SOIL TILLAGE IMPACT ON AGGREGATE HIDROSTABILITY, CARBON AND NITROGEN CONTENT FROM SOIL

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Abstract

The aim of this paper was to quantify the impact on soil quality induced by three tillage regimes: conventional tillage with plough at depths of 20 cm (CT), tillage with chisel plough (MT) and direct drilling (NT). Soil physical properties measured were aggregate size distribution (DSAS) and stability soil (WSA), soil water retention characteristics, soil organic carbon (OC) and total N content (N_{tot}), under local climatic conditions.
The experiment was conducted in the north-east of Romania at the Ezăreni experimental farm of the University of Agricultural Sciences and Veterinary Medicine Iaşi, during 2007-2009, in a cropping systems, viz., rape - wheat (*Brasica napus – Triticum aestivum*). Soil samples were collected (0-10; 10-20; 20-30 cm) from all treatments and separated into six aggregate size classes for assessing proportions of macro- (5-8; 2-5; 1-2; 0,5-1; 0,25-0,5 mm) and micro- (< 0,25 mm) aggregates by dry sieving.
Tillage treatments significantly influenced water stable aggregates (WSA) and distribution of soil aggregate size (DSAS). For 0-10 cm WSA and distribution of macro-aggregates (> 0,25 mm) were observed greater for CT that in others tillage treatments. Under this depth the relative proportion of macro-aggregates was more in NT. Those two physical properties increased with increase in sol depth and also from sowing time till wheat maturity. For the depth 0-30 cm, the higher organic carbon and total N concentration were found in NT treatment. The data obtained indicate the importance of NT in improving the soil quality.

Key words: Soil structure, Organic carbon, total N, No-till.

The plant growth and yield may be affect through deterioration of soil structure, decline in total porosity, change in pore-size distribution (Baker et al., 2004), and depreciation of soil organic matter (SOM) concentration (Mitra et al., 2005) and total nitrogen (N_{tot}). Land use and management practices, through intensive cultivation and removal of plant biomass from the fields, may affect SOM concentration, deteriorating implicit soil physical properties (Li X.G. et al., 2005), and also a rapid oxidation of SOM (Shang, C., Tiessen, H., 2003).

The beneficial effects of reduced tillage are improve of aggregate stability and distribution of aggregate size fraction, which are favorable for a better sequestration of C and N and reduction in bulk density (Madari, B. et al., 2005, Alan, L.W. et al, 2007; Abid, M. and Lal, R., 2008; Franzluebbers, A.J. and Stuedemann J.A., 2008; Kasper, M. et al., 2009). Soil aggregation influences seedling emergence and root growth (Anabi, M. et al., 2007), soil moisture retention and aeration (Madari, B. et al., 2005), and OC sequestration and dynamics (Denef, K. et al, 2004). The strong relationship between physical and chemical properties, help us to understanding how these properties are influenced by soil tillage, reduce of these is crucial to sustainable soil management of soil (Abid, M. and Lal, R., 2008). Besides, reduced costs of soil working make the alternative tillage systems to be more attractive because of economically and ecologically interest (Kasper, M. et al., 2009).

The SOM plays a key role in enhancing crop production (Causano, H.J. et al., 2006; Abid, M. and Lal, R., 2008; Franzluebbers, A.J., Stuedemann, J.A., 2008), improving stabilization of soil macro- and micro-aggregates (Gregorich, E.G. et al, 1994; Annabi, M. et al., 2007; Abid, M. and Lal, R., 2008; Kasper, M. et al., 2009) and mitigating climate change (Hao, Y. et al., 2003).

MATERIAL AND METHOD

The experiments were carried out at the Didactic Station of the „Ion Ionescu de la Brad" University of Agricultural Sciences and Veterinary Medicine of Iaşi, Ezăreni Farm, Romania, during farming year 2007-2009.

The experimental site is located on a chambic chernozem (SRTS-2003, or haplic chernozems after WRB-SR, 1998), with a clay-loamy texture, 6.8 pH units, 3.7 % humus content and a medium level of fertilization. The soil has high clay content (38-43 %)

and is difficult to till when soil moisture is close to the wilting point (12.2%). The experimental site has an annual average temperature of 9.40ºC and precipitation of 587 mm.

The experimental design was a "divided plots design" with three replications. We have investigated two variants of minimum tillage–Chisel variant and no-tillage variant, and one classic soil tillage system – plough at depths of 20 cm–in the crop rotation made of rape/wheat, with three replications with plots covered surface of 900 m^2.

This investigation analyses aggregate stability and aggregate-size distribution using the dried and wet sieving after Tiulin-Erikson procedure (Onisie T. and Jităreanu G., 2000). Samples were taken from tree depth profile (0-10, 10-20 and 20-30 cm). Each sample was air-dried. Twenty grams of dry soil aggregates were placed on a set of six nested sieves of 0.25, 0.5, 1, 2, 3, 5 mm diameter. The soil aggregate fraction retained on each sieve was gently back-washed off the sieve. The particle <0.25 mm were collected from the tank after 24 h, dried in a forced-air oven at ~105°C.

To determinate the C_{org} and N_{tot} content on experimental field under tillage systems and fertilization systems was taken samples for 0 and 20 cm depth. Both C_{org} and N_{tot} concentration were determinate by the dry combustion method (900°C) after Nelson and Sommers (1982) using a Vario Max CN Elementer Analyser Inc, Hanau, Germany (Model Ident-No.2500-5003).

Significance of differences in soil properties in response to the effects of tillage, subsurface drainage, and depth were assessed by computing the Analysis of Variance. Treatment means and interactions were separated by LSD multiple comparison procedure at $P \le 0.05$; $P \le 0.01$; $P \le 0.001$ level.

RESULTS AND DISCUSSIONS

The results obtain about effect of tillage systems on ASD, show that the soil aggregates with size >5 mm increase with the depth and with reduces soil tillage. Soil under NT had a greater proportion of the macro-aggregates and a lower proportion of ≤0.25 mm (*table 1*).

Soil aggregation and aggregate size distribution were significantly affected by tillage, special in 0-10 cm depth (Table 1, Table 2). For 10-20 and 20-30 cm depth, tillage effect was not-significant. For 0-10 cm, the WSA was significant more in CT that in unconventional tillage systems. Under this depth WSA was higher for NT that in the other tillage systems (Table 2). The effects of tillage on distribution of soil mass in WSA are manifested through change in OC concentration. There was a strong correlation between OC concentration and soil tillage depth.

Table 1

Effect of tillage on aggregate size distribution (g kg^{-1})

Tillage systems	> 10 mm		10-5 mm		5-3 mm		3-2 mm		2-1 mm		1-0,5 mm		0,5-0,25 mm		< 0,25 mm	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
0-10 cm soil layer																
CT	12.14	8.80	15.50	14.54	12.77	9.43	13.51	10.83	17.83	18.72	13.69	16.61	6.57	13.78	7.99	7.29
MT	10.23	12.87	12.71	17.55	12.93	8.10	14.80	8.93	19.83	18.95	14.16	18.01	6.19	8.26	10.15	7.33
NT	10.34	5.65	14.16	10.47	11.18	5.86	12.77	8.78	19.65	23.07	17.13	24.41	8.16	12.31	6.61	9.45
$LSD_{5\%}$ = 0.2 g kg^{-1}					$LSD_{1\%}$ = 0.3 g kg^{-1}						$LSD_{0,1\%}$ = 0.5 g kg^{-1}					
10-20 cm soil layer																
CT	12.80	17.43	23.27	24.09	13.77	14.25	13.85	12.57	17.79	13.73	10.17	8.95	5.08	3.92	3.37	5.06
MT	13.44	21.55	22.61	25.07	14.14	12.80	15.49	10.62	15.49	12.94	10.32	8.24	6.30	3.76	5.09	5.02
NT	17.17	21.62	20.84	24.69	16.02	11.47	12.38	9.57	16.72	13.78	9.62	9.82	4.82	4.32	2.43	4.73
$LSD_{5\%}$ = 0.5 g kg^{-1}					$LSD_{1\%}$ = 0.68 g kg^{-1}						$LSD_{0,1\%}$ = 0.91 g kg^{-1}					
20-30 cm soil layer																
CT	16.56	23.09	23.57	27.94	13.45	13.09	12.62	9.88	17.42	12.42	10.29	7.34	3.79	3.05	2.69	4.18
MT	21.86	34.85	20.46	24.11	12.85	9.26	12.27	8.77	14.67	10.21	8.94	7.22	4.50	2.65	3.11	3.73
NT	16.98	29.92	21.88	21.79	16.94	9.80	13.09	9.18	14.98	12.42	9.75	8.52	4.17	3.90	1.87	4.47
$LSD_{5\%}$ = 0.78 mm					$LSD_{1\%}$ = 0.106 mm						$LSD_{0,1\%}$ = 0.143 mm					

Table 2

Tillage effects on water stable aggregates (%)

Soil layer/ Tillage systems	0-10 cm		10-20 cm		20-30 cm	
	2008	2009	2008	2009	2008	2009
CT	64.69^o	69.46^o	70.82	74.39	75.70	79.30
MT	64.46^o	65.19^o	70.23	79.67	79.70	84.55^x
NT	62.74^o	58.83^o	72.38	78.10	79.81	86.28^{xx}
$LSD_{5\%}$ = 7.8 %		$LSD_{1\%}$ = 11.8 %		$LSD_{0,1\%}$ = 19.0 %		

This kind of reduction in aggregates stability with cultivation and other forms of soil disturbances have been reported also by Li, X.G. et al. (2007), Madare, B. et al (2005), Abid, M. and Lal R. (2008), Franzluebbers, A.J. and Stuedemann J.A. (2008) and Kasper, M. et al. (2009). The tillage x tillage interaction has significant impact on SOC and N_{tot} at 0-30 cm depth (*table 3*).

After one study year, the OC concentration was higher in NT (1.839 %) that MT (1.768 %) and CT (1.771 %), but at the result obtain from analyses of soil samples taken in summer, 2009 a higher content was find on MT. These results are in accord with those reported by Madari, B. et al. (2005), Li, X.G. et al (2007) and Abid, M. and Lal, R. (2008). The reduction in OC with tillage can be attributed to an increase in the soil contact.

Table 3

The tillage and fertilization effect on soil organic carbon and total nitrogen concentrations

Tillage systems	Fertilization systems	C_{org} (%)			N_{tot} (%)		
		2007	2008	2009	2007	2008	2009
CT	Nefertilizat	1.69	1.701^{oo}	1.657^{ooo}	0.174	0.171^{oo}	0.159^{ooo}
	$N_{64}P_{50}K_{40}$		1.731^{oo}	1.739^{o}		0.176^{o}	0.182
	20 t/ha SS		1.787	1.765		0.179	0.180
	$N_{96}P_{80}K_{60}$ + 20 t/ha SS		1.787	1.772		0.191	0.183
	$N_{96}P_{80}K_{60}$		1.765	1.768		0.177	0.185
	30 t/ha SS		1.800	1.776		0.191	0.181
	$N_{64}P_{50}K_{40}$ + 30 t/ha SS		1.828	1.817		0.194	0.186
Mean average		1.69	1.771	1.756	0.174	0.183	0.179
MT	Nefertilizat	1.69	1.698^{ooo}	1.754	0.174	0.174^{o}	0.181
	$N_{64}P_{50}K_{40}$		1.740^{o}	1.756		0.178	0.189
	20 t/ha SS		1.754	1.794		0.183	0.184
	$N_{96}P_{80}K_{60}$ + 20 t/ha SS		1.816	1.820		0.186	0.191
	$N_{96}P_{80}K_{60}$		1.743	1.782		0.179	0.194^{x}
	30 t/ha SS		1.780	1.869^{xx}		0.187	0.189
	$N_{64}P_{50}K_{40}$ + 30 t/ha SS		1.843^{x}	1.910^{xxx}		0.190	0.198^{x}
Mean average		1.69	1.768	1.812	0.174	0.182	0.189
NT	Nefertilizat	1.69	1.702^{oo}	1.712	0.174	0.176^{o}	0.172^{oo}
	$N_{64}P_{50}K_{40}$		1.762	1.759		0.184	0.192
	20 t/ha		1.813	1.820		0.187	0.185
	$N_{96}P_{80}K_{60}$ + 20 t/ha SS		1.901^{xx}	1.834		0.189	0.194^{x}
	$N_{96}P_{80}K_{60}$		1.786x	1.782		0.187	0.194^{x}
	30 t/ha SS		1.891^{xxx}	1.850^{x}		0.191	0.189
	$N_{64}P_{50}K_{40}$ + 30 t/ha SS		2.010^{xxx}	1.902^{xxx}		0.208^{xxx}	0.195^{x}
Mean average		1.69	1.838	1.808	0.174	0.189	0.189
Least significant difference (LSD)		$LSD_{5\%}$ = 0.049 % $LSD_{1\%}$ = 0.068 % $LSD_{0,1\%}$ = 0.092 %			$LSD_{5\%}$ = 0.008 % $LSD_{1\%}$ = 0.011 % $LSD_{0,1\%}$ = 0.015 %		

Total soil N concentration was not-significantly influenced by either tillage, but the fertilization influence is very interesting. The fertilization however, has a very significant ($P \leq 0.05$) effect on N concentration on 0-30 cm soil layer. On the first year after SS applied, N concentration was higher in NT and fertilization with $N_{64}P_{50}K_{40}$ + 30 t/ha SS (0.208 %), but on the second year in MT (0.198 %) and after these in NT (0.198 %), boot with the same fertilization system. These results are in agreement with those of Abid, M., Lal R. (2008) and Kasper, M. et al. (2009).

CONCLUSIONS

The benefit of reduce tillage on the soil surface on its improvement of soil organic matter content and soil structure are some of the advantages to use alternative tillage methods. That because structural stability can be controlled by management, and further research confirms that classical cultivation decreases this stability.

After 5 min of samples sieving appeared to disperse a large amount of macro-aggregates of the reduced tilled soil compared to conventional tilled. The aggregate stability was generally low in Ct and MT whereas NT plots contained the largest amount of stable aggregates. Therefore this method clearly differentiates between unconventional tillage and classical tillage and this pronounced difference is consistent with findings of other experiments.

There was no significant difference between tillage systems in the micro-aggregates fraction.

Connecting the results, OC measurements reveals that unconventional tillage systems have not only the higher C_{org} and N_{tot}, but also the most water stable aggregates. One year after applied SS, MT and CT have a similar content of C_{org} and N_{tot}, but in 2009 in MT is better soluble, having the same content in N_{tot} with NT. The nitrogen depletion in CT (*table 3*) demonstrates that intensive cultivation affects N_{tot}.

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