compaction level, solid tine cultivation increased the amount of intermediate sized pores when compared to hollow tine cultivation. Therefore, due to the increased amount of total soil pore space produced, hollow tine cultivation provided the most beneficial changes in soil porosity.

Soil strength within the zone of cultivation (surface 2 to 3 inches) was reduced after cultivation. Initially, solid tine cultivation was more effective in loosening the surface soil than hollow tine cultivation; however, this effect was reversed by the end of this study. Water conductivity rate dropped dramatically after cultivation, indicating that compaction at the bottom of the cultivation zone restricted water flow.

Compaction stress decreased root growth, while cultivation had a limited effect on root growth. Cultivation decreased surface rooting in non-compacted soil, but had no influence on rooting in compacted soil. Cultivation in non-compacted soil tended to increase rooting in June, but again, had no effect on rooting in compacted soil. Throughout the study, hollow tine cultivation ranked equal to or higher than solid tine cultivation in visual quality.

University of Georgia - Dr. Robert N. Carrow

Development of Cultivation Programs on Turfgrass to Reduce Water Use and Improve Turf Quality

The objective of this research project was to compare the relative effectiveness of different turf cultivation procedures to alleviate soil compaction, improve root and shoot growth, and increase soil water use. The most effective cultivation techniques were then incorporated into cultivation "programs." Each program was evaluated for its effectiveness in improving water use efficiency.

Poor soil physical conditions interfere with turfgrass management by limiting water movement, reducing soil aeration, and decreasing root and shoot growth. Compaction of the soil surface and excessively fine-textured soil profiles (i.e., high in clay and silt content) are two of the most common soil problems found on golf courses. Cultivation is an important method of alleviating these problems; however, comparative research studies to evaluate different techniques had not been conducted.

Five cultivation techniques were compared for their effectiveness in improving soil physical properties and growth of common bermudagrass (*Cynodon dactylon*). The soil was a Cecil clay loam, typical of the Piedmont region of the southeast. A non-compacted and compacted control were included, and all cultivation techniques were evaluated under compacted conditions. Severe compaction was applied with a smooth power roller in April, May and July, 1989, and in March and July, 1990. The cultivation treatments were hollow tine core aeration (3 inches depth of penetration), Verti-Drain (12 inches), Verti-Slicer (4.5 inches), Aera-Vator (3 inches), and Hydro-Ject (6 to 8 inches). Cultivation treatments were applied during May and July in 1989 and during April and August in 1990.

The first study indicated that the Verti-Drain reduced soil strength to a depth of 8 inches and improved infiltration. These effects on soil physical properties enhanced deep rooting in the late summer. The Aera-Vator reduced soil strength in the 2 to 4 inches soil zone on one date and enhanced infiltration. These improvements in the physical properties of the first few surface inches did not result in better rooting since deep root growth in late summer was less than the control.

Hollow tine core aeration improved soil surface conditions, as shown by low bulk density and higher aeration porosity; however, rooting was not affected. The Verti-Slicer and Hydro-Ject treatments did not influence the measured soil physical properties or rooting. Improved soil water extraction during dry-down periods was observed, at least one out of eight times measured, for all procedures. All methods, except the Hydro-Ject, caused some decline in visual quality and/or shoot density within a week after treatment on at least one occasion. The Verti-Slicer and hollow tine core aeration exhibited this trend most often (4 out of 5 treatments). Last, all cultivation procedures, except the Verti-Slicer treatment, resulted in some improvement in visual quality and/or shoot density during some period of the study.

From the previous study, the most effective cultivation technique for making improvements deeper in the soil profile was the Verti-Drain, while hollow tine coring improved soil surface conditions. Thus, the intensity of Verti-Drain treatment (i.e., 1X, 2X times over the plot area), as well as Verti-Drain plus hollow-tine coring combinations, were explored.

The Yeager-Twose Turf Conditioner (a subsurface aerification unit) was not evaluated in previous research studies for comparative effectiveness as a turfgrass cultivation unit. The vibrating shank of this device goes to a depth of 7 inches and, with proper attachments, can inject granular materials to this depth. Since high aluminum (Al) saturation of the cation exchange complex of Piedmont soils is a major cause of

limited rooting, the injection of gypsum and lime were included as additional treatments. Also, these soils have a high bulk density (i.e., soil strength), especially in the B horizon. Therefore, the Turf Conditioner was tested for its potential modification of both the physical and chemical properties of the soil.

All plots, except the non-compacted control, were compacted with a smooth power roller while at near soil saturation. The soil was a Cecil sandy clay loam with 55.1% sand, 17.6% silt, 27.3% clay and 2.14% organic matter content. A common bermudagrass mowed at 0.75 to 1.0 inch was used. Fertilization programs in both 1991 and 1992 were at 1.0 lb N/1000 ft^2 in mid-April (10-10-10), mid-June (33-0-0) and early August (33-0-0).

The Verti-Drain (2X) + Core Aeration combination caused the most rapid decrease in penetration resistance, with reductions from 43 to 45 percent throughout the surface 8 inches, compared to the compacted control. After the first year, elimination of the core aeration treatment in conjunction with the Verti-Drain (2X) produced similar penetration resistance results. The combination of the two cultivation techniques also produced the best root water extraction from deep within the soil root zone. The water extracted by roots from within 8 to 24 inches of soil was 33 to 71 percent greater than the compacted control.

The Verti-Drain (2X) + Core Aeration treatment reduced total root length and deep rooting; however, the remaining roots were more efficient and able to extract more water than roots in the compacted control. Thus, root data alone may not always correlate well to water uptake in cultivation studies. This treatment also enhanced overall water uptake as demonstrated by ET rates with values often 28 to 96 percent higher than the compacted control. Water infiltration and percolation, as measured by saturated hydraulic conductivity, was improved by Verti-Drain (2X) and Verti-Drain (1X) + Core Aeration treatments.

The Turf Conditioner + Lime was the most beneficial of the three treatments for this device in reducing penetration resistance (16 to 28 percent reduction compared to the compacted control). Better root water extraction and overall water uptake (ET) were greater than the compacted control for several measurements during the two year study.

Overall, the research indicated that a vigorous cultivation program (i.e., Verti-Drain + Core Aerification) greatly improved turfgrass water use efficiency by enhancing water uptake from deeper zones within a fine-textured soil profile prone to surface compaction. The Turf Conditioner cultivation method appeared to be suited for achieving physical and chemical modification, especially when lime is needed, for similar fine-textured soils.

Salt Screening

Texas A&M University - Dr. Garald L. Horst

Developing Salt, Drought and Heat Resistant Turfgrasses for Minimal Maintenance

The salt tolerance of turfgrass species has become more important as poor quality non-potable and effluent water use has increased on golf courses and other recreational turf. Dr. Horst ranked several of the major turfgrass species in order of their salt resistance (Table 14) and developed screening methods for salt resistance to evaluate selections from USGA/GCSAA sponsored buffalograss, zoysiagrass, and bentgrass breeding projects.

Some zoysiagrass selections from Dr. Engelke's breeding program appeared to have very good salt resistance. These selections could be useful in saline environments or as parents in future cultivar

Table 14. Relative salt resistance of several turfgrass species used in the United States.

Turfgrass Species[a,b]		Relative Ranking[c]
Cool-Season	Warm-Season	
Alkaligrass	Seashore paspalum	Excellent
	Zoysiagrass[d]	
	St. Augustine	
	Bermudagrass hybrids	Good
Bentgrass[d]	Bermudagrass	
Tall fescue	Bahiagrass	Fair
Perennial ryegrass	Centipedegrass	
Fine fescues	Carpetgrass	Poor
Kentucky bluegrass	Buffalograss[d]	

[a]Based on the most used cultivars of each species.
[b]Variable among cultivars within species.
[c]Ranked by Horst (1992).
[d]Species on which limited salt resistance screening was performed under USGA/GCSAA sponsored research.