A PRACTICAL RESEARCH DIGEST FOR TURF MANAGERS

TURFGRASS TRENDS

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PLANT HEALTH

Basic Plant Management Techniques — Part 1

Best management practices reduce organic materials in landscape plantings. This section looks at two turf irrigation options.

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Following proper management practices can significantly reduce the production of organic materials in landscape plantings. Implementing recommended irrigation, fertilization, and other cultural practices can reduce the vegetative growth of turfgrass and woody plants without sacrificing aesthetic appeal or performance. Employing the techniques described in this publication will enable landscape managers to achieve both of these goals.

Turfgrass irrigation management

Proper turfgrass irrigation management is important to optimize plant health and to reduce unnecessary production of organic matter. Scheduling irrigation based on water requirements of the turfgrass is one of the most important management practices available to promote healthy and attractive turfgrass plantings able to withstand traffic and other stresses. Irrigation scheduling involves applying the right amount of water over the correct amount of time, based on the evapotranspiration (ET) rate of the plant. (Evapotranspiration is the combined water loss from the soil surface and through the plant.)

Too much water can result in diseased turfgrass and unsafe, flooded parks and playing fields, while too little water can lead to a thin stand of poorly growing turfgrass with low vigor, poor recuperative ability and appearance and unsafe playing conditions for sports such as soccer and football.

There are two effective methods of scheduling turfgrass irrigation. While both methods result in effective irrigation and minimal water waste, *Method One* is especially targeted to those with limited time and resources who are interested in increasing turfgrass quality while decreasing an overabundance of clippings that make grasscycling difficult.

Method Two is targeted toward personnel with greater time and resources who are interested in fine-tuning their irrigation scheduling practices to an even greater extent and is based on results of a more precise 'can test' than Method One. It offers the option of using real-time reference evapotranspiration (ETo) information available through the California Irrigation Management Information System (CIMIS), discusses the use of tensiometers, and describes how to mathematically determine the distribution uniformity (DU), application

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While both methods result in effective irrigation and minimal water waste, Method One is especially targeted to those with limited time and resources who are interested in increasing turfgrass quality while decreasing an overabundance of clippings that make grasscycling difficult.

rate, net amount of water to apply, and sprinkler run times.

Method One will provide a close approximation of irrigation requirement when climatic conditions are near average. During an unusual weather pattern that persists for an extended period, Method One may not accurately predict ET, and the turfgrass should be monitored closely for signs of too much or too little water, with necessary corrections made.

How Method One works

This method of irrigation scheduling uses average (historical) ETo recorded over several years to estimate ET of warm and cool season turfgrasses on a weekly basis. Table 1 (Minutes to Irrigate Warm and Cool Season Turfgrasses per Week) was computed from these data. ETo is an estimate of the amount of water used by healthy 4- to 6-in. cool-season turfgrass. Table 1 reflects the fact that research indicates that warm season turfgrass require about 20 percent less water than cool-season turfgrass.

■ 1. Determine the sprinkler system precipitation rate. Set a minimum of six straight-sided cans of the same type (any straight-sided cans may be used or they can be purchased from a variety of grocery store suppliers) between sprinkler heads receiving water from the same valve. If possible, space cans on 10 or 15-foot centers for more accurate results. Run the sprinklers for 15 minutes and measure the depth of water in each can with a ruler; record each depth on a corresponding grid for future reference that indicates the field location of each of the cans.

Determine the average depth of water in

TABLE 1.

Minutes to Irrigate Warm and Cool Season Turfgrass per Week
NORTHEASTERN MOUNTAIN VALLEYS

Warm Season Turfgrasses: Not recommended	Cool Season Turfgrasses: Minutes to irrigate/week if hourly sprinkler output is:			
	0.5 in	1.0 in	1.5 in	2.0 in
JAN	17	08	06	04
FEB	34	17	11	08
MAR	59	29	20	15
APR	101	50	34	25
MAY	134	67	45	34
JUN	168	84	56	42
JUL	210	105	70	53
AUG	176	88	59	44
SEP	126	63	42	32
OCT	76	38	25	19
NOV	25	13	09	06
DEC	17	09	06	04

each can and multiply this number by four to determine the sprinkler output in inches per hour (precipitation rate).

If possible, conduct the 'can test' at the same time of day the turfgrass is ordinarily watered since water pressure often varies over a 24-hour period. Also, avoid conducting the test during an unusually windy period.

■ 2. Determine the length of time to irrigate the turfgrass. Use the appropriate geographical area in Table 1 that most closely matches the location of the turfgrass planting to be irrigated. Use the precipitation rate in the corresponding table that comes closest to, but does not exceed, the output rate determined in 1.

The columns of numbers in Table 1 indicate the total number of minutes to irrigate over a one-week period. Divide the total minutes into two, three, or four irrigations per week, depending on how many minutes a single irrigation can run before runoff starts.

Controllers should be reset at least monthly during the summer and at least quarterly the rest of the year to match seasonal changes in irrigation requirements.

Irrigation cycling is recommended on slopes and soils that do not absorb water quickly. This entails irrigating to the point that runoff starts, waiting 10 or 15 minutes, and irrigating a second time, and, sometimes, a third time, until the required amount of water for that particular day has been applied. Turfgrass benefits from drying down somewhat between irrigations, to encourage deep rooting.

In general, turfgrass should not be irrigated more often than four times a week, with the exception of some golf course putting greens. Controllers should be reset at least monthly during the summer and at least quarterly the rest of the year to match seasonal changes in irrigation requirements, based on Table 1.

The Extension service has recommendations for most major regions in the state. If your area is not here, contact the authors for specifics.

How Method Two works

This method of irrigation scheduling relies on results of a more precise 'can' test than Method 1, offers the option of using real-time ETo information available through the California Irrigation Management Information System (CIMIS), discusses the use of tensiometers and describes how to mathematically determine distribution uniformity (DU), application rate, net amount of water to apply, and sprinkler run times:

■ 1. Use either real-time or historical records to estimate reference evapotranspiration (ETo). ETo is an estimate of the amount of water used by healthy 4- to 6-in. tall cool-season turfgrass.

Real-time ETo is based on measurements of current environmental conditions that determine plant water use, as opposed to average conditions for a certain time of year, used in Method 1. These measurements include solar radiation, air temperature, wind speed, and relative humidity.

The California Irrigation Management Information System (CIMIS), managed by the California Department of Water Resources, provides real-time ETo data at several locations in Southern California. Turfgrass plantings in areas of close proximity to these locations have similar ETo requirements.

Real-time ETo from CIMIS can be downloaded on microcomputers. For more information on CIMIS, contact the California Department of Water Resources at 800/92-CIMIS.

■ 2. Assign an appropriate percentage of ETo to the turfgrass to be irrigated. Warm-season turfgrasses (bermudagrass, zoysiagrass, St. Augustinegrass) require about 20 percent less water than cool-season turfgrasses (tall fescue, annual and perennial ryegrass, bluegrass), and should be irrigated at 60 percent of ETo, while cool season tur-

Turfgrass plantings in areas close to locations in southern California have similar ETo requirements. Real-time ETo from CIMIS can be downloaded on microcomputers.

fgrasses require at least 80 percent of ETo to maintain optimum quality.

Example. In July, a bermudagrass park located in San Bernardino has the following water requirements for optimal growth in an average year:

6.82 Inches x .6 = 4.1 Inches

Table 2 indicates that historical ETo in July in San Bernardino (Southern Inland Valleys) totals 6.82 inches. Multiplying 6.82 times the suggested percent ETo for warm season turfgrass (.6) indicates the water requirement for July to be 4.1 inches.

■ 3. Determine an acceptable allowable soil-moisture depletion rate. Knowing when to irrigate is as important as knowing how much irrigation water to apply. While it is important to let turfgrass dry down some between irrigations, it is also important to apply water before significant symptoms of drought stress occur.

Tensiometers and other soil moisture measuring devices can be very helpful in determining maximum allowable soil-moisture depletion. During the summer, a tensiometer reading of 60 centibars at a six-inch to one foot soil depth approaches the maximum allowable soil-moisture depletion for warm-season turfgrass.

A reading of 40 centibars at a 4-in. depth identifies the maximum allowable depletion for cool-season grass. (Remember that the higher the centibar reading, the drier the soil.)

■ 4. Determine the distribution uniformity (DU) of the irrigation system. The easiest and most accurate method to determine the distribution uniformity (DU) of a sprinkler system is to conduct a 'can test'. A major goal of irrigating turfgrass is to obtain the highest DU possible to provide optimum conditions for turfgrass growth throughout the planted area and to reduce water waste.

Straight-sided cans are useful for conducting 'can tests' since water collected during the sample run can easily be measured with a ruler. Alternatively, cans without straight sides may be used, although volumetric measurements are then required.

After laying out the cans to perform the

TABLE 2.

Average Monthly Reference Evapotranspiration (ETo) Rates Throughout California

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
NE Mountain Valleys	0.62	1.16	2.17	3.60	4.96	5.70	8.06	7.13	4.80	2.79	0.90	0.62
Northern Coast	0.62	1.16	1.86	2.40	3.41	3.60	3.41	3.41	2.70	1.86	1.20	0.62
Northern Inland Valleys	0.93	1.16	2.48	3.30	4.96	6.00	7.13	6.20	4.50	2.79	1.20	0.62
Sacramento Valleys	1.24	1.74	3.10	4.50	5.89	7.20	8.06	6.82	5.10	3.41	1.80	0.93
San Joaquin Valleys	0.93	1.74	3.10	4.50	6.51	7.50	7.75	6.51	4.80	3.41	1.50	0.62
Central Coast	1.86	2.32	3.10	3.90	4.65	4.80	5.27	4.96	3.90	3.10	2.10	1.55
Central Inland Valleys	1.55	2.32	3.41	4.20	5.58	6.30	6.82	5.89	4.80	3.72	2.40	1.55
Sierra (Tahoe Basin)	—	—	—	3.00	4.03	4.80	6.20	5.27	3.00	2.79	—	—
Southern Coast	1.86	2.61	3.10	3.90	4.34	5.10	5.58	5.58	4.50	3.41	2.70	2.10
Southern Inland Valleys	1.86	2.61	3.41	4.20	4.96	6.00	6.82	6.82	5.10	3.72	2.40	1.80
Southern CA Deserts	2.79	3.77	5.89	7.50	10.23	11.40	11.47	9.61	8.40	6.20	3.60	1.86

'can test' in either 10- or 15-ft. centers, operate the sprinkler system for 15 minutes.

Then, measure and record the amount of water in each can on a site map. Determine the average (mean) amount of water per can.

Next, calculate the average amount of water that accumulated in the 'low quarter'. For example, if there were 100 total cans in the test, the overall mean average of water in all the cans should be determined first. Then, the average amount of water in the 25 cans that accumulated the least amount of water (the 'low quarter') is calculated and recorded.

The DU can then be determined using the following formula:

Distribution Uniformity (DU) = Mean of the Low Quarter x 100

Overall Mean

■ 5. Determine the amount of irrigation water to apply. Divide the monthly percent ETo used in 2 by the DU calculated in 4.

■ 6. Determine the hourly sprinkler system application rate. Multiply the average amount of water per can from the 'can test' (4) by four, since the system ran for 15 minutes.

■ 7. Determine the sprinkler run time. The sprinkler run time is the net amount of water to apply (determined in 5) divided by the sprinkler system application rate (determined in 6). This number multiplied by 60 equals the run times in minutes.

Example: If 0.50 inches of water needs to be applied during each irrigation and the application rate is 1.0 inch/hour, the run time equals 0.50 hours or 30 minutes:

0.50/1.0 = 0.50 hours,
and 0.50 x 60 = 30 minutes

Other considerations

It is important to maintain a high DU so irrigation water is evenly applied to the turfgrass area being irrigated to avoid unnecessary water waste. Table 1 assumes an 80 percent DU. A system with a DU of 40 percent requires twice as much water as a system with a DU of 80 percent!

Even with limited resources, conducting regular 'can' tests is a sound investment, and often leads to substantial savings of water and money, unnecessary greenwaste production and a healthier turfgrass planting less prone to pests.

Runoff is an excellent indicator of how long an irrigation cycle may run. Simply measure the length of time it takes for runoff to begin from the time the system turns on. This is the maximum run time per irrigation.

Runoff is an excellent indicator of how long an irrigation cycle may run. Simply measure the length of time it takes for runoff to begin from the time the system turns on.

If necessary, irrigations may be cycled by adding smaller amounts of water during each irrigation to allow the water to soak into the soil before adding more water. It is important that the cycles are repeated over a short period of time, before the soil dries significantly. Several cycles may be required.

Scheduling irrigations around sports field usage and golf rounds without sacrificing turfgrass quality or field safety is an important consideration for many turfgrass professionals. Early morning irrigation is preferred.

Irrigation should occur long enough before play to avoid wet conditions during games, since wet soils compact easily, leading to stressed plants and poor playing conditions.

Scheduling regular walk-throughs to identify and correct problems with irrigation equipment on-site is as important to the overall health and function of the turfgrass planting as is irrigation scheduling.

When an irrigation system is inoperative for even a day or two under high summer temperatures, drought stress can lead to temporary damage to the turfgrass. In many cases, substantial amounts of water

CALIFORNIA COASTAL IRRIGATION REQUIREMENTS

Table 1. NORTHERN COAST

Warm Season Turfgrasses:
Minutes to irrigate/week if hourly sprinkler output is:

JAN	NOT RECOMMENDED
FEB	NOT RECOMMENDED
MAR	NOT RECOMMENDED
APR	NOT RECOMMENDED
MAY	NOT RECOMMENDED
JUN	NOT RECOMMENDED
JUL	NOT RECOMMENDED
AUG	NOT RECOMMENDED
SEP	NOT RECOMMENDED
OCT	NOT RECOMMENDED
NOV	NOT RECOMMENDED
DEC	NOT RECOMMENDED

Cool Season Turfgrasses:
Minutes to irrigate/week if hourly sprinkler output is:

	0.5 in	1.0 in	1.5 in	2.0 in
JAN	15	07	05	04
FEB	36	18	12	09
MAR	55	27	18	14
APR	67	34	22	17
MAY	88	44	29	22
JUN	97	48	32	24
JUL	95	47	32	24
AUG	90	45	30	23
SEP	76	38	25	19
OCT	48	24	16	12
NOV	32	16	11	08
DEC	21	11	07	05

Table 2. CENTRAL COAST

Warm Season Turfgrasses
Minutes to irrigate/week if hourly sprinkler output is:

	0.5 in	1.0 in	1.5 in	2.0 in
JAN	38	19	13	09
FEB	50	25	17	13
MAR	63	32	21	16
APR	88	44	29	22
MAY	101	50	34	25
JUN	113	57	38	28
JUL	95	47	32	24
AUG	113	57	38	28
SEP	95	47	32	24
OCT	69	35	23	17
NOV	50	25	17	13
DEC	38	19	13	09

Cool Season Turfgrasses
Minutes to irrigate/week if hourly sprinkler output is:

	0.5 in	1.0 in	1.5 in	2.0 in
JAN	50	25	17	13
FEB	67	34	22	17
MAR	84	42	28	21
APR	118	59	39	29
MAY	134	67	45	34
JUN	151	76	50	38
JUL	126	63	42	32
AUG	151	76	50	38
SEP	126	63	42	32
OCT	92	46	31	23
NOV	67	34	22	17
DEC	50	25	17	13

Table 3. SOUTHERN COAST

Warm Season Turfgrasses
Minutes to irrigate/week if hourly sprinkler output is:

	0.5 in	1.0 in	1.5 in	2.0 in
JAN	44	22	15	11
FEB	57	28	19	14
MAR	63	32	21	16
APR	76	38	25	19
MAY	88	44	29	22
JUN	95	47	32	24
JUL	107	54	36	27
AUG	95	47	33	24
SEP	82	41	27	20
OCT	69	35	23	17
NOV	50	25	17	13
DEC	38	19	13	9

Cool Season Turfgrasses
Minutes to irrigate/week if hourly sprinkler output is:

	0.5 in	1.0 in	1.5 in	2.0 in
JAN	59	29	20	15
FEB	76	38	25	19
MAR	84	42	28	21
APR	101	50	34	25
MAY	118	59	39	29
JUN	26	63	42	32
JUL	143	71	48	36
AUG	126	63	42	32
SEP	109	55	36	27
OCT	92	46	31	23
NOV	67	34	22	17
DEC	50	25	17	13

CALIFORNIA INLAND VALLEY IRRIGATION REQUIREMENTS

Table 4. SACRAMENTO VALLEYS

Warm Season Turfgrasses

Minutes to irrigate/week if hourly sprinkler output is:

	0.5 in	1.0 in	1.5 in	2.0 in
JAN	19	09	06	05
FEB	44	22	15	11
MAR	69	35	23	17
APR	101	50	34	25
MAY	126	63	42	32
JUN	158	79	53	39
JUL	164	82	55	41
AUG	145	72	48	36
SEP	113	57	38	28
OCT	82	41	27	20
NOV	38	19	13	09
DEC	19	09	06	05

Cool Season Turfgrasses

Minutes to irrigate/week if hourly sprinkler output is:

	0.5 in	1.0 in	1.5 in	2.0 in
JAN	25	13	08	06
FEB	59	29	20	15
MAR	92	46	31	23
APR	134	67	45	34
MAY	168	84	56	42
JUN	210	105	70	53
JUL	218	109	73	55
AUG	193	97	64	48
SEP	151	76	50	38
OCT	109	55	36	27
NOV	50	25	17	13
DEC	25	13	08	06

Table 5. SAN JOAQUIN VALLEYS

Warm Season Turfgrasses

Minutes to irrigate/week if hourly sprinkler output is:

	0.5 in	1.0 in	1.5 in	2.0 in
JAN	19	09	06	05
FEB	38	19	13	09
MAR	69	35	23	17
APR	101	50	34	25
MAY	132	66	44	33
JUN	164	82	55	41
JUL	170	85	57	43
AUG	145	72	48	36
SEP	113	57	38	28
OCT	69	35	23	17
NOV	32	16	11	08
DEC	13	06	04	03

Cool Season Turfgrasses

Minutes to irrigate/week if hourly sprinkler output is:

	0.5 in	1.0 in	1.5 in	2.0 in
JAN	25	13	08	06
FEB	50	25	17	13
MAR	92	46	31	23
APR	134	67	45	34
MAY	176	88	59	44
JUN	218	109	73	55
JUL	227	113	76	57
AUG	193	97	64	48
SEP	151	76	50	38
OCT	92	46	31	23
NOV	42	21	14	11
DEC	17	08	06	04

Table 6. SOUTHERN INLAND VALLEYS

Warm Season Turfgrasses

Minutes to irrigate/week if hourly sprinkler output is:

	0.5 in	1.0 in	1.5 in	2.0 in
JAN	52	21	14	10
FEB	57	28	19	14
MAR	80	40	27	20
APR	96	48	32	24
MAY	119	60	40	29
JUN	144	72	48	36
JUL	165	83	55	41
AUG	155	77	52	39
SEP	124	62	41	31
OCT	88	44	29	22
NOV	54	27	18	14
DEC	42	21	14	10

Cool Season Turfgrasses

Minutes to irrigate/week if hourly sprinkler output is:

	0.5 in	1.0 in	1.5 in	2.0 in
JAN	56	28	19	14
FEB	75	38	25	19
MAR	106	53	35	27
APR	128	64	43	32
MAY	159	80	53	40
JUN	193	96	64	48
JUL	221	110	74	55
AUG	207	103	69	52
SEP	165	82	55	42
OCT	117	59	39	29
NOV	73	36	24	18
DEC	55	28	19	14

loss due to a low DU can be avoided by checking equipment regularly.

One of the most important steps to take to avoid low DU's leading to brown spots and wasted water is to maintain a well-stocked inventory of matched irrigation components for emergencies.

Additionally, parts such as piping, repair couplings, isolation valves, electric valves and other components should be readily available. It is wise to have at least one person knowledgeable in irrigation equipment and scheduling who can monitor irrigation functions regularly.

Sprinklers should be regularly checked for the following common causes of poor distribution uniformity and necessary repairs made as soon as possible: broken sprinklers; unmatched sprinklers; sunken sprinklers; crooked sprinklers; turfgrass growing around sprinklers; and, sand or debris plugging sprinklers.

Editors' note: Next month, Part 2 will review basic methods to reduce materials in landscape tree irrigation, pruning and fertilization.

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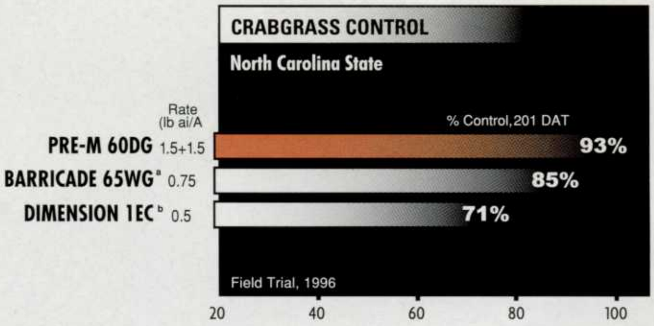

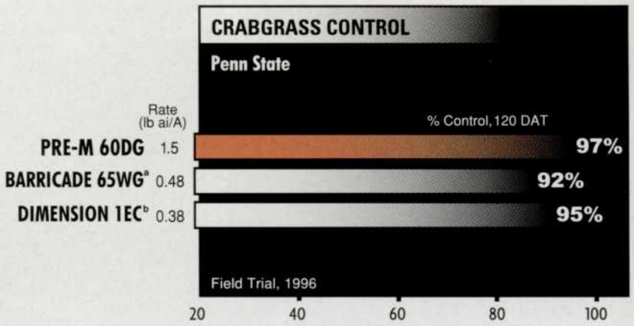

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TEAM[c]	H	M	M	M	M	M	NR	NR
RONSTAR[d]	M	H	NR	M	M	NR	NR	NR
SURFLAN[c]	H	H	H	M	MH	M	H	H
Level of control	*Medium*		*Medium–High*		*High*		*Not Registered*	

[a]™ Novartis [b]™ Rohm and Haas Co. [c]™ Dow AgroSciences [d]™ Rhône-Poulenc

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

Understanding Turfgrass Roots — Part 2

While water uptake is critical, nutrient absorption, hormonal balance and proper treatment also play major roles in the health of turfgrass roots

By Richard J. Hull

Editors' note: In Turfgrass Trends for October, Dr. Hull presented Part 1 of his Back to Basics information on turfgrass roots, which discussed root development and function, growth patterns, root structure, system operation and water uptake. This article finishes his discussion.

Nutrient absorption

The routes described above for water uptake by roots are the ones that nutrient ions must also take. Since nutrients are dissolved in soil water, they are carried along with water into the apoplasm of plant roots. The apoplastic barriers created by the endodermis and exodermis also effectively block the radial transport of nutrient ions into the stele and throughout the plant.

Ions differ from water in that they carry a positive (cation) or negative (anion) charge and cannot cross the plasma membrane into the symplast via aquaporins.

However, they can cross the plasma membrane and become concentrated within the symplasm via specific transporters energized by electrochemical gradients created across the plasma membrane through the consumption of ATP.

The mechanisms of nutrient uptake by roots was described in an earlier article (Hull, 1995) and will not be repeated here. It is only important to know that nutrient uptake requires the use of metabolic energy by root cells and that nutrients do not enter roots passively along with water.

The membrane transporters that couple the expenditure of energy with nutrient ion uptake into root cells have a high affinity for nutrient ions and this permits the concentration of nutrients within the roots to attain levels much greater than that present in soil water.

This mining the soil for essential nutrients constitutes one of the primary roles played by plants in the overall drama of life. All animal life depends on the minerals concentrated within plants for their source of such nutrients.

This mining the soil for essential nutrients constitutes one of the primary roles played by plants in the overall drama of life.

Nutrient ion absorption by roots is selective. Those ions essential for plant growth (potassium, nitrate, magnesium, sulfate, zinc, etc.) each enter root cells via their own membrane transporter.

Other less useful or even toxic ions (sodium, aluminum, selenium, etc.) are not accommodated by specific ion transporters and thus, do not enter roots readily.

Because some nutrient elements can be toxic at concentrations only slightly higher than what would be beneficial (boron, manganese, copper, etc.), their cellular levels must be tightly regulated. Specific ion transporters are responsible for maintaining optimum ion concentrations.

Nutrient ions absorbed into the proto-

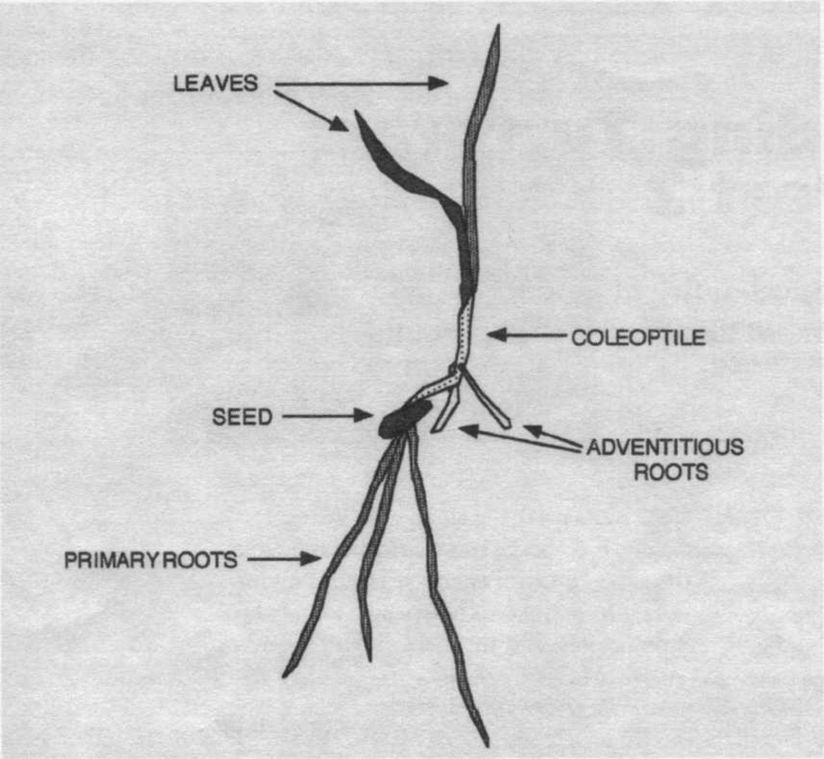

Fig. 1. Primary and adventitious roots developing from a turfgrass seedling.

plasts of epidermal and cortical cells can be transported via the symplast into cells of the stele by means of cytoplasmic streaming, diffusion and the flow of water through roots powered by transpiration.

Once in the stele, nutrients ions are again transported across cell membranes into the apoplast. Here they are carried to the shoots in large xylem vessels via transpirational flow eventually to be reabsorbed by living cells of stems and leaves.

Transpiration, of course, only occurs during the daylight hours so during the night, nutrient ions transported into xylem vessels of the roots are not carried to the shoots but rather become concentrated within the vessels.

This high solute concentration attracts water into xylem vessels creating substantial root pressure that sometimes causes guttation droplets to form on leaf tips visible during early morning. The suberized cell walls of the endodermis prevents ions and water concentrated in the xylem from back-flowing to the soil through the apoplast.

Thus, water and nutrients absorbed by roots are usually retained and loss to the soil normally occurs when cells die or sustain injury.

The energy required by roots is delivered from the leaves in the form of simple sugars (sucrose mostly) via interconnected living tube-like cells called sieve tubes. These, along with companion cells and other miscellaneous cells, make up the phloem that normally is located in the angles between xylem poles (Fig. 2).

Sugars released from the sieve tubes move via the symplasm to all living cells of the root. Releases of organic substances from root cells to the soil is normally a controlled process.

Mucilage is released by root cap cells for root lubrication and cells in the absorptive region of roots will excrete organic solutes during times of nutrient (especially phosphorus) deficiencies (Marschner, 1995).

The influence of morphological characteristics of turfgrass roots on nutrient uptake has received little attention. However, a recent study reported by our group (Sullivan et al., 2000) has demonstrated differences in the weight, length, surface area and diameter of roots (Fig. 4) among six cultivars of Kentucky bluegrass.

Below-ground organs were segregated into fine roots, adventitious roots and rhizomes (Fig. 5). Adventitious roots in this case, were those emerging from upper nodes of the crowns and plant stems and comprised only a small portion of the total root system all of which was technically adventitious, primary roots having been removed earlier.

These root characteristics were correlated with entire plant nitrate uptake. The six cultivars differed in their rates of nitrate uptake and these differences were positively influenced by weight, total length and

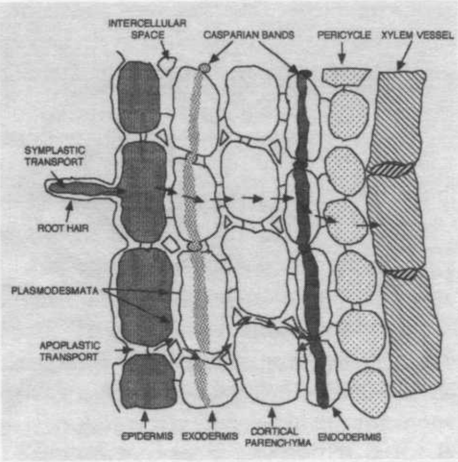

Fig. 3 Diagram of root (longitudinal view) showing apoplastic and symplastic transport routes.

surface area of fibrous and adventitious roots. Root diameter was negatively correlated with nitrate uptake indicating that total nutrient absorption was mostly a function of fine roots.

Of course in Kentucky bluegrasses, most of the root system is composed of fine roots. Nitrate absorption was negatively correlated with rhizome weight, length and surface area but the relationship was not simple. There appeared to be an optimum amount of rhizome production that resulted in the greatest nutrient uptake.

This is due to the increased number of new plants produced at rhizome nodes. These plants generate fibrous root systems that invade fresh soil and absorb nutrients.

However, excess rhizome growth constitutes a heavy demand for photosynthetic energy produced by the shoots and this energy is drawn away from root growth resulting in fewer roots and less nitrate uptake.

Thus, the finest turfgrass roots appear to be most responsible for nutrient recovery from the soil and rhizomes make a positive contribution only to the extent that they add to the number of functioning roots.

Hormonal balance

Beside their obvious roles in water and nutrient acquisition, roots also participate in the coordinated growth of plants and in their response to stress conditions. Roots and shoots mutually depend on the contributions of the other.

Roots cannot grow or function without the energy provided by the photosynthetic production of the shoots. Also, shoot growth is limited by the supply of nutrients and water provided by the roots.

It is important that the growth of roots and shoots be coordinated so that the growth of one is not always limited by the performance of the other. If plant growth were controlled by such a balance of limiting factors, one system, roots or shoots, would always be operating at full capacity while the other was limited by inadequate resources delivered to it.

This would make it difficult for the roots to grow and accumulate reserves if all their energy were being expended to supply water and nutrients to meet the demands of shoots. The same would hold for shoots if their productivity was devoted exclusively to meet the needs of roots.

To coordinate the activities of these two mutually dependent plant systems so each can grow and provide for its present and future needs, plants have evolved a hormonal control system.

> *The action of ABA allows a plant to conserve its resources during stress, making them available for growth to resume when conditions become favorable.*

There are many hormones involved in growth coordination but for simplicity, I will concentrate on the two that appear to be most involved: cytokinins and abscisic acid (ABA).

Cytokinins are derivatives of the purine adenine and they promote cell division and thereby growth. Cytokinins are synthesized in the roots and are carried in the xylem to the shoots where they counteract the inhibiting effects of the hormone auxin. Auxin is made in the shoot apex and moves down the stem inhibiting the growth of axilary buds causing the phenomenon known as apical dominance.

Cytokinins block the inhibitory action of auxin allowing lateral buds to grow and produce branches.

Because cytokinins are derived from the roots, it is the basal shoot buds that are most stimulated to grow. This is why grass stems rarely branch and tillers and rhizomes or stolons emerge from the basal buds of the crown (Hull, 2000).

If root growth is inhibited by stressful soil conditions or roots are damaged by disease or insects, the supply of cytokinins to the shoot is interrupted and shoot growth is inhibited. This is why a stem cutting rarely exhibits any growth until it has initiated adventitious roots.

This control of shoot growth works in the plant's best interest. If roots are injured or inhibited, shoot growth ceases making its photosynthetic products available to regenerate roots and reestablish the supply of water and nutrients for the shoot.

If shoots continued to grow when roots were hurting, there would be little energy available to restore the roots, the shoots would eventually suffer from lack of water or nutrients and the plant likely would die.

Abscisic acid (ABA) is an inhibiting hormone. It normally retards growth, induces dormancy in buds, causes stomates to close and generally induces a plant to become inactive. ABA synthesis can occur in any plant organ and is often promoted by stress conditions.

The action of ABA allows a plant to conserve its resources during stress, making them available for growth to resume when conditions become favorable. The role of ABA in root function is well illustrated by the phenomenon of early drought response (Davies and Zhang, 1991).

When a plant begins to experience a lack of water this is first perceived by the shallow roots. These roots become stressed for water and begin to synthesize ABA which is transported to the shoots. This occurs before the shoots have suffered any loss of water potential since deeper roots are providing all the water required by the plant.

However, the delivery of ABA to the shoot causes stomates to close in the leaves dramatically reducing transpiration and slowing the rate of water loss. ABA also inhibits shoot growth, greatly reducing the use of photosynthetic products by the shoot.

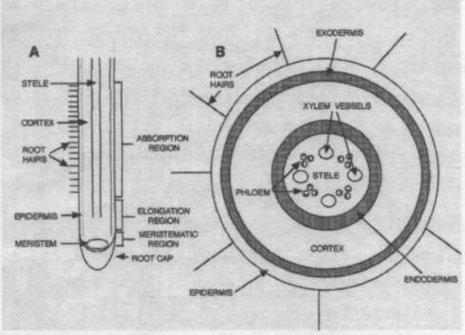

Fig. 2. Grass root structure.
A. Longitudinal diagram through a young root showing developmental regions.
B. Cross section of a grass root through the absorption (root hair) region showing tissue types.

This makes more photosynthate available to support root growth which occurs not in the drought stressed shallow roots but rather the deep roots that have adequate water and can respond to additional supplies of energy.

In this way, the first roots to experience drought stress use ABA as a signal molecule informing the plant to reduce its water use and allocate more of its energy to growing deep roots. This permits plants to respond to drying conditions in a timely manner and alter their growth pattern so as to avoid general drought injury.

Understanding this plant response mechanism has permitted turf managers to schedule irrigation for optimum water use efficiency.

Getting optimum root growth from turfgrass

Understanding turfgrass roots, their structure and function, can constitute information useful to the turf manager for growing more vigorous and stress tolerant grass. It might be helpful to link management practices with the basic requirements for good root growth.

1. Roots need space. To respond to environmental signals and prepare for stressful conditions, a turfgrass root system needs a sufficiently large soil volume so it can adjust its growth pattern and better utilize available resources. Implicit with this requirement is a growing medium that is conducive to root growth. In short, it must be well aerated, of suitable structure, have the capacity to hold an abundance of available water and be lacking in toxic substances.

A reasonable cation exchange capacity to insure nutrient retention would also be good. Thus, a good blend of sand and silt along with 4-6% organic matter, a pH of 5.5 to 6.5 and favorable particle structure to permit gas exchange should be provided.

A well designed sand/peat green should supply these conditions but a growth medium based on native soil may need to be amended to become optimum.

The root zone must be sufficiently large to accommodate stress induced changes in root system architecture. The depth should be such (1 to 1.5 ft.) that drought stimulated downward root extension can occur. If these soil conditions change over time, management practices should insure they are brought back to optimum levels.

Aeration will help maintain good soil structure, insure good aeration and incorporate organic matter to greater depths. It might be good to remember that root turnover is the best source of soil organic matter.

Thus, conditions that favor deep root growth will also help maintain a favorable organic content and a suitable water holding capacity. Scheduling irrigation so as to permit turf to suffer mild drought stress before supplying water will encourage deep rooting.

2. *Roots need energy*. Roots are not photosynthetic. Therefore, they depend absolutely on photosynthetic energy captured by the shoots. It is good to consider that the amount of photosynthetic energy available to a plant depends on its leaf surface, the duration of light and, in cool-season grasses, the extent by which production is decreased by heat stimulated photorespiration.

Sound turf management should encourage photosynthetic production and minimize whatever detracts from it. Mowing at the greatest height consistent with the use requirements of turf is a good guide. Increased mowing height during the hottest summer months will partly compensate for increased photorespiration.

Selecting grasses with leaf angles that will retain more leaf surface even if subjected to close mowing will also help maintain favorable energy relations. Limit durations of deep shade. Cool shade is attractive and refreshing during hot summer days but turf needs light.

Long durations of full sunlight are not essential and may even be harmful if excess heating and drought occur. Thin trees to provide moderate or broken shade. This will help the trees and improve air circulation while insuring sufficient light energy for the turf.

3. *Roots compete for energy.* During the heat of summer, the turf manager should be aware that roots are not the only sink for the photosynthetic product of leaves. Actually, roots of cool-season turfgrasses are normally not very strong sinks during the hot months often receiving less than 5% of total photosynthate (Hull, 1996).

If shoot growth is stimulated during summer, the roots experience even greater competition for available energy and their growth decreases and mortality likely will increase. Nitrogen fertilization should be avoided during the hottest summer months. Its metabolism will consume energy and it will invariably stimulate shoot growth that will compete with roots for limited available energy.

If turf needs a green-up, try an iron application with a little nitrogen. That will stimulate chlorophyll synthesis and might even improve the plant's energy status.

4. *Heat is the enemy of roots*. Heat is especially hard on roots of cool-season turfgrasses (Huang, 2000). If soil temperatures exceed 70 -75° F, roots decline rapidly. This is probably due to less available energy translocated from the shoots but whatever the cause, root heating should be avoided.

Again, a higher mowing height will provide more turf mass to insulate the soil better. Irrigate during the evening or at night. That will cool the soil and allow time for energy transport to roots, slow root respiration and permit some recovery. Partial shade during the heat of afternoon will also reduce the heat load on turf.

Maintaining adequate water so transpiration can cool the grass is critical during the hot season. Equipping putting greens with forced internal ventilation has the potential of keeping turf roots several degrees cooler. Equipment designed to draw excess water through the turf by applying a subsurface vacuum can be useful for providing root system ventilation. With some modification, the system can be run in reverse and force cooled air up through the turf.

This technology offers considerable promise for easing the management of greens in hot locations. Less ambitious efforts involving the installation of fans can improve air circulation and this will increase transpiration and cool the grass.

There are many ways turf management practices can be modified to favor good root growth and reduce summer decline. If a manager understands the structure and function of the turf root system, many desirable cultural modifications that would encourage good root conditions will become evident. This article is submitted with that hope.

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BUILD EXPECTATIONS

By Curt Harler

The recent uproar over the "unexpectedly" high test scores since California banned bilingual education is not about speaking Spanish or Vietnamese in the classroom. The lesson here – and it applies to turfgrass managers and the rest of us -- is about expectations.

For those of you not familiar, in June 1998 California voters overwhelmingly passed Proposition 227 which banned bilingual education in the state's schools. Everyone from President Clinton to local school teachers predicted disaster for non-English speaking students.

The children surprised everyone. The opposite happened. Their math scores went up 14 points. Reading (in English) scores jumped nine points. What happened?

Two things were at work here. First, it seems that those in charge had very low expectations of a group of normal kids. We've all seen it happen – the guy who was always raking leaves in the background turns out to have unexpected talent as a mechanic. Or the quiet one who didn't say six words all summer turns out to be a whiz handling the job-scheduler on the computer. By next season he's in the front office working with PCs.

It's just a reminder that we should give everyone a chance to shine. There likely is hidden talent on your team. But it requires taking time to find out just what a person's aspirations are. Many workers, especially newer ones, are simply too shy to speak up. Seek all of your employees out informally, perhaps on a lunch break, and find out what their goals are. Some will have none. But others will surprise you.

The second factor at work is acceptance. No one – student, summer help, supervisor – likes to be branded as different. It is both distracting and humiliating. Whether in school or on the golf course, it interferes with getting the job done.

Expect the most from people. True, you'll occasionally be disappointed; but for the most part you'll be pleasantly surprised. And your workers will be delighted.

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