1985

Spring 1985

Chris Beasley

James Beard

Robert N. Carrow

Chuck Wilson

TURF BULLETIN

MASSACHUSETTS TURF AND LAWN GRASS COUNCIL

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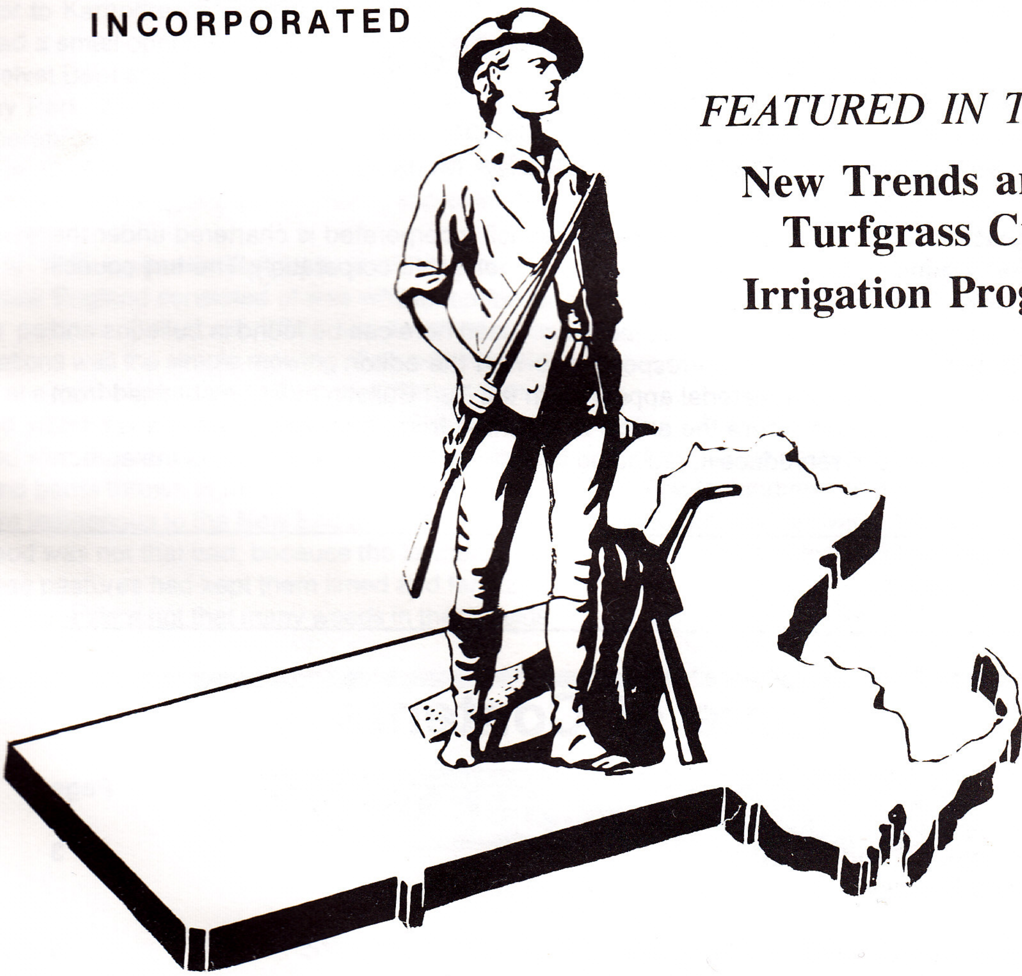

FEATURED IN THIS ISSUE:

New Trends and Research in Turfgrass Culture

Irrigation Programming

SPRING 1985
CONFERENCE ISSUE

BETTER TURF THROUGH RESEARCH AND EDUCATION

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The Massachusetts Turf and Lawn Grass Council Incorporated is chartered under the laws of the Commonwealth of Massachusetts as a non-profit corporation. The turf council seeks to foster "Better turf through research and education."

More detailed information on the subjects discussed here can be found in bulletins and circulars or may be had through correspondence with the editor.

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THE NEW ENGLAND SOD INDUSTRY

Chris Beasley
Tuckahoe Farms
Slocum, R.I.

History

Commercial sod operations really began in New England about 1955 when Karandrew Farms of Suffield, Conn. started with a few acres close to the Hartford, Conn. area and expanded to one of the larger sod farms we see today. Prior to Karandrew's entrance on the scene, Bill Mitchell had a small operation in New Hampshire where he grew Velvet Bent and Kentucky bluegrass on contract for Fenway Park. As time passed, more and more sod farming operations appeared on the scene so that we find ourselves in 1976 with about 15 commercial sod operations around the New England area growing approximately 3,000 acres.

Prior to 1955 (approximately) about all the sod industry in New England consisted of was what we refer to as field or pasture operations. What was involved with such operations was the simple mowing of an existing field or pasture at a low height ... about 2" ... and the harvesting of the field when the color became good. The field or pasture sod was essentially bluegrass with perhaps some fescues and bents thrown in for good measure. All these grasses are indigenous to the New England area and the resulting sod was not that bad, because the farmers who owned these pastures had kept them limed and fertilized for haying. There were not that many weeds in these fields as they were usually choked out by the grasses that grew into hay. Unfortunately, pasture sod had to be cut with a thick layer of soil (2" or more) because the grass was usually old and had a substantial root structure. (Like a big tree, you need to take a big root ball for it to survive). I say, unfortunately, because the popular conception of sod today is that it is still cut thick and that is just not the case. The sod that is produced by the commercial sod farms of New England today usually carries with it no more than ½" of soil. There is no need for more soil as the sod is young (1½-2 years) and, as long as it is quickly replanted, it will thrive. Thin cut sod roots faster, costs less to transport and allows for little or no soil depletion back at the farm.

Status of Industry Today

The commercial sod farm of today is a far cry from the historic pasture sod operations previously described. The techniques used now result from a lot of practical experience in growing grass on large acreages and from scientific and technical research conducted on turfgrasses by our agricultural colleges. The modern sod farm of today begins growing its turf by careful preparation of the soil. Soil analysis tests are made of each field prior to planting to determine lime and fertilizer application rates. Careful leveling of the fields after plowing is followed by harrowing and soil surface preparation using the latest equipment. Working of the top inch or so of the fields to accept the seed is followed by the actual seeding down, generally with Brillion seeders, where only the best of certified seed is used. Most, if not all, of the members of the NESPA use certified (blue or gold-tag) seed on their fields. They have found that it is less costly to pay more for high quality seed than it is to save a few dollars and have to sell at a lower price because of weeds or obnoxious grasses existing in the sod. The selection of seed used on the average New England turf farm is usually made from results of studies of performances of varieties of grasses grown and tested by our state agricultural colleges. Thanks to the research programs being conducted by Plant and Soil Science Departments throughout the United States the turf farms have a good idea of what to expect from a certain variety before they even begin to plant. Some of the varieties being used these days on the turf farms are:

Kentucky Bluegrasses	- Baron, Fylking, Victa, Merion Adelphi, Majestic, Glade, Bonnie Blue
Fescues	- Jamestown, Highlight, Pennlawn
Bentgrass	- Penncross

All of these varieties have proven characteristics in vigor, color and disease resistance.

Careful attention to weed control is given to the grass as it matures. With the application of herbicides to prevent the occurance of crabgrass and the growth of weeds one can usually expect to find weed free turf being shipped from our New England turf farms.

Little pest and fungus control is necessary on *most* turf farms because of the lack of thatch buildup. Only under severe weather conditions does commercially grown sod become susceptible to disease invasion.

Most of our New England farms operate and maintain irrigation systems. Careful watering programs are used on "near to harvest fields" and on the current "shipping fields" to insure good color and a healthy product upon delivery.

Taken from "Conference Topics", 7th Annual New Brunswick Turf Seminar, Lawn Institute Harvests, The Better Lawn and Turf Institute, Pleasant Hill, TN, Dr. Eliot C. Roberts, Editor, Vol. 31 (3), Oct. 1984, pp. 1-4.

New Trends and Research in Turfgrass Culture

Dr. James Beard
Texas A & M University
College Station, Texas

In an informal presentation, Dr. Beard touched on the following topics as evidence of new trends and research in turfgrass management and science:

Maintenance Level

• High, medium, or low. What does this mean? Is it a range between neglect and intensive culture? Perhaps four maintenance levels should be recognized - none, low, medium, or minimal and high.

• Management of turf with excesses is easy. Application of excesses involves multiple practices to constantly adjust and correct for changes in growth conditions.

• Low level management is more difficult. The turf must make its own adjustments.

Cultivars

• Varietal opportunities are almost unlimited. There are some 90 bluegrasses, 52 ryegrasses, 23 fine fescues, 8 turf type tall fescues and 16 bentgrasses from which to select. Use those grasses with turf characteristics that are best suited for adaption in the local environment.

• Penncross vs. Penneagle? Penncross is unique, time tested. Penneagle is new and observations indicate that it produces a faster putting surface, has less tendency to thatch, less disease, slower growth rate but more tendency for Poa annua invasion and less traffic tolerance. Perhaps, Penneagle fits best where there is less traffic and Penncross where there is more.

Mowing

• Use of the triplex mower on fairways is increasing the quality of the playing surface. In many situations, this is worth the increased cost. Poa annua control is aided by this process as bentgrasses benefit at the expense of the Poa. Where clippings are removed, more nitrogen is needed. Less water seems to be required where triplex mowing is practiced. Perhaps these same benefits could be realized from other practices.

Nitrogen

• Nitrogen is the nutrient needed in largest amounts. It is mobile within the plant, prone to leaching from the soil, and may be lost by volatilization.

• Nitrogen effects on growth vary from increases in shoots to reduction in roots. Sucrose is needed to make growth. Where there is excess nitrogen, the sucrose goes to stimulate shoots in response to clipping and there is less root activity. Shoots get the carbohydrate first.

• Controlled release nitrogen provides the right amount at any given time and the right total amount for the growth season. Readily available types may provide the right total amount, but too much or too little at specific times during the season.

• Excessive shoot growth must be avoided. It causes frequent mowing, less roots and exhausts carbohydrates. Use not more than one pound of nitrogen per 1000 square feet as water soluble N per application.

• Turfgrass color is important. Dark green foliage is generally not indicative of a healthy turf. Light green leaves are more likely to be correlated with healthy plants. Because green grass is the number one priority, difficulties in turfgrass culture arise. There must be reeducation on this point.

• High levels of nitrogen make grasses more prone to some diseases. Low levels cause the same effect with other grasses and other diseases - for example, red thread, rust and dollar spot.

• Time of nitrogen application is best in late fall. Some caution may be needed where snow mold is particularly severe.

• The more nitrogen used, the more potassium required. This is especially important for best cold survival. The balance between nitrogen and potassium is critical. The same relationship holds for heat and drought survival.

• More nitrogen is needed to grow grass than to maintain grass at an existing quality level.

• On greens, from 0.1 to 0.3 pounds of nitrogen per 1000 square feet every ten to fifteen days is a reasonable target. This amounts to 0.3 to 0.7 pounds of nitrogen per 1000 square feet every twenty to thirty growing days. Heavy applications are to be avoided. Small, frequent applications are desirable. A six thousand square foot golf green should yield from one to two baskets of clippings each day as an indication of proper growth.

• Shoot growth and root growth vary with month of the year. These differences are the basis for late fall fertilization.

• Fertilizer applications on dormant turf result in a spring response.

• Fertilizer applications in late fall benefit the turf prior to dormancy. Where winter desiccation or low temperature kill are common, the late fall application may not be beneficial.

• Oxamide nitrogen fertilizer is a new development with slow release characteristics. It has a residual activity of twelve to fourteen weeks. There is no initial flush of growth. A good level of green foliage is maintained without overstimulation. Less brown patch and rust have been noted where oxamide is used. A certain amount of growth regulation is common. In addition, anti-senescence characteristics of the grass are being evaluated. With new materials like this under development, the slow release nitrogen fertilizer picture is worth watching.

Phosphorus and Potassium

• Trends indicate use of less phosphorus on turfgrasses. Applications based on soil test data are recommended. Otherwise, phosphorus is generally not needed.

• Potassium is considered the overlooked nutrient in turfgrass culture.

• Luxury consumption of potassium is a yield concept of agriculture not related to turfgrass management.

• Potassium is subject to leaching, like nitrogen and is required in the plant in quantities second only to nitrogen.

• Major amounts of potassium are released from the soil.

• Potassium increases rooting, promotes wear tolerance, decreases proneness to disease and increases drought tolerance.

• Physiological adjustments within the plant that make it more hardy are brought about by potassium.

• Potassium benefits turfgrasses past the point of luxury consumption.

• Potassium is needed at rates of 50 to 75 percent of the nitrogen being utilized by the turf.

Interrelationships

• The following practices are interrelated in the production and maintenance of high quality turf:

—topdressing-frequent;
—thatch control
—smoothing ground surfaces;
—increasing speed (for golf greens);
—root zone modification - partial or complete;
—winter protection;
—correction of unfavorable soil conditions.

Sand Topdressing

• Conditions at the interface between turf and soil are responsible for the relative ease of maintenance.

• Sand topdressing must continue once started.

• The correct sand in terms of particle size distribution must be used.

Hydrophobic Soils

• Sands are most likely to be difficult to wet.

• Soil fungi, many of them basidiomyces, are the cause of hydrophobic soils.

• Coring of turf in spring helps prevent the formation of hydrophobic conditions. Coring doesn't help much after the condition develops.

• Wetting agents are essential. Hydrowet or Aqua-Gro watered in at once work well.

• Improved wetability may last from one to three years.

Oil Spills

• Gasoline, motor oil, hydraulic fluid, brake fluid and grease are spilled from time to time on fine turf. Use of detergents with suds picked up with a vacuum have been effective. Activated charcoal and calcined clays have not been as good.

Putting Green Speed

• The stimpmeter is used to determine the speed of golf greens. This is a good addition to other tools used to evaluate greens. The meter is being used to classify greens as follows:

	Inches for	
	Regular Play	Tournament Play
Fast	102	126
Medium fast	90	114
Medium	78	102
Medium slow	66	90
Slow	54	78

• Turf on fast greens thins out and algae and moss take over because of excessively close mowing.

• When competition develops as to which course has the fastest greens, everybody loses.

• Cultural manipulation of greens, including dew removal, coring, topdressing, mowing frequencies, cultivars, footprints, rounds of golf played, all have an effect on speed. Double mowing of greens does not increase speed much. Wind has more effect than any of the cultural and other factors studied.

Winter Injury

• With winter kill, soil temperature is the cause. This is a low temperature injury to the lower crown. Irrigation in the spring helps keep new roots coming. Cut a longitudinal section through the crown to see if the tissue is brown inside.

• Adjustments for cold hardening off occur at from 55 to 65 degrees F. The following temperature ranges have been correlated with turfgrass growth:

60 - 75° F	- Optimum shoot growth;
45 - 60° F	- Shoot growth declines;
35 - 45°F	- Plants harden;
32 - 35° F	- Winter dormancy;
25 - minus 15°F	- Low temperature kill.

• Hardening off is accompanied by increases in carbohydrate reserves and a decrease in tissue hydration to 60-65 percent.

• Plant hardiness zones and maps show the location of differences throughout the United States.

• Differences in low temperature kill are often difficult to explain. A green may be OK, while the approach is dead. In this case, the green may be Penncross, which is hardy, and the approach, Poa annua, which is not.

The following differences in cultivar tolerance have been noted:

	OK at Soil Temperature
Penncross bentgrass	-10
Toronto bentgrass	-10
Poa trivialis	-10
Merion bluegrass	- 5
Poa annua	- 5
Pennlawn fine fescue	0
Common perennial ryegrass	5

In general, the bents and Poa trivialis have excellent cold tolerance.

• The question still remains - at what soil temperature can winter kill be expected? There is no one answer. It depends on:

—plant hardiness level;
—degree of hydration;
—rate of freezing - more rapid, more kill;
—rate of thawing - more rapid, more kill;
—number of freeze and thaw cycles;
—length of time frozen.

Of all these, the hydration level is the most important.

• What can be done? Check the following:

—provide rapid surface drainage;
—provide adequate subsurface drainage;
—cultivation.

• Soils thaw from underneath where warm soil is located.

• An ice cover will trap water underneath.

• Grass may die from increase in hydration. As crown hydration increases, hardiness declines in late winter and early spring (March). In low spots, where water stands, low temperature kill occurs because of water standing.

• Prevent low temperature kill by checking the following:

—use moderate nitrogen;
—use high potassium;
—cut higher;
—eliminate thatch;
—avoid excessive irrigation.

For bluegrasses, use more potassium to balance increased nitrogen -2 to 1 or 3 to 2. For bentgrasses, the nutrition is not as important because these grasses have more inherent tolerance to cold.

• For bluegrasses, cutting heights of from one and one half to two inches are usually good. More carbohydrates accumulate and there is more biomass. Crowns are protected because of greater insulation.

• The principles are the same for warm season grasses. More winter kill is observed at low mowing heights.

• More winter kill is often observed where herbicides are used - particularly the pre-emergence type.

• Thatch raises the crown above the soil. Thatch also hold water and increases the hydration level.

• Leave aerification holes open to prevent low temperature kill.

• Never let an ice sheet stay on the alfalfa more than twenty days for it dies of suffocation. Injury from ice on turf is not due to suffocation, but to the probability of increased hydration. May remove ice and get winter kill from desiccation, or leave it on and get winter kill from crown hydration. Bentgrasses, bluegrasses and Poa annua have been kept in ice for as long as 75 days with no injury. At 90 days, Poa annua dies. Bentgrass and bluegrass have survived up to 150 days in ice.

• Traffic on frozen slush injures turf. This pushes water into the crown area and increases hydration so that low temperature kill is realized. Snow mobiles cause no injury to turf as long as there in one inch of snow cover. Snow mobiles on frozen slush cause increased low temperature injury.

• Another type of winter injury is caused by winter desiccation. During dry, open winters on sandy soils, turf injury may be significant. This type of injury is of less importance than low temperature kill.

• Grasses that are more salt tolerant are also more tolerant of desiccation. For example, Seaside bentgrass. Thus, cultivar variation does exist.

• Higher rates of nitrogen in the fall favor winter desiccation injury.

• The presence of thatch increases the likelihood of winter desiccation.

• Open aerification holes favor the development of winter desiccation injury.

• Covers protect turf from adverse winter conditions. Fungicides also prevent winter diseases.

• Soil warming also prevents injury from low temperatures.

• Desiccation affects the crown meristematic tissue. The crown must survive if the plant is to live. Cells in the lower crown are larger. When they are killed, roots are dead. Tops may be alive. If roots are not regenerated quickly, tops will also die.

PROGRAM

54th MASSACHUSETTS TURFGRASS CONFERENCE and 9th INDUSTRIAL SHOW

March 4-7, 1985
Springfield Civic Center, Springfield, Massachusetts
(I-91, Exit 6 from South, Columbus Avenue Exit from North)

Sponsored by Department of Plant & Soil Sciences, University of Massachusetts/Amherst
Massachusetts Turf & Lawn Grass Council
Golf Course Superintendents Association of New England

MONDAY, MARCH 4

—Afternoon—

12:30 PM-2:00 PM Registration
Banquet Hall Entrance

NEW

2:00 PM-4:00 PM Seminar
Banquet Room
Biology and Control of Turfgrass Insects
Dr. Patricia Vittum, Extension Entomologist, Suburban Experiment Station, Waltham, MA

TUESDAY, MARCH 5

—Morning—

8:30 AM- 4:00 PM Registration
Lobby, Banquet Hall Entrance

9:00 AM-12:45 PM Industrial Show Open
Exhibition Hall. Snack Bar

—Afternoon—

GENERAL SESSION
Banquet Room

Chairman: Dr. Joseph Troll
University of Massachusetts/Amherst

1:00 Welcome
Dr. E. Bruce MacDougall, Dean
College of Food & Natural Resources, University of Massachusetts/Amherst

1:15 USGA Slope System
Dean L. Knuth, Director of Handicapping, USGA, Far Hills, NJ

1:45 Fight to Protect Your Turf
James Brooks, Executive Director, Professional Lawn Care Association of America, Marietta, GA

2:15 How to Get Someone to Do What "You" Want
Patrick J. McLaughlin, Manager-Sales and Marketing, W. R. Grace and Co., Lexington, MA

2:45 PM-3:00 PM Break

3:00 Recruiting, Retaining and Managing Your Help
Dr. Gene Nutter, Buford, GA

3:45 Turf Around the World
Warren Bidwell, Tee-2-Green Corp. of Oregon, Matteson, IL

4:30 PM-6:30 PM Industrial Show Open
Exhibition Hall

WEDNESDAY, MARCH 6

8:00 AM-4:00 PM Registration
Lobby, Banquet Hall Entrance

GOLF COURSE SESSION
Banquet Room

—Morning—

Chairman: Prof. John M. Zak, Professor Emeritus
University of Massachusetts/Amherst

9:00 Managing Sandy Greens
Dr. Paul E. Rieke, Department of Crop and Soil Sciences, Michigan State University, East Lansing, MI

9:45 Light Frequent Sand Topdressing Influences on Putting Green Quality
Dr. Robert C. Shearman, Department of Horticulture, University of Nebraska, Lincoln, NE

10:30 Renovation of Water Hills Golf Club
Fred Meda, Superintendent, Myrtle Beach National Golf Club, Inc., Myrtle Beach, SC

11:00 AM-2:00 PM Industrial Show Open
Exhibition Hall

—Afternoon—

2:00 25 Years of Mistakes
Gordon Witteveen, Superintendent, Board of Trade Golf Course, Woodbridge, Ontario, Canada

2:30 Architectural Styles and Eye Appeal
Geoffrey S. Cornish, Golf Course Architect, Amherst, MA

3:00 Design Relative to Play
Robert Muir Graves, Golf Course Architect, Walnut Creek, CA

3:45 Design and Specifications Related to Maintenance
Dr. Michael J. Hurdzan, President, American Society of Golf Course Architects, Chicago, IL

4:30 PM-6:30 PM Industrial Show Open
Exhibition Hall

—Evening—

7:00 Banquet and Winter School Ceremony
"Why Do People Pick on People?"
Dr. John Denison, Dean
Stockbridge School of Agriculture, University of Massachusetts/Amherst

ALTERNATE SESSION
College Room

—Morning—

Chairman: Mr. Charles Mruk
Turfgrass Consultant,
Cranston, RI

9:00 Assume
Dr. Francis R. Gouin, Department of Horticulture, University of Maryland, College Park, MD

9:30 Insects Associated with Turf and Ornamentals
Dr. Paul Heller, Department of Entomology, Pennsylvania State University, University Park, PA

10:00 Update on Weed Control and Growth Regulators
Prof. John Jagschitz, Department of Plant and Soil Science, University of Rhode Island, Kingston, RI

10:30 Adjustments in Tree Care Procedures
Dr. Alex L. Shigo, Chief Scientist, Northeastern Forest Experiment Station, Durham, NH

11:00 AM-2:00 PM Industrial Show Open
Exhibition Hall

—Afternoon—

2:00 Diseases of Ornamentals
Dr. Henry T. Wilkinson, Department of Plant Pathology, University of Illinois, Urbana, IL

2:45 Maintenance of Athletic Fields
Dr. John C. Harper, II, Department of Agronomy, Pennsylvania State University, University Park, PA

3:30 An Overview of the Lawn Care Industry
James Brooks, Executive Director, Professional Lawn Care Association of America, Marietta, GA

4:30 PM-6:30 PM Industrial Show Open
Exhibition Hall

THURSDAY, MARCH 7

—Morning—

9:00 AM-10:00 AM Industrial Show Open
Exhibition Hall

GOLF COURSE SESSION
Banquet Room

Chairman: Donald E. Hearn, President
Golf Course Superintendents' Association
of New England, Weston, MA

10:00 The Fate of Nitrogen in Turf
Dr. Robert C. Shearman, Department of Horticulture, University of Nebraska, Lincoln, NE

10:45 Current Developments, Future Directions for Disease Control on Golf Courses
Dr. Henry T. Wilkinson, Department of Plant Pathology, University of Illinois, Urbana, IL

11:15 Turf Cultivation - Pros and Cons
Dr. Paul E. Rieke, Department of Crop and Soil Sciences, Michigan State University, East Lansing, MI

11:45 Problems the USGA Agronomist Encounters that May Effect You
James Snow, Northeast Director, USGA Green Section, Far Hills, NJ

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IRRIGATION PROGRAMMING

Dr. Robert N. Carrow
Kansas State University
Manhattan, KS

Efficient turfgrass irrigation has several components: (a) *frequency of application* - How frequent should the turfgrass be irrigated?; (b) *rate of application* - How much water should be applied to recharge the moisture in the root zone?; (c) *uniformity of application* - Is the water applied uniformly over the site or are certain areas receiving excess moisture while other areas do not receive enough?

Turfgrass irrigation systems can be designed and zoned to provide very good uniformity and to apply water only to the areas that require water - i.e., flexibility. However, turfgrass managers still are confronted with how often to irrigate and exactly how much water to apply per application.

The starting point to good irrigation programming is to understand the soil-plant-atmospheric system. One way to visualize turf water management is to consider a *budget approach* similar to a bank checking account (Figure 1). Certain additions (inputs) of moisture are made and there are losses (outputs) of moisture form the plant environment. At any point in time, the plant has available to it a certain reserve of available water. The objectives of a wise turfgrass manager are to maximize inputs, minimize outputs, and maintain a large reserve.

Inputs of moisture are precipitation, overhead irrigation, dew, and capillary rise of moisture from below the root system. Precipitation and overhead irrigation are the major inputs. Normally, capillary movement to turfgrass roots from below the root zone is minor except where a water table is within 2 to 4 feet of the roots. On flat sod farms where the water table level can be controlled, capillary rise can contribute water for plant growth. Also, the PURR-WICK and USGA Green Section golf green construction methods use this principle. Drainage is impeded by a barrier (PURR-WICK) or perched water table (USGA), which results in more water being retained. This water can then provide some of the plant's water need by capillary rise into the root zone.

Outputs or losses include runoff, leaching beyond the root zone, evaporation, and transpiration. Runoff would be a problem on sloped sites and can be increased by fine-textured soils, thatched turf, compacted soils, and by applying water faster than the soil can receive it. Runoff causes not only a dry site but also an excessively moist site. Reducing runoff requires correcting the above situations through cultivation, thatch control or proper application rates.

Water movement beyond the root system is often an unrecognized water loss. Irrigators who water based on the driest site, often over-irrigate other areas. Irrigating slightly beyond the existing root system is acceptable because it provides a moist zone for further root extension. In order to reduce leaching losses, the irrigator must have knowledge of the depth of rooting and depth of moisture penetration after applying a specific quantity of water. Well designed irrigation systems that apply water uniformly will reduce leaching losses. Also, proper zoning of irrigation heads is important. Heads in similar areas should be zoned together. Poor zoning with heads on slopes and low spots zoned together results in poor uniformity.

Evaporation is the vaporization of water from a surface. For turfgrasses, evaporation is mainly from the soil surface and moist leaf surfaces. When moisture evaporates, it removes energy (heat) from the surface. Thus, evaporation helps cool the soil and plant if free water is on the leaf surface, such as dew. Excessive evaporation is wasteful. Growers do have considerable control over the quantity of water lost by evaporation. For example, immediately after irrigation, evaporation rates from the soil will be high but as the surface dries, evaporation dramatically decreases. Thus light frequent irrigation results in high evaporative losses contrasted to heavier less frequent applications. Other ways to reduce evaporation are: have good infiltration rates to get the moisture into the soil; maintain a dense turf to shade the soil surface; mow your turf as high as feasible for your situation in order to insure further shading; avoid applying so much water that standing water occurs; and avoid afternoon irrigation.

Transpiration is the vaporization of water inside the plant leaf which then must diffuse through the open stomata. During this process, heat is removed from the plant. In many situations, over 90% of the moisture used by a turfgrass plant is utilized for cooling purposes. Transpiration is a desirable use of water, especially in hot conditions. However, excessive transpiration can occur and thereby waste water. Overwatering the turf will promote excessive transpiration.

The *reserve of plant available moisture at any point* in time is dependent primarily upon soil texture and extent of the plant root system (Figure 1). Obviously, *over a period of time,* irrigation and precipitation are the sources of this reserve moisture. As a generalization, sands do not retain as much plant available moisture as do loam soils. The turfgrass grower can improve the moisture reserve markedly by developing a good, deep, extensive plant root system. This will require careful mowing, irrigation, nitrogen fertilization, control of root feeding insects, reducing toxic substances (salts, herbicides), and possibly cultivation.

As we have observed, the sand-plant-atmospheric continuum is a complex system. Yet the irrigator desires a rapid, easy, inexpensive means of determining impending plant water stress. Should he turn to the plant, soil moisture, or some atmospheric parameter to measure and tell him when to irrigate? We shall look at each approach by reviewing methods currently found in the literature. Some of these methods will be of use only to researchers, while others will be useful to turf irrigators. In a few instances, the method discussed may not be applicable to turfgrass situations but has been presented because of its use on some irrigated crops in moisture related research studies.

A. Monitoring Soil Moisture Status

At first glance, it would appear that monitoring soil moisture would be a reasonable means of determining when to irrigate. When the soil water potential is high (i,e., soil water content is near field capacity), soil moisture is not the limiting factor for plant growth. There may be periods such as hot, dry afternoons, that the plant exhibits moisture stress under these conditions, but this is due to high evaporative demand, not limited soil moisture. However, as the plant extracts moisture, the soil water potential decreases and soil moisture does become limiting. For high quality rapidly growing turfgrasses, this soil may occur at soil water potentials of 0.40 to -0.70 bars (0 bar = saturation; -15 bar = permanent wilt point). Thus, monitoring soil moisture should aid in irrigation scheduling but it will not be a sensitive measure of temporary high evaporative demand periods. Methods based on monitoring soil moisture depletion are summarized below.

Feel or look at the soil. Moist versus dry soils exhibit different appearance and feel. With some experience, an irrigator can approximate soil moisture content based on these criteria. This requires an auger to look at several depths. While this is useful, it is often cumbersome and only accurate within the experience of the irrigator.

Use of a *soil probe* such as a screwdriver driven into the soil is a similar method. In this case, the grower relates mechanical resistance to moisture content. This method is quick but not very precise.

Tensiometers directly measure soil matrix potential, which is essentially the same as soil water potential except on salt affected soils. On such soils tensiometers will not be an accurate measure of soil water potential. Tensiometers have been used on turf for a number of years. They are very accurate between 0 to -0.80 bar, but will not perform below -0.80 bar. Generally, two are used, with one at 2 to 4 inches, and another at 6 to 12 inches, with the depths chosen based on turfgrass rooting patterns. Irrigation is initiated whenever either tensiometer registers a critical value, for example -0.45 bar. Irrigation is terminated when the shallowest tensiometer reads 0 (saturation). While tensiometers are accurate, they reflect only conditions at a particular point. Flat, uniform sites are especially well adapted for use of tensiometers. In cold climates, they must be removed for winter to prevent freeze damage.

Electrical resistance blocks monitor flow of electricity between wires imbedded inside gypsum or nylon. Blocks are calibrated to relate electrical resistance to soil matrix potential. Salts interfere but the gypsum blocks buffer, to some extent, against the salt influence. Unfortunately for high quality turfgrass situations, moisture blocks are not sufficiently sensitive in the moist range. They are accurate below -2.0 bar and monitor soil moisture status at a point. Unlike tensiometers, moisture blocks can be left in the soil year-round.

Electrical resistance probes are generally based on measuring electrical conductivity between two metal probes in the soil. These are very sensitive to salts and are difficult to calibrate versus soil moisture content. In moisture blocks, soil moisture is transferred via a porous material to the electrodes. This dampens the salt effect as well as standardizes the electrode geometry. With probes, neither factor is easily controlled without care by the operator. As a result, electrical probes are difficult to calibrate versus soil water content.

Neutron probes, gamma-ray attenuation, and *soil psychrometers* are available to measure accurately soil water content (first two) or soil water potential (latter). However, these are very expensive and in the case of psychrometers, difficult to calibrate since each psychrometer requires calibration with respect to soil water potential and temperature gradients. Psychometers are not as accurate in sandy soils. Also, neutron probes and gamma-ray attenuation techniques do not lend themselves to measuring soil moisture in the surface few inches, which is important for turf situations. These methods would be of interest to primarily research scientists.

Recent developments in the field of *time-domain reflectrometry* (TDR) may provide a practical tool for irrigation. It appears that the dielectric constant of soil (measure of the extent of polarization, in an electrical field) is primarily related to its water content. This technique measures the soil dielectric constant and this can be done in discrete

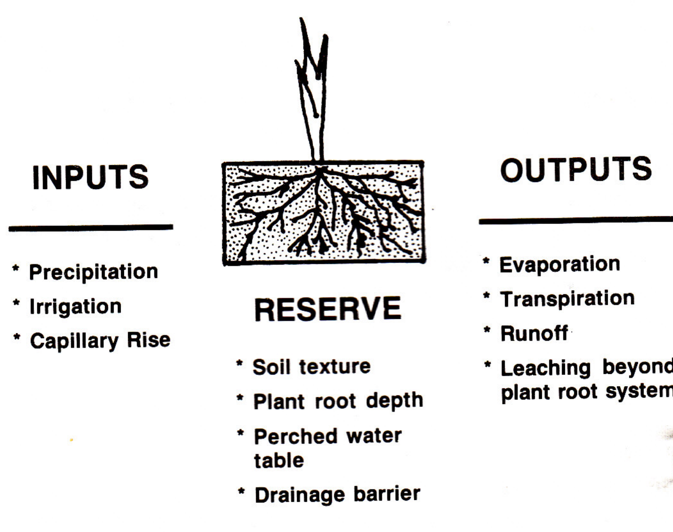

Figure I. Budget Concept of turfgrass water management.

zones in the soil including the soil surface layer. It is the author's understanding that a commercial unit should be available within the year. Such a unit may be programmed similar to a tensiometer. Certainly this could be a useful technique to monitor water flow in research studies. It appears to be sensitive over a wide soil moisture range.

B. Monitoring Atmospheric Demand

Using meteorological data to determine plant water requirements is another alternative for irrigation schedulers. This is based on the fact that atmospheric conditions dictate to a large degree the rate of soil water loss by evaporation and transpiration. However, the plant can reduce depletion by stomatal closure and when soil moisture declines, further extraction is at a much lower rate than potential evaporative demand would indicate.

Both mathematical and weather pan approaches have been used by scientists to estimate ET of plants as related to evaporative demand. Before discussing these two methods, I will present the basic, common theory behind both approaches. The first step is to estimate potential ET (ETp), where ETp = maximum evaporation and transpiration from a short green reference crop, assuming soil moisture is not limiting. Once a potential ET (ETp) is obtained, it is related to actual crop ET (ETc) by a crop coefficeint factor (k), which depends on crop age, growing season, crop characteristics, soil moisture status and prevailing weather conditions.

$$ETC = k\ ETp$$

Once a grower knows ETc on a daily basis, he can monitor turf water losses and use this to schedule irrigation. Ideally, the grower would collect these data (i.e., the ETp and k factor) for his specific site. Another possibility would be to collect the ETp data at several sites within a region and then announce the ETp each day. Growers would then use this as a guideline for their irrigation. In the latter method, the region would need to be zoned into similar areas and the grower provided with an estimated crop coefficient factor for his zone. It is the author's understanding that California is initiating such an approach to provide irrigation guidelines for homeowners as well as professional turf managers.

As noted previously, ETp can be estimated by either mathematical procedures or by weather pan data. Doorenbos and Pruitt (6) and Taylor and Ashcroft (15) provide good discussions of the different *mathematical procedures for estimating ETp from climatic data.* The methods can be classified as (a) energy balance methods, (b) mass transfer, or aerodynamic methods, (c) combination methods — where aerodynamic and energy balance concepts are combined and (d) empirical equations with various levels of theoretical basis. The empirical procedures (Penman, Thorthwaite, Blaney-Criddle, Jensen-Haise, locally developed equations, etc.) have been the most useful. These equations utilize various climatic data—air temperature, solar radiation, relative humidity, wind factors—to calculate ETp for a period of time, such as daily, weekly, monthly.

Several problems have been encountered when using empirical procedures for estimating ETp. No universal equation has evolved, but some seem to be more useful in certain climatic areas, such as arid, semiarid, cool-humid, etc. For turfgrasses, daily ETp data is a necessity, but all of the equations are most accurate over longer time periods. Many times, the climatic data are not available on a routine basis to the grower and monitoring equipment is expensive. Also, the calculations can be complex, but pocket calculator programs can be developed.

The *weather pan procedure for estimating ETp* has potential use for both the researcher and grower. Evaporation of free water from a weather pan integrates the effects of radiation, temperature, wind, and humidity—these are the same climatic factors that influence crop water use. Youngner et al. utilized this technique successfully on turfgrass.

Evaporation from a weather pan (Epan) can be correlated to ETp by a pan coefficient (Kp).

$$ETp = Kp\ Epan$$

Sometimes individuals have used a constant pan coefficient for all climatic conditions. This is not a good practice since Kp changes with different humidity, wind conditions and type of weather pan. Doorenbos and Pruitt provide tables for Kp under different wind and humidity conditions, and for two different weather pans. The U. S. Weather Bureau is most commonly used.

Once the daily ETp value is obtained, it is then related to actual crop evapotranspiration by the formula

$$ETp = k\ ETc$$

In some cases, researchers have converted directly from Epan to ETc. This is probably not the best situation since it combines the coefficients Kp and k.

$$ETp = Kp\ Epan = k\ ETc$$
$$ETc = Kp/k - Epan$$

As we have just seen, Kp is not a single unique value but is influenced by weather conditions.

Regardless of whether an ETp value is obtained from weather pan or mathematical procedures, it must be related to actual turfgrass evapotranspiration, ETc, by the crop coefficient, k. For crop plants in general, crop coefficient (k) is influenced by type of crop, stage of growth, climatic conditions, and soil moisture. For a mature turfgrass sod, major factors affecting k would be time of year (turf growth cycle), climatic conditions, and soil moisture status. The soil moisture aspect can often be ignored on well irrigated turf. If irrigation is not initiated until the turf undergoes at least moderate moisture stress (ψ s $\approx$ -2.00 to -4.00 bar), then the k value is different from less limiting soil moisture conditions. While k values can be taken from tables or derived from experimental results, the most accurate are obtained experimentally at the specific location (i.e., climatic zone). This can be done by using actual ETc values observed in lysimeter studies and relating these to ETp from weather pan or mathematical origin. From this discussion, it should be apparent the k values must be seasonally adjusted.

We have reviewed two procedures for monitoring atmospheric demand as a way to provide irrigation guidelines. Another alternative for researchers can be *lysimeters* to measure crop evapotranspiration, ETc, directly. These can be simple in design, such as buried lysimeters made from PVC pipe, or they can be elaborate weighing lysimeters with built-in weighing devices. The simpler bucket lysimeters require removal for weighing. To reflect growing conditions accurately, lysimeters should be placed carefully in sodded areas. In studies where root system distribution would influence the ET rates of a grass, such as comparing two tall fescues under limiting soil moisture, lysimeters may not reflect accurately a true field situation, since full root development may be restricted. This would be a problem on lysimeters that are shallower than the normal rooting depth. Another potential problem is impeded drainage, which could result in a positive pressure potential. Such ponded water can influence ET rates.

Recently, researchers reported on the *determination of resistance to sensible heat flux density* as a procedure to determine turfgrass ET. This method allows rapid determination of ET in the field using an infrared thermometer and a net radiometer. While this procedure should prove useful in ET rates at a point in time, such as in a study comparing tall fescue cultivars at a point in time, it does not provide a daily ET value. For irrigation scheduling purposes, a daily water use rate is necessary.

C. Monitoring Plant Water Status

Ideally, the grower would like to measure some parameter of the plant that would indicate impending moisture stress. Such a parameter would integrate all the soil-atmospheric-plant factors together. Researchers have investigated leaf water potential and stomatal diffusive resistance, but these techniques are not refined to the point of usefulness as irrigation criteria. They require many point measurements to reflect the turfgrass canopy conditions accurately.

A simple plant parameter that has been used to aid irrigation programming is *wilt.* One would like to irrigate before wilt symptoms appear, since irrigating at wilt does result in some deterioration of the turf. However, if a grower uses wilting of key *indicator spots,* this will indicate to him the moisture status of adjacent areas. On most turf sites, some area consistently exhibits wilt first. This will require experience but can be useful.

Infrared thermometry allows nondestructive monitoring of turfgrass canopy temperatures. It also averages many plants together. While under no moisture stress, turf canopy temperatures are near (some species are slightly below and others slightly above) ambient air temperatures. As stress is imposed, turf canopy temperatures rise above the ambient air temperatures. Monitoring and relating these temperature changes to plant water requirements could aid in programming irrigation. Phene and Stegman presented several articles relating to this technique and its potential. To date, the author knows of no research on use of infrared thermometry for turf irrigation scheduling. Such a project is currently being conducted at Kansas State University.

D. Combination Method

Previously we looked at the soil-plant-atmospheric system as a *budget system* with inputs, outputs, and a certain reserve of moisture at any one time (Fig. 1). Irrigators should keep this concept in mind and use it to fine-tune their irrigation programs. By measuring or estimating each of these components, the irrigator can more carefully use any of the techniques (soil, atmospheric, plant water status) just discussed.

Also, irrigation personnel—whether turf managers or researchers—need to answer the question "How much water and should I apply?", not just the question of "when should I irrigate?" The above techniques may guide in the latter question but not necessarily the former. How much moisture to apply requires knowledge of the depth of rooting, degree of moisture extraction, and soil water holding-drainage relationships. Adjusting irrigation application rates to the existing soil and plant rooting conditions will substantially contribute to water conservation.

LANDSCAPE DEVELOPMENT IN LARGE RESIDENTIAL COMMUNITIES

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I am involved in landscape services in various parts of the country. Some of the projects are in the Northeast where conditions are similar to Massachusetts and New England. The other locations may be of interest to you, and I will try to point out some of the more interesting situations unique to the locality.

I work for a large land developer. Our major products are adult and vacation communities. We build total communities rather than simply houses.

The word "developer" to many people, certainly environmentalists, is a larger than four letter dirty word. The developer has been accused of taking as much from the land as possible and leaving nothing. The F.H.A. landscape package of five small shrubs, one puny tree and the five pound ryegrass lawn, were for many years testament to the regard that builders, lending institutions and government gave to landscape and turf. Gone are those days along with open burning, cheap labor, and 15¢ per pound ryegrass. The housing tracts of the past were production oriented basically to see how many buildings could be crammed onto the land with little consideration to aesthetics. The market could not produce as much as the demand would require. If you didn't want it, someone else did. There were little or no amenities. The homeowner was left on his own to provide his own recreation. Grading was poor, paving wasn't much better, and builder topsoil could be best described as a heterogeneous conglomeration of debris.

Today's developer by contrast is forced by regulation, but more important, by the economics of the market place to conserve as much as possible of the natural tree cover. He wants to grade and clear as carefully as possible to preserve the natural enviornment. Open burning is no longer allowed in most places and disposal of stump and trees must be in selected landfill sites, at times considerably remote from the jobs adding to costs.

Today's buyers, particularly mature adults, look for more than just shelter. They look for a total community. They look for recreational amenities, such as pools, shuffleboard courts, marinas, ski slopes, etc. and pay premiums for lots on green belts and water frontage, some of which was at one time swamps, and of course on golf courses. Today's buyer is a much more sophicated and demanding individual. He also demands an intensified maintenance level, particularly if he is not actually the one who does the work. At the same time any turf areas and landscape must be sensitive to the maintenance costs since these costs impact severely on sales of houses.

Now that I have given you a quick background on the developer of the past, the developer of the present and the buyers as well, let me give you a brief outline of just how we operate a project.

We start with studies to determine the market for the buildings we would intend to construct. The next consideration is site selection; specifically, we are looking for a site which can easily and inexpensively be developed into the type of community that potential buyers will be proud of and that will sell well. After the site has been selected, we then hire a landscape architect, an engineer (local if possible), and a building architect. We evaluate site and project costs and at this point accountants come into the picture to determine whether the project will sell at a price that generates a profit.

The next item to obtain is an aerial photograph to scale of the specific location. We usually have these flown at a scale of 400 feet to the inch, which allows us to pinpoint certain locations, tree cover, natural or unique features and enlarge the area so that we can get a much better determination of what can or should be done. Next we position the buildings and the roads in such a way as to minimize the development cost and retain as much of the natural tree cover as possible. The landscape plan is developed to fill in the holes in natural areas and cover weak elevations. We try to select plants which are indigenous to the locality and are cost efficient in terms of maintenance and establishment. We now analyze the soils for ground cover or turf to determine the need for sprinklers, if any.

When we actually start field work, we first selectively clear the site, removing only that plant material which is necessary to effect construction. Much of this work is done by hand with specialized equipment used wherever deemed appropriate. Next we do the rough grading, this likewise done with considerable care so as not to disturb any more of the natural environment than is necessary. Then comes the installation of the buildings along with the underground utilities, such as the sewer, water, and electric systems. Then the walks, paving, sprinklers, finally the sod and or seed and landscape material. The foundations of each building are then planted with the required shrubs and lastly the common areas between the buildings are planted. At this point we inspect the area to be sure we have received what we contracted for and finally we formally turn the area over to the homeowners or a condominium association or some community body for their care, custody and maintenance.

During construction we must always be alert for potential problems and resolve them quickly. We must keep abreast of any new procedures, equipment and chemicals. One new item that we have had good luck with particularly in Southern California has been drip irrigation. Historically where shrub beds have required irrigation, we have accomplished this through a conventional overhead system. The new drip system is much easier to install, uses less water, creates fewer problems and is simpler to service. Specifically, after the shrubbery around the buildings has been installed, a ½ inch polyethylene supply line is snaked through the shrub bed in such a way as to come within a few inches of each plant. At that point an emitter or dribbler is installed in the pipe which allows a prescribed amount of water to escape from the pipe at the root zone of the plant. This system is operated at a pressure of between two to three pounds per square inch. The entire system is covered with mulch and is not visible.

Other considerations at this time are central irrigation programmers, some with electronic moisture sensors to automatically adjust water programs to pre-established water needs. We are also always on the lookout for new types of mulches. Over the years we have used a great variety of materials such as coffee grounds, pegboard slugs, cypress bark, stone, cocoa bean hulls, peanut shells and we are always alert to new possibilities.

A new field that we are looking into is the use of treated waste water for irrigation. There is considerable information on this subject available, but many of the regulatory agencies are reluctant to commit any large scale installations of this type until more is known about the long range effect of continued use of treated effluent. I believe that this is a field which in the very near future holds a great deal of promise, since sources of irrigation water have been increasingly difficult to obtain and the cost has been increasing at an alarming rate.

We are also constantly looking at new types of equipment such as the cord trimmers as well as chemicals such as growth retardants. Growth retardants are not new. They have been on the market for many years in many forms. One of the most difficult problems with most of the growth retardants in the past has been that they have been of limited use since they affect different genera and species of plant material in different manners and have been also limited by the critical timing required to make them effective.

At this point, I would like to get into some of the specifics of the areas that we are presently working. In the Midwest where landscape labor is unionized and costs are probably the highest of any area that we are operating in, the conditions are similar in many respects to the Northeast. Rainfall, temperature and soil pH are similar, but there is much peat or black dirt which overlays gravelly materials. The growing season here is shorter by about a month than areas in the Northeast. Winters are more severe with white pines winter burning and much winter rabbit and rodent damage to thin bark trees. There is considerable snow mold on turf. But that is better than the desiccation experienced with an open winter. Irrigation here is about the same as in the Northeast along with most of the common turf and landscape insects and diseases. The soil preparation here is devoted mostly to the removal of rocks and stones as the soils are generally rich in nature.

With landscape plants in the Midwest, we must be aware of the need to provide for the planting of trees and shrubs to effect natural snow fences as well as to provide large open lawn areas adjacent to roadways in order to deposit snow loads during the winter. By and large most of the plant material, trees, and shrubs that are utilized in the Northeast are readily adaptable to the Midwest.

In Southern California we have an entirely different breed of landscape. We have heavy mineral soils which require two to three weeks of dry weather to completely dry prior to commencement of work. We have microclimates where because of mountains or canyons, the climatic conditions of one particular area may be considerably different from those less than a mile away. Specifically, where we have a coastal influence we may be able to grow cool season grasses, where on the other side of the hill, less than a mile away, the only thing that may survive are the bermuda grasses and the plants of more of a desert nature.

The soils are basically alkaline, and require application of sulphur rather than lime, to correct pH. The soils, because of their high mineral and silt content, required the incorporation of four to six cubic yards of coarsely c[illegible] nitrogen stablized sawdust per one thousand square fe[illegible] incorporated into the top three inches of the seed bed prior to planting. Percolation is slow, less than ½ inch per hour, which requires light frequent shots of water. There is more evaporation since humidity is lower and water costs are approximately $150-$180 per acre foot of approximately 50¢ per thousand gallons. Natural rainfall consists of ten to thirteen inches annually, usually in the three months in December through February. This requires fence to fence irrigtation systems, with more spray heads and tigher spacing.

The spread in price between hydroseeding and sodding lawn areas in Southern California is much greater than any other place we work in the country. Hydroseeding costs in the order of 7¢ per squre foot installed depending upon quantities.

Most all plant materials used in Southern California are container grown, and are specifed by container size. Specifically, you purchase a one gallon, five gallon, or fifteen gallon shrub, and trees are specified by the size of the boxes which contain the root system. Since plants are container grown, they may be moved twelve months out of the year.

The residents of Southern California are much more aware of landscape. As a result, outside areas are much more intensively used and maintained. The grading here is very critical because of the water runoff and slope maintenance is extremely critical.

In the Northeast we work in New York, New Jersey and Pennsylvania. Soils in south Jersey and on Long Island are very sandy and have a good percolation but have little water retention capabilities. The pH's are very low because of oak mold and peat bogs, and some of the pH's will go as low as 2.5. Because of the porosity of the soil, it is necessary to irrigate for turf and landscape establishment. We find this is best done with an automatic sprinkler system. Overall landscape costs run slightly lower in Southern New Jersey than in New York. Here we hydroseed large open areas at costs of approximtely 3¢-4¢ per square foot, and sod areas close to buildings at costs ranging from 12¢-15¢ per square foot.

In some of our single family homes, we have experience some logistical difficulties which follow-up care. Many times the resident has not moved into the home at the time of the installation of the lawn and plant material when the watering is extremely critical. This may require labor to hand water certain areas which may be considerably remote from high volumes of water. In many cases we have used hydroseeders or water wagons to keep sod alive during the critical post-planting stages, particularly during an unexpected siege of 90 degree plus temperature.

On Long Island, we have similar challenges, but we also have something which is quite unique; they are called water retention basins. These can be many acres in size and quite deep. We do have a considerably difficult time in disguising them. We use a lot of evergreens, specifically pines, Spruce and Hemlock, but still, a hole with a six foot chain link fence around it by any other name is still a hole.

In Pennsylvania, our main difficulty is a lot of rock, with only thin amounts of expensive trucked-in top soils. In these areas, we attempt to use as much of the natural material as possible, to clear as little as possible and to use a maximum number of plants, a minimum amount of turf and no sprinklers.

In Florida we have basically sandy soils with good percolation, but we have a high ground water table. It it only approximately three feet down. Soils are mostly acid, but there are some alkali outcroppings. We experience heavy rainfall, four inches an hour is not uncommon, and we have high humidity which creates a lot of insect and disease problems.

We use many foliage plants, some of which are grown indoors in the Northeastern climates as exotics, some of these being Schaefferia, aralia, Norfolk Island pine and podocarpus. We use considerable numbers of palm trees. But the supply of palms is under a great deal of pressure because of a disease called lethal yellowing. We are attempting to mix foliage trees in amongst the palms, similar to the concept used in lawn seed mixtures, to diversify the tree cover and reduce problems. That way, if one genus or species becomes a disease target we haven't lost the entire tree cover.

The turf grown here is essentially Bermuda grass, Saint Augustine and a material called Argentine Bahia. Bahia is one of the nastiest looking grasses going down as sod, but in a matter of a few days, with a shot of liquid urea, and liberal applications of water, it becomes not only an acceptable, but in many cases a beautiful turf. It grows anywhere, and best of all, with minimum care.

Nematodes and mole crickets provide some new challenges along with army worms, chinch bugs and the like. However, because of the number of insects available, bird life abounds.

Many of the existing irrigation systems are hydraulically operated. However, most new systems being installed are electric. The water here has a heavy sulphur content and strains just about everything green, including buildings, sidewalks, golf carts and people if they stand in one place long enough. The water has a total salt content of approximately 1100-1200 parts per million. Turf will tolerate up to about 1300 parts per million. The situation will get delicate in times of drought when total salt concentrations exceed the 1300 parts per million limit.

Some of the plants grown here are field grown while others are grown in containers. The plants are very quick to establish and can soon become overgrown without care.

And so in summary, I have attempted to explain some of the conditions encountered by today's developers working in various places in the country, with different soils, weather, and labor conditions. I hope I have convinced you that today's builder/developer does care about the environment and is sensitive to the needs and desires of society. He like so many other persons, is trying as best he can to provide his customer with a dependable product that he can be proud of at a cost that he can afford, and at the same time make a reasonable profit in the bargain. But it isn't easy.

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