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# Quality assessment of three warm-season turfgrasses growing in different substrate depths on shallow green roof systems☆

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ABSTRACT

In an effort to increase the accessibility and functionality of shallow green roof systems, the ability of warm-season grasses to provide acceptable growth needs to be further investigated. In the current study, which was conducted during 2011 and 2012, three warm-season grasses (hybrid bermudagrass, *Cynodon dactylon* (L.) Pers. x *C. transvaalensis* Burtt-Davy 'MiniVerde'; seashore paspalum, *Paspalum vaginatum* Swartz 'Platinum TE' and zoysiagrass, *Zoysia japonica* Steud. 'Zenith') were established in outdoor lysimeters. The lysimeters were equipped with all necessary green roof layers placed below a coarse-textured substrate that comprised pumice, thermally treated attapulgite clay, peat, compost and zeolite. Half of the lysimeters had a substrate depth of 15 cm, while the other half had a substrate depth of 7.5 cm. Irrigation was applied at crop evapotranspiration ($ET_c$). Measurements included determination of substrate moisture content, green turf cover (GTC) and leaf stomatal resistance. Significant differences were observed in the values of GTC among the three turfgrass species and the two substrate depths. Zoysiagrass exhibited the best adaptation at the lower depths of shallow green roof systems. At 15 cm substrate depth, zoysiagrass managed to sustain green coverage for the two study periods. In addition, it was the only turfgrass species that managed to perform well at the substrate depth of 7.5 cm. Seashore paspalum exhibited limited green cover at both substrate depths, while hybrid bermudagrass could provide acceptable green coverage only at 15 cm substrate depth.



## 1. Introduction

Green roofing is an urban greening technique that provides several environmental benefits, such as amelioration of the urban heat-island effect (Takebayashi and Moriyama, 2007), building energy savings (Kotsiris et al., 2012), storm water management (Berndtsson, 2010), improvement of air quality (Yang et al., 2008), improvement of urban landscape aesthetics and provision of new flora and fauna habitats (MacIvor and Lundholm, 2011).

However, the above mentioned benefits are expected to accrue only provided that green roofing is implemented on broad city surfaces (Akbari et al., 2001; Getter and Rowe, 2006). Based on the latter, it is of great interest to select and investigate a methodology that is suitable for the application of green roofs to existing city buildings through retrofitting. This is of immense importance, considering that, in most cases, city buildings are aged and constructed based on obsolete design criteria, thus, being able to bear only minimal additional loads.

The green roof industry has termed constructions with minimal weight as "extensive" green roofs. In these green roof types, weight reduction has mainly resulted from very shallow substrate depths that may vary from 5 to 20 cm depth (FLL, 2008). Due to shallow substrate depths and lack of irrigation, extensive green roofs demand specific plant species for their planting that are mainly succulents. The lack of plant variability in conjunction with the minimal wear tolerance of succulent plants to traffic has led extensive green roofs to be considered as "environmental" building structures rather than as a functional open green space that is accessible by the building residents. The report of Fernandez-Cañero et al. (2013) demonstrates that local residents clearly preferred more aesthetically pleasing and accessible green roofs with variable plant types, such as groundcovers, shrubs and trees. In contrast, extensive green

*Abbreviations:* GTC, green turf cover; $ET_c$, crop evapotranspiration; NDVI, normalized difference vegetation index; SMC, substrate moisture content; LSR, leaf stomatal resistance.

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roofs planted with *Sedum* succulents received low ratings in the public perception and preferences measurement.

The preceding problems, concerning aesthetics and accessibility of extensive green roofs, become more severe in countries where governmental incentives are absent as well as in longitudes that are characterized by droughty summer periods such as in Mediterranean countries. As a result, Kotsiris et al. (2013) proposed the "adaptive green roofs" approach that focuses on light-weight green roof systems combined with improved aesthetics, accessibility and functionality. In adaptive green roofs, a shallow substrate depth provides a light structure that is compensated for by prudent irrigation applications along with the use of drought tolerant native species and turfgrasses (Ntoulas et al., 2013a).

Turfgrasses have a unique ability to fulfil aesthetic, functional and recreation requirements, which are demanded of urban plants (Beard and Green, 1994). However, they have rarely been evaluated in relation to extensive green roofs due to their increased water demands compared to succulents or other xerophytic plants. Ntoulas et al. (2013a) evaluated the establishment and growth of *Zoysia matrella* (L.) Merr. on adaptive green roof systems. They reported higher green turf cover (GTC) and normalized difference vegetation index (NDVI) values when the substrate depth was 15 cm compared to a shallower substrate depth of 7.5 cm, during both the establishment and the water deficit periods. Ntoulas et al. (2013b) evaluated *Z. matrella* performance in two different green roof substrate types and depths (7.5 and 15 cm) and under two different irrigation regimes (3 mm or 6 mm every 3 days). They reported that GTC and NDVI values were mostly affected by substrate depth, moderately by irrigation regime and to a lesser extent by substrate type. Ntoulas and Nektarios (2015) reported that *Paspalum vaginatum* Swartz provided better green cover and demanded less water to retain its visual quality at a 15 cm substrate depth compared to a 7.5 cm depth. They also reported that at the 7.5 cm substrate depth *P. vaginatum* growth is possible if water inputs increase by 40% compared to the 15 cm substrate depth. Nektarios et al. (2014) reported that *Festuca arundinacea* L. can grow in a reduced substrate depth of 7.5 cm without being stressed compared to a substrate depth of 15 cm, when irrigation is provided at 85% of evapotranspiration.

The variable response of different turfgrass species, growing on shallow green roof systems, indicated the need to perform a comparable study. The aim of the present study is to investigate the response of three warm-season grasses at different substrate depths of a shallow green roof system.

## 2. Materials and methods

### 2.1. Experimental setup and hypothesis

The outdoor study was conducted at the experimental field of the Laboratory of Floriculture and Landscape Architecture, Agricultural University of Athens, Greece. The initial study was performed from 3 Aug. until 10 Sep. 2011 and was replicated from 15 May until 19 July 2012. Treatments included: a) three warm season turfgrasses (hybrid bermudagrass, *Cynodon dactylon* (L.) Pers. x *C. transvaalensis* Burtt-Davy 'MiniVerde'; seashore paspalum, *Paspalum vaginatum* Swartz 'Platinum TE' and zoysiagrass, *Zoysia japonica* Steud. 'Zenith') and b) two green roof substrate depths (7.5 cm or 15 cm). Each treatment was replicated three times, totaling 18 lysimeters ($3_{species}$ x $2_{sub.depths} \times 3_{replications}$ = 18 lysimeters).

The hypotheses were to investigate whether the three warm season turfgrass species exhibit different green coverage when grown under green roof conditions and whether it improves as substrate depth increases.

### 2.2. Green roof construction within the lysimeters

The lysimeters had 30 cm internal diameter. Within each lysimeter a complete layered simulation of an extensive green roof system was constructed. The bottom of the lysimeter was covered with a protection mat that was a synthetic cloth made of non-rotting synthetic polyester fibers having 3 mm thickness and a dry weight of 0.32 kg $m^{-2}$. The mat also had the capacity to retain 3 L $m^{-2}$ of water (TSM32, Zinco, Egreen, Athens, 10672, Greece). A drainage board layer was placed on top of the protection cloth. The drainage layer was made of recycled polyethylene with 25 mm height and 1.5 kg $m^{-2}$ weight (FD25, Zinco, Egreen, Athens, 10672, Greece). It was equipped with water retaining troughs having a water holding capacity of 3 L $m^{-2}$ and openings for improving subsurface aeration. The drainage layer was covered with a non-woven geotextile (SF, Zinco, Egreen, Athens, 10672, Greece) that was made of thermally strengthened polypropylene having 600 μm thickness, a mass of 100 g $m^{-2}$, apparent opening size of $D_{90}$ = 95 μm and water flow rate of 0.07 m $s^{-1}$. The filter sheet was used to prevent fine particle migration from the substrate towards the drainage layer, thus ensuring that the drainage layer would not clog and would function effectively.

The lysimeters were filled with a specialized green roof substrate that comprised 40% pumice, 40% thermally treated attapulgite clay, 8% peat, 7% compost and 5% clinoptilolite zeolite by volume. Pumice (LAVA, Mineral & Quarry A.D., Athens, 14123, Greece) had a particle distribution of 0.05–8 mm, thermally treated attapulgite clay 1–10 mm (GeoHellas SA, Athens, 17564, Greece) and zeolite 0.8-2.5 mm (S&B Industrial Minerals A.D., Athens, 14564, Greece). The organic portion of the substrate contained sphagnum peat, with a corrected pH of 5.5 and an organic matter of 90% (w/w), and compost that comprised straw, sawdust, yard waste (clippings and wood chips) as well as dairy cow, horse and chicken manure. The mechanical analysis and the water potential curve of the substrate are presented in Fig. 1A and 1B, respectively.

Half of the lysimeters had a substrate depth of 7.5 cm and the other half had a 15 cm depth. Light compression and leveling was applied to the substrates after their placement into the lysimeters. The zoysiagrass lysimeters were seeded on 13 June 2011 and the hybrid bermudagrass and seashore paspalum lysimeters were sodded – using washed sod – on 22 June 2011. After seeding and sodding, the lysimeters were placed under a mist system in order to promote seed germination and sod rooting. Then, the lysimeters were transferred onto outdoor benches that were equipped with a rain-out shelter. However, no rainfall occurred during the first study year and only four minor rain events occurred during the second study year (Fig. 2).

### 2.3. Turfgrass maintenance and irrigation

Turfgrass sward was mowed at a height of 5 cm once a week with a handheld electric shear mower, and clippings were removed. Fertilization was applied once before the initiation of each study (6 July 2011 and 28 March 2012) with Floranid Permanent 16-7-15 (+2Mg, +7S + 0.5 Fe, Compo Hellas SA), at a rate of 10 g $m^{-2}$ of fertilizer.

At the initiation of each study, all lysimeters were irrigated close to saturation in order to produce uniform substrate moisture conditions. From then on, irrigation was performed on a daily basis using irrigation amounts at crop evapotranspiration ($ET_c$). Crop evapotranspiration was calculated based on the daily evaporation of a Class-A pan according to: $ET_c = E_{pan} \times K_p \times K_c$, where $E_{pan}$ is the evaporation of a Class-A pan, $K_p$ is the pan coefficient used to convert pan evaporation to reference evapotranspiration, and $K_c$ is the crop coefficient. Based on the weather data during the experimental periods, a $K_p$ value of 0.65 (Doorenbos and Pruitt, 1977) and a $K_c$