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Research efforts at New Mexico State University are underway to investigate whether greens type, irrigation type, and/or rootzone type affects turfgrass performance, irrigation efficiency, and subsequently irrigation water use in the desert Southwest. This paper summarizes the effect of those factors on establishment of creeping bentgrass.

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PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 290 projects at a cost of $25 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf.***

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Establishment of Golf Greens under Different Construction Types, Irrigation Systems, and Rootzones

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SUMMARY

Research efforts at New Mexico State University are underway to investigate whether greens type, irrigation type, and/or rootzone type affects turfgrass performance, irrigation efficiency, and, subsequently, irrigation water use in the desert Southwest. This study reports the establishment data. The study's findings include:

- When data were analyzed separately for each amendment, sprinkler-irrigated USGA greens and subirrigated ECS (Evaporative Control Systems) greens established faster on standard rootzones than drip-irrigated USGA greens and sprinkler-irrigated California greens.
- Sprinkler-irrigated California style greens and subirrigated ECS greens had the fastest establishment on the Fytofoam-amended (urea-formaldehyde polymer) rootzones.
- Subsurface drip and sprinkler-irrigated USGA greens showed the slowest establishment on Fytofoam-amended rootzones.
- Despite having received the highest quantities of irrigation water, subsurface-drip irrigated plots established the slowest. Capillary rise in the sandy rootzone may not have provided enough water to the seedlings at the surface.
- Plots irrigated with the ECS subirrigation system had the fastest (standard rootzone) or second fastest (Fytofoam-amended sand) establishment, despite having received the least amount of irrigation water. This can be explained by the permanent perched water table in the ECS system that delays or prevents drainage losses.

The rapid rate of urban development in the southwestern United States has led to the proliferation of recreational areas such as golf courses, athletic fields, and home lawns. Consequently, the irrigation of landscaped areas (including lawns) account for over 50% of total urban potable water use in the summer in the Southwest (6). Although present day water shortages in the Southwest clearly set limits on landscape quality expectations and water consumption for turf irrigation is frequently questioned, the turf and golf industry have gained economic importance that exceeds many agricultural food and feed crops for which irrigation with high quality water has been long accepted. In New Mexico alone, the turfgrass and golf sector contributed a total of $975,000,000 in revenues to the state's economy during the fiscal year of 2004-2005 (5). However, despite the economic importance and continued public demand for turf areas, turf managers and golf course superintendents will experience increasing pressure from government to conserve water and to adopt the most efficient available method of irrigation.

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

The patented subirrigation system ECS 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 1.5 m x 1.5 m and are surrounded by 13 cm high sidewalls.

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The research area was seeded with creeping bentgrass (*Agrostis stolonifera* L.) cultivar 'Bengal' at a rate of 5 g m^{-2}. The plots were seeded on May 16, 2003, subsequently rolled, and covered with a white woven tarp for 17 days to speed up germination.

in 1894 (3), 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 a lack of sufficient potable irrigation water are the two greatest challenges that turf managers face in the desert Southwest. Both contribute to poor turf quality on turf areas. Subirrigation systems that apply water laterally to the rootzone 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.

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 (9) and Chevallier et al. (2) reported water savings of up to 50% when using subirrigation, and Leinauer (7, 8) reported a 90% reduction of water used for irrigation on subirrigated turf plots compared to sprinkler irrigated plots. 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 sloped 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 rootzones used to construct athletic fields, golf tees, and golf greens. These areas are usually built

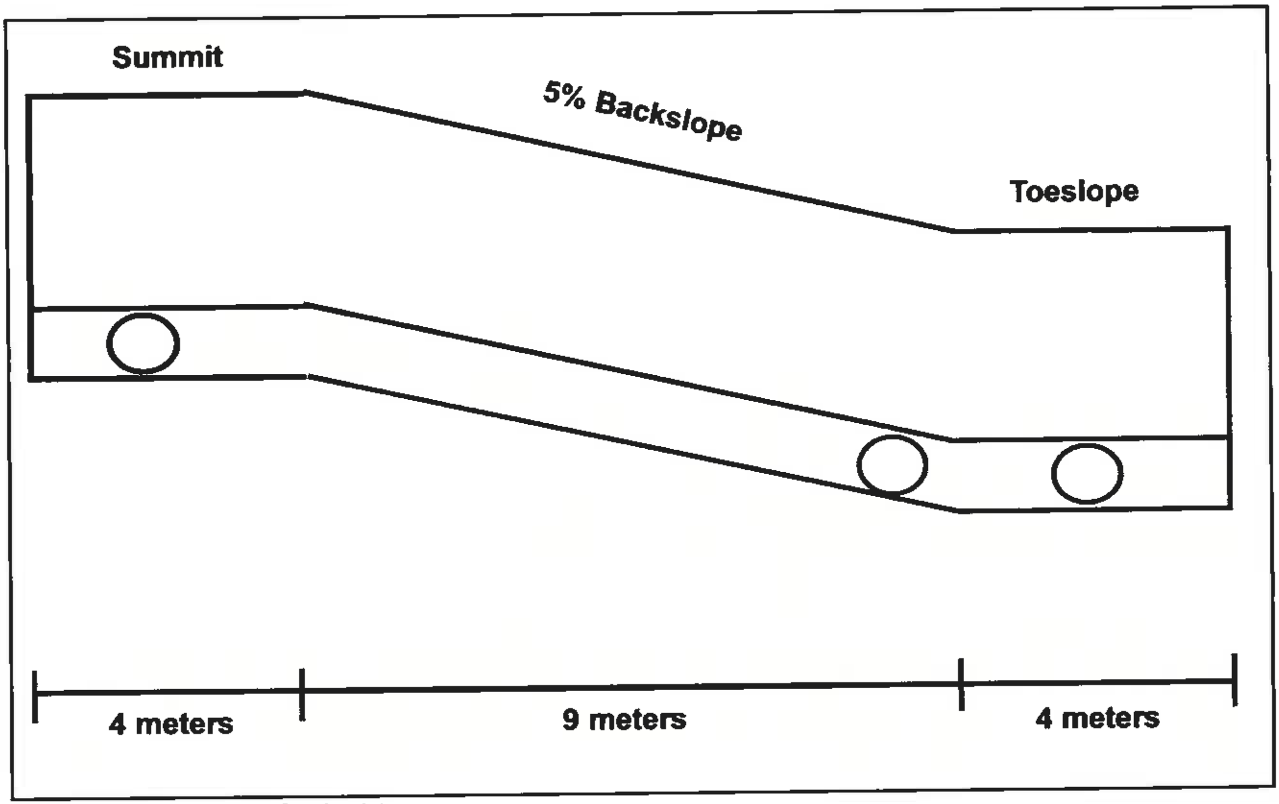

Figure 1. Cross section of main plot

with sandy rootzone mixes that have a 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 one layer with no gravel blanket underneath (4). 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 (10). These recommendations have become the standard in rootzone 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 rootzone with a 30-cm (12-inch) deep rootzone overlaying a 10-cm (4-inch) deep gravel blanket.

In exchange for high air-filled porosity, these high sand content roozones lack adequate water retention. To increase water-holding capacity, rootzones are usually amended with peat. However, during recent years, peat has become increasingly scarce, as bogs become more and more restricted for harvesting peat. Alternative inorganic amendments will therefore need to be considered in the future.

Inorganic amendments such as urea-formaldehyde polymers, could provide a viable alternative to organic amendments for use in sandy rootzones. Urea-formaldehyde polymers have been used as amendments for potting soil in greenhouse plants for decades. More recently, a urea-formaldehyde polymer with the trade name 'Fytofoam' has been used successfully throughout Central and Southern Europe to modify rootzones for green and tee construction, renovate and build athletic fields, and to produce sod. However, to date, no field research has been conducted to investigate the long-term effects of Fytofoam-amended turfgrass rootzones on turfgrass quality, water consumption, or soil physical properties.

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

Main plot		Split plot	
Construction type	Irrigation type	Standard Rootzone	Alternate Rootzone
USGA	Sprinkler	Sand - Peat	Sand - Fytofoam
USGA	Subsurface Drip	Sand - Peat	Sand - Fytofoam
California	Sprinkler	Sand	Sand - Fytofoam
ECS ← (Evaporative Control System)	Subirrigation	Sand	Sand - Fytofoam

Table 1. Construction types and associated irrigation type (main plot treatment) and rootzone material (split plot treatment)

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 soil amendments on irrigation efficiency, irrigation water use, plant stand quality, and soil physical properties of turf rootzones. The combination of 1) subsurface irrigation systems and 2) the amendment of rootzones with urea-formaldehydes could positively affect water retention in the rootzone and increase efficiency of irrigation systems in turf areas.

Study

A study was conducted at New Mexico State University to investigate whether greens type, irrigation type, and/or rootzone type affects turfgrass establishment and irrigation water use on golf greens 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. The four treatments (main plots) included in the study 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 (Evaporative Control System [ECS]). Each of the 12 main plots measures 17 m x 17 m (55 ft by 55 ft). 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), and followed again by a 4 m (12') long horizontal portion (toeslope). The slope magnitude is 5% (Figure 1).

Time Period	**CAL**	**ECS**	**USGA Drip**	**USGA Sprinkler**	**ET**
	…………………………	…………………………	mm	…………………………	…………………………
May 16 - 31	214	214	237	214	101
June 1 - 30	362	401	411	362	221
July 1 - 31	279	137	275	279	202
August 1 - 8	49	61	31	49	49
Total	904	813	955	904	573
Daily Average	10.8	9.7	11.3	10.8	6.8

Table 2. Monthly irrigation amounts (mm) for sprinkler irrigated California (CAL) and United States Golf Association (USGA Sprinkler) plots, subirrigated Evaporative Control System (ECS) plots, and drip irrigated USGA (USGA Drip) plots. Values represent averages of three replications. ET column lists evapotranspiration during respective time periods based on FAO 56 model (1)..

Construction/ Irrigation	Rootzone	
	Standard	Fytofoam
California/Sprinkler	0.97	0.97
ECS/Subirrigation	0.95	0.91
USGA/Drip	0.94	0.90
USGA/Sprinkler	0.94	0.82

Table 3. Regression coefficients (r^2) for percent ground cover and days after seeding (DAS) on sprinkler irrigated California and United States Golf Association (USGA) plots, subirrigated Evaporative Control System (ECS) plots, and drip irrigated USGA (USGA Drip). Data are pooled over three locations and percent establishment was calculated using a Boltzmann sigmoidal model association.

Each main plot contains two rootzone materials as split plot treatments: 1) the recommended rootzone for the respective construction type and 2) a sand mixed with urea formaldehyde polymer (trade name Fytofoam) (Table 1). Each treatment combination is replicated three times.

All main plots, including those that were subsurface-irrigated, had 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 system ECS 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 1.5 m x 1.5 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 height of 5 cm above the subgrade. Water movement into the rootzone (irrigation) and from the rootzone (drainage) is achieved only by capillary raise and by gravitation. For further system details refer to http://www.rehbein.com/epic.html. Barriers in the form of PVC liners separate the main plots (construction/irrigation type) and split-plots (rootzone mixes) from one another to prevent lateral water movement between the plots. Each split-plot received separate drainage at three strategic locations: the center of the summit, the bottom of the backslope, and the center of the toeslope (Figure 1).

The research area was seeded with creeping bentgrass (*Agrostis stolonifera* L.) cultivar 'Bengal' at a rate of 5 g m^{-2}. The plots were seed-

Construction/Irrigation	25% Rootzone		50% Rootzone		75% Rootzone	
	Standard	Fytofoam	Standard	Fytofoam	Standard	Fytofoam
California/Sprinkler	34	31	39	32b‡	44abA	33cB
ECS/Subirrigation	32	30	35	37b	39a	47b
USGA/Drip	34	33	42	46a	52bB	66aA
USGA/Sprinkler	31	32	36B	47aA	40aB	56abA

‡ Values followed by the same letter are significantly different at the 0.05 probability level. Lower case letters denote differences between construction/irrigation systems (columns. Upper case letters denote differences between rootzone types for each construction/irrigation system.

Table 4. Days after seeding (DAS) to reach 25%, 50%, and 75% cover for different construction/irrigation types and different amendments. Data are pooled over three locations.

ed on May 16, 2003, subsequently rolled, and covered with a white woven tarp for 17 days to speed up germination. Fertilizer during establishment was applied at the time of seeding and then biweekly between June 4 and July 24. A total of 26 g N m^{-2}, 17 g P_2O_5 m^{-2}, and 18 g K_2O m^{-2} was applied during this period. Irrigation was scheduled based on visual appearance and historic ET rates (1).

Because of the late seeding date and the record heat during establishment, all plots received supplementary light watering by sprinklers six times per day in addition to scheduled irrigation in the amount of 0.32 mm per cycle. This was to prevent serious drought damage for the creeping bentgrass seedlings. Mowing was started on July 23rd (69 days after seeding) to August 6 at 15 mm two times per week. Sand topdressing was applied on July 9th at a rate of 2.2 mm.

During the summer of 2003, the effect of irrigation type (sprinkler vs. subsurface drip irrigation vs. subirrigation) and type of rootzone mix (straight sand vs. sand mixed with peat vs. sand mixed with urea-formaldehyde polymer) on turfgrass establishment was investigated. To assess establishment, visual ratings were taken every two to three weeks, starting 21 days after seeding [DAS]. A 1 m^2 sized frame was placed randomly on the ground at the summit, the backslope and the toeslope. Percent ground cover was estimated visually inside the frame and an average of two readings per location was calculated. A Boltzmann sigmoidal model was used to calculate days after seeding to reach 25%, 50%, and 75% groundcover.

Results and Discussion

During the summer of 2003 (May 16 to August 8) sprinkler-irrigated California and USGA plots received daily irrigation averaging 10.8 mm. ECS plots were irrigated with a total of 9.7 mm day^{-1}, and drip--irrigated USGA plots received a total of 11.3 mm day^{-1} (Table 2). Fytofoam-amended sand and standard rootzones were irrigated equally. Percent ground cover correlated highly with days after seeding for all treatments when a Boltzmann sigmoidal model was used to describe the association (Table 3).

When data were analyzed separately for each amendment (standard vs. Fytofoam), sprinkler-irrigated USGA type greens and sand only subirrigated ECS established fastest on standard rootzones and needed fewest days to reach 50% and 75% coverage (Table 4). Sprinkler irrigated California style greens and subirrigated ECS greens had the fastest establishment on the Fytofoam-amended rootzones. Subsurface drip and sprinkler-irrigated USGA greens showed the slowest establishment on Fytofoam-amended rootzones (Figure 4). When Fytofoam replaced peat as amendment in USGA type greens, establishment slowed down significantly. In USGA type drip and sprinkler-irrigated greens, 75% cover was reached after 66 and 56 DAS, respectively for Fytofoam-amended sand compared to 52 and 40 DAS in peat-amended sand (Table 4). In sprinkler-irrigated California greens however, Fytofoam reduced establishment time significantly compared to a standard straight sand rootzone (Table 4).

Despite having received the highest quantities of irrigation water, subsurface drip-irrigated plots established the slowest (Table 4). Capillary rise in the sandy root zone may not have provided enough water to the seedlings at the surface. In contrast, plots irrigated with the ECS subirrigation system had the fastest (standard rootzone) or second fastest (Fytofoam-amended sand) establishment, despite having received the least amount of irrigation water. This can be explained by the permanent perched water table in the ECS system that delays and/or prevents drainage losses. Contrary to the ECS system, the USGA and California systems have an open drainage system that cannot be controlled and part of the irrigation water may have been lost through the drainage. Drainage outflow from the main plots was not measured during establishment.

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