Use of Transparent Columns for Demonstrating Water Movement in Golf Green Root Zones

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Abstract

Effective water management of golf greens is a central responsibility of turfgrass science graduates, yet difficult to demonstrate using a traditional lecture method. Slides and diagrams are helpful, but many students still have difficulty conceptualizing the effects of soil profile composition and placement on water movement. Thus, there is a need in turfgrass education for tangible models that directly demonstrate water movement in commonly used golf green construction methods. This need is especially apparent when one realizes there are several methods currently employed to build golf greens. The objective of this paper is to describe a more visual and hands-on method of teaching water movement in golf greens by describing how to construct and teach with soil columns built in transparent acrylic tubing. Four soil columns are described—the original U.S. Golf Association (USGA) method, the revised USGA method, the California method, and an amended California method. Construction of these four columns cost about $175.00 and took approximately 8 h. Once built, the columns can be repeatedly utilized with little additional maintenance, requiring only dark, vertical storage between uses. When students are employing the columns, soil moisture is monitored using laterally installed time domain reflectometry (TDR) probes at five predetermined depths. Time domain reflectometry measurements are taken 2 and 6 days after watering (DAW). Comparison of the four soil columns readily shows the range in water behavior one is likely to encounter with golf greens.

In 1960, The U.S. Golf Association (USGA) Green Section developed a specific method for putting green construction (*original USGA method*) (USGA, 1960). These specifications called for the placement of a predominately sand root zone mix, 31 cm thick, over a 5 cm thick coarse sand layer. Beneath this coarse sand layer and root mix is 10 cm of gravel used to expedite drainage. The placement of the coarse sand layer beneath the finer sand particle root zone mix disrupts the continuity of water flow and promotes a perched water table. The root zone layer must become entirely saturated before gravitational drainage occurs. This method of green construction provides a reserve supply of water to the plant roots, good internal drainage, and steadfast resistance to compacting forces.

Although the early specifications were adopted throughout the country, the proper placement of the coarse sand layer proved difficult and costly. In 1993, the USGA revised their original specifications allowing for elimination of the coarse sand layer (*revised USGA method*). However, to maintain the perched water table effect and prevent the movement of the root zone mix into the underlying gravel layer, the size relationship between the gravel layer and the root zone mix was restricted. These specifications are detailed in the published revision (USGA, 1993). Due to its reduced cost, the revised method is widely used today.

In addition to the two green construction methods discussed above, a third method (*California method*) was developed at the University of California about the same time the original USGA specifications were being finalized (Lunt, 1956). The California method has gone through a series of revisions, but currently differs from the USGA method by excluding the gravel blanket below the root zone mix (Davis et al., 1990; Prettyman and McCoy, 1999) and specifying a higher root zone permeability. The California method utilizes gravel only within the drain tile trenches. Sometimes sand substitutes in the root zone mix are used in variants of the California method (*amended California method*). Sand substitutes such as diatomaceous earth or calcined clay have been shown to increase the moisture retention capacity of sands (Montgomery, 1961).

The four basic methods of golf green construction described above are widely used throughout the country and much of the world. The theory and application of these four construction methods are important for students studying turfgrass management to understand. For many years in the intermediate turfgrass management course (CRSS 3270) at the University of Georgia, the construction methods were taught in the associated laboratory by traditional lecture and discussion using diagrams and slides. We tested the students' knowledge of these green construction methods and concepts, and deficiencies were apparent.

We assessed the presentation methods and realized the current approach lacked a tactile component. Undergraduate students possess preferences in methods by which they assimilate and process information (Felder, 1993). These preferences constitute their learning styles. Barbe and Swassing (1979) differentiate learning styles by modality or sensory channel as: auditory, visual, and kinesthetic (touching). Eiszler (1983) claims that varying teaching strategies to address all channels promotes learning, regardless of student preference. Dunn (1979) showed an increase in student achievement when multisensory methods were used as a form of instruction.

Additionally, review of educational literature revealed utility in transparent viewing panes, soil columns, and rhizotrons to illustrate chemical, biological, and physical properties of plant–soil systems in agricultural education. Reduced-scale rhizotrons have been used to demonstrate hydrological activity (Beck, 1984; Wilson et al., 1997) and plant–soil chemical processes (Heckman and Strick, 1996). Transparent soil columns and lysimeters have also been implemented in soil science laboratories to effectively illustrate water flow and solute transport (Bowman et al., 1988; Butters and Bandaranayake, 1993; Owens and Johnson, 1996).

With this in mind, a series of transparent plastic columns were built to scale for demonstration of the specifications

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Abbreviations: USGA, United States Golf Association; TDR, time domain reflectometry; DAW, days after watering.

Table 1. Construction and experimental materials cost (approximate) required for four columns.

Quantity	Item	Description	Vendor	Cost, $
1	Clear plastic tube	0.13 m i.d. by 2.4 m length	Consolidated Plastics, et al.	127.00
8	Plexiglas squares	0.2 by 0.2 m by 0.6 cm thick	Numerous	20.00
1	Dowel rod	3.0 cm diam. by 1.5 m length	Numerous	6.00
8	90° Corner brackets	Galvanized, four-hole, 7.6 cm length	Numerous	8.00
32	Wood screws	no. 6 by 1.9 cm length, galvanized†	Numerous	3.00
32	Machine bolts with nuts	no. 10 by 2.5 cm length, galvanized†	Numerous	4.00
1	Silicon glue/caulk	Waterproof, quick-drying	Numerous	2.00
1	Tygon tube	1.3 cm i.d. by 0.5 m length, flexible	Numerous	2.00
20 L	Sized sand/soil amendments	Various (sand/peatmoss/soil amendment)	Numerous	1.00
3 L	Gravel	Various (coarse and fine required)	Numerous	2.00
1	Soil moisture measuring device	Various (gravimetric, tensiometer, TDR)	Spectrum Tech., et al.	60.00–5000.00
			Total materials cost (four columns):	235.00–5175.00

† Approximate shank thickness of 0.35 and 0.48 cm for no. 6 screws and no. 10 bolts, respectively.

and subsequent hydrological performance of four widely used putting green construction methods. The objective of this paper is to describe this visual and hands-on method of teaching water movement in golf greens by describing how to construct and teach with soil columns built in transparent acrylic tubing.

Materials and Methods

Cylinder Construction

Construction of each column began with acquisition and preparation of materials (Tables 1 and 2). This was followed by insertion of the 1.3 cm i.d. Tygon tube through the center hole in the top Plexiglas square and silicon gluing it into place. Be sure to provide adequate length to exceed the height of the clay subsoil layer by 1 to 2 cm (Fig. 1 and 2). Cover the top end of this drainage tube with a stainless steel screen, and fasten with a wire twist. Next, secure each 12.7 cm i.d., 48 cm-long transparent plastic tube (Part 08056LJ, Consolidated Plastics, Twinsburg, OH) to the top Plexiglas 20.3 by 20.3 by 0.6 cm square using the corner brackets and bolt/nut hardware (Fig. 1; Tables 1 and 2). It is important to use sturdy corner-brackets to make the finished columns durable. Following this, apply a silicon bead at the tube–Plexiglas interface. The dowel segments and second square of Plexiglas (bottom) should then be attached with the wood screws. The above procedures require another 3 h in addition to the materials preparation described in Table 2.

Following the construction of the housing, the soil and root mix layers can be added in their prescribed fashion. This begins with a sieved clay subsoil (Cecil series; member of the clayey, kaolinitic, thermic family of the Typic Kanhapludults) packed into the cylinders as artificial subsoil in 2-cm increments to heights dictated by each specific method. In construction of the USGA and revised USGA columns (Fig. 2), the root mix was composed of 85% quartz sand and 15% peat moss (v/v). The particle size distribution for the sand met USGA specifications (USGA, 1993). In the original USGA method column, the intermediate layer was composed of a very coarse sand (>90% 1–4 mm diam.) above a coarse gravel (4–15 mm diam.) layer. The revised USGA cylinder differed in the size distribution of its gravel layer (>90% 2–12 mm diam.) and excluded the intermediate layer (Fig. 2). The root mix of the California method was nearly identical to that used in the USGA columns, except mixed with 5% (v/v) of the coarse sand in an effort to improve its permeability. The amended California method was similar to the California method, except diatomaceous earth (Prescription Soil Amendment, Richmond, VA) was added to the USGA 85/15 mix rather than coarse sand, resulting in a 10% diatomaceous earth, 77% quartz sand, and 13% peat moss (v/v) root zone mix. All root mixes were added in 5-cm increments and hand-tamped to prevent inconsistencies. Placement of the respective aggregate and root mix layers required an additional 3 h of preparation. Once constructed, 1 L of water was added to each cylinder to verify functioning drainage and promote settling. Material cost of the four finished columns was approximately $175.00 (U.S.) and required 8 h of construction time.

Table 2. Materials preparation required for four columns.

Quantity	Item	Preparation description	Requisite time, h
1	Clear plastic tube	Section tube into four 0.48 m lengths	0.5†
		Drill four 0.5 cm holes for corner bracket anchors	0.1
8	Plexiglas squares	Drill 0.4-cm holes into all corners of all squares	0.3
		In four of eight squares, drill four 0.5-cm holes for	0.3
		corner bracket anchors and a center 0.02-m diam. hole	0.2
1	Dowel rod	Section rod into 16, 0.08-m lengths	0.4
		Drill 32, 0.2-cm pilot holes into center of both ends	0.2
		Total preparation time (four columns):	2.0

† Skilled labor recommended for clear plastic tube sectioning (e.g., machinest, carpenter, etc.).

Laboratory Instruction

Students were given the opportunity to examine the labeled columns and become acquainted with the specifications of each construction method. Following this orientation, the students slowly added 1 L of water to each of the four cylinders. The columns were then placed in a greenhouse to allow for drainage. Following this period, the cylinders were returned to the laboratory and a TDR probe (TRIME-FM, Model P2D, Mesa Systems Co., Farmingham, MA) was horizontally installed at 5-cm depth increments and volumetric soil water (%) was determined (Fig. 3). If a TDR instrument is unavailable, a soil core can be removed from the interior of the column, sectioned by depth, and soil water determined gravimetrically. Core holes can then be refilled with appropriate replacement root mix and tamped to the original density. Because drainage is inherently rapid in these turfgrass root mixes, this exercise does not lend itself to the conventional weekly lab schedule. The authors recommend the initial column watering and 2 DAW measurement be scheduled during, before, or after a class lecture or similarly convenient session. This will permit final measurement and discussion to occur during the scheduled lab period. Following gravitational drainage, the soil columns can be stored intact with no loss of functionality. An opaque wrap is recommended to cover the acrylic side wall if the columns are stored in a day-lit location.

Results and Discussion

At 2 DAW, all root mixes had similar moisture contents at the 5- and 10-cm depths and distinct differences between the columns were not visibly apparent (Table 3). However, a marked increase in water retention was observed at deepest levels in the amended California method when compared to all other root mixes at 2 DAW. This is attributed to the high capillary porosity of diatomaceous earth products. Following 6 d of equilibration, differences in remaining water content of each root zone mix was easily observed. Time domain reflectometry measurements at 6 DAW showed greatest drying of root mix at the shallowest depths for all construction methods (Table 3). The greatest moisture content for all methods of construction occurred at the 25-cm depth. This agrees with convention and recent experimental profile comparisons (Prettyman and McCoy, 1999). At 6 DAW, the perched water table in both USGA columns was easily visible and the increasing soil moisture with greater depth closely followed the normal soil drying cycle that naturally occurs in golf course putting greens.

Conclusions

The use of transparent viewing planes, soil columns, and rhizotrons to illustrate chemical, biological, and physical properties of plant–soil systems have been effectively used in agricultural instruction (Beck, 1984; Bowman et al., 1988; Butters and Bandaranayke, 1993; Heckman and Strick, 1996; Owens and Johnson; 1996; Wilson et al., 1997). We found the use of transparent columns for demonstrating the various techniques of putting green construction to be a valuable learning tool for turfgrass students. Not only could students observe the differences in the physical make-up among the construction methods, but they could actually see and measure differences in water movement through the root zone mixes. This was a concept that was very difficult to demonstrate through the use of traditional lecture-type materials such as drawings and slides.

Candidly, the observed perched water effect from the discontinuous profile of both USGA method cylinders was not quite as stark as hoped and predicted. Reports of capillary continuity between gravel and root mix layers, limiting perched water table height in USGA putting greens to an extent greater than originally thought have been reported in other cylinder experiments (Bigelow et al., 1999). Either this effect or sidewall flow between the column interior and root mix may have contributed to the limited water retention in our original USGA column. Use of a hydrophobic coating on inner surfaces may easily have prevented side flow in the columns, but was excluded to optimize visibility of the root mix drying front.

It is our opinion these tactile teaching aides present root zone construction methods in a form easily understood by turfgrass students. The physical nature of the columns also provides a convenient opportunity for instructors to demonstrate the conceptual and operational hydrological properties of modern root zone construction techniques.

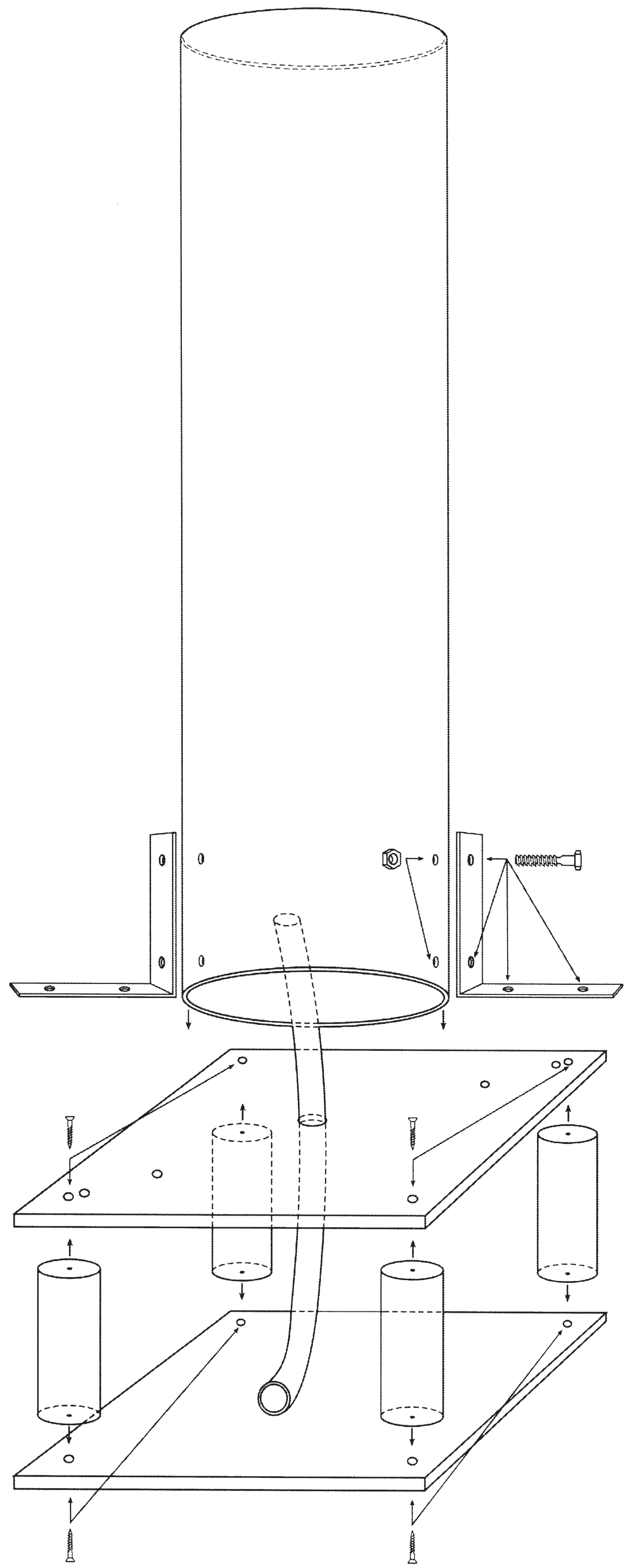

Fig. 1. Detailed construction procedures for soil column housing units.

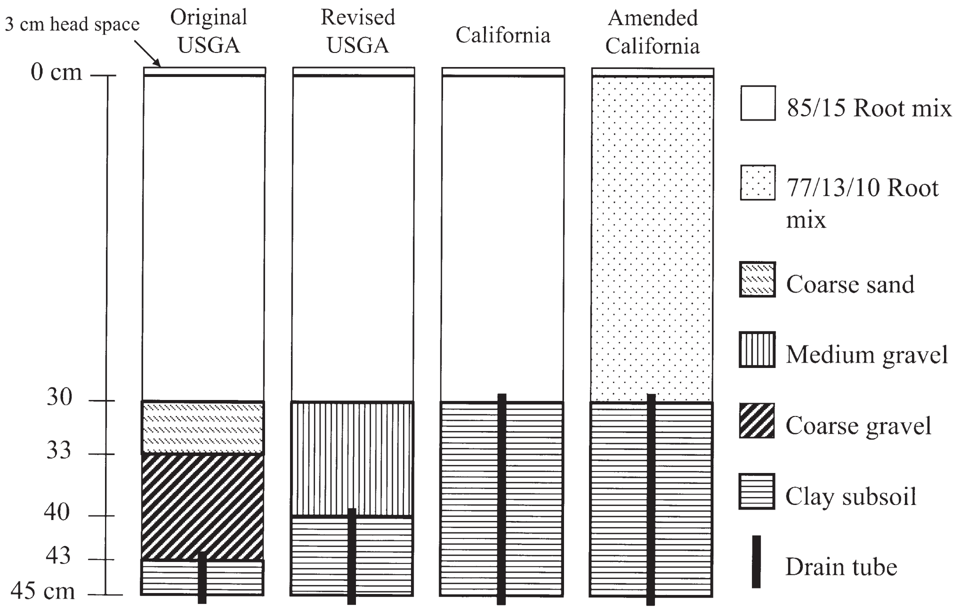

Fig. 2. Scaled diagrams of the four golf course putting green construction methods.

Fig. 3. Student measuring water content of soil column with time domain reflectometry (TDR) probe.

Table 3. Soil moisture readings of four root zone construction methods by depth and time.

	Original USGA method		Revised USGA method		California method		Amended California method	
Depth	2 DAW†	6 DAW	2 DAW	6 DAW	2 DAW	6 DAW	2 DAW	6 DAW
cm	Volumetric soil moisture, %							
5	11	8	9	7	11	8	11	8
10	10	7	11	8	12	10	10	7
15	13	11	10	7	15	9	17	14
20	17	9	20	12	13	9	29	21
25	23	16	21	19	23	12	29	23

† Days after watering.

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