7th ETS CONFERENCE 2020

# TURF SOLUTIONS for the FUTURE

Selected papers (Part 1/3) for the 7th ETS Conference 2020,
**cancelled due to Covid-19**

## Ausgewählte Fachbeiträge für die 7. ETS-Konferenz in Amsterdam geplant vom 29. Juni bis 01. Juli 2020

# Tagungsabsage wegen Corona-Pandemie

Dear ETS Friends,

it is with deep regret that we inform you of the cancellation of the 2020 ETS Conference in Amsterdam, The Netherlands.

Over the past few weeks, the ETS board have been monitoring worldwide developments related to COVID-19.

With many countries and regions recommending self-quarantine and many institutions strongly advising staff, faculty and students to restrict travel, we know it is no longer practical nor ethical to continue with our conference.

We trust you will understand the need for this and thank you all once again.

The ETS Board

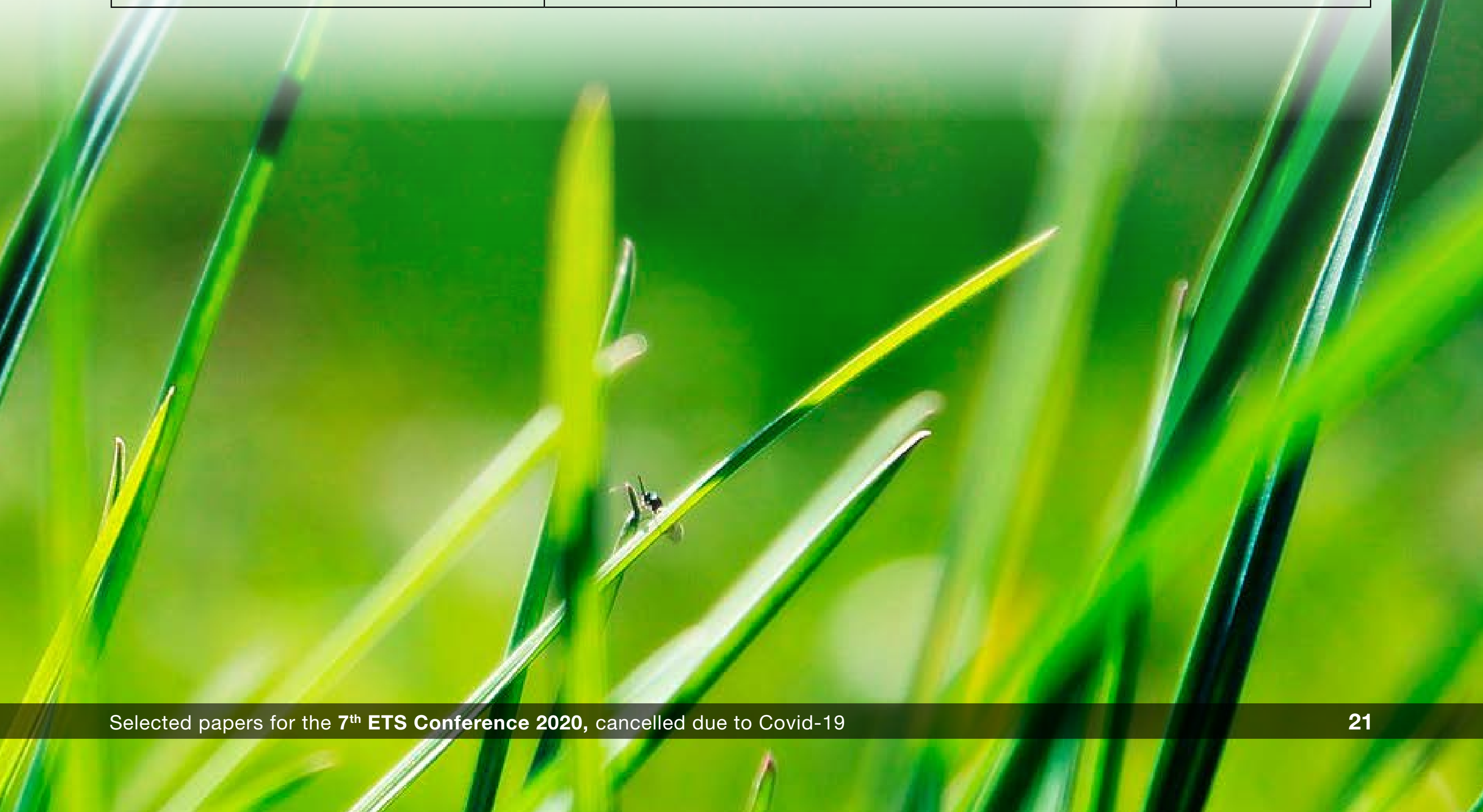
In Abstimmung mit dem ETS-Board und unter fachlicher Leitung der Deutschen Rasengesellschaft e.V. veröffentlicht die Köllen Druck + Verlag GmbH ausgewählte und „peer-reviewed 2-page-paper“ der geplanten ETS-Tagung.

In drei Ausgaben der Zeitschrift **„RASEN – European Journal of Turfgrass Science“** erscheinen Fachbeiträge zu folgenden Schwerpunkt-Themen:

- Ausgabe 02/20: **„Drought, Irrigation and Water consumption“**
- Ausgabe 03/20: **„Disease and Pest Management + Biostimulants“**
- Ausgabe 04/20: **„Maintenance and Nutrition + Impact for the Environment“**

## Inhalte Ausgabe 02/20





# Water use and drought resistance results from C3 grasses evaluated at ten sites in the united states

**Kevin, N., K.N. Morris and M.P. Kenna**

## Introduction

This project identified C3 turfgrass cultivars that deliver high quality turf while using significantly less water. Established at multiple locations in the U.S., this project: 1) measured the actual amount of water required to maintain a prescribed level of quality or green cover, and 2) documented the performance of cultivars under varying levels of reduced evapotransporation ($ET_o$) levels. This data will be used to develop and apply U.S. EPA WaterSense (http://www3.epa.gov/watersense/) certification (or another certification organization) label to grasses that qualify.

## Materials and Methods

Rain exclusion shelters were used to simulate 100-day drought periods in higher rainfall regions. Under the rain exclusion shelters we measured the amount of water needed to maintain a prescribed level of green cover, rated turfgrass quality and evaluated recovery from drought when irrigation was resumed.

The drier climate ETo-based sites evaluated performance at three deficit irrigation levels for 100-120-day periods. Data recorded included percent green cover over time, turfgrass quality and recovery rate after adequate irrigation was applied. The ETo-based locations determined the minimum level of deficit irrigation appropriate for, and thus the water savings from each entry.

The entries submitted included nineteen tall fescues (*Festuca arundinacea*), fifteen Kentucky bluegrasses (*Poa pratensis*) and one perennial ryegrass (*Lolium perenne*). In fall 2016 and spring 2017, these entries were established at ten locations, with five sites in higher rainfall regions utilizing a rain exclusion shelter, and five sites in low rainfall regions where irrigation was applied based on varying degrees of deficit ET replacement (40, 60 and 80% $ET_o$ replacement). Difficulties and delays in obtaining rain exclusion shelters, as well as developing irrigation infrastructure resulted in delayed plantings at some locations.

Trial locations were mowed at 5 – 6.25 cm and fertilized with 12.25 – 16.17 kg/ha of Nitrogen per growing month.

Percent green cover was monitored by collecting digital camera images on a bi-weekly basis. Data was analyzed using TurfAnalyzer software (www.turfanalyzer.com). Turfgrass quality ratings were collected monthly using a scale of 1-9, where 9=ideal turf and 1=dead turf.

Initially, a percent green threshold of 50% was used to determine when to apply 2.5 cm of water to individual plots in the rain exclusion shelters. Each time a plot was watered to maintain green cover above the threshold was recorded and the amount of water applied for the 100-day season was totaled. However, due to little or no statistical differences noted at the rain exclusion sites in 2017, changes were made to trial protocol and analysis. After consulting with our trial cooperators, the percent green threshold for re-watering was changed to 65% (from 50%) for 2018. Cooperators felt this change would more accurately reflect a homeowner's desire to maintain a consistent green lawn, as 50% showed too much brown (loss of color) and in some cases, did not allow for recovery from water lost in the plant and soil profile. Also, a change to the statistical analysis procedure, where species were grouped together and then analyzed, was suggested to better reflect performance.

## Results and Discussion

Of the ten locations planted, six were able to collect data on drought response and recovery in 2017 (we agreed that the remaining four locations did not have test plots that were fully mature, and therefore not ready to apply drought stress). The locations that did not simulate drought in 2017 (Logan, Utah; St. Paul, Minnesota; Ft. Collins, Colorado; Amherst, Massachusetts), initiated drought treatments in 2018.

The six cool-season trial locations that initiated drought treatments in 2017 include Fayetteville, Arkansas, College Park, Maryland, Griffin, Georgia and West Lafayette, Indiana (rain exclusion shelter sites); and Riverside, California and Las Cruces, New Mexico (deficit $ET_o$ replacement sites). Data from 2017 showed little statistical significance, leading to the changes in protocol and statistical analysis noted under 'Materials and Methods'.

Rain exclusion shelter data from the southern-most cool-season sites in 2018 (Griffin, Georgia and Fayetteville, Arkansas) showed a large range in water needed to maintain 65% green (i.e. 4.3 – 72 mm at Fayetteville, 123 – 262.7 mm at Griffin, Georgia) but with no statistical differences among entries. Possibly, the higher summer heat load at these sites masked the differences in drought tolerance.

Data from the Mid-Atlantic (College Park, Maryland) and Midwest (West Lafayette, Indiana) regions rain exclusion shelter sites had much greater statistical significance in 2018 with tall fescues generally maintaining green cover with less water than Kentucky bluegrasses. However, significant differences were also noted within species at both sites. For example, the lowest water-consuming tall fescue in Indiana (DLFPS 321/3678) used only 50.6% (161 mm) of the water used by the highest water-consuming tall fescue (LTP-SYN-A3, 317.7 mm). A similar result was seen for Kentucky bluegrass at the two locations with the lowest water-consuming bluegrass at College Park, Maryland (BAR PP 110358, 165 mm) using only 61.5% of the water needed by the highest-consuming bluegrass in 2018 (Dauntless, 275 mm).

The $ET_o$-based site at Riverside, California saw significant stress under 40% $ET_o$ replacement as plots recovered from 2017 damage. No entry provided acceptable turf quality under 40% $ET_o$

during the 120-day deficit irrigation period at this location in 2018. The 60% $ET_o$ replacement level also saw significant grass loss while very few statistical differences were noted among tall fescue entries. Statistical differences did occur among many Kentucky bluegrass entries during days 50-63 of the dry down period. Two Kentucky bluegrass entries did not perform well at the 80% $ET_o$ replacement level, hence those entries may not be adapted to the southern California climate. From these results, we noted that several Kentucky bluegrasses showed potential for irrigation reduction in a desert climate.

In 2017, significant differences in drought resistance and turf quality were noted among entries at Las Cruces, New Mexico as well as differences in recovery from drought. Data from the 40% $ET_o$ level in 2018 showed some entries delivering acceptable turf quality and performance throughout the trial period, albeit with little to no statistical significance.yaa The 60% $ET_o$ deficit level did show significant turf quality entry differences toward the end of the 2018 drought period (100-120 days), with greater differences noted among Kentucky bluegrass entries than tall fescues.

Three locations (Logan, Utah, Fort Collins, Colorado and St. Paul, Minnesota) collected their first data from this trial in 2018. With more favorable summer conditions for cool-season grasses, these locations have a greater potential for our lowest $ET_o$ level to deliver acceptable turf quality. For instance, under 40% $ET_o$ at Logan, Utah, tall fescues outperformed Kentucky bluegrass with some entries maintaining acceptable turf quality for up to 95 days. At Fort Collins, Colorado, significant differences were noted among tall fescue and Kentucky bluegrass entries under 40% $ET_o$, but none outperformed the perennial ryegrass entry.

Finally, the St. Paul, Minnesota site adjusted its irrigation levels to 0, 25 and 75% $ET_o$ conforming to local conditions and needs. Late spring rains in 2018 led to little early drought stress at the 0% $ET_o$ deficit replacement level, but by the end of the 120-day period, differences were notable. Many Kentucky bluegrasses held their turf quality for the first 40 days of drought under 0% $ET_o$ but declined as expected in the remaining 80 days. The tall fescues in general showed little statistical differences, but some entries maintained good turf quality well into the drought period.

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# LL002 Treatments delayed drought stress symptoms in turf – from pot to plot

**Corniglia, M., F. Guglielmi, C. Sudiro and A. Altissimo**

## Introduction

Golf courses and sports pitches are already coming under increasing abiotic stress pressure such as drought and heat. Moreover, also private and public lawns are subjected by increasing water deficit during the summer period that cannot always be alleviated by the use of constant irrigation[1]. Apart from the use of wetting agents and superabsorbents, that have an effect on water penetration and retention in the soil, the use of biostimulants is often encouraged to increase turf resistance against drought and heat stress, the two major trouble-makers for turf. Biostimulants are products that, in small quantities, stimulate plant growth, but stress tolerance is perhaps the most important benefit they bring. Seaweed, aminoacids and humic substances are among the most used biostimulants both in the agricultural and in turfgrass management[2]. However, these biostimulants have broad claims and, as they are often the end point for waste materials or byproducts, their composition of active substances can be rather casual.

The aim of this study was to test an innovative product in the biostimulant world, a completely characterized, standardized and optimized plant derived product, that showed good performances in the agricultural sector. LL002 is part of the bigger Plant for Plants® family of products that is specifically tailored to increase tolerance to drought stress in a variety of crops. LL002, a product extracted from a specific species and variety, has been completely characterized and the main a.i's are Polyphenols and Organic Acids.

## Materials and Methods

The first trial was performed in turf grown in pots filled with a sandy soil substrate, where 36 seeds per pot were sown (*Festuca arundinacea*). Three foliar treatments were performed before starting to decrease irrigation. LL002 was sprayed at three different dosages (LL002, low, 33%: 125 g/ha; LL002, medium, 33%: 250 g/ha; LL002, high, 33%: 375 g/ha, of active ingredient (A.I.)), and a benchmark was used as reference (dosage 4%; Benchmark, 4%), for a total of 6 treatments (with positive Untreated Control 85% -UTC 85%- and negative control – UTC 33%; fig. 1) per 8 replicates (one pot each). The drought stress consisted in keeping the soil at 33% of field capacity (FC), while the positive Untreated Control was kept at 85% FC. After the drought stress, recovery by increasing irrigation was performed. The second trial was performed in microplots un-

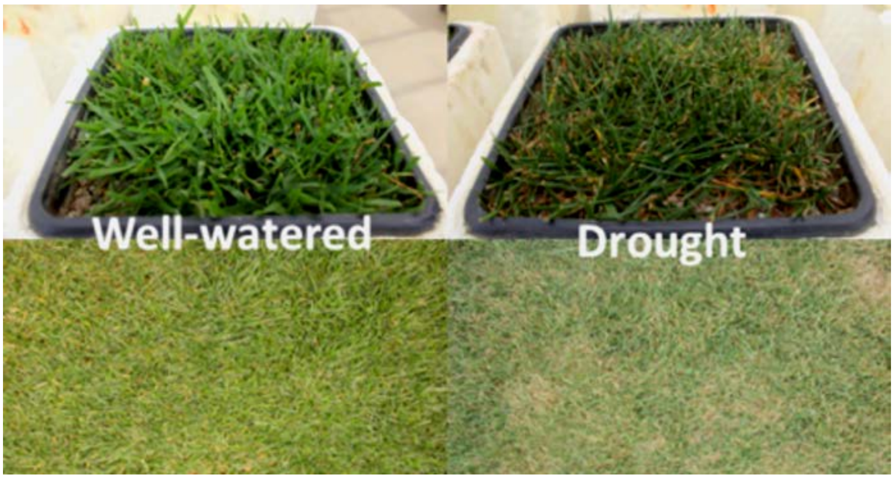


Fig. 1: Pot and plot trials: comparison pictures between well-watered and drought controls.

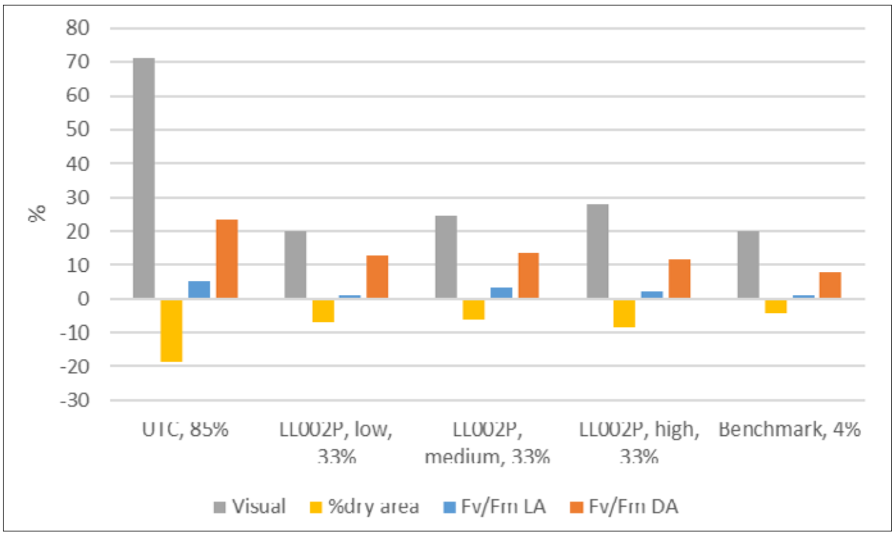


Fig. 2: Pots: % difference compared to UTC 33% of the average visual of wilting, % of dry area, and photosynthetic efficiency (Fv/Fm, light – LA – or dark – DA – adapted). Low, medium and high refers to the dosages of LL002, while 4% refers to the dosage of the Benchmark.

[1] JIANG, Y. and B. HUANG, 2001: Drought and heat stress injury to two cool-season turfgrasses in relation to antioxidant metabolism and lipid peroxidation. Crop Science, 41:436–442.

[2] DU JARDIN, P., 2015: Plant biostimulants: Definition, concept, main categories and regulation. Scientia Horticulturae, 196:3-14.

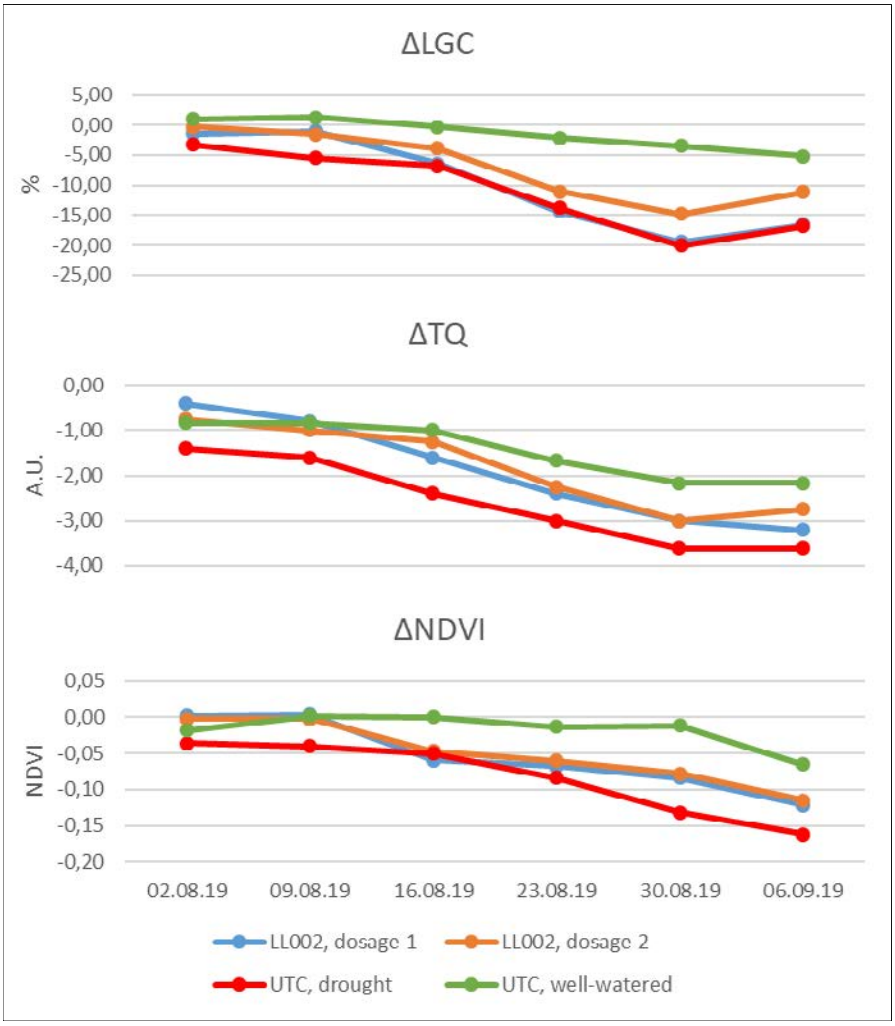


**Fig. 3: Plots: Trends of LGC, TQ (visual of Turf Quality) and NDVI compared to the first date of reduced irrigation (19.07.19): the first date shown (02.08.19) refers to 2 weeks after the start of the water stress.**

der tunnel, in order to avoid the rain. The drought stress was imposed after two foliar application of LL002 (LL002, dosage 1: 125 g/ha of A.I.; LL002, dosage 2: 250 g/ha of A.I.) as reduction of irrigation (restitution of 33% of Etc, while to the positive control the restitution was 100% of the Etc) compared to the positive control, for a total of 4 treatments (with positive – UTC, well-watered - and negative control – UTC, drought; fig. 1) per 5 replicates. In both trials, the effects of drought and products were assessed by visual evaluation of wilting, Living Ground Cover (LGC) through Digital Image Analysis (DIA) to assess green and dry areas, photosynthetic efficiency (Fv/Fm, only in the pot trial) and NDVI (only in the microplot trial) to evaluate plants health.

## Results and Discussion

Treatments with LL002 delayed drought symptoms in both trials and generally seem to be able to induce a better turf health status in critical conditions, compared to the negative control. In pots, treatments induced a statistically significant delay in the wilting appearance (visual score) and a lower % of dry area compared to the UTC 33%. Moreover, they induced also a lower decrease in photosynthetic efficiency (Fv/Fm, fig. 2). The trial on microplots showed that plots treated with the biostimulant LL002 reduced the impact of drought stress, in particular in the first weeks, as seen by a slower drop of LGC, Turf Quality (TQ) and NDVI compared to UTC drought (fig.3).

In conclusion, tools such as biostimulants, directly targeting the plants physiology without impacting the environment, are becoming of growing interest. The prototype LL002, studied in these experiments, proved to be an efficient tool to delay the appearance of negative symptoms such as loss of density/quality/color, generated by water deficiency on turf, in particular in the first weeks after the onset of drought stress both in pots and in field conditions.


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# Precision irrigation using sensor and mapping technologies

**Straw, C. and J. Friell**

## Introduction

The golf industry is under increasing public pressure to improve environmental impacts by reducing management inputs, particularly irrigation water. Precision irrigation is a relatively new concept intended to achieve reductions by irrigating only where, when, and in the amount needed[1]. The combination of currently available technologies, such as individual irrigation head control, Global Positioning System (GPS)-equipped handheld and mobile soil moisture sensors (SMS), and in-ground SMS, allows for precision irrigation, rather than traditional "blanket" applications based on when the golf course superintendent feels it is necessary. No published research has combined these tools on golf courses to determine water savings with precision irrigation but use of in-ground SMS alone on home lawns for irrigation scheduling has shown to reduce water use by up to 74 %[2]. Irrigated golf course fairways in the United States represent a significant potential for water savings because they occupy an average of 11.3 ha per course; yet, recent data suggests that adoption of handheld and in-ground SMS has been slow with just 29% and 4% of courses using them, respectively[3]. Precision irrigation implementation has been essentially nonexistent for this reason, as well as a combination of other factors, including lack of detailed protocols for soil moisture map creation, in-ground SMS placement, and irrigation system programming[4]. Therefore, the objective of this case study is to introduce a procedure that implements the aforementioned technologies to advance precision irrigation by mapping soil moisture and appropriately placing in-ground SMS.

## Materials and Methods

A golf course survey was conducted on 15 July 2019 to measure and map soil moisture (i.e. percent volumetric water content) variability on nine fairways at Edina Country Club (Edina, MN, USA) with the Toro Precision Sense 6000 (PS6000; The Toro Company, Bloomington, MN, USA). The PS6000 is a mobile, multi-sensor device capable of measuring hundreds of georeferenced soil moisture data points across a fairway in a timely manner[1]. A GPS receiver on the PS6000 georeferenced all soil moisture sample locations as they were being taken, and was also used for georeferencing all irrigation head locations on the nine fairways. Approximately 9 cm of rainfall was received 4 days prior to the survey. No additional rainfall or irrigation occurred, so soil moisture at the time of the survey was representative of near field capacity. Mapping soil moisture at field capacity is recommended because it has a stable pattern of spatial variation that can be strongly correlated with other stable soil properties (e.g. soil texture[1]).

Soil moisture map creation and irrigation management zone delineations and classifications were all conducted in ArcMap (ESRI, Redlands, CA, USA).

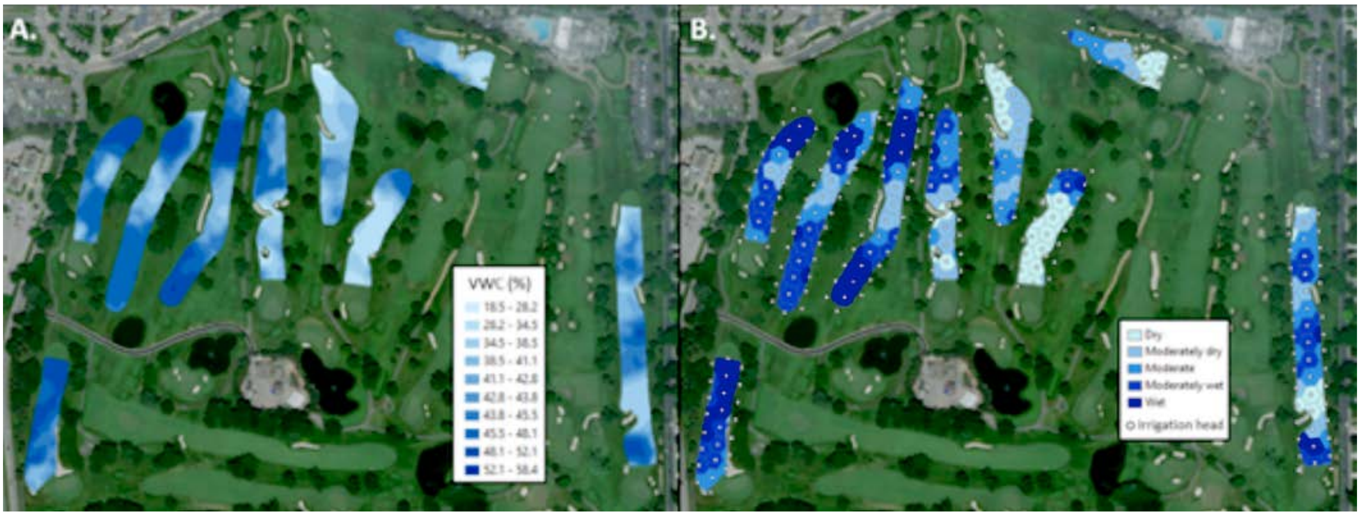


**Fig. 1: A) Soil moisture raster map and B) irrigation management zone classifications.**

[1] CARROW, R.N., J.M. KRUM, I. FLITCROFT and V. CLINE, 2010: Precision turfgrass management: challenges and field applications for mapping turfgrass soil and stress. Precision Agriculture, 11(2):115-134.

[2] McCREADY, M.S., M.D. DUKES and G.L. MILLER, 2009: Water conservation potential of smart irrigation controllers on St. Augustinegrass. Agricultural Water Management, 96(11):1623–1632.

[3] Golf Course Superintendents Association of America, 2015: 2014 water use and conservation practices on U.S. golf courses. Golf course environmental profile, phase II, volume I, p. 25.

[4] STRAW, C.M., W.S. WALDROP and B.P. HORGAN, 2019: Golf course superintendents' knowledge of variability within fairways: a tool for precision turfgrass management. Precision Agriculture, https://doi.org/10.1007/s11119-019-09687-1.

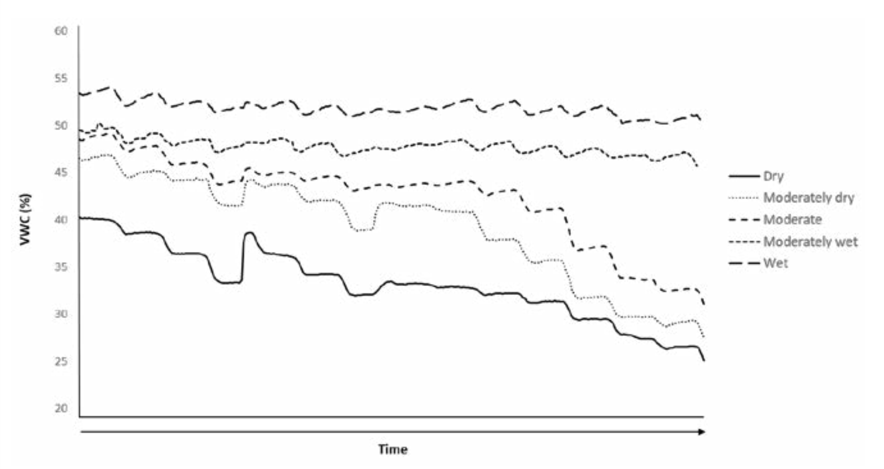


**Fig. 2: Example of data from five Toro TurfGuard in-ground soil moisture sensors that have been properly placed within five irrigation management zones.**

The georeferenced soil moisture data were interpolated via ordinary kriging to produce the soil moisture map, which was a raster map comprised of 1 $m^2$ pixels. Irrigation management zones were delineated around each irrigation head using Thiessen polygons. Zonal statistics were calculated using the soil moisture raster map to determine an average soil moisture value within each of the delineated irrigation management zones. Irrigation management zones were classified, based on their average soil moisture value, into one of five soil moisture classes using Jenks natural breaks. A combination of the interpolated soil moisture map and irrigation management zone classifications were used to inform in-ground SMS placement. One in-ground SMS was placed in a representative area within each moisture class, where, in theory, zones that have the same classification have comparable soil moisture values. Location effects (e.g. slope, shade) were also considered when determining in-ground SMS placement, as was historical knowledge of the area.

## Results and Discussion

The golf course did exhibit considerable soil moisture variability, as indicated by the interpolated soil moisture map (Figure 1A). In this case study, five irrigation management zones (i.e. soil moisture classes) were determined (Figure 1B), but this number may change among golf courses based on soil moisture variability or superintendent preference. Individual irrigation head control will make it possible to create programs so that all irrigation management zones with the same soil moisture classification irrigate together. Soil moisture thresholds to trigger irrigation for a program can be determined with the in-ground SMS data in each soil moisture class (Figure 2). For example, identifying upper and lower soil moisture limits for each in-ground SMS during a dry down period to determine plant available water, and then using that information to trigger future irrigation once plant available water has decrease to a certain percent. “Dry” classes would get irrigated more frequently, “wet” classes would get irrigated less frequently, and an entire fairway may never get completely irrigated during one irrigation session. It is hypothesized this method of irrigation scheduling can significantly reduce water use with more precise irrigation applications and should be the focus of further research.

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# Applying surfactants decrease turf water use under high evaporative demands in glasshouse conditions

**Giannakopoulos, V., J. Puertolas, A. Owen and I.C. Dodd**

## Introduction

Surfactant-based wetting agents (referred as surfactants) are amphiphilic molecules that decrease the surface tension of water and their effects on soil properties have been widely assessed[1]. Surfactant molecules decrease the contact angle between water molecules and soil particles, enhancing infiltration rate on hydrophobic substrates which can improve soil moisture distribution within the soil profile[2,3].

Much research on the impact of surfactants on plant growth has focused on turfgrass, as this is the current main market target of these products. Surfactant application to turfgrass improved plant colour, plant quality and biomass[4,5], by alleviating soil hydrophobicity that causes localised dry spots (LDS) in sand-based amenity pitches[6].

In non-hydrophobic soils, applying surfactants enhanced plant growth at drying soil[7]. However, very little research has explored the impact of surfactants on the regulation of plant water use. Surfactants decreased transpiration rates in New Guinea Impatiens, without compromising net photosynthesis, ultimately increasing plant water use efficiency[8]. However, such studies have not been conducted in turfgrass species.

Atmospheric vapour pressure deficit (VPD) is defined as the difference between the saturation vapour pressure and the actual vapour pressure. It is widely recognized that VPD is the evaporative driving force for transpiration[9]. To our best knowledge, no com-

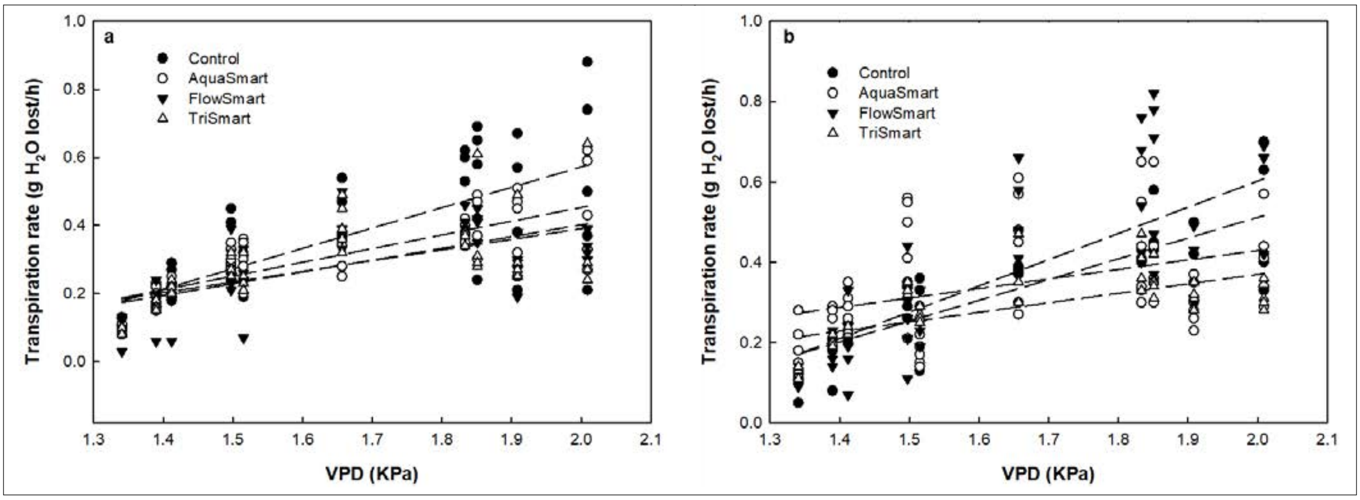


**Fig. 1: Relationship between E and VPD of *Lolium perenne* growing in low and high organic matter soils (panels a and b, respectively) without (black circles) and with addition of AquaSmart, FlowSmart, TriSmart (hollow circles, black triangles, hollow triangles, respectively). Each point is an individual plant and linear regressions are fitted.**

[1] URRESTARAZU, M., C. GUILLEN, P. MAZUELA and G. CARRASCO, 2008: Wetting agent effect on physical properties of new and reused rockwool and coconut coir waste. Scientia Horticulturae. 116(1):104-108.

[2] OOSTINDIE, K., L. DEKKER, J.G. WESSELING and C.J. RITSEMA, 2008: Soil Use and Management. 24(4): 409-415.

[3] CID-BALLARIN, C., R. MUÑOZ-CARPENA, A. SOCORRO-MONZÓN and G. GONZÁLEZ-TAMARGO, 1998: Wetting agent effects on peat properties related to nutrient solution losses and plant growth. Acta Horticulturae. 458: 161-170.

[4] YORK, C.A. and N.A. BALDWIN, 1993: Localized dry spot of UK golf greens, field characteristics, and evaluation of wetting agents for alleviation of localized dry spot symptoms. International Turfgrass Society Research Journal. 7: 476-483.

[5] CISAR, J.L., K.E. WILLIAMS, H.E. VIVAS, J.J. HAYDU, 2000. The occurrence and alleviation by surfactants of soil-water repellency on sand-based turfgrass systems. Journal of Hydrology. 231-232: 352-358.

[6] ALVAREZ, G., E. SEVOSTIANOVA, M. SERENA, R. SALLENAVE and B. LEINAUER, 2016: Surfactant and polymer-coated sand effects on deficit irrigated bermudagrass turf. Agronomy Journal. 108(6): 2245-2255.

[7] JAFARIAN, S., M.R. CHAICHI, M.G. MEHRDAD, 2016: Effects of surfactant and limited irrigation on forage yield and quality of alfalfa (*Medicago sativa L.*). Australian Journal of Crop Science. 10 (1): 386-393.

[8] SIBLEY, J., X. YANG, W. LU and D. EAKES, 2018: Effects of a nonionic surfactant on growth, photosynthesis, and transpiration of New Guinea impatiens in the greenhouse. Journal of Environmental Horticulture. 36(2): 73-81.

[9] JAUREGUI, I., S.A. ROTHWELL, S.H. TAYLOR, M.A.J. PARRY, E. CARMO-SILVA, I.C. DODD, 2018: Plant Methods. 14(97).

[10] RYAN, A.C., I.C. DODD, S.A. ROTHWELL, R. JONES, F. TARDIEU, X. DRAYE and W.J. DAVIES, 2016: Plant Science. 251: 101-109.

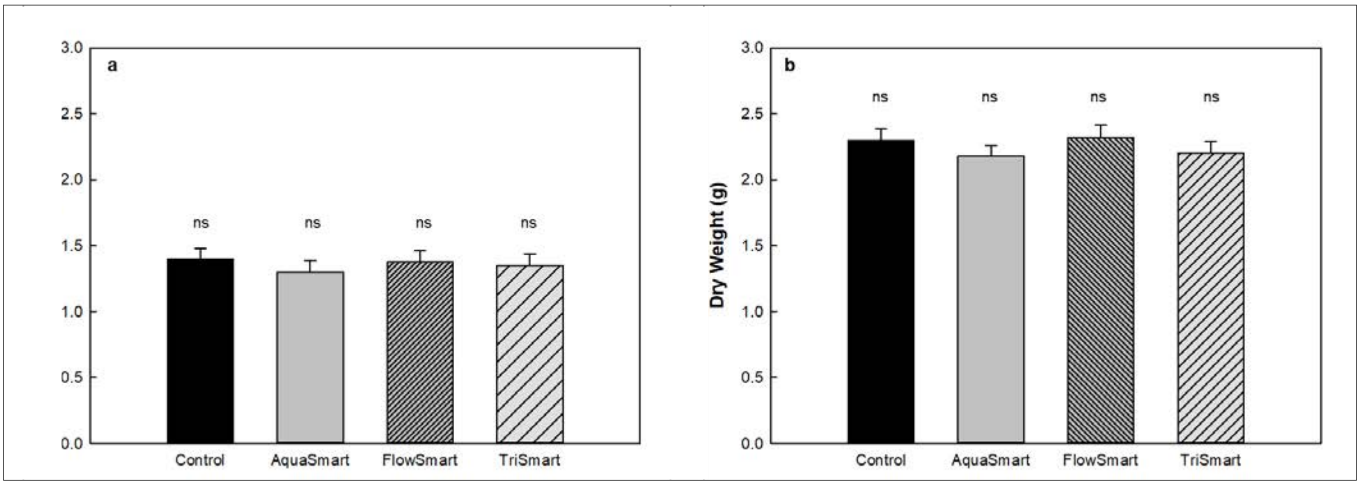


**Fig. 2: Dry weight of *Lolium perenne* growing in low (a) and high (b) organic matter soils without (black bars) and with addition of AquaSmart, FlowSmart, TriSmart (light grey bars, dark grey/striped bars, light grey/striped bars, respectively). Bars are means ± SE of six replicates, with no significant effects ($p > 0.2$) in either soil, thus non-significant results are reported as ns.**

prehensive evaluation of surfactant effects on plant water use under elevated VPD has occurred. Hence, the objective of this study was to determine the pot water losses in a high-throughput gravimetric platform installed at Lancaster Environment Centre[10], to evaluate the effect of surfactants on evapotranspiration (ET) in turfgrass species. Additionally, transpiration (E) responses under elevated VPD were compared between treatments, by distinguishing evaporative and transpiration components of ET.

## Materials and Methods

Turfgrass (*Lolium perenne*) was grown in pots filled with three different soils of contrasting organic matter content, in a glasshouse at Lancaster Environment Centre, in June 2019. Three different surfactant types and a no surfactant control were tested in a factorial 4 (surfactants) x 3 (soil types) experiment where ET losses were hourly estimated, and relative humidity and temperature were recorded (to calculate VPDs) using data loggers (hourly). Plant transpiration (E) was calculated as the difference between ET and evaporation of nearby bare soil pots. E and VPD data between 09:00 - 19:00 were selected and the E versus VPD relationship was established for well – watered (WW) plants whereas measurements occurred 21 days after seeding, when plants covered the entire surface of the pot.

## Results

Under well-watered conditions, E of surfactant-treated plants was lower under elevated VPD, in two of three substrates (low and high contents of organic matter). Hence, surfactant – treated plants tended to consume less water as evaporative demand was increasing (Figure 1). Since no differences were observed in biomass accumulation between treatments (Figure 2), surfactants increased water use efficiency of the turfgrass.

## Conclusion

Surfactant application decreased turf water use under high evaporative demand conditions without limiting plant growth, thereby increasing water use efficiency.

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# Wetting agent effects on plant available water for hydrophobic USGA root zones

**Mingyan Jiang, M., M.C. Fleetwood, S.H. Anderson and X. Xiong**

## Introduction

Soil water repellency or soil hydrophobicity, is a worldwide issue[1] that impacts agricultural fields, pastures, forests, grasslands, parks and turf areas across all major soil textures[2] in all major climatic regions[3]. On intensively managed turf, especially on sand-based golf course putting greens that are built based on U.S. Golf Association recommendations[4], the occurrence of soil water repellency is literally inevitable, likely due to the small specific surface area (area/mass) of sand as compared with peat and clay[5]. It is also argued that the higher distribution of macropores in sandy soils provides a preferred habitat for fungal growth rather than bacteria, which further promotes the development of soil hydrophobicity[6]. Subsequently, water bypasses the hydrophobic rootzones and causes preferential flow, leading to the development of localized dry spot.

To solve issues associated with soil hydrophobicity, application of wetting agents is the number one solution implemented by turf professional managers. In the U.S., 94% of golf courses use wetting agents as the most popular method for managing soil hydrophobicity[7]. Wetting agents are amphiphilic molecules that contain a hydrophobic/lipophilic region that are oil-loving and can adhere onto hydrophobic sand surfaces, and a hydrophilic region that can "hold" onto water molecules. The balance between the two regions, termed hydrophilic-lipophilic balance, determines the degree of lipid- or water-solubility of the wetting agents[8]. In other words, the chemical property of the wetting agent molecules determines if it is better to be used for accelerating water infiltration or increasing water retention. The complexity of the wetting agent chemistry and various purposes for which people use wetting agents, such as increasing soil water infiltration or improving water retention, explain our inability to answer the number one question superintendents have, "which wetting agent is the best?"[9].

Therefore, the objectives of this research were to evaluate the effects of selected wetting agents on water retention capacities by using a pressure chamber system, and subsequently determine compound influences on plant available water for a hydrophobic USGA sand.

## Materials and Methods

Hydrophobic sands were collected from a USGA green, and the hydrophobicity of the sands were determined at 3.4 M using the molarity of ethanol droplet test, which categorized the sands to be severe hydrophobic[10]. After packing to uniformity, the hydrophobic sands were saturated with various wetting agent solutions at label suggested rates, before subjecting them to pressure chamber treatments at two pressure points, -2.9 kPa and -1,500 kPa, for estimated field capacity and permanent wilting point, respectively[11]. After five days equilibration and oven drying, the gravimetric water content corresponding to each pressure value was calculated and adjusted to volumetric water content, and treatments' effect on plant available water was estimated. All treatments were arranged in a completely randomized design with four replications, and the entire experiment was repeated once. All data collected were subjected to analysis of variance using the PROC GLM procedure of SAS 9.4 (SAS Institute, Cary, NC), and significant means were separated based on Fisher's Protected LSD at $P \leq 0.05$.

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1 DEKKER, L.W., K. OOSTINDIE and C.J. RITSEMA, 2005: Exponential increase of publications related to soil water repellency. Australia Journal of Soil Research. 43: 403-441.

2 DOERR, S.H., R.A. SHAKESBY, L.W. DEKKER and C.J. RITSEMA, 2006: Occurrence, prediction and hydrological effects of water repellency amongst major soil and land-use types in a humid temperate climate. European Journal of Soil Science. 57: 741–754.

3 JARAMILLO, D.F., L.W. DEKKER, C.J. RITSEMA and J.M.H. HENDRICKX, 2000: Occurrence of soil water repellency in arid and humid climates. Journal of Hydrology. 231: 105–111.

4 U.S. Golf Association. USGA Recommendations for a Method of Putting Green Construction; USGA: Far Hills, NJ, USA, 2004; Available online: https://www.usga.org/content/dam/usga/images/course-care/2004%20USGA%20Recommendations%20For%20a%20Method%20of%20Putting%20Green%20Cons.pdf (accessed on February 3, 2020).

5 BLACKWELL, P.S., 1993: Improving sustainable production from water repellent sands. Western Australia Journal of Agriculture. 34: 160–167.

6 HALLETT, P.D., K. RITZ and R.E. WHEATLEY, 2001: Microbial derived water repellency in golf course soil. International Turfgrass Society Research Journal. 9: 518–524.

7 GELERNTER, W.D., L.J. STOWELL, M.E. JOHNSON, C.D. BROWN and J.F. BEDITZ, 2015: Documenting trends in water use and conservation practices on U.S. golf courses. Crop, Forage, & Turfgrass Management. Online. DOI: 10.2134/cftm2015.0149.

8 SCHOTT, H., 1995: Hydrophilic-lipophilic balance, solubility parameter, and oil-water partition coefficient as universal parameters of nonionic surfactants. Journal of Pharmaceutical Sciences. 84: 1215-1222.

9 KARNOK, K.J., 2006: Which wetting agent is best? Golf Course Manage. 74: 82-83.

10 KING, P.M., 1981: Comparison of methods for measuring severity of water repellence of sandy soils and assessment of some factors that affect measurement. Australian Journal of Soil Research. 19: 275-285.

11 OK, C.H., S.H. ANDERSON and E.H. ERVIN, 2003: Amendments and construction systems for improving the performance of sand-based putting greens. Agronomy Journal. 95: 1583-1590.

## Results and Discussion

Plant available water, determined as water retained between the two pressure points of -2.9 kPa and -1,500 kPa, was positively correlated ($R^2$=0.99) with water held at estimated field capacity but not at the permanent wilting point. The 21 wetting agents evaluated resulted in a wide spectrum of plant available water, ranging between 5.5% and 13.3%. The wetting agent InfilTRX resulted in the highest plant available water (13.3%), and the amount of water held at field capacity was 71% greater than Cascade Plus, another straight block copolymer[12]. InfilTRX yielded a high surface tension at 44.8 mN $m^{-1}$, compared to Cascade Plus with its surface tension determined at 29.9 mN $m^{-1}$ [13]. Early research has reported that surface tension is negatively correlated to hydraulic conductivity[14]; hence, InfilTRX-treated rootzone likely retains more water for a relatively longer period of time, compared to compounds that exhibit lower surface tension such as Cascade Plus. In contrast, the wetting agent Tournament Ready resulted in relatively lower amounts of plant available water at 5.6%. This result indicates that applications of this compound might lead to relatively drier rootzone conditions and hence, they may not be the best choice if water conservation is desired. However, early research reported that products like Tournament-Ready demonstrated a fast infiltration rate into hydrophobic sand with a hydraulic conductivity of 28 mm $min^{-1}$ [15]. Therefore, products like Tournament-Ready would be best used for fast drainage, especially following a major rainfall event.

## Conclusion

This research provided strong evidence that different wetting agents are likely designed for different purposes, and discriminant use is advised.


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[12] ZONTEK, S.J. and S.J. KOSTKA, 2012: Understanding the different wetting agent chemistries. USGA Green Section Record. 50: 1-6.

[13] FLEETWOOD, M.C., S.H. Anderson, K.W. Goyne and X. Xiong, 2017. Evaluation of surface tension and infiltration of wetting agents. ASA-CSSA-SSSA International Annual Meeting. Tampa, FL, October, 2017.

[14] SONG, E., J.G. SCHNEIDER, S.H. ANDERSON, K.W. GOYNE and X. XIONG, 2014: Wetting agent influence on water infiltration into hydrophobic sand: II. Physical property. Agronomy Journal. 106: 1879-1885.

[15] SONG, E., J.G. SCHNEIDER, S.H. ANDERSON, K.W. GOYNE and X. XIONG, 2014: Wetting agent influence on water infiltration into hydrophobic sand: I. Re-wettability. Agronomy Journal. 106: 1873-1878.

# Alternate Irrigation with Seawater and Potable Water affects green coverage of two Paspalum Vaginatum varieties grown on shallow green roof systems

**Ntoulas, N., C. Kalampogias and P.A. Nektarios**

## Introduction

The continuing decline in global drinking water reserves, necessitates the use of alternative water irrigation resources for turfgrasses grown on shallow green roof systems. Numerous green roofs have been established in the vicinity of coastal areas, especially in southern semi-arid Mediterranean countries. In such cases, partial irrigation of green roofs with seawater could contribute to the conservation of valuable drinking water supplies. Green roofs are appropriate candidates for irrigating with seawater due to the utilized substrates which are comprised of coarse-textured materials and thus they favor leaching of excess salts through their drainage layer. The aim of the current study was to evaluate two varieties of the warm-season turfgrass *Paspalum vaginatum*, ‘Marina’ and ‘Platinum TE’, grown on shallow green roof systems and irrigated with seawater alternated with potable water.

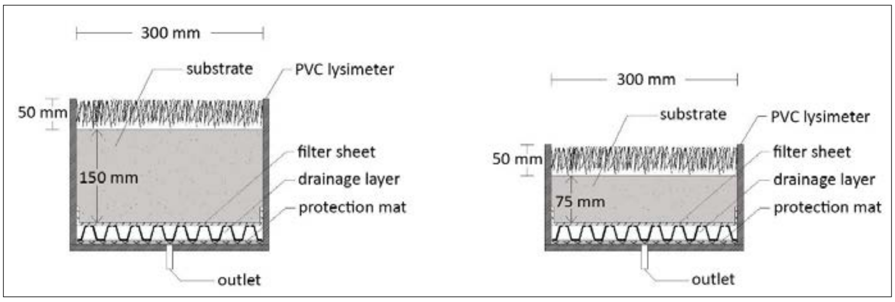


**Fig. 1: Construction detail of the experimental lysimeters indicating the different layers of the extensive green roof system at two substrate depths (75 mm and 150 mm).**

## Materials and Methods

The study was conducted from 4th July 2017 until 31st August 2017 in the experimental greenhouse of the Laboratory of Floriculture and Landscape Architecture, Agricultural University of Athens, Athens, Greece. It comprised of 48 lysimeters with 300 mm diameter. Within each lysimeter a complete layered simulation of an extensive green roof system was constructed (Fig. 1). The lysimeters were filled with a specialized and patented green roof substrate that comprised of 65% pumice,

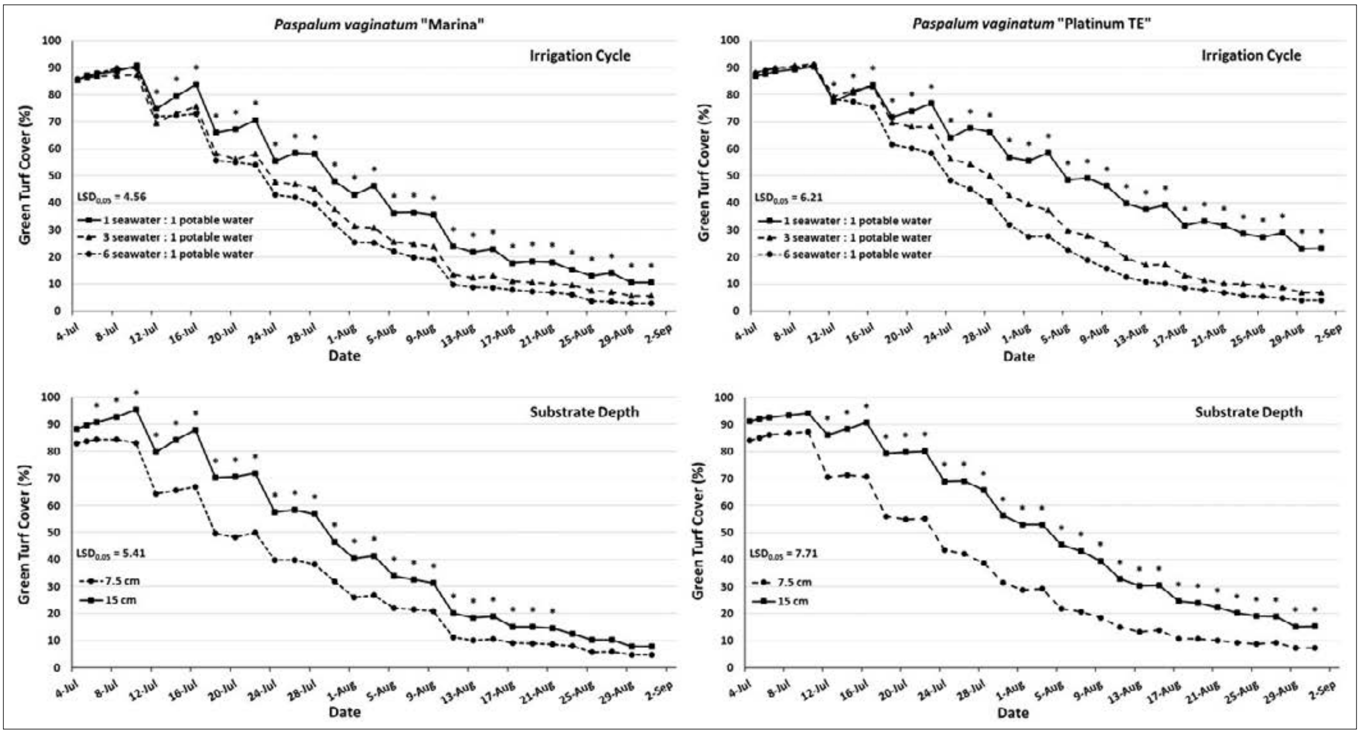


Fig. 2: Green turf cover (%) of the two *Paspalum vaginatum* varieties ‘Marina’ and ‘Platinum TE’, as affected by irrigation cycles (1:1, 3:1 or 6:1 alternation between seawater and potable water application, respectively) and green roof substrate depth (75 mm or 150 mm) during the stress period (4th Jul.-31st Aug. 2017). Values are the mean of 4 replications. Asterisks (*) represent significant differences in-between treatment means on a single sampling date, according to Fisher’ least significance difference (LSD) at P<0.05 following the repeated measures model.

15% thermally treated attapulgite clay, 15% compost and 5% clinoptilolite zeolite by volume. *Paspalum vaginatum* varieties ‘Marina’ and ‘Platinum TE’ were established in the lysimeters one year prior to the initiation of the current stress period using washed sod. Treatments included: a) two substrate depths of 75 mm and 150 mm and b) three irrigation cycles (1:1, 3:1 or 6:1 alternation between seawater and potable water application, respectively). Irrigation of either seawater (59.7 dS $m^{-1}$) or potable water (0.295 dS $m^{-1}$) was applied every second day at a height of 10 mm. Measurements included the determination of green turf cover (GTC) utilizing digital image analysis, clippings’ dry weight and electrical conductivity (not presented) of the lysimeters’ leachate. Turfgrass sward was mowed at a height of 50 mm once a week and foliar fertilization 20-20-20 (NPK) was applied every two weeks at a rate of 10 g $L^{-1}$ $m^{-2}$.

## Results and Discussion

During the study, GTC values and clippings’ dry weight were significantly affected by both substrate depth and irrigation alternation between seawater and potable water. GTC for both seashore paspalum varieties started to decline 6 days after stress initiation (Fig. 2). It was found that turfgrasses retained higher GTC values when irrigated with 1:1 cycle compared to the other two irrigation cycles. However, none of the irrigation cycles was able to maintain GTC of the two varieties above 50% at the end of the study. The increase of substrate depth from 75 mm to 150 mm improved GTC values for both varieties. Clippings’ dry weight supported the findings of GTC measurements (Fig. 3). More specifically, turfgrasses exhibited higher clippings’ yield in the deeper profiles of 150 mm as well as when they were irrigated with the 1:1 cycle between seawater and potable water. Comparisons between leachate electrical conductivity and GTC revealed that GTC reduction for both varieties was inversely proportional to the increase of leachate electrical conductivity (data not shown). The more frequent turfgrass irrigation with seawater in the 6:1 and 3:1 cycles resulted in a faster GTC reduction rate. In order to avoid GTC reduction below the 50% threshold when irrigation is applied at a 1:1 cycle between seawater and potable water, the leachate electrical conductivity should not exceed 35.79 dS $m^{-1}$ for “Marina” and 43.19 dS $m^{-1}$ for “Platinum TE” when grown on shallow green roof systems. Similar results to our findings were reported by other researchers who evaluated *Paspalum vaginatum* salinity tolerance (1, 2).

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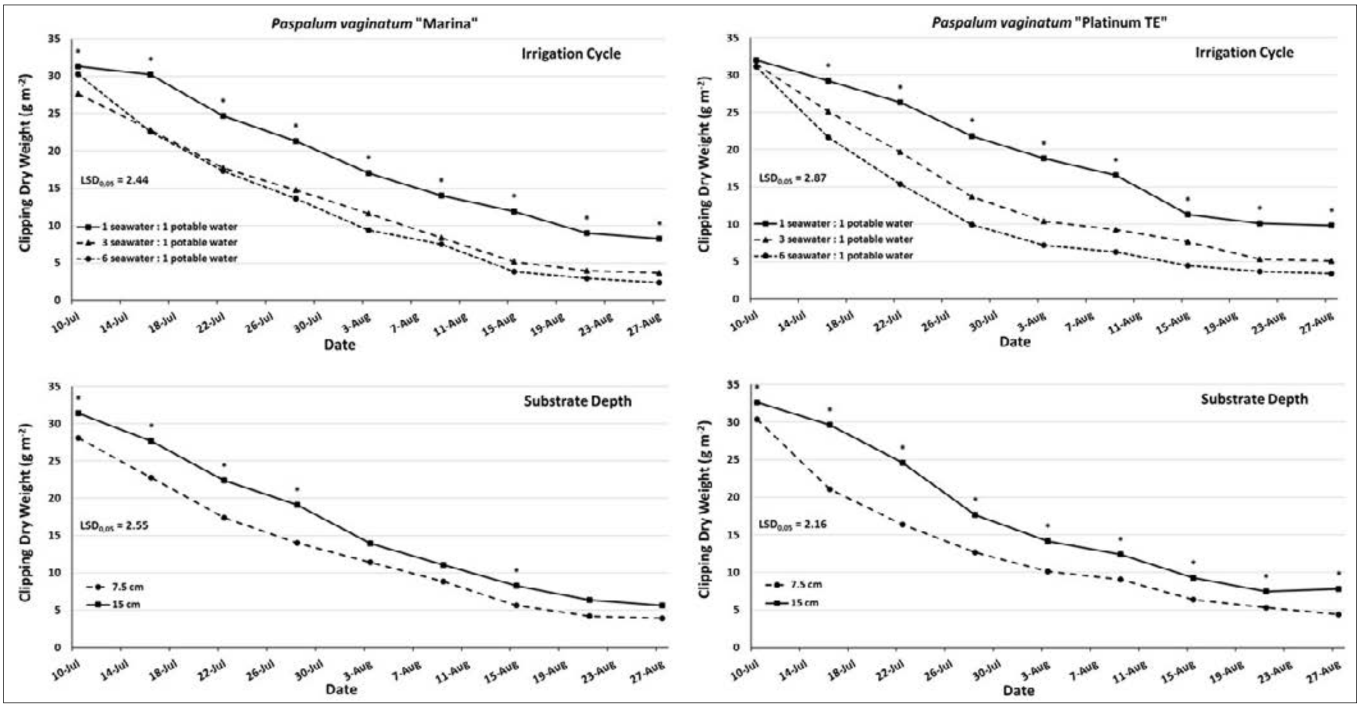


**Fig. 3: Clippings’ dry weight (g m-2) of the two *Paspalum vaginatum* varieties ‘Marina’ and ‘Platinum TE’, as affected by irrigation cycles (1:1, 3:1 or 6:1 alternation between seawater and potable water application, respectively) and green roof substrate depth (75 mm or 150 mm) during the stress period (4th Jul.-31st Aug. 2017). Values are the mean of 4 replications. Asterisks (*) represent significant differences in-between treatment means on a single sampling date, according to Fisher’ least significance difference (LSD) at P<0.05 following the repeated measures model.**

1 LEE, G., R.R. DUNCAN and R.N. CARROW, 2004. Salinity tolerance of seashore paspalum ecotypes: Shoot growth responses and criteria. HortScience, 39(5): 1138-1142.

2 UDDIN, M.K., A.S. JURAIMI, M.R., R. ISMAIL, R. OTHMAN and A.A. RAHIM, 2009. Growth response of eight tropical turfgrass species to salinity. African Journal of Biotechnology, 8 (21):5799-5806.

# Effect of GLYCINEBETAINE on a non-irrigated Bermudagrass Turf

**De Luca, V. and D. Gómez de Barreda**

## Introduction

Drought is a common issue in turfgrass management resulting in a poor turfgrass quality. When drought occurs, there is a cell adjustment in response to that stress. Glycinebetaine (GB) is the most abundant osmoprotectant produced in plants in response to dehydration induced by drought, salinity, and suboptimal temperatures[1] and many studies have indicated a positive relationship between accumulation of GB and plant stress in some species. For example, Yang et al (2012)[2] enumerated some cites which indicated that an exogenous application of GB increased endogenous GB content and enhanced plant tolerance to drought or salinity stress for some plant species; and Liu et al, (2017)[3] demonstrated an improvement on drought tolerance in creeping bentgrass by exogenous GB applications due to its contribution to osmotic adjustment by significant accumulation of endogenous GB; but less information is available related to foliar GB applications on bermudagrass under drought stress. The objective of the study was to determine if monthly foliar applications of GB could improve turf quality of a non-irrigated bermudagrass (*Cynodon dactylon* L.) turf.

## Materials and Methods

A field study was conducted from April to December in the Polytechnic University of Valencia, Spain (39°29'01.5"N 0°20'11.8"W). An established bermudagrass (cv. 'Princess 77') area was

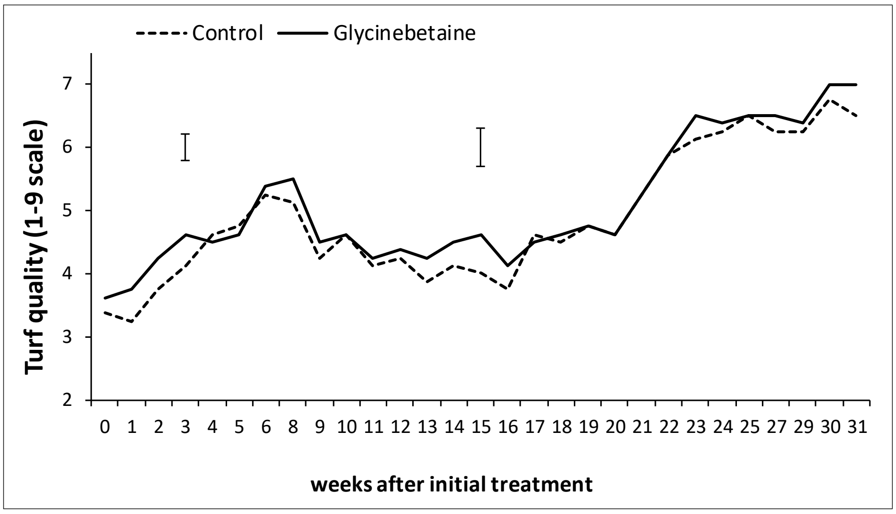


**Fig. 1: Turf quality (1-9 scale) of bermudagrass treated with glycinebetaine. Least significant differences (LSD) bars indicates significant difference between treated and untreated turf in a given day at 0.05 probability level.**

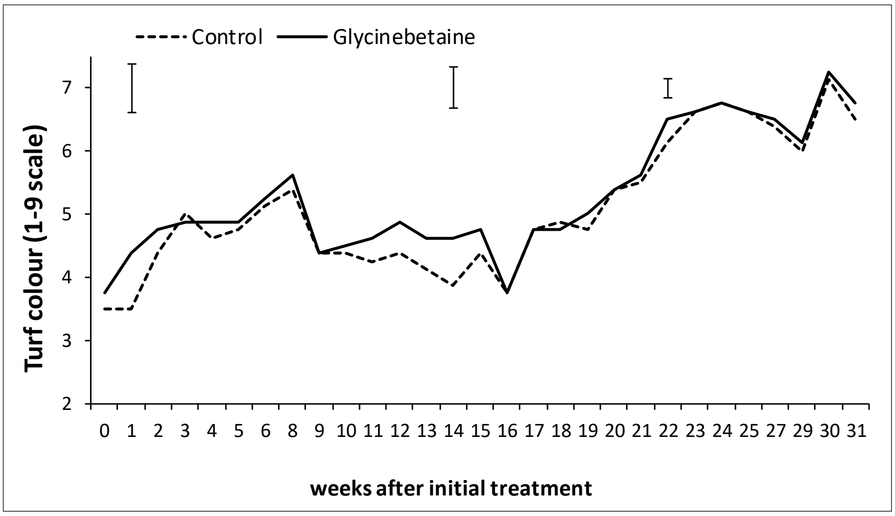


**Fig. 2: Turf colour (1-9 scale) of bermudagrass treated with glycinebetaine. Least significant differences (LSD) bars indicates significant difference between treated and untreated turf in a given day at 0.05 probability level.**

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1 ASHRAF, M. and M.R. FOOLAD, 2007: Roles of glycinebetaine and proline in improving plant abiotic stress resistance. Environ. Exp. Bot. 59:206–216.

2 YANG, Z., J. YU, E. MEREWITZ and B. HUANG, 2012. Differential effects of abscisic acid and glycine betaine on physiological responses to drought and salinity stress for two perennial grass species. J. Amer. Soc. Hort. Sci. 137:96–106.

3 LIU, N., S. LIN and B. HUANG, 2017: Differential effects of glycine betaine and spermidine on osmotic adjustment and antioxidant defense contributing to improved drought tolerance in creeping bentgrass. J. Amer. Soc. Hort. Sci. 142:20–26.

4 CARROW, R.N., 1997: Turfgrass response to slow-release nitrogen fertilizers. Agron. J. 89:491-496.

5 MORRIS, K.N. and R.C. SHEARMAN, 1998: NTEP turfgrass evaluation guidelines. In: NTEP Turfgrass Evaluation Workshop (p. 1-5). Beltsville, MD.

6 DU, H., Z. WANG, W. YU and B. HUANG, 2012: Metabolic responses of hybrid bermudagrass to short-term and long-term drought stress. J. Amer. Soc. Hort. Sci. 137:411–420.

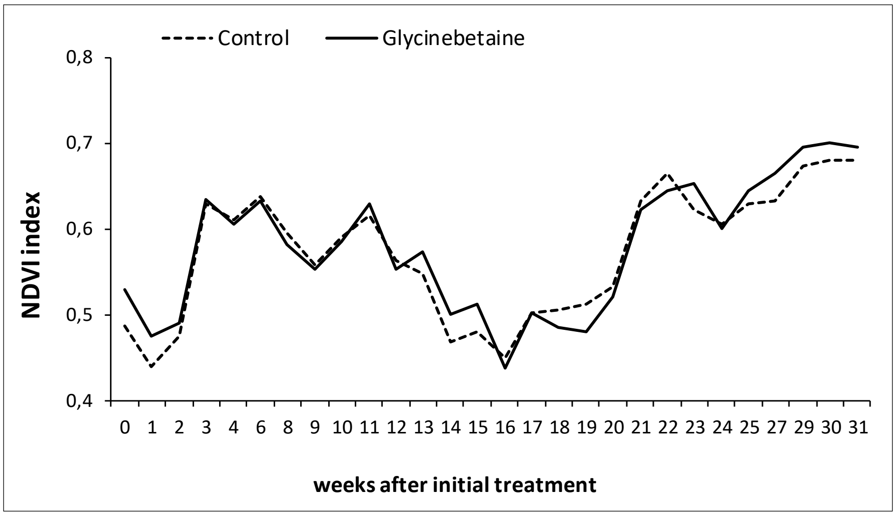


**Fig. 3: NDVI index of bermudagrass treated with glycinebetaine.**

treated with GB (98%) according to the following procedure: GB was monthly foliar applied on 4 out of 8, 1 $m^2$ elemental plots, at 10 $kg·ha^{-1}$ and diluted in 1000 $L·ha^{-1}$ of water. Applications were made using a CO2-pressurized sprayer calibrated at 2 bar with a single flat-fan nozzle (11002VH; TeeJet Spraying Systems). Turf was mowed weekly until November, and no irrigation was performed. The experimental design was a randomized complete block with one factor at 2 levels and four replications. The experiment evaluation consisted in a weekly evaluation of: i) turf quality with a subjective visual 1 to 9 scale where 1 is a dead turf and 9 is dark green, dense and uniform sward[4]; ii) turf colour with a visual rating on a scale of 1 to 9 where 1 is a light green turf and 9 is a dark green turf[5]; and iii) NDVI index as the average of 4 measurements per plot. At the end of the experiment, clipping fresh weight was determined, 20 days after last mowing in November. Fresh clipping samples were air-dried during 72 hours to obtain dry clipping weight. All statistical analysis were made with Statgraphics Centurion XVI where Fisher's protected LSD test was used at the 0.05 probability level to identify significant differences.

## Results and Discussion

There are three interesting periods in this experiment that can be highlighted. First period correspond to the beginning of the experiment, from 0 to 4 weeks after initial treatment (WAIT), coinciding with the bermudagrass green-up. Bermudagrass treated with GB seemed to accelerate that process with one statistical difference in turf quality (Figure 1) and colour (Figure 2), at 3 and 1 WAIT, respectively.

Second period runs from 9 to 16 WAIT which corresponds to the end of June and the beginning of August. During these weeks, turfgrass quality decreased to a minimum value of 3.8 at 16 WAIT. The same trend was observed for turfgrass colour (Figure 2) and NDVI index (Figure 3), with values dropping to 3.8 and 0.44 at 16 WAIT, respectively. The most interesting event in this period of quality decline was that turfgrass treated with GB lost quality slower than the untreated turf showing statistical differences at 15 and 14 WAIT for turf quality and turf colour, respectively, but not in terms of NDVI index. Yang et al, (2012)[2] reported that foliar applications of GB alleviate drought physiological damage of some turfgrasses by maintaining membrane stability mitigating stress effect. Du et al (2012)[6] also reported a loss of bermudagrass quality after 18 days of drought correlated with an increment of glycine among other free amino acids.

The third period is between 20 and 31 WAIT corresponding to the beginning of September and the end of November. There was a general improvement from 20 WAIT onwards due to some heavy rainfall events of 81 $L·m^{-2}$ in 1 week. In this case, there was only one statistical significant difference in terms of turf colour at 22 WAIT, whereas turf quality and NDVI index, for bermudagrass treated with GB, received values above the untreated ones but without statistical differences.

There were no differences between treated and untreated turf in terms of fresh and dry weight (data not shown).

## Conclusions

The use of GB on a drought stressed Princess 77 bermudagrass could be useful under these management procedures specially in the most important periods for this turf.

Further research should be conducted to discern whether actually GB has effect on this turfgrass variety.

## Acknowledgements:

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# Comparison of organic and conventional herbicides to control Bermudagrass

Reiter, M.

## Introduction

Removal of existing vegetation is an important step in renovation of turfgrass areas. Bermudagrass is a popular turfgrass in California, and is estimated to be the most common turf species on golf courses in the United States[1].

Beyond golf courses, bermudagrass is frequently used in other urban landscapes, like sports fields, parks, schools, and homes. Turf and landscape managers are looking for effective strategies to terminate bermudagrass before converting land to something else, like a naturalized, lower-maintenance area of grasses or forbs.

Industry standards for bermudagrass control are conventional herbicides like glyphosate and fluazifop-p-butyl (Fusilade II). Recently, turf managers are interested in alternative herbicides marketed as organic, especially in response to local restrictions on glyphosate and conventional herbicide use. The objective of this experiment was to compare conventional and organic herbicides for control of bermudagrass managed as a mowed turfgrass.

## Materials and Methods

The experiment was conducted on 'TifSport' hybrid bermudagrass [*Cynodon dactylon* (L.) Pers. × C. *transvaalensis* Burtt-Davy] located at Ridge Creek Golf Club in Dinuba, California, USA. Hybrid bermudagrass was mowed weekly at 4.45 cm and maintained as a golf course rough. Plots were 1.5 $m^2$ and arranged in a randomized complete block with 4 replications.

Treatments included 2 conventional herbicides, 5 organic herbicides, and an untreated control (Table 1). We used the highest label-recommended rates for all herbicides. Herbicide treatments were broadcast sprayed on 31 July 2019 with a $CO^2$-pressurized backpack sprayer delivering a water carrier volume of 935.4 L $ha^{-1}$. Applications were made around 12:00 PM with 0% cloud cover and air temperature approximately 32°C.

Bermudagrass control was measured with the plant health indicator normalized difference vegetation index (NDVI). NDVI was collected with a Greenseeker handheld crop sensor (Trimble Inc., Sunnyvale, CA, USA). Data was collected before the 31 July 2019 application, and every 1 to 7 days until 11 September 2019. Data was arcsine transformed, and Dunnett's test was conducted compare herbicide differences from the untreated control for each date. Orthogonal contrasts were used to compare organic vs. conventional herbicides. Data analysis was conducted in R.

## Results and Discussion

There were no significant differences for NDVI between the untreated control and treatment plots on the first rating date prior to herbicide application (Figure 1), ensuring uniformity in the bermudagrass field before treatments were applied.

Organic herbicides Avenger, Finalsan, Suppress, and WeedPharm showed significant injury 2 days after treatment (DAT) compared to untreated control plots. Suppress and Finalsan plots recovered by 19 DAT, while Avenger and WeedPharm plots recovered by 28 DAT. Throughout the entire trial, Burnout induced no injury compared to controls (Figure 1).

Significant injury was observed in Ranger PRO and Ranger PRO + Fusilade II plots at 5 DAT. The glyphosate-containing treatments maintained significant injury throughout

| Trade name | Active ingredient | Rate | Treatment group |
|---|---|---|---|
| Avenger | d-limonene | 25% v/v | Organic |
| Burnout | Citric acid + clove oil | 25% v/v | Organic |
| Finalsan | Fatty acids | 17% v/v | Organic |
| Suppress[a] | Caprylic acid + capric acid | 9% v/v | Organic |
| WeedPharm | Acetic acid | 100% (no dilution) | Organic |
| Ranger PRO[b] | Glyphosate | 918 g ai $ha^{-1}$ | Conventional |
| Ranger PRO + Fusilade II[b] | Glyphosate + fluazifop-p-butyl | 918 g ai $ha^{-1}$ + 69 g ai $ha^{-1}$ | Conventional |

[a] An organic acidifier (BioLink, Westbridge Agricultural Products, Vista, CA, USA) was added at a rate of 1% (v/v); product contains 50% citric acid

[b] A nonionic surfactant (Prefer 90, West Central, Inc., Willmar, MN, USA) was added at a rate of 0.25% (v/v); product contains 90% 1,2,3-propanetriol, diethylene glycol, alkyl polyglycoside.

**Tab. 1: Herbicide trade names, active ingredients rates, and conventional or organic designation.**

[1] GELERNTER, W.D., L.J. STOWELL, M.E. JOHNSON and C.D. BROWN, 2017: Documenting trends in land-use characteristics and environmental stewardship programs on US golf courses. Crop, Forage & Turfgrass Management 3:2016-10-0066.

[2] BARKER, A.V. and R.G. PROSTAK, 2009: Alternative management of roadside vegetation. HortTechnology 19:346-352.

[3] CHINERY, D., 2002. Using acetic acid (vinegar) as a broad-spectrum herbicide. Cornell Cooperative Extension.

[4] YOUNG, S.L., 2002. Exploring alternative methods for vegetation control and maintenance along roadsides. Cal EPPC News 10:5-7.

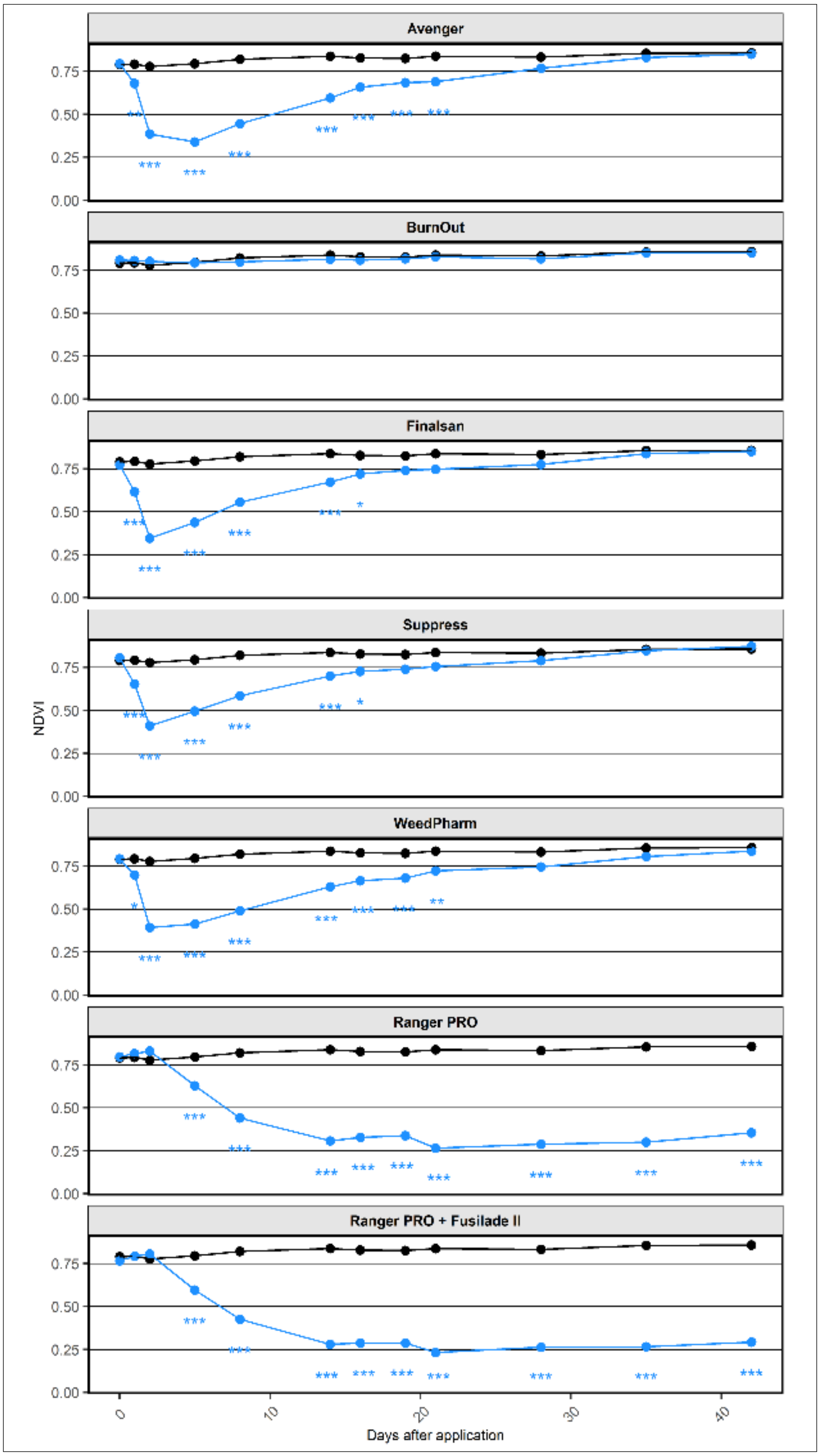


**Fig. 1: Normalized difference vegetation index (NDVI) for herbicide treatments (blue) compared to untreated control (black). * = p < 0.05, ** = p < 0.01, and *** = p < 0.001, according.**

the duration of data collection, up to 42 DAT (Figure 1).

Orthogonal contrasts showed Burnout (citric acid + clove oil) was not different than the untreated control, and Burnout was different from the rest of the organic herbicides. Because of this, Burnout was removed from the organic herbicides group before subsequent contrasts. Matran EC contained a similar active ingredient (clove oil) and previously showed no difference from untreated control for roadside vegetation management in Massachusetts[2].

Organic herbicides were characterized by an immediate burndown and ultimately complete recovery after a single application. Conventional products containing glyphosate had a delayed symptomology and provided significantly better control over time. Contrasts show that organic products had an advantage over conventional products only for the first 5 days (Figure 2). This burndown response from organic herbicide applications was documented in previous research on landscapes and roadsides[3,4].

Based on these findings, future research to support turfgrass managers should examine how these products work with multiple applications, in combination with other weed control approaches, in different climates, and on other turfgrass or weed species. Additionally, turf and landscape managers need to understand tradeoffs associated with organic weed control strategies. Switching from glyphosate-containing products to organic herbicides may require more frequent applications, higher product volumes, and increased product costs.

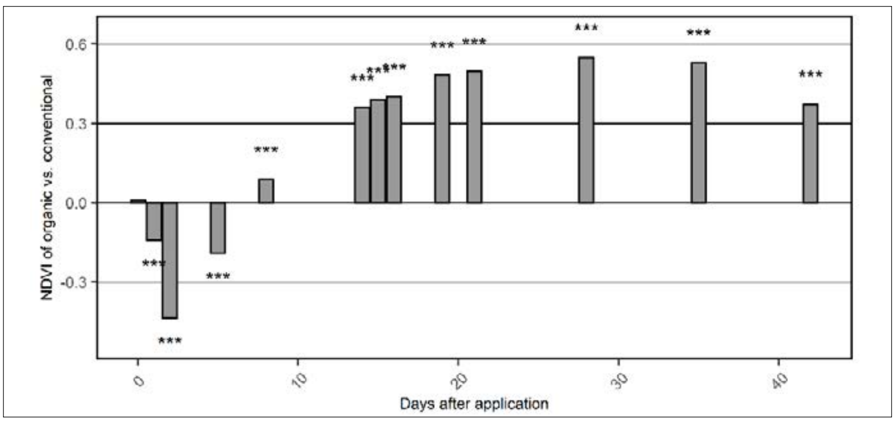


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**Fig. 2: NDVI for organic vs. conventional herbicide treatments over time. Negative values indicate organic herbicides had lower NDVI and comparatively better herbicide efficacy. Positive values indicate conventional herbicides had lower NDVI and comparatively better herbicide efficacy. *** = p < 0.001.**

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