NORMALIZED STABILITY INDEX AND MEAN WEIGHT DIAMETER IN A COMBINED NITROGEN FERTILIZATION X IRRIGATION EXPERIMENT ON HUNGARIAN CHERNOZEM SOIL

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Abstract: Soil management and tillage practices could be remarkable stress factors on structure of soil which might be ruined and therefore cause the reduction of crop yields. The effect of irrigation and fertilizers on soil structure may be diverse and often contradictory. In contrary to the often proved soil structure disrupting effect of irrigation, in our experiment, as the result of irrigation, increased aggregate water-stability was observed. In unfavorable conditions, or in large accumulation, ammonium fertilizers may cause the disruption of soil structural units, therefore decline of soil structure as it was observed in our experiment. These results were compared with the Normalized Stability Index and Mean Weight Diameter of which the second one showed significant differences among the treatments.

Keywords: soil structure, Normalized Stability Index (NSI), Mean Weight Diameter (MWD), irrigation, mineral fertilizer

Introduction

The aim of tillage is to reach the highest possible crop results that could be done by creating and maintaining optimal soil structure for cultivated plants. Nevertheless in contrast of this aim, tillage done in a non-optimal way or time could be a remarkable stress factor on structure of soil and may cause the decline of its quality, and therefore the reduction of agricultural productivity.

Optimal agronomical soil structure consists of 1-10mm discrete soil structural units**,** i.e. aggregates. This soil quality, the agronomical structure, i.e. the particle size distribution of soil, and the resistance of aggregates against water and tillage; determines its fertility and productivity. This property is might be characterized by the stability of these soil structural units against disrupting effects (Six et al., 2000). Soil aggregates could be disrupted by several effects, for example slaking in water i.e. because of too intense wetting during irrigation (Emerson, 1977), crusting effects of tillage, or because of the use of certain agrochemicals (Haynes et al., 1998), which cause the decomposition of aggregates into fragments and primary particles and alter their natural distribution in aggregate size and therefore cause decline of soil structure. Resistance of soil structural units against these disrupting effects and therefore soil structural quality might be investigated by wet sieving (Six, 2000).

In our paper we assessed the change of soil structural stability of a Chernozem soil (Látókép, South Hungary) as a result of irrigation and the use of mineral fertilizer by the Normalized Stability Index (NSI) proposed by Six (2000), and the Mean Weight Diameter (MWD) proposed by van Bavel (1953).

Materials and methods

Site description

Soil samples were taken in 22-23. 05. 2006, at the Látókép Experimental Station of the Centre of Agricultural Sciences, University of Debrecen. The experimental site is

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located in the north-eastern part of the Great Hungarian Plain. The soil of the experimental site was a lowland pseudomyceliar Chernozem (Calciustoll or Vermustoll, silt loam; USDA taxonomy). The climate is subhumid temperate continental, with a mean annual precipitation of 566 mm.

In this paper the effect of irrigation and N mineral fertilizer addition were investigated in four combinations: (1) irrigation – no mineral fertilizer, (2) irrigation – mineral fertilizer, (3) no irrigation – no mineral fertilizer (considered to be the control treatment), (4) no irrigation – mineral fertilizer. The site has been tilled by winter ploughing to 25-27cm depth. Soil samples were taken from 0-25 cm and 25-35 cm. Crop rotation was maize – maize – winter wheat – winter wheat. Samples were taken from the winter wheat field. In the case of mineral fertilizer addition 120 kg * ha^{-1} N mineral fertilizer was added. No farmyard manure was added. The used irrigation system was a line type (Valmont). The experimental site was irrigated in 2004 four times, adding 15 mm, 25 mm, and twice 30 mm water; in 2005, twice adding 30 mm water; in 2006, twice adding 25 mm of water.

Table 1. Main chemical characteristics of the investigated soil

Depth	pH		$CaCO_3$	Soil Organic Matter	Total Nitrogen	Ammonium-lactate-soluble	
cm	H_2O	KCl	%	%	%	P_2O_5 (mg kg^{-1})	K_2O (mg kg^{-1})
0-20	7.3	5.6	0	2.72	0.150	133.4	240.0
20-40	7.2	5.4	0	2.31	0.120	48.0	173.6

Method

The wet sieving method was done as by proposed by Huisz (2008). Two different wetting pre-treatment methods were investigated. (1) soil samples were rapidly immersed in tap water for 5min (Slaking (S)). (2) soil samples were capillary wetted to field capacity and left overnight to weight equilibrate (Capillary (C)). After these pre-treatments each sample was wet sieved for 2 min in an analytic sieve shaker machine with the following aperture sizes: 2 mm, 250 μm, 53 μm resulting 4 fractions: (1) the >2000 μm large macro- (2) the 250-2000 μm small macro-, (3) the 53-250 μm microaggregates, and (4) the <53 μm silt and clay fraction. All fractions were dried at 60°C and weighted. Then 5 g of 1-3. air dry aggregate fractions from the two different pre-treatment methods were separately suspended in 15 ml of 5 g*L^{-1} sodium hexameta-phosphate solution in a 50 ml centrifuge tube, shaken for 18 hours to disperse aggregates 25 μm. Then the suspension poured through a sieve with the same mesh size as the one with which the aggregates were collected. The sand fractions remaining on each sieve were collected, oven dried at 105°C and weighed. To avoid overestimating the mass of the aggregate fractions, aggregate-sized sand fraction was subtracted from the whole fraction masses (this method is called 'sand correction').

The effect of irrigation and N mineral fertilizer addition on soil aggregate fractions and therefore its structural stability were calculated by the Normalized Stability Index (NSI) (Six, 2000) and the Mean Weight Diameter (MWD) (van Bavel, 1953).

Results and discussion

Figure 1-4. show the effect of irrigation and mineral fertilizer on soil structural stability for each treatment and depth layer calculated by the NSI and MWD respectively. Asterisk (*) indicates significant effect on the water-stability of aggregates compared to the mean of the control (no irrigation – no mineral fertilizer combination) treatment in respective depth, within a pre-treatment shown by ANOVA at $p<0.05$. Statistical significance was determined at $p < 0.05$.

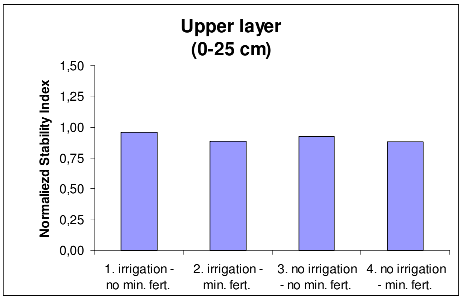

Figure 1.

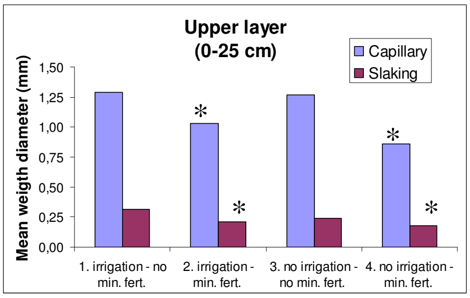

Figure 2.

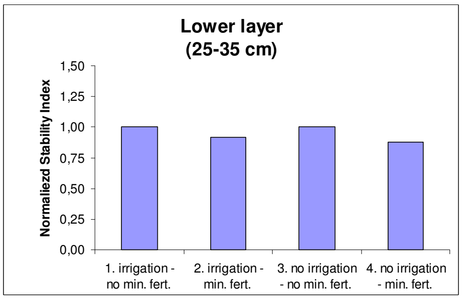

Figure 3.

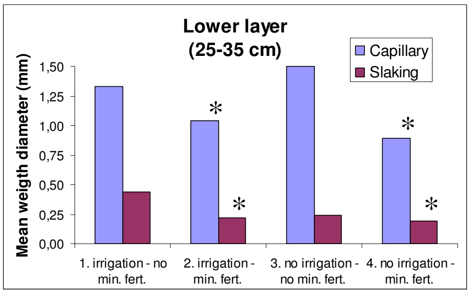

Figure 4.

Figure 1-4. Effect of irrigation and mineral fertilizer on soil structural stability characterized by the values of NSI and MWD

Tillage, in spite the aim to create optimal soil structure for plant growth, with soil management practices, irrigation and application of different kinds of fertilizers, often cause the decline of soil structure.

Too rapid wetting of surface soil layers by too intense irrigation may cause the slaking of soil aggregates, i.e. the decomposition of them into smaller particles (Emerson, 1977), mainly in the surface layer. In contrary, irrigation, by slaking the bigger and less water-stable aggregates into smaller clay particles, which clay particles build clay bridges and coatings on the outer surface of the remaining aggregates, and therefore stabilizing them; may cause the increasing of water-stability of aggregates (Attou et al., 1998). In our experiment, parallel with the results mentioned above, irrigation increased the stability of soil aggregates and therefore the values of NSI and MWD (Fig. 1-4.). This effect is significant in both soil layers, at the MWD-graphs (Fig. 2, 4). Other explanations might be for this phenomenon that as the less water-stable, bigger sized

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aggregate fractions slake into smaller fragments; their diameter increase in a high extent; or, the continuous wet condition of soil is favorable for microbial activity, which increases the biomass and therefore the gluing compounds produced by the microbes.
In the case of unfavorable conditions, low soil pH or low soil moisture content, ammonium fertilizers can have a soil structural disrupting effect. In the case of large accumulation of NH_4^+ ion, it acts as a dominant exchangeable cation, and like Na^+ it favors dispersion of colloids (Haynes et al., 1998). In our investigation, the addition of N fertilizer has decreased the values of NSI and MWD (Fig. 1-4.). This effect is significant in both soil layers, at the MWD-graphs (Fig. 2, 4.).

Conclusions

Tillage and soil management practices, like cultivation, irrigation and fertilization of soils may modify soil structure to a high extent. Irrigation in too intense application often causes slaking of soil structural units, and therefore may cause the decline of soil structure. In contrary, the loosening smaller (clay) particles produced by slaking of bigger aggregates, may stabilize the remaining aggregates; and irrigation therefore may increase water-stability and ameliorate soil structure as we observed in our experiment. The use of ammonium fertilizers in unfavorable conditions and high concentration, may cause disaggregating and therefore decline of soil structure as it was proved in our experiment. These soil structure modifying effects were assessed and proved by the Normalized Stability Index (NSI) and the Mean Weight Diameter (MWD).

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