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Root growth of turfgrass grown on amended sand-based profiles

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Zusammenfassung

Die Rasengräser gehören zu den flachwurzelnden Pflanzenarten und sind daher anfällig auf Dürreerscheinungen. Der Bodenwassermangel beeinflusst die Transpiration, das Pflanzenwachstum als auch die ästhetischen Eigenschaften der Rasengräser. Große Mengen an Bewässerungswasser werden eingebracht, um die Rasenqualität auf den Golfplätzen zu gewährleisten, da das übliche Golfgrünprofil aus reinem Sand besteht. Um die Bewässerungsmengen zu reduzieren, werden Unterflurbewässerungssysteme, die Wasser direkt zu den Pflanzenwurzeln transportieren und Bodenhilfsstoffe zur Erhöhung des Wasserspeicherungsvermögens empfohlen. Dieser Beitrag stellt die Ergebnisse einer laufenden Studie dar, die eine Kombination von Unterflurbewässerung und einem Bodenhilfsstoff auf Tonmineralbasis erforscht. Zwei Modifikationen des konventionellen Grün-Profils mittels Einbringung unterschiedlicher Anteile an Bodenhilfsstoffen zum Sand, wurden erprobt. Spezielle Boxen wurden konstruiert um die Wasserbewegung und das Wurzelwachstum im Profil zu beobachten und zu messen. Eine Mischung aus Grün-Rasengräser wurde in die Boxen eingepflanzt. Die Experimente untersuchen die kombinierten Effekte der Sandprofil- Modifikation und der Bewässerung auf die Wurzelentwicklung unter kontrollierten Bedingungen in einer Klimakammer.

Schlagwörter: Golfplatz, Wurzelzone, Rasengräser, Wurzelwachstum, Unterflurbewässerung

Summary

Turfgrasses have shallow root systems and therefore are susceptible to droughts. Water deficiency affects transpiration, plant growth and visual quality of grasses. A large amount of irrigation water is spent for keeping turfgrass quality on golf courses since the common method of the putting green construction is with sands. In order to minimize water demands, soil amendments for increasing water retention capacity, and subsurface drip irrigation (SDI), which conveys water directly to the rooting zones, are recommended. This paper presents results of an ongoing study aiming to evaluate a performance of combination of a SDI system and a mineral amendment on clay mineral basis. Two modifications of the conventional green-profile using amendment mixtures with sand are examined. For this, special boxes, equipped with TDR and pressure probes, were constructed. A mixture of cool-season grass species was grown on them under controlled conditions in a climate chamber. The experiments were designed to study the combined effects of the modified golf green profiles and irrigation regimes on root and shoot development.

Keywords: golf courses, green rooting zone, turfgrass root growth, SDI irrigation

Introduction

Golf courses are great consumers of irrigation water, especially during the seasonal peaks in summer. Turfgrasses for golf green areas generally have shallow root systems. For this reason, they are highly susceptible to soil water shortages. Permanent water deficiency affects visual quality (colour), rate of shoot and root growth, evapotranspiration demands, etc. At the same time, it has been reported that turfgrasses may tolerate certain levels of soil drought with insignificant quality failure. Drought resistant cultivars can overcome soil water shortage by either minimised transpiration needs via physiological adaptations or extending the root growth in moist soil regions (CARROW 2006, GITHINJI et al. 2009). For cool-season grasses with low mowing heights as on golf greens it was observed that the differences in water consumption are negligible (LEINAUER et al. 2004). Owing to a growing interest in water saving measures in recreation areas including golf courses, the question of how to maintain good quality turfgrass cover applying less irrigation water rises.

Alternative water saving strategies offer advanced irrigation techniques along with more precise irrigation scheduling based on plant or soil water status measurements. Subsurface drip irrigation (SDI) is assumed to be a very efficient irrigation approach which conveys water directly to the roots. More over, the subsurface water application supports deep rooting. The extended rooting depth in turn ensures that turfgrasses are able to take water and nutrients from greater soil volume and thus helps the plants to resist soil surface droughts. Putting green profiles are usually constructed using coarse and medium size sands. The sands provide favourable conditions for root growth in terms of good aeration, enhanced hydraulic properties and drainage, etc. (BILELOW et al. 2004). On the other hand, they have low

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retention capabilities leading to water and nutrient leaching and subsequent stress for the grasses. Adding organic and inorganic soil amendments is a promising method of increasing plant available water capacity of the sands (WALTZ et al. 2003, LEINAUER and MAKK 2007, GITHINJI et al. 2009). At present, many inorganic soil amendments have been marketed, i.e. porous ceramics, diatomaceous earth, zeolites, clay minerals, etc. Combining the advantages of subsurface drip irrigation and soil amendments, irrigation water can be saved along with keeping the grass cover green.

The main objective of the ongoing study is to examine the multiple effects of inorganic amendment mixtures with sands and subsurface drip irrigation (SDI) on turfgrass growth and root development under different climate conditions.

Materials and methods

An inorganic amendment on a clay mineral basis called Betasoil (Bt) was evaluated. First, a detailed study of soil physical characteristics of the amendment was carried out in order to determine optimal amendment-sand mixtures. Two mixtures of 2 % (Bt2) and 5 % (Bt5) amendment with sand (by mass) were selected with regard to the water storage and hydraulic properties as well as some economic aspects (SINAPSIS Interim report, 2010). The effect of Bt2 and Bt6 mixtures on plant and root growth was also tested in preliminary short-time tests with garden cress (*Lepidium sativum*). These tests are usually used to inspect germination of cress plants on growing substrates or waste materials for toxic effects. Following parameters were measured and compared to sand: germination, shoot and root production. Next, the amendment mixtures along with a SDI system were examined in specially constricted boxes in a climate chamber. The boxes (50 x 55 x 6 cm) were made from hard plastic or PVC combined with clear acrylic (Plexiglass) front (*Figure 1*). The plexiglass face was covered with a removable black cloth to protect roots from light exposure. The sand green-profiles were constructed using sands over drainage gravel following the United State Golf Association instructions (USGA 1993). The drip irrigation tube was positioned 26 cm beneath the soil surface. The Bt2 and Bt5 mixtures incorporated in the soil layer adjacent to the irrigation emitter. The conventionally build putting green sand profile without amendment, i.e. Sd treatment, served as a control. Six boxes (two replications per treatment) were constructed for simultaneous observation of water movement, plant and root growth. The boxes were equipped with regularly spaced TDR and pressure probes to monitor changes in soil water content and in matric potential through the rooting zone. Sensor readings and boxes outflows collected in water tanks on weighing scales were recorded in 3-minute steps.

A turfgrasses mixture of Bentgrasses: Browntop bent (*Agrostis capillaris*) and Creeping bent (*Agrostis stolonifera*), and Fescues: Chewings fescue (*Festuca rubra commutate*) and Red fescue (*Festuca rubra trichophylla*), was grown on the boxes for a duration of 9 to 11 weeks. These cool-season grass species are widely used for golf green areas in Austria (FLL Richtlinien 2008). Sod pieces (ca. 2 cm dick) were collected from two-year old putting greens plot in a golf course near Linz. Sods downside (roots) was washed free of soil before planting. Next, the sods were placed on the top of the preliminary saturated and drained for 3 days boxes, gently pressed and watered from above to facilitate the initial rooting. Controlled-release fertilizer (18N-24P-12K) was top dressed before the watering.

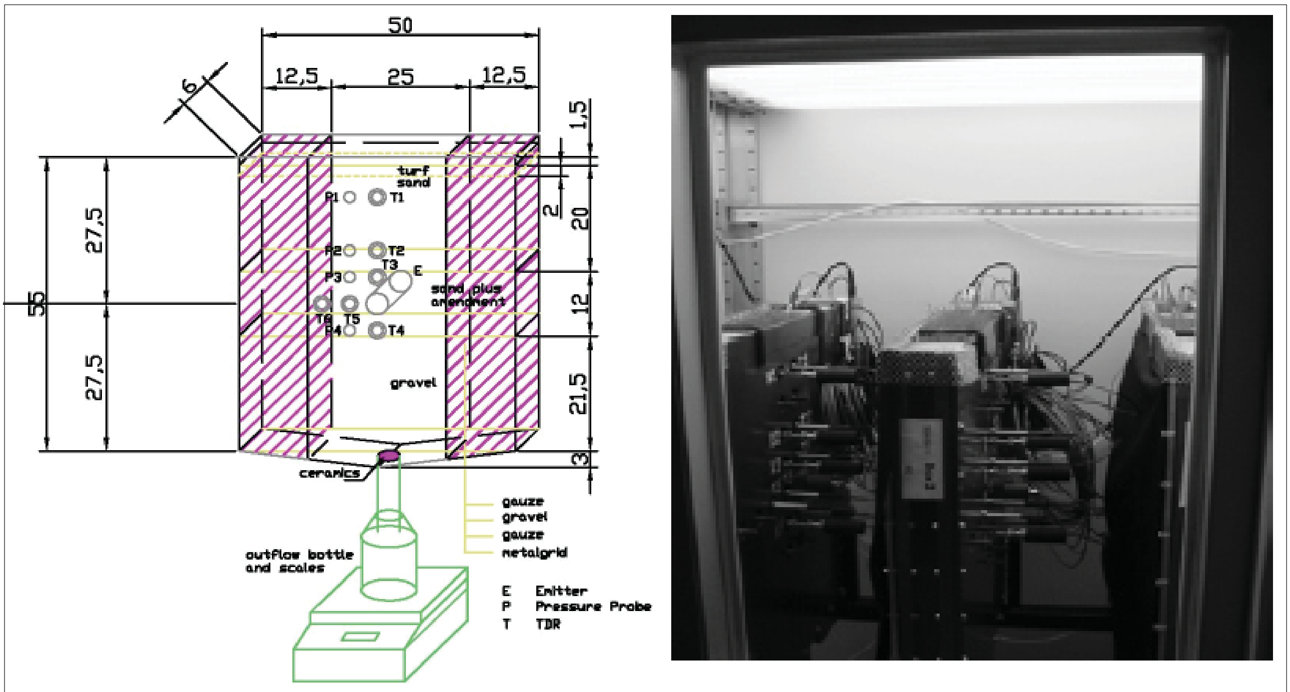

Figure 1: **Experimental boxes scheme and in a climate chamber**

The turfgrass boxes were irrigated based on the estimated potential turfgrass evapotranspiration (ETc). The well known method for the estimation of ETc, involving a calculation of the reference evapotranspiration (ETo) and then applying a suitable crop coefficients (Kc), was used in this study. The ETo was estimated on a basis of weather conditions of an study area near Linz, using Penman-Monteith equation (ALLEN et al. 1998). The weather parameters averaged for the last then seasons (i.e. irrigation periods) from May to September were used for a humid climate adaptation in the climate chamber (see below). The potential turfgrass ETc was calculated by multiplying the reference ETo with the proposed crop coefficient for cool-season turfgrasses of 0.8 (ALLEN et al. 1998, CARROW 2006). Three irrigation levels corresponding to 100 % (100 SDI, full irrigation), and deficit irrigations of 75 % (75 SDI), and 50 % (50 SDI) replacement of ETc are examined. The irrigation levels were first applied on a daily basis and then 3 times per weak, one after another. Irrigation water was pumped out from the underground tube at a rate of 1 l h^{-1}, the water sums were controlled on a balance. Just after sod planting, the boxes were also watered from above to ensure turfgrass rooting into the test profiles, accounted as “rainfall events“. For the experiments under humid conditions presented here, the turfgrasses were grown with maximum/ minimum (day/ night) temperatures of 24/15 °C and relative humidity of 56/80 % achieved gradually. The lights were turned on at 6 h and off at 20 h. The light regime was supplemented by metal halide lamps placed 0.5 m above the turf canopy. Photosynthetically active radiation (photosynthetic photon flux density) on a horizontal plane just above the canopy approximated 400 µmol m^{-2} s^{-1}.

Turfgrass growth and visual quality were monitored. Turf was hand clipped weekly at 1.5 cm height; clippings are collected, dried (60 °C) and analyzed for N contents. In each experimental box, turfgrass color (color number) was determined by comparing the canopy and the clips with a RAL color chart. Root growth was examined at the end of the experiment. Rooting depth was controlled; root bulk samples were taken at different soil depths and analyzed for morphological parameters following HIMMELBAUER et al. (2004).

Results and Discussion

An overview of the soil physical investigations based on the results of HAGER and HAMPL (2010) and SCHWEN and GLASER (2010) are presented in *Table 1*. The amendment-sand mixtures Bt2 and Bt5 showed higher clay and silt content, but less sand fraction than the control Sd. Nevertheless, all materials were in a in the range of the USGA classification (1993). The results showed also that the amendment-sand mixtures retained more water and exhibited higher plant available water sums than the sand. Plant available water was defined as a difference between the permanent wilting point (WP), the water held at -1.5 kPA, and water at field capacity (FC) assumed to be -4 kPa here as proposed for sand root zones by BIGELOW et al. (2004). At the same time, the amendment-sand mixtures showed lower values of total and macro porosity compared to pure sands, but higher percentage for the capillary pores. All estimated porosity values followed the USGA recommendations (1993).

The results of the garden cress- tests are presented in *Figure 2*. Better shoot growth (germination, shoot biomass and height) was observed on the amended Bt2 and Bt5 mixtures than on the sand with equivalent investment in root length and mass growth. In general, the cress plants developed very well in all treatment.

The experimental results under humid conditions in the climate chamber showed that the amendment-sand mixtures considerably decreased water losses via drainage, while the preservation of water increased. The results for the water storage in the soil profile and soil water content distributions for the Sd, Bt2 and Bt5 treatments are presented in *Figure 3*. Soil water content measurements in the modified profiles were higher than in the controls in both the amended layer close to the emitter at 26 cm depth and in the upper non-amended 20 cm sand layers, containing the largest part of the roots. This trend was to be observed at the beginning as well as at the end of the experiment, though the high variability between the single replications (*Figure 3*). The control Sd treatment exhibited an initial water storage of 0.9 mm, which halved to 0.45 mm after 11 weeks experimental period. The initial water storage of the Bt2 treatment approximated 1.05 mm, decreasing to 0.62 and for the Bt5 treatment was 1.16 mm dropping to about 0.64 mm until the end of the experiment.

Plant available soil water (AW) is essential for plant and root growth. The plant available water capacity denotes the difference between the water at field capacity (FC) and the permanent wilting point (WP) water held at -1500 kPa. Classically the field capacity is defined as the water left in soil after the gravitational water has been drained and

Table 1: **Selected soil physical characteristics of sand and amendment-sand mixtures**

Variant	Particle size distribution					Field capacity	Wilting point	Plant avail. water	Macro porosity	Total porosity
	Sand *Coarse* *2-0.63mm* %	fractions *Medium* *0.63-0.2mm* %	*Fine* *0.2-0.063mm* %	Silt *0.063-0.002mm* %	Clay *<0.002mm* %	*(FC)* *4kPa* vol. %	*(WP)* *1500kPa* vol. %	vol. %	vol. %	vol. %
Sd	15.3	68.0	12.3	4.4	0.0	12.2	3.0	9.2	29.7	41.9
Bt2	14.7	55.7	23.1	6.0	0.5	15.9	4.1	11.8	24.8	40.7
Bt5	28.5	50.9	10.0	6.9	3.6	18.3	5.0	13.3	22.8	41.1

Sd- Sand; Bt2 and Bt5 are amendment- sand mixtures corresponding to 2% and 5% percentage of amendment by mass

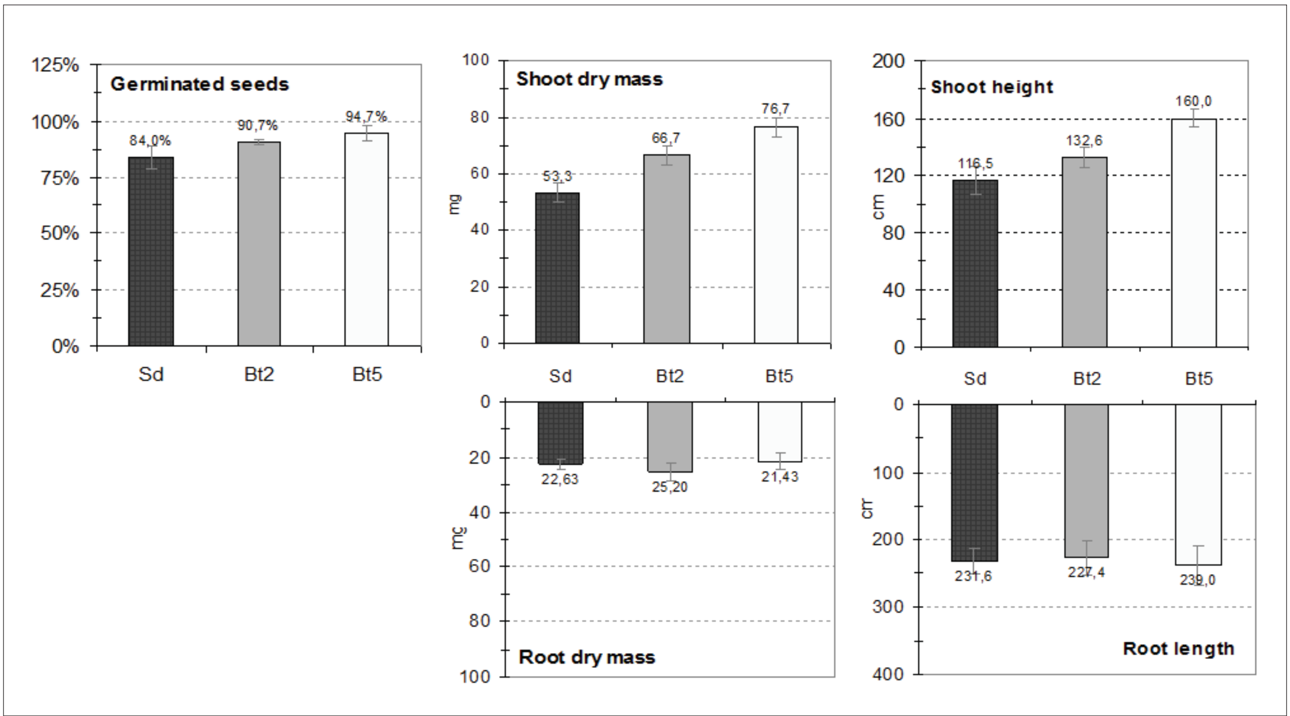

Figure 2: **Results of the garden cress test. Sd is sand; Bt2 and Bt5 are amendment- sand mixtures**

a downward movement became insignificant. FC is most common associated with water content at a threshold matric potential of -10 kPa to-30kPa. Some studies with inorganic amendment reported FC threshold matric potential of -4 to -30 kPa (e.g. BIGELOW et al. 2004, GITHINJI et al. 2009). For the boxes conditions, the FC threshold values were higher and approximating -2 kPa. Such readings were measured 3 days after the full saturation and drainage of the boxes. According to the retention curves, this corresponded to 20.2, 24.5 and 25.6 volumetric water contents for Sd, Bt2 and Bt5 treatments, respectively. Subsequent, the estimated water content at matric potential of -2 kPa was defined as a box field capacity (bFC in *Figure 3*, left hand site).

The plant available water in the 32 cm profile for each box was calculated. After 11 experimental weeks, the plant available water in the Sd boxes almost depleted, while the water reserves in Bt2 and Bt5 treatments dropped below 50 % of the available water (50AW). According to DOORENBOS et al. (1986), a threshold value used for irrigation timing called “onset of stress” is defined when 50 % of the available water remains. In the Sd and Bt2 treatments, the 50AW level is already reached at -5kPa, while at this matric potential there is still 70 % of AW offered in the Bt5 treatment. For golf turfgrasses and sand root zones, BIGELOW et al. (2004) stated that even water content at -50 kPa should be considered as water unavailable for the plants, while after GITHINJI et al. (2010) this water is not easily but moderate plant available. After elf weeks of experiment, the unavailable water (uAW) reference level was approached only in the control Sd treatment (*Figure 3*). In summary, the amended (Bt2 and Bt5) profiles generally exhibited higher proportion of stored as well as of plant available water reserved over longer periods compared with the pure sand profile.

The actual turfgrass evapotranspiration (ETa) was estimated using a balance method as a difference between the daily water supply and the outflow, and changes in the volumetric water storage using TDR readings in each Box. The soil evaporation was assumed to be negligible, since the grass was well established keeping 100 % coverage of the box surface during the experiment. The results for the ETa weekly sums were calculated and compared with the potential ETc sums and the water supply, total and via SDI (*Figure 4a*). The actual evapotranspiration ETa’ exceed the potential in the third week of the experiment (i.e. full irrigation), but decreased as soon as the irrigation rate was diminished, first in the Sd and Bt2 boxes (at 75SDI, 7th week) and later on in the Bt5 ones, but the variations between the replicates were high. At deficit irrigation of 50SDI (last two weeks), no significant differences were found either between the treatments or between the boxes. The shoot growth rate of the turfgrasses also diminished with the time. In one of the Bt2- boxes, the grassed grew even worse than in the controls, attributed also to the low shoot nitrogen content. The turfgrass growth rate on the Bt5-amended boxes was mostly higher. During the last week of experiment (50SDI) no treatment-related differences were any longer observed (*Figure 4b*). The decrease in the irrigation and in the ETa rates also resulted in a decrease in a turf quality, since a change in a turfgrass color was observed in all boxes as time progressed. Turfgrass color was determined weekly, color numbers were determined by comparing the canopy and the clips with a RAL color chart. The color number changed from dark (RAL 6010- Emerald green to RAL 6001- Grass green) to light green (RAL 6017- May green to RAL 6025- Fern green) in all treatments. As well known, the ETc reflects the climate conditions, while the crop coefficient represents the plant growth status on account of management and irrigation practices. In this study, the estimated crop

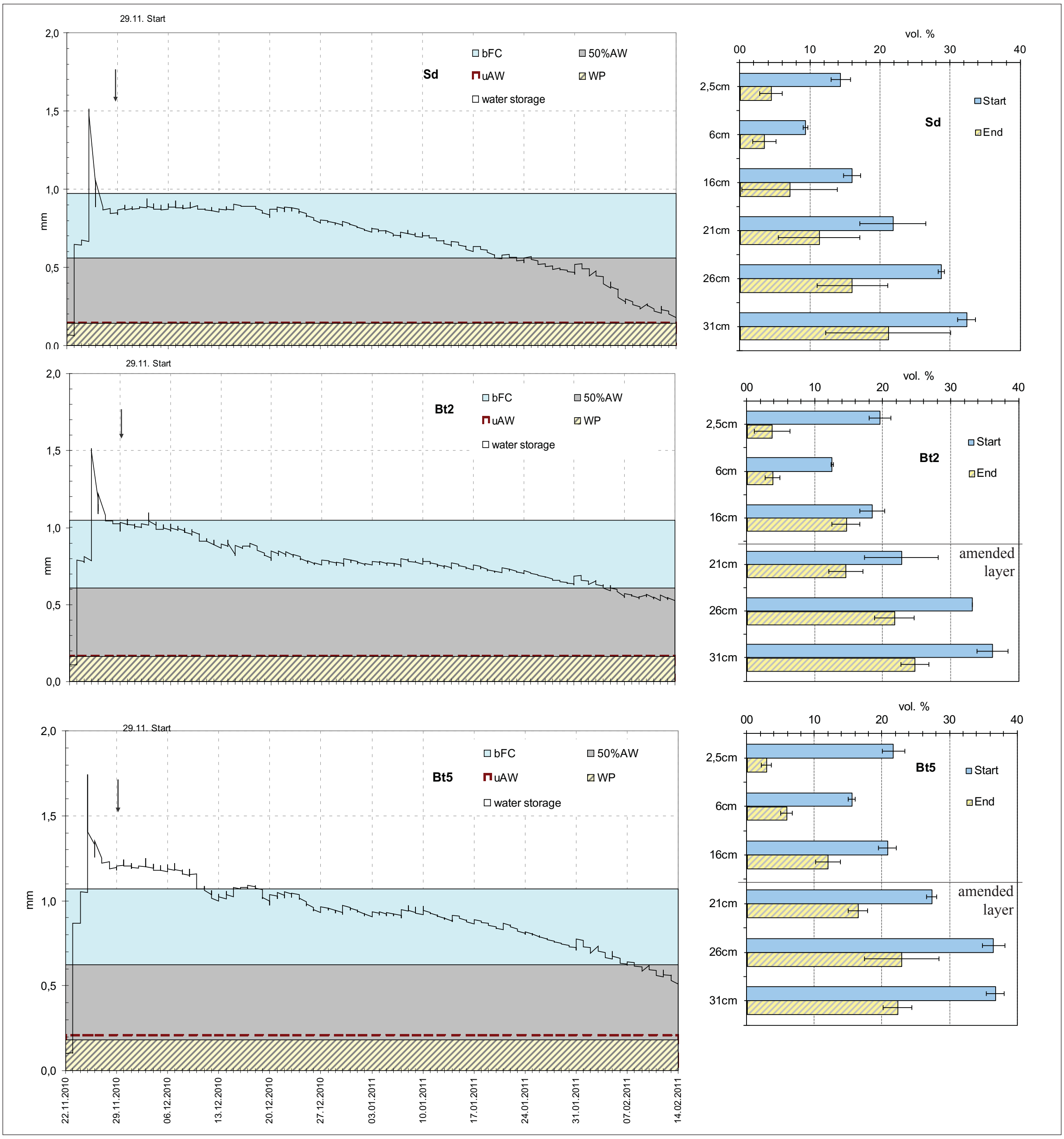

Figure 3: **Changes in the water storage (left) and profile distributions of the water content at the beginning and the end of the experiment (right). Sd- control with sands, Bt2 and Bt5- treatments using amendment-sand mixtures with 2 % and 5 % amendment, respectively; bFC- "box Field Capacity" matching an ascertain value of -2 kPa, 50%AW- half of the plant available water, uAW- water, at -50kPa defined as unavailable after BUGALOW et al. (2004),WP- permanent wilting point at -1500kPa.**

coefficients for the first weeks (full irrigations) were mainly higher than the proposed value of 0.8 (ALLEN et al., 1998). Then after the Kc' values dropped to 0.4 suggesting grass adaptations to drought conditions (*Figure 4c*). The highest values were calculated for the Bt5-boxes, with a maximum of 1.24, while the values for the Box1 (Sd) remained even below 0.8. The estimated transpiration efficiency was slightly higher for Sd and Bt5, with non-significant differences between the treatments.

Results of the root sampling at the end of the experiment showed that the roots in all boxes reached a depth of 20 cm (*Figure 5*). In the soil layers between 0 and 20cm depths were the largest fluctuations in the water content observed mainly owing to the root water uptake. In parallel to the cress tests results, the amended Bt2 and Bt5 boxes developed less roots (mass, length and surface density) with no significant differences between the treatments. In a view of the higher biomass production, this suggested higher root uptake ef-

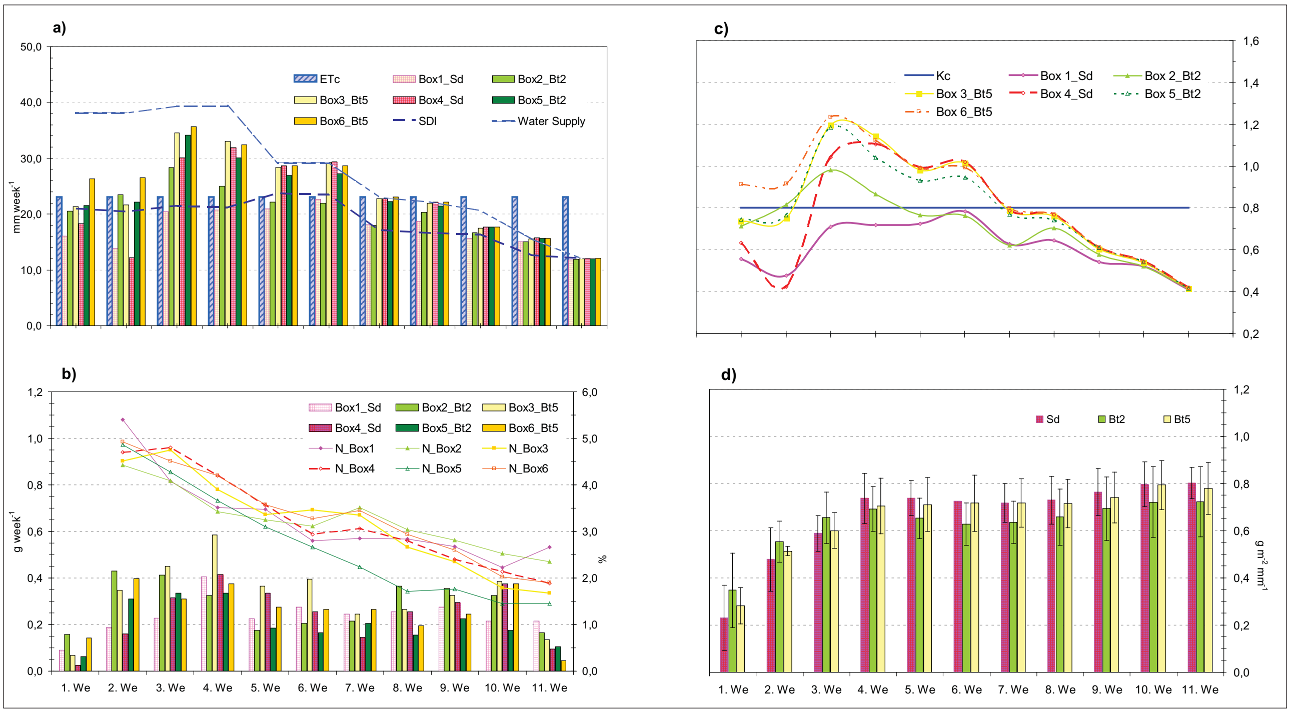

Figure 4: **Comparison between a) potential crop evapotranspiration (ETc), actual evapotranspiration per box, subsurface drip irrigating (SDI) and total water supply; b) biomass growth rates and shoot nitrogen content per box; c) potential crop coefficients Kc and actual crop coefficients per box, and d) transpiration efficiency per treatment. The parameters are estimated on a weekly basis.**

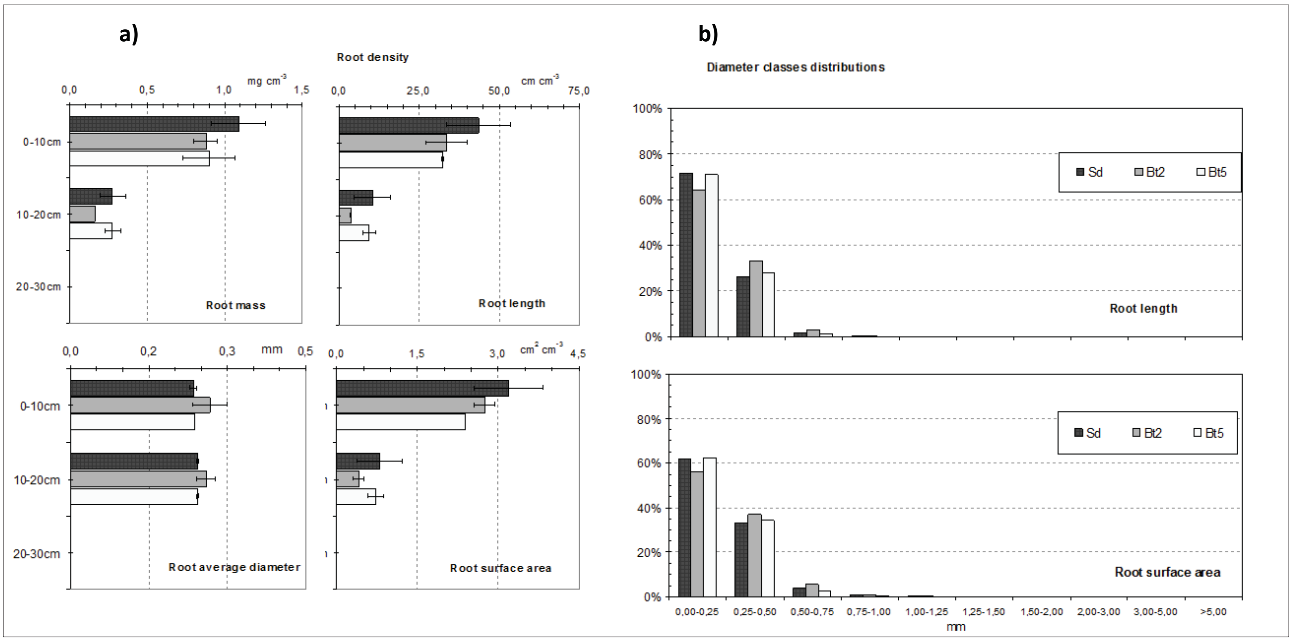

Figure 5: **Result of root analyses at the end of the experiment of a) root densities and b) diameter classes distributions. Sd- control, Bt2 and Bt5- treatments using 2 % and 5 % amendment-sand mixtures, respectively.**

ficiency for water and nutrients. The profile distribution in the Bt5 amendment-sand mixture showed a slight shift in the root density to the deeper 10 to 20 cm depth, where 30 % of the roots developed, against 15 % and 25 % for the Bt2 and the Sd - treatments, respectively. Results for the average diameter and diameter classes distribution were comparable for all boxes, with more then 95 % of the length and surface area thinner than 0.5 mm, i.e. very fine roots.

In order to clarify to which extend the soil amendments and reduced irrigation rates can be introduced in the praxis, further experiments in climate chamber and in the field are in progress.

Dedication

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