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WATER STABILITY OF SOIL AGGREGATES IN DIFFERENT SYSTEMS OF CHERNOZEM TILLAGE

J. Bartlová, B. Badalíková

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Abstract

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Effects of various agrotechnical measures on macrostructural changes in the ploughing layer and subsoil were studied within the period of 2008–2010. Soil macrostructure was evaluated on the base of water stability of soil aggregates. Altogether three variants of soil tillage were established, viz. ploughing to the depth of 0.22 m (Variant 1), deep soil loosening to the depth of 0.35–0.40 m (Variant 2), and shallow tillage to the depth of 0.15 m (Variant 3). Experiments were established on a field with Modal Chernozem in the locality Hrušovany nad Jevišovkou (maize-growing region, altitude of 210 m, average annual sum of precipitation 461 mm). In the first experimental year, winter rape was the cultivated crop and it was followed by winter wheat, maize and spring wheat in subsequent years. The aim of this study was to evaluate effects of different methods of tillage on water stability of soil aggregates and on yields of individual crops. An overall analysis of results revealed a positive effect of cultivation without ploughing on water stability of soil aggregates. In the variant with ploughing was found out a statistically significant decrease of this stability. At the same time it was also found out that both minimum tillage and deep soil loosening showed a positive effect on yields of crops under study (above all of maize and winter wheat).

soil tillage, water stability of aggregates, Chernozem, yield

The soil structure is one of very important soil properties and depends on the capability of soil particles to aggregate or disaggregate and create structural aggregates. It is the result of joint action of physical, chemical, and biological processes taking place in soil. Soil structure, which shows a different resistance to disintegration in water (called also water stability), may be used in studies on processes of soil degradation.

Soil aggregate stability is a product of interactions between soil environment, management practices, and land use patterns (Zhang *et al.*, 2008). Aggregate stability is dependent on soil type and texture class, on the content of organic matter (Javůrek & Vach, 2009), biological activity of soil (Oades, 2005), fertilizer application (Anabi *et al.*, 2007), and also on soil tillage practices and vegetative cover.

Kodešová & Rohošková (2009) observed coefficients of aggregate vulnerability which were resulted from the shaking after pre-wetting test (KV). The KV value depended mostly on cation exchange capacity, pH (KCl) and organic matter.

The differences in aggregate stability under different land use patterns are mainly due to the intensity of human disturbance and cultivation. Improper land use patterns will lead to the breakdown of unstable aggregates and production of finer and more-easily transportable particles and microaggregates (Zhang *et al.*, 2008).

Different authors (Panayiotopulus & Kostopoulou, 1989; Gajici *et al.*, 2010) mention that natural soils show a considerably higher stability of aggregates than cultivated soils. With a higher soil tillage intensity, the content of organic matter decreases and, consequently, the stability of soil aggregates gets lower.

Kasper *et al.* (2009) assessed the impact of different tillage systems on soils aggregates by measuring their stability. Soil samples were collected from the top 0 to 10 cm on a Chernozem fine sandy loam where methods of conventional tillage, reduced tillage and minimum tillage were applied. Using the SAS method, the above authors found out that conventional tillage and reduced tillage produced the least amounts of stable aggregates (18.2% and 18.9%, respectively), whereas the minimum tillage showed twice as much of stable aggregates (37.6 %). Their results demonstrated that the type off tillage influenced stability and chemical composition of soil aggregates.

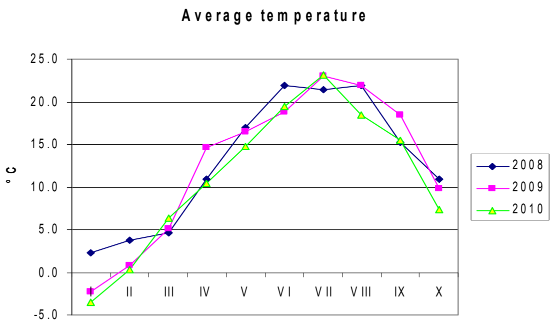
The stability of soil aggregates can be enhanced by growing catch crops, reducing application of mineral fertilisers and pesticides, and promoting biological activity of soil. A great effect is also exerted by long-term set aside periods (Eder *et al.*, 1993).

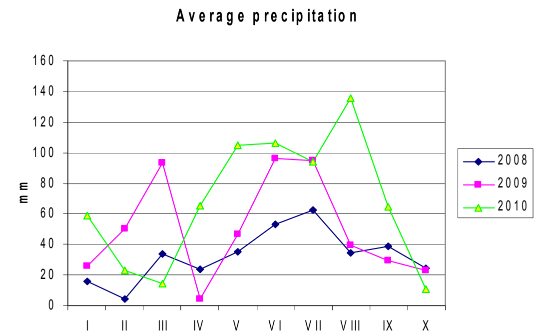
Huisz *et al.* (2009) proved that adding organic matter enhanced the transient and temporary binding agents between microaggregates grouped into macroaggregates but that these form of binding was only of a temporal nature.

In this study, effects of three different methods of tillage on water stability of soil aggregates and, thus, on yields of cultivated crops were followed and analysed.

MATERIALS AND METHODS

The trial was established on Modal Chernozem in the territory of the Hrušovany nad Jevišovkou municipality in a maize-growing region at 210 m altitude in the year 2007. The average annual sum of precipitation is 461 mm. The course of climatic conditions is presented in Fig. 1. In the year of trial establishment, winter rape (*Brassica napus* L.) was the first cultivated crop. In the next year, it was followed by winter wheat (*Triticum aestivum* L.), and in the year 2009 by maize *(Zea mays* L.*)*. In the last year (2010), spring wheat (*Triticum aestivum* L.) was the cultivated crop.





1: *The weather course in individual experimental years*

The three systems of tillage were as follows:
Variant 1 – ploughing to the depth of 0.22 m
Variant 2 – subsoil tillage (deep loosening) to the depth of 0.35–0.4 m
Variant 3 – minimum tillage with shallow soil cultivation to the depth of 0.15 m.

In years 2008–2010, soil samples were taken to determine the water stability of soil aggregates; soil samples were collected always in the spring at the beginning of growing season and in the autumn to the end of the growing season. In all cases, soil samples were taken from two depths, i.e. 0–0.3 m (topsoil) and 0.3–0.6 m (subsoil).

The water stability of soil aggregates was determined by wet sieving (Kandeler, 1996). This procedure enabled to separate the fraction of aggregates of 1–2 mm from soil samples dried at the laboratory temperature. A 3-g sample was washed with water over sieves for a period of 5 minutes. Then the samples were dried at 105 °C to a constant weight and after cooling down in the exsicator they were weighed. After weighing a solution of sodium pyrophosphate was added and samples were rinsed again to wash out all clay particles (so that only sand particles > 0.25 mm were left); thereafter they were dried and weighed.

Water stability of soil aggregates can be expressed as the percentage of water stable aggregates in the total amount of aggregates after subtracting the proportion of sand according to the formula:

$$\% \, SAS = ((M_2 - M_3) / W - (M_3 - M_1)) \times 100,$$

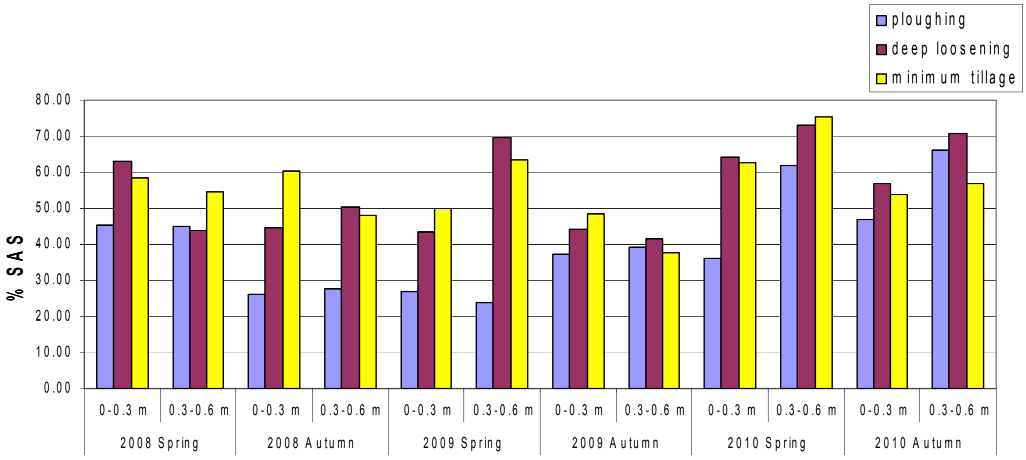
where:
% SAS........ percentage of stable soil aggregates
M_1 .... weight of the dish (g)
M_2 .... weight of the dish, stable aggregates and sand (g)
M_3 .... weight of the dish and sand (g)
$(M_2 - M_3)$ .. weight of stable aggregates
$(M_3 - M_1)$ .. weight of sand
W .... total weight of the sample (3 g).

Yields of individual crops were estimated in four replications after their manual harvest from an area of 0.25 m^2.

Experimental results were statistically processed by the multifactorial analysis of variance and then by Tukey's tests of simple contrasts. For statistical analysis, the program Statistica 7.1 was used.

RESULTS AND DISCUSSION

In the first experimental year, the best water stability of soil aggregates was observed in the subsoil at the beginning of growing season (Fig. 2). Also in the second year the highest values of water stability of soil aggregates were recorded in subsoil of Variant 2 in the spring. In the third year, the highest values of water stability were found out in the subsoil of Variant 3 also in the spring. The best values of water stability were recorded in the subsoil at the beginning of growing seasons in the year 2010.

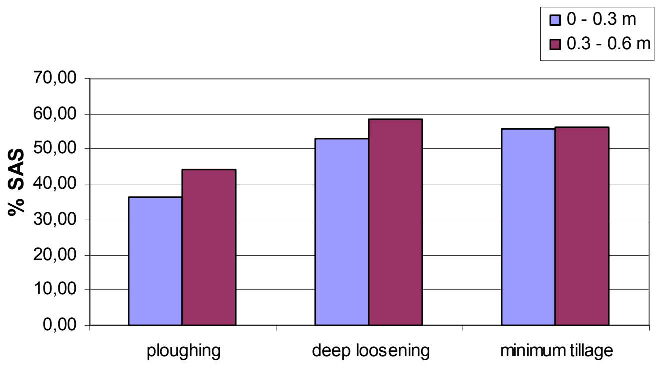


2: *Mean values of water stability (%) of soil aggregates in two soil profile depths (years 2008–2010)*

The worst values of water stability were recorded in the subsoil at the beginning of growing seasons in the year 2009.

Results of a three-year study on stability of soil aggregates indicated that the best values of this parameter were obtained after deep loosening (Variant 2; Fig. 3). An evaluation of effects of all three experimental variants of tillage on the stability of soil aggregates revealed a statistically significant difference between Variant 1 on the one hand and Variants 2 and 3 on the other (Tab. I. II). Javůrek & Vach (2009) demonstrated in their study that a long-term application of soil protection methods showed a positive effect on water stability of soil aggregates.

It was also possible to conclude that in the ploughing layer (0–0.3 m) the values of water stability were lower than in subsoil (0.3–0.6 m). The lowest values were recorded in Variant 1 (i.e. with ploughing). Mannering *et al.* (1975) observed after more intensive soil tillage a decrease in



3: *Average values of water stability (%) of soil aggregates in two depths of soil profile (years 2008–2010)*

I: *Analysis of variance for water stability of aggregates (years 2008–2010)*

Effect	Sum of squares	d.f.	Mean square	F-ratio	p-value
Variant	3826.3	2	1913.1	14.034	0.000008
error	9406.4	69	136.3		

II: *Multiple range analysis for variant (method: 95 LSD)*

Variant	Average
Ploughing	40.21818 [b]
Deep loosening	55.53083 [a]
Minimum tillage	55.82965 [a]

Note: Average values indicated by various letters are statistically different (P < 0.01) percent of water stable aggregates and Badalíková & Procházková (2002) demonstrated an increase in the share of water stable aggregates in the variant without ploughing. Also Tebrüge & Düring (1999) obtained similar results in their study and reported an increased stability of soil aggregates in the variant with zero tillage.

Yields of individual crops were dependent on the applied technology of tillage. They were influenced by soil, climatic conditions and (depending on individual crops) also by treatment and method of tillage. The degree of soil compaction and contents of organic matter and water in soil are of the same importance; besides, soil water contain nutrients that influence the yield. A good quality of soil structure also influences an easy availability of nutrients contained in soil.

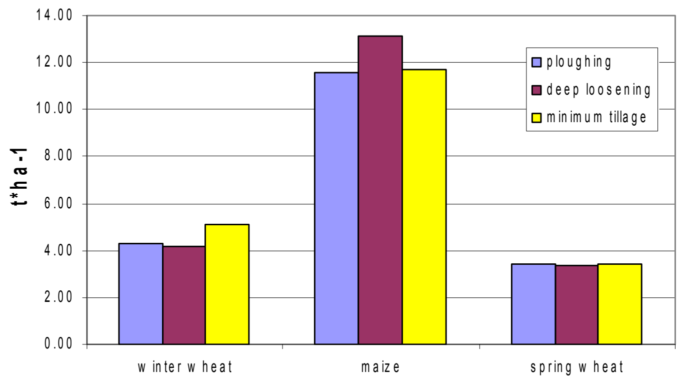
In 2008, the highest and the lowest average yields of winter wheat were obtained in Variant 3 and Variant 2, respectively (Fig. 4). The difference between Variant 3 on the one hand and the remaining two was statistically significant (Tab. III, IV).

Yields of maize for grain were evaluated in 2009. The highest yield was recorded in Variant 2 while the lowest one in Variant 1. The differences between all variants of tillage were statistically significant (Tab. III, IV). Yields of spring wheat were evaluated in 2010. As far as individual variants were concerned, yields were similar and did not show differences.

As compared with ploughing, the system of zero tillage generally increases yields of cereals, above all in Central and Southern Europe where the amount of annual precipitations is usually lower; similar results are obtained also on larger farms where a greater attention is paid not only to protection of soil *per se* but also to the content of soil water (Soane *et al.*, 2009).

CONCLUSIONS

The obtained results demonstrated that methods of soil tillage influenced not only the water stability of soil aggregates but also yields of cultivated crops. An overall evaluation revealed that, as compared without ploughing, the method of minimum soil tillage showed a positive effect on water stability of soil aggregates because the recorded values were significantly lower. In Variants 2 and 3 (i.e. deep loosening and minimum tillage) were relatively uniform and balanced. The water stability of soil aggregates was influenced also by the depth of tillage and date of sampling. Besides, it was also found out that yields of experimental crops were positively influenced by shallow tillage and deep loosening, i.e. Variants 2 and 3.



4: *Yields of crops under study (t.ha⁻¹)*

III: *Analysis of variance for yields of winter wheat and maize (years 2008–2010)*

	Winter wheat					Maize				
Effect	Sum of squares	d.f.	Mean square	F-ratio	p-value	Sum of squares	d.f.	Mean square	F-ratio	p-value
Variant	1.5755	2	0.7877	36.043	0.000454	4.811	2	2.406	2406	0.000000
Error	0.1311	6	0.0219			0.006	6	0.001		

IV: *Multiple range analysis for variant (method: 95 LSD)*

	Winter wheat	Maize
Variant	Average yield ($t*ha^{-1}$)	Average yield ($t*ha^{-1}$)
Ploughing	4.300000 [a]	11.54333 [a]
Deep loosening	4.166667 [a]	13.15666 [c]
Minimum tillage	5.11333 [b]	11.67666 [b]

Note: Average values indicated by various letters are statistically different (P < 0.01)

SUMMARY

This study deals with effects of various agrotechnical measures (i.e. methods of tillage) on macrostructural changes taking place in the ploughing layer and subsoil and also on subsequent yields of cultivated crops. The macrostructure of soil was evaluated on the base of water stability of soil aggregates. Experimental results were obtained in the locality Hrušovany nad Jevišovkou within the period of 2008–2010. This locality is situated in the maize-growing region with Modal Chernozem. Altogether three experimental variants of tillage were established, viz. ploughing to the depth of 0.22 m (Variant 1), deep loosening of subsoil to the depth of 0.35–0.40 m (Variant 2), and shallow tillage to the depth of 0.15 m (Variant 3). In the first experimental year, winter rape was the cultivated crop and it was followed by winter wheat, maize and spring wheat in subsequent years. Water stability of soil aggregates was determined using the method of wet sieving (Kandeler, 1996) and results was expressed as the percentage of water stable aggregates in the total amount of aggregates after subtracting the proportion of sand. In individual crops, yields after their manual harvest from an area of 0.25 m^2 were estimated in four replications. Results of a three-year study on water stability of soil aggregates indicated that not only this parameter but also yields of subsequently cultivated crops were influenced by the method of tillage. An overall analysis revealed a positive effect of minimum tillage on water stability of soil aggregates. In the variant with conventional method of tillage (Variant 1) the obtained values were statistically significantly lower. The highest values of water stability were recorded in Variant 2 with deep loosening of subsoil. It can be also concluded that in the ploughing layer (0–0.3 m), values of water stability were lower than in subsoil (0.3–0.6 m). A positive effect of minimum tillage and deep loosening was manifested also in yields of experimental crops. In case of winter wheat, a statistically significant difference between Variant 3 on the one hand and Variants 1 and 2 on the other was observed (yields in Variant 3 were the highest). The most marked effect of the method of tillage was observed in maize for grain (the difference was statistically significant). The highest yield of maize grain was obtained in Variant 2 (i.e. with deep loosening). In spring wheat, yields were relatively similar in all three experimental variants of tillage.

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Address

Ing. Jaroslava Bartlová, Ing. Barbora Badalíková, Zemědělský výzkum, spol. s r. o., Zahradní 1, 664 41 Troubsko, Česká republika, e-mail: bartlova@vupt.cz