Effect of Greens Construction, Irrigation Type and Root Zone Material on Irrigation Efficiency, Turfgrass Quality and Water Use on Putting Greens in the Southwest

Progress Report

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Introduction and Justification

Due to rapid population growth and urban development in the United States, future demands for water may soon exceed the supply required to satisfy present per-capita water-use rates. During times of water shortage, priority is given to water uses that are deemed more essential to human society. As a result, growing attention is being focused on the amount of water used to irrigate landscape and recreational areas such as home lawns, parks, golf courses and athletic fields. The rapid rate of urban development has led to increased demands for landscape irrigation in newly developed residential and commercial areas, and recreational areas such as golf courses and athletic fields. Irrigation of these areas accounts for a large percentage of total urban water use. In Southern California, for example, it is estimated that residential urban outdoor water demand in the region exceeded agricultural sector demand in 1990 by 60% and would be estimated to exceed agricultural sector demand the following year by 100% (UCRTRAC, 1999). With up to 50% of total urban water consumption in the Southwest being utilized for irrigation of landscapes (Kjelgren et. al, 2000), many municipalities have implemented water conservation strategies (El Paso Water Utilities Public Service Board, 1992; California State Water Resource Control Board, 1993; Arizona Dept. of Water Resources, 1995).

Despite the widely held belief of critics that water is being wasted for irrigating non-essential crops (turf), turfgrass areas have gained economic importance that exceeds many agricultural food and feed crops. In New Mexico, based on green fees and golf memberships alone, turfgrass is the number two cash crop in the state after alfalfa, and generates $120 million per year, based on a conservative estimate (Leinauer and Ludwig, 2001). Notwithstanding the economic importance and continued public demand for turf areas, the current water shortages in the Southwest clearly set limits on expectations and water consumption for irrigation. Turf managers and golf course superintendents will experience increasing pressure from government to adopt the most efficient available method of irrigation to conserve water.

Because of the high intensity of play and low cutting height of these recreational turf areas, additional irrigation is needed during the vegetative period, especially when natural precipitation is insufficient. Sprinkler irrigation has been the accepted practice for irrigating lawns since Joseph Smith patented the first swiveling lawn sprinkler in 1894 (Connolly, 2001), despite its low efficiency in distributing water to the plant stand. Sprinkler overlap, wind drift, and evaporation losses during the irrigation process all contribute to water losses that increase overall water consumption and/or decrease plant stand quality. Poor water distribution due to high winds and the lack of sufficient quantities of potable irrigation water are the two greatest challenges that turf manager face in the desert Southwest. Both contribute to poor turf quality on turf areas. Subirrigation systems that apply water laterally to the root zone from perforated tiles or emitters buried either close to the surface or just below the normal root penetration from beneath the surface (subsurface drip irrigation or subirrigation) have been shown to save substantial quantities of irrigation water compared to sprinkler systems. Many agricultural studies have demonstrated improved water use efficiency and crop productivity through subirrigation. These studies have shown increased yields in tomatoes, cotton, sweet corn, cantaloupes, alfalfa and other crops, without increases in applied water (Connolly, 2001). Although the benefits of subsurface irrigation have been extensively studied in agriculture, this irrigation method has received very little acceptance or attention in the field of turf irrigation. Stroud (1987) and Chevallier *et al.* (1981) reported water savings of up to 50% when using subirrigation, and Leinauer (1998, 2004) reported a 90% reduction of water used for irrigation on subirrigated turf plots compared to sprinkler irrigated plots. Golf courses in southern Portugal that use subsurface drip irrigation reportedly use 50% less irrigation water than other courses in the area that use sprinkler systems with no loss of turf quality (Fialho, personal communication, 1999). This region of Portugal has an annual precipitation rate of less than 250 mm (10") and temperatures during the growing season that are similar to those in the Southwestern USA. However, these numbers are based only on anecdotal information, and the systems have never been tested under rigorous experimental conditions. In addition to water savings, other advantages of subirrigation systems include the uninterrupted use of the turf area during irrigation and energy savings due to a lower operating water pressure. Despite the data demonstrating potential benefits of subirrigation systems, it still has a long way to go to achieve market acceptance. One argument against the use of subirrigation is that spacing and depth of emitters are extremely difficult to determine, especially in sloping areas. Other reasons for the limited success of subsurface irrigation are the relatively high cost of installation, the difficulty in monitoring underground systems, and the lack of urgency for water conservation.

Another factor that contributes to the increased water demands of these highly trafficked, low cut grass stands relates to the nature of the soil mixes used to construct root zones. These areas, which include athletic fields and greens and tees on golf courses, are usually built with sandy root zone mixes that have low water holding capacity. Two sets of guidelines are currently followed for the construction of golf greens. California style greens have a 30 cm (12 inch) deep straight sand root zone layer with no gravel blanket underneath. Trenches containing drain tiles and filled with gravel achieve drainage. The United States Golf Association (USGA) introduced specifications for the construction of golf greens four decades ago. These recommendations have become the standard in root zone construction, and since 1960 thousands of tees, putting greens, and athletic fields have been built in accordance to them. To provide optimum soil conditions for turfgrass growth, the USGA specifications include a stratified coarse-textured sandy root zone with a 30 cm (12 inches) deep root zone overlaying a 10 cm (4 inches) deep gravel blanket. In exchange for high air filled porosity, these high sand content root zones lack adequate water retention. To increase water-holding capacity, root zones are usually amended with peat. To date, peat is the only recommended organic amendment for root zone construction. However, during recent years, peat has become increasingly scarce, as bogs become more and more restricted for harvesting peat. Straight sand as alternative root zone or alternative organic and/or inorganic amendments will therefore need to be considered in the future.

Because of the increasing pressure to conserve water, it is imperative that efforts be made to determine the most efficient method of irrigation available and cost effective soil amendments to produce high quality turfgrass. No published studies are known that have investigated the effect of construction type (USGA vs. California style), irrigation type (sprinkler irrigation vs. subsurface drip irrigation vs. subirrigation), and root zone type on irrigation efficiency, irrigation water use, plant stand quality and soil physical properties of turf root zones.

Study

Research efforts at New Mexico State University are underway to investigate whether greens type, irrigation type, and/or root zone type affects turfgrass performance, irrigation efficiency, and subsequently irrigation water use in the desert Southwest. The project included the construction of a 3,700 m^2 (40,000 ft^2) research area, built and maintained in the same way as commercial golf greens.

Objectives

The objectives of the study are to investigate:

1. the effects of greens type, types of irrigation system, and type of root zone on turfgrass establishment.
2. the effects of greens type, types of irrigation system, and type of root zone on irrigation water consumption, turf quality and drought resistance in flat and sloping areas.
3. the long-term effects of greens type and irrigation system on turf quality on sloping and flat areas.
4. the long-term effects of different irrigation systems on changes in soil physical and chemical properties in root zones

Material and Methods

The construction of a 3,400 m^2 research area at the Fabian Garcia Research Center at New Mexico State University was finished in May of 2003. The four treatments (main plots) to be tested are: 1) sprinkler irrigated USGA type green, 2) subsurface drip irrigated USGA type green, 3) sprinkler irrigated California style green, and 4) a subirrigated straight sand system (trade name Evaporative Control System [ECS]) *(As of 5-2006 ECS is known as EPIC systems by Rehbein Environmental Solutions.)*. Each of the 12 main plots is 17 m x 17 m in size. The design of the main plot (cross section) includes a 4 m (12') long horizontal portion (summit), followed by a 9 m (27') south facing downhill slope (backslope), followed by a 4 m (12') long horizontal portion (toeslope). The slope magnitude is 5% (Figure 1).

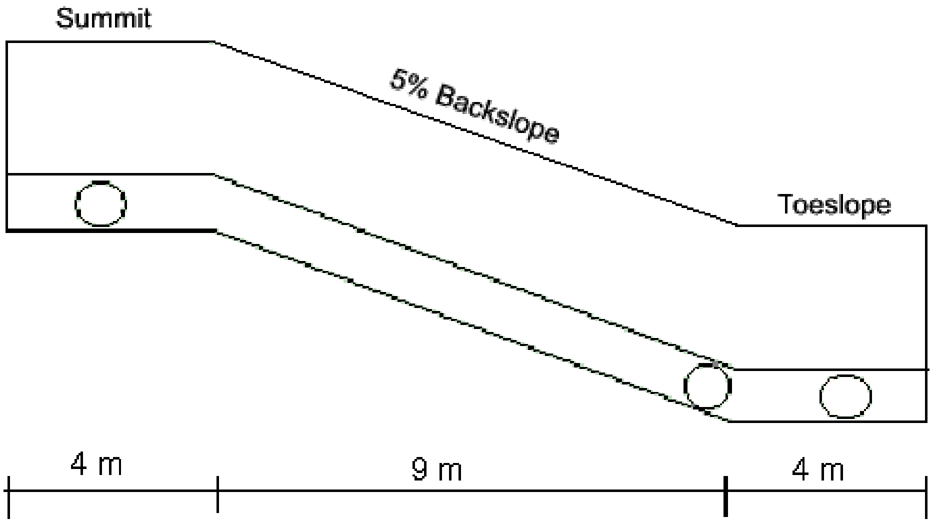

Figure 1: Cross section of main plot

Each main plot contains the recommended root zone material for the construction type (Table 1) and is replicated 3 times.

Table 1: Construction types and associated irrigation and root zone material

Construction type	Irrigation type	Root Zone
USGA (United States Golf Association)	Sprinkler	Sand – Peat

USGA	Subsurface Drip	Sand – Peat
California	Sprinkler	Sand
ECS (Evaporative Control System)	Subirrigation	Sand

All main plots, including those that were subsurface irrigated, have one pop-up sprinkler installed at every corner of the plot. Sprinkler heads and corresponding nozzles were selected and adjusted to ensure even irrigation and to prevent irrigation of adjacent plots. The subsurface irrigated main plots received the additional sprinkler heads for back-up purposes. The irrigation lines in the subsurface drip irrigated main plots are installed at a depth of 15 cm. Spacing between lines and emitters is 30 cm. Each emitter delivers irrigation water at 3.5 $l•h^{-1}$. The patented subirrigation and drainage system ECS (Evaporative Control System) is placed at a depth of 30 cm. Slitted pipes that achieve irrigation and drainage through the same pipe system are positioned centrally inside PVC trays that measure 1.7 m x 1.7 m and are surrounded by 13 cm high sidewalls. Solid PVC pipe (5 cm in diameter and 10 cm in length) at a height of 5 cm connect the trays. The elevated connection of the slitted pipes creates a permanent perched water table inside the tray to a height of 5 cm above the subgrade. Water movement into the root zone (irrigation) and from the root zone (drainage) is achieved only by capillary raise and by gravitation. For further system details refer to Evaporative Control Systems, 2000. Water supply lines to each main plot had a water meter installed that allowed for the determination of irrigation water use.

Barriers in the form of PVC liners separate the plots (construction/irrigation type) from one another to prevent lateral water movement between the plots. Each California and USGA plot received separate drainage with slitted drain tiles (5 cm in diameter) in trenches (10 cm wide) at 3 strategic locations: the center of the summit, the bottom of the backslope, and the center of the toeslope (Figure 1). The trenches were filled with gravel to cover the tiles and each tile was connected to a solid PVC pipe that discharges at the end of the toeslope into a 150 liter container. Because of the uniqueness of the ECS system and the importance of keeping each tray connected to one another, drainage water from the ECS plots cannot be separated for the 3 locations and was only collected from one outlet at the toeslope. To monitor volumetric soil moisture, each plot received a series of TDR sensors. Probes were placed in the center of the summit, the center of the backslope, and the center of the toeslope to measure at depths of 10 to 20 cm, 20 to 30 cm, and horizontally at a depth of 27 cm below the surface.

Maintenance

The plots were seeded with creeping bentgrass (*Agrostis stolonifera* L.) cultivar Bengal at a rate of 5 $g•m^{-2}$ in May of 2003. In 2004, plots were mowed 6 times per week at a height of 3.2 mm. Sand topdressing was applied monthly from February to September at a rate of 2.2 mm. Plots were core aerated to a depth of 63 mm on Sept 9 and Oct 4 (two passes on each date) with 12.5 mm diameter tines at a spacing of 50 x 50 mm. Irrigation was applied daily based on evapotranspiration rate (calculated from weather data from a nearby weather station), on visual appearance of the plots and on drainage losses from the plots. To avoid wind drift and to match real world situations, sprinkler irrigated plots were watered every morning between 5:00 and 7:00. ECS plots were watered between 9:00 and 10:30. Subsurface drip irrigation was applied between 12:00 and 15:00 in 7 pulses of 1 minute each with 20 minutes between irrigation pulses. Plots were fertilized with a total of 35 g N m^{-2}, 12 g P_2O_5 m^{-2}, 31.5 g K_2O m^{-2}, 2.5 g S m^{-2} and 1.2 g Fe m^{-2}.

Data collection

During the summer of 2004 the effect of irrigation type (sprinkler vs. subsurface drip irrigation vs. subirrigation) and type of root zone mix (straight sand vs. sand mixed with peat) on turfgrass quality, localized dry spot occurrence and on irrigation water use was investigated. Visual quality ratings of the main plot were taken bi-monthly on a scale of 1 to 9. Ratings are based on 9 being outstanding or ideal turf and 1 being poorest or dead. A rating of 6 or above was considered acceptable turf (Morris, 2004). Quality data were collected bi monthly from February 2nd to September 1st.

Water repellency (soil hydrophobicity) was determined on soil cores collected on June 29, July 12, August 18, August 30, September 13, and September 28. On each of these dates five soil cores 2.5 cm in diameter and approximately 10 cm length were taken at 3 locations (summit, backslope and toeslope) from each plot and subsequently air dried for two weeks at room temperature. Dried cores were then evaluated for hydrophobicity using the water droplet penetration test. Water droplets of 36 microliters of distilled water were placed at the interface of the thatch layer and the root zone (0.5 cm depth) and at one cm intervals from the interface to a depth of 5.5 cm. The time for the water droplet to penetrate the root zone was recorded in seconds.

Soil moisture was recorded hourly using permanently installed TDR probes. It would be impractical to present the over 460,000 soil moisture data points collected in 2004. For the purpose of this report, only data that were collected at 4:00 and at 17:00 from June 30 to July 5 will be presented. Total irrigation water use for each main plot was determined from water meter readings at each plot.

Statistical analysis

Data were analyzed with location as a split-strip treatment in a completely randomized design for greens construction. Based on Akaike's information criterion (Schabenberger and Pierce, 2002), date was analyzed as either repeated measure (auto regressive covariance structure among dates) or as an additional split treatment.

Results and Discussion

Turfgrass Quality

Overall analysis of variance of visual ratings for turfgrass quality revealed significant effects of construction type, location, and time (table 2). Table 2 lists the overall analysis of variance of quality ratings and the corresponding degrees of freedom, F values and level of significances for the effects. Interactions between location and construction type and construction and date were also significant. Table 3 lists the model estimates for the quality ratings pooled over all dates and locations. Significant differences were separated with date as an additional split treatment.

Table 2: Analysis of variance of quality ratings

Effect	DF	F Value	Pr > F
Location	2	20.23	0.0022
Construction	3	9.29	0.0113
Location*Construction	6	3.90	0.0215
Date	14	26.27	<.0001
Location*Date	28	1.00	0.4755
Construction*Date	42	3.26	<.0001
Construction*Location*Date	84	0.61	0.9960

Table 3: Estimates for quality ratings for the different construction types pooled over all sampling dates and locations.

Construction/Irrigation type	Estimate

California/Sprinkler	6.7b[¶]
ECS/Sub	8.1a
USGA/Drip	6.4b
USGA/Sprinkler	6.9b

[¶] values followed by the same letter are not significantly different (α=0.05)

Table 4: Estimates for quality ratings for the different locations pooled over all sampling dates and construction types.

Location	Estimate
Summit	7.1a[¶]
Backslope	6.8b
Toeslope	7.2a

[¶] values followed by the same letter are not significantly different (α=0.05)

When data were averaged over all dates and construction types, backslope turf rated significantly lower than turf grown on the summit and on the toeslope (table 4). Subirrigated ECS plots showed consistently highest quality ratings regardless of location and date (tables 5, 6 and 7 and figures 1, 2 and 3). Turf quality on sprinkler irrigated USGA and California plots and on drip irrigated USGA plots differed significantly from each other only on 4 sampling dates for the summit location and on two dates for the toeslope location (tables 4 and 6). No significant differences in turf quality were observed for the backslope location between sprinkler and drip irrigated USGA plots and sprinkler irrigated California style plots (table 5).

Table 5: Turfgrass quality estimates at the summit location for different construction/irrigation types and different dates.

Construction/ Irrigation	Date														
	Feb 2	Feb 20	Mar 19	Mar 26	Apr 8	Apr 23	May 10	May 24	Jun 7	Jun 12	Jul 23	Jul 30	Aug 6	Aug 20	Sep 1
California/Sprinkler	6.5ab[‡]	5.7b	7.2b	8.2a	8.2	7.0b	6.8b	7.3	6.3b	6.2b	7.0ab	6.7ab	5.8b	6.8b	6.7bc
ECS/Sub	7.5a	7.3a	8.7a	8.8a	9.0	9.0a	8.7a	8.0	8.3a	7.5a	7.7a	7.7a	7.8a	8.7a	8.5a
USGA/Drip	5.7b	6.0b	6.5b	6.5b	8.0	6.8b	6.5c	7.7	5.5b	6.0b	5.8c	5.7b	5.8b	6.3b	5.7c
USGA/Sprinkler	6.0b	6.3ab	7.2b	7.8a	8.2	7.5b	6.7c	7.2	5.8b	6.3b	6.8bc	6.7ab	6.7b	7.2b	7.2b

[‡] Values followed by the same letter are not significantly different at the 0.05 probability level.

Table 6: Turfgrass quality estimates at the backslope location for different construction/irrigation types and different dates.

Construction/ Irrigation	Date														
	Feb 2	Feb 20	Mar 19	Mar 26	Apr 8	Apr 23	May 10	May 24	Jun 7	Jun 12	Jul 23	Jul 30	Aug 6	Aug 20	Sep 1
California/Sprinkler	6.7b[‡]	6.0	7.3b	8.2a	7.2b	6.8ab	6.5b	6.8	6.0b	6.2b	6.7ab	6.0b	5.3b	6.0bc	6.5b
ECS/Sub	7.3a	6.5	8.0ab	8.2a	8.7a	7.7a	7.8a	6.8	8.0a	7.5a	8.0a	7.5a	7.7a	8.8a	8.5a
USGA/Drip	6.0b	6.0	6.0c	6.2b	7.5b	6.2b	6.0b	6.8	6.0b	6.2b	5.7b	5.7b	6.2b	5.8c	5.8b
USGA/Sprinkler	6.7b	6.7	7.2b	8.0a	7.7ab	6.8ab	6.7b	6.5	6.2b	6.3b	7.0ab	6.3b	6.2b	7.0b	6.8b

[‡] Values followed by the same letter are not significantly different at the 0.05 probability level.

Table 7: Turfgrass quality estimates at the toeslope location for different construction/irrigation types and different dates.

Construction/ Irrigation	Date														
	Feb 2	Feb 20	Mar 19	Mar 26	Apr 8	Apr 23	May 10	May 24	Jun 7	Jun 12	Jul 23	Jul 30	Aug 6	Aug 20	Sep 1
California/Sprinkler	6.2b[‡]	6.0b	7.2b	7.8b	8.0ab	7.0b	6.7b	7.2b	6.2b	6.0b	7.3a	6.3b	5.8c	7.2b	6.8b
ECS/Sub	7.5a	7.3a	8.7a	9.0a	9.0a	8.7a	8.5a	8.7a	8.2a	7.7a	7.5a	7.5a	7.7a	8.3a	8.3a
USGA/Drip	7.0ab	6.7ab	6.5b	7.0b	8.3ab	6.8b	6.7b	7.8ab	7.0b	6.5b	6.0b	6.3b	7.0ab	7.3ab	6.3b
USGA/Sprinkler	6.7ab	6.7ab	7.2b	8.0ab	7.8b	7.3b	6.7b	6.8b	6.3b	6.2b	7.0ab	6.7ab	6.3bc	7.8ab	7.3ab

[‡] Values followed by the same letter are not significantly different at the 0.05 probability level.

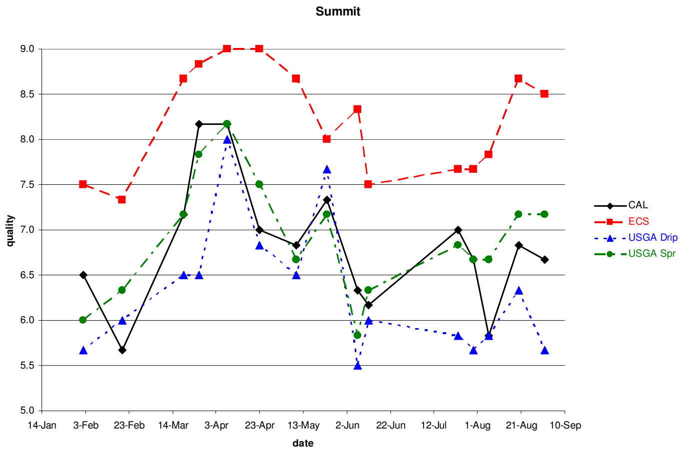

Figure 1: Turfgrass quality ratings at the summit location for four different construction/irrigation types during 2004.

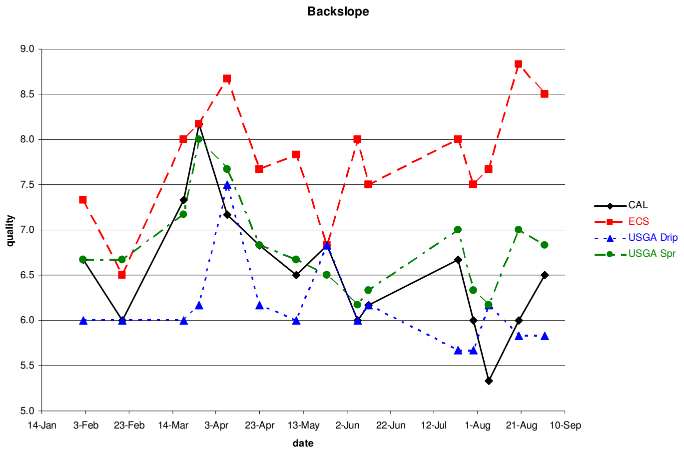

Figure 2: Turfgrass quality ratings at the backslope location for four different construction/irrigation types during 2004.

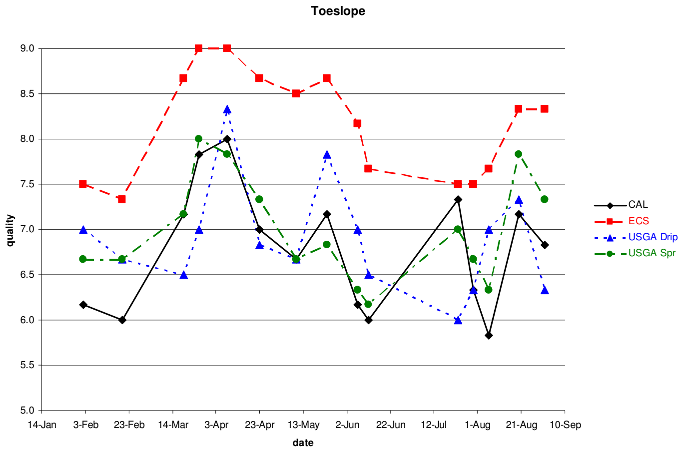

Figure 3: Turfgrass quality ratings at the toeslope location for four different construction/irrigation types during 2004.

Root Zone Water Repellency

Overall analysis of variance of water droplet penetration time revealed no significant construction and location effects (Table 8). The location on the core (corresponding to different vertical depths) where the droplet was placed and the date that cores were taken had a significant effect on droplet penetration time. There were significant treatment by depth, treatment by time, and depth by time interactions. All three way and four way interactions between treatments had no significant effect on penetration time. Table 8 lists the analysis of variance and the corresponding degrees of freedom (DF), F values and level of significances for the treatment effects.

Table 8: Analysis of variance of water droplet penetration time.

Effect	DF	F Value	Pr > F
Location	2	1.19	0.3681
Construction	3	2.44	0.1799
Construction*Location	6	2.90	0.0664
Depth	5	23.38	<.0001
Location*Depth	10	3.01	0.0032
Construction*Depth	15	1.21	0.3073
Construction*Location*Depth	30	0.99	0.4964
Date	5	38.43	<.0001
Date*Location	10	1.25	0.2523
Date*Construction	15	3.05	<.0001
Date*Construction*Location	30	1.28	0.1499
Date*Depth	25	13.57	<.0001
Date*Location*Depth	50	1.27	0.1046
Date*Construction*Depth	75	1.02	0.4364
Date*Construction*Location*Depth	150	0.67	0.9984

Table 9 lists the model estimates for the water droplet penetration time (in seconds) pooled over all locations and depths. Treatment differences were separated with date as an additional split treatment. Lower numbers indicate reduced or no water repellency of the root zone.

Table 9: Estimates for water droplet penetration time (seconds) for different construction and irrigation types pooled over all sampling locations and depths.

	Date					
Construction/Irrigation	29 Jun	12 Jul	18 Aug	30 Aug	13 Sep	28 Sep
California/Sprinkler	8	16	7	36a¶	51a	23ab
ECS/Sub	5	5	4	10b	10c	8b
USGA/Drip	13	12	7	39a	40ab	23ab
USGA/Sprinkler	9	14	8	44a	36b	26a

¶ values followed by the same letter are not significantly different (α=0.05)

ECS subirrigated plots showed lowest water droplet penetration times at all sampling dates indicating no or very little localized dry spot occurrence for this irrigation type. On 3 of the 6 sampling dates the difference between ECS and other construction and irrigation types were significant (Table 9).

Soil Moisture

Table 10 lists the analysis of variance for soil moisture of all treatment effects and the corresponding degrees of freedom (DF), F values and level of significances for the treatment effects.

Table 10: Analysis of variance for volumetric soil moisture content collected daily (June 30 to July 5) at 4:00 and 17:00.

Effect	DF	F Value	Pr > F
Location	2	11.57	0.0008
Construction	3	19.31	0.0005
Location* Construction	6	1.29	0.3160
Depth	2	120.79	<.0001
Location*Depth	4	0.82	0.5191
Construction *Depth	6	5.51	0.0002
Location* Construction *Depth	12	1.19	0.3203
Date	5	9.24	<.0001
Location*Date	10	3.48	0.0002
Construction *Date	15	2.24	0.0046
Location*Construction*Date	30	1.88	0.0034
Depth*Date	10	2.02	0.0289
Location*Depth*Date	20	0.78	0.7403
Construction*Depth*Date	30	1.1	0.3277
Location*Construction*Depth*Date	60	0.86	0.7639
Time	1	4.47	0.0348
Location*Time	2	0.93	0.3968
Construction *Time	3	0.38	0.7687
Location* Construction*Time	6	0.96	0.4492
Depth*Time	2	0.01	0.9857
Location*Depth*Time	4	0.86	0.4857
Construction *Depth*Time	6	1.07	0.3811
Location*Construction*Depth*Time	12	1.23	0.2591
Date*Time	5	0.71	0.6166
Location*Date*Time	10	0.37	0.9576
Const*Date*Time	15	0.37	0.9854
Location*Construction*Date*Time	30	0.56	0.9718
Depth*Date*Time	10	0.67	0.7499
Location*Depth*Date*Time	20	0.82	0.6926
Construction*Depth*Date*Time	30	0.64	0.9298
Location* Construction*Depth*Date*Time	60	0.92	0.6376

Table 11: Model estimates for volumetric soil moisture content (kg kg^{-1}) pooled over all locations, depths, and sampling dates and times.

Construction/Irrigation	Soil moisture (kg kg^{-1})
California/sprinkler	26.2b[¶]
ECS/sub	35.3a
USGA/drip	27.8b
USGA/sprinkler	26.8b

[¶] values followed by the same letter are not significantly different (α=0.05)

Table 12: Estimates for volumetric soil moisture content (kg kg^{-1}) for different construction and irrigation types pooled over all sampling dates and times.

Depth	Construction/ Irrigation	Location Summit	Backslope	Toeslope
10 – 20 cm	California/sprinkler	17.1b[¶]	17.6b	22.3b
	ECS/sub	31.9a	32.1a	35.9a
	USGA/drip	19.7b	21.0b	23.9b
	USGA/sprinkler	19.8b	18.5b	22.6b
20 – 30 cm	California/sprinkler	27.6b	26.2b	29.2
	ECS/sub	35.3a	37.1a	32.9
	USGA/drip	26.8b	25.7b	32.4
	USGA/sprinkler	26.0b	22.2b	32.6
27 cm	California/sprinkler	28.6a	31.1ab	36.2
	ECS/sub	37.2b	36.7b	38.4
	USGA/drip	31.2ab	32.5ab	37.1
	USGA/sprinkler	30.6a	29.4a	39.3

[¶] values for each depth and location followed by the same letter are not significantly different (α=0.05)

ECS subirrigated plots showed highest overall soil moisture content (table 11) and highest moisture at every depth for each location (table 12). Moisture content in ECS plots was significantly higher at all depths in the summit, at the toeslope location, and at the 10 to 20 cm depth in the toeslope (table 12). Soil moisture at a depth of 10 to 20 cm in the California plots (straight sand) was consistently lowest, however it did not differ significantly from soil moisture in peat amended root zones in the USGA greens.

Irrigation water use

Table 13 lists total irrigation water use, drainage losses, and net water use (total water applied minus drainage losses) from January 1st to August 31st 2004.

Table 13: Total irrigation water use (mm), drainage losses (mm), net water use (mm), and relative difference between subirrigation systems and sprinkler irrigation systems for January 1st to August 31st 2004.

Construction/Irrigation	Total Irrigation (gross)	Drainage (mm)	Net irrigation (Irrigation – Drainage)	Relative difference to sprinkler irrigation gross	net
California/sprinkler	856	124	732	n.a.	n.a.
ECS/sub	514	82	432	– 40%	– 41%
USGA/drip	678	199	479	– 21%	– 35%
USGA/sprinkler	854	117	737	n.a.	n.a.

In summary, ECS subirrigated plots received the least amount of irrigation water (40% less than sprinkler irrigated plots), had the lowest drainage losses, expressed the lowest hydrophobicity, and had the highest turf quality. Sprinkler irrigated plots needed the most irrigation water to sustain adequate turf quality, yet still expressed severe localized dry spot occurrence.

2003 Deliverables

Establishment results were presented at the Nebraska turf conference in Omaha, at the Southwest Turf Association's annual meeting in Albuquerque, and at the United States Golf Association's golf course construction workshop in Nebraska City. A progress report will be posted at the New Mexico State University's turfgrass web page. Oral presentations on the progress of the research project were given at the Southwest Turf Association's annual meeting in Albuquerque, at the Turf and Tree field day held at New Mexico State University, at the Rio Grande Golf Course Superintendents meeting in Las Cruces, and at the Dona Ana County Master Gardener training seminar series. On site presentation on irrigation technology and efficient irrigation water use were given to Dona Ana County Master Gardeners, to the board members of the Rio Grande Golf Course Superintendents Association and the Southwest Turfgrass Association, and to numerous turf managers and other individuals visiting the turfgrass research facilities. At all events acknowledgment was given to associations providing funding for the project.

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