A PRACTICAL RESEARCH DIGEST FOR TURF MANAGERS

TURFGRASS TRENDS

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BACK-TO-BASICS

Understanding Turfgrass Roots — Part 1

By Richard J. Hull

Part 1 of this Back to Basics series on turfgrass roots details system development, function and dependence on water uptake. Part 2 in next month's issue will cover nutrients, hormonal balance and proper cultivation techniques

It might be safe to say that the secret to effective turfgrass management is developing the art of growing and maintaining healthy roots. Although roots are not generally visible, they are so essential to the well-being of turf that the turf manager who neglects them does so at considerable peril. This is the second of a three part series on turfgrass morphology, function, physiology and management. The first explored the turfgrass crown (Hull, 2000) and a future article will discuss turfgrass leaves.

Water uptake by roots is controlled by two conditions: the contact of soil water with root cell membranes and the number and permeability of aquaporins.

Development and function

In the initial article, I noted that the young turfgrass plant has two root systems: a primary system that originates from the radical (seed root) after it emerges from the germinating seed and an adventitious system initiated at the first stem node that develops in the coleoptile (shoot emerging from the seed) after its tip reaches the soil surface and experiences light (Fig. 1).

This initial node eventually develops into the crown of the grass plant (Hull, 2000). During the seedling year, both root systems are functional but thereafter the adventitious roots comprise the entire functional root system.

Adventitious roots can also emerge at the nodes of horizontal stems (rhizomes and stolons) and these too can become part of the plant's permanent root system. Nodes of a tiller just above the soil can, under favorable conditions, produce short prop roots that may penetrate the soil but their contribution to turfgrass plants is questionable.

The longevity of roots in perennial grasses is a matter of some debate. Turgeon (1999) describes Kentucky bluegrass as a perennial rooting grass while some bentgrasses, perennial ryegrass, bermudagrass and rough bluegrass experience yearly root replacement and are considered annual rooting grasses. However, in her classical studies of the annual growth cycle of perennial cool-season grasses, Stuckey (1941) concluded that perennial grasses renew their root systems each year. My own experience with cool-season grasses would lead me to agree with Stuckey but clearly under favorable conditions, roots that do survive the rigors of summer heat,

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may resume growth in the fall and contribute to the newly developing root system that over-winters and supports grass growth in the spring.

Root growth

Even if turfgrass roots are capable of living for more than a single year, the practical reality is that few do. Most root growth of cool-season grasses occurs during the mid to late fall with the greatest flush recorded during the early to mid spring (Turgeon, 1999). Even during the winter, if the soil is not frozen, roots continue to grow and can acquire much of their photosynthetic energy from shoots during the coldest time of the year.

When the heat of summer raises soil temperatures to above 75° F, root growth is depressed and can stop altogether. The reasons for this summer decline in root growth of cool-season grasses is complicated and not completely understood but it probably results from high temperature induced inefficiency of photosynthesis caused by elevated rates of leaf photorespiration (Hull 1999b).

In short, when soil temperatures rise, turfgrass roots experience their greatest demand for carbohydrates, but heat induced photorespiration in leaves reduces photosynthetic production and less energy is transported to roots. As a result, roots consume most of their carbohydrates and become starved (Huang, 2000).

Root decline slows water uptake resulting in less transpirational cooling of leaves and this reduces photosynthetic efficiency even further. This bad situation is made even worse by heat stimulated soil-born diseases and root feeding by soil insects and nematodes. As a result, most cool-season turfgrasses will have lost more than 75% of their roots by late summer, necessitating the regeneration of a new root system during the cooler times of the year.

By comparison, warm-season turfgrasses produce most of their roots during late spring and summer (Turgeon, 1999). Because such grasses do not experience heat-induced photorespiration, their photosynthetic rates actually increase during the heat of summer supplying adequate carbohydrate energy to support root growth. Warm-season grasses suffer a rapid decline in photosynthesis during the onset of cool temperatures and this denies roots the means for continued growth.

While studies indicate that many roots can survive the winter and even manage some growth, this is always much less than will be observed in cool-season grasses. Dr. James Beard and his colleagues (Sifers et al., 1985) reported a spring phenomenon in warm-season turfgrasses that they called spring root decline. This is most evident during years when soil warming occurs rapidly, stimulating root metabolism and growth before the shoots have regenerated sufficiently to supply the photosynthetic energy necessary to support this root activity.

The result can be a rapid death of the root system which must then be regenerated before normal grass growth can proceed. This rapid root decline delays spring rejuvenation of the turf and can make it vulnerable to drought and slows recovery from mechanical injury. Spring root decline does not occur every year but is frequent enough to give southern turf managers reason for concern during the early spring.

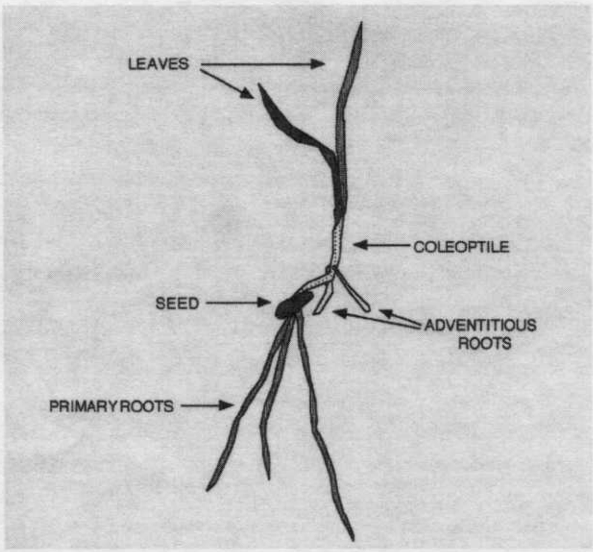

Fig. 1. Primary and adventitious roots developing from a turfgrass seedling.

It is evident that root health is essential for optimum turfgrass performance, but to understand how roots conduct their vital functions, it is necessary to appreciate the physiology of root systems and the structures that assist in their function. This article will concentrate on the structure and function of turfgrass roots and conclude with some ideas of how management strategies can maximize root survival and performance.

Root structure and function

Turfgrass roots are the organs through which turf receives most of its water and mineral nutrients and by which it is anchored in the soil. This latter function is especially critical for athletic field turf and any grass subjected to physical stress or wear. Also, as an integral part of a turfgrass plant, roots contribute to the hormonal balance within the plant by which grasses can respond to environmental and management variables such as water uptake.

Water uptake: Among the most important functions of plant roots is the acquisition of soil water. Without water there is no life and this is as true for turfgrasses as for any living organism. Seed germination is first noted by the emergence of a primary root emphasizing the importance of soil contact and a water supply for further plant growth. The ability of roots to acquire water depends on their surface area (contact with water), their growth rate (exploration for water sources) and their maintenance of a water potential more negative than that of the soil (energy powering water uptake). We have discussed the physiology of water uptake by roots in an earlier article in this series (Hull, 1999a); here more attention will be devoted to structural considerations.

A grass root consist of a cylinder that grows from a region of cell division and elongation near the tip and acquires water and nutrients primarily throughout a region of absorption often recognizable by numerous root hairs (Fig. 2). The meristematic (dividing) cells of the root tip are protected by a root cap as the elongating cells push the tip through the soil. Cells of the root cap also are formed by the meristem but they excrete mucilage and are themselves dislodged from the root as they lubricate the passage of the tip past soil particles. This process occurs more easily in soils that are moist, friable and enriched with organic colloids. Hard, dense, dry soils restrict root extension.

Water absorption occurs when soil water crosses the plasma membrane of root cells. For this to happen, soil water must make contact with the outer membrane of root cells and its activity (mostly concentration) must be greater than water within the cells.

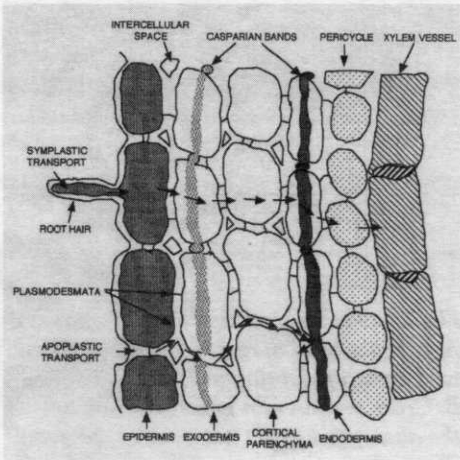

Fig. 3 Diagram of root (longitudinal view) showing apoplastic and symplastic transport routes.

Because cell membranes are largely composed of lipids, there must also be pores in the membranes through which water can pass from the soil into the root cells. These pores or aquaporins are protein channels that permit water molecules to pass single file across the membranes (Maurel, 1997). Water moves from the soil into the root cells as long as there is more free water in the soil than there is within the cells.

Thus, it is important for root cells to maintain a high solute (mineral ions, sugars, organic acids, etc.) concentration that will dilute the cell water making it less free than water in the soil. Energy is required to accumulate and retain solutes, as we will see in the next section, and this energy ultimately comes from photosynthesis.

Water uptake by roots is controlled by two conditions: the contact of soil water with root cell membranes and the number and permeability of aquaporins. At this point, it is good to remember that plant cells are enclosed within a cell wall so the plasma membrane never directly contacts the soil. Water moves from the soil into the cell walls and there makes contact with the cell membrane.

Cell walls are composed of long polymers of carbohydrates (sugars); some are well ordered and reasonably rigid (cellulose) while others are more random and gel-like (hemicellulose and pectin). All these sugar molecules contain several hydroxide (-OH) groups that have a high affinity for water. As a result, the cell wall is highly hydrated and allows the free passage of water so long as there is a water potential gradient moving it along.

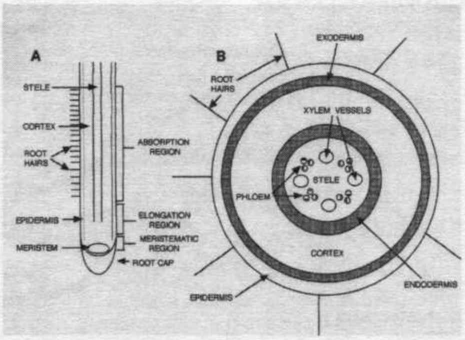

Fig. 2. ***Grass root structure.***
A. Longitudinal diagram through a young root showing developmental regions.
B. Cross section of a grass root through the absorption (root hair) region showing tissue types.

Because every cell of the root is enclosed in its cell wall, plant tissues, including roots, consist of two continuous phases: the nonliving cell wall phase and the living protoplasts that are enclosed within their plasma membrane. The protoplasts are not isolated islands of living stuff imbedded randomly in a matrix of cell walls but rather are also interconnected by thin proplasmic tubes (plasmodesmata) that cross the cell walls between adjacent cells.

Thus the living protoplasts of plant tissues comprise an interconnected protoplasmic continuum (the symplasm) imbedded in a nonliving cell wall continuum (the apoplasm). This structural concept of plant tissues is important because it defines two transport routes that water and nutrient ions can take as they move throughout the plant body.

Therefore, water being absorbed by a root first enters the cell walls of epidermal cells that comprise the outer layer of a root. This water can move through the apoplast of epidermal and cortical cells around the living protoplasts and never actually enter a cell as it is drawn through the root (Fig. 3). If water and soluble mineral ions could pass unobstructed throughout the plant in the apoplastic phase, there would be no way for a plant to regulate what passes from the soil to the shoots.

To prevent this uncontrolled movement, some root cells insert waxy materials (suberin) into their cell walls. These waxy walls block the free movement of water and solutes within the apoplasm forcing them to cross a protoplasmic plasma membrane and continue their movement within the symplasm. Suberized cell walls are located at two regions of a root: the hypodermis and endodermis (Schreiber et al. 1999).

Both of these barriers to unobstructed apoplastic transport are located in the root cortex (Fig. 2). The hypodermis is a layer of cells just inside the epidermis while the endodermis is the inner-most cell layer of the cortex that borders the stele: the vascular core of a root. Normally the endodermis differentiates first forming a suberized band within its radial walls: a Casparian strip.

Fig. 4 A dispersed fibrous root system of Kentucky bluegrass. From such scanned images, root length, diameter and surface area can be determined and partitioned into several size classes.

This may be followed by a similar suberization of hypodermal walls forming an exodermis that is often induced by some stress condition. As these cells differentiate further, their entire cell walls can become suberized and apoplastic transport of water and ions across the root is effectively blocked.

Water normally can enter the symplasm via aquaporins that span the plasma membranes. Once within the symplasm, the apoplastic barriers pose no obstruction to radial transport of water and it can enter the vascular cells of the stele (vessels) and be drawn through the length of the root, to the stem and into the leaves following the water potential gradient created by transpirational water loss from the leaves. Because the passage of water through aquaporins can be controlled by root cells, the plant can regulate the amount of water passing through it (Maurel, 1997).

Most of the observations described in the sidebar "Root system anatomy" (see below) have been made in roots of corn and small grains and it is difficult to say how directly they apply to closely mowed perennial turfgrasses.

It is likely that xylem maturation may be delayed or even inhibited because of the reduced leaf surface maintained and the lower supply of photosynthetic sugars transported to roots. What likely does apply to turfgrass roots is the importance of fine branch roots in both water and nutrient acquisition. Also, the greater drought tolerance of tall fescue and some cultivars of other grasses that grow more of their roots at greater soil depths (Sheffer et al., 1987) may not only be a function of having access to more water but also maturing more large xylem vessels that can deliver water more efficiently to the shoots. Much useful research on turfgrass root anatomy and maturation remains to be done.

ROOT SYSTEM FUNCTIONS

Consider a root system in its entirety how its functions are organized. The adventitious roots emerging from the crown or nodes of rhizomes and stolons elongate and grow mostly in a downward direction. These nodal roots become the framework roots that pretty much shape the general architecture of a root system.

From these roots, numerous fine lateral or branch roots emerge a few inches or more behind the root tip and often do not grow to more than an inch in length (McCully, 1999). Branch roots may themselves branch but this varies with grass species and soil conditions.

Many lateral roots and their branches are determinate, meaning that their apical meristem matures and stops producing new cells, allowing the root to mature right to its tip where the root cap is lost and root hairs may be found. These fine roots can be long-lived and are generally considered the most important component of the root system for water and nutrient acquisition. These roots have the greatest surface area and make the greatest contact with the soil and its moisture.

The fine absorptive roots have all the cell types normally comprising a root but their cortex may consist of little more than an exodermis and endodermis and their stele may contain only a few vessels (3 to 4), an equal number of small phloem clusters and several undifferentiated parenchyma cells.

Unlike the framework roots that lose their epidermis and some cortical cells as they mature beyond the absorptive region and develop a true rhizosphere, fine roots retain a functioning epidermis with long-lived root hairs and an intact cortex. Such roots do secrete high concentrations of organic acids and chelating compounds that enhance the availability of soil phosphorus and iron.

Recent evidence has established that the largest vessel elements mature several inches from the root tip of framework roots and not within the root hair zone as had been thought (McCully, 1999). These large, late metaxylem vessels may be present in the young regions of a root but do not mature and become functional until the region of lateral root production is reached.

These large vessels develop as functional conduits for water and nutrients closer to the tip in branch roots where most absorption occurs. In the younger regions of a root, water conduction occurs through much smaller protoxylem and early metaxylem vessels.

Even these are immature and largely nonconducting in those root tip regions that have been most studied in experimentation. In corn, the maturation of large metaxylem vessels increases the water conducting capacity 1800 times. Because water moves out of such mature roots so rapidly, their relative water content decreases as does their water potential.

Editors' note: Part 2 will be published in the November issue of Turfgrass Trends.

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Relative Salinity:
Comparing tolerances of turfgrass species and cultivars

Growth of development in coastal areas is pushing the development of salt-tolerant turfgrasses

Dr. Ken Marcum

The need for salt tolerant turfgrasses is ever increasing. Rapid urban population growth has put enormous pressures on freshwater supplies, prompting many state and local government restrictions on potable water use for irrigating turfgrass landscapes.

This is especially true in western states, where current water use policies require the use of saline secondary water sources (such as effluent) for irrigation of golf courses and other large turfgrass landscapes.

Also, in rapidly urbanizing coastal areas, over-pumping has resulted in salt water intrusion of wells used for irrigating turf facilities.

Tolerance defined

Substantial differences in relative salinity tolerance exist among turfgrasses. However, the "absolute" salinity tolerance of a given turfgrass cannot be specified, because environmental, soil, and plant factors interact with salinity level to influence turf salinity tolerance. For example, the salinity tolerance of Tifway bermudagrass, indicated by the salinity level causing 50% shoot dry weight reduction, was reported as 33, 27, 18.6, and 12 dS m-1 in four published studies.

Climatically, turfgrasses are more sensitive to salinity under hot, dry conditions, probably due to increased evapotranspiration, resulting in increased salt uptake. Soil factors such as water content, texture, and mineral status (particularly calcium) also have a major effect on turfgrass salinity tolerance.

Soil water content changes have a direct, immediate effect on root zone salinity, which varies with time and also with depth. Soil salinity increases greatly as the soil dries between irrigations, and also as depth increases, with salt concentrations approximately that of the irrigation water near the surface, to several times higher at the bottom of the root zone. Also, in most saline situations sodicity problems can occur, as the primary ion in most saline soils is sodium.

Salinity tolerance is not only a function of salt level, but also of total time of exposure. Turfgrass injury from salinity is cumulative.

In finer textured soils, this can result in anaerobic conditions in the root zone, which can have a more profound effect on turfgrass growth than the salinity itself.

Finally, salinity tolerance is not only a function of salt level, but also of total time of exposure. Turfgrass injury from salinity is cumulative.

Relative tolerance studies

Even though the "absolute" salinity tolerance of a particular turfgrass cannot be specified, relative salinity tolerance (ex. "turfgrass A is more salt tolerant than turfgrass B") can be determined, provided that the other non-salinity growing factors listed above are held constant. To minimize the effects of variable soil and climatic conditions on plant responses to salinity, researchers have utilized solution or hydroponic culture under controlled environmental conditions (growth chambers, greenhouses) in turfgrass salt tolerance research.

In this paper, published turfgrass salt tolerance studies (approximately 80) were compared in attempt to summarize the relative salinity tolerance of turfgrass species. When cultivar comparisons within a given species have been made, I have included name(s) of salt tolerant cultivars immediately below the turfgrass species.

Due to water restrictions, salinity is becoming a major turfgrass management issue.

Salt tolerance comparisons were made difficult, due to the different methods and growing conditions used in the studies, as well as different criteria used to measure salinity tolerance, for example: shoot growth rate reduction, root growth, shoot visual injury, plant survival, and seed germination.

However, comparisons of results between studies were possible if the studies had some turfgrass entries in common. I have summarized results in the table below. Salinity levels are only approximate, and represent the level of soil salinity that the turfgrass can tolerate and maintain reasonable quality.

Due to water restrictions, salinity is becoming a major turfgrass management issue. When saline water sources are used for turfgrass irrigation, proper irrigation and soil maintenance practices are essential (see TurfGrass Trends, September 2000, page 9). Also, choosing a salt tolerant turfgrass is equally important for long-term success.

— Ken Marcum is assistant professor of turfgrass management with the Department of Plant Sciences at the University of Arizona. He specializes in environmental (drought, salinity, and heat) stress of turfgrasses. Marcum has his Ph.D. from the University of Hawaii.

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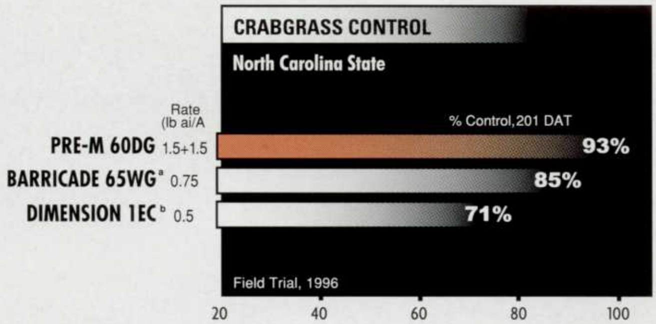

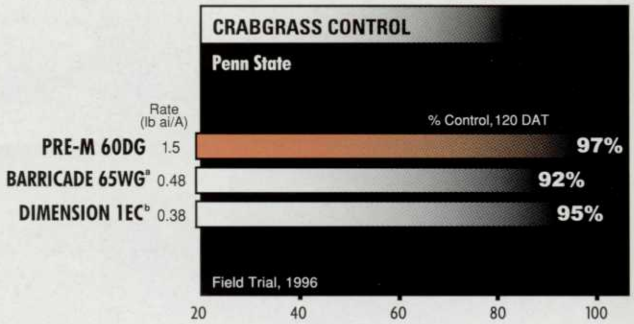

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TEAM[c]	H	M	M	M	M	M	NR	NR
RONSTAR[d]	M	H	NR	M	M	NR	NR	NR
SURFLAN[c]	H	H	H	M	MH	M	H	H

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*Source: Kline & Company Report, US Acre Treatments by Turf Management.

RELATIVE SALT TOLERANCE OF TURFGRASSES

C3 (cool season) Turfgrasses	Salinity Tolerance*	C4 (warm season) Turfgrasses
	30+ dS m-1	Saltgrass (Distichlis)
		Sporobolus virginicus
	25 dS m-1	Manilagrass
		'Diamond'
		Mascarenegrass
		Seashore paspalum
Nuttall alkaligrass	18 dS m-1	St. Augustinegrass
Weeping alkaligrass		'Seville'
'Fults'		
Lemmon alkaligrass		
	16 dS m-1	Bermudagrass
		'Tifway'
		Hybrid zoysiagrass
		'Emerald'
	14 dS m-1	Japanese lawngrass
'El Toro'		
'Crowne'		
Creeping bentgrass	9 dS m-1	
'Mariner'		
'Seaside I & II'		
'Grand Prix'		
Tall fescue	7 dS m-1	
'Alta'		
Creeping red fescue	6 dS m-1	
'Dawson'		
'Oasis' (slender c.r.p.)		
'Ruby' (strong c.r.p.)		
Perennial ryegrass	5 dS m-1	Buffalograss
'Manhattan'		Gramagrasses
Redtop		
Rough bluegrass	3 dS m-1	Centipedegrass
Kentucky bluegrass		Carpetgrass
'Nugget'		
Chewings fescue		
Hard fescue		
Sheep fescue		
Meadow fescue		
Annual ryegrass		
Annual bluegrass	2 dS m-1	Bahiagrass
Colonial bentgrass		
Velvet bentgrass		

**Salinity level of soil saturated paste extract (ECe).*

Got Hybrids?

Researchers are consolidating information on grass hybrids. Your participation can be an important part of their success

By Lee Menconi-Steiger

What roles do grasses play in our lives? They play a major role in the development or preparation of: bread, rice, pasta, tortillas, porridge, haggis, oil, sugar, spices, beer, grain-fed meat, bamboo fences and tropical housing, rattan furnishings, straw hats; "fuel" for transportation and farm machinery powered by horses and oxen (and, by extension, manure to fertilize other plants or burn as fuel); soil binders, ornamental plants, and, of course, home lawns, sporting fields and recreation grounds.

The Hybrid Grass Database is a free, searchable, online list of natural and bred grass hybrids.

Grasses, in other words, are central to human civilization, whether one is considering nutrition, ecology, aesthetics, athletics or simply dollars and cents.

Hybrids' genetic information

We know more about the 8,000-10,000 species of grasses than about any other family of plants. Grass hybrids are potentially a rich source of biological, genetic and genomic information, to be extracted for a wide range of purposes, and yet there is no comprehensive database of authenticated grass hybrids.

Mike Freeling and Toby Kellogg are changing that. Professors at University of California-Berkeley and the University of St. Louis, MO, respectively, they've created the Hybrid Grass Database; a free, searchable, online list of natural and bred grass hybrids.

Starting with Irving Knobloch's "A Checklist of Crosses in the Gramineae" from 1968 and his previously-unpublished update and corrections, Mike and Toby have added data gleaned by their researchers from published sources worldwide. Their ambition is to list all known hybrids.

Taxonomists, gardeners, turf breeders and naturalists are all invited to contribute data. Mike says, "We're interested in stories that can be verified by samples, photos, notebooks, and/or maps. The wider the cross, the more extreme the phenotypic differences, the better!"

Contribute your hybrids and help build the database; your work will be included as a permanent part of the database, to inform and inspire others. Use the Hybrids List as a forum to let people know about your commercial hybrid, and add to the world's store of available knowledge; use the database as a research tool to discover what others have hybridized, or to come up with ideas to use in your own research.

The Grass Hybrids Database exists only to collect and disseminate information. The submission form requests the hybrid's name and parentage, information about fertility, origin and propagation, and the availability of the hybrid and parent plants. Contact information is included for commercially valuable hybrids.

Mike and Toby may add taxonomic verification or perform molecular fingerprinting to verify hybrids when material is donated for this purpose. Of course, not all this information is available for every plant.

Technical note: Hybrids are often important as plants, or as the starting point to introgress wild alleles (genes) into a cultivar. Perhaps more importantly, fertile hybrids permit genetic mapping of any allelic difference. Using genomic biology (maps and sequence databases), it will often be possible to locate this allele in the deduced ancestral grass genome that existed about 70 million years ago, and, thus, in any grass descendent.

In other words, wide hybrids enable one way to discover useful genes (alleles). If you want more specific information on hybrids as gene discovery tools, visit the website or inquire. Contribute data or search the database at http://128.32.88.35/grassweb/ ; email at grasshyb@nature.berkeley.edu, or use the address or fax number on the form.

The author is an administrator with the Department of Microbial Biology at the University of California - Berkeley.

Add a Grass Hybrid to the Database

Please complete a separate form for each hybrid on which you report; include all the information you have; we really don't expect you to fill ALL the boxes! Information may become a listing in The Hybrids List public database.

SUBMITTED BY

Your Name: ____________________

E-mail address: ____________________

Website address:(URL) ____________________

Mailing address: ____________________

FAX: ____________________

Phone(s): ____________________

WHERE THE INFORMATION ABOUT THIS HYBRID CAME FROM

Publication/Authors: ____________________

Website: ____________________

Other: ____________________

ABOUT THE HYBRID

Female parent; Genus, Species, Variety ____________________

Male parent; Genus, Species, Variety ____________________

Hybrid Name ____________________

Fertile? (%) ____________________

Distribution/where described: ____________________

FURTHER INFORMATION IF AVAILABLE

Artificially hybridized? ____________ *Naturally occurring?* ____________

Date described/made: ____________ *Ploidy* ____________

How propagated?: ____________________

Is hybrid available?: ____________ *Where?:* ____________

Are parental plants available?: ____________ *Where?* ____________

Please list publications, if any

Please explain who described or made this hybrid, and how it was confirmed.

Please provide technical information if embryo rescue or similar technologies were used.

Please describe hybrid in contrast to parents.

Photos?

Clarify any proprietary considerations pertaining to obtaining seed or plants.

Expand on any or all topics with additional pages. Return this form to: L. Menconi, Administrator, Department of Plant and Microbial Biology, 111 Koshland Hall, Berkeley, California 94720-3102 or FAX: 510/642-4995

Or search and add to the database on line at http://128.32.88.35/grassweb/

Golf: Positive economic impacts for local economies

There are ways to document golf's positive effect on the community. This study compares local and visitor contributions

By Mike D. Woods

The game of golf can have a very positive impact on local economies where golf courses are located (1). Construction expenditures, operational expenditures, and dollars spent by visiting golfers can all add income and jobs to the local economy.

A recent report by the National Golf Foundation (NGF) indicates the number of rounds played annually reached a record high of 564 million in 1999 (2). The NGF also reports there are over 26 million golfers in the U.S. with 6 million of them labeled "avid" golfers (who play 25 or more rounds per year). Clearly, these golfers and rounds-played are not evenly distributed throughout the country. The impacts vary from state to state and even from community to community. Some states are already known as golfing destinations while others are enhancing their marketing efforts. The purpose of this article is to review the potential impact of golf courses on the local economy.

A recent survey of Oklahoma golf courses reported a per course expenditure of $86,294 annually in non-labor expenses.

Local economic impacts

There are several sources of economic impact related to golf courses. Construction of golf courses brings dollars to the community during the construction phase. The National Golf Foundation reported over 500 courses were opened in 1999, including 13 reconstructed courses. Expenditures for materials, supplies, earth moving, sod, etc. all can bring dollars to a local economy. The maintenance of golf courses can have a more long-term impact. A recent survey of Oklahoma golf courses reported a per course expenditure of $86,294 annually in non-labor expenses (3). An additional $77,000 was spent on new equipment and new irrigation expenses.

These expenses varied by type of course: public or private; 9 hole vs. 18 hole; etc. The significant point is — these courses generated local economic activity through maintenance expenditures for fertilizers, herbicides, fuel, equipment repair, topdressings, seed, sod, trees, shrubs, ornamentals and other items. There is also a significant direct employment impact for accountants, caddies, club managers, golf pros, golf teachers, secretaries, security, food/beverage service and others. The Oklahoma survey reported an average employment of 18 ftes per course (non-maintenance).

Typical impacts on the economy

Local golf courses certainly generate impacts through expenditures, employment, and payroll. Another impact relates to the golfers who play the course. However, using traditional economic impact analysis, we must be careful not to double-count the impacts. Visitor expenditures can however, be another measure of impact. Golfers pay green fees and pur-

TABLE 1.

Percent of Out-of-Town Guests	Dollars Spent Per Day Per Visitor		
	$5	$10	$15
60	$135,000	$270,000	$405,000
70	$157,000	$315,000	$472,000
80	$180,000	$360,000	$540,000

chase food and golf supplies at the club or proshop. They stop at local restaurants or purchase gasoline and other supplies. These expenditures impact the local community beyond the direct impacts of the golf course and are similar to tourism economic impacts.

There are also impacts of golf courses which are more difficult to quantify. Many local residents feel good golf courses add to the local quality of life. Existing residents may desire a quality course. Often, building a golf course is seen as part of a business development strategy; it will attract new business opportunities when perceived as enhancing the local quality of life. In Oklahoma, many community groups have requested assistance in establishing a course to enhance the local economy. Building a golf course alone will not turn a local economy around but it can help. The local community must have an overall plan and sound leadership for promoting the entire community (4).

A final thought on the impact of golf courses relates to retirees. The demographics of the country are changing. The baby boom generation is nearing retirement and many boomers have taken up golf. This is a lifelong sport that can be enjoyed well into their retirement years. Some communities have adopted a strategy of attracting retirees as an economic development strategy (5). These retirees look for many amenities including health care and public safety. Accessible golf courses are one part of the equation that retirees may consider.

Visitors add to the pot

Perkins is a community in central Oklahoma with a population of around 2000, but is within easy driving distance of several larger urban centers. The Cimarron Trails golf course was constructed with an initial capital investment of approximately $5 million including the course, clubhouse and real estate. Initial employment included five full time employees and 35 seasonal or part time employees. Initially, the golf course expected to host 100 to 110 tournaments with rounds played per year expected to total 40,000 to 45,000.

Impacts of the course include dollars spent by golfers who visit the course. Dollars spent by golfers (out-of-town visitors) are critical since they bring in money that would not otherwise be spent in the local economy. The following table represents potential impact for a range of expenditures.

Dollars spent by golfers (out-of-town visitors) are critical since they bring in money that would not otherwise be spent in the local economy.

45,000 Annual Rounds

Dollars spent per day in the above example are above and beyond the expenditures for green fees and supplies or food within the proshop. Often out of town golfers will expend dollars on gasoline, restaurants, or other retail items. The only way to know for sure about these expenditures is to survey the golfers. Of course, only out-of-town visitors are counted as net addition to the economic impact.

TABLE 2.

1. Number of rounds played-number of golfers;
2. Proportion of out-of-town golfers and guests;
3. Dollars spent per golfer on the golf course/proshop and in the community; and
4. Dollars spent by employees of the golf course in the local economy.

Key variables in an analysis of expenditures related to golf courses include those listed in Table 2:

Each of these variables must be assessed carefully. The number of rounds played is information easily collected for courses already in operation. The proportion of out-of-town golfers is a more difficult bit of required information. Course records will usually help and the proshop will usually have a "feel" for this number. Dollars spent on green fees and other proshop expenditures should be available from proshop records. Additional dollars spent in the local economy will be more difficult to obtain.

Surveys of golfers can be conducted but care must be taken to collect accurate information (and to not intrude on the positive recreational experience the golfers are enjoying). This kind of information, if collected, will allow an assessment of the golf course impacts to be described and, quite possibly, will deliver a positive message about local economic impacts.

Analysis of the expenditures of golfers and employees in the Perkins example led to estimates ranging from $40,000 to $69,000 per year in additional sales tax revenues (6).

Adding the figures

Golf courses definitely have a positive economic impact on local economies. These impacts are demonstrated in the form of new jobs and payroll impacts. Golf courses have a significant impact in terms of local expenditures for supplies, repairs, maintenance, etc. Visitors and golfers from out of town also can provide impacts both on the golf course and in the local community. The future growth potential of golfers is steady and holds much potential for many local areas (7). Local communities should consider a quality golf course as part of an overall community economic development strategy.

— Mike Woods is Professor and Extension Economist at Oklahoma State University. He can be reached at 405-744-9837 or e-mail: mdwoods@okstate.edu

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