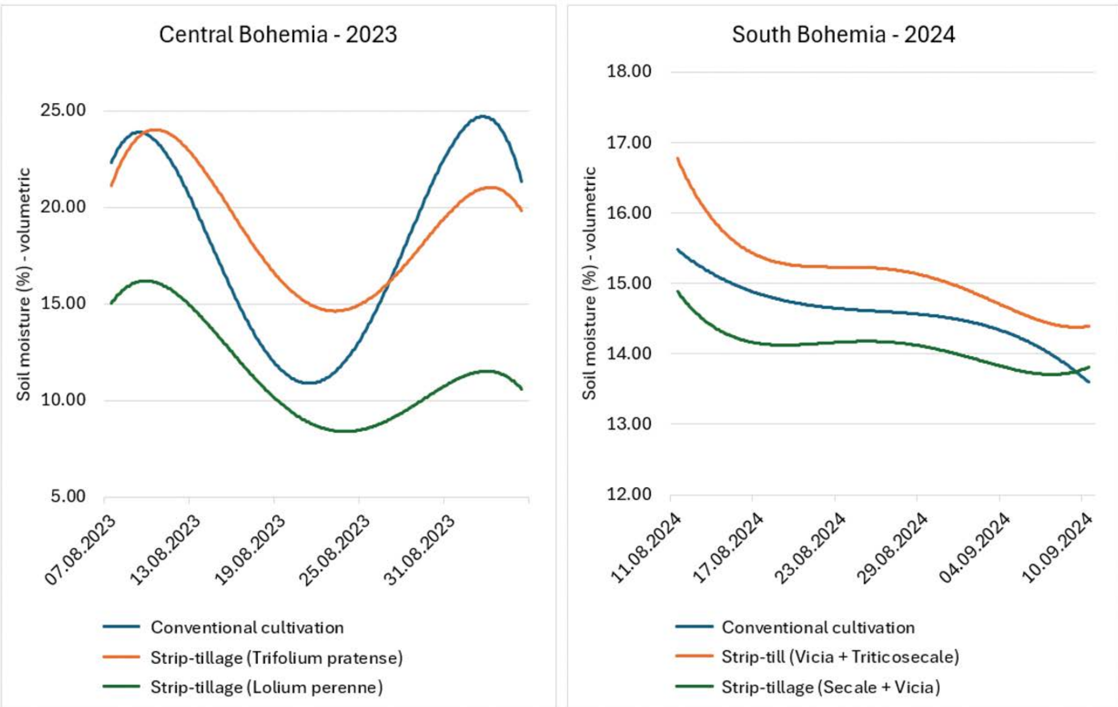

Figure 4. Trend of soil moisture in the experimental plots in the third period (polynomial trend line, fourth degree)

Table 5. Statistical evaluation of soil moisture in each period using One-Way ANOVA and Tukey HSD test (*P*=0.05)

Period	Central Bohemia - 2023			South Bohemia - 2024		
	Variants	One Way Anova	HSD Tukey Test	Variants	One Way Anova	HSD Tukey Test
First	x1-x2	1.43E-02	4.45E-02	x1-x4	8.61E-08	3.46E-04
	x1-x3		1.97E-02	x1-x5		4.84E-08
	x2-x3		9.36E-01	x4-x5		8.45E-03
Second	x1-x2	4.30E-02	2.74E-01	x1-x4	1.23E-01	1.06E-01
	x1-x3		5.53E-01	x1-x5		6.98E-01
	x2-x3		3.47E-02	x4-x5		4.12E-01
Third	x1-x2	6.30E-05	9.33E-01	x1-x4	1.70E-04	2.46E-02
	x1-x3		4.50E-04	x1-x5		1.19E-01
	x2-x3		1.70E-04	x4-x5		1.10E-04

* x1 – conventional cultivation; x2 strip-till (*Trifolium pratense*); x3 strip-till (*Lolium perenne*); x4 – strip-till (*Vicia + Triticosecale*); x5 – strip-till (*Secale + Vicia*)

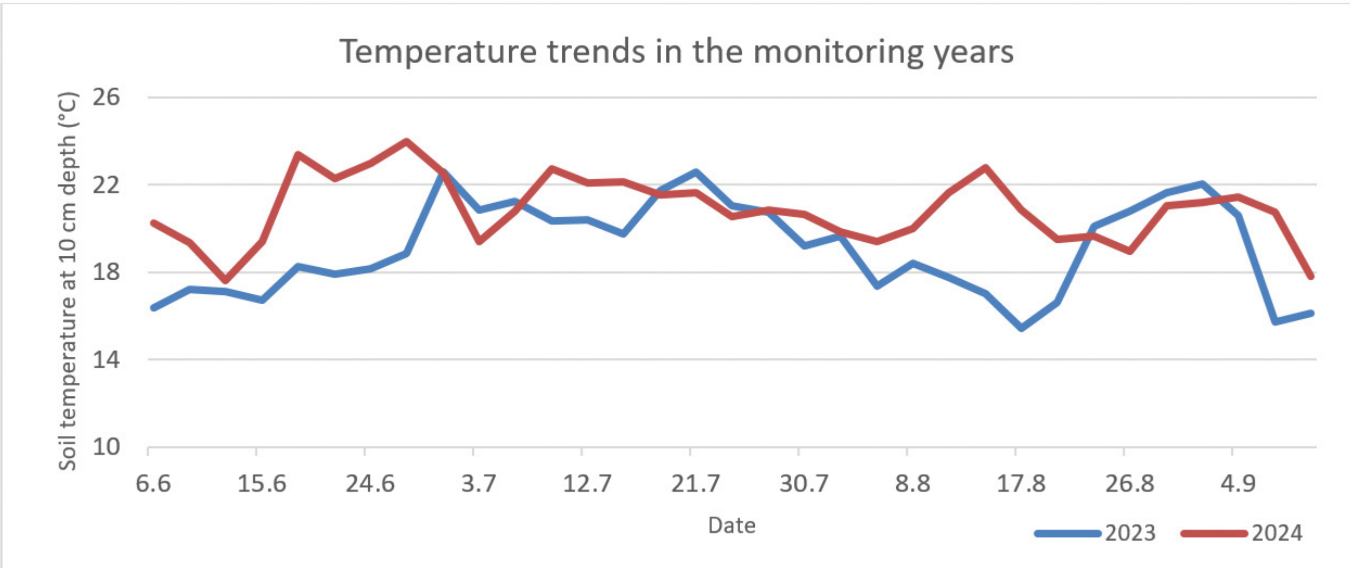

Figure 5. Evolution of soil temperature in the experimental plots in 2023 and 2024

The average soil temperature, regardless of the variant, was 19.19 °C in 2023 and 20.96 °C in 2024. This information is important for the interpretation of the soil moisture results, as two temperature-different years are being compared. Although the soil temperature was statistically different, the trend in soil moisture on the tested variants was essentially maintained in both years. This indicates that soil temperature did not affect the moisture trend.

In addition to the comparison of the two years, the soil temperature was further divided into three periods, as well as the moisture, in order to compare the temperature evolution of conventional cultivation and strip-till. The average results for each variant for the two years evaluated are shown in Table 7, and the statistical evaluation in Table 8. Potentially, the largest difference in soil temperature between the variants should have been in the first period, as was the case for soil moisture.

Table 6. Statistical evaluation of temperature in 2023 and 2024 using One-Way ANOVA and Tukey HSD test (*P*=0.05)

Parameter	2023	2024	One-Way ANOVA (Tukey HSD) *P* = 0.05
Average temperature (°C)	20.96	19.19	2.51E-09
Standard deviation (°C)	1.63	2.21	

Table 7. Average temperature values for each variant in 2023 and 2024

	Central Bohemia - 2023						South Bohemia - 2024					
	Temperature in °C											
Period	Conventional cultivation		Strip-till: *Trifolium pratense*		Strip-till: *Lolium perenne*		Conventional cultivation		Strip-till: *Vicia + Triticosecale*		Strip-till: *Secale + Vicia*	
	Average	SD	Average	SD	Average	SD	Average	SD	Average	SD	Average	SD
First	19.5	0.7	18.8	0.6	18.1	0.6	21.0	1.1	21.3	1.0	21.0	0.9
Second	20.3	0.7	19.3	0.6	19.2	0.6	20.9	0.7	20.9	0.6	21.3	0.6
Third	18.5	0.7	18.0	0.7	18.2	0.7	20.4	0.6	20.1	0.6	21.1	0.7

* SD - standard deviation

Table 8. Statistical evaluation of temperature at 3-day intervals in each period using One-Way ANOVA and Tukey HSD test (*P*=0.05)

Period	Central Bohemia - 2023			South Bohemia - 2024		
	Variants	One Way Anova	HSD Tukey Test	Variants	One Way Anova	HSD Tukey Test
First	x1-x2	2.81E-01	6.74E-01	x1-x4	8.96E-01	9.15E-01
	x1-x3		2.50E-01	x1-x5		1.00E+00
	x2-x3		7.23E-01	x4-x5		9.11E-01
Second	x1-x2	2.65E-01	3.78E-01	x1-x4	5.71E-01	9.90E-01
	x1-x3		2.96E-01	x1-x5		6.76E-01
	x2-x3		9.85E-01	x4-x5		5.91E-01
Third	x1-x2	2.65E-01	3.78E-01	x1-x4	5.71E-01	9.90E-01
	x1-x3		2.96E-01	x1-x5		6.76E-01
	x2-x3		9.85E-01	x4-x5		5.91E-01

* x1 – conventional cultivation; x2 strip-till (*Trifolium pratense*); x3 strip-till (*Lolium perenne*); x4 – strip-till (*Vicia + Triticosecale*); x5 – strip-till (*Secale + Vicia*)

This was partially fulfilled in 2023, when the average temperature was higher in the first period for conventional cultivation (Table 7). However, the differences between the variants were very small and, when the standard deviation was considered, there was an overlap of values, which had a major impact on the statistical evaluation, in which no statistical difference was confirmed. In 2024, the results for all variants show very similar values in all three periods. It is important to mention here again that this is the temperature at a depth of 15 cm, as some differences could be expected in the case of surface measurements due to the presence of plant residues. However, at 15 cm depth, their effect was not apparent, which means that hypothesis 3 was not confirmed

DISCUSSION

Copec et al. (2015) studied the effect of different tillage methods (conventional cultivation, conservation tillage, no-till) on soil water content and yields in maize and wheat cultivation in Croatia. For example, the authors report the highest soil water content during maize cultivation in the no-till variant at a depth of up to 20 cm (increased infiltration and reduced evaporation); the least soil water was found in conventional cultivation. The absence of tillage can lead to lower or higher crop yields (or no effect on yields) compared to conventional cultivation. For maize, Copec et al. (2015) report lower yields for the no-till compared to conventional cultivation, but only in some years. In contrast, Sun et al. (2024) report in an extensive review that yields can be comparable in some cases for conventional cultivation and soil conservation techniques. Wang et al. (2024) studied the effect of different strip-till strip widths when it is used in maize cultivation on the water content (and temperature) of the soil layer up to 20 cm soil depth (and other soil properties). The authors report the differences in water content (and changes in soil water content during and after rainfall) between the variants with different strip-tilled strip widths. Licht and Al-Kaisi (2005) studied the effect of tillage methods, namely conventional, strip-till and no-till, on the soil temperature pattern during selected days characterized by different weather conditions and soil volumetric moisture content. These authors reported that soil volumetric moisture at depths up to 120 cm was maximum for no-till and strip-till, but that the differences between the technologies studied were small.

Gałęzewski et al. (2023) also studied soil water content and soil temperature (at a depth of 5 to 15 cm) under conventional cultivation versus strip-till in winter barley. The authors reported higher soil water content for the strip-till only during part of the growing season (BBCH 87 versus BBCH 77); for both variants, soil water content was higher between rows compared to within rows. Jaskulski (2019) studied changes in soil water content when winter wheat, winter canola, and maize were grown using strip-till. The authors reported that during wheat cultivation, soil water content was higher between rows than in rows in the absence of rain for at least 14 days or at least 5 days after rain; in contrast, just after rain, soil water content was higher in rows.

For soil temperature monitoring, Wang et al. (2024), in their study on different strip widths for strip-till (maize), report differences between the variants with different strip widths treated to a depth of 20 cm (including the amplitude of daily soil temperature fluctuations and the time of occurrence of maximum and minimum temperatures) determined directly in and outside the cultivated strips. For soil temperature, they report the maximum differences between the variants during the first weeks after sowing, whereas before harvest, these differences were small.

However, Wang et al. (2024) assume that given soil temperature (or soil water content) results may not be evident under other climatic conditions. Gałęzewski et al. (2023) state lower temperatures (and amplitude of temperature fluctuations) in the case of strip-till in winter barley cultivation by an average of 0.64 °C (for both row and inter-row) for almost the entire growing season. Compared to conventional cultivation, strip-till heated and cooled the soil more slowly due to its higher water content. For conventional cultivation, soil temperature was slightly higher in the rows compared to between rows (and for strip-till, soil temperature was slightly higher between rows). Licht and Al-Kaisi (2005) reported the highest soil temperatures in the top 5 cm of soil for the conventional cultivation and the lowest for the no-till (comparing conventional cultivation, strip-till, and no-till - for maize); however, there were noticeable differences between techniques as the day progressed (and as weather conditions changed - clear sky, cloudy, rain).

CONCLUSION

Sufficient water in the soil is essential for plant growth. The results show that the strip-till technique contributes to a higher infiltration of water into the soil shortly after sowing of maize due to the higher surface roughness, and therefore to a higher moisture content. This is one of the reasons why strip-till is considered a highly effective soil conservation technique. In this context, the quality and type of crop residues in strip-till are very important, as this tends to influence the results considerably. Nevertheless, in all cases, a significantly higher soil moisture was confirmed in the first period (from sowing to one month after sowing), regardless of the quality of the crop in strip-till. The effect of plant residues on the soil surface decreases with time in strip-till. More than one month after sowing, the higher soil moisture may no longer be noticeable with this technique, as confirmed by the measured results. Due to the decomposition of crop residues and the growth of maize, the differences between the evaluated variants decreased. From the second period between the conventional cultivation and the strip-till, there was no longer a statistically significant difference in soil moisture at a depth of 15 cm.

In terms of temperature, the years evaluated were statistically different, but the effect of plant residues on soil moisture was maintained in the first period. No statistically significant differences were detected in the evaluation of temperature for the individual variants, which confirmed the fact that it is a more stable soil parameter than soil moisture, where more significant fluctuations were observed.

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REFERENCES

Blacklow, W. M. (1972) Influence of Temperature on Germination and Elongation of the Radicle and Shoot of Corn (*Zea mays* L.) 1. Crop Science, 12 (5), 647-650.

Brant, V., Zábranský, P., Škeříková, M., Pivec, J., Kroulík, M., Procházka, L. (2017) Effect of row width on splash erosion and throughfall in silage maize crops. Soil and Water Research, 12, 39–50. DOI: https://doi.org/10.17221/121/2015-SWR

Copec, K., Filipovic, D., Husnjak, S., Kovacev, I., Kosutic, S. (2015) Effects of tillage systems on soil water content and yield in maize and winter wheat production. Plant, Soil and Environment, 61, 213–219. DOI: https://doi.org/10.17221/156/2015-PSE

Faligowska, A., Kalembasa, S., Kalembasa, D., Panasiewicz, K., Szymańska, G., Ratajczak, K., Skrzypczak, G. (2022) The nitrogen fixation and yielding of pea in different soil tillage systems. Agronomy, 12 (2), 352. DOI: https://doi.org/10.3390/agronomy12020352

Gaile, Z. (2012) Maize (*Zea mays* L.) response to sowing timing under agro-climatic conditions of Latvia. Zemdirbyste, 99 (1), 31–40.

Gałęzewski, L., Jaskulska, I., Kotwica, K., Lewandowski, Ł. (2023) The dynamics of soil moisture and temperature–strip-till vs. plowing–a case study. Agronomy, 13 (1), 83. DOI: https://doi.org/10.3390/agronomy13010083

Heinze, J., Gensch, S., Weber, E., Joshi, J. (2017) Soil temperature modifies effects of soil biota on plant growth. Journal of Plant Ecology, 10 (5), 808-821.

Hůla, J., Kovaříček, P., Vlášková, M. (2019) Water infiltration into soil at strip tillage. Listy cukrovarnické a řepařské, 135 (3), 93–98.

Jaskulski, D. (2019) Spatial differentiation of soil moisture in strip-till one-pass technology. Acta Scientiarum Polonorum Agricultura, 18, 109–118.

Kopecký, M., Hederová, L., Macek, M., Klinerová, T., Wild, J. (2024) Forest plant indicator values for moisture reflect atmospheric vapour pressure deficit rather than soil water content. New Phytologist, 244 (5), 1801-1811.

Kabelka, D., Kincl, D., Vopravil, J., Vráblík, P. (2021) Impact of cover crops in inter-rows of hop gardens on reducing soil loss due to water erosion. Plant Soil and Environment, 67 (4), 230-235.

Kämpf, I., Hölzel, N., Störrle, M., Broll, G., Kiehl, K. (2016) Potential of temperate agricultural soils for carbon sequestration: A meta-analysis of land-use effects. Science of the Total Environment, 566–567, 428–435. DOI: https://doi.org/10.1016/j.scitotenv.2016.05.067

Kurtyka, R., Burdach, Z., Karcz, W. (2011) Temperature dependence of growth in maize seedlings and excised coleoptile segments. Polish Journal of Environmental Studies, 20 (5), 1221–1225.

Licht, M. A., Al-Kaisi, M. (2005) Strip-tillage effect on seedbed soil temperature and other soil physical properties. Soil and Tillage Research, 80, 233–249. DOI: https://doi.org/10.1016/j.still.2004.03.017

Maitah, M., Malec, K., Ge, Y., Gebeltová, Z., Smutka, L., Blažek, V., Pánková, L., Maitah, K., Mach, J. (2021) Assessment and prediction of maize production considering climate change by extreme learning machine in Czechia. Agronomy, 11 (11), 2344.
DOI: https://doi.org/10.3390/AGRONOMY11112344

Matus, A., Derksen, D. A., Walley, F. L., Loeppky, H. A., Van Kessel, C. (1997) The influence of tillage and crop rotation on nitrogen fixation in lentil and pea. Canadian Journal of Plant Science, 77 (2), 197–200. DOI: https://doi.org/10.4141/P96-078

Mhlanga, B., Chauhan, B. S., Thierfelder, C. (2016) Weed management in maize using crop competition: A review. Crop Protection, 88, 28-36.

Mohammed, S., Alsafadi, K., Enaruvbe, G. O., Bashir, B., Elbeltagi, A., Széles, A., Alsalman, A., Harsanyi, E. (2022) Assessing the impacts of agricultural drought (SPI/SPEI) on maize and wheat yields across Hungary. Scientific Reports, 12 (1), 8838.
DOI: https://doi.org/10.1038/s41598-022-12799-w

Nazari, M., Sadeghi, S. M. M., Van Stan, J. T., Chaichi, M. R. (2020) Rainfall interception and redistribution by maize farmland in central Iran. Journal of Hydrology: Regional Studies, 27.
DOI: https://doi.org/10.1016/j.ejrh.2019.100656

Nýč, M., Brant, V., Kroulík, M., Smutný, V., Kusá, H., Růžek, P., Zábranský, P., Neudert, L., Lukas, V. (2015) Technologické postupy využití strojů pro diferencované zpracování půdy a cílenou aplikaci hnojiv do půdy – certifikovaná metodika. Kurent, s. r. o.

Onwuka, B., Mang, B. J. A. P. A. R. (2018) Effects of soil temperature on some soil properties and plant growth. Adv. Plants Agric. Res, 8(1), 34-37.

Procházková, E., Kincl, D., Kabelka, D., Vopravil, J., Nerušil, P., Menšík, L., Barták, V. (2020) The impact of the conservation tillage" maize into grass cover" on reducing the soil loss due to erosion. Soil & Water Research, 15 (3), 158-165.

Różewicz, M. (2022) Review of current knowledge on strip-till cultivation and possibilities of its popularization in Poland. Polish Journal of Agronomy, 49, 20–30.

Santos, H. O. dos, Vasconcellos, R. C. C., Pauli, B. de, Pires, R. M. O., Pereira, E. M., Tirelli, G. V., Pinho, É. V. R. V. (2018) Effect of soil temperature in the emergence of maize seeds. Journal of Agricultural Science, 11 (1), 479. DOI: https://doi.org/10.5539/jas.v11n1p479

Singh, M., Banotra, M., Sharma, B.C., Sharma, C., Sharma, R. (2024) Yield prediction in maize (*Zea mays*) using weather parameters *Zea mays* under subtropical and intermediate regions of North-Western Himalayas. Indian Journal of Ecology, 51 (1), 187-190.
DOI: https://doi.org/10.55362/ije/2024/4214

Stipešević, B., Kladivko, E. J. (2005) Effects of winter wheat cover crop desiccation times on soil moisture, temperature and early maize growth. Plant, Soil and Environment, 51(6), 255–261.
DOI: https://doi.org/10.17221/3583-pse

Sun, Z., Li, Z., Li, B., Sun, T., Wang, H. (2017) Factors influencing corn canopy throughfall at the row scale in northeast China. Agronomy Journal, 109 (4), 1591–1601.
DOI: https://doi.org/10.2134/agronj2016.02.0116

Sun, J., Niu, W., Du, Y., Ma, L., Huang, S., Mu, F., Zhang, Q, Li, G., Zhu, J., Siddique, K. H. M. (2024) Regionally adapted conservation tillage reduces the risk of crop yield losses: A global meta-analysis. Soil and Tillage Research, 244, 106265.

Torabian, S., Farhangi-Abriz, S., Denton, M. D. (2019) Do tillage systems influence nitrogen fixation in legumes? A review. Soil and Tillage Research, 185, 113–121.
DOI: https://doi.org/10.1016/j.still.2018.09.006

Vâtcă, S. D., Stoian, V. A., Man, T. C., Horvath, C., Vidican, R., Gâdea, Ștefania, Vâtcă, A., Rotaru, A., Vârban, R., Cristina, M., Stoian, V. (2021) Agrometeorological requirements of maize crop phenology for sustainable cropping—A historical review for Romania. Sustainability (Switzerland), 13 (14), 7719.
DOI: https://doi.org/10.3390/su13147719

Vopravil, J., Formánek, P., Heěmanovská, D., Khel, T., Jacko, K. (2021) The impact of agricultural land afforestation on soil water content in Central Bohemia. Journal of Forest Science, 67 (11), 512-521.

Wild, J., Kopecký, M., Macek, M., Šanda, M., Jankovec, J., Haase, T. (2019) Climate at ecologically relevant scales: A new temperature and soil moisture logger for long-term microclimate measurement. Agricultural and Forest Meteorology, 268, 40-47.

WRB (2022) World Reference Base for Soil Resources. International soil classification system for naming soils and creating legends for soil maps. 4th edition. International Union of Soil Sciences (IUSS), Vienna, Austria.

Wang, C., Ai, S., Chen, Q., Li, J., Ding, J., Yang, F. (2024) Effect of strip tillage widths on soil moisture, soil temperature and soil structure in northeast China. Frontiers in Environmental Science, 12, 1404971.

Zábranský, P., Brant, V., Pivec, J., Gemerlová, M., Kroulík, M. (2013) Vliv struktury porostů kukuřice seté na distribuci srážek. Vliv abiotických a biotických stresorů na vlastnosti rostlin – Praha, 13 – 14. 2. 2013. Česká zemědělská univerzita v Praze, pp. 310 – 313.