Removing Soil Compaction by Deep Grouting

Luboš Sedlák[1,2], Lubica Pospíšilová[1,2], Aleš Kučera[2], Jakub Prudil[1,3], Vlastimil Skoták[2], Radomír Ulrich[4], Michal Rábek[5]

[1]Department of Agrochemistry, Soil Science, Microbiology and Plant Nutrition, Faculty of AgriSciences, Mendel University in Brno, Zemědělská 1665/1, 613 00 Brno, Czech Republic
[2]Department of Geology and Soil Science, Faculty of Forestry and Wood Technology, Mendel University in Brno, Zemědělská 1665/1, 613 00 Brno, Czech Republic
[3]Agricultural Research, Ltd. Troubsko, Zahradní 1, 66 441 Troubsko, Czech Republic
[4]Department of Engineering, Faculty of Forestry and Wood Technology, Mendel University in Brno, Zemědělská 1665/1, 613 00 Brno, Czech Republic
[5]Department of Agrosystems and Bioclimatology, Faculty of AgriSciences, Mendel University in Brno, Zemědělská 1665/1, 613 00 Brno, Czech Republic

Abstract

Soil compaction causes many serious problems in agriculture and the environment. Mainly improper intensive farming, heavy machinery, and reduced organic fertilizer supplements increase soil ocompaction. It results in the compression of pores and impedes root growth, disturbing water and air transport, and yield decreases. The issue of soil quality and health cannot be solved without the determination of the soil's physical parameters and penetration resistance. The study aims at the reduction of soil compaction using three technologies of deep grouting: (1) the control site; (2) the Vogt Geo Injector; (3) the Vogt Geo Injector enriched Diatomaceous earth; (4) the tractor with air injector. The soil injection was done with high-pressure air at 8,5 bar (123psi) and penetration resistance was registered by the electronic penetrologger Eijkelkamp 06.15.SA with GPS localization. The distances from the drilling point were: 0.10 m, 0.40 m, 0.70 m and 1 m. It was supposed, that after amending soil with Diatomaceous earth, voids were filled with low decomposable material, which improves the effectivity of injections. The obtained results showed that using the Vogt Geo Injector enriched with Diatomaceous earth gave the lowest values of soil penetration resistance. In both variants, the Vogt Geo injector decompaction area was about 1 m^2 from the drilling point to a depth of 1 m. In both variants, the Vogt Geo injector decompaction area was about 1 m^2 from the drilling point. The drilling depth was 0.80 m and the maximum effect of grouting was approximately 0.40 m.

Keywords: *soil compaction, high-pressure injection, penetration resistance*

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1 Introduction

Soils are exposed to a wide range of exogenous factors, which can have a positive or negative effect on their properties. One of the negative factors is soil compaction, which means that the density of the soil increases when it is compressed. Globally, around 68 million ha of agricultural land has been compacted (Flowers and Lal, 1998). In other words, the soil becomes denser, when the pores are compressed (Smith *et al.*,1997; Bedrna, 2002). Soil compaction is a natural process (e.g. heavy textured soils), which can be accelerated by farming systems, agrotechnical measures, cropping and tillage systems. These are critical factors for soil compaction (Javůrek and Vach, 2008). A direct correlation between soil compaction and texture was reported by Byrd and Cassel (1980). Soil compaction can be easily and rapidly measured and the penetration resistance is registered. The relationships between soil compaction levels and penetration resistance have been described in many studies (e.g. Grunwald *et al.*, 2001; Ferrero *et al.*, 2005; Dexter *et al.*, 2007; Usowicz and Lipiec, 2009; Liu *et al.*, 2022). Furthermore, the penetration resistance was the essential variable in developing water, air and heat pedotransfer functions (Usowicz *et al.*, 2006; Usowicz and Lipiec, 2009). Besides agriculture, penetration resistance is important in civil engineering for assessing the accessibility of construction sites. A high level of soil resistance to penetration can prove to be essential for the foundation of buildings. According to Hakansson *et al.* (1988) and Whalley *et al.* (1995), soil compaction affects nearly all the soil properties and functions of the soil. Therefore, the identification of factors affecting soil compaction is important for evaluating soil quality, rooting depth, trafficability, and timing of tillage operations. Compaction increases the mechanical resistance of the soil by pressing soil particles more closely together resulting in root growth being restricted. On the other hand, decreases in the number and size of large pores (macropores) disturb both air and water soil regimes. As a result, there are fewer pores with a diameter larger than roots in which the roots can grow freely, without mechanical resistance. To avoid soil compaction, it is important to employ remedial measures including drainage, supplying organic materials, improving soil structure, liming, keeping the soil covered with vegetation, and other agrotechnical measures. The most important consideration is to avoid tillage when the soil is too wet. A dry soil has greater bearing capacity for loads, while a wet soil is compressed under a similar pressure. Having a large contact area with the help of broad tyres or dual wheels results in a lower wheel load and it is also connected with higher financial costs of soil cultivation and the soil vulnerability to erosion increases as well (Batey, 2009; Keller et al., 2019; Polcar *et al.*, 2021).

The preliminary study aims at the evaluation of soil compaction and reduction of penetration resistance using three technologies of deep grouting: (1) the control site; (2) the Vogt Geo Injector; (3) the Vogt Geo Injector enriched Diatomaceous earth; (4) the tractor with air injector.

2 Material and methods

A field experiment with various treatments of deep grouting was carried out on a Haplic Luvisol near the village of Zbýšov, southern Moravia (Czech Republic). The soil was clayic textured (clay 58%; silt 37%; sand 5%), with low organic matter content 1.42% (w/w). The research area has rather uniform soils to genesis and textural composition, with gradual increasing of clay content is a depth – see Tab 1. The other basic properties of the study soil are given in Tab. 1. The experiment was done in May 2024 on the plot used as arable soil for crop cultivation with localisation at N: 49.14523; E:16.35890, and altitude 348 m a.s.l. Soil samples were collected from a depth of 0–0.20 m; 0.20–0.40 m; and 0.40–0.60 m with a probe. An average sample was composed of 5–10 individual punctures. Standard analytical methods were used to determine total carbon content, texture, moisture, and soil pH (Pospíšilová *et al.*, 2016).

Depth (m)	pH/KCl	TOC (%)	Clay (<2µm) (%)	Silt (50-2 µm) (%)	Sand (2000-50 µm) (%)	Moisture (weight %)
0–0.20	7.01	1.42	58	37	5	23.7
0.20–0.40	6.84	< 1	66	29	5	20.7
0.40–0.60	7.01	< 0.5	60	33	7	17.2

Tab. 1 *Basic soil properties – average values*

The resistance to penetration was registered by the electronic penetrologger Eijkelkamp 06.15. SA (Royal Eijkelkamp, the Netherlands). Penetrologger parameters were as follows: the cone base area 2 cm^2; angle 60 deg.; and penetration speed 2 cm/sec. The following technologies of deep grouting were studied: (1) the control site; (2) the Vogt Geo Injector; (3) the Vogt Geo Injector enriched Diatomaceous earth; (4) the tractor with air injector The measurements distances from the drilling point were as follows: 0.10 m, 0.40 m, 0.70 m. The drilling depth was 0.80 m. The number of replicate measurements depends on the accuracy required and on the natural variability of the soil. Campbell and O'Sullivan (1991) recommend 10 measurements per plot. The distance between the plots is minimally 50–60 cm given possible soil deformation resulting from the insertion of the cone. In our case, 16 replications per plot were taken in the north-easterly direction (8 replications) and south-westerly direction (8 replications).

3 Results

Results of the soil penetration resistance (PR) in studied variants are documented in Fig. 1 and Fig. 2. The character of PR curves is very similar and can be described as linear till the depth of 0.40 m. Generally, the measured PR values varied between 1.036 and 3.149 MPa within the soil profile. The lowest PR values were after the application of the Vogt Geo Injector enriched Diatomaceous earth. In the upper horizon (0–0.20 m) the measured PR value is less than 1.50 MPa. These findings can be interpreted as the favourable conditions for uninterrupted root growth. PR values at about 2 MPa and higher were registered at 0.30–0.40 m depth. According to Sáňka *et al.* (2008), these conditions are unfavourable for root growth. Measured

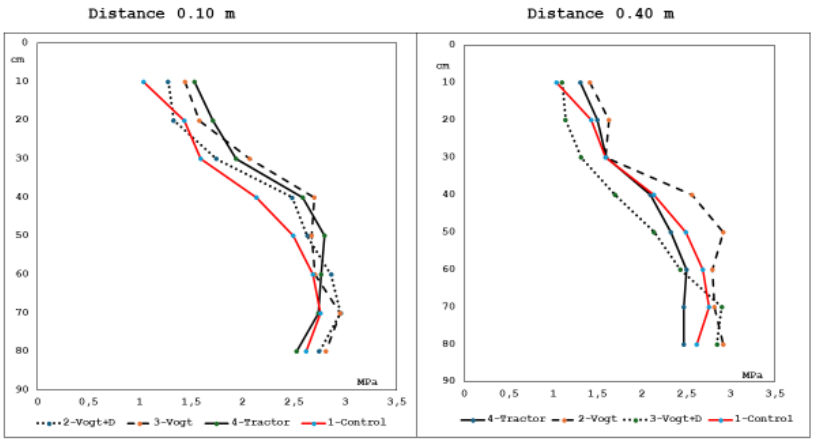

Fig. 1: *Penetrogram at 0.10 m and 0.40 m from a drilling point*

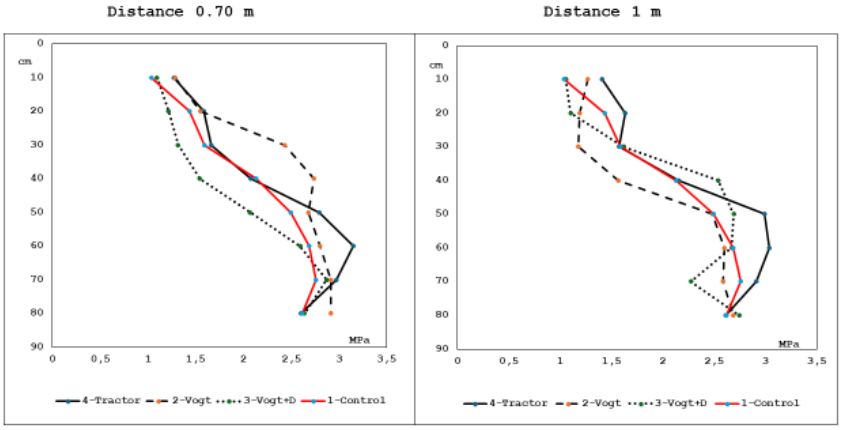

Fig. 2: *Penetrogram at 0.70 m and 1 m from a drilling point*

PR values were evaluated as high. Approximately 3 MPa can be regarded as the upper limit for uninterrupted root growth. This value was registered in a depth of more than 0.50 m. The obtained results are preliminary, and the research will continue. However, the decreasing tendency of PR after deep grouting is evident. Especially, the variant with Diatomaceous earth enrichment showed promising results at all studied distances from a drilling point. Further research is necessary to study the effect of aeration on PR values and the measurements before, during and after vegetation periods are recommended

4 Discussion

Knowledge of the spatial distribution of the penetration resistance after deep grouting can help identify zones with soil compaction (strength) problems and develop management options that minimize crop production risks and the harmful impact of traffic on the environment. As quoted by Usowicz and Lipiec (2009) and Liu *et al.* (2022) soil penetration resistance data are valuable mainly in precision agriculture to establish adequate management measures. The obtained results indicated that PR values are too high, and this level of soil resistance may cause many problems in the studied locality. A depth of about 0.20 m is insufficient for the root growth and the yield will be negatively affected. Interrupted root growth leads to reduced water and nutrient absorption, and ultimately to reduced crop production. Similarly, Locher & De Bakker (1990) stated that PR less than 1.5 MPa in the upper horizon (0–0.30 m) is desirable. Too much compaction may hinder the rootage of crops or the supply of oxygen for soil biota and roots. Too low PR level, on the other hand, renders insufficient bearing capacity to carry the weight of heavy machinery or other agricultural implements. In this study, a value of 3 MPa was registered at a depth of 0.60 m. This study represents preliminary results and further research is necessary to understand the effect of aeration on PR values.

5 Summary

Improper intensive farming, heavy machinery, and reduced organic fertilizer supplements increase soil compaction. It results in the compression of pores and impedes root growth, disturbing water and air transport, and yield decreases. Soil compaction causes many serious problems in agriculture and the environment. In this study, various treatments of deep grouting were performed on a Haplic Luvisol to reduce compaction, improve porosity, water, and air regime. The soil was clayic textured, with low organic matter conten 1.42% (w/w). The research area has rather uniform soils concerning genesis and textural composition. Three technologies of deep grouting were studied: (1) the control site; (2) the Vogt Geo Injector; (3) the Vogt Geo Injector enriched Diatomaceous earth; (4) the tractor with air injector. The soil injection was done with high-pressure air at 8,5 bar (123psi) and penetration resistance was registered by the electronic penetrologger Eijkelkamp 06.15.SA with GPS localization. The distances from the drilling point were: 0.10 m, 0.40 m, 0.70 m and 1 m. Measurements were done in May 2024 on the plot used as arable soil for crop cultivation with localization at N: 49.14523; E:16.35890, and altitude 348 m a.s.l. Soil samples were collected from a depth of 0–0.20 m; 0.20–0.40 m; and 0.40–0.60 m with a probe. An average sample was composed of 5–10 individual punctures. Standard analytical methods were used to determine total carbon content, texture, moisture, and soil pH. The obtained results showed that using the Vogt Geo Injector enriched with Diatomaceous earth gave the lowest values of soil penetration resistance. In both variants, the Vogt Geo injector decompaction area was about 1 m^2 from the drilling point. The drilling depth was 0.80 m and the maximum effect of grouting was approximately 0.40 m.

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Contact information

Luboš Sedlák: e-mail: lubos.sedlak@mendelu.cz