Assessment of Soil-Amendment Mixtures for Subsurface Drip Irrigation Systems

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Abstract

Subsurface drip irrigation (SDI) is the most water saving irrigation system. Inorganic soil amendments (IA) emplaced around the irrigation tubes can increase the water retention potential and might reduce the loss of water due to leaching. We analysed mixtures of sand for golf putting green construction and IA additions up to 10 mass percent by measuring their water retention in soil cores and modeling soil water storage and drainage under a reaslistic water application schedule. A simulation of the soil water dynamics was used to assess the effect of IA in terms of irrigation water conservation and drainage losses. Two different climatic situations, represented by climatic data of Brussels, Belgium (humid) and Cordoba, Spain (arid) were compared in the simulation. The irrigation schedules for each location with respect to the soil amendment were calculated employing a deficit-based protocol.

The addition of IA increased the available water capacity and resulted in a significant reduction of scheduled irrigation events and also a reduction of annual irrigation water requirements and water loss due to drainage for both climatic conditions. The observed water saving effect was larger for humid climatic conditions. Thus, the combination of subsurface drip irrigation with IA addition leads to additional water saving for irrigation on golf putting greens.

Key Words

Subsurface drip irrigation, inorganic soil amendment, simulation, deficit irrigation

Introduction

In times of increasing droughts and water shortages effective irrigation systems become more important. Regarding the losses by evaporation subsurface drip irrigation (SDI) is the most water saving irrigation system. Nevertheless, especially in sandy soils with low natural water holding capacity, the loss of water and nutrients due to leaching is still a serious disadvantage. Inorganic soil amendments (IA) emplaced around the irrigation tubes might increase the water retention potential.

In the present case study we assessed the potential of IA addition to reduce irrigation water requirements using SDI on golf putting greens. We compared the effect for humid and arid climatic conditions, represented by Brussels, Belgium and Cordoba, Spain, respectively. We used a numerical simulation of the soil water dynamics to evaluate the potential reduction of irrigation water requirements and the losses due to drainage.

Methods

Sand as proposed by the United States Golf Association (USGA) for golf putting green construction was mixed with an IA consisting of bentonite, silica gel, and volcanic tuff. Soil-amendment mixtures in a range between 0–10 mass percent were put in 200 cm^3 steel cores for analysis with three replicates. The saturated hydraulic conductivity K_s was measured using the falling head method. The water retention curves $\theta(h)$ were determined using a capillarimeter with pressure heads up to −150 cm. The parameters of the lognormal retention model of Kosugi (1994) were fitted to the data using RETC (US Salinity Laboratory; Fig. 1). Daily climatic data for Brussels (Belgium) and Cordoba (Spain) were available from the United Nations Food and Agriculture Organization (FAO) for 1990 and 1986, respectively. AquaCrop 3.0 (FAO) was used to calculate an irrigation schedule for each location employing a deficit-based protocol (Allen *et al.* 1998). The Richards' equation (1931) was solved numerically using HYDRUS 2D/3D (Šimunek *et al.* 2006). Simulations were done for both locations with hydraulic properties of pure sand and 10 mass percent IA addition for one year. The 2D model geometry consisted of an upper rootzone layer (width: 100 cm, depth: 40 cm) and a lower gravel layer for drainage (depth: 15 cm). Two irrigation pipes with an diameter of 1 cm were implemented with a lateral distance of 50 cm in a depth of 30 cm. The upper boundary condition accounted for precipitation and evaporation. Turf grass transpiration was implemented as sink term according to Feddes *et al*. (2001). The lower boundary was set to a free drainage condition and the lateral boundaries were set to no-flux.

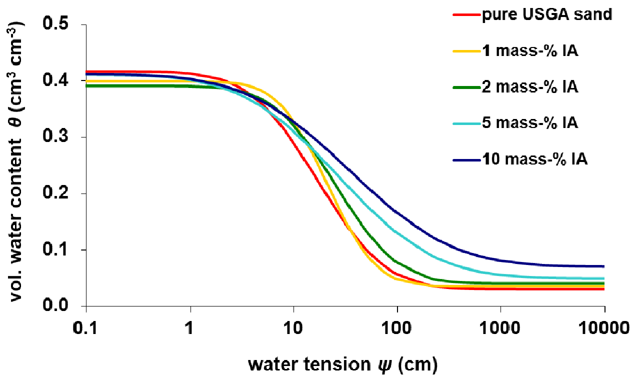

Figure 1. Water retention curves for USGA-conforming sand with different amounts of inorganic soil amendment (IA).

Results and Discussion

The addition of IA increased the available water capacitiy from 120 mm/m for pure sand up to 210 mm/m for 10 mass percent IA (Figure 1). The simulation revealed a significant reduction of scheduled irrigation events and also a reduction of annual irrigation water requirements and water loss due to drainage for humid and arid climatic conditions (Table 1, Figure 2). However, the observed water saving effect was larger for humid climatic conditions. This can be explained by a greater probability of precipitation events to replenish the available water capacity. These results are in agreement with McCoy and McCoy (2005). Nevertheless, the addition of 10 mass percent AI within a thickness of 40 cm might be very cost-intensive and need to be assessed in terms of its cost-benefit ratio in future investigations.

Table 1. Summary of the simulation results. The results base on climatic conditions as provided by the FAO (Brussels: 1990, Cordoba: 1986).

simulation result	Brussels	Cordoba
irrigation events for pure USGA-conform sand	68	225
irrigation events for sand + 10 mass-% amendment	61	177
reduction of irrigation events (%)	10.3	21.3
reduction of irrigation water requirement (%)	6.0	3.5
reduction of water loss due to deep drainage (%)	4.9	3.5

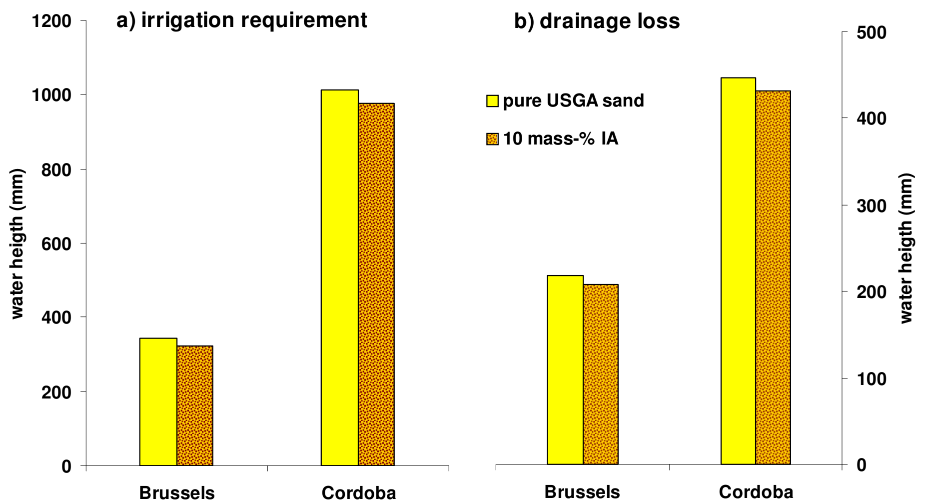

Figure 2. Results of the study. a) Calculated annual water requirement for irrigation. b) Water loss due to deep drainage. The results are on basis of the climatic data provided by the FAO (Brussels: 1990, Cordoba: 1986).

Conclusion and Perspective

The combination of subsurface drip irrigation with IA addition leads to additional water saving for irrigation on golf putting greens. The magnitude of water conservation depends on the climatic conditions and is higher for humid conditions than in arid areas.

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