The effect of soil conservation tillage on soil moisture dynamics under single cropping and crop rotation

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ABSTRACT

During 1993–1995 the effect of conventional tillage, reduced till, mulch till and no-till technology on soil moisture dynamics has been studied in field experiment on Haplic chernozems near Piešťany. The tillage treatments were evaluated under a single cropping of maize and spring barley – common peas – winter wheat crop rotation. Soil samples for gravimetric determination of moisture content were collected from six layers up to 0.8 m, three times per year (April–July). The soil moisture was highly significantly influenced in order of importance by date of sampling, year, growing crops, tillage treatments, soil layer and by interactions year × crops, year × date of sampling, crops × date of sampling, tillage × date of sampling, year × tillage, date of sampling × layer and significant influences by interactions, tillage × crops. The soil under conventional tillage had significantly higher moisture content than tested reduced till, mulch till and no-till treatments. The significant influence of maize stand on better soil humidity condition (16.35%) in comparison to crops grown in a crop rotation (in average 14.10%) has been ascertained.

Keywords: tillage; soil moisture dynamics; crop rotation; maize; spring barley; common peas; winter wheat

A major objective of soil- and water-management systems is to encourage water infiltration rather than runoff. This may be achieved by enhancing soil surface storage and improving the soils physical and hydro-physical properties (Brady and Weil 1999). The change of physical condition immediately influence not only water regime but also aeration, biological and temperature status. Conservation tillage systems offer a possibility to cover more than 30% of the soil surface by plant residues (Miština et al. 1993). This natural mulch reduces runoff, increases infiltration rate and decreases the evaporation of the soils water (Arshad et al. 1999, Rasmussen 1999).

Good soil water storage depends not only upon tillage management but also upon the forecrop. The least soil storage water was left by alfalfa, sugar beet and in a single cropping of maize. The biggest deficit of water was ascertained after alfalfa and the least after growing of peas.

The investigation of different tillage treatments and crop rotation on water balance was reported by several authors such as Procházková (1986), Kováč and Žák 1999, and others. The influence of crop rotation on water balance is revealed predominantly in warmer and semi-arid (non irrigated) areas with a deep water table level (Fulajtár 1986). The identification of alternative tillage practices requires field studies of crop responses to provide appropriate information (Reeder 2000).

The aim of this paper was to evaluate the combined effects of different soil tillage (conventional, reduced tillage, mulch tillage, no-tillage system) and cropping system (single cropping, three year crop rotation) on the timing and profile of soil moisture dynamics.

MATERIAL AND METHODS

A field stationary experiment was carried out during 1993–1995 at the Research Farm Borovce, Research Institute of Crop Production, Piešťany, Slovakia. The long-term average annual temperature of the site is 9.2°C and 15.5°C during the vegetation period. The average rainfall is 595 mm, including 358 mm during the vegetation period. The soil is classified as a medium-heavy (loamy, ČMm) Haplic Chernozems formed on alluvial deposits.

The bulk density (before the foundation of the experiment) of topsoil was 1.49 t/m^3. The chemical properties are characterised by pH 6.9–7.1, with a good storage of available potassium (116–140 mg/kg according Schachtschabel) and a medium content of phosphorus (35–42 mg/kg according Egner). The rate of maximum capillary capacity and the retentive capacity (Table 1) indicated the high retentive capability of water and a good wilting percentage which conditioned a high

Table 1. Soil properties (%), before establishment of experiment

Layers (m)	C_{ox}	P	MCC	MRC	WP
0.10–0.15	1.41	44.03	36.06	33.33	15.10
0.28–0.33	1.07	44.19	32.55	30.18	14.75
0.40–0.45	0.61	48.00	34.50	31.49	12.88
0.60–0.65	0.51	50.83	34.74	31.27	11.87
0.90–0.95	0.38	50.79	35.71	32.08	9.31

C_{ox} – organic carbon content, P – total porosity, MCC – maximum capillary capacity, MRC – maximum retentive capacity, WP – wilting percentage

use of soil water. The water table is 18–20 m deep. The strip-plot design with four tillage treatments in four replications and two cropping systems: a single cropping of maize (*Zea mays* L.) and crop sequences of spring barley (*Hordeum vulgare* L.) – common peas (*Pisum sativum* L.) – winter wheat (*Triticum aestivum* L.) was established.

The tillage treatments were evaluated under single a cropping of maize for grain and spring barley (1993) – common peas (1994) – winter wheat (1995) rotation.

The tillage treatments were as follows:

O1 – conventional tillage, stubble ploughing (after winter wheat and peas), mouldboard ploughing to

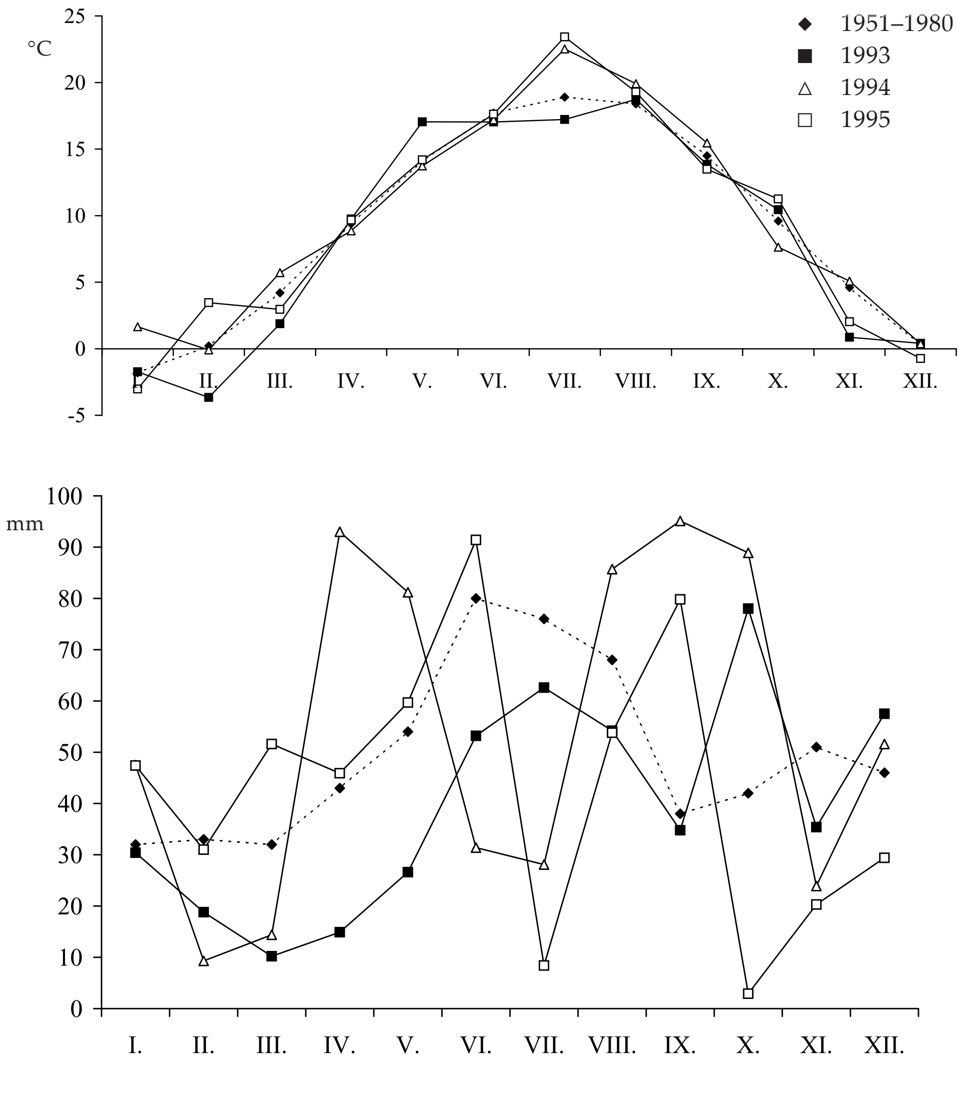

Figure 1. Weather conditions

the depth of 0.28–0.30 m (maize) and 0.20–0.22 m (other crops). For the seedbed preparation a disc tiller was used.

O2 – reduced tillage, shallow loosening by the stubble tiller Lemken-Smaragd 90/380 to the depth 0.08–0.10 m (spring barley and common peas); deep loosening by the loosener Amazone TL 301 to the depth 0.28–0.30 m (maize) were used. The seedbed preparation was made by a rotary tiller Amazone KG equipped with a press wheel used in a single operation (joined) with a drill machine Amazone D8/30 (maize by Kinze).

O3 – mulch tillage, crop residues were chopped with a combine harvester chopper and spread over the surface of the field as a mulch. The basic cultivation was made by the loosener Amazone TL301 to the depth of 0.08 m; maize was sown by a Kinze 2000 sowing machine, and Moore All Till model 4 for the other crops. Before sowing, the systemic herbicide was used.

O4 – no-tillage, all the remaining crop residues which were chopped by harvester chopper on the surface, no-till drill Kinze 2000 were used for maize sowing, no-till drill Moore All Till model 8 for the other crops, systemic herbicide was used before sowing.

Soil moisture was determined gravimetrically, using a core sampler. Soil samples for moisture content determination were collected from each plot in all four replications, three times per year (April, May, June in 1993, May, June, July in 1994, 1995) from 0.05–0.10 m, 0.15–0.20 m, 0.25–0.30 m, 0.35–0.40 m, 0.45–0.60 m, 0.65–0.80 m layer. During the 10 day period, before the date of sampling, we noted precipitation only in the May sampling dates: 1993 – 5.1 mm (4 days before), 1994 – 9.4 mm (4 days before) and 1995 – 16 mm, 14 mm and 7.5 mm (2, 3 and 8 days before). The dates were subjected to an analysis of variance (software KANRO).

Table 2. The effect of tillage treatments, crops, date of sampling and layer on soil moisture

Factor		Soil moisture in % by weight			
		1993	1994	1995	1993–1995
Tillage	conventional O1	12.77 a	16.31 a	18.17 a	15.75 a
	reduced O2	13.58 b	15.08 b	17.08 b	15.24 b
	mulch O3	13.06 abc	15.28 b	15.89 c	14.74 c
	no-tillage O4	12.79 ac	15.39 b	17.2 b	15.10 bc
	LSD P < 0.05	0.75	0.76	0.82	0.47
Crop	single cropping of maize	15.08 a	16.51 a	17.38 a	16.32 a
	crop rotation	11.02 b	14.52 b	16.75 b	14.10 b
	LSD P < 0.05	0.40	0.41	0.44	0.25
Date of sampling	1st sampling	17.61 a	18.01 a	20.74 a	18.79 a
	2nd sampling,	11.75 b	17.37 b	17.09 b	15.41 b
	3rd sampling	9.79 c	11.15 c	13.36 c	11.43 c
	LSD P < 0.05	0.59	0.60	0.64	0.37
Layer	0.05–0.10 m	12.57 a	15.18 a	16.52 a	14.76 a
	0.15–0.20 m	12.52 a	15.55 ab	16.75 a	14.94 ab
	0.25–0.30 m	13.26 ab	15.38 ab	16.95 a	15.20 abc
	0.35–0.40 m	13.13 ab	15.36 ab	17.38 a	15.29 abc
	0.45–0.60 m	13.69 b	15.20 a	17.53 a	15.48 bc
	0.65–0.80 m	13.14 ab	16.40 b	17.26 a	15.60 c
	LSD P < 0.05	1.03	1.05	1.13	0.64
Total average		13.05	15.51	17.06	15.21

Means followed by the same letter are not significantly different within columns (ANOVA, $P < 0.05$)

Table 3. Soil moisture in % by weight at individual technologies according to, sampling, crops and layers (average values for the years 1993–1995)

Factor		Tillage				*LSD* $P < 0.05$
		conventional O1	reduced O2	mulch O3	no-tillage O4	
Date of sampling	1st sampling	19.50 a	18.26 b	19.32 a	18.07 b	1.04
	2nd sampling	14.73 a	16.47 b	14.34 a	16.09 b	1.04
	3rd sampling	13.02 a	11.00 b	10.58 b	11.14 b	1.04
Crop	single cropping of maize	16.89 a	16.42 a	15.51 b	16.46 a	0.78
	crop rotation	14.61 a	14.07 ab	13.97 ab	13.74 b	0.78
Layer	0.05–0.10 m	15.36 a	14.54 a	14.60 a	14.53 a	1.65
	0.15–0.20 m	15.55 a	14.96 a	14.73 a	14.53 a	1.65
	0.25–0.30 m	15.54 a	15.37 a	14.59 a	15.29 a	1.65
	0.35–0.40 m	16.01 a	15.17 ab	14.28 b	15.69 ab	1.65
	0.45–0.60 m	16.25 a	15.79 ab	14.54 b	15.32 ab	1.65
	0.65–0.80 m	15.79 a	15.64 a	15.73 a	15.23 a	1.65

Means followed by the same letter are not significantly different within lines (ANOVA, $P < 0.05$)

RESULTS AND DISCUSSION

The long-term average precipitation of this site is 595 mm for year. Distribution of precipitation varied between cropping seasons and there was also a substantial difference (177 mm) between the wettest (1994) and driest (1993) evaluated years (Figure 1). In 1993, there was a very dry period during March–May. In 1994, the rainfall was over the long-term average, exceptionally large precipi-

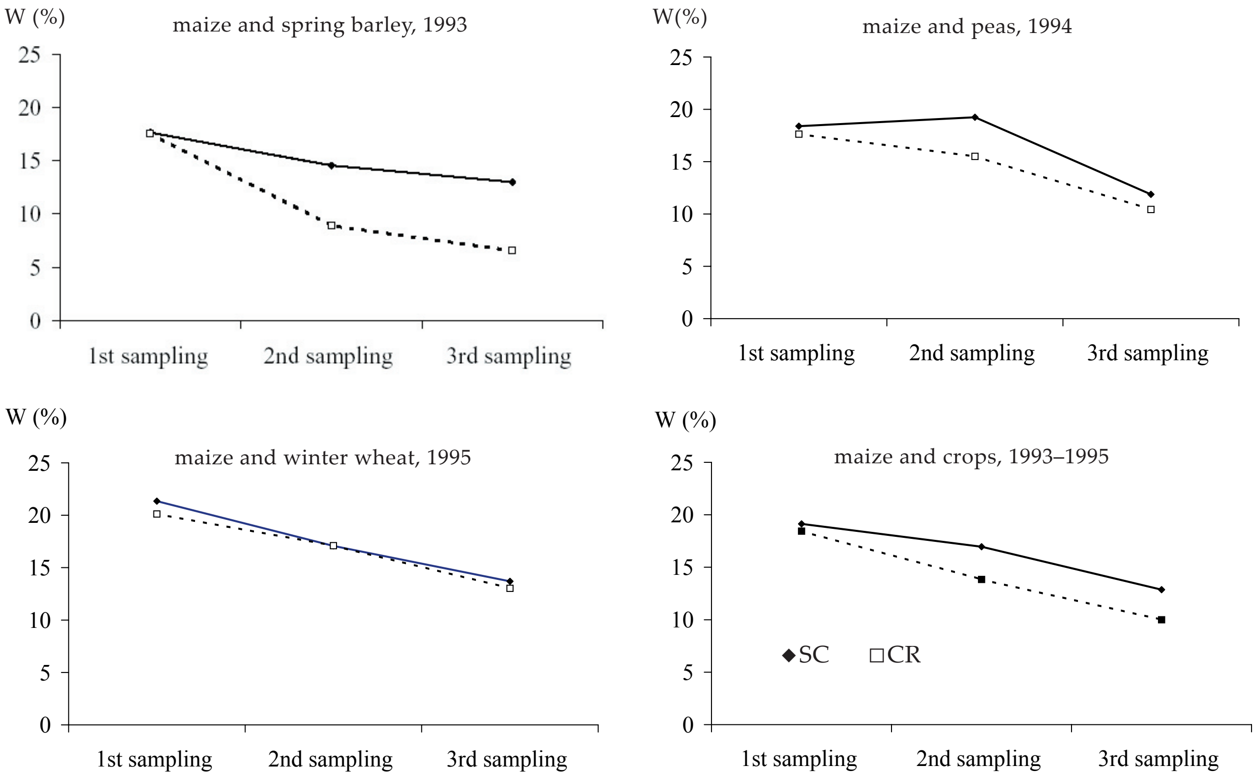

Figure 2. Soil moisture dynamics under single cropping of maize and spring barley, common peas and winter wheat in crop rotation at different sampling dates during 1993–1995

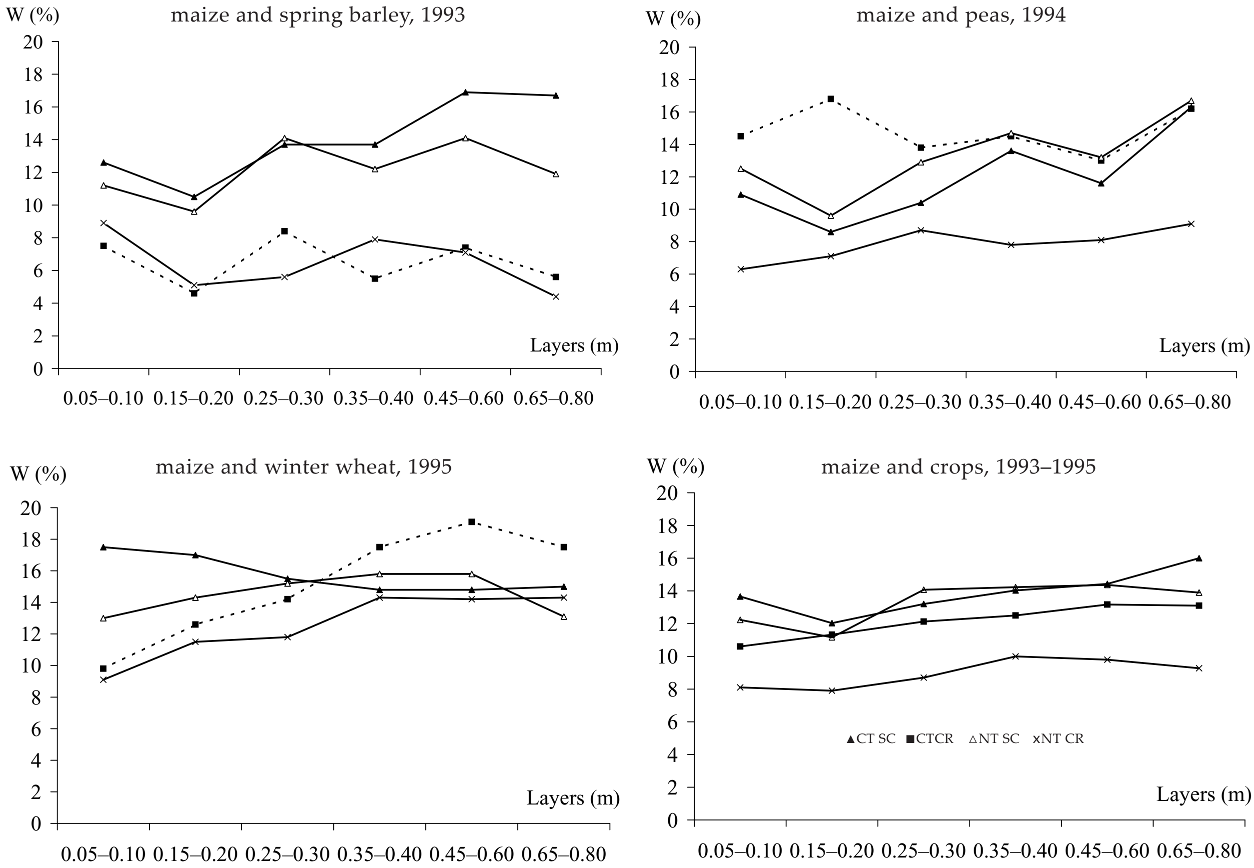

Figure 3. Soil moisture profile (W%) under single cropping of maize and spring barley, common peas and winter wheat in crop rotation under conventional tillage (CT) and no till (NT), 3rd sampling 1993–1995

tation occurred early in the season (April 93.0 mm, May 81.2 mm). The high amount of precipitation in June (91.4 mm) and extremely low in July (7.4 mm) we noted in 1995. The total sum of precipitation of the evaluated years was 476 mm, 653 mm, and 522 mm. The temperature conditions of the cropping season were very similar in 1994, 1995. The driest year 1993 was also characterised by higher temperatures in May (17.05°C) and colder in July (17.22°C).

During 1993–1995 the soil moisture was highly significantly influenced ($P < 0.01$) in order of importance by the date of sampling, weather condition of the evaluated years, crops grown, tillage treatments and soil layer and interactions year × crops, year × date of sampling, crops × date of sampling, tillage × date of sampling, year × tillage, date of sampling × layer and significantly influenced ($P < 0.05$) by tillage × crops.

The average moisture of the soil samples in 1993 (13.05%) was significantly less (*LSD* 5% – 0.37) than in the years 1994 (15.51%) and 1995 (17.06%) and a significant difference between the average soil moisture in 1994 and 1995 years was also noted (Table 2). Soil moisture dynamics is related not only to the total amount of precipitation but also with its distribution and evapotranspiration intensity. The highest moisture percentage in soil samples was from the first sampling (Table 2). The significant decrease in soil moisture between each date of sampling has been noted. In dry weather conditions (year 1993), the highest percentage of moisture was conserved by reduced tillage (13.58%), whereas the significantly lower (12.77%) moisture was conserved by conventional tillage and no tillage technology (12.79%). In the years 1994–1995, the highest content of moisture was noted on conventional treatments. In the year 1994, soil moisture content by conventional tillage (16.31%) was significantly higher with comparison to other testing tillage technologies. No significant differences of soil moisture between reduced, mulch tillage and no-tillage treatments have been noted. Next year 1995, the same benefit of conventional tillage on soil moisture balance has been statistically confirmed (18.17%) with comparison to reduced tillage (17.08%), mulch tillage (15.89%) and no-tillage (17.12%). Significant differences between mulch tillage on the one hand and reduced tillage and no-tillage on the other hand have been also noted. During the three-year trial, the soil had tendency to conserve significantly more moisture by conventional tillage (15.75%), significantly less moisture was available on mulch till treatments (14.74%). In spite of ascertained significant differences of soil moisture between tested tillage treatments, it represents a relatively small amount of soil water content (up to 2.28 percentage of moisture in 1995). Suškevič and Odložilík (1989) also ascertained small differences of soil moisture in soil with different tillage technology during a trial lasting 13 years. Many authors (Procházková 1986, Lacko-Bartošová 1992, Miština et al. 1993, Aura 1999) indicated a better soil water balance by conservation tillage than by a conventional one. According to our results on Haplic chernozems, conventional tillage conserved more soil moisture than all tested conservation tillage (mulch till, reduced till and no-till treatment). Also Matula (2003) according to a three-year trial gave the conclusion, that reduced till and no-till show a significant decrease in the infiltration rate on Orthic luvisol.

The date of soil moisture as affected by the date of sampling, cropping system and layer in different evaluated tillage technologies are presented in Table 3. In the first spring sampling the highest soil moisture was noted on conventional tillage treatments (19.50%) and mulch tillage treatments (19.32%). Significantly less moisture content was on reduced tillage (18.26%) and no-tillage (18.07%) treatments. In the second date of sampling (May–June) there was inversed soil moisture condition. The significantly better soil moisture conditions have been noted on reduced (16.47%) and no-tillage (16.09%) treatments. In the third date of sampling (June–July) the significantly higher amount of moisture was conserved by using conventional tillage technology (13.02%) in comparison to all alternative practices (10.58–11.14%). The date of sampling influenced the soil moisture markedly more than the tested tillage treatments. The same results were also noted by Pabin and Runowska-Hryńczuk (1998) in field trials lasting several years. They observed that soil moisture was more influenced by weather condition than tillage technology.

The advantages of tillage options may include increased crop establishment, improved infiltration and reduced runoff, the principles behind the tillage are also to increase soil porosity and to manipulate surface roughness to improve water intake (Cogle et al. 1997).

The data of soil moisture presented in Table 2 confirming a significant influence of maize canopy on better soil water balance with comparison to spring barley, common peas and winter wheat in each evaluated year. The highest difference in soil moisture (4.06%) has been noted between soil from maize growing treatments and spring barley in the dry year of 1993. The differences among soil moisture under different crops according to the date of sampling indicated in Figure 2.

Significant interactions (Table 3) between the growing of crops and tillage treatments on soil humidity have been noted during each year of the trials. The significantly higher soil moisture was conserved by maize grown under conventional tillage (16.89%), reduced tillage (16.42%), no-tillage (16.46%) with comparison to mulch tillage 15.51%. The interaction of crops grown in rotation (spring barley – common peas – winter wheat) with tillage treatments also revealed a significant difference in soil moisture content between conventional (14.61%) and no-tillage treatment (13.74%).

The different influences of conventional tillage and no till technology on soil profile moisture are clearer in the third sampling (Figure 3). Conventional tillage treatment with interaction of crops created the better soil moisture condition after a cropping of common peas (1994) and winter wheat (1995) with comparison to no till technology.

According to the date of soil moisture profile (1993–1995), the driest soil condition was noted in surface layer with a tendency to increase soil moisture towards the deeper layers (Table 2). We noted a statistical soil moisture difference (Table 3) in two layers 0.35–0.40 m and 0.45–0.60 m influenced by conventional tillage (16.01–16.25%) and mulch (14.28–14.54%).

On the basis of this study we suggest that improving the rate of infiltration has a bigger benefit and influence on soil moisture balance than a reduction of soil moisture loses due to mulch treatment or no-tillage. The results support the need to look for new technological procedures for maintaining the maximum soil moisture, which is dependent on atmospheric precipitation.

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ABSTRAKT

Vliv půdoochranného zpracování půdy na změny půdní vlhkosti v monokultuře kukuřice a v osevním postupu

V polním stacionárním pokusu v Borovcích u Piešťan byl v letech 1993–1995 sledován vliv konvenční, redukované, mulčovací a bezorebné technologie na dynamiku půdní vlhkosti na degradované černozemi na spraši, a to při pěstování monokultury kukuřice a v osevním postupu plodin: ječmen – hrách – ozimá pšenice. Půdní vzorky na gravimetrické hodnocení půdní vlhkosti byly odebrány třikrát ročně (duben–červenec) ze šesti půdních vrstev do hloubky 0,8 m. Půdní vlhkost byla vysoce průkazně ovlivněna (řazeno podle významu) datem odběru, počasím v jednotlivých ročnících, pěstovanou plodinou, zpracováním půdy a odběrnými vrstvami půdy, dále interakcemi ročník × plodina, ročník × datum odběru, plodina × datum odběru, zpracování půdy × datum odběru, ročník × zpracování půdy, datum odběru × odběrná vrstva, resp. průkazně ovlivněna interakcí zpracování půdy × plodina. Vyšší obsah vlhkosti půdy byl zaznamenán při konvenčním zpracování půdy ve srovnání s půdoochrannými technologiemi (redukovaná, mulčovací a bezorebná). Byl zjištěn vyšší obsah vlhkosti půdy v porostu kukuřice (16,35 %) v době odběru v porovnání s osevním postupem (14,10 %, ječmen – hrách setý – ozimá pšenice).

Klíčová slova: zpracování půdy; dynamika půdní vlhkosti; střídání plodin; kukuřice; jarní ječmen; hrách; ozimá pšenice

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