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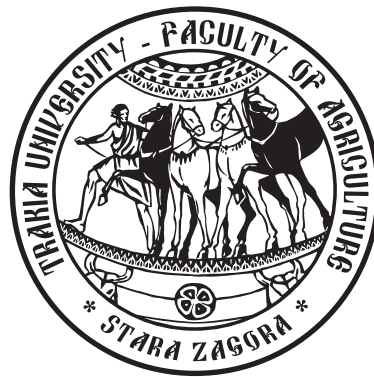
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Variation of capillary rise of water in the slightly leached chernozem soil of Dobrudzha region under the effect of long-term use of some soil tillage practices

P. Yankov*

Dobrudzha Agricultural Institute, 9520 General Toshevo, Bulgaria

Abstract. The capillary water is of major importance for the growth, development and productivity of plants. The use of different ways of soil tillage affects the natural position and entity of the soil layer, which, on its side, causes variations in the capillary rise of the water. The investigation on the variation of the capillary rise of water in the slightly leached chernozems in Dobrudzha region under the effect of the long-term application of some soil tillage practices was carried out during 2008 – 2010 in the trial field of Dobrudzha Agricultural Institute. Twenty-four soil tillage systems based on different soil tillage tools and operations were tested in a stationary field trial. In this analysis the following variants of main soil tillage were used: plowing at 24–26 cm (check); cutting at 24–26 cm; double cutting at 10–12 cm; direct sowing – pre-sowing treatment of the area with total herbicide. The reading of the capillary rise of water in undisturbed soil condition in the 0–10, 10–20 and 20–30 cm layers was done under laboratory conditions. Total porosity was determined by the values of bulk density and relative weight every 10 cm to depth of 30 cm. The capillary rise of water in the soils with minimal and no tillage was higher in comparison to the soils subjected to intensive tillage. The independent application of plowing reduced the capillary rise of water in the slightly leached chernozem soils. The highest weight coefficients with regard to capillary rise of water were determined in the 10–20 and 20–30 cm layers. In these layers after minimal and no tillage the system of capillary pores and the network of inter-aggregate cavities formed by the roots of the plants remained intact in soil and hence the capillary rise of water was higher. After plowing the large-sized structural soil units along the entire profile of the cultivated layer increased the cavities of non-capillary origin.

Keywords: main soil tillage, capillary rise of water, rate of capillary rise of water

Introduction

Capillary water is of primary importance for the growth, development and productivity of the plants. It is retained and moves under the effect of meniscus forces. The capillary phenomena in soil are determined by the available system of capillary pores and depend to a large extent on the porosity of soil (Penkov, 1986). The use of various ways of soil tillage affects the natural position and the intactness of the soil layer, which, on its hand, causes changes in the capillary rise of water. The height of capillary rise is reversely proportional to the diameter of the capillaries, i.e. the narrower the capillaries, the higher the rise of the water.

When investigating the effect of plowing and no-tillage on the hydraulic properties of soil, Dunn and Phillips (1990) have established that the movement of water inside the pores of different sizes has higher values after direct sowing in comparison to plowing. Bhattacharyya et al. (2006) point out that minimal tillage preserves moisture more efficiently in comparison to traditional plowing due to the greater number of fine pores which remain after this type of cultivation. In their study on the effect of various ways of soil tillage on the hydraulic properties and macro porosity of loamy and sandy-loamy soils, Buczek et al. (2006) made the conclusion that the hydraulic conductivity is predominantly influenced by the soil structure.

According to Miglierina et al. (2000) the medium-sized pores are also affected by the amount of plant residues after harvesting of the field crops and the content of organic substance in soil. In laboratory analyses Gordienko and Kostogryz (1991) have established that by increasing bulk density of chernozem soil from 0.90 to 1.15 g/cm³, the rate of capillary rise of water also increased. With the further increase of bulk density the capillary rise decreased.

The aim of this investigation was to follow the changes in the capillary rise of water in the slightly leached chernozem soils of Dobrudzha region under the effect of the long-term use of some types of soil tillage.

Material and methods

The effect of various soil tillage systems on the physical and agro-chemical characteristics of the slightly leached chernozem (Haplic Chernozem, FAO, 2002) is being investigated in a stationary field trial at Dobrudzha Agricultural Institute since 1987. The following field crops are grown in six-field crop rotation: wheat, grain maize, bean and sunflower.

This investigation was carried out during 2008 – 2010. The reading of capillary rise of water in undisturbed soil in the 0–10, 10–20 and 20–30 cm layers was done under laboratory conditions. Total porosity was determined by the values of bulk density and relative weight every 10 cm to depth of 30 cm.

The samples for laboratory analyses were taken from the following variants of main soil tillage:

- Plowing at 24–26 cm, autumn disking and double spring cultivation (check variant);
- Cutting at 24–26 cm, autumn disking and double spring cultivation;
- Double disking at depth 10–12 cm accompanied by autumn disking and double spring cultivation;
- Direct sowing with pre-sowing treatment of the areas with total herbicides.

The statistical processing of data was done with the help of SPSS 16.0 and Statistica 7.0.

* e-mail: p_s_yankov@abv.bg

Results and discussion

The disturbance of the natural position and entity of the soil layer when applying tillage and leaving the soil layer undisturbed for a shorter or longer period of time cause changes in the system of capillary pores, which, on its hand, contribute to the rise of the water from the underlying to the upper soil horizons. The capillary rise of water as determined in undisturbed soil was the highest in the first ten minutes after no-tillage and disking (Figure 1). In this 10-minute period capillary rise was the lowest after annual plowing. After cutting without turning of the layer the capillary rise was within 2.6 cm. During the next ten minutes this tendency remained the same. On the 30th minute from the observation the capillary rise after plowing remained stable, while after all other types of tillage it increased. On the 60th minute it was the highest after direct sowing, followed by disking and cutting without turning of the soil layer. After constant plowing the rise was stable. In two hours and thirty minutes of the observation the capillary rise of water accelerated with higher rates after disking, and less after the other types of soil tillage. On the

fourth hour the rise was still the highest after constant direct sowing. According to Gordienko and Kostogryz (1990; 1991), the reason for this is the higher bulk density, as well as the undisturbed system of capillary pores and the network of inter-aggregate cavities formed by the roots of the plants in the uncultivated soil. Direct sowing is followed by minimal tillage, disking and cutting. This tendency remained the same for the next one hour and thirty minutes. After approximately 24 hours, the capillary rise of water was the highest after constant direct sowing, followed by minimal disking and tillage without turning the soil layer. The observed index was the lowest after constant plowing. The capillary rise decreased in parallel with the higher number and depth of the soil tillage operations.

The rate of capillary rise of water at the beginning of the observation was the highest after no-tillage and annual disking and reached up to 0.6 cm/min (Figure 2). After the other types of soil tillage it was within 0.4 – 0.5 cm/min. The rate of capillary rise decreased with time, maintaining for a certain period of time comparatively high values after all types of soil tillage, then gradually decreased toward zero. Total porosity is the highest in the three studied layers by the annual plowing (Figure 3). Values of this index

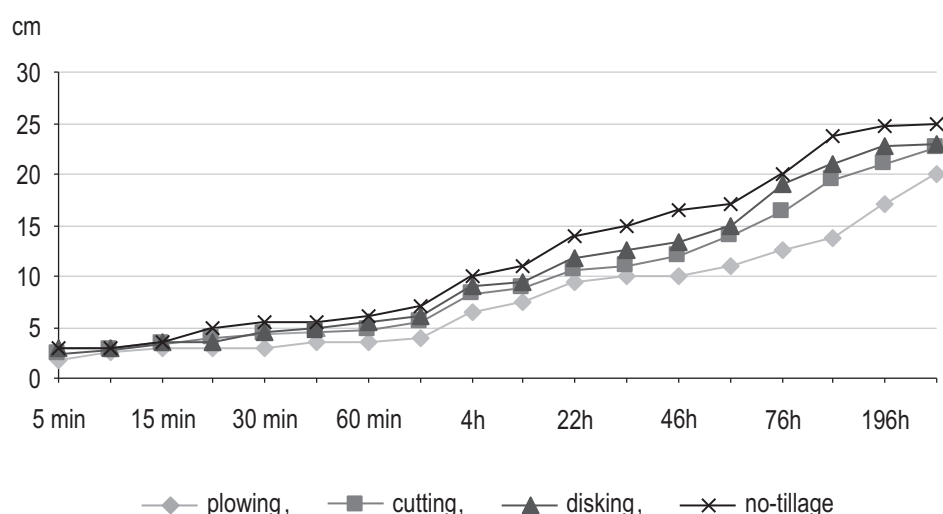


Figure 1. Capillary rise of water at different types of main soil tillage (cm)

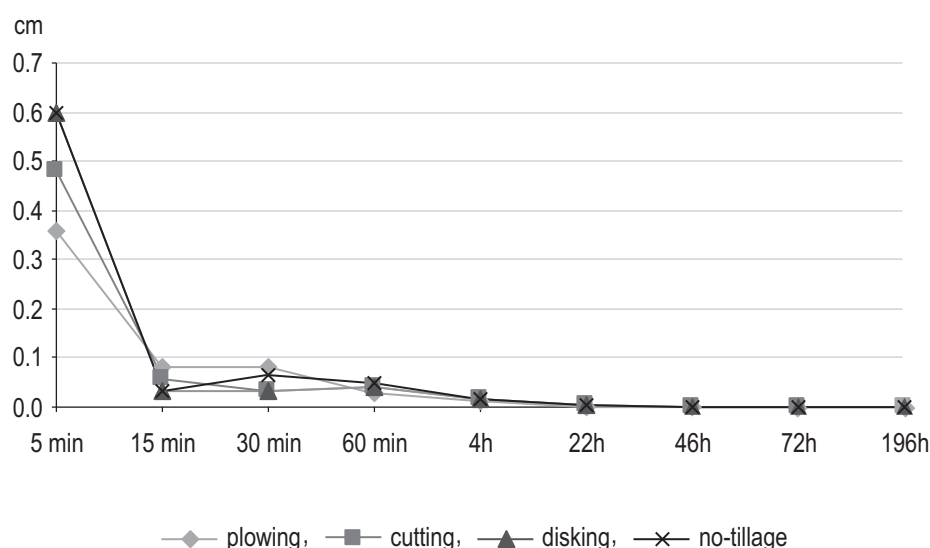


Figure 2. Rate of capillary rise of water at different types of main soil tillage (cm/min)

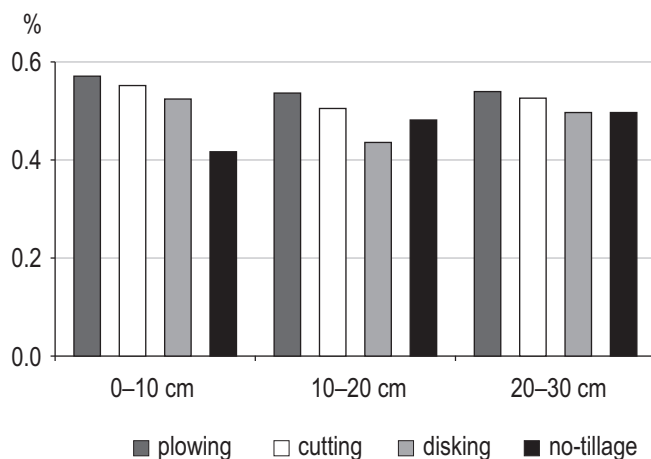


Figure 3. Total soil porosity after different types of main soil tillage (%)

decreased from minimal tillage to no-tillage soils.

The analysis of variances showed that the type of main soil tillage affected significantly the capillary rise of water (Table 1). The effect of the investigated factor on the studied character was significant at $P = 0.001$. However, the considered types of soil tillage had no significant effect on the rate of capillary rise of water. The probable reason for the lack of statistical significance of the effect of the investigated factor is that the capillary phenomena depend mainly on the type of porosity, which, on its side, depends on the mechanical composition and structure of the respective soil.

Table 1. Dispersion analysis on the effect of soil tillage on capillary rise of water and its rate

Index	df	F	Sig
Capillary rise of water			
Main soil tillage	3	10.168	.004
Rate of capillary rise			
Main soil tillage	3	1.063	.417

Table 2. Statistical groups of soil tillage types based on capillary rise of water and its rate (Duncan)

Main soil tillage	Capillary rise of water	Rate of capillary rise
	Groups (Values)	
Plowing	a (16.9)	a (0.17)
Cutting	b (21.0)	a (0.19)
Disking	b, c (22.3)	a (0.22)
No-tillage	c (24.8)	a (0.23)

Duncan's test proved that the independent use of plowing, which was divided into a separate group, decreased capillary rise of water in the slightly leached chernozems (Table 2). The effect of disking was similar to both cutting and no-tillage, since it belonged to the two groups, i.e. with regard to the considered character this minimal tillage can be successfully used as an alternative to the other two types of soil tillage. The test also revealed that the used types of soil tillage had the same effect on the rate of capillary rise of

Table 3. Regression models on the effect of total soil porosity on capillary rise of water after different soil tillage types

General regression model	$Y = a + b_1x_1 + b_2x_2 + b_3x_3^*$	R^2
Plowing	$Y = 0.726 + 0.153x_1 + 0.439x_2 + 0.890x_3$	0.99
Cutting	$Y = 1.295 + 0.204x_1 + 0.499x_2 + 0.955x_3$	0.99
Disking	$Y = 1.359 + 0.214x_1 + 0.519x_2 + 0.999x_3$	0.99
No-tillage	$Y = 0.345 + 0.268x_1 + 0.679x_2 + 1.097x_3$	0.99

* x_1 —total porosity of soil in the 0–10 cm layer;
 x_2 —total porosity of soil in the 10–20 cm layer;
 x_3 —total porosity of soil in the 20–30 cm layer.

water since they belonged to the same group.

To determine the relation between the capillary rise of water and soil porosity, regression analysis was applied. On the basis of the established model (Table 3) and the obtained experimental data, a graphic model was made of the respective equations (Figure 4). The respective weight coefficients were designated as follows: b_1 for total porosity of soil in the 0–10 cm layer (%), b_2 for total porosity of soil in the 10–20 cm layer (%), b_3 for total porosity of soil in the 20–30 cm layer (%). On the basis of the applied analysis it was found that among the investigated ways of main soil tillage the 20–30 cm layers had the highest weight coefficient, followed by the 10–20 cm layer.

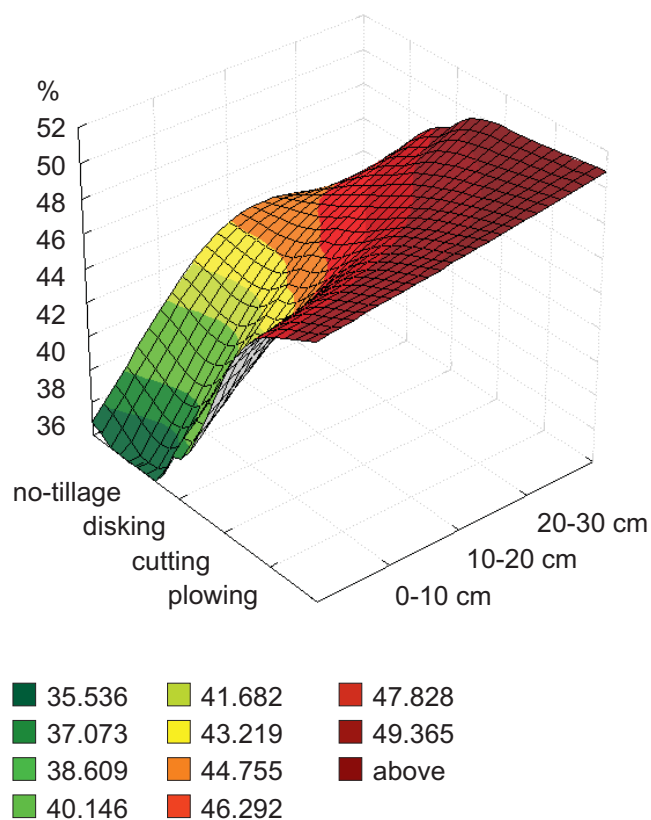


Figure 4. Graphic representation of the regression model of total soil porosity

The effect of the surface 0–10 cm layer was the lowest. The greater capillary rise of water at nil and minimal soil tillage was probably a result from the preserved system of capillary pores and the network

of inter-aggregate cavities formed by the plants' roots in the lower soil layers (10–20 and 20–30 cm). The lower capillary rise after plowing is related to the presence of large-sized structural soil units (Yankov, 2009), which cause deterioration of the texture along the entire depth profile of the cultivated soil layer; as a result the cavities of non-capillary origin increased. The coefficient of determination (R^2) for the respective equations of the linear regression after the different ways of soil tillage was 0.99, i.e. 99 % of the total variation of the resultant character can be explained by the factor-characters x_1 , x_2 and x_3 . This means that the total porosity in the 0–10, 10–20 and 20–30 cm layers significantly affected the capillary rise of water, i.e. its involvement in the constructed model was correct. The regression model allowed predicting the expected value of the specific character at given or expected values of the factor included in the model.

Conclusion

The capillary rise of water in soils with minimal and no-tillage was higher in comparison to the soils subjected to intensive tillage. The independent use of plowing decreased the capillary rise of water in the slightly leached chernozem soil.

The highest weight coefficients with regard to capillary rise of water were measured in the 10–20 and 20–30 cm layers. In these layers the soil with minimal and no-tillage preserved the system of capillary pores and the network of inter-aggregate cavities formed by the plants of the roots; this determined higher capillary rise of water. After plowing the presence of large-sized soil units along the entire cultivated profile lead to greater cavities of non-capillary origin.

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