A PRACTICAL RESEARCH DIGEST FOR TURF MANAGERS

TURFGRASS TRENDS

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WEED CONTROL

Weeds
Shedding Light on an Old Foe

Karl Danneberger, Ph.D., Department of Horticulture and Crop Science, The Ohio State University

Weeds are opportunistic plant species that possess the ability to colonize open or thinned areas of turf quickly. Human activities and disturbances are the major means for introducing weeds. It should be no secret then, that the great majority of the 2,000 plant species considered weeds are not native to the United States.

Weeds are often grouped into broad groups according to life cycle (winter or summer annual, biennial or perennial), and morphological characteristics (monocot, dicot). Recognizing other ways of grouping weeds can help turfgrass managers devise effective management control programs.

Classification based on Carbon Fixation

Classification of weeds can also be based on their photosynthetic pathway. All plants carry on photosynthesis, the process whereby a plant captures radiant energy (light) from the sun and converts it into a usable form.

Photosynthesis is comprised of two main steps. The first is the light-dependent reaction where radiant energy is converted into biologically useful energy called ATP (adenosine triphosphate). The second, or dark (light independent), step is the storage of this energy into the chemical bonds of sugars and carbohydrates. Central to the light-independent reaction is the fixation of carbon dioxide (CO_2) known as the Calvin cycle. The cycle is a series of reactions where CO_2 is fixed. The initial step is the attachment of CO_2 to a 5-carbon compound, ribulose bisphosphate (RuBP) that quickly divides into two 3-carbon compounds. The term C3 cycle comes from the catalyzation of the 3-carbon compounds. Cool-season turfgrasses are often referred to as C3 plants.

Some plants however fix CO_2 differently. In many tropical plants, CO_2 is initially fixed to phosphoenolpyruvate (PEP) prior to entering the Calvin cycle. This additional reaction step is known as the C4 Dicarboxlic Acid Pathway. Most C4 plants are warm-season grasses. Generally speaking, C4 plants capture CO_2 more efficiently under increasing light and temperature conditions. Conversely, C3 plants capture CO_2 more efficiently under more moderate light and temperature conditions.

In 1969, Black proposed that plant-weed competition could be based on photosynthetic efficiency. Based on the efficiency of capturing CO_2, the competitive outcome between a C3 and a C4 plant is predictable. Under increasing temperature and light intensity, the more efficient capture of CO_2 (C4) would provide a competitive advantage over

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the less efficient C3 plants. The competitive outcome between C3 and C4 plants will not always result in a C4 advantage. In turf, this generalization will hold true under many high light and temperature situations.

For example, Kentucky bluegrass has a distinct disadvantage against C4 weeds like crabgrass, goosegrass and foxtail during the summertime. Under high temperatures and light intensities, Kentucky bluegrass does not capture CO_2 efficiently. The end result is less energy is produced reducing carbohydrate formation in the plant. The C4 weeds, on the other hand, are capturing CO_2 at an increasing rate under increasing temperatures and light conditions. Thus, during the summer, the C4 weeds are accumulating energy (carbohydrates) while the Kentucky bluegrass is losing energy. The opposite situation occurs in shaded environments. Kentucky bluegrass will capture CO_2 more efficiently under cooler temperatures and lower light levels than C4 weeds. Crabgrass and goosegrass are not found in high populations in shaded environments.

Control measures can be adjusted to account in the different carbon fixing mechanisms of plants. Pre-emergent herbi-

COMMON MONOCOT WEEDS OF TURF

Table 1. Description and characterization of common monocot weeds found in turf.

Common Name	Botanical Name	Photo-synthetic Apparatus	Origin
Quackgrass	*Elytrigia repens* L. Nevski	C3	Europe
Alexandergrass	*Brachiaria plantaginea* Hitchc.	C4	Central America
Smallflowered Alexandergrass	*Brachiaria subquandripara* Hitchc.	C4	Asia
Sandbur	*Cenchrus longispinusp* Fern.	C4	Central America
Yellow Nutsedge	*Cyperus esculentus* L.	C4	Europe/Native
Purple Nutsedge	*Cyperus rotundus* L.	C4	Asia
Smooth crabgrass	*Digitaria ischaemum* Schreb.	C4	Europe
Large crabgrass	*Digitaria sanguinalis* L.	C4	Europe
Blanket crabgrass	*Digitaria serotina* Mitch.	C4	Europe
Barnyardgrass	*Echinochloa crusgalli* L.	C4	Europe
Goosegrass	*Eleusine indica* L.	C4	Asia
Tall fescue	*Festuca arundinacea* Schreb.	C3	Europe
Bearded sprangletop	*Leptochloa fascicularis* Lam.	C4	Central America
Nimblewill	*Muhlenbergia schreberi* Gmel.	C4	Native
Carpetweed	*Mullugo verticillata* L.	C3 - C4	Central America
Witchgrass	*Panicum capillare* L.	C4	Native
Fall panicum	*Panicum dichotomiflorum* Michx.	C4	Native
Torpedograss	*Panicum repens* L.	C4	Europe
Dallisgrass	*Paspalum dilatatum* Pior	C4	Europe
Kikuyugrass	*Pennisetum clandestinum* Hochst.	C4	Europe
Annual bluegrass	*Poa annua* L.	C3	Europe
Giant foxtail	*Setaria faberi* Hevrm.	C4	Europe
Green foxtail	*Setaria virdis* (L.) Beauv.	C4	Europe
Smutgrass	*Sporobolus indicus* L.	C4	Central America

Photosynthetic apparatus refers to the carbon dioxide fixing pathway. Sources for some of the information in the table were obtained from: 1) Elmore, C.D. and R.N. Paul. 1983. Weed Science 31:686-692. 2) Muenscher, W.C. 1987. Weeds. Cornell University Press. Ithaca. 3) Murphy, T.R. Weeds of Southern Turfgrasses. Alabama Cooperative Extension Service, ANR 616.

COMMON DICOT WEEDS OF TURF

Table 2. Description and characterization of common dicot weeds found in turf.

Common Name	Botanical Name	Photo-Synthetic Apparatus	Origin
Common Yarrow	*Achillea millefolium* L.	C3	Native
Wild Onion	*Allium canadense* L.	C3	Native
Wild Garlic	*Allium vineale* L.	C3	Europe
Yellow Rocket	*Barbarea vulgaris* Br.	C3	Eurasia
Sheperdspurse	*Capsella bursa-pastoris* L.	C3	Europe
Mouse-ear Chickweed	*Cerastium vulgatum* L.	C3	Europe
Common Lambsquarters	*Chenopodium album* L.	C3	Eurasia
Prostrate Spurge	*Euphorbia supina* Raf.	C4	Native
Ground Ivy	*Glechoma hederacea* L.	C3	Eurasia
Hawkweed	*Hieracium pilosella* L.	C3	Europe
Pennywort	*Hydrocotyle sibthorpioides* Lam.	C3	Asia
Purple Deadnettle	*Lamium pupureum* L.	C3	Eurasia
Henbit	*Lamium amplexicaule* L.	C3	Eurasia
Mallow	*Malva neglecta* Wallr.	C3	Eurasia
Black Medic	Medicago lupulina L.	C3	Eurasia
Yellow Woodsorrel	*Oxalis stricta* L.	C3	Native
Cinquefoil	*Potentilla* spp. L.	C3	Native
Buckhorn Plantain	*Plantago lanceolata* L.	C3	Eurasia
Broadleaf Plantain	*Plantago major* L.	C3	Europe
Prostrate Knotweed	*Polygonum aviculare* L.	C3	Eurasia
Common Purslane	*Portulaca oleracea* L.	C4 - CAM*	Europe
Healall	*Prunella vulgaris* L.	C3	Native/Europe
Curly Dock	*Rumex crispus* L.	C3	Eurasia
Largeflower Pusley	*Richardia grandiflora* Steud.	C3	South America
Common Chickweed	*Stellaria media* L.	C3	Europe
Common Dandelion	*Taraxacum officinale* Weber	C3	Native/Eurasia
White Clover	*Trifolium repens* L.	C3	Europe
Puncturevine	Tribulus terresris L.	C4	Mediterranean
Speedwell	*Veronica* spp.	C3	Europe
Field Pansy	*Viola arvensis* Murr.	C3	Europe

* Crassulacean Acid Metabolic Pathway (CAM) which is often found in succulent desert plants.

cide applications targeted at C4 weeds might be reduced or eliminated in shaded conditions where the existing cool season turfgrass is well established. In hot, dry areas found along sidewalks and driveways, the rate of pre-emergent herbicide may need to be increased to account for the increased pressure of C4 weeds.

Conversely, the major weeds associated with shaded conditions are C3 weeds. If a warm season turfgrass is growing in shade, the major weed pressure will come from C3 carbon fixing weeds.

Major weeds are summarized according to their carbon fixing pathway in the accompanying tables. In determining management programs for weeds, consider the carbon-fixing pathway. Increased weed control and more efficient use of herbicides will be the outcome.

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Gifford, R.M. 1974. Aust. Journal Plant Physiology 1:107-117.

Not All Microbes Are Created Equal
Identifying Beneficial Ones

By David J. Drahos, Ph.D.

Research has revealed that both plants and soil microbes seek to function in symbiotic relationships. In other words, they seek to live together in a way that benefits both of them. Under ideal conditions, beneficial microbes aid a plant's health and vigor, while the roots provide food to sustain the microbes. For this reason, many turf managers turn to microbial products to add 'beneficial' microbes to a soil's profile in hopes that these microscopic organisms will help their turf resist disease and stay healthy.

There are millions of microbes competing for the right to live in tandem with plants, and not all of them will survive the competition for a home in the root zone.

Unfortunately, not all microbes are created equal. There are millions of microbes competing for the right to live in tandem with plants, and not all of them will survive the competition for a home in the root zone. This fact raises several questions for anyone using microbial products:

- How can these products guarantee that the *right* microbes are selected?
- If they are, how do they ensure those microbes survive in the root zone long enough to provide benefits for the turf?

While suppliers of many currently available microbial products can't provide solid answers to these questions, the technology does exist.

DNA Fingerprinting

DNA fingerprinting, protein fingerprinting, and enzyme analysis allow companies to identify specific microbes with proven beneficial traits and to verify their presence in soil after application. This procedure, using new genetic technology, enables comparative identification of an unknown microbial strain based on its unique fingerprint -- much like human fingerprints are used for identification purposes.

All microorganisms, including bacteria, possess a unique complex set of genes (DNA) which act as a blueprint for behavior, growth and survival. In fact, each individual bacterial strain type has a special DNA fingerprint, which has been shown to remain virtually the same over many years, through many generations, no matter what materials the microbe is growing on or where the strain has been in the environment. These DNA fingerprints are unique not only to the identification classes of Genus and Species, but below even the Subspecies level.

In the DNA fingerprinting method, a small amount of DNA is isolated and purified from an overnight laboratory culture of a particular microbe. This DNA from each bacterial cell looks like a microscopic "ribbon." Since each cell is an identical clone of its parent, all the DNA strands are also identical, with the same sequence of building block components that make up the DNA ribbon.

Next, the DNA strands are treated with special restriction enzymes, which look for very specific locations (coding sequences) on the DNA. These restriction enzymes act as molecular scissors to slice the DNA ribbon into fragments of different lengths, corresponding to the location of the cut sites on the DNA strands. Sites, which are close together, produce shorter length fragments; sites farther apart give longer fragments. The mix of fragments are then separated based on size by placing the cut DNA into a gelatin-like material (agarose), then subjecting this to an electric field. Since DNA is naturally negatively charged, it will move toward the positive anode. However, the smaller fragments will migrate faster than the larger, since they move more freely in the agarose gel than larger pieces.

The DNA thus spreads out, forming a pattern or fingerprint, which appears much like an IUPC bar code seen on many product packages in stores. The DNA pattern can be stained and photographed, providing a permanent record of the fingerprint. No two patterns are alike, unless they came from the same parental microbial strain, just as no two human individuals have the same fingerprints (unless of course they are identical twins). The entire fingerprinting process can be completed in less than eight hours.

DNA fingerprinting provides a very powerful tool in the successful application of microbes for environmentally beneficial processes. It provides a means to know for certain that the specific inoculated strain is truly present where it needs to be, even though there may be hundreds of very similar look alike (but less effective) strains naturally present. This is particularly true when live microbial strains are applied in the turf foliar or soil environment where they encounter and must compete with a population of millions of well-adapted natives.

For inoculated bacteria with strong plant-beneficial effects, a low-level presence is often all that is needed to tip the balance in favor of the plant. Actually, the most effective strains are those that do not significantly alter the overall indigenous microflora population, but specifically target themselves to the root or leaf surface finding a small niche to grow. These strains directly respond to the plant's needs, providing powerful beneficial materials, such as plant hormones (phytohormones), precisely when they can be most helpful to the plant. Only very minute quantities of these phytohormones are required for full effect (about 1 millionth of a gram per plant root system), and too much at the wrong time may be quite detrimental for overall plant health. This precision injection method is far more effective than simply a chemical dump of phytohormones on the soil surface, hoping some (but not too much) gets where it needs to go. DNA fingerprinting provides a means to be certain that these pre-identified, beneficial microbes have really shown up for work, despite the crowds of native strains around them.

DNA fingerprinting provides a very powerful tool in the successful application of microbes for environmentally beneficial processes. It provides a means to know for certain that the specific inoculated strain is truly present where it needs to be.

Finally, the quality of products containing the chosen strains of microbes can be verified definitively for the types and amounts of bacteria present using the DNA fingerprinting method. The presence of inoculated strains in environmental samples can be confirmed to aid in determining survival, optimal dosage, and growth. Also, in the process of isolating new natural active microbes, DNA fingerprinting insures that such isolates are, in fact, unique and different from formerly isolated strains. Furthermore, legal protection of patented strains from use by competitors can also be insured using this procedure.

Protein Fingerprinting

The protein fingerprinting technique also provides a strongy indication of strain identity, though this method is more effected by the culture history (i.e. how the strain was grown in the lab, or where it was isolated in the environment). Nevertheless, since this method is more rapid than DNA fingerprinting (about 2 hours for protein prints rather than 6 hours for DNA prints), it offers an up-front check and broader assessment approach, usually as a precursor to DNA fingerprint confirmation.

For this procedure, cultures of all strains to be tested are first grown in a very defined liquid medium. Care is taken to ensure that samples of growing cultures are taken in the same growth phase for all strains to be compared. Protein is isolated from each individual culture, separate from other cell material, such as lipids, polysaccharides and nucleic acids. These proteins represent the large number of active enzymes (over 5,000 different enzymes being made by the cell at once), which each bacterium must produce to survive and compete.

When the proteins are separated by size through a plastic-like matrix (polyacrylamide) in an electric field, a banding pattern can be observed after a protein-binding stain is applied. While similar to, but less complex than the kind of pattern seen for the DNA fingerprinting method, the banding pattern obtained with proteins still allows effective differentiation of similar microbial strains.

Fast Enzyme Analysis

The ability to accurately determine the amount of certain enzymes produced by active microbial isolates is vital in assuring an active and effective biological product. The best strains in our products will be those very rare microbes with the robust ability to make substantial amounts of vital enzymes at the right times under the toughest conditions. But how do we find them?

A new system helps evaluate microbial growth rates to gauge their competitive fitness under the adverse conditions encountered in the sand/soil environment of a typical USGA putting green.

Typically, we select strains able to grow the best on certain media in the laboratory, then assay the amount and types of enzymes they make. In the past, however, accurate enzyme analysis had often been a laborious time-consuming procedure.

The multiple assessments and simultaneous analysis of enzyme standards necessary to gain statistical confidence in the enzyme readings often made it impossible to truly follow enzyme production by a particular microbe under actual environmental conditions.

New technology has all but eliminated these constraints. The new Plate Reader System allows for 96 samples to be analyzed for enzymes simultaneously every five seconds by one technician. Coupled with an on-board computer system, full automated analysis, instant standardization with known amounts of enzymes and accurate statistical verification, definitive enzyme levels can be determined for over 25 individual microbial samples in under 103 minutes. The production and longevity of multiple enzymes can now be followed under nearly real-time conditions. In other words, it helps find those rare, robust, high performance microbes.

In addition, the Plate Reader System is also proving valuable in streamlining the microbial characterization and naming process. Further, the system also aids in our evaluating microbial growth rates under a variety of media and conditions.

For example, the ability of key strains to grow on the exudate from plant roots often indicates competitive fitness under the adverse conditions encountered in the sand/soil environment in a typical USGA putting green.

David J. Drahos, Ph.D. is group leader, Research & Development, with Sybron Biochemical Division.

Documenting Irrigation Systems Accurately
With Global Positioning

By Cory D. Metler, CLIA

Documenting irrigation systems through the use of the Global Positioning System (GPS) is fast becoming the standard means of site documentation. GPS technology is redefining the way irrigation system managers and irrigation designers collect and process data. GPS is the fastest, most cost-effective way to capture data on large turf irrigation systems, allowing for managers to make more informed decisions more quickly.

GPS is a satellite-based radio navigational system that provides 24-hour, three-dimensional information on position, velocity and time. It was developed and is operated by the U.S. Department of Defense and consists of a $12 billion constellation of military satellites. It is the only system available today capable of shooting your exact position on earth any time and in any weather.

The principle behind GPS is calculating distance measurements among the user and the satellites. Measurements from four satellites are needed when mapping in three dimensions.

GPS data is being used in many aspects of large irrigation documentation, among these are:

- base map development;
- precise irrigation auditing;
- accurate (submeter) irrigation record drawings; and
- producing maps for today's computerized irrigation central control systems.

Base Map Development

Several techniques are used for developing large turf irrigation system base maps. The most popular are traditional and modern surveying (tape measures, measuring wheels and total stations), aerial photography and GPS. All of these techniques have unique benefits, as well as limitations that limit their usefulness under certain conditions.

Traditional surveying of large turf areas using tape measures and measuring wheels can result in variations in a property's true layout and size. Mapping a property with traditional tools has been proven to be very inaccurate. Reproducing results with reasonable accuracy is nearly impossible.

Mapping a property with traditional tools has been proven to be very inaccurate. Reproducing results with reasonable accuracy is nearly impossible.

On the other hand, modern surveying methods that use total stations are very accurate. But there are disadvantages. Total stations rely on line of site to a benchmark location. This can be difficult at sites with dense vegetation or extreme terrain. Developing a base plan in this manner is often a two-person operation and is very time and labor intensive, and therefore expensive.

Aerial photography has been the most popular source of base map development. Date is an important issue with aerial photography. An outdated photo can lead to inaccuracies due to changes at the site since the photo was taken. Important site features, such as buildings and ponds, can be obstructed by tree cover at certain times of the year.

There is also the potential of error due to the size of the image. When an aerial photo is taken of a site that exceeds 3,000 feet in length in any direction, the curvature of the earth causes error in measurement. Errors in scale can result if photos aren't taken on a true horizontal axis. Digital orthophotos can alleviate distortion problems, but can be expensive and impractical because of issues with vegetation.

GPS data collection is the fastest and easiest means for base map development. Depending on the accuracy of the equipment gathering the data, centimeter and even millimeter accuracy is obtainable. Advantages of GPS for base map development include very high accuracy and cost savings from the speed and ease of data collection. Data collected is directly imported as a digital format and each feature collected has a geographic coordinate and structured attribute.

A comparison of the architect's master plan and the actual site documented by GPS revealed significant differences in size and location of major course features.

Following are two different scenarios of base map development.

Scenario One: An irrigation system design was developed using a course map owned by a golf course. This course layout was the architect's master plan, which was used to develop the base map for the irrigation. As the design process continued, the design drawing and course layout had several discrepancies resulting in a drastic change in the number of rotors needed to properly irrigation the golf course.

Changes to the plan resulted in additional man-hours in the field for staking and installation, in addition to the extra rotors and materials caused by the inaccuracy of the map. Throughout construction there were several material change orders for the irrigation contractor. A comparison of the architect's plan and the actual site revealed significant differences in size and location. To resolve these differences, the entire golf course and the irrigation system were documented using GPS.

Scenario Two: An irrigation system design was developed using an aerial photograph supplied by a golf course. This aerial photograph was taken a few years prior to the development of the proposed irrigation system. Any features not represented via the photo were site located on the base map by the golf course superintendent. After numerous man hours in the development of the irrigation system design, materials take-off and bid documents, there were several discrepancies found among the three contractors bidding the project because each determined a different scale from the original aerial. These discrepancies varied from the total materials estimate for the job and not only impacted pipe and wire sizing, but ultimately requirements for the pump station.

The discrepancies were the direct result of the aerial photograph used for developing the base plan. Even though the irrigation system designer used an aerial photograph which accurately illustrated the golf course layout, the field measurements were only verified with measurements from one hole. Without measurements from multiple golf holes, the error in the aerial photograph was not evident until the system was staked. These errors were a result of the aerial photograph not being taken while the plane was on a true horizontal axis. Distance errors ranged from 50 to 400 feet across the property. This was not evident until GPS was used to map out several holes across the property as a control measure.

Irrigation Audits

GPS is also being used for auditing existing irrigation system performance. Catch can tests can be performed on various areas of the site. A single leg profile can be generated and entered into a computer to instantly tabulate a geographical representations of system uniformity. This allows a graphical representation for calculating the desired application, required application, and effect on wettest area per golf hole feature.

As before, here is a real-life scenario to help explain the usefulness of GPS:

A golf club is in the process of evaluating the efficiency of its existing single-row irrigation system. The system has deteriorated to a state that the pop-up rotors around the greens are no longer used for greens irrigation. The superintendent has opted to hand water the greens daily. The single-row fairway system is also not delivering adequate coverage into the rough where it is needed to establish the thick, healthy stand of turfgrass required for tournament conditions. Consequently, portions of the rough are also being hand watered. An audit was recommended to quantify the performance of the 25-year-old system to help justify the expense of installing a new multi-row system.

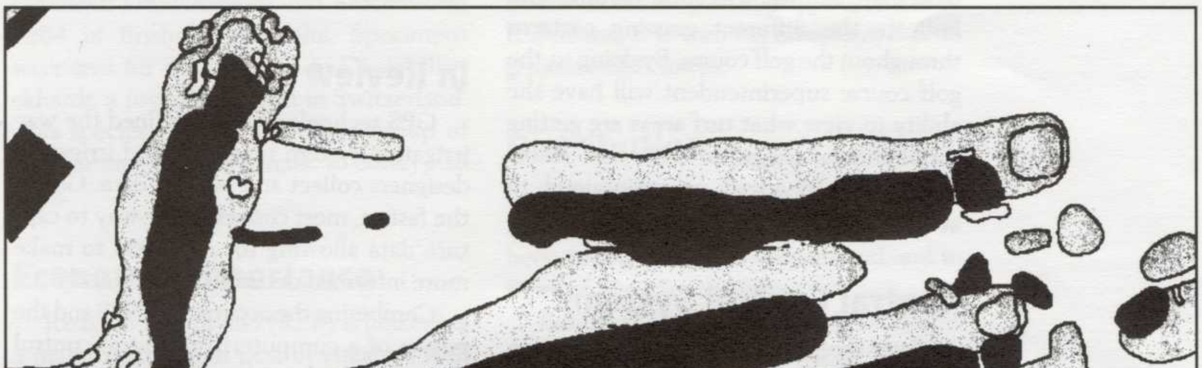
After performing catch-can tests, the data was entered into a computer software package and single-leg profiles were created for all areas tested. The results were entered into the GPS base map and a coverage map was produced to demonstrate the effective coverage of the sprinkler heads and to calculate the distribution uniformity (DU) of the irrigation system.

The results of this test helped illustrate not only to the golf course staff, but to the golf course membership, where the weak areas were and what needed to be considered in the design of a new multi-row irrigation system. These results also aided in the management of the existing system while the design process evolved.

Accurate Record Drawing

One of the most obvious advantages to GPS is the development of an accurate "Record Drawing" for system management and system documentation. A record drawing is a very valuable tool. It identifies any individual attribute (sprinkler head, isolation valve, wire splice) with submeter accuracy. System managers no longer have to hunt for system components with a metal detector. Instead, they can locate these important components quickly and accurately.

Record drawings are often created while out in the field and they consist of several pages. Even though these pages can be very accurate, the scale can be lost when several pages are combined onto one sheet. With the aid of GPS and a CAD viewing software package, system managers can have an irrigation record drawing in front of them at



A comparison of the architect's master plan (gray above) and the actual site documented by GPS (dark) revealed significant differences in size and location of major course features.

any time and view any attribute. Since CAD drawings are built in layers, you can turn on or off layers according to need.

Buried components can be found by measuring from two known, visible components. The computer can calculate the distances for you.

Scenario One: A local golf course that utilizes a spreadsheet-based central control system is in the preliminary stages of evaluating the efficiency of their existing irrigation system. The system is multirow and was designed to furnish enough coverage to allow the new construction project to fully grow-in.

Now that the course is established, several native areas do not need supplemental irrigation. Since the irrigation system was installed during construction of the course, no turf areas are delineated on the record drawing. This restricts the superintendent's ability to visualize where the rotors are and what turf areas they cover.

The main intent is to develop a GPS base map, add the irrigation features and indicate the different grassing patterns throughout the golf course. By doing so, the golf course superintendent will have the ability to view what turf areas are getting supplemental irrigation and what rotors need to be changed or maintained to achieve better water distribution.

Central Control Systems

Over the past few years, the irrigation industry has felt the direct benefits of advancements in computer technology. Incorporating computer-aided design drawings generated by GPS technology, irrigation central control systems can graphically recreate a golf course layout with actual irrigation system layouts down to the individual rotors. This technology allows more advanced control and precision over previous computer central control systems.

These multimanagement control systems take advantage of Microsoft's Windows Operating System with true 32-bit graphics. The end-user can turn on and off desired GPS map layers and zoom in an out to monitor every detail of the course. Users are no longer restricted to long repetitious spreadsheets. This Windows environment eliminates tedious keystrokes and layers of spreadsheets, replacing them with point and click simplicity.

Using a GPS map with an advanced irrigation central control system results in a very flexible, accurate and powerful management tool. As technology advances, more design information will be available through the development of georeferenced information. Georeferenced information will help provide more site-specific information for every aspect of facility management. Having the ability to use georeferenced information and to import it directly into an irrigation central control system can only aid in the development of highly efficient and functional irrigation systems.

Users will have the ability to look at several different watering scenarios, treat site-specific microclimates, soil characteristics and problem areas with the attention that they deserve.

In Review

GPS technology has redefined the way irrigation system managers and irrigation designers collect and process data. GPS is the fastest, most cost-effective way to capture data allowing for managers to make more informed decisions more quickly.

Combining the accuracy of GPS and the power of a computerized central control system will take cultural practices to the next level. As technology advances, more design information will be available with the development of georeferenced information. This information will provide the irrigation designer and facility manager with site-specific information that will only aid in the development of an efficient and functional irrigation system.

Cory D. Metlar is the GPS mapping coordinator for S.V. Moffett Co. in West Henrietta, NY. He is a certified landscape irrigation auditor.

Imported Pest Defoliates
Redgum Eucalyptus in West

By Rosser Garrison,
Los Angeles County Agricultural Commissioner's Office

On June 17, 1998, Los Angeles County Agricultural Inspector Cindy Werner brought some leaves to me that she had gathered from three redgum eucalyptus trees bordering a major freeway in El Monte. The leaves were covered with honeydew and curious, small white mounds. I determined that the cones were lerps (protective domes) of a completely new psyllid, one unlike any known from California or the United States.

Within four days after notifying Biosystematic Entomologist Ray Gill of the California Department of Food and Agriculture, he reported the pest was the psyllid, *Glycaspis brimblecombei*, last described in 1964 in Brisbane, Australia. Specimens were sent for confirmation to Daniel Burckhardt, a psyllid specialist in Switzerland. This species belongs to a large group of lerp-forming psyllids specific to eucalyptus trees.

Economic Importance

Redgum lerp psyllid (RLP) is becoming a major ornamental pest of eucalyptus in California. RLP heavily infests redgum eucalyptus, *Eucalyptus camaldulensis*, but also occurs on sugar gum (*E. cladocalyx*) blue gum (*E. globulus*), *Eucalyptus rudis*, and three other species.

RLP forms a lerp, which is a structure of crystallized honeydew produced by larvae as a protective cover. The lerp resembles armored scale insects.

The psyllids produce large amounts of honeydew that coats leaves, falls to the ground, and stains any surface it hits. A blackish, sooty mold grows on honeydew covered surfaces. In severe infestations, thousands of lerps cover the ground and understory, giving the appearance of hail. The lerps and the honeydew stick to shoes.

Heavy infestations cause severe leaf drop. Extensive defoliation weakens trees and increases susceptibility to wood boring pests, such as the eucalyptus longhorned beetle. These beetles, if successful in attacking trees weakened by RLP, can kill branches or entire trees. Infested eucalyptus will turn brown completely.

Heavy psyllid infestations cause severe leaf drop. Extensive defoliation weakens trees and increases susceptibility to wood boring pests, such as the eucalyptus longhorned beetle.

RLP has been implicated in serious outbreaks in native vegetation in Australia. It has been known to feed on a localized population of the redgum eucalyptus, as well as *E. dealbata, E. tereticornis, E. blakelyi, E. bridgesiana* and *E. nitens*.

Distribution

RLP was originally described by K. M. Moore in Brisbane, Australia. It has also been found in central Queensland and in more of New South Wales.

Besides the initial discovery in El Monte, CA, RLP has been identified in northern California. Samples there were first collected in July 1998 in Alameda County near Fremont, at Stanford University in Santa Clara County and in San Mateo County. It has also been found in Alameda, Oakland, Hayward and San Francisco.

The El Monte infestation has spread to most cities in the Los Angeles basin, and to Orange, San Diego, western San Bernardino and Riverside counties.

Identification

The young larvae build a conical lerp by excreting a gelatinous honeydew. The larger larvae are found beneath the lerps and resemble an armored scale insect. The conical lerps reach about 3 mm in width and 2 mm in height. The larvae are yellow or yellow and brown. The adults are 3 mm long, slender, and pale green with areas of orange and yellow. They differ from other California psyllids in having long genal cones (hornlike) protruding from their face.

Females lay eggs on succulent leaves and young shoots, so population increases often follow new plant growth.

Like other psyllids, redgum lerp psyllid develops through gradual metamorphosis, which includes egg, several increasingly larger larval stages and adult. There is no pupal stage.

Development time from egg to adult varies from several weeks during warm weather to several months during prolonged cool temperatures. In mild coastal areas, all stages can be present throughout the year.

Females lay eggs on succulent leaves and young shoots, so population increases often follow new plant growth. However, all psyllid life stages can occur on both new and mature foliage.

In its native Australia, the psyllid has two to four generations per year. A similar number of generations would be expected in California.

Cultural Control

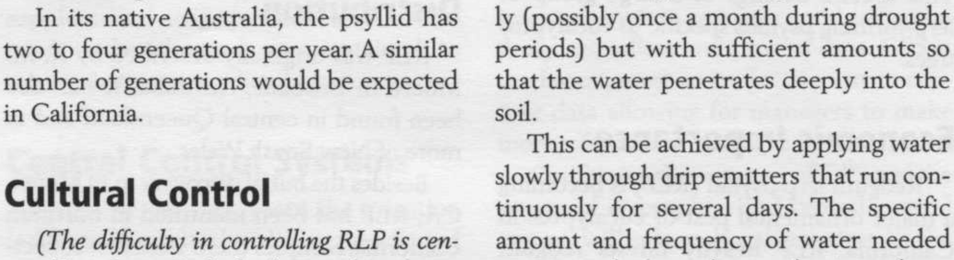
(The difficulty in controlling RLP is centered largely on the lack of natural predators in California. Repeated defoliation by RLP and attack of weakened trees by the eucalyptus longhorned borer are serious threats, especially when no natural predator is present to contain outbreaks. A number of predatory wasps imported in 1999 from Australia have not been fully evaluated for their effectiveness in California. — Editor)

Minimize tree stress by providing eucalyptus with proper cultural care and protecting trees from injury. Nitrogen levels in foliage may increase when eucalyptus is stressed. Increased foliar nitrogen increases reproduction and survival of psyllids.

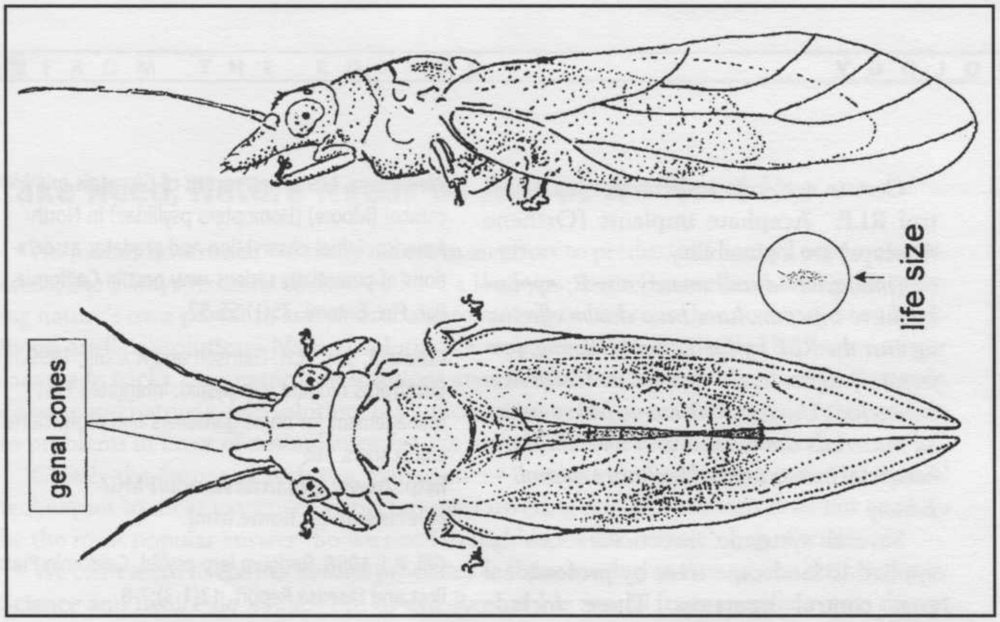
To minimize stress, consider providing trees with supplemental water during periods of prolonged drought, such as during summer and fall in much of California when rain in infrequent or nonexistent. Drought stress increases damage to trees from both RLP and eucalyptus longhorned borers. RLP outbreaks may also follow prolonged rain, possibly because excessively wet soil prevents roots from obtaining adequate oxygen, causing small roots to die.

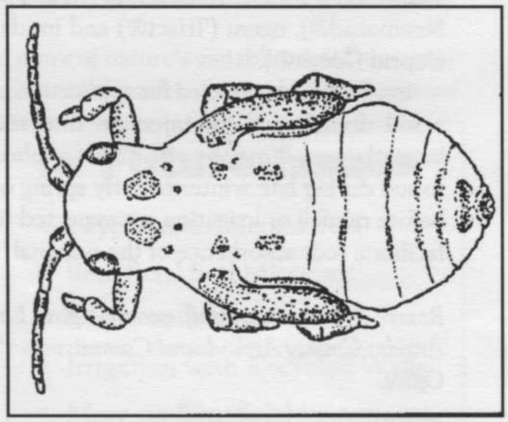
When irrigating trees, apply water beneath the outer canopy, not near trunks. Avoid frequent, shallow watering that is often used for lawns. A general recommendation is to irrigate eucalyptus infrequently (possibly once a month during drought periods) but with sufficient amounts so that the water penetrates deeply into the soil.

This can be achieved by applying water slowly through drip emitters that run continuously for several days. The specific amount and frequency of water needed varies greatly depending on the site and tree species.



Larvae are protected from insecticide sprays by lerps, domes made of crystallized honeydew.





Redgum lerp psyllid adults (above) are pale green with orange and yellow spots and have genal cones between their antennae. The larvae (right) are yellow or yellow and brown and protect themselves with dome-like lerps.

Avoid fertilizing eucalyptus. Use slow-release nutrient formulations if other plants near the drip line of eucalyptus require fertilization. Psyllid larvae and egg-laying females prefer the abundant, succulent new shoot growth stimulated by excess nutrients that occur following the application of quick-release fertilizer formulations.

(Experts recommend that you do not prune branches infested by RLP, especially during the summer. This stimulates new growth which promotes further infestation and can provide entry for the longhorned borer from March to November. — Editor)

Remember that RLP attacks only certain species of eucalyptus. Some eucalyptus species are avoided by this psyllid. Eggs laid on certain other eucalyptus species are unable to complete their development, so psyllid populations do not build to bothersome levels. The number of eucalyptus species attacked may decrease later if this pest is brought at least partly under biological control.

Chemical Control

Foliar sprays generally are not recommended, and will most likely not be cost-effective. It is difficult to spray large urban trees without pesticide drift. The lerp covering may provide psyllid larvae with some protection from contact sprays.

If honeydew becomes intolerable and foliar spraying is used, consider using a mixture of insecticidal soap (potassium salts of fatty acids) and horticultural oil. These low-hazard insecticides can be combined at one-half of the labeled rate or the full labeled rate (commonly 1 to 2% active ingredient each).

Unlike many other insecticides, oil can kill psyllid eggs, in addition to other life stages. Insecticidal soap helps to wash off honeydew and kill psyllids. Thorough foliar coverage is essential, so effective spraying may be limited to smaller trees. Soap or oil applications will likely provide only temporary control, and application may need to be repeated after about two weeks.

Certain systemic insecticides may control RLP. Acephate implants (Orthene Acecaps) are a possibility.

(Imidacloprid and metasystox-R, applied by micro-injection, have been shown effective against the RLP by Dr. Lester C. Young, professor of agricultural biology at California Polytechnic University, Pomona. Micro-injected materials are labeled and will not harm beneficial insects utilized for future control. — Editor)

Several systemic insecticides can be applied to landscape trees by professional pest control operators. These include abamectin (Avid®), azadirachtin (Azatin®, Neemazad®), neem (Triact®) and imidacloprid (Merit®).

Imidacloprid is labeled for application as a soil drench and for injection into soil beneath trees. It may be effective if applied to soil during late winter to early spring or before rainfall or irrigation are expected to facilitate root absorbence of the material.

Rosser Garrison is staff entomologist, Los Angeles County Agricultural Commissioner's Office.

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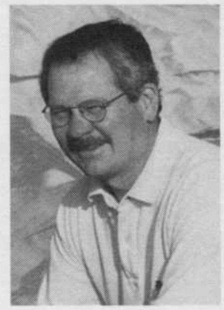
Take Heed, Nature Needs Us Just as We Need Her



Bruce Shank

No matter how much we study nature in an effort to predict and control economic disasters, she always reminds us that we have a long way to go. But we keep trying. Harnessing nature's own power to correct imbalances seems to be wiser than to depend too heavily on artificial solutions. Natural solutions are slower and less reliable than some of our manmade tricks. Our manmade solutions are often necessary to bridge the gap between disaster and nature's own solution. It's ludicrous to condemn our laboratory-born answers to problems in favor of natural answers. We have both and we should use both.

Clearly the future of turfgrass management involves increased application of natural techniques to meet manmade expectations. Lowering our expectations does not seem to be the most popular answer. So we need to dig deeper into nature's bag of tricks.

We can't seem to control natural processes to the same degree that we can artificial ones. Science and nature do not see eye to eye. Repeatable results from specific events do not always occur in nature because nature has variables we don't see or know how to manipulate.

Modern technology is helping us understand more of nature's variables. Satellites, computers, and gene manipulation are bringing us closer to the rules of science. This is viewed as interference to some because the potential for misuse generates fear. Nevertheless, that is the way we are headed and there seems to be no turning back.

Turfgrass management is not exempt from the modern technology. Turf managers will need to have a broader education in the future to fully appreciate the impact of their work. Few occupations are as exposed to nature as we are. Therefore, our responsibility to protect nature is greater.

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