TILLAGE EFFECTS ON SOIL STRUCTURE AND GRAIN YIELD OF MAIZE

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Abstract

To conserve soil fertility and prevent erosion, soil management regimes based on reduced tillage are highly suited to integrated production systems. Tillage effects on soil properties are usually site specific and depend upon the interaction of soil and climatic conditions, with soil and crop management practices. Field experiment were carried out in 2010-2012 at The Experimental Farm of the Agricultural University of Iasi, in the NE of Romania (47^{o}07’ N latitude, 27^{o}30’E longitude), on a cambic chernozem (SRTS-2003, or haplic chernozems WRB-SR, 1998), with a clay-loamy texture, 6.8 pH, 2.7% humus content and a medium level of fertilization. Long-term amount of precipitation at this site is 517.8 mm at an average air temperature of 9.4^{o}C. However, significant deviations from the long term average and temperature have been observed in recent years. The aim of this study is to evaluate the influence of tillage on soil structure and yield in the pedoclimatic conditions of the Moldavian Plain. The experimental soil tillage systems were as follows: V_1 – disc harrow , V_2 – paraplow, V_3 – chisel plow + rotary harrow, V_4 – plough at 20 cm and V_5 – plough at 30 cm (control variant). One of the main objectives for the soil tillage system was to create an optimal physicochemical state of the soil and to preserve this state over the whole vegetation period. Tillage systems significantly affected the maize yield. In Moldavian plain, in normally climatic conditions, the highest yield was recorded in the control treatment, plough at 30 cm and fertilized (9471 kg ha^{-1}), followed by conservation tillage – chisel (9054 kg ha^{-1}), but under water stress (2011-2012) we observed that the highest yields was at minimum tillage variants (chisel 3956 kg ha^{-1}, paraplow 3918 kg ha^{-1}).

Key words: conservative tillage, water stable aggregates, maize yield

Agricultural tillage practices have changed in Romania over decades. Soil conservation tillage, which intend to leave residues on the soil surface and may include reduced till (using disks or chisel plough, for example) or no-till, has become a popular practice recently in Romania.

Maize *(Zea mays L.)* is the most widely grown cereal in the world. It is the third most important and highest industrial valued cereal in the world after wheat and rice.

Tillage effects on soil properties are usually site specific and depend upon the interaction of soil and climatic conditions, with soil and crop management practices. Soil management regimes based on conservation tillage (no till and reduced tillage) are highly suited to integrated production systems in order to conserve soil fertility and prevent compaction and soil erosion. In the scope of the increasing concern for soil conservation, reduced tillage (RT) agriculture is growing more important in today’s agriculture in Europe.

Soil compaction in agriculture and is of growing concern. In order to maintain soil functions on a sustainable basis, strategies against further compaction are necessary. The governments and administrations in several countries recently started to react on the problem of soil compaction.

One of the most important negative consequences of modern agricultural production is probably the soil physical degradation resulting in erosion and soil compaction, which is attributed to deep and intensive tillage practices (Esteve et al., 2004; Bronick and Lal, 2005; Hamza and Anderson, 2005).

Compaction causes deterioration of soil physical properties, evidenced by increasing the bulk density, penetration resistance, high specific resistance to soil tillage operations and reduced porosity, soil structure stability, with direct impact on yield, fuel consumption and production costs (Jităreanu G., 2005, Rusu T. et al., 2006, Dexter A.R. 2004, Botta et al., 2007, 2008).

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MATERIAL AND METHODS

Field experiment were carried out since 2006, at The Experimental Farm of the Agricultural University of Iasi, in the NE of Romania (47°07' N latitude, 27°30'E longitude), on a cambic chernozem (SRTS-2003, or haplic chernozems WRB-SR, 1998), with a clay-loamy texture, 6.8 pH, 2.7% humus content and a medium level of fertilization, at an altitude of 125 m above sea level. Long-term amount of precipitation at this site is 517.8 mm at an average air temperature of 9.4°C. However, significant deviations from the long term average and temperature have been observed in recent years.

In this paper, we investigate the effect of conventional and conservation tillage intensity on water stable aggregates and maize yield on 2011 and 2012.

The experimental soil tillage systems were as follows: V_1 – disc harrow , V_2 – paraplow, V_3 – chisel plow + rotary harrow, V_4 – plough at 20 cm and V_5 – plough at 30 cm (control variant).

Treatments were arranged in a "split plot" design with three replicates. All subplots were separated by a 1-m buffer zone. Plots covered an area of 60 m^2 with a rotation of soybean - winter wheat – maize, with the current experiment in maize *(Zea Mays*). Pioneer PR38V91 (Pioneer Hi-Bred Seeds Romania) was planted at 60.000 seeds ha^{-1} and 0.7 m row spacing using a SPC 6 vacuum planter. Appropriate herbicides were used to control weeds as needed, and no disease or insect pest controls were utilized

The experimental maize plots were comprised of 2 rows, 10 m long, chosen from the middle and were harvested by a Wintersteiger Delta (Wintersteiger AG, Ried, Austria) combine, of 2 m work width. The yields and the quality characteristics of maize are reported at standardized moistures, 15.5%.

The grain yield components (1000 grain weight, test weight and seeds humidity) were determined by harvesting 30 plants, chosen randomly, from each plot.

The soil aggregate stability was assessed in each plot through the measurements of the water stability of 1–2 mm diameter aggregates ($WSA_{1–2mm}$), since such aggregates are sensitive to short term management of soils (Kemper and Rosenau, 1986). Replicate 4 g samples of soil aggregates per subplot were moistened with deionised water by capillary action for 10 min. Water stability of aggregates was then measured using the wet sieving method described by Kemper and Rosenau (1986). The initial and final weights of aggregates were corrected for the weight of coarse particles using the formula: final weight = initial weight _ coarse particles weight. Coarse particles were fraction of soil contained in the last sieve of the manipulation. The $WSA_{1–2mm}$ was calculated by weighting the mass of soil aggregates remaining after wet sieving and expressed as a percentage of the total mass of aggregates at the beginning of the experiment.

The ANOVA procedure was used to evaluate the significance for the split plot design in three replicates. Treatment means were separated by the least significance difference (LSD) test and all significant differences were reported at 5%, 1% and 0.1% levels.

RESULTS AND DISCUSSION

Cultivation can alter the physical, chemical, and biological properties of the soil, whereby plant growth, development, and yield are influenced. The aim of this study is to evaluate the influence of tillage on water stable aggregates (WSA) and yield. Wet aggregate stability suggests how well a soil can resist raindrop impact and water erosion.

Table 1

The influence of "tillage systems x nutrients level" interaction on yield

Treatment		Grain yield (kg ha^{-1})	
Tillage	Fertilization level	2011	2012
Disc harrow	$N_{80}P_{80}$	6287 $^{(ooo)}$	2580 ^{ns}
	N_0P_0	4955 $^{(ooo)}$	2056 $^{(oo)}$
Paraplow	$N_{80}P_{80}$	8535 $^{(ooo)}$	3918 $^{(xxx)}$
	N_0P_0	5987 $^{(ooo)}$	2578 ^{ns}
Chisel	$N_{80}P_{80}$	9054 $^{(o)}$	3956 $^{(xxx)}$
	N_0P_0	6322 $^{(ooo)}$	2786 $^{(xxx)}$
Plough 20 cm	$N_{80}P_{80}$	8387 $^{(ooo)}$	2639 $^{(x)}$
	N_0P_0	5544 $^{(ooo)}$	1986 $^{(ooo)}$
Plough 30 cm	$N_{80}P_{80}$ control	9471	2387
	N_0P_0	6587 $^{(ooo)}$	1723 $^{(ooo)}$
		DL5% = 322.4	DL5% = 194.2
		DL1% = 442.2	DL1% = 266.3
		DL0.1 = 601.9	DL0.1 = 362.4

Continuous ploughing at the same depth leads to the formation of a hard pan in the lower layers over a period of time (Aggarwal et al., 1995; Kukal and Aggarwal, 2003), which hinders the deeper penetration of roots into soil and a direct negative influence on yield.

Climatic conditions and tillage systems, which influenced the grain yield, affected similarly the 1000-grain weight and test weight.

In 2011, in normal climatic conditions, the highest yield was determined in control variant, plough at 30 cm and fertilized (9471 kg ha^{-1}). The conservative variant chisel $N_{80}P_{80}$ recorded 9054 kg ha^{-1}, representing 95.6% from the yield of the control treatment (*table 1*).

Analyzing 2012, the yield of field crops is negatively affected of the lack of rainfall and extended droughts during the vegetation period but we can see how in these conditions the conservative tillage may influence positively the yield, proved to be in a very significant positive correlation, exception is the disc variant. The grain yields ranged on fertilized variants from 2580 kg ha^{-1} on disc to 3956 kg ha^{-1} on chisel.

Table 2

The influence of "tillage systems x nutrients level" interaction on 1000-grain weight and Test weight at maize crop

Treatment		1000-grain weight (g)		Test weight (kg hl^{-1})	
Tillage	Fertilization level	2011	2012	2011	2012
Disc harrow	$N_{80}P_{80}$	311 (ooo)	165 (ooo)	68 (ooo)	73 ns
	N_0P_0	294 (ooo)	153 (ooo)	64 (ooo)	70 ns
Paraplow	$N_{80}P_{80}$	323 ns	173 ns	71 (ooo)	73 ns
	N_0P_0	303 (ooo)	153 (ooo)	69 (ooo)	68 (o)
Chisel	$N_{80}P_{80}$	323 ns	179 ns	72 (o)	73 ns
	N_0P_0	310 (ooo)	155 (ooo)	71 (ooo)	70 ns
Plough 20 cm	$N_{80}P_{80}$	319 (ooo)	173 ns	72 (o)	73 ns
	N_0P_0	308 (ooo)	153 (ooo)	70 (ooo)	70 ns
Plough 30 cm	$N_{80}P_{80}$ (control)	325	175	74	72
	N_0P_0	308 **(ooo)**	150 **(ooo)**	71 **(ooo)**	69 **ns**
		DL5% = 2.3 DL1% = 3.2 DL0.1 = 4.4	DL5% = 4.1 DL1% = 5.6 DL0.1 = 7.6	DL5% = 1.5 DL1% = 2.1 DL0.1 = 2.9	DL5% = 3.5 DL1% = 4.8 DL0.1 = 6.6

As shown in Table 2, on unfertilized maize (N_0P_0), the mean values of 1000 grain weight ranged in 2011 between 294 g for the disc harrow treatment to a maximum of 325 g for the control (plowed at 30 cm). Tillage systems affected thousand kernels weight (g) very significantly on all variants accept chisel and paraplow on $N_{80}P_{80}$.

Test weight (kg hl^{-1}) was also significantly influenced by years and by tillage system *(table 2).* The highest average value of this trait was recorded in 2012 (73 kg hl^{-1}), on chisel. Analyzing the values from 2012 we can see that only the paraplow N_0P_0 has a significant negative difference.

The WSA is influenced by soil management practices such as zero-tillage, minimum tillage, conventional tillage, use of ploughs and harrows and cropping sequences.

The mean values of WSA recorded during 2010-2012, reveal positive statistically significant differences between chisel, paraplow variants and the control treatment (plough at 30 cm) *(figure 1).*

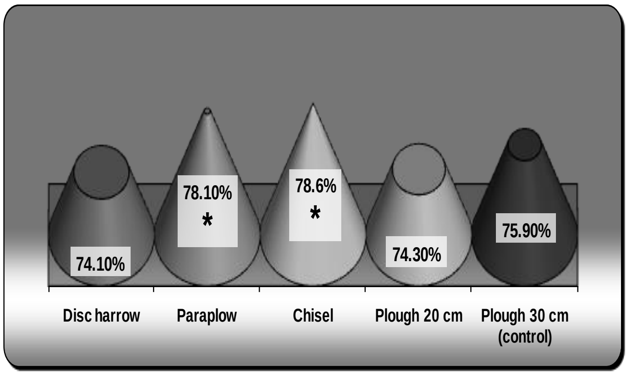

Figure 1 - **The influence of tillage systems on WSA at harvesting on 0-30 cm – mean values 2010-2012**

The lowest water stability under conventional tillage compared to all treatments with less tillage intensity can be associated with loose particle-to-particle associations (Kemper et al., 1987)

The higher percent of stable aggregates contribute to bigger inter-aggregate porosity at the surface of the soil and infiltration, preventing the onset of runoff (Rhoton et al., 2002).

CONCLUSIONS

Tillage systems have significant effect on the physical properties of soil and our results confirmed the hypothesis that reduced tillage would improve soil structure.

Analyzing the result we observed that in drought conditions over 2011-2012 the yield is significant lower compared with 2010-2011 on all variants of tillage. Droughts caused a lack of balance between evapo-transpiration and soil water absorption, and this stress reduces the yield and its quality. Also has been observed that in 2011-2012, the RT, chisel and paraplow, had slightly higher yield compared with control treatment, plough at 30 cm and $N_{80}P_{80}$.

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