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CO-HORT

A NEWSLETTER FOR TURFGRASS, LANDSCAPE, AND NURSERY ISSUES.

TURFGRASS TABLE TALK

by Victor A. Gibeault

RESEARCH RESULTS

The Turfgrass and Environmental Research Program that is sponsored by the United States Golf Association (USGA) was initiated in 1982. It is conducted in cooperation with the Golf Course Superintendents Association of America (GCSAA). Nearly $1.2 million was expended in 1995 for projects that were focused in the research categories of turfgrass breeding, alternative pest management, cultural practices and best management practices, pesticide and nutrient fate, golf course benefits and putting green construction. Dr. Michael Kenna, Director of the USGA Green Section Research, has assembled the 1995 annual report, summarized significant findings or results, and they follow.

- CRENSHAW (Lofts Seed) and CATO (Pickseed West) creeping bentgrasses continue to do well in the southern United States. CATO has done very well in some northern variety tests.

- MARINER (Syn1-88), a re-selection from SEASIDE, was released to Pickseed West for low-maintenance areas using poor quality irrigation water.

- CENTURY (Syn92-1) and IMPERIAL (Syn92-5), selected for improved heat tolerance and rooting, were released to Burlingham & Sons.

- PENNLINKS (Tee-2-Green) and PROVIDENCE (Seed Research) creeping bentgrasses are still used very successfully throughout the United States.

- OKS 91-11 has demonstrated superior cold tolerance among seeded bermudagrass and will be released in 1996.

- A seeded bermudagrass study conducted at the University of Georgia indicated that three of the Oklahoma State University experimental varieties were consistently better than Arizona Common.

- TIFTON 94 (MI-40), a mutant of vegetatively propagated MIDIRON bermudagrass, was released by Dr. Wayne Hanna from the USDA-ARS at Tifton, Georgia, for use on golf course fairways.

- TW-72 was developed by Dr. Wayne Hanna and has performed well in a bermudagrass putting green management study at Auburn University.

- MN 184 creeping bluegrasses *(Poa annua var. reptans)* was released to Peterson Seed by the University of

INSIDE THIS ISSUE

Minnesota. Small quantities of seed will be available for testing on golf courses in 1997.

• Several of the vegetatively propagated zoysiagrasses developed by the Texas A&M University Agriculture Experiment Station at Dallas have performed well. DIAMOND (DALZ 8502) was released. Three other zoysiagrasses will be released in 1996.

• CODY and TATANKA seeded buffalograss were released by the University of Nebraska to the Native Turf Group (NTG).

• The vegetative buffalograss varieties '609', '315', and '378' all continue to perform well on golf course roughs.

• Close mowing trials have helped identify several seashore *Paspalums* for fairways that will be useful for golf courses in the south that irrigate with water high in salts.

• Results from University of Nevada indicate that buffalograss can provide adequate turf for roughs with deficit irrigation of 50 to 60 percent of evapotranspiration (ET).

• Five methods of evaluating ET_0 (reference evapotranspiration) vary by as much as 20% according to the results of the University of Arizona study.

• Molecular genetics techniques continue to provide information on how some bermudagrass plants tolerate lower cold temperatures.

• Creeping bentgrass plants resistant to glufosinate ammonium herbicide (Finale or Ignite) were successfully produced using genetic engineering technology.

• Biological technology is being used to produce disease resistant bentgrasses by introducing genes that produce the chitinase protein.

• Bentgrasses resistant to brown patch *(Rhizoctonia solani)* were successfully selected using the Host Plant Interaction System (HPIS) developed at Mississippi State University.

• Several bacteria are under evaluation for their disease suppressive characteristics on summer patch *(Magnaporthe poae)* and *Pythium*-incited diseases of creeping bentgrass.

• Results at the University of Kentucky suggest that the number of grubs required to cause noticeable injury was much higher than prevailing rule-of-thumb estimates used by the turf industry.

• Mowing at 1/8 or 3/16 of an inch removes nearly all of the black cutworm eggs laid on bentgrass greens. This suggests that cutworm infestations may originate from larger larvae that migrate onto greens from surrounds.

• A new species of bacteria which parasitizes the sting nematode *(Belonolaimus longicaudatus)* is under evaluation at the University of Florida.

• Mole cricket behavior studies conducted at Cornell and NC State University indicate that their tunneling is affected by the presence of other crickets, soil type and subsurface placement of insecticides.

• A bioassay technique developed at the University of Arkansas indicates that perennial ryegrass produces an allelopathic substance. Field studies are underway to examine if the allelopathic substance reduces crabgrass infestations.

• Pesticide and nutrient runoff research at Oklahoma State University has demonstrated that untreated buffer strips reduce the amount of chemical in runoff water. However, when the soil is saturated from extended periods of rain, the buffers strips have little or no effect.

• The volatilization research at University of Massachusetts has shown the importance of considering the vapor pressure of a pesticide. Pesticides with higher vapor pressures are more prone to volatilization.

• Research at University of California has shown that the amount of chlorothalonil and metalaxyl to volatilize from putting green field plots is less than 1% over a 10-day period .

• University of Florida research indicates that irrigation amount and frequency influence the amount of fenamiphos and its metabolites that leach through high-sand putting green rootzones. However, after a heavy rainfall, the amount of metabolite leaching through the green was the same for the high and low irrigation treatments.

- The results for nine pesticide products produced a high correlation ($r^2 = 0.91$) between the amount of pesticide found in runoff water and the pesticide's water solubility. Less than 1% of the applied chlorothalonil, chopyrifos, benefin, and pendimethalin was transported from the plots in runoff water. However, as much as 9 to 16% of the 2,4-D, dicamba, mecoprop, and nitrate were transported in the surface runoff.

- Purdue University results show that concentrations of metalaxyl, triadimefon, and vinclozolin fell below detectable limits within 13, 10, and 17 days, respectively. At the termination of the experiment, chlorothalonil was detectable at low levels from clippings collected 27 days after application.

- The USGA and GCSAA will fund 10 "Construction and Maintenance of Greens" research projects over the next five years. The overall goal of the research is to identify the best combinations of construction, grow-in procedures and post-construction maintenance practices that prevent long-term problems, reduce environmental impacts, and produce high quality playing surfaces.

- The USGA continues to support the Audubon Cooperative Sanctuary Program for golf courses and is in the final stages of selecting Wildlife Links projects to produce educational materials on how to enhance wildlife habitat on golf courses.

RECENT NEWSLETTER SUMMARIES

The following releases are from a recently initiated newsletter "Better Turf Through Agronomics", which is an activity of the University of California, Riverside Turfgrass Research Advisory Committee (UCR-TRAC). The intent is to present summaries of turfgrass research results and topical information of interest to the Southern California turfgrass industries. The newsletter is edited by Vic Gibeault and Deborah Silva.

UCRTRAC -- A New Linkage Between Researchers and Industry Clientele

The new Turfgrass Research Advisory Committee at the University of California, Riverside, known as UCR-TRAC, is addressing the research and educational needs of the Southern California turfgrass industries.

The group was established for the purpose of industry betterment, to provide a formal industrywide linkage between the University of California and the turfgrass industries in Southern California. Member organizations contribute to UCRTRAC research and education efforts.

Member organizations represent golf course superintendents, sod producers, general turfgrass interests, professional golfers, and UCR researchers with expertise in turf improvement, physiology, and culture.

UCRTRAC has identified 11 research and education industry needs.

- Irrigation-Water Use Efficiency (includes effluent water)
- Environmental Impact of Turf Chemicals and Fertilizers
- Unbiased, Specific Issue Analysis Reports
- Unbiased Product Testing (fertilizer, pesticides, equipment)
- Unbiased Cultivar Evaluations
- Wear/Traffic Issues -- Safety, Playability
- Production of Quality Putting Greens
    - Annual bluegrass/creeping bentgrass summer decline
    - Managing/controlling annual bluegrass
    - Wear/traffic issues
    - Pest control
    - Soil compaction and salinity issues
- Accessible, User-Friendly Research/Education Reports
- Pest Control (IPM, Biological Control, Other Methods)
- Ability to Respond to Sudden Research and Education Industry Needs
- Management and Control of Kikuyugrass

Two delegates represent each member organization for a three-year period. Current industry members are the California Golf Course Superintendents Association (**Tracy Barcelona, John Pollock**), California Sod Producers Association (**Jurgen Gramckow**), Golf Course Superintendents Association of Southern California (**Bert**

Spivey, Steve Sinclair), Hi-Lo Desert Golf Course Superintendents Association (**Craig Shafer, Ty Broadhead**); San Diego Golf Course Superintendents Association (**Tim Barrier**), Southern California Golf Association (**John Martinez, Kevin Heaney**), Southern California Section, Professional Golfers Association of America (**Tom Gustafson, Scott Walter**), Southern California Turfgrass Council (**Mark Hodnick, Fred Eckert**), Southern California Turfgrass Foundation (**Neal Beeson, Chuck Wilson**), and United States Golf Association (**Pat Gross**).

UCR members are **Vic Gibeault**, Cooperative Extension Environmental Horticulture Specialist, **Robert Green**, Turfgrass Research Agronomist, and **Steve Cockerham**, Superintendent, Agricultural Operations. Cooperating researchers include their staffs at UCR and at the South Coast Research and Extension Center and UC farm advisors in the Southern California counties.

The Turgrass Research Facilities and Program at UCR provide resources to accomplish UCRTRAC goals and objectives.

Fate of Pesticides and Fertilizers in a Simulated Golf Course Turfgrass Environment

Little potential exists for contamination of ground water and air from fertilizers and pesticides applied to turf in a golf course environment if management practices that minimize detrimental environmental impacts are used.

Fertilizers and pesticides applied to turf on golf course greens and fairways do not contaminate ground water or air if management practices that minimize detrimental environmental impacts are used, according to the results of a simulation study conducted by **Marylynn Yates**, Environmental Microbiology and Ground Water Quality Specialist at the University of California, Riverside (UCR).

Management practices in the study included nitrogen fertilizer applied once every 2 weeks as sulfur-coated urea or urea at rates of 1.0 and 0.5 lb N per 1,000 ft^2 per month to the green and fairway plots, respectively. Irrigation was 100% or 130% ET.

Since fairways are similar to many general turfgrass sites, the results can be extrapolated to general turf situations if similar management practices are used, Yates said.

The 12 putting green test plots were constructed with a typical greens sand with 15% sphagnum peat moss and sodded with Penncross creeping bentgrass. The 24 fairways test plots consisted of 12 sandy loam and 12 loamy sand soils sodded with Tifway II bermudagrass.

Nitrate-N, phosphate-P, 2,4-D, and carbaryl (Sevin) concentrations were analyzed weekly in samples collected from drains and soil-water samplers in each of the 36 plots. The mass of pesticide and nutrients leached and the amounts volatilized were also determined.

Leaching Results

- Little leaching of nitrate-N (<1% of the amount applied) was measured. Neither irrigation amount nor fertilizer type resulted in significant differences in percent leached.
- Leaching of 2,4-D was very low in soils that contained some clay to adsorb the pesticide; however, up to 7.5% leaching was measured in the putting green plots where the soil was too sandy to prevent the movement of a portion of the chemical below the root zone. Irrigation amount did not significantly affect the amount leached.
- Less than 0.1% of the carbaryl (Sevin) leached, regardless of soil type. Irrigation amount applied did not significantly affect amount leached.

The rates of leaching could increase if higher concentrations of fertilizer are used or if more frequent applications are made, Yates said.

Volatilization Results

- Little volatilization of 2,4-D was measured (<1.0%) from any of the plots, although there was a significant difference between the two turfgrass species.
- Little volatilization of carbaryl was measured (<0.05%) from any of the plots. No significant differences occurred between the treatments.

Public concerns about potential nitrate and pesticide contamination of ground water and air prompted the study, which was funded by the United States Golf Association.

Additional studies are underway at UCR using different fertilization regimes and other management practices to identify even more precisely the best management practices that yield good-looking, high quality turf for putting greens and fairways, while at the same time protecting ground water resources.

Bentgrass Variety Trials

UCR's first creeping bentgrass variety trials are underway at The Springs Club in Rancho Mirage, Industry Hills Golf Course, and Rancho Santa Fe Golf Club.

The three locations provide desert, midland, and coastal sites for unbiased, representative evaluations of creeping bentgrass performance on putting greens.

"We are evaluating 20 of the same creeping bentgrass genotypes and/or blends in the desert climate, where heat is the major issue and there is generally no annual bluegrass and in midland and coastal climates where most putting greens are a mixture of creeping bentgrass and annual bluegrass, in which superintendents are managing both species because of the mild climate," said **Robert Green**, UCR Turfgrass Research Agronomist and study leader.

"We hope to add several *Poa* genotypes to the study this fall," Green said.

Genotype x environment interactions may lead to location-specific creeping bentgrass cultivar and/or blend recommendations that golf course superintendents can rely on in the future, Green said.

Standardized visual turfgrass ratings are collected every 4 to 6 weeks and may include overall quality, color, texture, density, stress and pest tolerance, traffic and injury tolerance, and other characteristics.

Results are too preliminary to report. The first year of the three-year study will be completed this fall.

Green's cooperators are UC Cooperative Extension environmental horticulture advisors for five Southern California counties: **Janet Hartin, David Shaw**, and **Mike Henry**. Cooperating golf superintendents include **Bert Spivey, Tim Barrier**, and **Mike Kocour**. Industry cooperators are **Tracy Barcelona** and **John McShane**.

Topdressings for Disease Control on Turf

Biocontrol-fortified composted municipal biosolids provided control of dollar spot.

Composted municipal biosolids topdressings applied to Penncross creeping bentgrass provide significant control of *Sclerotinia homoeocarpa*, the fungus that causes dollar spot, says **Marcella Grebus**, Extension Plant Pathologist at UC Riverside.

Grebus recently completed three years of study comparing a commercial fungicide (chlorothalonil) with various compost topdressings (composted yard waste, leaf humus, and municipal biosolids) and an untreated control for managing dollar spot disease.

When fortified with two biological control agents, the composted municipal biosolids topdressing provided significant disease control ($p=0.05$) as did the chlorothalonil treatment. The two biocontrol agents were *Trichoderma hamatum* 382 and *Flavobacterium balustinum* 299r_2.

Topdressing frequency ranged from quarterly to annually, depending on the specific study.

"Compost topdressings on turf hold promise for facilitating the reduction of chemical use as well as improving overall growth and plant quality," Grebus said.

Other benefits of organic topdressings include reduced input costs and decreased health and environmental hazards, Grebus said.

Public concerns about pesticide efficacy and regulation are prompting research on the use of organic amendments to reduce or replace the use of synthetic pesticides, Grebus said.

Improved Winter Color of Warm-Season Turfgrasses: NTEP Variety Trial Results

Newly patented UCR zoysiagrasses and three bermudagrass cultivars provide improved winter color. Over-

seeding trials and management studies are continuing for enhanced winter color.

To address industry and consumer demand for green lawns and playing fields year-round, UCR turf researchers have systematically evaluated newly developed experimental lines and existing cultivars of bermudagrass and zoysiagrass for improved winter color.

Traditionally, in Southern California, winter discoloration of dormant warm-season turf is overcome by overseeding, using colorants, fertilizing with higher rates of nitrogen, or by planting cool-season turf, even though warm-season species have lower irrigation water requirements.

Results of a UCR zoysiagrass breeding program and NTEP study showed that 'De Anza' (UCRZ88-8), 'Victoria' (UCRZ88-14), and a Texas A&M University release, 'Diamond' (DALZ8502) consistently held the best color during the fall and winter months at research sites in Riverside and Irvine, said **Vic Gibeault**, UCR Environmental Horticulture Specialist.

The two UCR zoysiagrasses were patented recently and will be commercially available soon.

Of the commercially available bermudagrasses tested, Tifway, Tifway II, and Santa Ana held the best color during the winter months. Tifgreen, Midiron, and Guymon had the longest, most intense dormancy.

Bermudagrass cultivars differed in their dormancy patterns, but average soil temperature below 50°F for more than one week resulted in color loss for all cultivars, due to chlorophyll degradation.

Based on the results of these NTEP variety trials at UCR, consumers can now choose warm-season cultivars with improved winter color.

In addition, perennial ryegrass and *Poa trivialis* overseeding trials for improved winter color on warm-season turf are currently being evaluated by **Mel Robey**, Bermudagrass Triangle Research Center, with data analysis assistance provided by **Robert Green**, UCR Turfgrass Research Agronomist. Also, recent work by Gibeault shows that substantial winter color can be maintained with late fall and winter nitrogen and iron applications.

LANDSCAPE LIGHTINGS

by Dennis R. Pittenger

MEASURING LIGHT IN HORTICULTURE

What is sufficient light for plant growth and development and how can it be measured? One or both of these questions frequently arise when plants are grown indoors or when light conditions need to be documented in plant research projects.

Light from the sun is transferred to plants as radiant energy (solar radiation). Solar radiation is important to plants in four main ways:

1 <u>Thermal effects</u> which drive transpiration and temperature dependent processes.

2 <u>Photosynthesis</u> in which solar radiation is absorbed and used to synthesize reduced carbon compounds and energy-rich chemical bonds.

3 <u>Photomorphogenesis</u> in which the amount and spectral distribution of solar radiation plays a role in regulating growth and development.

4 <u>Mutagenesis</u> in which short-wave solar radiation can affect the structure of genetic material.

The limited portion of radiant energy that we see is known as "light". Radiant energy occurs in waves yet also behaves like a stream of particles termed "photons". As a result, it is most accurately characterized by measuring its irradiance, flow rate or energy content. The specific units selected to measure solar radiation or light depend on the objective.

In horticulture and other plant sciences, irradiance is usually the appropriate term for quantifying solar radiation. It is often incorrectly called "intensity". Irradiance is the radiant energy flux <u>received</u> on a unit plane surface and is expressed on a photon basis as moles per meter squared per second (mol m^{-2} sec^{-1}), or on a total energy basis as Joules per second per meter squared (J sec^{-1} m^{-2}). Intensity, on the other hand, describes only the energy or light <u>emitted</u> from a source.

Photosynthetically active radiation, or PAR, is commonly used in horticulture and related sciences to express irradiance in units of the total energy in the wavelengths most active in photosynthesis (400 to 700 nm). The SI units for PAR are Wm^{-2} (watts per meter squared). Similarly, photosynthetic photon flux (PPF) is also referred to as PAR, although it expresses the photons per unit area per unit time that are absorbed from photosynthetically active light. PPF units are moles per meter squared per second ($mol\ m^{-2}\ sec^{-1}$).

Historically, irradiance and light and intensity were measured in units of illumination or how bright the light source looks, rather than in units of photons or total energy received from the source. The units of "foot-candle", "lux", and "lumen" measure illumination. Foot-candles are from the English system where one foot-candle (ft-c) is the amount of light received from one "standard candle" on one square foot of surface that is one foot from the candle. The lux is from the metric system and is the amount of light received from a standard candle on a square meter of surface that is one meter from the candle. The lumen (luminous flux) is used to express the brightness of the light emitted by a source, where one lumen is the total light emitted from a standard candle.

The mathematical equivalents of these units are expressed below.

1.0 ft-c = 10.76 lux = 1.0 lumen per square foot
1.1 lux = 0.09 ft-c = 1.0 lumen per square meter

These units are scientifically obsolete because they are defined in terms of the inexact sensitivity of the human eye, while plants respond to the radiation and light spectrums quite differently. However, even units that express the energy or photons of radiation can be of limited use unless the wavelength distribution is also described.

There are special instruments for scientifically measuring solar radiation. Instruments for measuring PAR as irradiance in the PAR or as photon irradiance in the PAR (PPF) are called photosynthetic energy sensors or quantum sensors, respectively. Radiometers, net radiometers, and solarimeters (pyranometers) measure total radiant energy flux.

For home horticulturists and others that want a reasonable estimate of the amount of light that plants receive, simple light meters are available which measure the intensity of visible light in foot-candle units. Full sun outdoors, at mid-day will reach about 10,000 ft-c. The interior of a lighted home will range from about 40 to 500 ft-c in the center of rooms, while areas at or near windows will range from about 200 to 5,000 ft-c. Foot-candles of light can also be roughly estimated by using a 35 mm camera with a built-in light meter. Various methods are reported for estimating light intensity with a camera, but their accuracy is not documented. Two methods are summarized below in Table 1.

Table 1. Estimating foot-candles of light using the light meter of a camera.

Method 1: (from Unknown, 1975)

Take your reflected reading off a piece of white paper large enough to completely fill the field of view of the camera or meter.

Set the ASA to 200 and the speed to 1/500 sec.

Aperture	Foot-candles
f/22	5000
f/16	2500
f/11	1200
f/8	550
f/6.3	300
f/4.5	150

Method 2: (from Schumann, 1980)

Set the ASA exposure index to 100.
Set the lens opening to f/4.
Place a sheet of matte-finished paper in the location to be read. Fill the view with the paper.
Read the exposure time for the approximate number of foot-candles at the spot being viewed, e.g., 1/60 = 60 fc, 1/1000 = 1000 fc, etc.

Although the general relationship of light meter foot-candle readings to PAR measurements is not very meaningful (as they measure entirely different characteristics of light), it is interesting to see how the two units compare. In a non-replicated experiment, simultaneous readings were taken outdoors in both low and high light conditions with a light bar to obtain PAR (μ mol m^{-2} sec^{-1}), with a G.E. #214 hand-held light meter to obtain foot-candles, and with a 35 mm camera to obtain f-stop settings needed for proper exposure using a 50 mm lens set at ASA 200 and shutter speed at 1/500 sec. Foot-candle readings and f-stop settings were taken as reflection off white paper at each light level. The comparisons are found in Table 2, and illustrate the limitations in using camera light meters to gauge light conditions and in comparing PAR with foot-candle measurements.

Table 2. Simultaneous measurements of PAR, Ft-Candles and Camera F-stop Settings Under a Range of Natural Light Conditions.

PAR[1] (μ mol m^{-2} sec^{-1})	Ft-Candles[2]	Camera[3] f-stop
6.0	14	*
7.7	16	*
8.0	21	*
10.0	25	*
12.5	33	*
15.0	40	*
21.0	52	*
30.0	82	<2.8
45.0	108	2.8
55.0	135	3.0
60.0	146	<3.5
75.0	175	4.0
92.0	275	>4.0
122.0	295	5.0
715	4150	16
980	5200	16
1100	6000	22-32

*Light was too low to get a reading.
[1]Light bar measurement.
[2]Reflected measurement off white paper using G.E. #214 light meter.
[3]Reflected reading off white paper using 50 mm lens at ASA 200 and shutter speed 1/500 sec.

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ADDITIONAL INFORMATION AND CORRECTIONS TO OLEANDER LEAF SCORCH ARTICLE (CO-HORT, VOL. 2.2 & 2.3, P. 3)

Michael Henry, *Env. Hort. Advisor, University of California Cooperative Extension, Riverside and Orange Counties*

The original article on this subject triggered some calls about the wording of the title and requests for more information. Further background information on *Xylella fastidiosa* can be found in the brief bibliography below, which served as the basis for the original *Co-Hort* article.

With regard to the title of the article, Dr. Don Cooksey, Chair of the Plant Pathology Department at UC Riverside, specializing in bacterial diseases, pointed out that it is incorrect. It should read "Landscape Plants Known to be Susceptible to Various Strains of *Xylella fastidiosa*." As the text indicates, this bacterial species has numerous strains that are quite specific in their pathogenicity. It is the causal organism for various leaf scorch diseases (Pierces Disease, [Anaheim Disease] of grapes, Alfalfa Dwarf, Almond Scorch, etc.), but is yet to be verified as the pathogen suspected of causing Oleander Leaf Scorch. The fact that one strain can cause disease in Elm does not automatically mean that a new Oleander strain will also cause other plants to become infected and die. Once the causal organism for Oleander Leaf Scorch has been positively verified, Cooperative Extension researchers will begin testing various ornamentals for susceptibility and resistance and will report on progress as it becomes fully verified scientifically.

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NURSERY NOVELTIES

by Ursula K. Schuch

CULTURAL PRACTICES AND CHRYSANTHEMUM - How fertilizer, irrigation, and cultivar choice affect plant growth and insect pests

U.K. Schuch, R.A. Redak and J. Bethke

In a recent study, we showed that cultivar choice, fertilizer and irrigation regimes in the production of poinsettias affected not only plant growth, but also survivorship and development of the silverleaf whitefly. Many chrysanthemum cultivars are produced commercially, and changes in cultural practices often result in cultivar-specific responses. One aspect of environmentally responsible plant production should be to use minimum amounts of fertilizer and water during the production of a high quality crop, thereby conserving resources and minimizing runoff problems from production areas.

Insect damage on ornamental plants is primarily controlled through the application of pesticides. Public awareness about the hazards of insecticide use, and buildup of insecticide resistance in several insect populations have started inquiries to develop and integrate new pest control techniques that minimize environmental hazards associated with new control tactics. A possible alternative is the utilization of effective plant resistance characteristics to manage and reduce insect populations in ornamental crops. A second factor which may affect plant resistance is manipulation of the growing environment. It has been well documented that water stress, plant nitrogen status, and other management and cultural practices will influence the susceptibility of plants to their insect pests (*see also related article Plant - Insect Interactions in this issue*).

The two objectives of this study were to 1.) determine vegetative growth characteristics, and 2.) investigate the potential use of plant resistance of six chrysanthemum cultivars to differential watering and fertilization regimes on regulating populations of leafminers, thrips, and mealybugs on chrysanthemum.

We grew six chrysanthemum cultivars ('Fontana', 'Iridon', 'Pink Lady', 'Splendor', 'White Diamond', and 'White View Time') under three N concentrations (80, 160, or 240 mg N l^{-1} continuous fertigation) and two irrigation levels (high or low) for a period of ten weeks of vegetative growth. Plants grown under high irrigation received sufficient water and showed no symptoms of water stress, while plants under low irrigation showed water-stress symptoms and generally started to wilt between irrigations. Runoff water from 'White Diamond' was collected weekly to monitor EC levels.

Plant responses: Plants fertilized with 80 mg N l^{-1} had lower leaf and stem dry weight, smaller leaf area, and less leaf N than plants fertilized with twice the amount of N (Table 1). The highest stem dry weight was produced with 160 mg N l^{-1} fertilization. Leaf and stem dry weight were 25% lower in plants under low irrigation than in those under high irrigation. The largest leaf area was produced by 'White Diamond' and 'Fontana' fertilized with 160 mg N l^{-1} under high irrigation; low irrigation at that fertilizer level caused the highest reduction in leaf area. In general, leaf area increased when fertilizer was raised from 80 to 160 mg N l^{-1} but differed by cultivar and irrigation treatment when fertilizer was increased to 240 mg N l^{-1}.

Table 1. Leaf and stem dry weight of six chrysanthemum cultivars grown for 10 weeks under three fertilizer and two irrigation treatments.

	Dry Weight (g)	
	Leaf	Stem
Fertilizer (mg N l^{-1})		
80	31.3 b^z	25.1 c
160	36.3 a	30.5 a
240	34.5 a	27.1 b
Irrigation		
Low	29.1 b	23.4 b
High	39.1 a	31.9 a
Cultivar		
'White Diamond'	31.1 c	26.4 b
'Fontana'	38.3 a	30.3 a
'Iridon'	33.7 bc	26.5 b
'Pink Lady'	32.9 c	28.3 ab
'Splendor'	35.6 b	27.9 ab
'White View Time'	32.3 c	26.1 b

^{z} Means within a column followed by different letters are significantly different at $P \leq 0.05$, Duncan's multiple range test.

Average EC of the applied irrigation solutions was 1.2, 1.8, and 2.4 dS/m for the three fertilizer treatments. The level of weekly EC of runoff from 'White Diamond' was significantly higher for plants fertilized with 240 mg N l^{-1} than for those under the other two fertilizer treatments, starting 1 week after treatment began until the end of the experiment. This fertilizer treatment resulted in EC levels as high as 3.86 dS/m which often exceeded the levels of the lower fertilizer treatments by 1.6 dS/m.

Potting medium of plants fertilized with 240 mg N l^{-1} contained EC levels above 3.0 dS/m for 'Fontana', 'Iridon', 'Pink Lady', and 'White View Time' at the end of the experiment. This fertilizer treatment also reduced stem dry weight (11% less) compared with the 160 mg N l^{-1} treatment, most likely as a result of the high medium EC.

Insect responses: Melon aphid nymphs were significantly affected in longevity and fecundity by the chrysanthemum cultivar, but were unaffected by irrigation or fertilizer treatment of the host plant. Overall, 'Pink Lady' seems to be a relatively resistant cultivar, and 'White Diamond' seems to be susceptible to melon aphids based on survivorship, number of young produced, and longevity.

Leafminers caused 80% fewer punctures and subsequent mines on the resistant cultivar 'Splendor' compared to the relatively susceptible cultivar 'White Diamond'. Leafminers were not affected by the different water or nutrition status of their host plants.

Similar number of thrips infested chrysanthemum, regardless of the fertilizer or irrigation treatments. However, cultivar 'Iridon' was least susceptible to infestation by thrips and supported 47% fewer thrips than the most susceptible cultivar 'Pink Lady'.

These results lead to the following ranking of chrysanthemum cultivars:

Grower ranking	Insect ranking	Leafminer	Aphids	Thrips
Bad	Good	White Diamond	White Diamond	Pink Lady
↑	↑	Pink Lady	Splendor	Fontana
		White View Time	White View Time	White Diamond
		Iridon	Fontana	Splendor
↓	↓	Fontana	Iridon	White View Time
Good	Bad	Splendor	Pink Lady	Iridon

Conclusions:

These results show that cultivar choice of chrysanthemum may have a great effect on a specific insect problem, depending on whether a susceptible or resistant cultivar is grown, but that fertilizer or irrigation regime had no effect on insect populations. However, addressing one insect problem with resistant cultivars may favor conditions for another pest. Growers therefore need to know common local pest problems and possible future pests through detailed, high-quality scouting.

KNOW YOUR WORMS: FOLIAR NEMATODES

J. Ole Becker, *Department of Nematology, University of California, Riverside*

Diagnosis of nematode damage on ornamentals is often difficult. All plant parasitic nematodes are microscopically small and ordinarily live hidden below ground or in plant tissues. Above-ground disease symptoms caused by root-parasitizing nematodes, such as wilting, nutrient deficiency symptoms or chlorosis are usually nonspecific and can be attributed to various other biotic and abiotic problems. Foliar nematodes, also known as bud and leaf nematodes, should be suspected when susceptible hosts show localized chlorotic lesions which are typically delineated by their leaf veins. The infestation usually starts at the base of the leaf with interveinal, angular blotches and spreads upward. The lesions eventually turn blackish-brown and parts of the leaf may shrivel (Fig. 1). If young leaves or shoots are infested, they may not develop properly and may become deformed. In certain plants, such as dahlia, necrotic lesions on leaves often disintegrate. On African violets lesions appear as sunken areas between leaf veins on the lower leaf surface, which eventually extend through to the upper surfaces. In begonias the lesions are not angular but instedol bronzing, yellowing or reddening of foliage occurs. Leaves ultimately desiccate but usually remain on the plant.

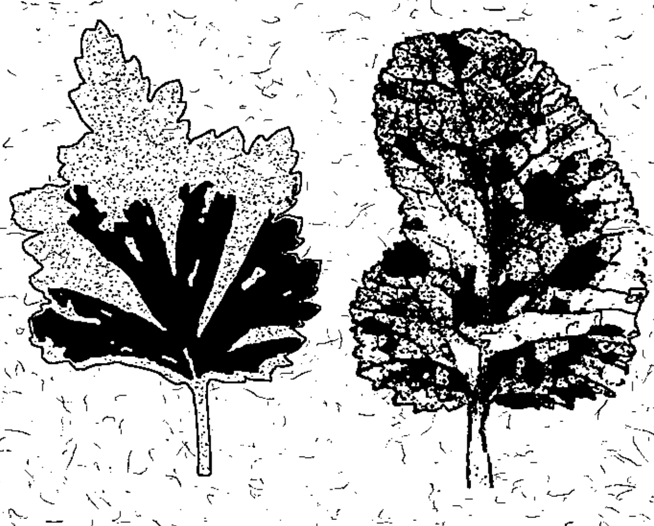

Figure 1. Disease symptoms caused by foliar nematodes (chrysanthemum left, primula right).

Leaf-parasitic nematodes of the genus *Aphelenchoides* occur commonly throughout the world. They prefer cool, moist conditions and are therefore more of a problem in temperate regions. In our climate symptoms become most distinct during the winter and early spring. *Aphelenchoides ritzemabosi* and *A. fragariae* are the most damaging species on ornamental plants and have been reported on more than 250 plant species in 47 families. Examples of host plants are ageratum, anemone, aster, begonia, calceolaria, cheiranthus, chrysanthemum, crowfoot, cyclamen, dahlia, delphinium, doronicum, fig, foxglove, goldenrod, groundsel, helenium, hydrangea, iris, lily, narcissus, pelargonium, peperomia, phlox, primula, rhododendron, rudbeckia, saxifrage, scabiosa, snapdragon, statice, stonecrop, tagetes, Uzambar violet, verbena, veronica, zinnia, and others. *A. fragariae* is also common on numerous genera of ferns.

Adults of foliar nematodes are about 1mm long. Under a dissecting microscope, they appear as slender nematodes with conical tails. They have a delicate mouth stylet and a large metacorpus occupying three-fourths or more of the width of the body (Fig. 2). The nematode multiplies by bisexual reproduction.

Fertilized females lay 25-30 eggs in a compact group and young larvae hatch within 3 to 4 days. The juveniles mature through a series of four molts to become adults. Reproduction is rapid and the life cycle can be completed in 12-14 days. Sperm is stored in fertilized females which allows continued reproduction for half a year without refertilization. Numerous generations follow one another and more than 16,000 nematodes have been found in one small chrysanthemum leaf. Due to their short life cycle and damage potential, only a zero threshold level for these nematodes is tolerable in potted plant production.

Hygiene and propagation in soil-free media have greatly reduced the occurrence of foliar nematodes. They are typically introduced into ornamental plant production by infested but asymptomatic vegetative propagation material, such as cuttings or rooted seedlings. Field soil should never be used in planting mixes unless it is treated appropriately to eliminate nematodes and soilborne pathogens. Plants with symptoms or infested old foliage should be destroyed.

Foliar nematodes do not survive in soil for more than a few months, but in slowly drying leaf tissues the adults of *A. ritzemabosi* are able to undergo fascinating physiological changes. They enter a stage of anhydrobiosis which is characterized by a lack of detectable metabolism while the organism's structural integrity is maintained. In desiccated plant tissues some *Aphelenchoides* species can survive several years. Once they are allowed to rehydrate they resume activity.

Foliar nematodes, as all nematodes, depend on water films to move. On moist plant tissues, these nematodes are able to overcome forces of gravitation and migrate up the plant. They enter leaf intercellular spaces through the stomata and feed on the cells of the mesophyll which results in necrosis of damaged tissues. In most hosts the leaf veins provide barriers which prevent nematode movement within the tissues. This explains the shape and pattern of symptoms. If moist conditions prevail, the nematodes migrate out of the stomata and infest other areas of the leaf.

When infestations are observed, crowding of plants and overhead watering should be avoided to lessen the risk of dissemination via water films on plant surfaces. Currently there are no nematicides registered for postplant control of foliar nematodes.

Figure 2. Anterior region of *Aphelenchoides ritzemabosi*.

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PLANT - INSECT INTERACTIONS

The question how plant water and nutrient status affect plant - insect interactions has long been of interest. While the view that plant stress exerts strong positive effects on herbivore populations has gained almost paradigm status in ecology, there is still no clear understanding how herbivores typically respond to stressed host plants. Although a number of studies found that herbivores responded positively to stressed plants, meaning that insect survivorship, growth rate, and/or fecundity increased on stressed versus non-stressed control plants, an almost equal number of studies found negative or no response.

Environmental stress is known to change the defense chemistry of plants, alter levels of nitrogen, reduce growth, and increase leaf temperature and water potential among other responses. Waring and Cobb (1992) have reviewed more than 450 studies on herbivorous insects and mite response to nutrient and water deficits in plants. Following is a summary how different feeding guilds of insects (sucking, chewing, mites, galling) respond to artificial or natural water stress or nitrogen fertilization, and how plant type affected herbivore responses to water stress or nitrogen amendments.

Water stress: Insect response to water stress depends on whether plants were experimentally stressed or suffered from natural lack of water by drought or chronic water stress. About half of the herbivores responded negatively to experimental water stress (51% of 99 cases), while the majority of herbivores responded positively to naturally water stressed plants (68% of 75 cases) (Fig. 1). Herbivore response to experimental water stress was highly variable as indicated by the number of positive, nonlinear, or no responses. Studies reporting herbivore response to drought or chronic water stress quantified insect response, but did not quantify the level of stress on the plants; rather they assumed stress and generally had no unstressed control conditions for comparison.

Plant type greatly affects how herbivores respond to water-stressed plants. Herbivore response to water-stressed conifers was overwhelmingly positive, while responses to stressed broadleaf trees were half positive, half negative (Fig. 2). The majority of herbivores exposed to smaller plants, including shrubs and vines or herbs responded negatively to water stress (Fig. 2). Another interesting finding was the differential herbivore response to stressed wild or cultivated plants. Most herbivores responded negatively to experimentally water-stressed wild plants (72%), versus only 37% negative response to water-stressed cultivated plants. This may suggest that water stress possibly increases the defense system in wild plants, while this mechanism may be lacking in cultivated plants.

The varied responses of herbivores to different types of water-stressed plants indicate that insect - plant interac-

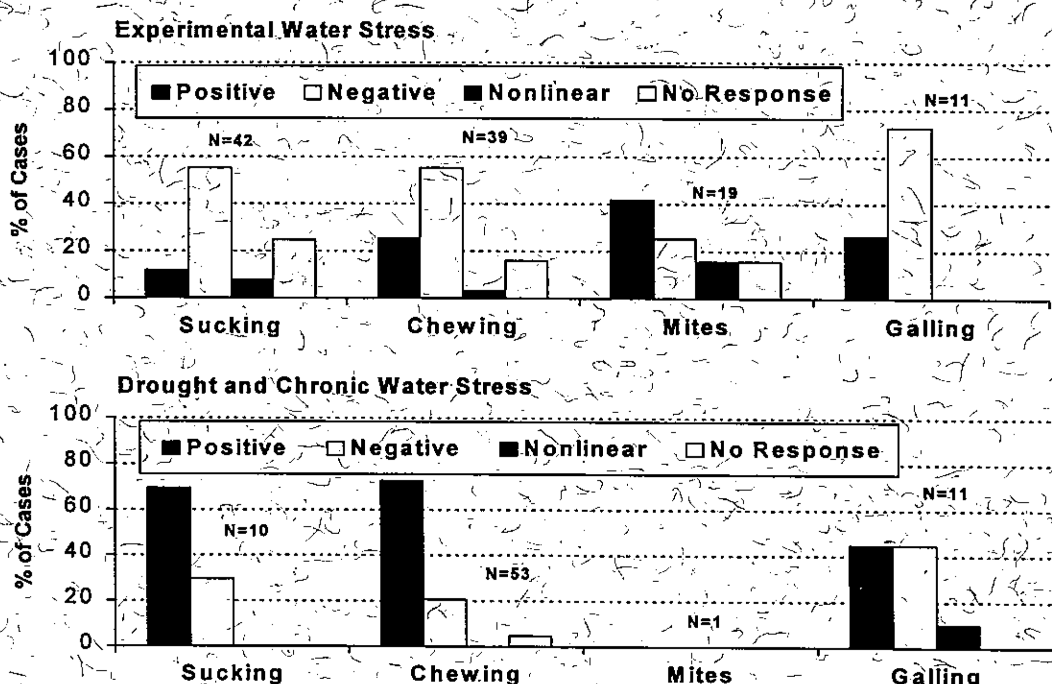

Figure 1. Herbivore response to experimentally induced water stress or drought and chronic water stress, measured as percentage of studies.

tions are complicated. These results also emphasize that we need better understanding of how level of stress, timing, and duration in experimental or drought and chronic water stress are related to each other and why they can significantly affect the outcome of a study. Quantification of plant stress as well as further examination of plant defense chemistry in future plant - insect interaction studies may help to better understand these relationships.

Nitrogen fertilization: Nitrogen enhancement of plants has a strong positive effect on insects, as shown by almost 60% positive herbivore response (Fig. 3). Only 11% of studies reported negative herbivore response. Herbivore response to nitrogen-fertilized broadleaf trees and herbs was positive in more than 80% of the studies, but herbivores showed no distinct preference for fertilized conifers (Fig. 4). This may suggest that fertilized conifers are more likely to become more resistant or less attractive to herbivores than fertilized broadleaf trees or herbs.

Overall, the positive response of herbivores to nitrogen-fertilized plants emphasizes that nitrogen seems to be limiting and valuable to insects. It also seems that herbivore performance on nutrient-poor plants was generally lower, and that these insects could not compensate for poor nutrient quality with quantity. Mechanisms of why fertilization renders improved host plants for herbivores are unclear and could be due to increased nutrient levels, decreased defenses, or a combination of both.

From: Waring, G.L. and N.S. Cobb. 1992. The impact of plant stress on herbivore population dynamics. *In:* Bernays. E. (Ed.) Insect - Plant Interactions. Vol. IV. p.167-226.

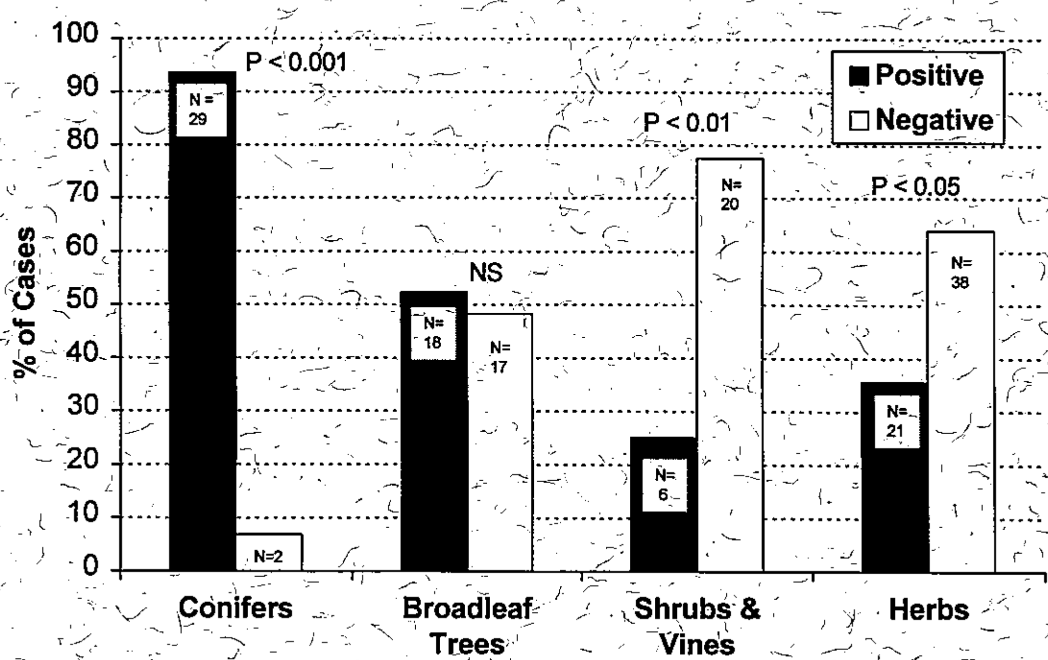

Figure 2. Percentage of studies in which herbivores responded positively or negatively to all forms of water stress in different types of plants.

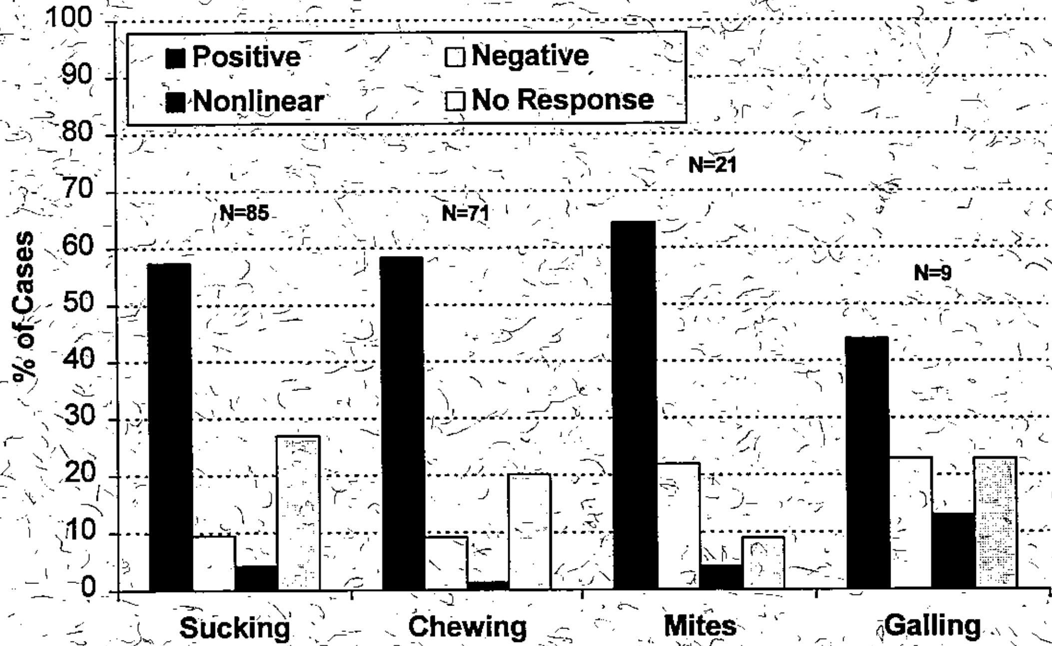

Figure 3. Responses of different feeding guilds of herbivores to nitrogen fertilization, measured as percentage of studies.

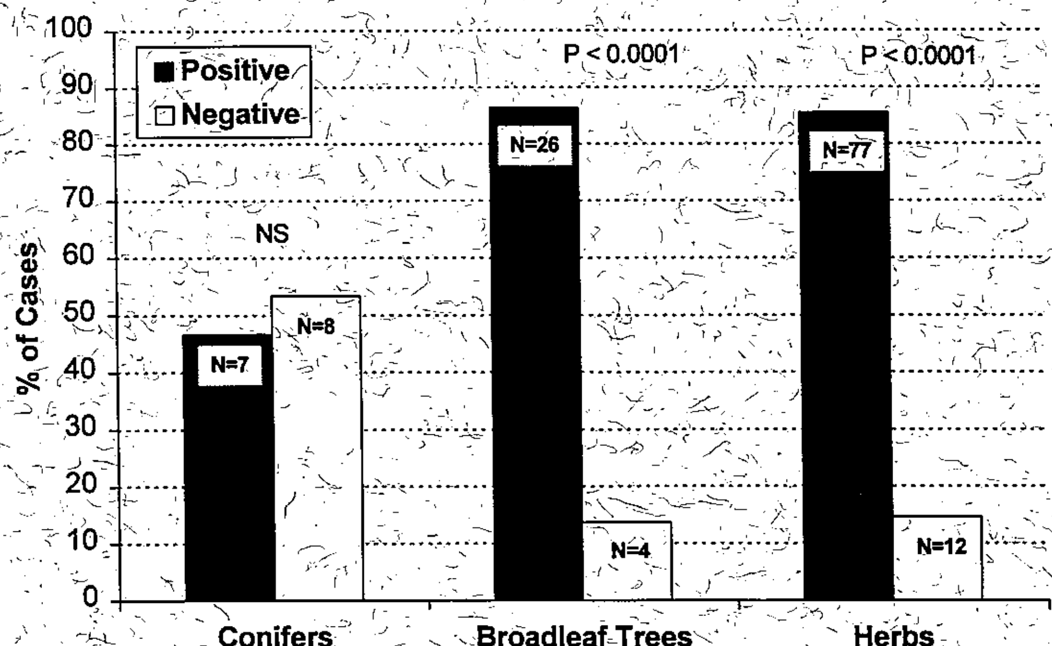

Figure 4. Response of herbivores to nitrogen fertilization in conifers, broadleaf trees, and herbaceous plants.

CALENDAR

MONTH	EVENT AND LOCATION	CONTACT
January 8, 1997	Turfgrass, Landscape, and Sports Turf Institute, Sequoia Athletic Club and Conference Center, Buena Park, CA	Pam Pavela, (800) 500-SCTC
January 20-22, 1997	California Weed Science Society Conference, Fess Parker's Red Lion Inn, Santa Barbara, CA	Wanda Graves, (510) 790-1252
January 22-23, 1997	Western Plant Growth Regulator Society Conference, Fess Parker's Red Lion Inn, Santa Barbara, CA	Wanda Graves, (510) 790-1252
February 6-7, 1997	Weed Management and Horticultural Crops Workshop, Clarion Plaza Hotel, Orlando, FL	ASHS, (703) 836-4606

Victor A. Gibeault
Extension Environmental Horticulturist
Department of Botany and Plant Sciences
University of California, Riverside

Dennis R. Pittenger
Area Environmental Horticulturist
Southern Region and Los Angeles County
University of California

Ursula K. Schuch
Extension Ornamental Horticulturist
Department of Botany and Plant Sciences
University of California

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