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OPTIMIZING THE COHESION OF POND DAMS IN RELATION TO THE CONTENT OF ORGANIC MATTER IN THE SOIL

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Abstract

Soil organic carbon was monitored from 2013 to 2016 in two fishpond dikes of different variants of grass species composition: variant 1 – grass mix for extensively dry conditions, variant 2 – heavy duty grass mix, variant 3 – grass mix for intensively moist areas.
The monitored grass vegetation was mowed twice a year. In terms of texture, the dike of Pond Rohatec is composed of sandy soil, while the dike of Pond Podhorský consists of loam to clay-loam soils. As to soil structure, the most suitable variant on the Rohatec dike proved to be the mix for extensive drought, while the best variant on the Podhorský dike was the mix for heavy duty areas. The highest organic carbon (C_{org}) content has been found in the above-mentioned variants. It is obvious that C_{org} content and suitable grass mixture thus positively affect soil structure. The dike of Pond Rohatec showed higher humus quality than Pond Podhorský, which reflected the overall more favourable composition of the dike of Pond Rohatec. These results are important as to the protection of dikes against erosion effects and for faster growth of grass mixtures.

Keywords: structure coefficient, organic material, humus quality, grass mixtures, water erosion, soil properties, tractor mulcher

INTRODUCTION

Biotechnical stabilisation offers a cost-effective and attractive approach in stabilising slopes against erosion and shallow mass movement. Biotechnical stabilisation is characterised by combined or integrated use of live vegetation with retaining structures and revetments. Soil bioengineering primarily entails the use of plants and parts of live plants as such. Plant roots and stems serve as the main structural and mechanical elements in a slope protection system. These approaches capitalise on the advantages and benefits that vegetation represents in erosion control and slope protection and offset the limitations in the use of conventional slope plantings by themselves (Vrána and Beran, 2005).

After the establishment and the use of a pond dike is possible erosion effects caused by rainfall. For this reason, they stabilised the sandy slopes by seeding grass and legumes. Pohl and Vavrina (2008) also state that resistance of dikes to hydrodynamic effects of rainfall is based on functioning interaction of the sand core, cohesive layer, and turf cover. Zhan *et al.* (2007) mention that grass-covered slopes showed much higher water infiltration and lower surface runoff as compared to bare non-seeded slopes. Ambasht (2008) confirms that riparian vegetation is of high importance. It retains soil, water, and dissolved nutrients in river corridors and around lakes, mitigates eutrophication and related risks resulting in biochemical consumption of oxygen. Vegetated slopes are more resistant to mass movement and water erosion. Vegetation contributes to soil stability, especially by increasing the shear strength provided by roots (Barbosa and de Lima, 2013). Establishment of leguminous grasses may represent an effective and applicable measure to enhance the content of soil nutrients and prevent further soil degradation and erosion (Wang and Wang, 2013).

According to Janeček *et al.* (2012), occasional dike overflow is generally considered unfavourable and deserves particular attention. Clay soils of a dike body dry out when the reservoir is empty. As they dry out and shrink, continuous transverse cracks are formed. The technical measures adopted to mitigate these effects involve establishment of facing zones from cohesionless coarse-grain soils enhanced with humus and grass cover, and use of drainage carpets on the stream side of the dike to drive the water through the mentioned cracks.

For its characteristics of having long and strong roots, the Vetiver Grass is being effectively used in many countries to protect embankments and slopes. It is revealed from field tests that the shear strength of vetiver rooted soil matrix is higher than that of unreinforced soil. The soil reinforced with vetiver roots also shows ductile behaviour. It has been found that reinforcement with vetiver roots enhances the bearing capacity of the grounds and stabilises the embankment slopes (Islam and Shahin, 2013). Work of Panitnok e*t al.* (2013) showed that treatment with the Vetiver Grass could increase the content of organic matter and saturated hydraulic conductivity; however, the bulk density and soil hardness decreased, and the total porosity and available water-holding capacity were not affected.

As confirmed by Paluszek (1994), the content of organic matter in soil is essential for retaining the favourable soil structure, which reduces susceptibility of soils to water erosion. Interaction of organic matter with clay has a multitude of consequences that are reflected in the physical, chemical and biological properties of the matrix. These interactions often form "organo-mineral" complexes in soils. Most of these complexes serve to bridge soil particles together, thereby forming stable aggregates (Stevenson, 1994). Soil organic carbon is an important component of the global carbon cycle. Yet, it is rarely quantified adequately in terms of its spatial variability resulting from losses of soil organic carbon due to erosion by water.

The aim of the manuscript was to propose measures based on the methods of grass cover management on pond dams and the selection of a suitable composition of grass cover in relation to soil conditions, as an important factor in the stability of water reservoir dams.

MATERIALS AND METHODS

The evaluation was carried out between 2013 and 2016 on two locations in the Czech Republic: Pond Rohatec – Soboňky near Hodonín and Pond Podhorský – near Křižanov. Both locations are characterised by ruderal vegetation on the banks of the ponds which are not subject to any effective management or use.

Characteristics of the Monitored Sites

Pond Podhorský – is located in a Hercynian mesophytic area in a warmer part of the Bohemian-Moravian Highlands (Českomoravská vrchovina), i.e. a moderately warm and moderately humid climate at the elevation of 540 m a.s.l., in Žďár nad Sázavou district. The surroundings are formed by fields used for intensive agricultural production. The dike is made of stone riprap and an impervious core filled with individually established and compacted layers of soil and clay. As to grain size, the soil is classified as loam to clay-loam.

Pond Rohatec – the pond is situated in the Pannonian Thermophytic area in a warm climate of the Dolnomoravský úval Lowlands, moderately dry, at the altitude of 187 m a.s.l., Hodonín district. The pond is surrounded by non-native pine forests planted to mitigate sand drifts occurring in this area. In terms of texture the soil in the dike is classified as sandy.

Evaluation of Variants with Different Grass Mixes

Three different variants were established on the dikes, involving specific grass mixes with a potentially varied significance as to coherence of the dike. The mixtures were sown by hand in autumn at the beginning of the project solution. The amount of seed was given by the area of the dike given by the % of the individual components (see the individual variants below), (Kadlček *et al.*, 2020). The monitored grassland was cut twice a year with a small tractor. Grass mixtures were mown by usage tractor with mulch hydraulic arm equipment. Lateral stability was ensured with the tractor mulcher mounted on a hydraulic arm connected to the tractor using a 3 point hitch. The results of the tractor stability analysis were found with respect to the torque forces caused by the mulcher support arms weight and other present forces during its work operation (Bartoň *et al.*, 2017).

Variant 1 – grass mix for extensively dry conditions: 20% *Lolium perenne*, 40% *Festuca rubra*, 23% *Festuca ovina*, 15% *Poa pratensis*, 2% *Trifolium repens.*

Variant 2 – heavy duty grass mix: 38% *Lolium perenne*, 40% *Festuca arundinacea*, 20% *Poa pratensis*, 2% *Trifolium repens*.

Variant 3 – grass mix for intensively moist areas: 32% inter-genus hybrid of *Festuca*, 20% *Lolium perenne*, 25% *Phleum pratense*, 10% *Poa pratensis*, 10% *Trifolium pratense*, 3% *Trifolium repens.*

Sampling and Analytical Procedures

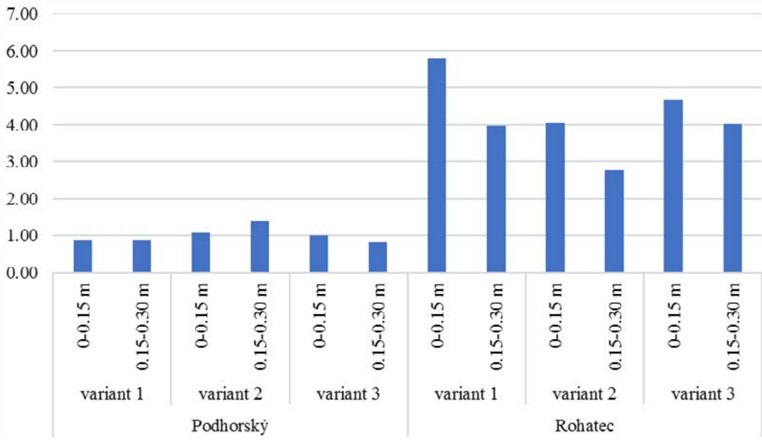
Soil samples for C_{org} and humus quality (humic acid HA/fulvic acid FA) were taken in spring (at the beginning of the growing season) and in autumn (at the end of the growing season). The soil structure was only evaluated in autumn as no significant changes are expected to occur during the year. In all cases, soil samples were taken from two depths, i.e. 0–0.15 m and 0.15–0.30 m in three replications. The total carbon content (C_{ox}) was determined using a redox titration method according to Nelson and Sommers (1982). The quality of humus was determined by defining its fractional composition (Kononová and Bělčiková, 1963). The soil structure was evaluated on the basis of the structure coefficient (SC), (which expresses the degree of destruction of soil structure) and of the ratio between agronomically valuable (0.25–0 mm) and less valuable (> 10 and < 0.25 mm) structural elements. The higher the structure coefficient means the better the soil structure. Lower SC value than 1 indicates poor soil structure. The results of the experiment were statistically processed using multi-factor analysis of variance and Tukey's test of simple contrasts. The statistical analysis was performed using the Statistica 12 programme.

RESULTS AND DISCUSSION

Soil structure (SC) is one of the most important soil properties and depends on the ability of soil particles to aggregate or disaggregate and create structural aggregates.

During the given years, the SC was always lower in the dike of Pond Podhorský and higher in the dike of Pond Rohatec (Fig. 1). When compared to other variants, the SC in the dike of Pond Podhorský was determined conclusively higher in variant 2 (heavy duty grass mix) (Tab. I and II). As to the depth of the soil profile, higher SC was determined in the depth of 0.15–0.30 m. In contrast, the dike of Pond Rohatec showed a conclusively higher SC in variant 1 (grass mix for extensively dry conditions) when compared to other variants (Tab. I and II). This dike always manifested a higher SC in the top soil layer (0.0–0.15 m). The values of SC correspond with the site conditions and composition of the dike.

Supply of organic matter in soil represents an important factor for maintaining favourable soil structure. The decisive role in the process of soil structure formation is attributed to active root systems of plants, which, along with their decayed root remains, directly or indirectly affect the formation of soil structure aggregates and their subsequent stability (Badalíková and Hrubý, 2006). The stability of soil structure represents an indicator of soil quality. According to Borůvka *et al.* (2002), the strongest influence on the coefficients of aggregate vulnerability to destruction was found as to fine silt content in three tests (fast wetting, slow wetting and drying, mechanical forces). The higher the fine silt content was, the more stable the aggregates were. In contrast, higher silt content increased aggregate vulnerability to destruction by fast wetting. A similar effect on aggregate vulnerability to destruction by



1: *Average values of SC on monitored sites (2013–2016)*

I: *Analysis of variance for SC (years 2013–2016)*

Site	Effect	d.f.	Mean square
Podhorský	Variant	2	0.96 ***
	Error	54	0.018 n. s.
Rohatec	Variant	2	13.52 ***
	Error	54	0.36 n.s.

*** P = 0.001; **P = 0.01; *P = 0.05; n.s. non-significant

II: *Tukey's HSD test of SC*

Site	Variant	Average
Podhorský	1	0.87 a
	2	1.23 b
	3	0.91 a
Rohatec	1	4.89 c
	2	3.41 a
	3	*4.35 b*

Note: Average values indicated by various letters are statistically different (P < 0.05)

mechanical forces was caused by higher content of very fine sand. There was a trend of increasing aggregate stability with increasing C_{org}.

Positive correlation between stability of soil aggregates and HA or FA concentration and their ratio was also demonstrated by Piccolo *et al.* (1997).

Organic Matter

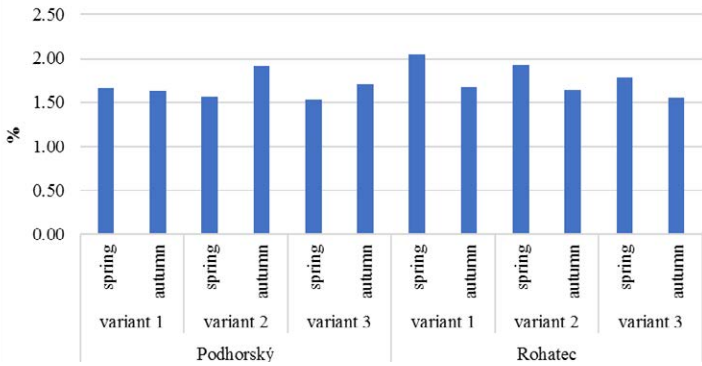
The content of OM in the soil on the monitored sites is shown in Fig. 2. It has been found that the highest content of C_{org} was, on average, in variant 2 in the dike of Pond Podhorský; nevertheless, the difference between individual variants was not conclusive (Tab. III and IV). The dike of Pond Rohatec showed the highest content of C_{org} in variant 1 with the only conclusive difference from variant 3 (Tab. III and IV). The content of humus thus correlated with the SC values. The dike of Pond Podhorský showed a very low content of C_{org} in its entire profile, while the values of C_{org} content in the dike of Pond Rohatec were determined as medium. Both sites manifested higher values at the beginning of the growing season.

It has been determined that common soils in the Czech Republic contain 1.5–7% of C_{org}, mostly 2–3%. The entire soil profile thus mostly contains 100–200 t/ha of humus. The material for humus formation and conditions for humification are significant indicators of the quality of organic matter.

Soil fertility is largely determined by the content and quality of soil organic matter. Detailed characterisation of humic acids structure confirmed that the chemical structure of humic acids depends on soil types (Barančíková, 2002).

Many physical soil characteristics (structural development, aggregate stability, cation exchange capacity, etc.) and chemical soil characteristics (e.g. nutrient pools, buffering, chelation, etc.) are modified to a certain degree by the influence of organic matter in the soil. It can be seen as resulting from the quality and quantity of organic material and the manner in which it is mixed and aggregated with mineral matter. Soil organic matter is also closely linked to soil biodiversity, providing a food source for microflora and microfauna. Additionally, the increasing recognition of the importance of the soil carbon pool within the Terrestrial Carbon Pool has further emphasised the importance of soil organic matter. The perception of soil organic matter is generally positive and is often considered as a major determinant of the health and quality of soil (Doran *et al.*, 1996; Badalikova *et al.*, 2020; Prudil *et al.*, 2021).

The levels of carbon in humic and fulvic acids may increase or decrease according to the cultivated crop. The content of organic carbon in soil then depends on the site conditions and enzyme activity. The increase in organic carbon content in soils of buffer zones (including fishpond dikes) resulted in favourable changes in monitored enzyme activity (Bielińska and Futa, 2016). This also enhances the quality of organic matter, i.e. humus.



2: *Average values of C_{org} (%) on monitored sites (2013–2016)*

III: *Analysis of variance for C_{org} (years 2013–2016)*

Site	Effect	d.f.	Mean square
Podhorský	Variant	2	0.10 n.s.
	Error	54	0.03 n. s.
Rohatec	Variant	2	0.23 **
	Error	54	0.04 n.s.

*** P = 0.001; **P = 0.01; *P = 0.05; n.s. non-significant

IV: *Tukey's HSD test of C_{org}*

Site	Variant	Average
Podhorský	1	1.65 a
	2	1.74 a
	3	1.62 a
Rohatec	1	1.86 b
	2	1.79 ab
	3	1.67 a

Note: Average values indicated by various letters are statistically different (P < 0.05)

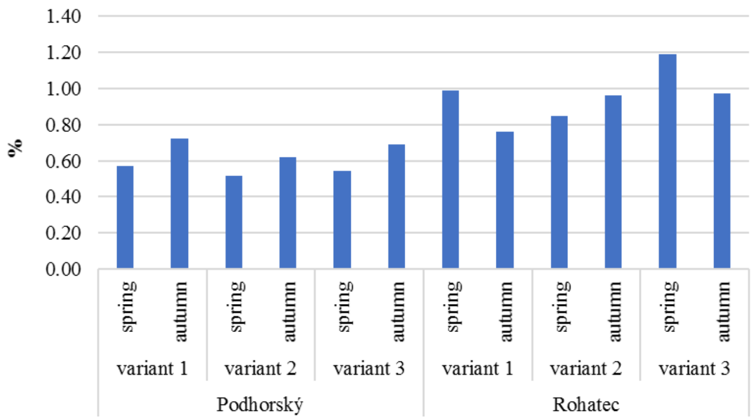
Quality of Humus

While evaluating the quality of humus, emphasis is placed on the humic-fulvic acid ratio (HA/FA). The more the humic acids prevail, the higher the quality of humus is. One of the most important items of soil science is soil organic matter and its quality. Fertility of arable soils is widely defined by the humus quality (Pospíšilová *et al.*, 2006). According to Stevenson (1982), humic acids are product of the most efficient humification processes. Their composition is influenced by the quality of OM, conditions for humification, the soil type, and whether they are partially soluble in water or not.

Tab. III depicts the results of analysis of humus quality as to the ratio of humic and fulvic acids. It demonstrates that the quality of humus in all three variants at the site of Pond Podhorský was much inferior (below 1) to the one at the site of Pond Rohatec. It was ascertained that the best HA/FA ratio was on average in variant 1 at the dike of Pond Podhorský, the difference being conclusive only against variant 2 (Fig. 3). As opposed to other variants, the dike of Pond Rohatec showed a conclusively higher HA-FA ratio in variant 3 (Tab. V and VI). Better humus quality was determined on both sites in spring. This is given by more intense microbial activity and more favourable weather conditions.

The quantity and quality of soil organic matter affect physical, chemical, and biological soil properties, and are pivotal to productive and healthy grasslands (Lehtinen *et al.*, 2015). In field studies on effects of humic substances on soil structure, Mbagwu and Piccolo (1989) found that application of four rates of humic substances to a series of soils representing a wide range of physical properties greatly enhanced soil aggregation. Aggregate stability was found to be increasing with growing rates of humic acid application. Higher application rates induced stabilities that were significantly higher than those found for the controls. Soils originally exhibiting low aggregate stability was improved to a greater extent in response to HA additions.

Humus quality is affected not only by the volume of organic matter left in soil and the crop or any other growing vegetation, but also by a number of other factors, such as soil adsorption complex, conductivity, or nutrient content. These findings corresponded with results of Jerzykiewicz *et al.* (2016) state that the quality of humus also changes based on soil reaction.



3: *Average values of HA/FA (%) on monitored sites (2013–2016)*

V: *Analysis of variance for HA/FA (years 2013–2016)*

Site	Effect	d.f.	Mean square
Podhorský	Variant	2	0.04 ***
	Error	54	0.002 n. s.
Rohatec	Variant	2 0.30 **	
	Error	54	0.04 n. s.

*** P = 0.001; **P = 0.01; *P = 0.05; n.s. non-significant

VI: *Tukey's HSD test of HA/FA*

Site	Variant	Average
Podhorský	1	0.65 a
	2	0.57 b
	3	0.62 a
Rohatec	1	0.88 a
	2	0.91 a
	3	1.08 b

Note: Average values indicated by various letters are statistically different (P < 0.05)

CONCLUSION

The acquired results show that variant 2 (heavy duty grass mix) on the dike of Pond Podhorský manifested a conclusive improvement in soil structure. In addition, the C_{org} content was higher than in any other grass mix. The quality of OM (humus) was higher in the grass mix for extensively dry conditions (variant 1). At the dike of Pond Rohatec, the conclusively highest quality of soil structure and the highest C_{org} content against other grass mixes was proven in the grass mix for extensively dry conditions (variant 1). A sufficient increase in above-ground grass biomass guarantees a higher growth of the root system and thus an increase in organic material in the soil. This improves the soil structure, which guarantees the strengthening of the dams. Humus demonstrated higher quality in the grass mix for intensively moist areas (variant 3).

The results reflect the grain-size composition of the dikes and the weather conditions. Based on the above mentioned results, it may be stated that choosing appropriate grass mix for a given site is essential in order to retain favourable conditions for the growth of plants and to prevent damage to dike. The higher Corg content in the soil showed higher cohesion of the pond dikes because there was no soil leaching.

From the point of view of practical recommendations for grass on pond banks, it is advisable to choose more types of grasses and clovers. Their growth success varies according to the location and climatic conditions.

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