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Influence of simulated traffic and roots of turfgrass species on soil pore characteristics

Tomasz Głąb [a,*], Wojciech Szewczyk [b]

[a] Institute of Machinery Exploitation, Ergonomics and Production Processes, University of Agriculture in Krakow, ul. Balicka 116B, 31-149 Krakow, Poland
[b] Institute of Plant Production, University of Agriculture in Krakow, Poland

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ABSTRACT

A field experiment was conducted during the period of 2011 to 2012 to study the effect of traffic on physical properties of soil when different turfgrass species were cultivated. Experimental plots were established with three replications in a split-plot design with species as a main plot and traffic treatment as a subplot. The traffic treatment was applied to the turfgrass using Brinkman traffic simulator (BTS). Two levels of treatments were applied: non-trafficked vs. trafficked. Four grass species were used, *Festuca arundinacea*, *Festuca rubra*, *Poa pratensis* and *Lolium perenne*. The BTS compaction was applied every week since the beginning of April to the end of November. Physical parameters of soil, bulk density, total porosity and penetration resistance were determined. Based on the water retention characteristic curve, the pore size distribution, available water content (AWC), productive water content (PWC) and relative water capacity (RWC) were calculated. Root parameters like length density (RLD) and dry matter (RDM) were determined as well.

Both experimental factors, grass species and BTS compaction, changed soil physical parameters, penetration resistance, bulk density and total porosity. These changes were results of modification of pore system. Large pores were modified by grass species and BTS compaction. However, storage pores of 0.5–50 μm in diameter were affected only by grass roots. This reflected in the water retention characteristics of the soil. The RWC ratio indicated poor water conditions prevailing in the soil except trafficked two grass species, namely *F. arundinacea* and *L. perenne*. The highest water retention in the range of the AWC was noticed for *F. arundinacea* (0.191 $cm^3\ cm^{-3}$) and for *L. perenne* (0.187 $cm^3\ cm^{-3}$). Significantly lower AWC was recorded for *F. rubra* and *P. pratensis*, 0.151 and 0.141 $cm^3\ cm^{-3}$, respectively. The similar relationship was also observed for the PWC. It was found that changes in the AWC and PWC can be explained by the root parameters. The higher root biomass concentration in the soil had a beneficial effect on the soil water retention. It can be concluded that *F. arundinacea* and *L. perenne* can be recommended for turfgrasses with irrigation system where the water resources are limited.

1. Introduction

Irrigation is an important and integral part of the sport turfgrass management, which is necessary to keep the high quality playing surfaces. Nowadays the water availability for irrigation purposes becomes an increasing problem in light of growing scarcity and rising costs of water. So it is observed that the need for more efficient use of water by turfgrass managers arises. To manage adequately irrigation scheduling, timing of irrigation and the amount of water, it is important to know the water retention characteristics of the different soil layers, particularly rootzone (Dane et al., 2006).

The typical soil profile under sport turfgrass contains sand-enriched rootzone laying on a coarse-textured sand or gravel. The principal motivation for the use of the high sand content rootzone is to resist soil compaction from frequent foot traffic. It is in contradiction with the main function of rootzone which is to store water and nutrients (McCoy and McCoy, 2009). It is widely recognized that volume of water retained in soil profile is correlated with particle size distribution, bulk density and organic matter content (Grosbellet et al., 2011; Nasta et al., 2009; Walczak et al., 2006). Texture is the most important factor which determines water retention characteristics. Generally, the coarse structured soil with lower clay content is characterized by lower water retention (Nasta et al., 2009). Thus, the sand-based system is characterized by lack of water retention and nutrient holding capacity necessary for healthy turf growth. It is commonly known that soil organic matter content can modify water retention. According to Rawls et al. (2003) the soil water content at high water potential is affected more strongly by the organic carbon than water content at low water potential. Water retention of soils with coarse texture is substantially more sensitive

* Corresponding author. Tel.: +48 12 662 45 51.
E-mail address: rtglab@cyf-kr.edu.pl (T. Głąb).

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to the amount of organic carbon as compared with fine-textured soils. To improve the volume of water retained in the soil mixture at the sport turfgrass it is recommended to add more organic matter such as sphagnum peat moss (Bigelow et al., 2004) or composted sewage sludge (Cheng et al., 2007). The second recommendation is to use inorganic amendments with silt and clay texture (Li et al., 2000). A combination of these two options is also proposed to apply (Shao-Hua et al., 2012). Andry et al. (2012) reported that hydrophilic polymers are capable of retaining additional water and increases the amount of available moisture in the rootzone, thus permitting longer intervals between irrigations.

The different turf species and their genotypes varied in their water requirement and drought resistance. This is the result of morphological, anatomical and physiological adaptations to limited soil water resources. Carrow (1996) reported that drought resistance of *Festuca arundinacea* was the result of high root length density in the deeper rootzone and the ability to maintain evapotranspiration as the soil dries. Zhou et al. (2013) suggested that superior drought resistance of *Cynodon* spp. genotypes was correlated with a lower stomatal conductance. Carrow (2006) concluded that the water conservation strategies should include not only soil mixture, variety selection, but also irrigation system, turf management, and traffic intensity.

Traffic is widely recognized as an important abiotic stress that can impose two distinct forms of injury that occur on sport turf (Shearman, 2006). The first form is a wear injury to shoot tissue, mainly leaf tissues, that results in the reduction of photosynthesis. It is usually followed by susceptibility to insects and fungal diseases and increased weed pressure (Martiniello, 2007). The second type of traffic damage to turf is the soil compaction that can influence the root system growth (Trenholm et al., 2000). Soil compaction increases mechanical impedance, creates unfavorable growing conditions for roots and restricts oxygen, water and nutrients supply (Chen and Weil, 2010; Głąb and Kopeć, 2009). Strongly compacted soils are usually penetrated by roots in cracks, fissures and biopores (macropores formed by earthworms). This provides advantage to elongating roots but also results in a heterogeneous root distribution. However, changes in root system appearance do not necessarily cause an alteration in above-ground growth or yield (Kristoffersen and Riley, 2005). Researchers reported that a common response of the root system on increasing bulk density is to decrease its length and concentration roots in the upper soil layer (Lipiec et al., 1991, 2003). Previous studies conducted by Głąb (2013) and Głąb and Kopeć (2009) also confirmed this trend for *Festuca pratensis* and *Poa pratensis*. Sometimes the positive correlation between soil density and roots characteristics was observed, particularly for perennial crops (Cannell and Hawes, 1994; Schoonderbeek and Schoute, 1994). In the investigation with *F. arundinacea* the soil compaction increased the dry matter, length of roots and their diameter (Głąb, 2007). Furthermore, sometimes the bilateral interaction was observed in soil–root relationship. Głąb (2005) in his previous research found that the roots of perennial plants, especially legumes, can positively influence the physical properties of strongly compacted soils. Therefore, the relationships between soil physical properties and turfgrass root subjected to traffic compaction needs further investigation.

We hypothesize that the soil compaction and roots of turfgrass affect the soil pore system. The objective of this study was to determine the effect of traffic simulation on water retention characteristic of soil under turfgrass when different grass species were used. Knowledge of the relation between water retention properties, soil compaction and grass species will be useful for turfgrass management in the irrigation point of view.

2. Methods

2.1. Experimental design

This study was conducted as a field experiment located at the Krakow Valley Golf & Country Club near Krakow, south of Poland (50°10′N, 19°39′E, 440 m a.s.l.) over a two-year period, 2011–2012. The climate of the experimental site is temperate-continental. The average annual precipitation reaches 881 mm per year and mean daily temperature of 7.7 °C.

The experiment was established on the 15 cm soil mixture as a rootzone with a loamy sand texture (81% sand, 14% silt and 5% clay). The plots were mowed three times per week at a height of 25 mm, with clippings returned, using a Jacobsen triplex mower (Ransomes Jacobsen Ltd., Ipswich, Suffolk, UK). Automatic irrigation system (Perrot, Althengstett, Germany) was installed before grass sowing. The system was based on soil moisture measurements with the setpoint of 75% of the water content at field capacity. Turf was fertilized with 250 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1} and 120 kg K_2O ha^{-1} per year.

Experimental plots were established with three replications in a split-plot design with species as a main plot and traffic treatment as a subplot. The area of the subplot was 1 m^2. Two levels of the treatments were applied: non-trafficked vs. trafficked. Four grass species used were: *F. arundinacea* Schreb. cv. Barleroy, *Festuca rubra* L. spp. *commutata* Gaud cv. Bargreen II, *P. pratensis* L. cv. Limousine and *Lolium perenne* L. cv. Bargold. The seedbed was prepared and grass varieties were sown in 2010 to establish the turfgrass.

Traffic treatments were applied as a strip within replicates using Brinkman traffic simulator (BTS). The BTS weighed 336 kg and had two heavy, studded rollers geared to move at different speeds and impose both compactive and tearing forces on the turf. The BTS is a type of traffic simulator that is used widely in the United States as a sports field traffic simulator (Cockerham and Brinkman, 1989). The traffic simulated by the BTS is uniform and reproducible, similar to natural wear, and can cover a large area in reasonable short time. Each roller had a 29.2 cm diameter and was 100 cm wide. The BTS produced the unit pressure of 33.6 kPa. The traffic simulation consisted of six passes per week. Traffic treatments were applied every year since the beginning of April to the end of November.

2.2. Sampling and measurements

Dry bulk density (BD) was measured by taking samples of soil using metal cylinders of approximately 100 cm^3 volume (5.02 cm diameter and 5.05 cm length) with six replicated samples taken from each plot. The samples were collected from the 0–15 cm soil layer. The core samples were collected there in October 2011 and 2012. The samples were weighed and dried (105 °C) until they reached a constant weight. Total porosity (TP) was calculated on the basis of results of particle density (PD) and bulk density (BD). The PD was determined using pycnometric method. The mean value of the PD was 2.648 g cm^{-3} in the 0–15 cm soil layer.

A soil cone penetrograph (STIBOKA, Eijkelkamp Agrisearch Equipments, Giesbeek, The Netherlands) with a base area of 100 mm^2 and 60° cone angle was used to make measurements of the penetration resistance (PR). The PR was measured in October 2011 and 2012. The penetrograph was inserted at an approximately constant insertion rate of 20 mm s^{-1} throughout the depth of 0–15 cm. The PR was measured at the soil moisture corresponded with the field water capacity (0.27 cm^3 cm^{-3}). We use a portable probe with an ECH2O EC5 sensor (Decagon Devices, Pullman, Washington, USA) to measure soil moisture during the PR measurements. At the beginning of the experiment the probe was calibrated for the trial site using the gravimetric samples.

The soil moisture characteristic curve was determined in pressure chambers with ceramic plates according to Richards' method (Klute and Dirksen, 1986). The undisturbed soil samples were collected using metal cylinders of 100 cm^3 capacity in six replications for every plot. The soil samples were placed in the pressure chambers and seven different water levels were set (−3.9, −15.6, −33.0, −77.9, −195.7, −491.7 and −1554.8 kPa).

The equilibrium was determined in the extractor using the burette system for measuring the outflow water capacity. The soil water