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Bulletin 359 Revised 2012

Total Plant Management of Herbaceous Perennials

With an emphasis on plant nutrition, managing growth, and breaking the cycle of weeds, insects and diseases through Integrated Pest Management (IPM)

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This publication is a joint effort of the University of Maryland, Virginia Tech and Cornell University and their specialists in various environmental fields

Integrated Pest Management for Commercial Horticulture
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http://ipmnet.umd.edu

Authors and Publication Coordinators:

Stanton A. Gill
Extension Specialist, IPM and Entomology
Central Maryland Research and
Education Center
301-596-9413, sgill@umd.edu

Debby Smith-Fiola,
Consultant, Landscape IPM
landscapeipm@hotmail.com

Co-Authors:

University of Maryland:

John Lea-Cox
Extension Specilaist, Nursery Research
University of Maryland, College Park
301-405-4323, jlc@umd.edu

Karen Rane
Extension Specialist, Plant Pathology
Plant Diagnostic Lab, College Park
301-405-1611, rane@umd.edu

Andrew Ristvey
Extension Specialist, Nutrient and Water
Management
Wye Research and Education Center
410-827-8056, aristvey@umd.edu

Virginia Rosenkranz
Faculty Extension Assistant, Horticulture
University of Maryland Extension
410-749-6141-, rosnkrnz@umd.edu

David Ross
Professor Emeritus and Extension Specialist,
Agricultural Engineering
University of Maryland

Chuck Schuster
Extension Educator, Horticulture
University of Maryland Extension
301-590-2807, cfs@umd.edu

Virginia Tech:

Joyce Latimer
Professor, Horticulture
Virginia Tech
540-231-7906, jlatime@vt.edu

Holly Scoggins
Associate Professor, Horticulture
Virginia Tech
540-231-5783, perennials@vt.edu

Cornell University:

Andrew Senesac
Extension Specialist, Weed Management
Cornell Cooperative Extension
631-727-3595, afs2@cornell.edu

Irene Tsontakis-Bradley
Program Educator
Cornell Cooperative Extension
631-727-3595, it21@cornell.edu

Formatting, Editing, and Image Management:
Suzanne Klick, Technician
University of Maryland Extension

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Preface

Herbaceous perennial plant use in residential and commercial landscapes has increased dramatically in the past 25 years. Consequently, demand has increased for nursery and greenhouse produced herbaceous perennials. Customers often request large plants in high quanitites and of the highest quality. The challenge for growers and managers is to produce and maintain high quality by managing fertility, irrigating correctly, controlling weeds, and preventing insects and diseases from destroying the beauty of the plants.

This manual is designed for use by herbaceous perennial growers, greenhouse and nursery managers, and Extension educators involved with the floriculture industry. Our goal with this manual is to help growers and landscape managers produce and maintain the highest quality plants with minimal loss. This publication is based on the extensive experience of Maryland growers, independent Total Plant Management and Integrated Pest Management (TPM/ IPM) scouts, and faculty and specialists of the University of Maryland Extension, Virginia Tech and Cornell University. It is our intent that this manual serve as a valuable tool for improved management of herbaceous perennial crops. We have created charts for easy access to information and text for more in-depth information on key subjects.

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Chapter 11
Invasive Weeds

Chuck Schuster, Extension Educator, Horticulture

Introduction

Weeds in general are of concern for perennial plant growers. Weeds will compete for moisture, nutrients and sunlight. Control of all weeds will reduce irrigation needs and nutrient costs. Invasive weeds are a greater issue because of the methods of growth and reproduction which may impact the long term growth of the desired plant species. Plants can be designated as invasive by state or federal regulations or recognized by plant biologists. These regulations consider the economic impact to agriculture, natural resources and recreational areas as well as if the plant will impact native species and in some cases cause serious human health concerns. These plants may actually be purchased in some establishments that do not recognize the potential damage that may be done.

Invasive Species

Identification is the first step in prevention of these plant species in perennial production. Inspection of plant material when it arrives will help, but some species can be propagated by seed, rhizomes or stolons, so a careful inspection of the complete plant is important. When possible, selecting a source for perennial plants known to be free of invasive species is very beneficial. Knowing which weeds are considered invasive is also very important. Many printed texts are available as well as the internet to aid in proper identification. A list is provided below to assist in knowing which plants are currently considered invasive in the State of Maryland. Check your local regulations to determine if others are regulated or considered invasive in your region or state.

Table 11.1 Plants Considered Invasive By Maryland Or Federal Laws

Scientific Name	Plant Common Name	Herbicides
Allium vineale	Wild Garlic	2,4-D, MCPA,
Carduus acanthoides	Plumeless Thistle	2,4-D and dicamba; glyphosate
Carduus nutans	Musk Thistle	2,4-D with chlorsulfuron, and dicamba; bentazon (Basagran); glyphosate
Cirsium arvense	Canada Thistle	2,4-D with chlorsulfuron, and dicamba; glyphosate
Cirsium vulgare	Bull Thistle	2,4-D with chlorsulfuron, and dicamba; glyphosate
Heracleum mantegazzianum	Giant Hogweed	Garlon 3A, Glyphosate
Lythrum salicaria	Purple Loosestrife	Glyphosate
Phragmites australis	Phragmites	
Sorghum bicolor	Shattercane	Glyphosate
Sorghum halepense	*Johnsongrass*	Glyphosate

Table 11.2 Plants Recognized By Biologists And Natural Resource Managers To Impact Native Species Or Economic Impact To Agriculture/ Natural Resources

Scientific Name	Plant Common Name	Herbicides
Acer platanoides	Norway Maple	Cut trunk applications work well in most temperatures unless the ground is frozen. Products that can be used include 25% glyphosate, triclopyr (Garlon). Trunk girdling may also be used.
Ailanthus altissima	Tree of Heaven	Use 20% triclopyr (Garlon 4) in an oil base carrier for basal application; triclopyramine (Garlon 3A); glyphosate - foliar application.
Alliaria petiolata	Garlic Mustard	Bentazon (Basagran T/O) with methylated seed oil (MSO) or crop oil concentrate (COC); glyphosate. Glyphosate can be applied during the dormant season.
Ampelopsis brevipedunculata	Porcelainberry	Cut the vine to cause resprouting. Use Garlon, a triclopyr amine product, in the summer to early fall, and glyphosate products in the fall directed onto the leaves. Will take repeated treatments.
Artemisia vulgaris	Mugwort	Good sanitation is important. Difficult to control. Glyphosate with two applications in both May and August.
Berberis thunbergii	Japanese Barberry	Mechanical removal. Foliar applications can be used for large areas using a 2% glyphosate or triclopyr with a surfactant.
Celastrus orbiculatus	Oriental Bittersweet	Triclopyr (Garlon 4) or glyphosate (Roundup and others) at a 25% solution using cut stem method; in open settings, mow followed by above materials.
Centaurea maculosa	Spotted Knapweed	Limit control with 2, 4-D; good control with dicamba in turf; glyphosate in nursery and landscape settings.
Elaeagnus umbellata	Autumn Olive	Foliar applications can be used for large areas using a 2% glyphosate or triclopyr with a surfactant. Cut trunk applications work well in most temperatures unless the ground is frozen. Products that can be used include 25% glyphosate, triclopyr (Garlon).
Hedera helix	English Ivy	Foliar applications can be used for large areas using a 2% glyphosate or triclopyr with a surfactant. Repeated applications will be required. Never apply this when the invasive is growing on the trunk of a desired plant.

Table 11.2 Plants Recognized By Biologists And Natural Resource Managers To Impact Native Species Or Economic Impact To Agriculture/ Natural Resources (continued)

Scientific Name	Plant Common Name	Herbicides
Humulus japonicus	Japanese Hops	Glyphosate. Prevent seed production. Pre-emergent control using pendimethalin (pendulum).
Lonicera japonica	Japanese Honeysuckle	Foliar applications can be used for large areas using a 2% glyphosate or triclopyr with a surfactant. Cut stem applications work well in most temperatures unless the ground is frozen. Products that can be used include 25% glyphosate, triclopyr (Garlon).
Lonicera maackii	Amur Honeysuckle	Foliar applications can be used for large areas using a 2% glyphosate or triclopyr with a surfactant. Cut stem applications work well in most temperatures unless the ground is frozen. Products that can be used include 25% glyphosate, triclopyr (Garlon).
Lonicera morrowi	Morrow's Honeysuckle	Foliar applications can be used for large areas using a 2% glyphosate or triclopyr with a surfactant. Cut stem applications work well in most temperatures unless the ground is frozen. Products that can be used include 25% glyphosate, triclopyr (Garlon).
Lonicera tatarica	Tartarian Honeysuckle	Foliar applications can be used for large areas using a 2% glyphosate or triclopyr with a surfactant. Cut stem applications work well in most temperatures unless the ground is frozen. Products that can be used include 25% glyphosate, triclopyr (Garlon).
Microstegium vimineum	Japanese Stiltgrass	Barricade- pre emergent; glyphosate 2% solution; sethoxydim (Poast) with surfactant.
Miscanthus sinensis	Eulalia	Glyphosate: Apply a 2% solution of glyphosate surfactant to thoroughly wet all foliage. Sethoxydin (Poast) and non-phytotoxic vegetable-based oil to all foliage on a spray-to-wet basis.
Perilla frutescens	Perilla	2 4-D; glyphosate products.
Polygonum cuspidatum	Japanese Knotweed	Foliar applications can be used for large areas using a 2% glyphosate or triclopyr with a surfactant. Cut stem applications work well in most temperatures unless the ground is frozen. Products that can be used include 25% glyphosate, triclopyr (Garlon).
Polygonum perfoliatum	Mile-a-Minute	Prevent seed production. Glyphosate.

Table 11.2 Plants Recognized By Biologists And Natural Resource Managers To Impact Native Species Or Economic Impact To Agriculture/ Natural Resources (continued)

Scientific Name	Plant Common Name	Herbicides
Pueraria montana var. *lobata*	Kudzu	Foliar applications can be used for large areas using a 2% glyphosate or triclopyr with a surfactant. Cut stem applications work well in most temperatures unless the ground is frozen. Products that can be used include 25% glyphosate, triclopyr (Garlon).
Pyrus calleryana 'Bradford'	Callery/ Bradford Pear	Cut trunk applications work well in most temperatures unless the ground is frozen. Products that can be used include 25% glyphosate, triclopyr (Garlon).
Ranunculus ficaria	Lesser Celandine	Glyphosate (Rodeo is labeled for wetland areas)products early in the season, mid February to May, as long as the temperature is 50 degrees Fahrenheit and no rain is anticipated within 12 hours.
Rosa multiflora	Multiflora Rose	Glyphosate.

Control

Control programs need to be developed to prevent the spread of these weeds to other plants in the nursery or to the landscape when planted. As stated before, the best control method is the selection of clean plant material to propagate. If invasive weeds are found in plant material then determine a method of control that will be effective and not decrease plant quality. When invasive plant material is found in the growing environment, then Rapid Response and Eradication will be the first option. Pull, cut, spray or deadhead problem plants before they go to seed. Preventing seed reproduction by problematic plant species is the first step. This method will not necessarily stop the species from growing, but it will lessen the spread. Preventing seed production can be managed by manual removal if the problem is small, or in some cases, through the use of herbicides carefully placed. While the most difficult is manual removal, it can be used with invasive species that are not harmful and are small enough to not damage the desired plant species. On some occasions an over-the-top material can be used that will not damage selected species but will control the problem plant materials. Control can also include destruction of some plants to gain the control of certain invasive species. If it is determined that a potential invasive weed may be present, then the use of preemergence herbicides may be considered if the species is an annual. It is best to consider preemergence weed control whenever possible, as less potential damage will be done to the desired species in many cases.

Chapter 12
Weed Management Guide For Herbaceous Perennials

Irene Tsontakis-Bradley, Program Educator
Andrew Senesac, Extension Specialist, Weed Management

Weed Management Options

Weed management is an integral and important part of all commercial herbaceous ornamental production. Weeds compete and interfere with plant growth and devalue the yield and quality of ornamental plants. It is important to develop a weed control strategy that uses all the available options. These options include preventive measures such as organic and inorganic mulches, preemergence herbicides, and sanitary practices that prevent weed seeds and vegetative parts from spreading. This is especially important in container operations where the potting medium is often soilless and initially weed-free.

Several pictorial guides and botanical identification keys are available to identify the most common weeds. It is essential to know the correct names to understand herbicide labels and control guidelines. Most weeds that infest ornamentals have one of four life cycles: summer annuals, which emerge in the spring, flower, and set seed before the first frost; winter annuals, which germinate at the end of the summer and overwinter as small dormant but green plants; biennials, which are similar to winter annuals but germinate earlier in the summer; or perennials, which survive more than two seasons and can propagate by seed or vegetative reproduction. Knowing the weed life cycle is key to determining the optimal timing of a herbicide application or cultural practice. It is important to scout the weed population during and after the growing season to assess the success of the weed control program. For instance, at the end of the season in the fall, escaped summer annuals and some perennials will be dead but can be identified by their characteristic "skeletons." Escaped winter annuals, biennials, and most perennial weeds will survive the winter as dormant rosettes, crowns, or underground rhizomes.

Several herbicides are available that can be used safely and legally to control weeds in herbaceous ornamentals. Herbicides are commonly classified by their mechanism of action and use pattern. Preemergence herbicides are applied before weeds emerge and generally provide residual control of weed seedlings for several weeks.

Postemergence herbicides, applied after the weeds have emerged, are of two types. Contact herbicides kill only the portion of the plant with which the herbicide actually comes in contact. Good spray coverage is important when using contact herbicides. Systemic herbicides are absorbed and move through the plant, and are useful for controlling the creeping roots and rhizomes of perennial weeds. With systemic herbicides, the weeds must be actively growing so that the herbicide can be fully translocated. The post emergence herbicides that are labeled for herbaceous ornamentals are nonresidual and have little or no soil activity.

In many situations, herbicides cannot be used or are not effective in controlling all the weeds. In these cases, cultivation and hand pulling are often the only available options. There are two important facts to remember about mechanical cultivation. Hoeing and tilling will control small annual weeds fairly well. However, successive flushes of germinating weeds, stimulated by the cultivation itself, need to be controlled on a two- to three-week cycle. Once residual herbicides are applied and activated with water, they need to be in intimate contact with the germinating weed seedlings to work well. Mechanical cultivation will often destroy this contact.

Hand pulling is often an important, if backbreaking, component of a weed management program. It should be considered when no other cultural or herbicide options are available and when weeds are present, that will disperse their seed by wind to weed-free areas.

Types Of Herbaceous Ornamentals

Plant species that are listed on herbicide labels have been tested by independent researchers and approved or registered by state and federal agencies. Because of the great number of herbaceous species, it is possible to test only a small fraction of all plants that are commercially grown. Table 12.1 contains information regarding herbicides that are currently registered on herbaceous ornamentals, and Tables 12.2 and 12.3 contain information about efficacy.

Spring-flowering bulbs that are planted in the fall can be treated with preemergence herbicides shortly after planting and again in the spring. If the planting is late, herbicides can be applied in early spring before summer annual weeds germinate.

Annual bedding plants are generally seeded in the greenhouse and transplanted in the landscape bed in midspring. In most cases, preemergence herbicides should be applied after transplanting to weed-free soil and then irrigated in. Research has shown that cultivars of a species can respond differently to the same herbicides. If possible, always test any herbicide on a small area first.

Perennials are propagated in several ways—e.g., seed, transplants, vegetative division—and are grown in the landscape, as well as containers and the field. Most preemergence herbicides should be applied soon after transplanting.

Cut flowers are usually started from transplants, divisions, or tubers but sometimes are grown in the field from seed. For the most part, preemergence herbicides should be applied after transplanting. Research has shown that most field-seeded flowers are not as tolerant of the same herbicides that are safe on transplants. To achieve the same level of safety, the herbicide usually should not be applied until after plants emerge and are established.

Herbaceous and semi-woody groundcovers are generally fairly tolerant of preemergence herbicides. In the landscape, it is crucial that weeds be controlled for the first two years of establishment. Using organic mulches in combination with pre- and postemergence herbicides is usually the most successful strategy. The mulch material chosen must not inhibit rooting or spread of the groundcover.

Growing Situations

A chemical weed control program in a commercial or home landscape is complicated by the diversity of plants being grown. Bulbs, annual bedding plants, perennials, and ground covers are often planted in a single bed. Good record keeping of weeds, herbicides, and ornamentals is important for site preparation, planning the planting, and avoiding injury to sensitive species.

An herbicide program should be devised for multi-species container operations so that ornamentals that are tolerant of similar herbicides are grown in the same area. Because preemergence herbicides will not control emerged weeds, containers should be treated shortly after the plants are potted or the weeds are removed from established plants. For control of winter annual weeds in the fall, preemergence herbicides should be applied at least two weeks before container houses are covered. Never apply preemergence herbicides in heated or unheated covered houses or greenhouses. Several herbicides that are otherwise safe can volatilize under these conditions and cause injury.

When growing any herbaceous ornamentals in the field, the most important weed management jobs are done before planting. Good site preparation includes scouting for perennial weeds and controlling them with cultivation and herbicides the season before planting. If the field is heavily infested, soil fumigation should be considered, especially if no effective herbicides are registered for the crop.

Herbicide Application

Injury Symptoms
Most of the preemergence herbicides registered for herbaceous ornamentals act by inhibiting the normal root development of small weeds before they emerge. In some cases, the ornamental species are inherently tolerant of the chemical, but more often selectivity and safety are attained by placement. Because most weed seeds germinate in the upper half-inch of the soil, surface herbicide applications control them without injury to the ornamental, which has roots normally growing well below the treated zone. When injury does occur it is often manifested by stunted and malformed roots and general failure to thrive. This may be difficult to detect sometimes if, for instance, all the plants in a bed are uniformly injured. Any stress to the plants will exaggerate the symptoms and worsen the injury.

Formulations and Application
For several preemergence herbicides, a choice of formulations is available. The sprayable formulations (emulsifiable concentrates, wettable powders, dry flowables, water-dispersible granules) are usually less expensive than granular formulations. These can be applied through a tractor-mounted sprayer or by a hand-held backpack sprayer equipped with a spray boom. When using backpack sprayers it is important to apply as uniformly as possible by maintaining a constant foot pace and even spray pressure and using uniform nozzle orifices.

Granular formulations are often used in landscapes and containers where spraying is not practical. Rates for granules should be calculated on an area basis and applied uniformly over the entire area. Granular herbicides should not be applied with a tablespoon to individual containers. This will concentrate the herbicide, which increases the chance of plant injury and decreases weed control.

Herbicide Resistance
Any weed population may contain or develop plants resistant to a herbicide or class of herbicides (herbicides with the same mode of action or the same target site of action). Weed species with acquired resistance may eventually dominate the weed population if herbicides from the same class are used repeatedly in the same field or in successive years as the primary method of weed control. This may result in partial or total loss of control of those species by the group of herbicides. In some species, repeated use of one herbicide class may lead to the selection of naturally occurring biotypes that are resistant to these products.

If poor performance occurs and cannot be attributed to adverse weather or application conditions, a resistant biotype may be present. This is most likely to occur in fields where other control strategies such as crop rotation, mechanical removal, and other classes of herbicides are not used from year to year.

To delay herbicide resistance:
- Use best practices, including IPM (integrated pest management) to develop an overall weed management strategy,
- Monitor weed populations, especially treated weeds for loss of herbicide efficacy,
- Avoid the consecutive use of the same herbicide or herbicides from the same class,
- Use tank mixtures or premixes with herbicides from different classes (as long as all products are registered for the same use and are effective at the mix rate on the weed of concern).

Descriptions and Characteristics Of Herbicides Registered For Nursery And Landscape Use

Acclaim Extra

Trade Name: Acclaim Extra **Common Name:** fenoxaprop **Formulation:** 0.57 EC

Uses: Postemergence control of annual and perennial grass weeds in established turfgrass, nursery crops, and landscape ornamentals, including many trees, shrubs, herbaceous perennials, and annuals.

	Amount of active ingredient	*Amount by formulation*
Per acre	0.1 to 0.3 lb.	3.5 to 39 oz.
Per 1000 ft²		0.08 to 0.90 oz.

Recommended rates for annual grass control:

	oz./A	*oz./1,000 ft²*
seedling (untillered)	13	0.30
1–2 tillers	20	0.46
3–4 tillers	28	0.64

Major Weeds Controlled: Annual grasses such as crabgrass, goosegrass, barnyardgrass, foxtails, and panicums.

Major Weeds Not Controlled: Annual bluegrass, broadleaf weeds, or sedges. Most perennial grasses are tolerant.

For Best Results: Apply to young (seedling to 3-tiller) actively growing grasses. May be tank mixed, following label directions with other pre- and postemergence herbicides. Thorough spray coverage is essential for optimal results. Flat fan nozzles are recommended. Addition of a surfactant is generally not recommended.

Cautions and Precautions: Do not use on Bar Harbor juniper, *Salvia, Philodendron, Podocarpus*, or *Pittosporum*. Check label for other species restrictions. Weed and crop tolerance may vary according to environmental conditions, and tolerance should be determined before extensive use. Do not apply more than a total of 138 oz. per acre per growing season. Do not apply more than 28 oz./A to Kentucky bluegrass or zoyziagrass.

Residual Activity: Up to two weeks of residual control has been reported.

Volatility and Leaching Potential: Loss from volatility is minimal. Leaching is negligible.

Symptoms and Mode of Action: Growth inhibition occurs within 48 hrs. Meristems turn black shortly thereafter. Yellow to red foliage develops in about 7 to 10 days, leading to death within about 14 days. Mechanism of action involves inhibition of lipid synthesis at the root and shoot meristems.

Manufacturer: Bayer Environmental Science **EPA Reg. No.:** 432-950

Barricade**

Trade Name: Barricade **Common Name:** prodiamine **Formulation:** 65WG, 4FL

Uses: Selective preemergence residual control of many annual grasses and broadleaf weeds in landscapes, field-grown nursery stock, container-grown nursery stock, Christmas trees, and established turfgrass (excluding golf course putting greens), lawns, and sod nurseries.

	Amount of active ingredient	*Amount by formulation*	
		65WG	**4FL**
Per Acre	0.325 to 1.5 lb.	0.5 to 2.3 lb.	21 to 48 oz.
Per 1,000 ft^2		0.185 to 0.83 oz.	0.5 to 1.1 oz.

Major Weeds Controlled: Annual grasses such as crabgrass, goosegrass, foxtails, barnyardgrass, and johnsongrass (from seed). Some annual broadleaf weeds such as carpetweed, chickweed, shepherdspurse, prostrate spurge, lambsquarters, and pigweed.

Major Weeds Not Controlled: Established weeds, perennial grasses, and large-seeded broadleaf weeds. Weak on galinsoga, common groundsel, ragweed, nightshades, and velvetleaf. High application rates are required for prostrate knotweed control.

For Best Results: Incorporated with ½ inch of rainfall or irrigation or with shallow cultivation as soon as possible after application. Incorporation should not be delayed more than 14 days after application. Irrigation or rainfall soon after application is necessary to activate herbicide and to wash residual off foliage. May be applied to shadehouses and uncovered polyhouses (must remain uncovered for 7 days).

Cautions and Precautions: On landscape ornamentals, no more than 1.5 lbs. AI per acre may be applied. In newly planted nursery stock or landscapes, delay applications until the soil has settled around the base of the plants. This is especially important in transplant beds.

Residual Activity: Season-long annual grass control is provided in many situations. Control of many broadleaf weeds will be shorter.

Volatility and Leaching Potential: Photodecomposition and volatilization occur when the product remains on the surface for prolonged periods without incorporation. Strongly adsorbed by soil; not readily leached.

Symptoms and Mode of Action: Absorbed through roots and inhibits root and shoot growth through interference with cell division.

Manufacturer: Syngenta **EPA Reg. No.:** 65WG: 100-834, 4FL: 100-1139

**Restricted use pesticide.

Basagran T/O

Trade Name: Basagran T/O **Common Name:** bentazon **Formulation:** 4L

Uses: Postemergence control of seedling broadleaf weeds, yellow nutsedge, and annual sedges in field-grown ornamental trees, shrubs, and ground covers, established turf, and noncrop sites.

	Amount of active ingredient	*Amount by formulation* **4FL**
Per Acre	0.75 to 1 lb.	1.5 to 2 pt.
Per 1,000 ft²		0.55 to 0.75 fl. oz.

Major Weeds Controlled: Annual sedges, yellow nutsedge, groundsel, ragweed, purslane, smartweed, wild buckwheat, wild mustard, and Canada thistle. Control of spring-germinating horseweed has also been observed: Fall-germinating horseweed was not controlled.

Major Weeds Not Controlled: Grasses, perennial broadleaves, and mature weeds are not controlled. Lambsquarters, galinsoga, pigweed, shepherdspurse, spurge, and woodsorrel are not well controlled.

For Best Results: Apply as a directed spray to small and actively growing weeds under good soil moisture. For yellow nutsedge control two applications are recommended, the first in late June and the second 7 to10 days later. For Canada thistle control, apply bentazon when the weed is between 8 inches tall to the bud stage; make a second application 7 to 10 days later. The addition of 1 qt./A of crop oil concentrate is recommended for yellow nutsedge, Canada thistle, and several other species (see label for details). Do not cultivate or mow five days before or after application. Rainfall or irrigation within eight hours of application may reduce effectiveness.

Cautions and Precautions: Do not apply more than 1 lb. AI per acre per application or 2 lbs. AI per acre (and no more than 1 lb. AI per acre in perennial ryegrass) per season. Addition of crop oil concentrates will increase activity however crop injury may be a problem when humidity and temperature are high. Spraying near the base of rhododendron and sycamore may result in injury. Not recommended for golf course greens or collars. See label for additional restrictions and limitations.

Residual Activity: No soil residual activity should be expected.

Volatility and Leaching Potential: No loss from volatility or photodegradation. Not absorbed by soil but rapidly incorporated into organic matter and rapidly broken down by microbes, therefore leaching potential is low.

Symptoms and Mode of Action: Contact burning action. Translocation is minimal. Mechanism involves inhibition of photosynthesis, therefore symptoms may take up to several days to develop. Higher temperatures and addition of crop oil may accelerate and increase the incidence and severity of burn.

Manufacturers: BASF Corporation **EPA Reg.** No.:7969-45

Corral

Trade Name: Corral **Common Name:** pendimethalin **Formulations:** 2.68G

Uses: Preemergence control of grasses and certain broadleaf weeds in established liner-, field-, and container-grown ornamentals.

	Amount of active ingredient	*Amount by formulation*
		2.68G
Per Acre	2 to 4 lb.	76 to 114 lb
Per 1,000 sq. ft.		1.7 to 2.6 lb.

Major Weeds Controlled: Annual grasses including crabgrass, foxtail, and some annual broadleaves including prostrate spurge, yellow woodsorrel, chickweed, purslane, knotweed, and henbit.

Major Weeds Not Controlled: Mature, established weeds are not controlled.

For Best Results: Apply to weed-free soil. For container-grown ornamentals, delay first application to bare root liners two to four weeks.

Cautions and Precautions: Corral is intended for use by commercial nursery, cutflower, foliage, and landscape professionals. Do not apply in enclosed greenhouses. See each label for additional information as uses and precautions differ.

Residual Activity: Three to five months of grass control can be expected at normal use rates.

Volatility and Leaching Potential: Slight loss from the soil surface can result from photodegradation and volatility. Irrigation soon after application will limit these losses. Strongly adsorbed to soil organic matter and clay and not leached.

Symptoms and Mode of Action: Inhibits root development by affecting cell division. Typical injury symptoms include swollen, stubby roots. These symptoms are most commonly seen on affected grasses.

Manufacturer: The Scotts Company **EPA Reg. No.:** 538-188

Devrinol

Trade Name: Devrinol **Common Name:** napropamide **Formulations:** 2G, 50DF

Uses: Preemergence herbicide for control of many annual grasses and broadleaf weeds in container and field-grown trees and shrubs, turfgrass, and herbaceous ornamentals and ground covers. May be used in liner beds, newly transplanted or established nursery crops, landscape plantings, and Christmas trees.

	Amount of active ingredient	*Amount by formulation*	
		2G	**50DF**
Per Acre	4 to 6 lb.	200 to 300 lb.	8 to 12 lb.
Per 1,000 sq. ft.		4.6 to 6.9 lb.	3 to 4.5 oz.

Major Weeds Controlled: Annual grasses and some annual broadleaves including chickweed, crabgrass, bromes, groundsel, knotweed, and filaree.

Major Weeds Not Controlled: The following are generally not controlled from seed: bindweed, morningglory, mustard, nightshade, horsenettle, jimsonweed, yellow woodsorrel, horseweed, and spurge. Large-seeded broadleaf weeds, perennials, and established weeds are not controlled.

For Best Results: Apply to freshly weeded (or cultivated) soil before weeds germinate. Dormant-season treatments, i.e., November through March, have been successful. Incorporate immediately by tillage, irrigation, or rainfall. Control may decrease if water is not provided within two to three days of application. See label for use on potting soil mixes.

Cautions and Precautions: Apply to newly planted container stock after soil is settled from first watering. The 50DF formulation can burn young, tender foliage on some plants. It is best applied before budbreak or after the new growth has matured. Devrinol is registered for use in warm-season turf but will injure cool-season species.

Residual Activity: Full-season grass control can be expected from a single spring application. At the higher rates, carryover can affect the establishment of grass cover crops seeded in late summer or early fall.

Volatility and Leaching Potential: Moderately volatile. Photolabile. Incorporation via irrigation or cultivation will reduce losses caused by volatility and photodegradation. Leaching is negligible.

Symptoms and Mode of Action: Inhibits root growth. Susceptible weeds do not emerge. Crop injury may be associated with inhibited root growth, manifested in wilting during periods of stress, or with the contact-type burning action on young, tender foliage (primarily with the 50DF). Also, rarely, can reduce plant height and vigor of herbaceous ornamentals.

Manufacturer: United Phosphorus, Inc. **EPA Reg. No.:** 2G: 70506-33, 50DF: 70506-38

Dacthal**

Trade Name: Dacthal **Common Name:** DCPA **Formulation:** 75WP, 6FL

Uses: For selective preemergence control of crabgrass and other annual grasses and certain broadleaf weeds in ornamentals and nursery stock. Dacthal 6FL also for use in non-residential turf.

	Amount of active ingredient	*Amount by formulation* **75WP**
Per Acre	10.5 to 12 lb.	14 to 16 lb.

Major Weeds Controlled: Annual grasses such as crabgrass, annual bluegrass, and foxtail grass and certain broadleaves such as carpetweed, purslane, spotted spurge, and prostrate spurge.

Major Weeds Not Controlled: *Galinsoga*, jimsonweed, johnsongrass (from rhizome), mustards, nutsedge, ragweed, smartweed, velvetleaf.

For Best Results: For use in nursery stock, application should be made to soil recently cultivated to a uniform texture and free of weeds. Application can be made immediately following lining-out of stock.

Cautions and Precautions: A degradate of DCPA is known to leach through soil and has been found in groundwater. Do not apply Dacthal to permeable soils or where groundwater is close to the surface. DCPA can contaminate surface water through spray drift. Do not apply when wind speed favors drift. DCPA may also contaminate surface water through runoff for several weeks post-application. Do not apply Dacthal to poorly drained, erodible, or wet soils sloping toward surface water or shallow groundwater. See label for additional precautions. Do not use on bugleweed, germander, phlox, pansy, and others (see label).

Residual Activity: Weed control for up to three months may be expected with proper application. Replanting crops other than those listed on the label within eight months of application may result in crop injury.

Volatility and Leaching Potential: Volatility is negligible. Although the parent compound did not leach in soils tested, the metabolite, tetrachloro-terephthalic acid (TTA or diacid), is more water soluble and is subject to leaching in some soils. This metabolite has been detected in groundwater.

Symptoms and Mode of Action: Inhibits cell division by affecting cell wall formation. Due to inhibition of germination and meristem growth, seedlings do not emerge.

Manufacturer: Amvac Chemical **EPA Reg. No.:** 75WP: 5481-490, 6FL: 5481-48

**Restricted-use pesticide.

Dimension**Δ**

Trade Name: Dimension **Common Name:** dithiopyr **Formulation:** 2EW, 2SC, 40WP, others

Uses: Selective preemergence control of summer annual grasses and broadleaf weeds in turf and landscape ornamentals. Dimension Ultra 40WP and 2EW also for use in noncropland, industrial sites, and field-grown nursery ornamentals. Dimension 2EW also for use in some container-grown ornamentals. Postemergence control of crabgrass is possible when applied before crabgrass has tillered.

	Amount of active ingredient		*Amount by formulation*	
			2SC and 2EW	**40WP**
Per Acre	0.25 lb.	1 pint	10 oz.	
Per 1,000 sq. ft.			0.37 fl. oz. (2.2 tsp.)	0.23 oz. (2 pkts.)

Major Weeds Controlled: Preemergence control of crabgrass, goosegrass, annual bluegrass, speedwell, lespedeza, bittercress, chickweed, and henbit. Higher rate is needed for goosegrass and broadleaf weeds. Postemergence control of smooth and large crabgrass if applied before tillering.

Major Weeds Not Controlled: Weeds that are established. Weak on many broadleaf weeds.

For Best Results: Apply as directed spray to tolerant established ornamentals. Some over-the-top application on selected species is allowed with 2EW and 40WP (see label). Apply before weeds have emerged. Activate with 0.5 inches of rainfall or irrigation. Two applications are generally necessary for full-season grass control.

Cautions and Precautions: Over the top applications will injure the foliage of ornamentals, except as allowed per labeling with Dimension 40WP and 2EW on some ornamentals (see labels). In landscape beds, apply Dimension as a directed application, avoiding contact with foliage of ornamental plants. Safe on most cool- and warm-season turfgrass species if well established; consult label for variety and species restrictions.

Residual Activity: Two applications are necessary for full-season grass control.

Volatility and Leaching Potential: Moderately high volatility. Incorporation via irrigation is necessary. Leaching is negligible.

Symptoms and Mode of Action: Inhibits root growth by blocking cell division in a manner similar to nitroanaline herbicides, but the exact site of action is different.

Manufacturer: Dow AgroSciences

EPA Reg. No.: Dimension 2EW: 62719-542,
Dimension Ultra 2SC: 62719-468,
Dimension Ultra 40WP: 62719-445

**Restricted-use pesticide.

ΔRate or other application restrictions apply. See label for more information.

Envoy**Δ**

Trade Name: Envoy, Envoy Plus **Common Name:** clethodim **Formulation:** 0.94EC, 0.97EC

Uses: Selective postemergence control of annual and perennial grass weeds in conifer trees, non-bearing food crops, ornamentals, and noncrop areas. Can be used in Christmas tree farms, conifer nurseries, greenhouses, shadehouses, and around outdoor ornamentals including nurseries, parks, roadside plantings, and structure landscapes.

	Amount of active ingredient	*Amount by formulation*	
		0.94EC	**0.97EC**
Per Acre	0.06 to 0.25 lb.	9 to 34 fl. oz.	9 to 32 fl. oz.
Per 1,000 sq. ft.		0.2 to 0.8 fl. oz.	0.2 to 0.7 fl. oz.

Major Weeds Controlled: Many annual and some perennial grasses such as barnyardgrass, crabgrass, foxtails, bermudagrass, johnsongrass, and quackgrass. Annual bluegrass (*Poa annua*) is well controlled.

Major Weeds Not Controlled: Sedges and broadleaf weeds.

For Best Results: Apply to actively growing grasses that are not under environmental stress. Consult label for appropriate application method and timing for perennial grass control.

Cautions and Precautions: Unsatisfactory control may result if grasses are stressed or if grasses are not at the correct growth stage at the time of application. Do not cultivate treated grasses seven days before or seven days after application or control may be reduced. Do not apply a broadleaf herbicide within one day following application. Do not apply if rainfall is expected within one hour of application. Do not apply more than 0.5 lb AI per acre per season (and no more than 0.25 lb AI per acre per season on Long Island, New York). Sugar maples cannot be tapped for syrup within one year of application. Repeated use of postemergence grass herbicides with the same mode of action may lead to selection of resistant biotypes. See label for list of species on which foliar or flower speckling has been observed.

Residual Activity: No residual activity.

Volatility and Leaching Potential: Little volatility. Clethodim is rapidly degraded through activity of microbes and exposure to sunlight. The chemical is only slightly adsorbed and has the potential to leach, but degradation is very rapid so the actual amount of leaching is probably slight.

Symptoms and Mode of Action: Slow-acting herbicide; requires 7 to 14 days for control. Inhibits acetyl coenzyme A carboxylase, an important enzyme for many biosynthetic pathways. Classified as a Group 1 Herbicide.

Manufacturer: Valent USA Corporation **EPA Reg. No.:** Envoy 59639-78, Envoy Plus: 59639-132

**Restricted-use pesticide.
ΔRate or other application restrictions apply. See label for more information.

Fusilade II**

Trade Name: Fusilade II **Common Name:** fluazifop-P-butyl **Formulation:** 2EC

Uses: Selective postemergence control of annual and perennial grasses. May be applied as an over the top or directed spray in many ornamentals including many woody and herbaceous ornamentals in container and field nurseries and landscapes.

	Amount of active ingredient	*Amount by formulation*
		2EC
Per Acre	0.25 to 0.4 lb.	1 to 1.5 pt.
Per 1,000 sq. ft.		0.4 to 0.6 oz.
Spot Treatment		0.75 fl. oz./gal. water

(spray solution - add nonionic surfactant per label directions)

Major Weeds Controlled: Annual and most perennial grasses.

Major Weeds Not Controlled: All broadleaf weeds, sedges, rushes, lilies, and other nongrasses. Bluegrass, red fescue, and sweet vernal grass have shown considerable tolerance.

For Best Results: Mix with nonionic surfactant. Some ready-to-use formulations are available; do not add additional surfactant to such formulations. Spray annual grasses at 2 to 8 inches tall before tillering. For perennial grass, spray during the spring growth flush. Cultivation two to three weeks before or after treatment may assist weed control. Thorough coverage is essential for optimal results; spray to cover but not to runoff.

Cautions and Precautions: Use only a nonionic surfactant on ornamentals. Do not apply if rainfall is expected within one hour. Do not tank mix with other pesticides or fertilizers except as instructed on the label. Do not apply to ornamentals that may be harvested for food within one year. Naturally occurring resistant biotypes of some species are known to exist. If resistance is suspected, additional treatments with this or other herbicides with similar mode of action are not recommended.

Residual Activity: Up to two weeks of soil residual activity has been reported.

Volatility and Leaching Potential: Low volatility and negligible leaching when used as directed.

Symptoms and Mode of Action: Growth inhibition occurs within 48 hours. Meristems turn black shortly thereafter. Yellow to red foliage develops in about 7 to 10 days, leading to death within about 14 days. Inhibits cell division by blocking acetyl Co A carboxylase, an enzyme involved in lipid biosynthesis.

Manufacturer: Syngenta **EPA Reg. No.:** Fusilade II 2EC: 100-1084

*Restricted-use pesticide.

Kansel+**

Trade Name: Kansel+ **Common Name:** oxadiazon + pendimethalin **Formulations:** 2 + 1.25G

Uses: Preemergence control of certain grass and broadleaf weeds around and over the top of established landscape, field grown, and container ornamentals. Also contains fertilizer (20% total nitrogen).

	Amount of active ingredient	*Amount by formulation*
		3.25G
Per Acre	3.25 lb.	100 lb.
Per 1,000 sq. ft.		2.3 lb.

Major Weeds Controlled: Annual grasses including crabgrass, barnyardgrass, foxtails, and panicums, and annual broadleaves including prostrate spurge, bittercress, yellow woodsorrel, chickweed, pigweeds, and lambsquarters.

Major Weeds Not Controlled: Germinating and established weeds.

For Best Results: Apply to weed-free soil. Irrigate immediately with ½ to 1 inch water to activate and remove granules from foliage.

Cautions and Precautions: Do not apply to wet foliage. Do not destroy the chemical barrier by raking or tilling. Do not apply product in enclosed structures.

Residual Activity: Three to five months of grass control can be expected at normal use rates.

Volatility and Leaching Potential: Slight loss from the soil surface can result from photodegradation and volatility. Irrigation soon after application will limit these losses. Adsorbed to soil organic matter and clay and not leached.

Symptoms and Mode of Action: Pendimethalin inhibits root development by affecting cell division. Typical injury symptoms include swollen, stubby roots. Oxadiazon caused emerging seedlings to wilt followed by necrosis and desiccation.

Manufacturer: The Scotts Company **EPA Reg. No.:** 538-257

** Restricted use pesticide.

Lontrel**Δ

Trade Name: Lontrel **Common Name:** clopyralid **Formulation:** 3A

Uses: Selective postemergence control of some very difficult to control broadleaf weeds in non-residential turf, sod farms, and certain ornamental plantings, such as conifers, nonleguminous woody species, and ornamental grasses in landscapes and nurseries.

	Amount of active ingredient	*Amount by formulation*
		3A
Per Acre	0.1 to 0.25 lb.	0.25 to 0.66 pt.
Per 1,000 ft²		0.1 to 0.24 fl. oz.

Major Weeds Controlled: Emerged broadleaf weeds.

Major Weeds Not Controlled: Grass weeds.

For Best Results: Apply, as an over-top broadcast or as a spot treatment, to actively growing weeds. Extreme conditions before, at, and following time of application may reduce weed control and increase crop injury. Control may decrease if foliage is wet. Product becomes rainfast in two hours.

Cautions and Precautions: Do not make broadcast applications to ornamental plantings in landscape settings; spot applications are permissible. Do not apply to legumes (pod-bearing plants such as locust, mimosa, redbud), shallow-rooted trees and shrubs, or Tilia species. Do not allow sprays to contact exposed suckers or roots of susceptible trees or shrubs. Do not allow drift to contact composites or solaneaceae (nightshade) species because severe plant injury or death may occur. Do not use in greenhouses. Do not apply to container-grown ornamentals. Do not compost grass clippings.

Residual Activity: No soil residual activity should be expected.

Volatility and Leaching Potential: Loss from volatility is insignificant. Leaching potential is moderate. Users are advised not to apply clopyralid where soils have a rapid to very rapid permeability and the water table is shallow.

Symptoms and Mode of Action: Symptoms include bending and twisting of stems and petioles, stem swelling and elongation, and leaf cupping and curling followed by chlorosis and necrosis. Mode of action is thought to involve cell wall plasticity and nucleic acid metabolism.

Manufacturer: Dow AgroSciences **EPA Reg. No.:** 62719-305

** Restricted use pesticide. May be purchased and used only by certified pesticide applicators or by someone under the direct supervision of a certified applicator.

Δ Rate or other application restrictions apply. See label for more information.

OH2

Trade Name: OH2 **Common Name:** oxyfluorfen+pendimethalin **Formulation:** 2+1G

Use: Preemergence control of grass and broadleaf weeds in container- and field-grown woody ornamentals.

	Amount of active ingredient	Amount by formulation **3G**
Per Acre	3 lb.	100 lb.
Per 1,000 ft^2		2.3 lb.

Major Weeds Controlled: Many annual grasses and broadleaf weeds.

Major Weeds Not Controlled: Perennial weeds.

For Best Results: Do not incorporate physically. Irrigate immediately after application with ½ to 1 inch water to remove particles from foliage and to activate herbicide. Repeat application at three-month intervals for season-long control.

Cautions and Precautions: Apply to dry foliage only. Do not apply while plants are producing a new flush of spring growth. Do not apply to plants with leaves that channel granules to the leaf base. Do not use in greenhouses. Do not apply when extreme cold (35° F or lower) is expected. Do not use on Erica mediterranea, Rhododendron 'Hinocrimson' and 'Snow', Sarcococca hookeriana var. humilis, Euonymus alata 'Compacta,' or Potentilla fruticosa 'Goldfinger'.

Residual Activity: Eight to 12 weeks of weed control can be expected, depending on the growing medium and irrigation practices.

Volatility and Leaching Potential: Low volatility and low leaching potential. However, do not apply in enclosed structures because volatilization is possible. In container nurseries, surface runoff may result when broadcast applications are employed, because many granules fall between pots. Otherwise, the potential for leaching and surface runoff is very low.

Symptoms and Mode of Action: Oxyfluorfen acts as a contact herbicide, disrupting cell membranes via a mechanism that requires light for activation. Pendimethalin inhibits root development by affecting cell division. See the descriptions for Goal and Pendulum for more details. Injury symptoms on ornamentals include contact-type burn where granules are trapped on the foliage and girdling at the soil line on some azalea cultivars.

Manufacturer: The Scotts Company **EPA Reg. No.:** 538-172

Pendulum

Trade Name: Pendulum **Common Name:** pendimethalin **Formulations:** 3.3EC, 2G, 3.8ACS

Uses: Preemergence control of grasses and certain broadleaf weeds, for use on established field and container grown ornamentals including commercial and residential landscapes, turf, and noncrop land areas.

	Amount of active ingredient	*Amount by formulation*		
		3.3EC	**2G**	**3.8ACS**
Per Acre	2 to 4 lb.	2.4 to 4.8 qt.	100 to 200 lb.	2.1 to 4.2 qt.
Per 1,000 ft^2		1.8 to 3.6 fl oz	2.3 to 4.6 lb.	1.6 to 3.2 fl oz.

Major Weeds Controlled: Annual grasses including crabgrass, foxtails, and some annual broadleaves including yellow woodsorrel, chickweed, pigweeds, lambsquarters, and velvetleaf.

Major Weeds Not Controlled: Mature, established weeds are not controlled.

For Best Results: Apply to weed-free soil. Irrigate to activate and remove granules from foliage.

Cautions and Precautions: See label of each product before use as allowable uses and precautions differ. Do not apply granules to wet foliage. Do not incorporate or apply directly to bare roots of woody ornamentals. Overapplication in cool, wet soils can increase injury. Persistent yellow color can stain equipment and landscape areas. See each label for additional information.

Residual Activity: Three to five months of grass control can be expected at normal use rates.

Volatility and Leaching Potential: Slight loss from the soil surface can result from photodegradation and volatility. Irrigation soon after application will limit these losses. Strongly adsorbed to soil organic matter and clay and not leached.

Symptoms and Mode of Action: Inhibits root development by affecting cell division. Typical injury symptoms include swollen, stubby roots. These symptoms are most commonly seen on affected grasses.

Manufacturer: BASF Corporation

EPA Reg. No.: Pendulum 3.3EC: 241-341,
Pendulum 2G: 241-375,
Pendulum Aquacap 3.8ACS: 241-416

Pennant Magnum**

Trade Name: Pennant Magnum **Common Name:** s-metolachlor **Formulation:** 7.62EC

Uses: Preemergent control of certain annual grasses, broadleaf weeds, and yellow nutsedge in noncrop land, in and around container- and field-grown ornamentals, non-bearing nursery stock, and on turf.

	Amount of active ingredient	*Amount by formulation* **7.62EC**
Per Acre	1.2 to 2.4 lb.	1.3 to 2.6 pt.
Per 1,000 ft^2		0.5 to 1.0 fl. oz.

Major Weeds Controlled: Some annual grasses and some annual broadleaf weeds and yellow nutsedge.

Major Weeds Not Controlled: Germinated weeds.

For Best Results: Apply Pennant Magnum in sufficient carrier to obtain thorough coverage. Apply before grass, broadleaf weeds, or yellow nutsedge emerge or after existing weeds have been removed.

Cautions and Precautions: Do not use in greenhouses or other enclosed structures. Do not apply under conditions that favor runoff or wind erosion of soil containing this product to non-target areas. Do not exceed 4.2 pints per acre per year.

Residual Activity: High stability on soil, moderate persistence.

Volatility and Leaching Potential: Leaching generally is insignificant when soil organic matter is greater than 2 percent. Volatilization is generally low, but losses can be significant under certain conditions. Do not apply in enclosed structures.

Symptoms and Mode of Action: As weeds grow through the chemical barrier formed on soil surface, they are killed. Perennial weeds are usually vigorous enough to grow through.

Manufacturer: Syngenta **EPA Reg. No.:** 100-950

** Restricted-use pesticide.

Ronstar**

Trade Name: *Ronstar **Common Name:** oxadiazon **Formulation:** 2G

Uses: Preemergence control of annual grasses and broadleaf weeds in field- and container-grown woody ornamentals, landscapes, and turf. Not for use on home lawns. Also used in some loblolly, slash, and white pine seedbeds (applied after emergence of the crop).

	Amount of active ingredient	*Amount by formulation*
		2G
Per Acre	2 to 4 lb.	100 to 200 lb.
Per 1,000 ft²		2.25 to 4.5 lb.

Major Weeds Controlled: Goosegrass, crabgrass, other annual grasses, woodsorrel, bittercress, velvetleaf, and many other annual broadleaves.

Major Weeds Not Controlled: Only partial control of galinsoga and spurge should be expected. Emerged weeds are not controlled.

For Best Results: Apply before rainfall or irrigate for improved control. Do not disturb the soil surface by cultivation after treatment.

Cautions and Precautions: Do not incorporate. Do not apply granular to wet foliage or under conditions in which granules will collect on leaves. Do not use on plants that will bear edible fruit within one year. Some varieties of the following plants have been found to be sensitive under some growing conditions: andromeda, azalea, cotoneaster, heath, hemlock, hibiscus, rhododendron, lagerstromia, spruce, and viburnum.

Residual Activity: Effectiveness may be expected to last three to four months. However, residual effects on grass cover crops have been observed five months after treatment.

Volatility and Leaching Potential: Volatility is low to moderate. Very low water solubility and adsorption to organic matter prevent leaching.

Symptoms and Mode of Action: Contact action by affecting the young shoot as it grows through the treated zone. Symptoms of injury generally consist of areas of necrotic tissues where the granules have adhered to the foliage.

Manufacturer: Bayer Environmental Science **EPA Reg. No.:** 432-886

**Restricted-use pesticide.

Roundup Pro, Roundup Original, Glyfos, Others

Trade Names: Roundup Pro, Roundup Original Glyfos, others **Common Name:** glyphosate **Formulations:** 4EC, others

Uses: Nonselective postemergence control of most herbaceous and many woody plants. Used for preplant cleanup before all types of planting and as a postdirected or spot spray for general weed control in established woody crops including Christmas trees. Also labeled for weed control in greenhouses, for use under benches and in walkways, not in growing media.

	Amount of active ingredient	*Amount by formulation*
		4L
Per Acre	1 to 5 lb.	1 to 5 qt.
Per 1,000 ft²		0.7 to 3.7 fl. oz.
Spot Treatment (spray solution)		1.3 oz./gal. water

Major Weeds Controlled: Nonselective herbicide. Nearly all plants are controlled or severely injured. Some perennial weeds are controlled only at certain times of the year.

Major Weeds Not Controlled: Weeds under poor growing conditions (i.e. water stress, disease, insect damage) may show erratic or reduced control. Many perennial weeds, particularly woody species, are not well controlled when treated at non-optimal times. Field horsetail (*Equisetum arvensis*) is not well controlled.

For Best Results: Apply to actively growing plants. Do not apply if rainfall or overhead irrigation will occur within six hours. Treat before mowing or after regrowth to specified size as described on the label. Coverage should be uniform and complete but not wet to point of runoff. Season of application is very important for controlling many species.

Cautions and Precautions: Avoid contact with foliage, green stems, or fruit of crops and desirable plants because severe injury or death may result. Injury to plants receiving small amounts of drift may be expressed one to two years after occurrence. Do not use more than 10.6 quarts of this product per acre per year. Keep people and pets off treated areas until dry to prevent transfer to desirable foliage. Limited amounts of drift to leaves will damage many plants.

Residual Activity: Glyphosate is rapidly bound by clay particles, resulting in n soil residual activity. However, in soilless media or pure sands crop injury from root uptake has been observed.

Volatility and Leaching Potential: Nonvolatile. Although glyphosate is very water soluble, it binds rapidly and tightly to soil colloids; consequently, leaching does not occur.

Symptoms and Mode of Action: Absorbed through foliage and green stems and translocated throughout the plant. Growth inhibition occurs within days, but symptoms of injury may take 7 to 10 days to develop. Symptoms include general chlorosis in 7 to 10 days followed by senescence. Woody plants that are not killed may show injury symptoms on the new growth for two or more years. The symptoms may include chlorotic, strap-shaped leaves, shortened internodes, and witches'-brooming. Specific mechanism of action involves the inhibition of aromatic amino acid synthesis, a process unique to the plant kingdom).

Manufacturer: Monsanto Company

EPA Reg. No.: Roundup Pro: 524-475, Roundup Original: 524-445, Cheminova Glyfos 4EC: 4787-31

Scythe

Trade Name: Scythe **Common Name:** pelargonic acid **Formulation:** 57% L

Uses: Nonselective postemergence contact herbicide for control or burn down of most young, succulent, and actively growing weeds. May be used as a directed spray in and around walks, driveways, flowerbeds, trees, and shrubs. Also labeled for use in greenhouses.

	Amount of active ingredient	*Amount by formulation* **57% L**
Spot Treatment (spray solution)	3 to 10%	4 to 13 fl. oz./gal. water

Major Weeds Controlled: Nonselective herbicide; nearly all plants are controlled or suppressed.

Major Weeds Not Controlled: Older annual and perennial weeds will only be suppressed with top kill.

For Best Results: Ensure thorough wetting and complete coverage of all unwanted vegetation, but avoid runoff. Apply in warm, dry weather for most rapid results. Use higher rates for weeds greater than six inches in height or in flowering stage.

Cautions and Precautions: Avoid contact with desirable vegetation. Do not apply using hose-end sprayers. Keep people and pets off treated areas until dry. The odor can be offensive. Avoid skin and eye contact because irritation is likely.

Residual Activity: No soil residual activity has been reported.

Volatility and Leaching Potential: Volatility and leaching are negligible.

Symptoms and Mode of Action: Disrupts cell membranes causing rapid cell desiccation. On a sunny, warm day initial symptoms of water-soaked foliage may be observed within minutes.

Manufacturer: Mycogen **EPA Reg. No.:** 53219-7

Sethoxydim

Trade Name: Sethoxydim G-Pro **Common Name:** sethoxydim **Formulation:** 1EC

Uses: Selective broad spectrum postemergence, over the top, or directed herbicide for the control of annual and perennial grasses in trees, ornamentals, ground covers, bedding plants, and Christmas trees.

	Amount of active ingredient	*Amount by formulation* **1EC**
Per Acre	0.3 to 0.5 lb.	2.25 to 3.75 pt.
Per 1,000 ft^2		0.8 to 1.4 fl. oz.
Spot Treatment (spray solution)		2 to 3 fl. oz./gal. water

Major Weeds Controlled: Emerged annual and perennial grasses.

Major Weeds Not Controlled: Annual or perennial sedges, annual bluegrass, and broadleaf weeds. Red, chewing, and hard fescues, sweet vernal grass, and dicondra turfs are also tolerant.

For Best Results: Apply to small, actively growing grasses that have not been mowed. Spray to wet but not to the point of runoff. Thorough coverage is essential. For optimal control of perennial grasses, apply in the spring when grasses are 4 to 8 inches tall.

Cautions and Precautions: Do not cultivate within five days before or within seven days following application. Do not apply when rain or irrigation will occur within one hour. Injury has been reported on some varieties of azalea, potentilla, Japanese privet, and red and white oak. These instances have usually been associated with higher than labeled rates. Do not apply to nonbearing food crops within one year of harvest. Repeated use may lead to selection of naturally occurring biotypes with resistance to this product.

Residual Activity: Primarily a foliar-applied, postemergent herbicide. No soil residual activity should be expected. However, do not seed grass crops for two weeks following applications.

Volatility and Leaching Potential: Loss from volatility is minimal. Little potential for leaching because sethoxydim is rapidly decomposed in soil.

Symptoms and Mode of Action: Growth inhibition occurs within 48 hr. Meristems turn black shortly thereafter. Yellow to red foliage develops in about 7 to 10 days, leading to death within about 14 days. Inhibits cell division by blocking acetyl Co A carboxylase, an enzyme involved in lipid biosynthesis.

Manufacturers: Gro-Pro **EPA Reg. No.:** 79676-4

Surflan

Trade Name: Surflan **Common Name:** oryzalin **Formulation:** 4AS, 85WDG

Uses: Selective preemergence, surface-applied herbicide for control of annual grasses and many broadleaf weeds in established and newly planted field grown trees and shrubs, ground covers, bulbs, landscape ornamentals, Christmas trees, and container grown ornamentals.

	Amount of active ingredient	*Amount by formulation*	
		4AS	**85WDG**
Per Acre	2 to 4 lb.	2 to 4 qt.	2.4 to 4.7 lb.
Per 1,000 ft²		1.5 to 3 fl. oz.	0.8 to 1.6 oz.

Major Weeds Controlled: Annual grasses such as crabgrass, barnyardgrass, ryegrass, and johnsongrass (from seed). Broadleaf weeds controlled include pigweed, bittercress, common chickweed, spurge, and yellow woodsorrel. At the higher rate partial control of velvetleaf, horseweed, and smartweed is obtained.

Major Weeds Not Controlled: Established weeds. Poor or erratic control of ragweed, asters, groundsel, jimsonweed, galinsoga, nightshade, morningglory, mouseear chickweed, dodder, and Venice mallow has been reported.

For Best Results: Apply 0.5 in. of water to activate. May be shallowly cultivated (1 to 2 inches) to improve effectiveness. May be tank mixed for improved broadleaf control following label directions.

Cautions and Precautions: Do not use in conifer seedbeds or transplant beds. Rooted cuttings should be established two weeks or more before application. Overapplication may result in crop injury. Do not apply to pots smaller than four inches wide. Residues from spring applications may inhibit the establishment and growth of fall-seeded grasses (such as oats or rye) used as a winter cover crop. Injury has been observed on slender deutzia, Douglas fir, techny arborvitae, and eastern hemlock.

Residual Activity: Two to eight months of weed control depending on rate, irrigation practices, weed spectrum, and soil type.

Volatility and Leaching Potential: Little volatility or photodegradation. Stable on the soil surface for several weeks without incorporation. On coarse soils low in organic matter a limited amount of leaching can occur.

Symptoms and Mode of Action: Inhibits root development by affecting cell division. Typical injury symptoms include swollen, stubby roots. These symptoms are most commonly seen on affected grasses. No significant absorption or translocation. May cause girdling and stem swelling when used on young fir or spruce seedlings.

Manufacturer: United Phosphorus

EPA Reg. No.: Surflan AS: 70506-44,
Surflan WDG: 70506-50
Farm Saver Oryzalin 4 Pro:
72167-15-73220

TerraCyte**

Trade Name: TerraCyte **Common Name:** sodium carbonate peroxyhydrate **Formulation:** 34%G

Uses: Granular algaecide/fungicide that treats, controls, and prevents liverworts, algae, moss, bacteria, and fungi for residential, horticultural, and commercial use on ornamental plants and well-established turf.

	Amount by formulation **34%G**
Per 1,000 ft^2	5-15 lb.

Major Weeds Controlled: Liverworts, algae, and moss.

Major Weeds Not Controlled: Control expected for only the plants listed

For Best Results: For ornamental plants in plant beds, greenhouse bench areas, mature potted plants, and seedlings or recent transplants, apply over thoroughly watered soil surface. Thoroughly rinse granules off foliage and water soil surface immediately after application as TerraCyte is activated by moisture. For initial curative application on ornamental plants, use 10 to 15 lbs. per 1000 ft^2. For prevention on ornamental plants, follow up with weekly or biweekly applications at 5 lbs. per 1000 ft^2.

Cautions and Precautions: Increases soil pH by 0.5 pH units (makes the soil more alkaline). Incompatible with metal-based fungicides and fertilizers. Do not apply within three days of metal-based applications. Rinse granules off foliage immediately after application to prevent contact burn. A broad spectrum of plants has been found to be tolerant of TerraCyte however, a test of phytotoxicity should be conducted prior to widespread use.

Residual Activity: Highly degradable. No bioaccumulation.

Volatility and Leaching Potential: Stable under normal conditions.

Symptoms and Mode of Action: Mode of action is oxidation, a chemical reaction that reacts with proteins and enzymes found in cell membranes of microbial organisms. Upon activation with water, sodium carbonate peroxhydrate breaks down into sodium carbonate and hydrogen peroxide.

Manufacturer: BioSafe Systems **EPA Reg. No.:** 70299-3

** Restricted-use pesticide.

Treflan, Preen, others

Trade Name: Treflan, Preen, others **Common Name:** trifluralin **Formulations:** 5G, 1.5G, others

Uses: Selective preemergence control of annual grasses and broadleaf weeds in field- or container-grown nursery stock, landscape ornamentals, ground covers, and many annual and perennial flowers.

	Amount of active ingredient	*Amount by formulation*	
		5G	**1.5G**
Per Acre	2 to 4 lb.	40 to 80 lb.	272 lb.
Per 1,000 ft²		0.6 to 1.8 lb.	6.25 lb.

Major Weeds Controlled: Annual grasses such as crabgrass, barnyardgrass, foxtail, and panicum. Annual broadleaves controlled include pigweed, lambsquarters, and chickweed.

Major Weeds Not Controlled: The following are generally not controlled: cocklebur, velvetleaf, jimsonweed, groundsel, Venice mallow, and nutsedge. Erratic or partial control of ragweed, purslane, and galinsoga has been observed.

For Best Results: Apply before germination of weed seeds or to clean, cultivated weed-free areas. Must be incorporated within a few hours of application. Use lower rates if physically incorporated and higher rates if applied to the surface and watered in. May be combined with other herbicides for an expanded spectrum of weed control.

Cautions and Precautions: Do not apply granules to wet foliage. Not recommended for muck soils. Do not apply over 12 lb. AI/A within a 12 month period.

Residual Activity: Two to three months of residual control can be expected.

Volatility and Leaching Potential: Moderately volatile and subject to photodegradation. Insoluble; leaching is negligible.

Symptoms and Mode of Action: Inhibits root development by affecting cell division. Typical injury symptoms include swollen, stubby roots. These symptoms are most commonly seen on affected grasses. No significant absorption or translocation.

Manufacturers: Lebanon **EPA Reg. No.:** Treflan 5G: 961-405
Preen 1.5G: 961-280

XL 2G

Trade Name: XL 2G **Common Name:** benefin + oryzalin **Formulation:** 1+1G

Uses: Preemergence control of many annual grasses and some broadleaf weeds in established container or field nursery stock and landscape plantings, including some flower bulbs, ground covers, and Christmas tree plantations. Product used in warm-season turf but will injure cool-season turf.

	Amount of active ingredient	*Amount by formulation*
		2G
Per Acre	4 to 6 lb.	200 to 300 lb.
Per 1,000 ft²		4.6 to 6.9 lb.

Major Weeds Controlled: Annual grasses such as crabgrass, foxtail, and barnyardgrass and a few broadleaf weeds such as common chickweed and carpetweed. Provides partial control of horseweed, ragweed, and nightshade.

Major Weeds Not Controlled: Established weeds. Do not expect the same level or longevity of weed control as from the labeled rate of Surflan.

For Best Results: Apply before weed germination. Irrigation or rain (0.5 inches), or shallow cultivation (1 to 2 inches) is needed for activation. Cultivation or otherwise disturbing the soil surface after the initial incorporation may reduce control.

Cautions and Precautions: Do not use in seedbeds or transplant beds. Not for use in greenhouses. May thin some established warm-season grasses at higher rates. Do not apply more than 800 to 900 lb. product per acre per year. Do not use on slender deutzia, Douglas fir, techny arborvitae, or eastern hemlock.

Residual Activity: About six to eight weeks of residual grass control may be expected. Residual control of broadleaves may be shorter.

Volatility and Leaching Potential: Some volatility and photodecomposition may occur. Irrigation immediately after application will minimize these effects. A limited amount of leaching can occur on coarse soils with low organic matter content.

Symptoms and Mode of Action: Both benefin and oryzalin inhibit cell division by disrupting tubulin formation. Classic symptoms of injury in grasses are stubby (short, thickened) roots. Diverse symptoms occur in susceptible dicots, from puckered and mottled foliage in herbaceous species to stem girdling and swelling at the ground line in fir, hemlock, and spruce seedlings.

Manufacturer: Setre Chemical **EPA Reg. No.:** 70506-45-38167

Table 12.1 Herbicides Registered For Use On Herbaceous Ornamentals

		Post	Pre	Post	Pre	Pre	Pre	Pre	Post	Post	Pre	Post	Pre	Pre	Pre	Pre	Pre	Post	Pre	Pre	Post	Pre
KEY: y = registered for some species of this genus e = registered for some species of this genus, apply only after established d = registered for some species of this genus, directed application only x = NOT registered/prohibited from use on some species		Acclaim Extra	*Barricade	Basagran T/O	Corral	*+Dacthal	Devrinol	*+#Dimension	*#Envoy	*Fusilade II	*Kansel!	*+#Lontrel	OH2	Pedulum 3.3EC,ACS	Pedulum 2G	*+Pennant Magnum	*Ronstar G	Scythe	Surflan	Treflan 5G	Sethoxydim G-Pro	XL
Genus	**Common Name**																					
Achillea	Yarrow	e	y	d	y	y		d	y	y	e				e	y		d	e	e	y	e
Acorus	Sweet Flag			d	y			d	y						e			d			y	
Agapanthus	Lily-of-the-Nile (African Lily)		y	d	y		y	d		y	e			e	e	y	e	d	e	e	y	e
Agastache	Hyssop			d											e			d				
Ageratum	Ageratum			d		y	y		y	y	e				e	y		d		e		
Ajuga	Bugleweed	e		y	y	x	y	d	y	d	e			e	e	y	e	d	e		y	e
Alcea	Hollyhock			d						y								d				
Allium	Allium		y	d												y		d				
Alstroemeria	Peruvian Lily			d			y											d				
Alyssyum (Lobularia)	Alyssum, Sweet	e		d		y			y	y					e	y		d		e	y	
Amaranthus	Love-Lies-bleeding			d														d				
Ammophila	Beach Grass			d	y			d						e	e			d		e		
Anagallis	Pimpernel	e		d														d				
Anemone	Wind Flower		y	d											e			d				
Antirrhinum	Snapdragon	e		y		y		d		y					e	y	e	d	e	e	y	e
Aquilegia	Columbine	e	y	d		y		d		d	e				e	y		d			y	
Arctotheca	Capeweed			d	y					y				e	e			d	e	e	y	e
Arctotis	African Daisy			d			y											d		e		
Arenaria	Sandwort			d														d				
Arisaema	Jack-in-the-Pulpit			d														d			y	
Armeria	Sea Pink			d											e			d		e	y	
Artemesia	Wormwood		y	d		y					e				e	y		d				
Arundo	Reed, Giant			d	y									e	e			d				
Asclepias	Butterflyweed (Milkweed)			d	y										e	y		d			y	
Asparagus	Asparagus Fern			d	y		y	d	y	y				e	e			d	e	e	y	
Aspidistra	Cast Iron Plant			d											e			d				
Aster	Aster		y	d	y	y	y				e				e	y		d	e	e	y	
AStible	Astilbe (False Spirea)	e		d				d			e				e			d	e	e		
Athyrium	Fern, Lady (Japanese)		y	d														d	e	e		
Aurina (Alyssum)	Basket of Gold, per.			d														d				
Baptisia	Indigo			d							e				e			d				
Begonia	Begonia, Fibrous (Wax)	e	y	d				d		d					e			d		e	y	x
Bergenia	Bergenia		y	d							e				e			d			y	
Boltonia	Boltonia		y	d					y									d				
Bougianvillea	Bougainvillea		y	d			y	d		y						y	e	d			y	e
Bouteloua	Grama			d								e						d				
Brassica	Cabbage (Kale), Ornamental			y											e			d	e			
Caladium	Caladium (Elephant Ear)			d											e			d	e			e
Calamagrosits	Reed Feather Grass			d							e	e						d				
Calendula	Pot Marigold			d						y								d		e	y	
Callistpehus	Aster, China			d				d							e			d	e			
Calluna	Heather		y	d			y			y				e	e		e	d		e		
Campanula	Bellflower	e	y	d		y				y					e	y		d	e	e	y	e
Canna	Canna			d							e			e	e	y		d			y	
Capsicum	Pepper, Ornamental			d														d				
Carex	Carex			d				d							e	y		d		e		
Catharanthus	Periwinkle (beddign plt)			d						d					e			d			y	
Celosia	Cockscomb			d				d							e			d			y	

Table 12.1 Herbicides Registered For Use On Herbaceous Ornamentals (continued)

KEY: y = registered for some species of this genus e = registered for some species of this genus, apply only after established d = registered for some species of this genus, directed application only x = NOT registered/prohibited from use on some species		Post	Pre	Post	Pre	Pre	Pre	Pre	Post	Post	Pre	Post	Pre	Pre	Pre	Pre	Pre	Post	Pre	Pre	Post	Pre
		Acclaim Extra	*Barricade	Basagran T/O	Corral	*+Dacthal	Devrinol	*+#Dimension	*#Envoy	*Fusilade II	*Kansel!	*+#Lontrel	OH2	Pedulum 3.3EC,ACS	Pedulum 2G	*+Pennant Magnum	*Ronstar G	Scythe	Surflan	Treflan 5G	Sethoxydim G-Pro	XL
Genus	**Common Name**																					
Centaurea	Cornflwoer	e		d				d										d		e	y	
Cerastium	Snow-in-Summer	e		d					y	y								d		e		
Ceratostigma	Leadwort (Plumbago)			d														d		e	y	
Chasmanthium	Sea Oats (Woodoats)			d								e						d				
Chrysanthemum	Chrysanthemum	e		d		y	y		y						e	y	e	d	e	e	y	e
Cirsium	Thistle			d														d				
Clarkia	Godetia	e		d														d				
Clematis	Clematis			d														d				
Coleus	Coleus	e		d		y		d	y	y								d			y	x
Consolida	Larkspur			d														d				
Convallaria	Lily-of-the-Valley			d														d				
Coreopsis	Coreopsis (Calliopsis)	e	y	d		y		d	y	y	e				e	y	e	d	e	e	y	e
Coronilla (Vicia)	Crown Vetch			d											e			d		e		
Cortaderia	Pampas Grass		y	d	y			d				e	y	e	e	y		d	e	e		e
Cosmos	Cosmos	e		d		y												d		e	y	
Crocosmia	Crocosmia		y	d										e	e			d				
Crocus	Crocus			d											e	y		d				
Cuphea	Heather, False			d					y									d	e		y	
Cyperus	Cyperus			d						d								d				
Dahlia	Dahlia			d		y	y		y						e		e	d		e	y	
Daucus	Queen Anne's Lace			d												y		d			y	
Delosperma	Ice Plant, Hardy		y	d			y	d							e			d	e			e
Delphinium	Delphinium		y	d				d								y		d				
Dennstaedtia	Fern, Hay-scented			d														d				
Deschampsia	Tufted Hair Grass			d	y			d				e		e	e			d		e		
Dianthus	Carnation		y	d		x											y	d		e	y	
Dianthus	Sweet William	e		d		x		d			e				e	y	e	d	e	e	y	e
Dianthus	Pink	e	y	d		x			y									d	e	e	y	
Dicentra	Bleeding Heart	e		d		y			y					e	e			d	e		y	e
Digitalis	Foxglove			d		y					e				e		e	d	e		y	
Dimorphotheca	Cape Marigold			d														d	e	e		e
Doronicum	Leopards Bane	e		d							e				e		y	d	e			
Dryopteris	Fern, Log (Shaggy Shield)			d														d				
Echinacea	Coneflower	e	y	d		y		d							e			d	e		y	e
Epimedium	Barrenwort			d							e							d				
Equisetum	Horsetail			d														d				
Erianthus	Plume Grass			d														d				
Erica	Heath			d				d					x					d		e		
Erysimum	Wallflower	e		d			y											d				
Eschscholzia	Poppy, California	e		d											e			d		e	y	
Eupatorium	Joepyeweed (Boneset)			d							e				e			d				
Euphorbia	Snow-on-the-Mountain	e		d						y								d		e		
Festuca	Fescue, Blue			d	y			d			e			e	e			d	e	e	y	e
Fragaria	Strawberry, Ornamental			d	y										e			d		e		
Freesia	Freesia			d										e	e			d				
Gaillardia	Blanketflower	e	y	d		y		d			e				e	y	y	d	e	e	y	
Galium	Sweet Woodruff			d														d				
Gaultheria	Wintergreen			d														d				

Table 12.1 Herbicides Registered For Use On Herbaceous Ornamentals (continued)

KEY: y = registered for some species of this genus e = registered for some species of this genus, apply only after established d = registered for some species of this genus, directed application only x = NOT registered/prohibited from use on some species		Post	Pre	Post	Pre	Pre	Pre	Pre	Post	Post	Pre	Post	Pre	Pre	Pre	Pre	Pre	Post	Pre	Pre	Post	Pre
		Acclaim Extra	*Barricade	Basagran T/O	Corral	*+Dacthal	Devrinol	*+#Dimension	*#Envoy	*Fusilade II	*Kansel!	*+#Lontrel	OH2	Pedulum 3.3EC,ACS	Pedulum 2G	*+Pennant Magnum	*Ronstar G	Scythe	Surflan	Treflan 5G	Sethoxydim G-Pro	XL
Genus	**Common Name**																					
Gaura	Gaura		y	d							e							d				
Gazania	Gazania	e		d	y		y		y	d	e			e	e	y	y	de	e	y	e	
Gentiana	Gentian		y	d														d				
Geranium	Cranesbill (True Geranium)		y	d					y	y						y		d			y	
Gerbera	Gerbera Daisy			d														d			y	
Geum	Avens			d											e	y		d	e	e	y	e
Gilia	Gilia	e		d														d				
Gladiolus	Gladiolus		y	d		y	y			d	e				e	y	e	d	e	e	y	e
Goniolimon	Statice, German			d														d				
Gypsophila	Baby's Breath	e	y	d		y					e				e		e	d	e	e	y	e
Hedera	Ivy	e	y	y	y	y	y	d	y	y	e			e	e	y	y	d	e	e	y	e
Helianthemum	Sunrose		y	d														d				
Helianthus	Sunflower			d											e			d		e		
Helichrysum	Strawflower			d														d				
Heliotropium	Heliotrope			d													e	d	e			
Hemerocallis	Daylily	e	y	d	y			d	y	y					e	y		d	e	e	y	e
Herniaria	Rupturewort			d						d								d		e	y	
Hesperis	Dames Rocket	e		d														d				
Heuchera	Coral Bell (Alum Root)			d					y						e			d	e		y	
Heucherella	Foamy Bells		y	d														d				
Hibiscus	Rosemallow		y	d			y	d			e					y	e	d	e			
Hosta	Hosta (Plantain-Lily)	e	y	d	y		y	d	y	y	e			e	e	y		d	e	e	y	e
Houttuynia	Chameleonplant		y	d														d				
Hyacinthoides	Hyacinth, Wood			d												y		d				
Hyacinthus	Hyacinth			d												y		d	y	y		y
Hypericum	St. Johnswort			d	y		y						y		e	y		d	e		y	e
Iberis	Candytuft	e		d		y		d	y	y							e	d	e		y	
Impatiens	Impatiens (Balsam)			y				d	y						e	y		d	e	e	y	e
Imperata	Blood Grass			d								e						d				
Ipomea	Morningglory (Sw. Potato V.)			d		y												d		e		
Iris	Iris, Bulbous	e	y	d		y		d	y	y						y		d	y	y	y	y
Iris	Iris, Rhizomatous	e	y	d		y		d	y	y						y		d	e	e	y	e
Kniphofia	Poker Plant			d		y									e			d				
Lamiastrum	Archangel, Yellow			d							e							d				
Lantana	Lantana		y	d		y	y	d	y	d					e		e	d		e	y	
Lathyrus	Sweet Pea			d		y												d		e		
Laurentia (Isotoma)	Laurentia			d						y								d				
Lavandula	Lavender		y	d							e			e	e			d	e	e	y	
Layia	Tidy Tips	e		d														d			y	
Leucanthemum	Daisy, Shasta	e		d						y					e			d			y	e
Leymus	Lyme Grass			d								e						d				
Liatris	Blazing Star (Gayfeather)	e		d						y	e				e		e	d	e		y	e
Lilium	Lily		y	d		y					e	y		e	e	y		d				
Limonium (Statice)	Statice (Sealavender)	e		d						y					e	y	e	d	e	e	y	
Linum	Flax, Scarlet or Blue	e		d											e			d			y	
Liriope	Lilyturf	e	y	y	y		y	d	y	y				e	e	y		d	e	e	y	e
Lobelia	Cardinal Flower		y	d	y													d	e	e		
Lonicera	Honeysuckle		y	d			y	d	y	d	e		y			y	e	d	e	e	y	e

Table 12.1 Herbicides Registered For Use On Herbaceous Ornamentals (continued)

KEY: y = registered for some species of this genus e = registered for some species of this genus, apply only after established d = registered for some species of this genus, directed application only x = NOT registered/prohibited from use on some species		Post	Pre	Post	Pre	Pre	Pre	Pre	Post	Post	Pre	Post	Pre	Pre	Pre	Pre	Pre	Post	Pre	Pre	Post	Pre
		Acclaim Extra	*Barricade	Basagran T/O	Corral	*+Dacthal	Devrinol	*+#Dimension	*#Envoy	*Fusilade II	*Kansel!	*+#Lontrel	OH2	Pedulum 3.3EC,ACS	Pedulum 2G	*+Pennant Magnum	*Ronstar G	Scythe	Surflan	Treflan 5G	Sethoxydim G-Pro	XL
Genus	**Common Name**																					
Lupinus	Lupine			d		y									e	y		d		e	y	
Lysimachia	Moneywort (Loosestrife)			d					y	y					e			d			y	
Lythrum	Loosestrife, Purple		y	d	y				y						e	y		d			y	
Matricaria	Chamomile	e		d														d				
Matthiola	Stock			d														d		e	y	
Mertensia	Bluebells	e		d														d				
Mirabilis	Four O'Clock			d		y												d		e		
Miscanthus	Maiden Grass		y	d	y			d			e	e			e			d		e		
Molucella	Bells of Ireland			d														d				
Monarda	Beebalm			d				d										d			y	
Moraea	Fortnight Lily			d	y										e	y		d				
Muscari	Hyacinth, Grape			d												y		d				
Myosotis	Forget-Me-Not	e		d		y												d		e		
Narcissus	Daffodil		y	d			y	d							e	y		d	y	y	y	y
Nemophila	Baby-Blue-Eyes	e		d														d			y	
Nepeta	Catmint			d							e							d				
Nephrolepis	Fern, Boston (Sword)			d						y					e			d				
Nicotiana	Flowering Tobacco			d					y									d		e	y	
Nipponanthemum	Daisy, Montauk	e	y	d														d				
Oenothera	Evening-primrose (Sundrops)	e	y	d		y										y		d			y	
Ophiopogon	Mondo Grass		y	d	y			d	y					e	e	y		d	e	e	y	e
Opuntia	Prickly Pear			d						d					e			d				
Ornithogalum	Star-of-Bethlehem			d							e			e	e	y	e	d		e		
Osmunda	Fern, Royal (Cinnamon)			d														d				
Osteospermum	Cape Daisy	e	y	d	y		y	d	y	y				e	e		y	d	e		y	e
Pachysandra	Pachysandra			y	y	y	y	d	y	y	e		y	e	e	y	e	d	e	e	y	
Paeonia	Peony	e	y	d		y					e			e	e		e	d				
Panicum	Switchgrass			d								e						d				
Papaver	Poppy	e		d														d		e	y	
Pelargonium	Geranium, Zonal	e		d	y		y	d	y	y	e			e	e	y		d	e			e
Pennisetum	Fountain Grass		y	d	y			d		d	e	e		e	e		e	d	e	e	y	
Penstemon	Beardtongue	e		d	y						e				e			d				
Perovskia	Sage, Russian		y	d							e				e			d				
Petunia	Petunia	e		y		y	y	d	y	y					e	y		d	e	e	y	e
Phalaris	Ribbon Grass			d	y			d				e		e	e			d		e		
Phlox	Phlox			d		x			y						e	y	e	d		e	y	
Physostegia	Obedient Plant		y	d											e	y		d				
Platycodon	Balloon Flower			d											e			d				
Polygonum	Clover, Pink			d						y								d				
Polystichum	Fern, Tassel (Christmas)			d														d		e		
Portulaca	Moss Rose			d		y		d	y	y					e			d	e	e	y	e
Potentilla	Cinquefoil			d	y			d	y	d	e			e	e	y	e	d		e		e
Primula	Primrose			d														d				
Ranunculus	Ranunculus			d														d	e			e
Ratibida	Coneflower, Prairie	e		d														d				
Rosa	Rose	e	y	d		y	y	d	y	y	e				e	y	e	d	e	e		e
Rosmarinus	Rosemary		y	d	y			d		y					e			d	e	e	y	e
Rubus calycinoides	Raspberry, Creeping			d					y									d	e	e	y	e

Table 12.1 Herbicides Registered For Use On Herbaceous Ornamentals (continued)

KEY: y = registered for some species of this genus e = registered for some species of this genus, apply only after established d = registered for some species of this genus, directed application only x = NOT registered/prohibited from use on some species		Post	Pre	Post	Pre	Pre	Pre	Pre	Post	Post	Pre	Post	Pre	Pre	Pre	Pre	Pre	Post	Pre	Pre	Post	Pre
		Acclaim Extra	*Barricade	Basagran T/O	Corral	*+Dacthal	Devrinol	*+#Dimension	*#Envoy	*Fusilade II	*Kansel!	*+#Lontrel	OH2	Pedulum 3.3EC,ACS	Pedulum 2G	*+Pennant Magnum	*Ronstar G	Scythe	Surflan	Treflan 5G	Sethoxydim G-Pro	XL
Genus	**Common Name**																					
Rudbeckia	Black-Eyed Susan	e	y	d				d			e				e			d	e	e	y	e
Rumohra	Fern, Leatherleaf		y	d						y				e	e	y		d				
Salvia	Salvia (Sage, ann.)	x		d		y			y	y					e			d	e	e	y	e
Salvia	Salvia (Sage, per.)	x		d				d	y	y	e							d	e	e		e
Sanguisorba	Burnet	e		d														d				
Santolina	Lavender Cotton		y	d		y				y			y					d			y	
Sanvitalia	Zinnia, Creeping	e		d														d				
Saponaria	Soapwort			d														d		e		
Saxifraga	Saxifrage		y	d					y									d				
Scabiosa	Pincushion Flower		y	d		y					e							d		e		
Schizachyrium	Little Bluestem			d								e						d				
Scilla	Squill			d												y		d				
Sedum	Stonecrop		y	d		y	y	d	y	y					e	y	e	d	e	e	y	e
Sempervivum	Hens and Chicks			d						y								d				
Senecio	Dusty Miller			d				d	y						e			d	e			
Silene	Catchfly	e		d														d			y	
Solanum	Potato Vine (Nightshade)			d	y										e			d				
Stachys	Lamb's Ear			d												y	e	d		e	y	
Stipa	Feathergrass (Needlegrass)			d								e						d				
Stokesia	Stokes' Aster			d	y										e			d	e	e		e
Strelitzia	Bird of Paradise			d			y			y								d	e			e
Tagetes	Marigold			y		y		d	y	y					e	y		d	e	e	y	e
Teucrium	Germander		y	d		x												d		e		
Thalictrum	Meadow Rue		y	d														d				
Thymus	Thyme, Ornamental	e		d		y											e	d				
Tradescantia	Spiderwort			d		y					e						e	d		e	y	
Trientalis	Starflower			d														d				
Tropaeolum	Nasturtium			d		y												d		e		
Tulipa	Tulip		y	d				d							e	y		d	y	y	y	y
Verbena	Verbena (Vervain)			d	y			d	y						e			d	e	e	y	
Veronica	Speedwell		y	d						y				e	e	y		d	e	e	y	
Vinca	Periwinkle (perennial gr cvr)		y	d	y		y	d	y	y			y		e	y	y	d	e	e	y	e
Viola	Pansy (Violet)			d				d	y						e	y		d	e		y	e
Yucca	Spanish Bayonet	e	y	d											e	y		d	e			e
Zantedeschia	Calla lily			d										e	e			d				
Zinnia	Zinnia	e		d		y	y		y	y					e	y		d	e	e	y	e

* Restricted use pesticide. May be purchased and used only by certified pesticide applicators or by someone under the direct supervision of a certified applicator.

+ Not for use in Nassau and Suffolk Counties, New York. Pesticides that indicate "Not for use on Long Island, NY" mean that use is prohibited in Nassau and Suffolk Counties only.

Rate or other application restrictions apply. See label for more information.

Table 12.2 Broadleaf Weed Susceptibilities To PREemergence Herbicides

KEY: ful = Full control is expected par = Partial control is expected		*Barricade	*+Dacthal	Devrinol	*+#Dimension	*Kanse+	OH2	Pendulum	*+PennantMagnum	*Ronstar	Surflan	Treflan	XL
Genus, species	**Common Name**												
Abutilon theophrasti	velvetleaf							ful			par		par
Amaranthus albus	pigweed, tumble	ful						ful	ful		ful	ful	ful
Amaranthus blitoides	pigweed, prostrate	ful						ful	ful		ful	ful	ful
Amaranthus hybridus	pigweed, smooth	ful						ful	ful		ful	ful	ful
Amaranthus retroflexus	pigweed, redroot	ful	par	ful	ful	ful	ful	ful	ful	ful	ful	ful	ful
Amaranthus spinosus	pigweed, spiny	ful				ful		ful	ful	ful		ful	ful
Amaranthus spp.	pigweed species	ful						ful	ful			ful	ful
Ambrosia artimisiifolia	ragweed, common			par							par		par
Amsinckia spp.	fiddleneck			ful		ful		ful		ful	ful		ful
Anagallis arvensis	pimpernel, scarlet												
Anthemis cotula	chamomile, mayweed												
Artemisia vulgaris	mugwort												
Aster spp.	aster												
Atriplex rosea	orach, red												
Borreria laevis	buttonweed												
Capsella bursa-pastoris	shepherdspurse	ful			ful	ful	ful	ful		ful	ful		ful
Cardamine spp.	bittercress				ful	ful	ful			ful	ful		ful
Cassia obtusifolia	sicklepod												
Cerastium vulgatum	chickweed, mouseear	ful						ful					
Chenopodium album	lambsquarters	ful	ful	ful		ful		ful		ful	ful	ful	ful
Chenopodium botrys	goosefoot, Jerusalem oak												
Chenopodium spp.	goosefoot species											ful	
Chorispora tenella	mustard, blue												
Cirsium arvense	thistle, Canada												
Cirsium vulgare	thistle, bull												
Citrullus lanatus	citronmelon												
Conyza canadensis	horseweed/marestail				ful		ful				par		par
Coronopus didymus	swinecress									par			
Cuscuta spp.	dodder		par										
Datura stramonium	jimsonweed												
Daucus carota	carrot, wild												
Descurainia pinnata	tansymustard												
Descurainia sophia	flixweed												
Epilobium angustifolium	fireweed					ful	ful			ful			
Equisetum spp.	horsetail												
Erigeron spp.	fleabane						ful						

Table 12.2 Broadleaf Weed Susceptibilities To PREemergence Herbicides (continued)

KEY: ful = Full control is expected par = Partial control is expected		*Barricade	*+Dacthal	Devrinol	*+#Dimension	*Kanse+	OH2	Pendulum	*+PennantMagnum	*Ronstar	Surflan	Treflan	XL
Genus, species	**Common Name**												
Eriodium moschatum	filaree, whitestem							ful			ful		ful
Erodium botrys	filaree, broadleaf							ful					
Erodium cicutarium	filaree, redstem			ful				ful			ful		ful
Eupatorium capillifolium	dogfennel/mayweed												
Euphorbia hirta	spurge, garden				ful		ful	ful		ful			
Euphorbia humistrata	spurge, prostrate	ful	par		ful	ful	ful	ful		par	ful		ful
Euphorbia maculata	spurge, spotted		par		ful		ful	ful			par		par
Euphorbia peplus	spurge, petty							ful		ful			
Euphorbia vermiculata	spurge, hairy							ful					
Galinsoga ciliata	galinsoga, hairy								ful	par			
Gallium aparine	bedstraw, catchweed												
Gnaphalium falcatum	cudweed, narrowleaf												
Gnaphalium spp.	cudweed						ful	ful					
Helianthus tuberosus	artichoke, Jerusalem												
Hypochoeris radicata	catsear, spotted					ful				ful			
Ipomea hederacea	morningglory, ivyleaf												
Ipomea purpurea	morningglory, tall												
Ipomea spp.	morningglory, annual										par		par
Kochia scoparia	kochia	ful						ful				ful	
Lactuca serriola	lettuce, prickly			ful							par		par
Lamium amplexicaule	henbit	ful			ful			ful			ful		ful
Lamium purpureum	deadnettle		par										
Lepidium perfoliatum	pepperweed, yellowflower												
Lepidium virginicum	pepperweed, Virginia						ful						
Malva spp.	mallow		par			ful				ful	par		par
Marchantia spp.	liverwort									par			
Matricaria matricarioides	pineappleweed			ful	ful								
Medicago hispita	burclover												
Medicago lupulina	medic, black				ful								
Mollugo verticillata	carpetweed	ful	ful	ful	ful	ful		ful	ful	ful	ful	par	ful
Montia perfoliata	lettuce, miners												
Moss (several genera)	moss												
Oenothera laciniata	eveningprimrose, cutleaf									par			
Oenothera spp.	eveningprimrose							ful		par			
Oxalis corniculata	woodsorrel, creeping				ful								
Oxalis stricta	woodsorrel, yellow	ful			ful	ful	ful	ful		ful	ful		ful

Table 12.2 Broadleaf Weed Susceptibilities To PREemergence Herbicides (continued)

KEY: ful = Full control is expected par = Partial control is expected		*Barricade	*+Dacthal	Devrinol	*+#Dimension	*Kanse+	OH2	Pendulum	*+PennantMagnum	*Ronstar	Surflan	Treflan	XL
Genus, species	**Common Name**												
Physalis spp.	groundcherry												
Plantago spp.	plantain species												
Polygonum aviculare	knotweed, prostrate	ful	par	ful	ful	ful		ful			ful	ful	ful
Polygonum convolvulus	buckwheat, wild												
Polygonum pensylvanicum	smartweed, Pennsylvania							ful		ful	par		par
Polygonum persicaria	ladysthumb/smartweed										par		par
Portulaca oleracea	purslane, common	ful	ful	ful	ful	ful		ful	par	ful	ful	ful	ful
Raphanus raphanistrum	radish, wild												
Richardia scabra	pusley, Florida	ful	ful					ful	ful		ful	par	ful
Rumex acetosella	sorrel, red												
Rumex crispus	dock, curly												
Sagina procumbens	pearlwort, birdeye						ful						
Salsola kali	thistle, Russian											ful	
Senecio vulgaris	groundsel, common			ful		ful	ful		par	ful	ful		ful
Sida spinosa	sida, prickly												par
Sinapis arvensis	mustard, wild				ful						par		
Sisymbrium altissimum	mustard, tumble												
Sisymbrium irio	rocket, London				ful			ful			ful		ful
Solanum nigrum	nightshade, black		par						ful		par		par
Solanum nodiflorum	nightshade, Amer. black												
Solanum sarachiodes	nightshade, hairy								par				
Sonchus arvensis	sowthistle												
Sonchus oleraceus	sowthistle, annual			ful		ful	ful			ful	par		par
Spergula arvensis	spurry, corn												
Spergularia rubra	sandspurry, red												
Stellaria media	chickweed, common	ful	ful	ful	ful	ful	ful	ful			ful	ful	ful
Taraxicum officianale	dandelion						ful						
Trifolium pratense	clover, red												
Trifolium procumbens	clover, hop							ful					
Trifolium repens	clover, white												
Urtica dioica	nettle, stinging											ful	
Urtica urens	nettle, burning		ful										
Veronica arvensis	speedwell, corn				ful	ful		ful					
Veronica persica	speedwell,Birdeye	ful				ful							
Veronica spp.	speedwell species					ful				ful			
Xanthium strumarium	cocklebur, common												

Table 12.2 Weed Susceptibilities To PREemergence Herbicides (continued)

KEY: ful = Full control is expected par = Partial control is expected		*Barricade	*+Dacthal	Devrinol	*+#Dimension	*Kanse+	OH2	Pendulum	*+PennantMagnum	*Ronstar	Surflan	Treflan	XL
Genus, species	**Common Name**												
Grasses and Sedges													
Avena fatua	oats, wild			ful	ful	ful				ful	ful	ful	ful
Avena sativa	oats, volunteer												
Barbarea vulgaris	rocket, yellow												
Bromus catharticus	rescuegrass	par			ful								
Bromus mollis	brome, soft			ful	ful								
Bromus rigidus	brome, ripgut			ful	ful	ful				ful			
Bromus secalinus	brome, cheat			ful	ful							ful	
Bromus tectorum	brome, downy			ful	ful								
Cynodon dactylon	bermudagrass												
Cyperus compressus	sedge, annual					ful			ful	ful			
Cyperus esculentus	nutsedge, yellow								ful				
Dactylis glomerata	orchardgrass												
Digitaria ischaemum	crabgrass, smooth	ful	ful	ful	ful	ful		ful	ful	ful	ful	ful	ful
Digitaria sanguinalis	crabgrass, hairy/large	ful	ful	ful	ful	ful	ful	ful	ful	ful	ful	ful	ful
Echinchloa crus-galli	barnyardgrass	ful	par	ful	ful	ful	ful	ful	ful	par	ful	ful	ful
Eleusine indica	goosegrass	ful	par	ful	ful	ful		ful	ful	ful	ful	ful	ful
Elytrigia repens	quackgrass												
Eragrostis spp.	lovegrass/stinkgrass	ful	ful	ful				par			ful	ful	ful
Festuca arundinacea	fescue, tall												
Hordeum jubatum	barley, foxtail				ful								
Hordeum leporinum	barley, wild/hare			ful	ful							ful	
Hordeum pusillum	barley, little				ful						ful		ful
Hordeum vulgare	barley, volunteer				ful								
Leptochloa uninervia	sprangletop, red	ful		ful			ful	ful	ful		ful	ful	ful
Lolium multiflorum	ryegrass, Italian/annual			ful	ful								ful
Lolium perenne	ryegrass, perennial				ful								
Panicum capillare	witchgrass	ful	ful	ful				ful	ful		ful	ful	ful
Panicum dichotomiflorum	panicum, fall	ful		ful		ful		ful	ful	ful	ful	ful	ful
Phalaris canariensis	canarygrass												
Phleum pratense	timothy												
Poa annua	bluegrass, annual	ful	par	ful	ful	ful	ful	ful	ful	ful	ful	ful	ful
Poa pratensis	bluegrass, Kentucky												
Setaria faberi	foxtail, giant	ful		ful				ful	ful		ful	ful	ful
Setaria italica	millet, foxtail	ful							ful			ful	ful
Setaria spp.	foxtail species	ful										ful	ful

Table 12.2 Grass Weed Susceptibilities To PREemergence Herbicides

KEY: ful = Full control is expected par = Partial control is expected		*Barricade	*+Dacthal	Devrinol	*+#Dimension	*Kanse+	OH2	Pendulum	*+PennantMagnum	*Ronstar	Surflan	Treflan	XL
Genus, species	**Common Name**												
Setaria lutecens/glauca	foxtail, yellow	ful	ful	ful	ful	ful		ful	ful		ful	ful	ful
Setaria vertcilla	foxtail, bristly	ful		ful		ful				ful		ful	ful
Setaria viridis	foxtail, green	ful	ful	ful	ful	ful		ful	ful	ful	ful	ful	ful
Sorghum bicolor	shattercane								par			par	
Sorghum halepense	johnsongrass (rhizome)												
Sorghum halepense	johnsongrass (sdlg)	ful	par	ful				ful	par		ful	par	ful
Triticum aestivum	wheat, volunteer										par		par
Vulpia myuros	fescue, rattail											ful	

* Restricted-use pesticide; may be purchased and used only by certified applicators or used by someone under the direct supervision of a certified applicator.
+ Not for use in Nassau and Suffolk Counties. Pesticide labels that indicate "Not for use on Long Island, N.Y." mean that use is prohibited in Nassau and Suffolk Counties only.
# Rate or other application restrictions apply. See label for more information.

Table 12.3 Broadleaf Weed Susceptibilities To POSTemergence Herbicides

KEY: ful = Full control is expected par = Partial control is expected no = No control is expected.		AcclaimExtra	Basagran	*#Envoy	*FusiladeII	*+#Lontrel	Scythe	Sethoxydim
Genus, species	**Common Name**							
Abutilon theophrasti	velvetleaf	no		no	no		par	no
Acalypha virginica	copperleaf, Virginia	no		no	no		par	no
Acer spp.	maple	no		no	no		par	no
Allium canadense	onion, wild	no		no	no		par	no
Amaranthus blitoides	pigweed, prostrate	no		no	no		par	no
Amaranthus hybridus	pigweed, smooth	no		no	no		par	no
Amaranthus retroflexus	pigweed, redroot	no		no	no		par	no
Amaranthus spinosus	pigweed, spiny	no		no	no		par	no
Amaranthus spp.	pigweed species	no		no	no		par	no
Ambrosia artimisiifolia	ragweed, common	no	ful	no	no	par	par	no
Ambrosia trifida	ragweed, giant	no	ful	no	no	par	par	no
Amsinckia intermedia	fiddleneck, coast	no		no	no		par	no
Anagallis arvensis	pimpernel, scarlet	no		no	no	ful	par	no
Anoda cristata	anoda, spurred	no	ful	no	no		par	no
Anthemis cotula	chamomile, mayweed	no		no	no	ful	par	no
Apocynum cannabinum	dogbane, hemp	no		no	no		par	no
Arctium minus	burdock, common	no		no	no	ful	par	no
Artemisia vulgaris	mugwort	no		no	no		par	no
Asclepias	milkweed	no		no	no		par	no
Aster spp.	aster	no		no	no	ful	par	no
Atriplex rosea	orach, red	no		no	no		par	no
Barbarea vulgaris	rocket, yellow	no		no	no		par	no
Bidens spp.	beggarticks	no		no	no		par	no
Brassica nigra	mustard, black	no		no	no		par	no
Brassica rapa/campestris	mustard, field	no		no	no		par	no
Campsis radicans	trumpetcreeper	no		no	no		par	no
Capsella bursa-pastoris	shepherdspurse	no	ful	no	no		par	no
Cardamine spp.	bittercress	no		no	no		par	no
Carduus nutans	thistle, musk	no	ful	no	no	ful	par	no
Centaurea solsitalis	starthistle, yellow	no		no	no	ful	par	no
Cerastium vulgatum	chickweed, mouseear	no		no	no		par	no
Chenopodium album	lambsquarters	no	ful	no	no		par	no
Chorispora tenella	mustard, blue	no		no	no		par	no
Cirsium arvense	thistle, Canada	no	ful	no	no	ful	par	no
Cirsium vulgare	thistle, bull	no		no	no	ful	par	no
Clematis spp.	clematis	no		no	no		par	no
Commelina spp.	dayflower	no	ful	no	no		par	no

Table 12.3 Broadleaf Weed Susceptibilities To POSTemergence Herbicides (continued)

KEY: ful = Full control is expected par = Partial control is expected no = No control is expected		AclaimExtra	Basagran	*#Envoy	*FusiladeII	*+#Lontrel	Scythe	Sethoxydim
Genus, species	**Common Name**							
Conium maculatum	poison hemlock	no		no	no		par	no
Convolvulus spp.	bindweed	no		no	no		par	no
Conyza canadensis	horseweed/marestail	no		no	no	ful	par	no
Cuscuta spp.	dodder	no		no	no		par	no
Cynara cardunulus	thistle, artichoke	no		no	no		par	no
Datura stramonium	jimsonweed	no		no	no	ful	par	no
Daucus carota	carrot, wild	no		no	no	ful	par	no
Descurainia pinnata	tansymustard	no		no	no		par	no
Descurainia sophia	flixweed	no		no	no		par	no
Epilobium angustifolium	fireweed	no		no	no		par	no
Equisetum spp.	horsetail	no	no		no	no	par	no
Erigeron spp.	fleabane	no		no	no		par	no
Erodium botrys	filaree, broadleaf	no		no	no		par	no
Erodium cicutarium	filaree, redstem	no		no	no		par	no
Eupatorium capillifolium	dogfennel	no		no	no	ful	par	no
Euphorbia esula	spurge, leafy	no		no	no		par	no
Euphorbia humistrata	spurge, prostrate	no		no	no		par	no
Euphorbia maculata	spurge, spotted	no		no	no		par	no
Euphorbia spp.	spurge species	no		no	no		par	no
Galinsoga ciliata	galinsoga, hairy	no	ful	no	no	ful	par	no
Gallium aparine	bedstraw, catchweed	no		no	no		par	no
Geranium carolinanum	geranium, Carolina	no		no	no		par	no
Gnaphalium spp.	cudweed	no		no	no	ful	par	no
Helianthus annus	sunflower, wild	no	ful	no	no	ful	par	no
Holosteum umbellatum	spurry, umbrella	no		no	no		par	no
Ipomea hederacea	morningglory, ivyleaf	no		no	no		par	no
Ipomea purpurea	morningglory, tall	no		no	no		par	no
Ipomea spp.	morningglory, annual	no		no	no		par	no
Kochia scoparia	kochia	no		no	no		par	no
Lactuca serriola	lettuce, prickly	no		no	no	ful	par	no
Lamium amplexicaule	henbit	no		no	no		par	no
Lepidium perfoliatum	pepperweed, yellowflower	no		no	no		par	no
Lepidium virginicum	pepperweed, Virginia	no		no	no		par	no
Lespedeza spp.	lespedeza	no		no	no	ful	par	no
Lonicera spp.	honeysuckle	no		no	no		par	no
Malva spp.	mallow	no		no	no		par	no
Marchantia spp.	liverwort	no		no	no		par	no

Table 12.3 Weed Susceptibilities To POSTemergence Herbicides (continued)

KEY: ful = Full control is expected par = Partial control is expected no = No control is expected		AclaimExtra	Basagran	*#Envoy	*FusiladeII	*+#Lontrel	Scythe	Sethoxydim
Genus, species	**Common Name**							
Matricaria matricarioides	pineappleweed	no		no	no	ful	par	no
Mollugo verticillata	carpetweed	no		no	no		par	no
Moss (several genera)	moss	no		no	no		par	no
Oenothera laciniata	eveningprimrose, cutleaf	no		no	no		par	no
Oenothera spp.	eveningprimrose	no		no	no		par	no
Oxalis corniculata	woodsorrel, creeping	no		no	no		par	no
Oxalis stricta	woodsorrel, yellow	no		no	no		par	no
Parthenocissus quinquefolia	Virginia creeper	no		no	no		par	no
Physalis spp.	groundcherry	no		no	no		par	no
Plantago spp.	plantain species	no		no	no	par	par	no
Polygonum aviculare	knotweed, prostrate	no		no	no	ful	par	no
Polygonum coccineum	smartweed, swamp	no		no	no	par	par	no
Polygonum convolvulus	buckwheat, wild	no	ful	no	no	par	par	no
Polygonum pensylvanicum	smartweed, Pennsylvania	no	ful	no	no	par	par	no
Polygonum persicaria	ladysthumb/smartweed	no	ful	no	no	par	par	no
Portulaca oleracea	purslane, common	no	ful	no	no		par	no
Rannunculus spp.	buttercup	no		no	no	par	par	no
Raphanus raphanistrum	radish, wild	no		no	no		par	no
Rhus spp.	sumac species	no		no	no		par	no
Richardia scabra	pusley, Florida	no		no	no		par	no
Robinia spp.	locust	no		no	no		par	no
Rosa spp.	rose	no		no	no		par	no
Rubus spp.	blackberry	no		no	no		par	no
Rumex acetosella	sorrel, red	no		no	no	ful	par	no
Rumex crispus	dock, curly	no		no	no	ful	par	no
Sagina procumbens	pearlwort, birdeye	no		no	no		par	no
Salsola kali	thistle, Russian	no		no	no		par	no
Senecio vulgaris	groundsel, common	no	ful	no	no	ful	par	no
Sida spinosa	sida, prickly	no	ful	no	no		par	no
Sinapsis arvensis/Brassica kaber	mustard, wild	no	ful	no	no		par	no
Sisymbrium altissimum	mustard, tumble	no		no	no		par	no
Sisymbrium irio	rocket, London	no		no	no		par	no
Sisymbrium officinale	mustard, hedge	no		no	no		par	no
Smilax spp.	briar, green/cat	no		no	no		par	no
Solanum elaeagnifolium	nightshade, silverleaf	no		no	no		par	no
Solanum nigrum	nightshade, black	no		no	no	ful	par	no
Solanum sarachoides	nightshade, hairy	no		no	no	ful	par	no

Table 12.3 Weed Susceptibilities To POSTemergence Herbicides (continued)

KEY: ful = Full control is expected par = Partial control is expected no = No control is expected		AcclaimExtra	Basagran	*#Envoy	*FusiladeII	*+#Lontrel	Scythe	Sethoxydim
Genus, species	**Common Name**							
Solidago	goldenrod	no		no	no	ful	par	no
Sonchus oleraceus	sowthistle, annual	no		no	no	ful	par	no
Spergula arvensis	spurry, corn	no		no	no	ful	par	no
Spergularia rubra	sandspurry, red	no		no	no		par	no
Stellaria media	chickweed, common	no		no	no		par	no
Taraxicum officianale	dandelion	no		no	no	ful	par	no
Thlaspi arvense	pennycress, field	no		no	no		par	no
Toxicodendron spp.	poison ivy	no		no	no		par	no
Trifolium pratense	clover, red	no		no	no	ful	par	no
Trifolium repens	clover, white	no		no	no	ful	par	no
Urtica urens	nettle, burning	no		no	no		par	no
Verbascum thapsus	mullien, common	no		no	no		par	no
Verbena hastata	vervain, blue	no		no	no		par	no
Veronica persica	speedwell, Persian/birdseye	no		no	no	ful	par	no
Veronica spp.	speedwell species	no		no	no	ful	par	no
Vicia sativa	vetch, common	no		no	no	ful	par	no
Xanthium strumarium	cocklebur, common	no		no	no	ful	par	no
Grasses and Sedges								
Adropogon virginicus	broomsedge		no			no	par	
Argostis tenuis	bentgrass, colonial		no			no	par	ful
Arundo donax	reed, giant		no			no	par	
Avena fatua	oats, wild		no	ful	ful	no	par	ful
Avena sativa	oats, volunteer		no	ful	ful	no	par	ful
Bromus secalinus	brome, cheat		no	ful		no	par	
Bromus tectorum	brome, downy		no	ful	ful	no	par	ful
Cortaderia spp.	pampasgrass		no			no	par	
Cynodon dactylon	bermudagrass	par	no	ful	ful	no	par	ful
Cyperus esculentus	nutsedge, yellow	no	ful		no	no	par	no
Dactylis glomerata	orchardgrass	no	no			no	par	par
Digitaria ischaemum	crabgrass, smooth	ful	no	ful	ful	no	par	ful
Digitaria sanguinalis	crabgrass, hairy/large	ful	no	ful	ful	no	par	ful
Echinoloa crus-galli	barnyardgrass	ful	no	ful	ful	no	par	ful
Eleusine indica	goosegrass	ful	no	ful	ful	no	par	ful
Elytrigia repens	quackgrass	no	no	ful	ful	no	par	ful
Eragrostis spp.	lovegrass/stinkgrass		no	ful		no	par	ful
Festuca arundinacea	fescue, tall	no	no			no	par	par
Festuca longifolia	fescue, hard		no			no	par	

Table 12.3 Weed Susceptibilities To POSTemergence Herbicides (continued)

KEY: ful = Full control is expected par = Partial control is expected no = No control is expected		AcclaimExtra	Basagran	*#Envoy	*FusiladeII	*+#Lontrel	Scythe	Sethoxydim
Genus, species	**Common Name**							
Festuca ovina	fescue, sheep		no			no	par	
Festuca rubra	fescue, red	no	no			no	par	
Festuca spp.	fescue species	no	no			no	par	
Holcus molis	velvetgrass, German		no			no	par	ful
Hordeum vulgare	barley, volunteer		no	ful	ful	no	par	ful
Leptochloa fascicularis	sprangletop, bearded	ful	no	ful		no	par	
Leptochloa spp.	sprangletop	ful	no			no	par	ful
Lolium multiflorum	ryegrass, Italian/annual		no	ful	ful	no	par	ful
Lolium perenne	ryegrass, perennial	no	no	ful		no	par	
Muhlenbergia frondisa	muhly, wirestem		no	ful		no	par	ful
Panicum capillare	witchgrass		no	ful	ful	no	par	ful
Panicum dichotomiflorum	panicum, fall	ful	no	ful	ful	no	par	ful
Panicum miliaceum	millet, proso		no	ful	ful	no	par	ful
Panicum spp.	panicum species	ful	no			no	par	
Phalaris canariensis	canarygrass		no	ful		no	par	
Phleum pratense	timothy	no	no			no	par	
Phragmites spp.	reed, common		no			no	par	
Poa annua	bluegrass, annual	no	no	ful		no	par	
Poa bulbosa	bluegrass, bulbous		no			no	par	
Rottbellia exaltata	itchgrass		no	ful	ful	no	par	ful
Secale cereale	rye, volunteer		no	ful	ful	no	par	ful
Setaria faberi	foxtail, giant	ful	no	ful	ful	no	par	ful
Setaria lutecens/glauca	foxtail, yellow	ful	no	ful		no	par	ful
Setaria spp.	foxtail species	ful	no			no	par	
Setaria viridis	foxtail, green	ful	no	ful	ful	no	par	ful
Sorghum bicolor	shattercane		no	ful	ful	no	par	ful
Sorghum halepense	johnsongrass (mature)	par	no	ful	ful	no	par	ful
Sorghum halepense	johnsongrass (sdlg)	ful	no	ful	ful	no	par	ful
Triticum aestivum	wheat, volunteer		no	ful	ful	no	par	ful
Vulpia myuros	fescue, rattail		no			no	par	
Zea mays	corn, volunteer		no	ful	ful	no	par	ful

* Restricted-use pesticide; may be purchased and used only by certified applicators or used by someone under the direct supervision of a certified applicator.
+ Not for use in Nassau and Suffolk Counties. Pesticide labels that indicate "Not for use on Long Island, N.Y." mean that use is prohibited in Nassau and Suffolk Counties only.
# Rate or other application restrictions apply. See label for more information.

Chapter 13
Greenhouse Substrates

Andrew Ristvey, Extension Specialist, Nutrient and Water Management

Introduction

This chapter will discuss the physical and chemical properties of soilless substrates or "potting soils" and will provide in-house tests to examine these properties for developing management strategies for better plant growth. Other terms for soilless substrates are organic substrates, media, or medium.

Substrate Basics

There are several important aspects of choosing a substrate for a nursery or greenhouse. Substrates, fertilizers, and irrigation water quality and quantity, are linked together and each has an effect on the other and on plant growth (Fig. 13.1). The way a substrate holds air, water and nutrients is vital to the health of the roots and consequently the growth of the plant. Changing one will affect the others. Choice of substrate will have an effect on fertility and irrigation management. The information here will help a grower understand substrates and develop management programs to suit the nursery or greenhouse operation.

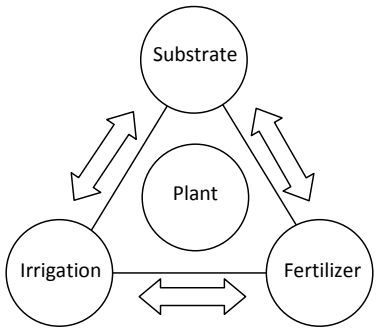

Figure 13.1 Substrate, Irrigation and Fertilizer Triangle
Source: MacEwan RJ (2007) Soil Health for Victoria's Agriculture. Context, Terminology and Concepts. Department of Primary Industries, Primary Industries Research Victoria, Bendigo, Australia. ISBN 978-174199-036-2

Substrate Components

There are a variety of organic and inorganic substrate components presently utilized in the industry, and each of which has its own physical and chemical properties. These components can be used individually or mixed together to create substrates with different physical and chemical properties suited to the requirements of a particular crop. The following is a list of typical components commonly found in most soilless substrates.

Peat moss: There are several types of peat. Sphagnum is the most widely utilized as a main component in commercial mixes because of its stability and high water holding capacity. Sphagnum peat usually has a low pH and often is amended with lime.

Pine bark: Pine bark is another popular component used especially for increasing the pore size and aeration in a substrate. Pine bark is relatively stable because it is made of lignin, a material not easily degraded by microorganisms. There are different grades and sizes of pine bark that undergo various aging processes. One should inquire about these factors before buying. Ideally, aged or composted pine bark fines of sizes no more

than 3/8 inch are best. Bark should contain little to no cellulose (wood). Pine bark is known to reduce the effectiveness of plant growth regulators applied as a drench.

Coir: This is coconut fiber and has been studied extensively as an alternative to peat moss because of the environmental issues surrounding peat extraction. Coir has a high water holding capacity and is easier to re-wet than peat. Depending on its source, coir may have very high chloride content. Consider lab analysis to determine chlorine contents before use.

Perlite: Perlite is a commonly used substrate component often used as an amendment to increase the pore space in peat-based substrates. It is an inert volcanic silica that is expanded or "puffed" by exposure to high temperatures. Because of the internal pores within the perlite, it can actually hold water, however, most of that water is not available to plants. Perlite comes in different particle sizes from fine to course grade. Typically, medium and course grades are mixed with peat moss to make bedding- plant or propagation substrates.

Vermiculite: Like perlite, vermiculite is a mineral extracted from mines and heat expanded. Vermiculite has desirable characteristics as an amendment for peat substrates as it optimally retains water and air.

Rockwool: Fibrous material manufactured by liquefying basalt rock, steel mill slag or other minerals, and then spinning into fibers. It is very porous with a high water holding capacity with much of that water easily available to plants. Rockwool is good for hydroponic or subsurface irrigated crops. Use only the basalt rock-based material because it is the most inert and will not interact with nutrient solutions. Rockwool has a relatively high pH so fertility levels must be monitored. Since it is only useful for a few growing cycles, disposal can be a problem because of its bulky volume.

Peanut Hulls: Peanut hulls are becoming a popular component in substrate mixes. Peanut hulls are approximately 37% lignin and are slower to degrade than other materials with greater cellulose content.

Rice Hulls: Rice hulls are also available for use as a substrate component. Rice hulls increase porosity when mixed with other components like pine bark or peat. However, some have experienced rice hulls settling and forming layers which restrict water infiltration throughout the substrate.

Whole Tree: With the high demand for pine bark increasing and supplies dwindling, new substrates are being developed. Whole Tree is a substrate made from all parts of the tree, including the bark, wood and leaves. While research has shown that it can be safely used as a growing medium, it is primarily cellulose and may need up to 30% or more nitrogen to overcome nitrogen drawdown from microorganism competition.

Other Common Substrate Components And Amendments

Sand: Concrete grade sand is typically used to improve ballast (increase weight) to prevent blow-over when using light weight mixes like peat. However, the extra weight may also increase shipping costs and increase the workload on labor. Concrete grade sand is recommended because it has large particles and is washed of silt or clay particles. Therefore drainage can be increased if used. Smaller sand particles may help to increase water holding capacity.

Lime: Comprised of mostly calcium carbonate (calcitic) or calcium magnesium carbonate (dolomitic), this material is used to buffer organic substrates and regulate pH. Dolomitic lime is most often used because it provides both calcium and magnesium. There are different grades of lime. Pulverized lime has small particles and is very reactive, quickly adjusting, buffering and raising pH in substrates, however it has little longevity when incorporated. Pelletized lime is pulverized lime with a dissolvable coating. Its longevity is only slightly

longer than pulverized lime. Granular lime has larger particle sizes than pulverized or pelletized lime, and therefore less reactive but with greater longevity. Granular lime can be mixed with pulverized lime to get the benefits of both quick reactivity and longevity for buffering. The addition of lime should be based on water quality, specifically, the alkalinity of the irrigation water.

Gypsum: Used to add calcium and sulfur to substrates without increasing or decreasing pH. Typically found in most commercial substrates along with dolomitic lime.

Other Nutrient Amendments

The addition of other nutrient amendments can be made, including granular micronutrient amendments. A variety of metal (nutrient) chelates, especially for iron, are used to improve nutrient availability. Chelates differ in form and effectiveness. The pH level can have an effect on the availability of the chelated nutrient. Iron sulfate was used in the past to manage the pH level. However, it can increase EC dramatically, and is short-lived in organic substrates, quickly leaching out with irrigation water.

One popular amendment called superphosphate is **no longer recommended** as an addition to soilless substrates. Superphosphate leaches from soilless substrates very quickly. Phosphorus is a pollutant in fresh water systems and is a very problematic nutrient. There are now better methods to apply phosphorus contained in low phosphorus soluble fertilizers and slow or controlled release fertilizers.

Choosing A Substrate

Based on physical and chemical properties, choose a substrate that fits the growing system. Most commercial substrates are developed for particular growing conditions and are labeled for specific uses. For the most part, commercial brands can be relied upon to give consistent substrate properties based on plant needs, however to be on the safe side, before planting, send a sample to a laboratory for analysis. At the very least, check pH and EC of each lot purchased. Some substrates have preincorporated amendments that increase EC to over 2.5 dS/m which can be initially high if irrigation is not immediately applied after planting.

Physical Properties

What are the key factors that determine how a substrate holds air and water? These properties are Air-Filled Porosity (AFP) and Water Holding Capacity (WHC). Air-Filled Porosity is the amount of air, by volume, that a substrate holds after irrigation and after drainage. Water Holding Capacity is the amount of water, by volume, that a substrate holds after irrigation and drainage.

There are many factors that determine AFP and WHC in organic substrates, but specifically the direct factor is the porosity and pore size created by the components of the substrate. Pore size and the distribution of pores in soilless substrates influences AFP and WHC. While particle size plays a direct role in soils, there is less influence of particle size to AFP and WHC in soilless substrates. While it is true that large particles like pine bark create large pores, the bark itself also has internal pore space that holds water. However this water may not necessarily be available to plants. Of course, substrates with a lot of small particles will have a high WHC. So, to some extent, particle size does play a role in AFP and WHC, but it is the composition of the substrate itself that is the primary factor.

Capillary forces are the attraction of water to surfaces strong enough to overcome gravitational forces. The smaller the pore space the stronger the capillary force, and the more water a substrate will hold, including internal pores within large particles.

Other Factors Affecting AFP And WHC Of The Substrate

Age: Substrates degrade as they age which increases the amount of small particles and decreases pore size. The aging process will typically increase WHC and decrease AFP. It is not recommended to reuse a substrate for successive growing cycles. Doing so avoids the need to adjust irrigation management among pathogen problems carried on from the last use.

Container Geometry: Given the same substrate, smaller and squatter containers will hold more water than larger taller containers on a percent volume basis.

Handling: Poor handling habits of substrates can reduce the pore size of the substrate. Smaller pores will increase WHC and reduce AFP. For example, when placing plugs in pots, do not compress the substrate around the plug and do not stack trays or pots on top of each other. This compresses the substrate and reduces pore size and AFP. Allow irrigation water to naturally compress the substrate around the roots.

Field Test For AFP And WHC

An in-house field test can be performed to determine AFP and WHC of substrates in containers. This test uses water to determine the % volume of AFP and WHC.

What is needed:

1) A typical growing container; 2) A scale that can measure at least 15 pounds or 7 kilograms or a beaker to measure water volume; and 3) A measuring device that utilizes the metric system of measurement

This method is designed to measure the AFP and WHC as % volume by taking weight measurements. Note that one gram (a unit of mass) of water is equal to one cubic centimeter or one milliliter (a unit of volume) and mass can be converted to volume with the metric system. If a metric measuring device is not available, ounces can be converted to grams. One ounce = 28 grams.

Steps:

1. Find a common container, tape the holes and weigh it. Record the weight as W4.
2. Fill the container with water to the level of which it is typically filled with substrate and weigh it. Record the weight as W3. Alternatively, directly measure the volume to which the container is filled.
3. Fill the container with substrate to the level of the water in the first measurement. The substrate should not be completely dry, in fact, the next step will go quicker if the substrate is moist. Most organic substrates repel water when completely dry.
4. Slowly add water to the container, saturating the substrate and allowing the water to evacuate the air. Water should be visible at the top of the substrate. Weigh the container and record the weight as W1.
5. Remove the tape and allow the water to drain for an hour, letting the substrate come to container capacity. Weigh the container making sure to keep the container level. Tipping the container will allow more water to come out. Record the weight as W2. Alternatively, the water can be captured and be directly measured as the volume that came out of the container.
6. % AFP = (W1 – W2) ÷ (W3 – W4) x 100
7. If the volumes have been recorded directly, the volume of water that came out of the container is the AFP. Calculate % AFP by dividing the volume that drained from the total volume of the container and multiplying by 100.
8. To test for WHC dry the same substrate in an oven for 48 hours at 180 °F. Weigh the substrate and record as W5.
9. % WHC = (W2 – (W5 +W4) ÷ W3) x 100. Remember to do the math inside the ( ) first, then subtract from W2, and then divide by W3. Multiply by 100.

Recommendations

For this field test, substrates growing plants and plugs in small containers, it is recommended that AFP is around 15 to 20%. If the AFP is any lower than that, then the roots should be monitored often. For containers greater than 1 pint and substrates with pine bark, AFP's should be between 20 and 35%. Some nurseries choose to have AFP's greater than 35% mainly when growing fine-rooted ericaceous species like azalea. These highly porous substrates hold very little water and leach quickly. In this case, the irrigation manager needs to water these plants often in short durations. The irrigation manager should manage irrigation carefully as these highly porous substrates are prone to leaching and nutrient loss.

Chemical Properties

Organic substrates are not inert, although they are not as chemically reactive as soils. Since soilless substrates are comprised mainly of organic components, they have more cation exchange capacity (CEC) and less anion exchange capacity. Cations are positively charged ions and include most of the micronutrients and many macronutrients. They include iron, magnesium, calcium, potassium etc.. The anions are negatively charged ions and they include nutrients like sulfur in the form of sulfate, phosphorus in the form of phosphate and nitrate. Anions are not held by organic substrates and are easily leached. The most important nutrients for management are both anions, nitrate and phosphate, which is why an irrigation manager must know the water holding capacity of their substrate to prevent leaching. Another important factor that plays a role in nutrient availability is pH. Both CEC and pH affect nutrient availability.

Substrate Cation Exchange Capacity

Cation exchange capacity (CEC) is the ability of the soil or soilless substrate to exchange cations. Since many nutrients are cations, it is a direct relation to fertility. Buffering capacity is also associated with CEC as this helps substrates to resist sudden changes in pH. The more aged or humified (biologically aged organic matter) components in the substrate, the higher the CEC. Organic substrates, including those with sphagnum peat or aged pine bark typically have good CEC.

Substrate pH

Nutrient availability depends on pH in soils and in soilless substrates. The pH is the amount of hydrogen ions (H+) in an aqueous solution (water) and ranges from 0 (most acidic) to 14 (most basic). The amount of hydrogen ions are exponentially and inversely related to the pH value. There are 10 times more hydrogen ions in a solution with a pH of 2 than in a solution with a pH of 3, and 100 times more than a solution of 4 and 1000 times more than a solution of 5. Since the hydrogen ion is positively charged, it interacts with nutrients, making them more or less available for uptake by plants depending on the pH level. For instance, low pH makes iron and manganese more available and high pH makes the same nutrients less available (Table 13.1). In soilless substrates it is recommended that the pH be between 5.5 and 6.2 for optimal nutrient availability, but the pH may need to be adjusted for a specific plant's needs (Fig. 13.2).

Table 13.1 Effects Of pH On Nutrient Availability In Soilless Substrates

Nutrient Availability	**Very low pH (less than 5.0)**	**Low pH (5.0 - 5.5.)**	**Optimum pH (5.5 - 6.4)**	**High pH (6.4+)**
Soluble: available to plant roots		Manganese, iron, copper, zinc, and boron	Maximum availability of essential nutrients	Molybdenum, magnesium, calcium
Insoluble: not available to plant roots	Magnesium, calcium	Molybdenum, calcium, magnesium, sulfur		Phosphorus, iron, manganese, copper, zinc, boron
Highly soluble: toxic levels	Manganese, iron, copper, zinc, boron			

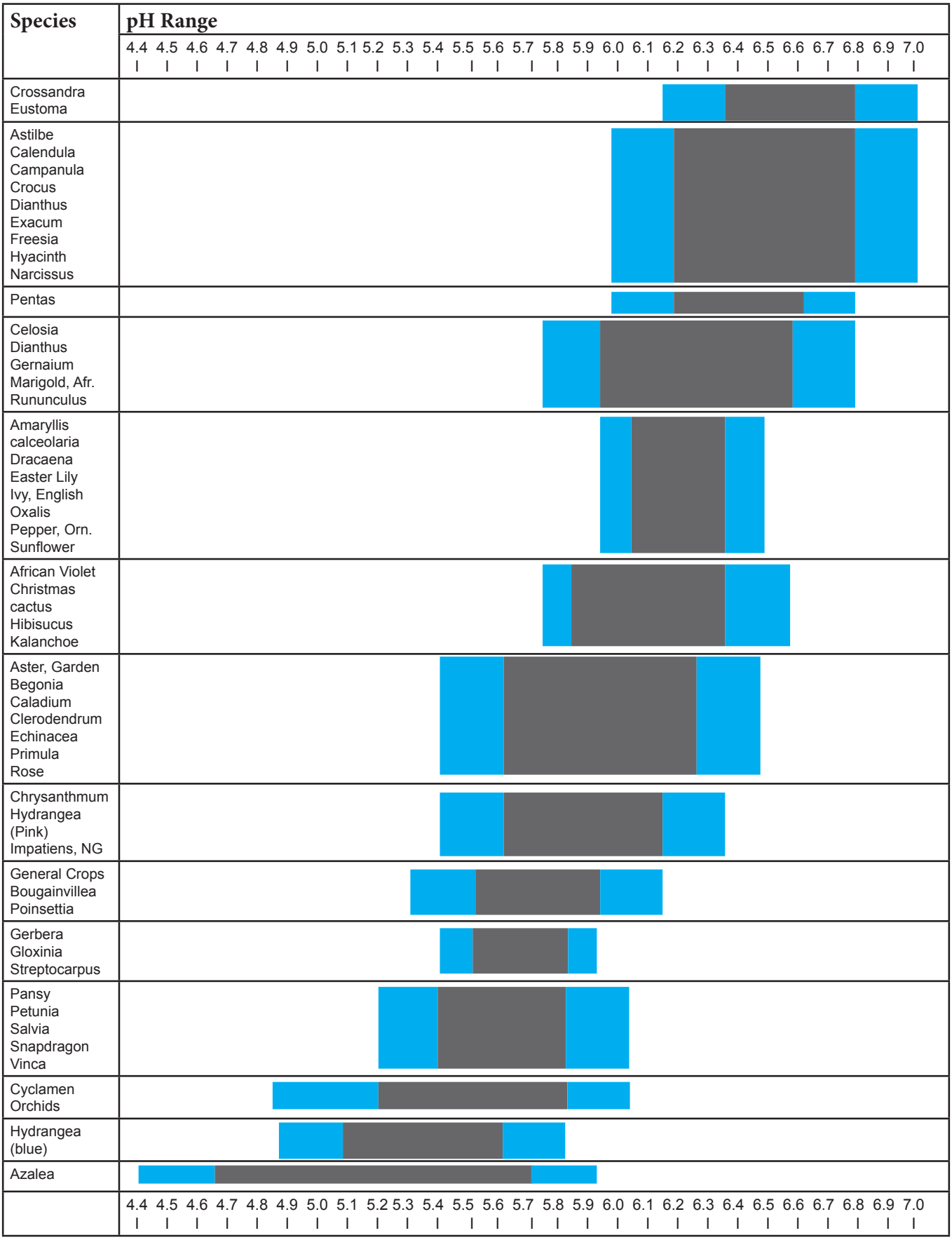

Figure 13.2 Suggested Substrate pH Ranges For Specific Greenhouse Crops In Soilless Substrate
Source: Whipker, B.E., W. Fonteno, D. Baily, and T. Calvins. N.d. Recording, Interpreting, and Managing Substrate pH. In PourThru Nutritional Monitoring Manual. North Carolina State University.

Irrigation Water Quality: Effects On Substrates

Water alkalinity is the amount of carbonates and bicarbonates dissolved in the irrigation water. The higher the alkalinity, the greater the buffering against change in pH as carbonates absorb hydrogen ions. However, a water supply can have too much alkalinity (above 150 ppm) which can eventually increase the pH in a substrate, leading to certain nutrient deficiencies like iron or manganese. The addition of an acid injection system can alleviate problems with alkalinity. Be sure to have the irrigation water tested to determine alkalinity. Check with an extension agent for help in determining what actions to take, whether it is acid injection or through amending a substrate with lime.

Managing Substrate pH

There are several biological and cultural reasons that cause pH to increase or decrease apart from irrigation water quality. Some plants like salvia, larkspur, and phlox naturally acidify the substrate so they require slightly higher pH substrates than other species. Other species like petunias, pansies and vinca naturally increase substrate pH.

Nitrogen fertility plays a large role in substrate pH. The use of nitrate increases the pH of substrates and the use of ammonium acidifies substrates. If there is a requirement for one of these in the fertility management, especially for the use of nitrate, it is recommended that consistent substrate monitoring be part of the management strategy.

Amending Substrates And Adjusting pH

Since pH plays an important role in nutrient availability, some modifications may need to be made to substrates if they are being mixed at the nursery. Preincorporating (mixing before potting) amendments to control pH, cation exchange capacity, or nutrition is common for nurseries that have decided to make their own mixes. After planting there are methods for managing substrate pH including use of specific fertilizers.

Lowering pH

Organic substrates, especially sphagnum peat moss and pine bark are naturally acidic so little needs to be done pre-planting to maintain low pH. Some amendments have been used in the past including elemental sulfur or iron sulfate. However, the most effective methods for keeping pH low are using acid fertilizers or acid injection (typically with 35% sulfuric acid). Remember that sulfuric acid is a very strong acid which requires great care in handling.

Recommendations for sulfuric acid injection are based on the water test and the meq/L of alkalinity shown on the test results. Eleven ounces of sulfuric acid (35%) per 1000 gallons of water are required to mitigate each meq/L of alkalinity. This procedure may need to be adjusted depending on the irrigation water's pH. For a quick remedy, an iron sulfate drench at 1.5 lbs per 100 gallons can be used but this dramatically increases EC and can damage foliage if applied on leaves. Care must be taken and EC monitoring is essential.

Increasing pH - Liming Substrates

The main reason to add lime is to buffer the substrate from rapid changes in pH. There are two main types of lime: dolomitic with both magnesium and calcium carbonates and oxides; and calcitic lime that only contains calcium carbonate and oxide. Dolomitic lime is usually recommended because it contains both calcium and magnesium in the correct proportions for plants. There are three types of liming materials. Pulverized lime is powdered lime. It has a quick effect but does not last long in the substrate. Pelletized lime is pulverized lime with a sticking agent that dissolves with water. Its longevity is only slightly longer than pulverized lime alone. Granular lime has larger particles so it lasts much longer than pulverized lime. For crops that stay in the nursery for longer than 6 months, it is recommended that a mixture of pulverized and granular lime be incorporated. So is there a magic formula or rate of lime for all substrates? The answer is

no. Actually, liming depends on something apart from the substrate. The most important factor the substrate manager must consider is water quality and water alkalinity.

Liquid lime is most often used as a management tool for the immediate increase of pH in substrates that have become too acidic during the growing cycle. It is a mixture of lime and water. It is typically used at a rate of between 1 and 4 quarts of lime to 100 gallons of water and applied directly to the surface of the substrate. The higher the concentration of lime, the more effectively it raises the substrate pH. Residues on plant tissue should be rinsed immediately after treatment to prevent burn. Substrate pH should be monitored within 24 hours after use and consecutively throughout the week after application. After 24 hours, if the pH range is above 7.0, irrigate plants to leach and continue to monitor.

Chemical Properties Monitoring

Monitoring pH and Electrical Conductivity (EC) in the nursery or greenhouse is a vital management strategy for ensuring plant root health. Electrical conductivity is a measurement of soluble salts in the media and can give an indication of the nutrient load in a container. Measuring EC is a management tool for quickly detecting problems. It cannot give any specific information about which nutrients are in the substrate or their concentration.

There are several methods for testing for pH and electrical conductivity including the Pour Through, Saturated Media Extract (SME), or a ratio of substrate and water as in a 1:1.5 dilution. The Pour Through is the easiest and least disruptive but may incur the most error. The SME will be most consistent but will require samples of media from the root area of the plants. It is most important to choose one method and continuously use it. With each of these methods, distilled water should be used. If distilled water is not available then irrigation water will suffice, but the EC of that water should be subtracted from the final EC result. High alkalinity water will skew pH results. The two tests most commonly used are the Pour Through and the SME, which are explained below. Some growers have hand-held probes that can be stuck directly into the substrate. Substrate must be moist for consistent results.

Monitoring should be done on a frequent basis, but at least during times of low humidity and hot temperatures, as soon as amendments are incorporated into substrates, or even over winter when warm temperatures exist in the greenhouses or overwintering houses.

Pour Through Method

- This method should be performed after an irrigation event when the containers are at or near saturation.
- Place a tray under the plant container to collect water.
- For a 6 inch diameter container, pour about 3 ounces (approx. 100 ml) of distilled water evenly over the top of the substrate or enough to collect about 2 ounces (approx. 60 ml) of leached water.
- Measure the EC and pH of the sample.
- For containers 1 pint and larger, tip the container 45 degrees and collect a sample of water from the drain hole instead of pouring water into the container. Be sure there is enough sample to cover the probes electrodes.
- This process should be repeated on as many containers and in different places as possible to access the population of containers and determine where plants need water or nutrients.

Saturated Media Extract (SME)

- Collect substrate from individual containers or collect any subsamples and combine. For smaller containers such as plug trays, plants will need to be sacrificed in order to obtain substrate samples. Grow extra trays for monitoring purposes and disperse them throughout the growing area to have representative samples within the nursery or greenhouse.

- Collect about 1 pint (about 500 mls) of substrate.
- Add distilled water until substrate becomes saturated with water just appearing at the top of the substrate. Be consistent with the appearance and it will not matter to what level the water saturates the substrate.
- Let the sample equilibrate for at least 30 minutes.
- Carefully place probe in saturated media and measure EC and pH in sample.

Dilution

- This method is simpler in procedure than the SME.
- Take one part substrate, by volume and add 1.5 parts water.
- Allow to sit for an hour and test liquid portion.

Saturated media extract is ideal for testing substrate before planting, however a Pour Through is useful when monitoring containers with plants. Electrical conductivity values decrease with the amount of water used. Discussion with Maryland growers, professional IPM specialists and other University of Maryland faculty concluded that the original interpretive values should be lowered to reflect the trends of lower fertilizer concentrations being used (Table 13.2).

Table 13.2 Interpreting Electrical Conductivity Values From Different Extraction Methods

These EC recommendations are adapted from "On-site Testing of Growing Media and Irrigation Water", a British Columbia Ministry of Agriculture fact sheet revised in 1999. Values have been adjusted to meet present fertility strategies. Values differ greatly within Indication levels, and merely serve as a guideline. Experience is necessary with each of these methods.

1:5	1:1.5	SME	Pour Through[1]	Indication
0 to 0.11	0 to 0.35	0 to 0.50	0 to 0.50	Low – nutrient levels may not be sufficient for some plants. High-end of range suitable for seedlings and salt sensitive plants.
0.11 to 0.35	0.35 to 1.25	0.50 to 2.0	0.50 to 2.0	Normal – Standard root range for most established plants. Lower-end of range typical for normal fertility.
0.35 to 0.65	1.25 to 2.5	2.0 to 3.5	2.0 to 4.6	High – suitable for salt tolerant plants but mid to high end of this range may damage roots.
0.65 to 1.1	2.5 to 3.5	3.5 to 4.5	4.6 to 6.5	Very High – May result in salt injury, reduced growth and root death. Dilution or Leaching by irrigation necessary.
> 1.1	> 3.5	> 4.5	> 6.6	Extreme – Immediate leaching is required.

[1]Due to the variability of the Pour Through technique results, growers should always compare their results to the SME method to establish acceptable ranges.

Making Home-Made Substrate

Start by finding components like the ones listed at the beginning of this chapter that will give adequate moisture retention but are porous enough to permit the exchange of oxygen. The mix should have a low initial electrical conductivity and should have some ability to freely exchange nutrients with the plant roots. The substrate should be stable, able to resist breaking down, and free of pathogens. Finally, a substrate that is reliably consistent with these properties from batch to batch is important so continual adjustment of management strategies, especially irrigation will not be necessary. Some typical recipes are as follows: Germination and annual mixes should have a relatively high water holding capacity because the plants are growing in small containers with limited volume like plug trays or cell-packs. Plant containers larger than plug and cell packs may require substrate components with larger particle sizes like pine bark.

The following are typical substrates with a wide range of component ratios by volume, depending on the plants being grown or the containers in which they are grown.

- Germination, Annual, and Bedding Mixes for plug trays and cell packs
  0-20% Pine Bark, 40-80% Sphagnum Peat, 10-40% Perlite, with dolomitic lime and gypsum

- Perennial Mixes for containers 1 gallon or less in size:
  25-60% Pine Bark, 40-60% Sphagnum Peat, 0-40% Perlite with dolomitic lime, and gypsum

- Woody Shrubs and Trees for containers of a gallon or more
  70-100% Pine Bark, 0-30% Sphagnum Peat, 0 to 20% concrete grade sand, with dolomitic lime, and gypsum.

Other components or amendments that may be considered for incorporation in the mix are nutrients in the form of controlled release fertilizers or micronutrient charges. Substrates with pre-incorporated controlled release fertilizers should be utilized quickly and should not sit for more than a week or two. Substrates with incorporated controlled release fertilizer that are exposed to rain and sun may begin to release fertilizer salts into the substrate. A very high electrical conductivity may result which could kill tender new roots after potting. Be sure to consistently monitor substrates with preincorporated fertilizers for pH and EC, especially before potting.

Surfactants or wetting agents are often utilized in commercial substrates to aid in irrigation, especially if substrates become dry. Consider using these materials to help get the substrates wet after potting and to assist irrigation during the crop cycle. They are available in liquid and granular form.

Monitoring Equipment, Care And Calibration

Hand held pH and EC sensors are available from a variety of manufacturers. These meters are necessary for substrate monitoring.

Most good pH and EC probes need care and calibration. Many are made of glass membranes which need to remain moist and be contained in a special buffer solution. After purchasing a pH and EC probe, remember to also purchase electrode buffer solution and calibration solutions for both electrical conductivity and pH (7.01 and 4.01). Different EC meters require different calibration solutions. Remember to inquire about which calibration solutions to purchase for the EC probe as they come in several different strengths.

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Chapter 14
Landscape Soil Management

Andrew Ristvey, Extension Specialist, Nutrient and Water Management
Virginia Rosenkranz, Extension Educator, Horticulture

Introduction

Soil management in the landscape environment is an important component in ensuring the long-term health of plantings. Disturbed soils in suburban and urban environments, and around newly built homes, yield landscape soils that are typically poor in quality. The objectives of this chapter are to offer suggestions for managing the quality of these poor soils, promoting the survivability of the plantings and upholding the reputation of the installation company.

Physical Characteristics Of Soils

Soil exists in three parts or phases; solid, liquid and gaseous (Fig. 14.1). The solid portions are composed of both mineral and organic materials. The liquid and gaseous components exist in the pore spaces created by the solid portion of the soil. The portions of the liquid and gaseous phases vary based on the physical qualities of the soil and exist temporally based on water input, plant transpiration and evaporation, and the changing of the soils physical qualities, either by natural or human-made action. Understanding the way in which a soil holds water begins first with recognizing the factors determining water and air holding capacities.

A soils texture is a measurement of the particle size distribution. The United States Department of Agriculture classifies fine soil particles as sands, silts and clays in decreasing order of size (Fig. 14 2). Together, these particles along with particles larger than two millimeters (about 1/16 inch) in various proportions are classified (Fig. 14.3.). The proportions and arrangement of particles of the soil determines the porosity and how water and air is held.

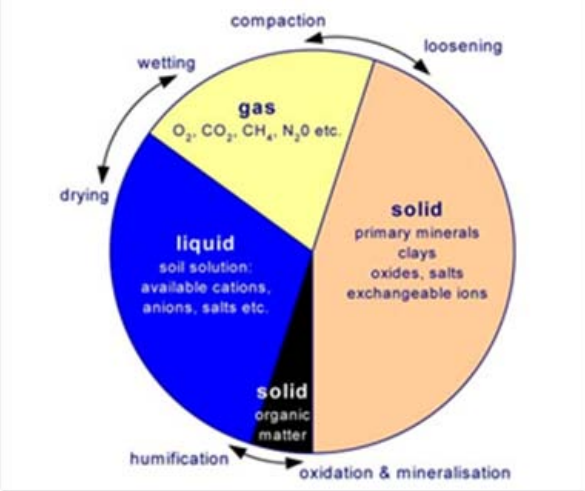


Figure 14.1 Representation Of Bulk Soil Composition In Relation To The Three Phases Of Matter: Solid, Liquid And Gaseous
Source: Department of Primary Industries, Victoria Australia, Resouces online. The Soil System and Soil Health Monitoring.

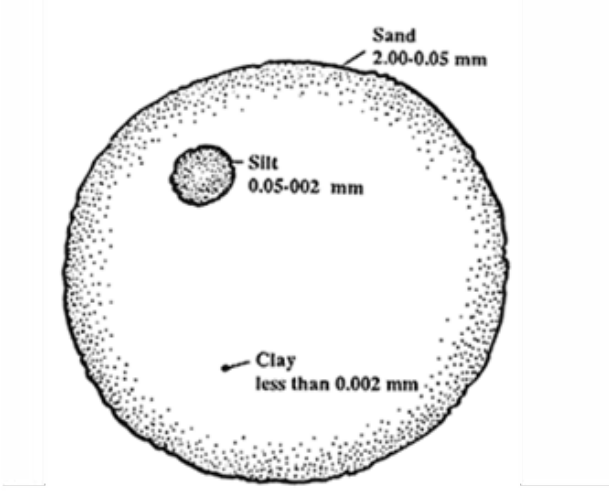
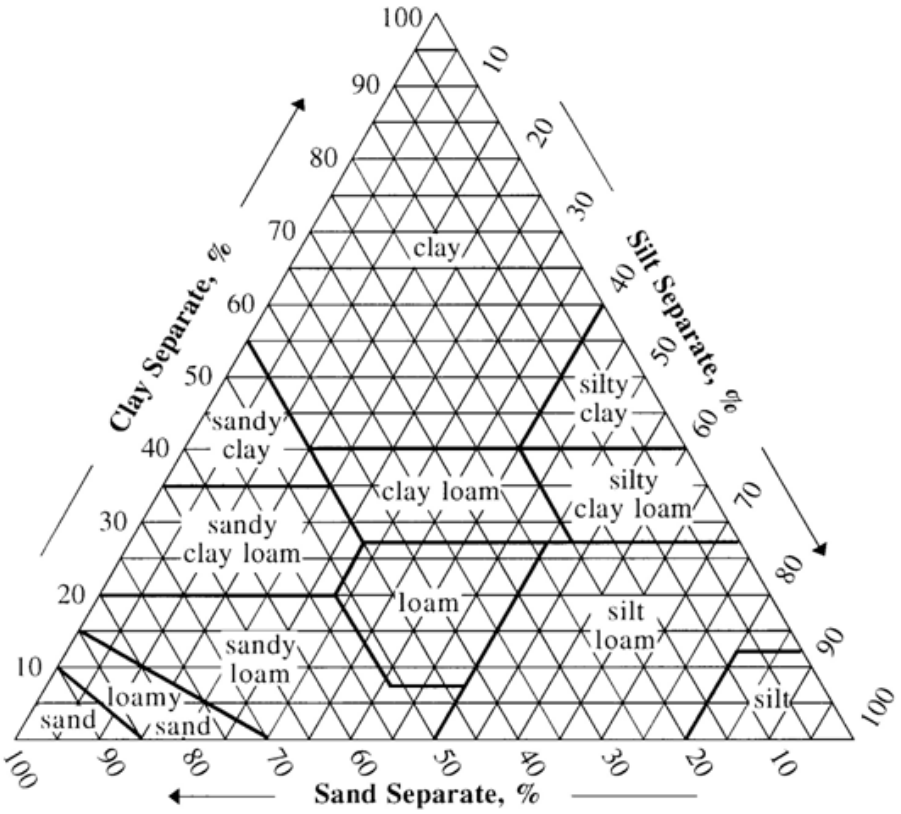


Figure 14.2 Relative Size Comparison Between Sand, Silt, And Clay



COMPARISON OF PARTICLE SIZE SCALES

USDA	GRAVEL	SAND					SILT	CLAY
		Very coarse	Coarse	Medium	Fine	Very Fine		

UNIFIED	GRAVEL		SAND			SILT OR CLAY
	Coarse	Fine	Coarse	Medium	Fine	

AASHO	GRAVEL OR STONE			SAND		SILT - CLAY	
	Coarse	Medium	Fine	Coarse	Fine	Silt	Clay

Figure 14.3 Soil Texture Triangle For Comparison Of Component Ratios And The Classification Given To Those Ratios

Basically, small particles create small pores which tend to hold water tightly, with larger particle sizes creating large pores which tend to hold air. For example, soils containing clay and silt will tend to hold more water and soils containing sand and larger particles will hold more air. Obviously, a balance between holding air and holding water is necessary for healthy plant growth. Additionally, the amount of organic matter will positively affect water holding capacity of the soil.

Should You Use Organic Matter As A Soil Amendment?

Much of the soils that are encountered in the landscapes of newly-built homes and suburban and urban areas are typically backfill or sub-soils with poor drainage and little fertility. There are presently two trains of thought. First, against common practice, research has shown that for persistent landscapes (where plants are not rotated like a garden or annual bed), it is best not to back-fill with organics. Alternatively, compacted urban soils need some form of amending with organics– up to 1/3 by volume. Which is correct?

As stated above, the soil structure determines how water infiltrates and is held, along with air. Poorly structured soils, created from disturbance and compression are not good for plant roots and some

researchers say adding organic matter (OM) beyond 5% is not necessary. Adding too much organic material can also lead to nitrogen depletion if organics are not well composted. Excess use of OM can also lead to plant settling, creating a low point for collecting storm water, and potentially water-logging roots. This situation occurs especially when planting trees in holes; the most recent thought is to use unamended native soil when backfilling. Research has shown that roots growing in holes that were amended with organics would not penetrate into the surrounding native soils, eventually causing girdling. Roots that could not grow into the native soils were also not able to make use of the surrounding available soil moisture.

Some new ideas presently being researched on amending urban soils is the addition of OM to the surface of the urban soil and turning it under to depth of 24 to 36 inches without a thorough mixing. This might create OM channels from the surface to lower soil profile for water infiltration.

The most recent recommendations are to not use organic matter as a soil amendment, and simply apply mulch on the surface after planting to slow water evaporation from the soil. Good soil structure will develop in time as the biological portion of the soil develops and increases. For establishing plants, irrigation is recommended as water is the most important growth regulator.

Use Of Sand

Clay soils tend to hold water and become very tight and solid when dry. While sand may be considered as an amendment to increase the portion of large particles and pores, unless the soil contains at least 50% sand, there may be little to no affect on the clay soil. Furthermore, that sort of disruption in the soil profile upsets the biological communities (beneficial fungi and other microorganisms) and could make the soil more problematic in the long term as such disturbances destroy the already forming structure needed for water infiltration. It is also impractical to remove 50% of the soil and replace it with sand.

As above, the recommendations to manage clay soils are to retain the moisture content by applying a surface mulch. Doing so allows the organic leachates to slowly move into the soil profile, retaining water by prevention of evaporation and promoting a healthy biological system.

Chemical Characteristics Of Soils

Soil pH

Nutrient availability depends on pH, the amount of available or loose hydrogen ions (H+) in an aqueous solution (water). The pH range is from 0 to 14, 0 being the most acidic and 14 being the most basic. The amount of hydrogen ions are exponentially and inversely related to the pH value. For example, there are 10 times more available hydrogen ions in a solution with a pH of 2 than in a solution with a pH of 3, a 100 time more than a solution of 4 and 1000 times more than a solution of 5. Since the hydrogen ion is positively charged, it interacts with nutrients, in some cases making them more available for uptake by plants and in other cases making them less available. For instance, low pH makes iron and manganese more available and high pH makes the same nutrients less available. A pH be between 6 and 7 is needed for optimal nutrient availability (Fig. 14.4). This level may need to be adjusted according to specific plant needs.

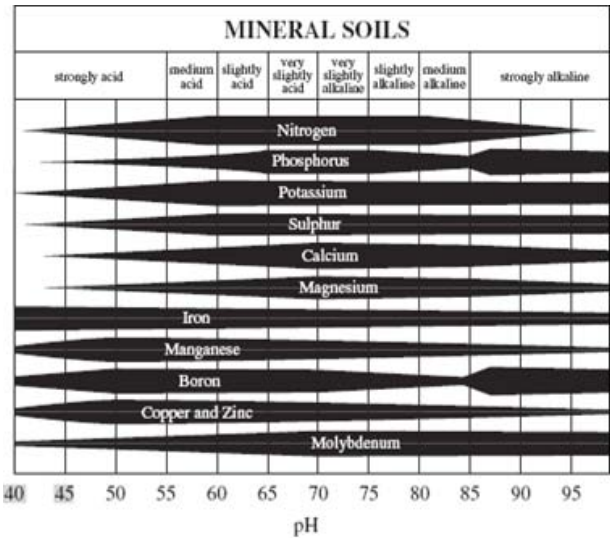


Figure 14.4 Effect Of pH On Nutrient Availability: Thicker black lines ndicate greater availability.

Cation Exchange Capacity

Cation Exchange Capacity (CEC) is the ability for the soil to exchange cations. Since many nutrients are cations, it is a direct relation to fertility. Buffering capacity is also associated with CEC as this helps substrates to resist sudden changes in pH. Cation Exchange Capacity is affected by pH and the amount of negatively charged particles in the soil. These chemically reactive particles in the soil called colloids are made of clays and humic (organic) components. The negative charges can hold and exchange positively charged nutrients. A soil with high CEC will tend to be fertile as long as the nutrients are relatively balanced for plant needs.

Soil Testing

Before planting or fertilizing, a soil test will give the most accurate information about the nutrient activity. Presently, all landscaping companies in Maryland utilizing fertilizers and managing more than 10 acres of landscape are required to furnish Maryland Department of Agriculture soil analyses once every three years from each of the individual landscapes as part of the nutrient management regulations. Basic soil tests are relatively inexpensive and include pH, organic content, primary macronutrients like phosphorus, potassium and secondary macronutrients like calcium and magnesium. Analyses including all the micronutrients and cation exchange capacity cost a little more, but may be valuable, although much can be interpreted from the basic test.

The procedure for soil sampling is as follows:

- Collect 15 to 20 samples in a clean plastic bucket.
- Take samples from throughout the entire area of the unit.
- Follow a sampling pattern that will give the best overall sample.
- Avoid sampling unusual areas such as windbreaks, old fence lines, wet areas or areas near lime rock roads or driveways.
- Scrape away any surface residues.
- Sample to the depth of 8 inches for fertility samples.
- Mix samples thoroughly, breaking any clods apart.
- Place a sample from the bucket in the sample bag.

Analysis Interpretation And Necessary Corrective Actions

Interpretation of soil analyses can be difficult. The type of soil, the pH, the CEC and the amount of organic material all play a role in interpretation of the nutrient levels. While no specific amendment rates are given here, they can easily be accessed online or offered by the laboratory along with the soil analyses.

pH

One of the most important factors in the analysis is the soil pH. It will determine the availability of nutrients in the soils. Nutrients are made optimally available for plants between a pH of 6 and 7 (Fig. 14.4). For most plants, this pH range is ideal, however there are exceptions, especially with "acid-loving" species like blueberry, *Pieris*, rhododendrons and azaleas. While soil can be amended with chemicals to adjust pH, when and where possible, utilize plants that will adapt well to the local conditions.

Acidifying high pH soils (above 7.2) may be necessary to increase the availability of nutrients like iron, manganese, zinc, and copper, or may be needed to drop soil pH below 5 for growing acid-loving plants. This can be done with elemental sulfur, but this is a slow process and should be done the year before planting. A quicker change can be made with iron sulfate (3 to 4 weeks), and from the use of ammonium based fertilizers. Care should be taken not to over acidify a soil. At pH of less than 5, iron, manganese and aluminum become very available with concentrations that are toxic to most plants. Unless changing flower color for *Hydrangea macrophylla* cultivars, aluminum sulfate should not be used to acidify soils because aluminum is toxic.

The soil pH can be increased by using lime. There are several forms of lime available including: fast acting pulverized lime, pelletized lime (pulverized lime with a water soluble coating) with a slightly slower acting time, and granulated lime. Calcitic lime only contains calcium, where dolomitic lime contains calcium and magnesium. You can determine which to use depending on your calcium and magnesium sufficiency level (total parts per million), as per your soil test results.

Buffer Index
Buffer index is a laboratory test in which a specific amount of lime-like material is applied to an acidic soil and a pH is taken. It shows the available or reserve acidity in that soil. The higher the pH, the less reserve acidity and the less lime is needed to raise the pH to a specific level. It is typically done on soils of pH 6.5 or less and is the test used for determining lime applications.

Calcium and Magnesium
Types of lime and rates are usually given based on the ratio of calcium (Ca) and magnesium (Mg) on the cation exchange complex. This analysis, called the Base Cation Saturation Ratio (BCSR), tells the percentage of calcium, magnesium, potassium and hydrogen (sometimes sodium) attached to the cation exchange complex. However, it is incorrect to adjust ratios of calcium and magnesium based solely on the BCSR. First, the soil may have the correct ratios, but still be depleted in either or both calcium and magnesium. On the other hand research has shown that if calcium and magnesium are sufficiently present in the soils, the ratio has no influence on plant productivity. Additions of calcium and magnesium should be made based on sufficiency, not ratios.

If the soil does not need pH adjustment and calcium and/or magnesium are deficient, gypsum (calcium sulfate) and Epsom salts (magnesium sulfate) can be used to supply additional Ca and Mg, respectively. The use of gypsum is also recognized as a conditioner, flocculating (loosening) heavy soils, specifically in clay soils that are high in sodium.

Organic Amendments
While the addition of organic amendments into the soil profile are thought to perform many valuable functions, recent research shows that only short term benefits are seen, with little to no long term benefits. Annual and vegetable gardens along with other short term plantings may benefit from the addition of well-composted organics. On the other hand in some cases, the addition of organics can be detrimental for plant health, especially if the organics are not properly composted or have high concentrations of salts or certain micronutrients that could cause toxicities. Furthermore, over time the soil can compress, leaving the planting subject to potential flooding if in a low area.

In planting beds with excessively poor soils, clay or sand with very low organic content (below 3%) or a low CEC (below 10 meq/100g), well-composted organic matter should be applied to reach a final organic content of around 5%, little more. As was stated earlier, do not apply organics only in a single planting hole (as only native soil is necessary); rather, incorporate organic material throughout planting bed to a depth of 6 – 8". Consider testing the organic material to be used beforehand and watch for high concentrations of manganese, boron, copper and zinc. If any of these are in high concentrations, consider using another organic source.

The Maryland Fertility Index Value (FIV)

Apart from nitrogen, all fertilizer recommendations should be made after a soil test. For phosphorus, potassium, calcium, and magnesium, the Fertility Index Value (FIV) was established for Maryland farmers, turf specialists and tree plantations. The FIV was created to standardize the sufficiency values of these nutrients because different laboratories perform different analyses for nutrient sufficiency. For example, given the same soil, each laboratory may give a different sufficiency value for phosphorus because the tests

procedures are different. No nutrient application rates have been developed for in-ground ornamental plantings based on FIV. However, when values are within medium to optimal levels, no nutrient addition is necessary.

Table 14.1 Nutrient Levels Based On FIV Value. Fertility Recommendations Are Based On These Values

Soil Test Category				
FIV Level	**0-25**	**26-50**	**51-100**	**>100**
Nutrient status	Low	Medium	Optimum	Excessive

Landscape Fertility

All fertility except nitrogen should be based on soil analyses. Proactive application of nutrients before knowledge of what is needed, not only can be a waste of time and money, but also a detriment to plants and the environment. Plants have the remarkable ability to acclimate to landscape soils with low fertility. In many cases high fertility causes lush growth, attracting insects. High soil-salts weakens roots leaving plants open to disease.

Nitrogen is usually the limiting nutrient in many landscape soils. While phosphorus is commonly deficient in many soils, in most landscape situations, it is adequately present along with potassium. Fertility recommendations for landscape plantings --both new and established --vary considerably.

Some research suggests plants do not respond to fertility the first year. The first season's growth depends on nutrients reserved from the previous year. In most cases, plants coming out of nurseries have been well fertilized and will not need fertilizer during planting. Fertilizer tends to promote shoot growth over root growth, potentially delaying establishment and reducing tolerance to drought. However, nutrients applied to newly planted landscapes may be stored in the plants and utilized the following spring. If fertility is utilized in any new landscape, either during or after establishment, it should be applied at a low rate.

Recommendations of rates of nitrogen to apply to established landscape plantings vary, but are usually made on an area basis of 1000 ft^2. Nitrogen recommendations for fertilizing established trees and shrubs vary considerably. Amounts of nitrogen between 0.25 to 1 lb. N per 1000 ft^2 (annually) are probably sufficient for the needs of these plants. Nitrogen deficiencies in mature trees and shrubs may be corrected with higher rates in the area of 2 to 4 lbs. N per 1000 ft^2 per year for a couple of seasons. As always, fertilizer applications should be made after soil and leaf tissue analyses to properly identify deficiencies.

Timing of fertilization also varies based on the type of plantings. In Maryland and in other northern states, trees should be fertilized either before leaf fall in the autumn or before bud break in the spring as roots are relatively active during these periods. Do not fertilize after the beginning of July as this may delay bud set and cold hardiness. In sandy soils, a split application is recommended to reduce nutrient leaching. Keep up-to-date with regulations for turf fertility.

Table 14.2 Recommended Site Requirements For Selected Perennials

Species	Common Name	Soil Type	Light	pH	Drought Tolerance	USDA Zone
Achillea sp	Yarrow	Well drained	Full	6.8 – 7.2	High	4-8
Agastache sp	Anise Hyssop	Well drained	Full	6 – 7.2	High	6-9
Allium sp	Ornamental Onion	Well drained	Full to partial	6 – 7	High	5-10
Amsonia sp	Blue Star Flower	Moist, well-drained	Full to partial	6 – 7	Moderate	5-9
Aquilegia canadensis	American Columbine	Moist, well-drained	Partial to shade	6.7 – 7.2	High	4-10
Aquilegia spp	Columbine	Moist, well-drained	Partial to shade	6.7 – 7.2	Moderate	4-10
Asclepias tuberosa	Butterfly weed	Well drained	Full	6.8 – 7.2	High	3-9
Baptisia australis	False Blue Indigo	Moist, well drained	Full	6 – 7	High	3-9
Chelone glabra	Turtlehead	Moist	Partial	6 – 6.5	Low	3-8
Coreopsis verticillata	Thread-leaf Coreopsis	Well drained	Full	6 – 7	High	3-9
Coreopsis grandiflora	Tickseed Coreopsis	Moist, well drained	Full	6 – 7	Moderate	5-10
Chrysanthemum spp.	Daisy	Moist, well drained	Full	6.5 – 7.0	Moderate	
Delosperma spp.	Ice Plant	Well drained	Full	6 – 7	High	5-9
Delphinium exaltum	Bee Delphinium	Moist, well drained	Partial to shade	6 – 7	Low	3-7
Dianthus spp.	Pinks, Carnations	Moist, well drained to dry	Full to partial	6 – 7	High	4-10
Dicentra spp.	Bleeding Hearts	Moist, well drained	Partial	6.5 – 7	Low	4-8
Echiniacea purpurea	Purple Cone Flower	Well drained	Full	5.0 – 7.5	High	3-10
Eryngium yuccifolium	Sea Holly	Moist to well drained	Full	6.5 – 7.5	High	5-10
Eupatorium fistulosum (and other Joe-Pye)	Joe Pye Weed	Moist	Full	6.5 – 7.5	Low	3-9
Eupatorium hyssopifolium	Boneset, Thoroughwort	Well drained	Full	5.5 – 7	High	3-10
Eupatorium rugosum	White Snakeroot	Moist, well drained	Partial	5.5 – 7	Moderate	4-8
Gaillardia spp	Indian Blanket	Well drained	Full	5.5 – 7.5	High	3-9

Table 14.2 Recommended Site Requirements For Selected Perennials (continued)

Species	Common Name	Soil Type	Light	pH	Drought Tolerance	USDA Zone
Geranium spp	Wild Geranium	Well drained	Full to partial	6.5 – 7.0	Low to moderate	4-9
Helenium spp.	Sneezeweed	Moist, well drained	Full	6.5 – 7.0	Low to moderate	4-8
Helianthus spp.	Sunflower	Well drained	Full	6.5 – 7.5	Moderate to high	4-9
Heliopsis spp	Sunflower	Well drained	Full	6.5 – 7.0	Moderate	4-10
Helleborus spp.	Hellebore	Moist, well drained	Partial to Full shade	6.5 – 7.5	Moderate	6-9
Hemerocallis spp.	Daylily	Moist to well drained	Full to partial	6.5 – 7.5	Moderate to high	4-10
Heuchera spp.	Coral Bells, Alumroot	Moist, well drained	Full to partial	6.5 – 7.0	Moderate	4-9
Hibiscus spp.	Hibiscus	Moist	Full	6.5 – 7.0	Low to moderate	4-9
Hosta spp.	Plantain Lilly	Moist, well drained	Partial to full shade	6.8 – 7.2	Low to moderate	4-9
Iris cristata	Crested Iris	Moist, well drained	Partial to full shade	6.8 – 7.2	Moderate	5-9
Iris germanica	German Bearded Iris	Well drained	Sun	6 – 7	High	4-10
Kniphofia	Red Hot Poker	Well drained	Sun	6 – 7	High	6-9
Lamium maculatum	Spotted Dead Nettle	Moist, well drained	Partial to full shade	6.5 – 7.5	Moderate	4-10
Lavendula angustifolia	English Lavender	Well drained	Full	6.0 – 7.0	High	6-11
Leucanthemum superbum	Snowflake	Moist, well drained	Full	6.5 – 7.5	Moderate	5-9
Liatris spp	Blazing Star	Moist to well drained	Full	6.5 – 7.5	Moderate to high	3-9
Lillium spp.	Lily	Moist, well drained	Full	6.5 – 7.0	Moderate	4-9
Liriope muscari	Blue Lily Turf	Moist to well drained	Full to Full shade	6.5 – 7.0	Moderate to high	5-10
Lobelia cardinalis	Cardinal flower	Moist, well drained	Full to partial	6.5 – 7.0	Low	3-9
Lobelia siphilitica	Big Blue Lobelia	Moist, well drained	Partial	6.5 – 7.0	Low to Moderate	5-9
Lupinus hybrids	Lupine	Moist, well drained	Full	6.5 – 7.0	Low to Moderate	5-9
Monarda spp.	Bee Balm	Moist, well drained	Full to partial	6.5 – 7.0	Moderate	4-10

Table 14.2 Recommended Site Requirements For Selected Perennials (continued)

Species	Common Name	Soil Type	Light	pH	Drought Tolerance	USDA Zone
Nepeta spp.	Catnip	Moist, well drained	Full	6.5 – 7.0	Moderate to high	3-10
Oenothera fruticosa	Sundrops	Well drained	Full	6.5 – 7.5	High	4-7
Penstemon spp.	Beardtongue	Moist, well drained	Full to partial	5.5 – 7.5	High	4-7
Phlox divaricata	Woodland Phlox	Moist, well drained	Partial to full shade	5.5 – 7.0	Moderate	3-9
Phlox paniculata	Garden Phlox	Moist, well drained	Full to partial	6.5 – 7.0	Moderate	4-9
Phlox maculata	Wild Sweet William	Moist, well drained	Full to Full shade	6.0 – 7.0	Moderate	3-8
Phlox stolonifera	Creeping Phlox	Moist to well drained	Partial to full shade	6.0 – 7.0	Moderate	4-9
Phlox subulata	Moss Phlox	Moist, well drained	Full to partial	6.0 – 7.0	High	3-10
Physostegia virginiana	Obedient plant	Moist, well drained	Full to partial	6.5 – 7.0	Moderate	4-10
Rudbeckia fulgida	Orange Coneflower	Moist, well drained	Full to partial	6.0 – 7.0	Moderate to high	4-8
Rudbeckia hirta	Black Eyed Susan	Moist well drained	Full	6.0 – 7.0	High	4-9
Rudbeckia lacinata	Cutleaf Coneflower	Moist, well drained	Full to partial	6.0 – 7.0	High	3-10
Salvia spp.	Sage	Moist to well drained	Full to partial	6 – 6.5	High	5-9
Scabiosa spp.	Pincushion Flower	Moist to well drained	Full to partial	6.8 – 7.5	Moderate	5-9
Sedum spp.	Stonecrop	Well drained	Full to partial	6.5 – 7.5	High	4-9
Solidago spp.	Goldenrod	Moist, well drained	Full to partial	5.5 – 7.0	High	5-10
Symphiotrichum novea-angliae	New England Aster	Moist, well drained	Full	6 – 6.5	Low to moderate	4-9
Symphiotrichum novi-belgii	Michaelmas asters	Moist, well drained	Full	5.1 – 6.5	Low to moderate	3-9
Tiarella cordifolia	Foam flower	Moist, well drained	Partial to full shade	6.0 – 7.0	Low to moderate	3-9
Tradescantia spp	Spiderwort	Moist to well drained	Full to partial	5.5 – 7.0	Moderate	3-9
Veronica spp.	Speedwell	Moist, well drained	Full to partial	6.0 – 7.0	Moderate to high	4-10

Table 14.3 Recommended Site Requirements For Selected Grasses

Species	Common Name	Soil Type	Light	pH	Drought Tolerance	USDA Zone
Calamagrostis spp.	Feather Reed Grass	Moist, well drained	Full to partial	5.0 – 7.5	Moderate	4-9
Carex spp.	Sedge	Moist, well drained to wet	Partial to full shade	6.0 – 7.0	Moderate	5-9
Eragrostis spectabilis	Lovegrass	Well drained	Full	5.5 – 7.0	High	5-8
Panicum virgatum	Switchgrass	Well drained	Full	6.5 – 7.5	High	5-9

Chapter 15
Fertility Management

Andrew Ristvey, Extension Specialist, Nutrient and Water Management

Introduction

Since soilless substrates contain little to no native nutrients, fertilizers are applied to overcome deficiencies and optimize growth. By far, the most important plant growth factor is water. Nutrients move with water in the substrate and in the plant. Irrigation management is the primary concern and is the basis of nutrient management. This chapter will discuss nutrients and plant fertility. Although specific recommendations for nutrient solutions are not given, this chapter will assist in making the right choices for nutrient applications. With nutrient management regulations and more importantly the price of fertilizer increasing, more judicious applications of fertilizer are necessary.

Plant Nutrition Introduction

There are seventeen recognized elements that are considered essential for plant growth. Three of these are non-mineral elements that are acquired from the air and water; Carbon (C), Oxygen, (O) and Hydrogen (H). The others are considered mineral nutrients (Tables 15.1 and 15.2). There are some nutrients which will be addressed in this chapter that are not considered essential either because they are not needed by all plants or that they provide an extra function beyond growth and reproduction, e.g. pest or pathogen resistance. Arnon and Stout (1939) listed three criteria essential for plant growth:

1. Required for the completion of the life cycle of the plant.
2. Must not be replaceable by another element.
3. Must be directly involved in plant metabolism, that is, it must be required for a specific physiological function.

An additional criteria should be added:

4. The element must be required by a substantial number of plant species.

These rules are general and new knowledge of plant nutrition increases. In ideal circumstances, plant growth may be limited only by the speed in which biological and genetic processes can take place. However, in the natural environment plant growth is limited by many factors including light, water, and temperature, which may constrain growth before nutrition plays a role.

Justus von Liebeg, a nineteenth century German chemist developed his Law of the Minimum principle, which states that plant growth progresses to the limit imposed by the resource in least relative supply. Liebig suggested that the yield potential of a crop is like a barrel with staves of unequal length (Fig. 15.1). The staves represent resources. The capacity of the barrel is limited by the length of the shortest stave and can only be increased by lengthening that stave. When that stave is lengthened, another stave becomes the limiting factor.

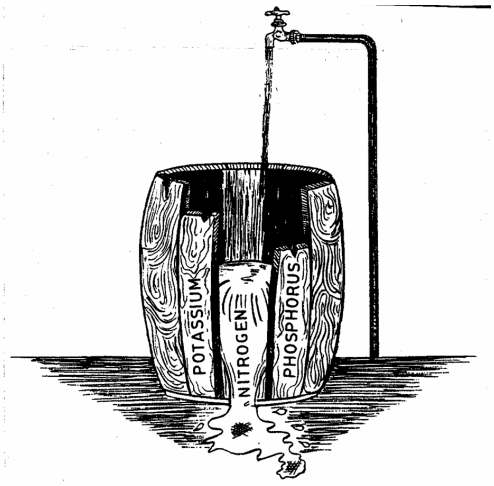


Figure 15.1 Law Of The Minimum Principle

The truth is that plant nutrition is far more complicated. What does least relative supply suggest? In a plant, one nutrient may be needed in far greater supply than another. A nutrient may be in greater supply than any other nutrient, but is needed by the plant in such quantity, that the amount available is relatively insufficient for growth.

Non Mineral Nutrients

Carbon serves as the main building block for all organic compounds and life itself. Carbon in the form of carbon dioxide is reduced and converted to carbohydrates during the process of photosynthesis. Carbohydrates serve as a the primary storage medium. The ability to synthesize amino acids, nucleic acids and lipids from those carbohydrate reserves are processes found only in plants and some bacteria. Carbon is the most abundant element in plants.

Oxygen serves as an important factor during the process called respiration where carbohydrates and other carbon containing compounds are broken down for energy. Oxygen is also a main constituent of organic compounds. Oxygen is obtained from the atmosphere and from the break-down of water during photosynthesis.

Hydrogen is used for carbohydrate production both as a primary constituent and cofactor for production. Hydrogen is formed during photosynthesis where it is split from water. Hydrogen, oxygen, and carbon are considered non-mineral nutrients because they are derived from the atmosphere or water. They are needed by plants in large quantities compared to other nutrients.

Mineral Nutrients

There are now fourteen recognized essential mineral nutrients. All nutrients are elements. Nickel was most recently added to the list. These nutrients are derived either from the soil or atmosphere (as in nitrogen) and enter the plant through the roots and in some cases the leaves. The mineral nutrients are classified as either macronutrients or micronutrients. Macronutrients are further classified into primary and secondary nutrients. Macronutrients are required in far greater amounts than micronutrients. There is a range of concentrations of many of the essential nutrients as they exist in plant leaves (Fig. 15.2). The dark shaded portion of the bars represents deficiency. For example, on average, nitrogen is sufficient at 2%. Below 2% nitrogen becomes deficient and above 2% where the bar is light-colored, concentration is in an acceptable range.

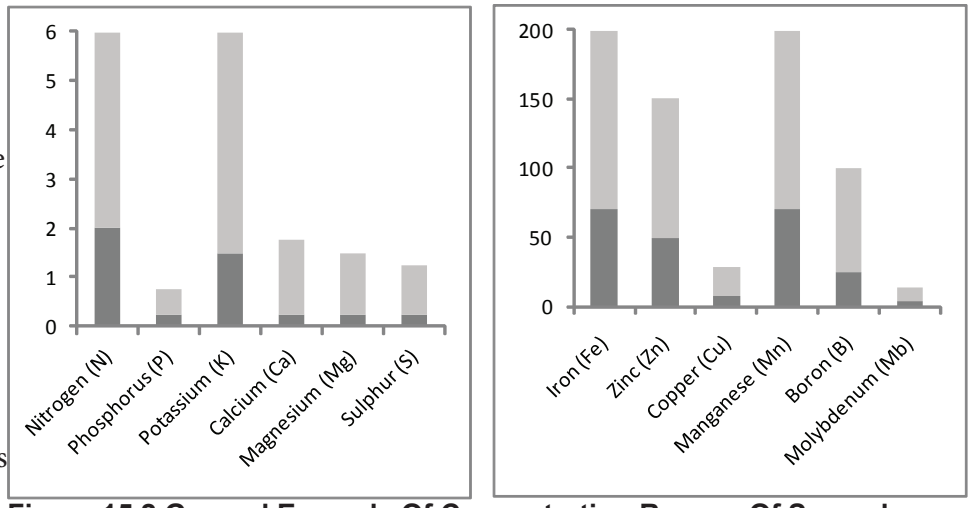


Figure 15.2 General Example Of Concentration Ranges Of Several Nutrients Found In Plant Leaves

Macronutrients are on the left and micronutrients are on the right. Note the link between macro and micronutrients. A concentration of 0.02% is 200 ppm. Dark shaded portion of bars represents deficiency to just sufficient concentrations. (Handrek and Black, 1994).

Macronutrients

Six essential nutrients are considered macronutrients. They are required by plants in relatively large amounts at levels from 10 to 5,000 times greater than those of many micronutrients. Macronutrients are divided into

primary and secondary macronutrients. Primary macronutrients include nitrogen, phosphorus, and potassium. These are nutrients which are typically limiting to plant growth and are applied to soil as fertilizer. Secondary macronutrients are those that are typically found in soil at relative concentrations to satisfy plant growth. However, these and other nutrients need to be applied with organic substrates.

Nitrogen is the most important of the nutrients applied and is the basis of fertility programs. Nitrogen has two forms, nitrate and ammonium, that are important as a plant nutrient. Nitrogen is very reactive and is affected by many factors including microorganisms. Additionally, the two forms of nitrogen can be changed by biological processes to atmospheric nitrogen (denitrification) or become part of the biology (immobilization) of the substrates inside the containers.

Micronutrients

Micronutrients or trace elements are those elements that are required by the plant in quantities from 10 to 5,000 times less than macronutrients. There are eight recognized essential micronutrients. Micronutrients are mostly metals, except chlorine and boron (which is a metalloid), which are used for enzymatic processes.

Fertility Management

Management of fertilizers is based on many other aspects of the nursery or greenhouse apart from what is in the fertilizer bag. First, irrigation water quality will have an effect on the availability of nutrients in the substrate, specifically, the alkalinity. As cited in the chapter on substrates chapter (page 230), alkalinity will affect the substrate pH and in turn, nutrient availability. Nutrients are affected by pH in organics substrates (Fig. 15.3). The thicker the black line, the more available a nutrient. Note that iron's line is very thin at high pH and decreases in thickness as pH increases. The pH for optimum nutrient availability is between 5.4 and 6.2 and most plants should be grown within this pH range. There are however some plants that require pH greater or less than the suggested range.

Fertilizer Forms

Various nutrients are available in the form of fertilizers (Tables 15.1 and 15.2). Regardless of source, the same nutrient is assimilated by the plant. For instance, organic nitrogen sources contain ammonium nitrogen. The same ammonium is assimilated in a non-organic mineralized source like ammonium sulfate. Non-organic or conventional fertilizers come in a variety of forms.

The three numbers on a fertilizer bag indicate the % ratio of nitrogen, phosphate and potash, or N, P_2O5 and K_2O. The second and third numbers are not specifically phosphorus (P) and potassium (K). Phosphate is approximately 44% phosphorus and potash is approximately 83% potassium. Keep this in mind when calculating P and K rates.

The nitrogen form will also change the pH of the substrate. The decision to use specific fertilizers should be based on irrigation water quality, specifically, the alkalinity of the irrigation water.

The different types of commercially available fertilizers can change substrate pH based on their potential acidity or

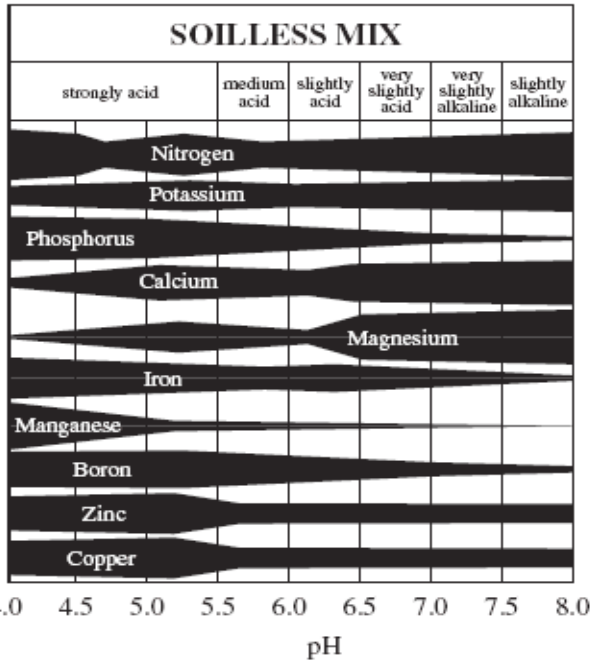


Figure 15.3 The Effects Of pH On Nutrient Availability In Soilless Organic Substrates
Nutrient availability is depicted with increasing pH by the thickness of the back lines. The thicker the line, the more available the nutrient.

basicity (Table 15.3). The example is not to be taken literally, but to provide an illustration of how acidifying an ammonium based fertilizer can be. Potential acidity is the amount (lbs) of calcium carbonate to neutralize one ton of the acid fertilizer. Simply, the higher the % of ammonium (NH_4), the more calcium carbonate would be needed to neutralize it. For example, if 100 lbs of 21-7-7 is used, it would need 85 lbs of calcium carbonate to neutralize the acidity. Additionally Table 15.3 shows fertilizers with potential basicity, the use of which is equivalent, by weight, to adding calcium carbonate. For example, if 100 lbs of 15-0-15 is used, it would be equivalent to adding 21 lbs of calcium carbonate. Note that even though some of the fertilizers with relatively high ammonium concentrations are neutral (see 20-0-20), they are a source of calcium.

With water alkalinity of less than 50 ppm, consider using fertilizers with potential basicity. With alkalinity above 150 ppm, consider fertilizers with potential acidity. In any case, monitoring the substrate pH level is necessary.

Some believe that the nitrogen form will dictate the growth of the plant, specifically, internode length. New research is showing that ammonium does not increase internode length and the use of nitrate fertilizers is not the reason for compact plants, rather low phosphorus in nitrate fertilizers may be the reason for compact growth. Do not use nitrate solely to control plant growth if high alkalinity water is present. Find ammonium based fertilizers with a very low phosphate content such as 20-1-20.

Phosphorus was always associated with improving root growth, but research has proven that incorrect. It is recommended that low phosphorus fertilizers with NP_2O_5 ratios higher than 2 to 1 (e.g. 20-10-20) be used.

Table 15.1 Formulas, Molecular Masses And Compositions Of Common Fertilizers Used For Macronutrient Fertility

Adapted from Handrek and Black, 1994

Compound (Sources of major nutrients)	Formula	Percent of Elements
Ammonium chloride	NH_4Cl	N, 26
Ammounium nitrate	NH_4NO_3	N, 35
Ammonium sulfate	$(NH_4)2SO_4$	N, 21.2; S,24.3
Calcium carbonate (limestone, calcite)	$CaCO_3$	Ca, 40.0
Calcium chloride	$CaCl_2.6H_2O$	Ca, 18.3
Calcium hyrdoxide (slaked lime)	$Ca(OH)_2$	Ca, 54
Calcium nitrate	$Ca(NO_3)_2.4H_2O$	Ca, 17.0; N, 11.9
Calcium sulfate (gypsum)	$CaSO_4.2H_2O$	Ca, 23.3; S, 18.6
Diammonium phosphate	$(NH_4)_2HPO_4$	N, 21.2; P, 23.5
Dicalcium phosphate	$CaHPO_4.2H_2O$	Ca, 23; P, 18
Di-potassium phosphate	K_2HPO_4	K, 44.9; P, 17.8
Dolomite	$CaCO_3.MgCO_3$	Ca, 21.7; Mg, 13.2
Magnesium carbonate (magnesite)	$MgCO_3$	Mg, 28.8
Magnesium nitrate	$Mg(NO_3)_2.6H_2O$	Mg, 9.5; N, 10.9
Magnesium sulfate (epsom salts)	$MgSO_4.7H_2O$	Mg, 9.9; S, 13.0
Monoammonium phosphate	$NH_4H_2PO_4$	N, 11.8; P, 26
Monocalcium phosphate	$Ca(H_2PO_4)2.H_2O$	Ca, 16; P, 24.6
Phosphoric acid	H_3PO_4	P, 31
Potassium chloride	KCl	K, 52.4
Potassium dihydrogen phosphate	KH_2PO_4	K, 28.7; P, 23.5
Potassium nitrate	KNO_3	K, 38.7; N, 13.8
Potassium sulfate	K_2SO_4	K, 44.9; S, 18.4
Sodium nitrate	$NaNO_3$	N, 16.5
Superphosphate: single triple	-- --	P, 9; S, 11; Ca, 21 P, 20; Ca, 23.6
Tetra-potassium pyrophosphate	$K_4P_2O_7.3H_2O$	K, 40.7; P, 16.1
Urea	$CO(NH_2)_2$	N, 46.7

Table 15.2 Formulas, Molecular Masses And Compositions Of Common Fertilizers Used For Micronutrient (Trace Elements) Fertility

Adapted from Handrek and Black, 1994

Compound (Sources of trace elements)	Formula	Percent of Elements
Ammonium molybdate	$(NH_4)_6Mo_7O_{24}.4H_2O$	Mo, 53
Boric acid	H_3BO_3	B, 17.5
Copper sulphate	$CuSO_4.5H_2O$	Cu, 25.4
Iron (ferrous) sulphate	$FeSO_4.7H_20$	Fe, 20.1; S, 11.5
Manganese chloride	$MnCl_2.4H_2O$	Mn, 27.7
Manganese sulphate	$MnSO_4.5H_2O$	Mn, 22.8
Manganese sulphate	$MnSO_4.H_2O$	Mn, 32.4
Manganese sulphate	$MnSO_4.4H_2O$	Mn, 24.6
Sodium borate (borax)	$Na_2B_4O_7.10H_2O$	B, 11.3
Sodium molybdate	Na_2MoO_4	Mo, 46.6
Sodium molybdate	$Na_2MoO_4.2H_2O$	Mo, 39.6
Zinc sulphate	$ZnSO_4.7H_2O$	Zn, 22.7

Table 15.3 Commercially Available Fertilizers That Either Acidify Or Increase Substrate pH Based On Potential Acidity Or Basicity

Fertilizer (N-P_2O_5-K_2O)	NH_4 (%)	Potential Acidity (lb calcium carbonate to neutralize per 100 lb of fertilizer)	Potential Basicity (lb calcium carbonate equivalent)	Ca (%)
21-7-7 acid	90	85.0	-	0
24-9-9	50	41.1	-	0
20-2-20	69	40.0	-	0
20-18-18	73	36.5	-	0
24-7-15	58	30.6	-	0
20-18-20	69	30.5	-	0
20-20-20	69	29.2	-	0
20-9-20	42	25.5	-	0
20-20-20	69	23.7	-	0
16-17-17	44	22.0	-	0
20-10-20	40	21.1	-	0
21-5-20	40	20.9	-	0
20-10-20	38	19.6	-	0
20-8-70	39	19.0	-	0
15-15-15	52	13.0	-	0
17-17-17	51	10.9	-	0
15-16-17	47	10.8	-	0
15-16-17	30	8.2	-	0
20-5-30	56	7.6	-	0
17-5-24	31	6.2	-	0
20-5-30	54	5.9	-	0
17-4-28	31	5.2	-	0
20-5-30	54	5	-	0
15-11-29	43	4.5	-	0
15-5-25	28	3.8	-	0
15-10-30	39	3.8	-	0

Generally, increasing percent of ammonium increases potential acidity or the amount of calcium carbonate needed to neutralize a ton of the fertilizer. Potential basicity is the amount of equivalent calcium carbonate used per ton of fertilizer. Note that some fertilizers have a percent of ammonium yet have little potential acidity because of the calcium content (Adapted from Nelson, 2002).

For instance, a 20-10-20 is suitable for optimum plant growth and recent research suggests that even lower P rates can be used, especially to prevent stem stretch and for non-flowering foliage plants. Some growers successfully utilize 20-5-20 with an N/P_2O_5 ratio higher than 20-10-20. Fertility can be changed based on the plant's growing cycle. Use very low P formulations during vegetative growth and change to higher P formulations right before flower formation. **Do not use superphosphate** as an amendment as this and all forms of soluble phosphorus leaches quickly from organic soilless substrates.

Other Than N-P-K

There are a variety of N-P-K formulations in fertilizers (Table 15.3). Commercial fertilizers may or may not come with additional nutrients other than N, P and K. The "complete" fertilizer will have all of the essential macro- and micronutrients nutrients needed for a plant's life cycle. There are a variety of fertilizers that offer different blends of nutrients other than N, P and K. These blends are formulated to give a variety of choices depending on the plants grown and the quality of the irrigation water. For example, a Cal-Mag fertilizer has above average concentrations of calcium and magnesium. In combination with high nitrate, the fertilizer can have high potential basicity. With more ammonium, the same can have a relatively low potential basicity. Some growers have needed to supplement these complete fertilizers with extra micronutrients, like iron or boron, when fertilizing at low rates. It is possible that in this situation, substrate or irrigation water chemistry negatively affects micronutrient availability. Supplements increase the concentration of micronutrients to overcome inhibitive effects.

Additionally, the plants being grown may require specific nutrition (Fig. 14.2). For example, azaleas require a pH of between 4.6 and 5.6 for optimal growth. If alkalinity is low in the irrigation water, a fertilizer with relatively high potential basicity that contains low ammonium and/or extra calcium and magnesium can be utilized.

Water Soluble Fertilizers

Application of soluble fertilizers through irrigation is called "fertigation". It is the most widely used application method in greenhouses. Fertigation can be an efficient method for delivering nutrients to the plant because the application rate and delivery can be adjusted based on plant needs. However, fertigation can be very inefficient if care is not taken to apply irrigation directly to the plant or if injection equipment is not calibrated. It is essential that careful attention is paid to irrigation management, injectors are calibrated and leaching fraction is minimized to reduce nutrient runoff. The present best management practice recommendation is no more than a 15% leaching fraction.

Stock Solutions

The most efficient method of applying soluble fertilizers is through an injection system using concentrates or stock solutions. When mixing fertilizers from scratch, it will be necessary to have two or more injection systems. Certain nutrients like calcium will bind with phosphorus and the resulting calcium phosphate will become insoluble and unavailable for plant use. Fertilizer components containing calcium and magnesium should be mixed separately from components containing phosphorus and sulfate.

Developing soluble mixtures may be less expensive but can be complicated from the standpoint of choosing the correct types of fertilizers and the amounts to mix together. A knowledge of chemical formulas and chemistry is needed. Use Tables 15.1 and 15.2 to assist with determining what fertilizers are available and the amounts of each constituent nutrient contained. North Carolina State University has a downloadable program (FERTCALC) to assist in calculating the right amount of fertilizer to add to the stock solutions.

The fertilizer rates are merely a suggested range and may differ between species and growth phase (Table 15.4). For instance, fall mums may require no fertilizer during propagation. During vegetative growth one can use low phosphorus fertilizers to prevent stretch or rotate a 20-10-20 fertilizer with no P fertilizer. Fertilization can stop a few weeks before sales to harden plants for cooler temperatures. Keep up-to-date with the most recent fertility guidelines provided by your extension agent.

Table 15.4 Suggested Rates For Fertilizing Different Crop Types (ppm N)

Plant Type	Feed Program (ppm N) (Constant)	Feed Program (ppm N) (Twice Weekly)
Plugs	50 – 125	150– 250
Bedding Plants and Annuals	50 – 150	200 – 300
Woody Plants	75 – 150	200 – 400

Calculating Parts Per Million

Recommendations for applications of liquid fertilizer, chemical growth regulating compounds, and root-promoting compounds appear in parts per million (ppm). Accurate applications can be made only if the grower has a working knowledge of how to make some basic calculations. Parts per million refers to the concentration of a material for any specific unit of weight or volume (Table 15.5). For example, one purple flower growing among 999,999 white flowers would represent .0001 percent of the flower colors or 1 part per million. Growers use a rule of thumb (though it is not scientifically accurate) that 1 ounce of material in 100 gallons of water is equivalent to 75 ppm. Use this rule of thumb to calculate fertilizer applications.

Example: A grower wants to apply 200 ppm nitrogen to a salvia crop. The soluble fertilizer is 20-10-20. How much 20-10-20 should be dissolved per 100 gallons of water?

Solution: 1 ounce per 100 gallons of water = 75 ppm; 200 ppm divided by 75 ppm = 2.66; 2.66 ounces supplies 200 ppm. The fertilizer is 20-10-20; 5 ounces of 20-10-20 = 1 ounce N (20% of 5) 2.66 x 5 = 13.3 ounces of 20-10-20 in 100 gallons of water to give 200 ppm N to the crop.

Mixing Fertilizers

To obtain a desired parts per million (ppm) at the water hose, use the following to mix the stock solution:

$$\frac{\text{(proportioner ratio): 1}}{\text{(\%) nitrogen}} \times \frac{\text{(desired ppm)}}{100} \times 1.35 = \text{ounces per gallon stock solution}$$

Example:
You have a 20% N fertilizer and a 1:100 injector
You desire 200 ppm at the water hose.
How many ounces of fertilizer do you add per gallon in the stock tank?

$$\frac{100}{20} \times \frac{200}{100} \times 1.35 = 13.5 \text{ oz fertilzer per gallon water}$$

To obtain an unknown ppm at the water hose when adding a known fixed amount of stock solution:

$$\frac{\text{(\%) nitrogen}}{\text{(proportioner ration): 1}} \times \frac{\text{(oz)/gal stock}}{1.35} \times 100 = \text{ppm N at hose}$$

Example: You have a 15% N; a 1:100 injector; and someone has put 18 ounces of fertilizer per gallon in your stock tank. What is the ppm N coming out of the hose?

$$\frac{15}{100} \times \frac{18}{1.35} \times 100 = 200 \text{ ppm N at end of hose}$$

Tables 15.5 Injection Ratios And Nitrogen Concentration For Constant Feeding

Ratio	30% Formula[a]			25% Formula[b]		
	100 ppm N	150 ppm N	200 ppm N	100 ppm N	150 ppm N	200 ppm N
1:300	13.5	20.2	27.0	16.5	24.7	33.0
1:200	9.0	13.5	18.0	11.0	16.5	22.0
1:150	6.7	10.1	13.5	8.2	12.3	16.5
1:128	5.7	8.6	11.5	7.0	10.5	14.0
1:100	4.5	6.7	9.0	5.5	8.2	11.0
1:50	2.2	3.3	4.5	2.7	4.1	5.5
1:30	1.3	2.0	2.7	1.6	2.4	3.3
1:24	1.0	1.6	2.1	1.3	1.9	2.6
1:15	0.67	1.0	1.3	0.82	1.2	1.6

Ratio	20% Formula[c]			15% Formula[d]		
	100 ppm N	150 ppm N	200 ppm N	100 ppm N	150 ppm N	200 ppm N
1:300	20.2	30.3	40.5	27.0	40.5	54.0
1:200	13.5	20.2	27.0	18.0	27.0	36.0
1:150	10.1	15.4	20.2	13.5	20.2	27.0
1:128	8.6	12.9	17.2	11.5	17.2	23.0
1:100	6.7	10.1	13.5	9.0	13.5	18.0
1:50	3.3	5.0	6.7	4.5	6.7	9.0
1:30	2.0	3.0	4.0	2.7	4.0	5.4
1:24	1.6	2.4	3.2	2.1	3.2	4.0
1:15	1.0	1.5	2.0	1.3	2.0	2.7

[a] e.g., 30-10-10
[b] e.g., 25-5-10, 25-10-10, 25-0-25
[c] e.g., 20-20-20, 20-5-30, 21-7-7
[d] e.g., 15-15-15, 15-30-15, 16-4-12

Controlled And Slow Release Fertilizers

Controlled release fertilizers (CRF) have become a popular method of fertilizing plants from the standpoint of labor and efficiency. These fertilizers are coated with materials which make them "slow to release" and regulate their release rates. In most cases, these fertilizers have improved plant fertility management because nutrients are slowly made available to plant roots. The release of nutrients may not be in tune with plant requirements. Popular controlled release fertilizers are coated with either plastics, resins or polymers that permit water to enter the "prill" to dissolve nutrients and ready them for release. Release rates are dependent upon the specific coating material and temperature. Since temperature is often uncontrollable at certain times of the year, there is little that is "controlled" about the way nutrients are released. High temperatures will increase the rate of release, regardless of the labeled release rates which are typically tested between 65 and 77 °F, depending on the manufacturer. They tend not to release when temperatures are cooler and, in many cases, when the plants need the nutrients. They release when temperatures are very warm resulting in salt loading in containers. These fertilizers are typically incorporated into the substrate or placed on top of the substrate. Fertilizers tend to release quicker when incorporated because of consistently higher temperatures within the container as opposed to the temperatures on top of the substrate.

If fertilizer has been incorporated in the substrate, utilize the substrate as soon as possible. Do not allow the substrate to sit in large piles where it may begin to compost. The heat generated within the pile will quicken the release of the fertilizer in the prills. Salts will accumulate in the substrate and, upon use, may burn plant roots. Before using a substrate that has been stored, check the electrical conductivity. If the electrical conductivity is above 2.5, leach the substrate or irrigate the plants immediately upon potting. Monitor the substrate electrical conductivity for the next few days.

In some cases nutrients from CRF's may be released immediately because of broken prills, imperfect coating, or from uncoated nutrients added for an initial quick release. The degree of this release can be easily checked by placing some prills in water and taking electrical conductivity measurements two or three times in a 24 hour period.

Some growers, especially those who grow plants in greenhouses, prefer to limit CRF use because greenhouse temperatures can become very warm inside, promoting release of nutrients too quickly. Use of CRF's in greenhouses should be done with caution and constant monitoring of substrate salts is necessary.

Slow release is another form of nitrogen based fertilizers. These types of fertilizers are released by hydrolysis (dissolved by water) or by microbial degradation. They include:

Sulfur Coated Urea– similar to CRF's, the thickness of the sulfur coating determines nutrient release by water absorption.

Urea formaldehydes – release based on microbial degradation.

Isobutydine diurea (IBDU) – release based on hydrolysis which is affected by substrate moisture and pH.

These forms of fertilizers are urea or ammonium based and are not recommended to be used in greenhouse culture because of the danger of ammonium toxicity. When utilizing these types of fertilizers, monitor substrates and check plants for ammonium toxicity.

A new set of management skills are needed for these fertilizers. Substrate monitoring is essential for plant health when utilizing these CRF fertilizers.

Advantages of using CRFs:
- Can minimize nutrient loss and runoff if manual watering is used.
- Can minimize nutrient loss from leaching from gradual nutrient release rates.

Disadvantages of using CRFs
- Release of nutrients are not constant because of fluctuations in temperature and moisture in the substrate.
- Release of nutrients may not coincide with plant needs because of inconsistent nutrient release due to the above factor.

Application Methods for Controlled Release Fertilizers
There are two methods (incorporation and top dressing) for controlled release fertilizer application. Each has benefits and drawbacks (Table 15.6).

Incorporation
Controlled release fertilizers can be incorporated into the substrates, however a mixing device is needed to assure uniformity of distribution. This method is considered a best management practice since fertilizer is

contained within the substrate and there is little chance for loss from spilling. There is, however, a danger for quicker release rates because of consistently higher temperatures and moisture within the substrate. As noted above, substrate temperatures within the container have been measured well above the labeled release temperature for CRF's, therefore there will be times when excessive nutrient release will occur beyond the plant's ability to assimilate. Nutrient salts will build up in the container. Therefore, monitoring is essential for plant root health. Do not allow substrates with incorporated fertilizer to sit unused. Nutrient release will occur and plant roots will be damaged by excessive salts.

Top Dress

Fertilizers are placed on the top of the surface of the container. This method is utilized when plants are held an extra season and there is no intention of repotting. If using plug trays or similarly small sized containers when top dressing, it will be difficult to obtain even distribution of fertilizer. Soluble fertilizers applied through an irrigation system may be considered instead. When top dressing containers, use the manufacturers recommended rates, usually based on container size. The rates are suggested in ounces or grams and typically the manufacturer will suggest a volume that will be close for applying the recommended weights. For instance, 1/4 cup will equal 61 grams. Note that a medium rate of CRF will be sufficient for most crops.

Table 15.6 Suggestions For Controlled Release Fertilizer Use And Precautions

Method	Advantages	When	Precautions	Management
Incorporate	Considered a Best Management Practice. Minimize labor of applying fertilizer.	When adding other amendments or before planting.	Mixing machines may damage prills making nutrient salts immediately available.	Monitor substrate for EC before planting. Do not put plants in substrate with an EC higher than 3. Substrate must be irrigated to reduce EC to below 3 before planting.
			Use piles of substrate quickly and do not let them sit for more than a week or so. Prills will release nutrient salts within the pile. Nitrogen may be depleted even though you have high EC.	Monitor substrate for EC before planting. Do not put plants in substrate with an EC higher than 3. Substrate must be irrigated to reduce EC to below 2 before planting. Continue to monitor or test substrate in lab for N. Nutrients (especially N) may have depleted. May need additional fertilizer.
			Incorporated prills will tend to release quicker especially during hot periods.	Monitor substrate EC. Should be between 0.5 and 1 dS/m. If above 3 dS/m, you must irrigate. Check EC again. Leach if EC is still not below 2 dS/m. Maintain high moisture levels in substrate. Minimize leaching by continually monitoring substrate.
Top Dress	Can be applied as additional nutrients if necessary. Can be applied at any time.	If holding plants for another season or overwintering. If additional nutrients are needed in the middle of a cycle. Not recommended to top dress plug trays and cell packs. Rely on soluble feed.	Take care to keep container upright as to not spill CRF. Apply rates according to manufacturer's recommendations, usually not more than medium rate. Do not broadcast prills, apply to each individual container.	Prevent pots from knocking over and losing prills on ground. Take care when hand watering to prevent splashing prills out of container. Monitor substrates.

Management Of High Electrical Conductivity (EC) Levels

Leaching is the inevitable solution to high electrical conductivities in your substrate. If you have EC levels that are above 2.5 dS/m early in the day, irrigation to container capacity will be necessary to dilute the salts. Monitor after irrigation. If EC levels have not decreased, continue irrigation until you have water coming out the bottom of the pot (leaching). Continue to take Pour Through samples so as not to over-leach.

EC is only a measurement of salts in solution and does not tell which salts are available. Use EC measurements only as a guide, and do not rely on them to tell you how much nitrogen or phosphorus is available. This recommendation is especially true if a substrate with incorporated fertilizer has been sitting in a pile for a couple weeks or longer. The nitrogen could have been completely used by microorganisms as they composted the substrate. A high EC reading may occur because of the other salts in the fertilizer which without nitrogen, are useless to a plant.

Selection Of Fertilizer

There are many factors to consider when selecting a fertilizer for a nursery or greenhouse. The cost is actually less important than the quality, i.e. nitrogen source for acidifying, primary macronutrient balance, and micronutrient content. Factors like plant selection and irrigation water quality will determine what is used. In some operations a "one fits all" approach may work, and in others the plants grown will require different formulations, even different fertilizers throughout the cycle of the crop. Some fertilizer manufacturers will custom blend fertilizers and may offer a monitoring package to ensure that the product is being utilized efficiently. Some slow release fertilizers offer blends of different release rates to compensate for low temperatures common during spring. Manufacturers want your business so be demanding.

Use Of Organic Fertilizers Or Composts

The addition of organic fertilizers or composts to your substrate may interest organic producers. The most critical issue about the use of organic fertilizers is the physical and chemical consistency of the product each time. Soluble organic fertilizers injected through the irrigation system may clog emitters. Be aware that you may need to flush and clean the irrigation system. Make sure the materials used are consistent in nutrients supplied. Have your composts and organic fertilizers tested regularly at a certified laboratory. The amount of nitrogen in organic fertilizers is usually low and the N/P_2O_5 ratio is also usually low which means more phosphorus may be applied than necessary. Since these materials can contain nitrogen and phosphorus, Maryland growers will need to keep track of their additions for nutrient management planning.

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Chapter 16
Irrigation

David Ross, Professor Emeritus and Extension Specialist, Agricultural Engineering

Introduction
Water is a critical commodity in producing herbaceous perennials. This chapter discusses water quantity, several key methods of irrigation, the necessity of water application efficiency and runoff prevention, and the importance of water testing to ensure the high quality of water needed to prevent clogging in microirrigation (drip/trickle) systems.

Water Quantity: Source And Supply
Before irrigation is feasible, you must have a large enough water supply. Because overhead irrigation uses more water than trickle irrigation, water supply may influence the type of irrigation system you use. Check small sources of water for worst-condition flow rates; mid- to late-summer flows may be very low. One way to utilize a small source of water is through intermediate storage: water is collected 24 hours a day into a pond or into tanks for use on the crop during an 8- to 10-hour irrigation schedule. Another way to stretch the supply is to use an efficient system, such as microirrigation.

Wells are generally the best source for irrigation because well water is cleaner than surface water. Surface water is acceptable for trickle, but it does require filtration to remove organic and inorganic particles that might cause clogging. Some water sources may need chemical treatment. An irrigation water test is recommended for identifying problems of quality.

The quantity of water needed depends on the irrigation system. A broadcast application by overhead sprinkler requires the largest quantity. You can water plants with less water using trickle irrigation because you are applying water only to the crop's root zone—not everything is wetted. Usually, only a small percentage of the ground area receives water. Crops with a lot of foliage, however, may require a lot of water, regardless of the system.

Irrigation Systems
Although irrigation is a common activity for crop production, some important considerations such as pressure, flow, and head spacing are sometimes overlooked. Some of these points are highlighted below to help the reader make the irrigation system functional and efficient.

Practice good management. Make maintaining the soil or substrate at a good moisture level for crop production a primary goal. To meet nutrient management requirements and to operate efficiently, make avoiding water and nutrient runoff a close secondary goal.

Equipment Considerations
Overhead sprinklers require the proper flow rate of water and the correct operating pressure. Provide these and the sprinklers will do what they were designed to do. Space the sprinkler heads properly to try to ensure a uniform application. Microirrigation equipment comes in several styles for different applications; the styles are individual emitters, row-crop tape, spray stakes, and microsprinklers. Because microsprinkler orifices are small, water flowing through the orifices must be clean. Use the proper filter—usually 80 micron, 200 mesh, at most. Generally, a 100- to 200-mesh filter is specified. Again, use the proper pressure and flow rate.

Most of these units will discharge more or less water as the pressure increases or decreases. On slopes with elevation changes, try to keep lateral lines on the contour. Use pressure-compensating emitter systems or use pressure regulators on water lines coming off a mainline going up or down a hill to establish the discharge rate.

When designing the irrigation system, set up irrigation zones to match the water available to the water demand. Use electric solenoid valves in conjunction with time controllers to automate the irrigation. Automation is a good management tool because it is consistent and it frees the individual to manage operations better.

Overhead Sprinklers

Stationary overhead sprinkler irrigation systems are easy to set up. To design a system properly, space sprinklers to allow adequate overlap for uniform coverage; size water distribution systems (pipelines) to minimize friction loss, which will keep operating pressures fairly uniform in the system; and, then, maintain the system. Use pressure gauges for monitoring the system. Low pressure can mean a break in the pipes, too many sprinklers in operation, or a pump problem.

Large traveling overhead sprinklers can require high operating pressures as the sprinklers (nozzles) get larger and water power (pressure) is used to operate hydraulic motors, such as the motors in hose reel portable travelers. These systems use high water pressure and a high flow rate to be able to propel the water as far as it must go.

Trickle Irrigation

Spraystakes and Microsprinklers

Spray stakes and microsprinklers were created to spread the water out over more surface area so the substrate is wetted more uniformly. They represent a broadcast-type of trickle irrigation system designed to be placed in individual plant containers to spread the water over the surface. Most of the devices are designed to discharge water at a specified rate at a specific operating pressure. Pressure-regulating devices are available at low cost to control the pressure. Water under low pressure discharges a different quantity than water under high pressure; the wrong pressure can distort the distribution pattern. Water distribution can be poor as a result.

- Substrate in containers wets more uniformly if the application rate is slow and the distribution is over most of the surface. The substrate typically wets from the bottom up if the application is point source and quickly applied.
- Use filters to keep the water clean and exercise care to keep dirt out of the water lines.
- Use pressure gauges and pressure-regulating devices. Evaluate the system design. Size the pipes to carry water at low water velocities. Trying to put too much water through a water line requires a high water velocity which causes excessive friction losses (pressure losses). Non-uniform pressures cause nonuniform application of water.
- Microsprinklers are essentially small-diameter, low-flow-rate sprinklers. Again, proper spacing and overlap are needed for uniform coverage. When the sprinklers are used outside, droplets need to be large enough to keep the wind from blowing them away; wind can significantly distort the watering pattern.

One of the problems with microsprinklers is that though they have a low flow rate individually, collectively their use adds up to a high flow rate. The small water distribution diameter means many microsprinklers are needed to cover a given crop area. Growers with small water sources may have trouble operating many sprinklers at the same time. These systems operate at low pressure, typically in the range of 8 to 20 pounds per square inch (psi), depending on the system.

Row-Crop Tubing Or Tape

Row-crop tubing was designed to wet a continuous strip along a crop row. While small orifices at regular spacings in the tubing emit water, the wetted patterns all come together in a continuous strip. Only when emitters are widely spaced apart do individual wetted circles result. The tubing works well with individual crop rows or can be used to wet many closely spaced rows. Raised beds and plastic mulch work well with trickle irrigation. The raised bed helps to provide drainage and the plastic mulch helps prevent weed growth and reduces evaporation by helping to hold water.

The bed defines the root zone width for irrigation. One length of tubing will work in most cases; if, however, many crop rows are placed on the raised bed, you might use two lengths of tubing for watering the width evenly. The width of the raised bed and the type of soil will determine the need for two lengths of tubing to provide even watering. Water moves farther laterally in fine clay or loamy soils than in sandy soils.

Individual Emitters

Containers are usually watered by individual emitters or spray stakes that discharge water at a specific rate and a specific pressure. The emitters discharge water at a specific rate in gallons per hour (gph), typically 1 or 2 gph. The individual emitter may be designed into the spray stake. The spray stake helps to spread the water over the substrate.

Pulse Irrigation

A relatively new system, pulse irrigation shows promise of accomplishing a desirable goal in watering crops—a slow rate of application to avoid leaching or runoff. The pulse system uses a device, the pulsator, to regulate the water. The pulsator fills with water under pressure; at a set point, the pulsator releases the water suddenly. The water moves quickly through the system and out the emitter (discharge point); the system pauses until the next pulse.

Because the pulsator releases less water than a typical trickle system, the small amount of water released first wets the top of the container. As more water is released, it gradually wets down through the substrate. The application rate is so slow that the substrate is wetted from the top down, which should minimize leaching. The irrigation system has to run for a long time to apply the necessary amount of water. The pulsator has the potential of maintaining a good moisture level without overwatering. The application is in organic substrates which hold little water.

Trickle irrigation has advantages over an overhead sprinkler system. Water is applied only to the crop root zone, not broadcast. Row middles are not wetted which discourages weed growth. Cultural operations can take place during irrigation. Foliage is not wetted which discourages diseases from developing. Less water is used because of more efficient application. The lower operating pressure saves energy.

Pressure And Pipe Flow

Elevation affects the pressure of water in an irrigation system; this can be significant when low-pressure trickle irrigation systems are in use. Static pressure in a water pipeline will change 1 psi for each 2.31 feet of rise or fall in elevation. A pipeline going uphill will have 10 psi less available pressure at a point 23 feet higher than the initial point. Likewise, gravity's force on the water will increase the pressure by 10 psi at a point 23 feet lower in elevation. The weight of the water upon itself causes this pressure change.

In a low-pressure trickle irrigation system that operates at 8 to 10 psi, 2.31 feet of elevation causing 1 psi of pressure change is quite large in percentage. For this reason the regular trickle tape must be used on fairly level land. On a slope it's better to supply water from the higher end of the lateral. Gravity will add pressure going down slope while some pressure is lost to friction; they even things out.

Given two pipelines of different diameters but the same flow rate, the smaller pipeline will have a higher water velocity and a higher energy loss to friction. Pipe flow rate is directly related to changes in the pipe cross-sectional area and the water velocity. The larger pipeline has a larger cross-sectional area and the water can move slower while maintaining the same flow rate as the smaller-diameter pipe. The slower flow rate causes less friction against the sides of the pipe and less energy (pressure) is lost. Be careful in selecting the pipe size to use so that the friction loss will not be too large. Conserve the pressure. Compare the higher cost of the larger pipe to the cost of generating the pressure that is lost.

Water Quality

Water quality is important in crop growth as well as in how well fertilizers dissolve in the stock tank. Test water sources through a qualified commercial laboratory to ensure no quality problems exist. If problems are found, take corrective measures. Table 16.1 is designed to help interpret water test results.

Table 16.1 Desired Range For Specific Elements (in ppm)

Elements	Irrigation Water[1]	Typical Tap Water[2]
Phosphorus (P)	0.005 – 5.0	0.3 – 1
Potassium (K)	0.5 – 10.0	<10
Calcium (Ca)	40.0 – 120.0	<100
Magnesium (Mg)	06.0 – 24.0	<25
Manganese (Mn)	00.5 – 2.0	0.01 – 0.5
Iron (Fe)	02.0 – 5.0	0 – 4
Boron (B)	0.2 – 0.8	0 – 0.5
Copper (Cu)	0 – 0.2	0.02 – 0.04
Sulfates (SO4)	0 – 414.0	<100
Zinc (Zn)	1.0 – 5.0	0.08 – 0.1
Sodium (Na)	0 – 5.0	<30
Aluminum (Al)	0 – 5.0	<0.2
Molybdenum (Mo)	0 – .02	0.02 – 0.04
Chloride (Cl)	0 – 140.0	<50
Fluoride (F)	0 – 1.0	0 – 0.25
Nitrate (NO3)	0 – 5.0	<5
Ammonium (NH4)	Undetermined	<8
Alkalinity (bicarbonate)	1 – 100	<183
Soluble Salts	0 – 1.5 mmhos	<1
SAR*	0 – 4	<4

* Sodium absorption ratio. It is used to quantify sodium levels in relation to calcium and magnesium levels in water, is used to evaluate potential for permeability problems after long-term use of irrigation water.

1 Ohio State University. February 1988. "Water Quality: Some Things You Should Know." BPI News. Bedding Plants, Inc. East Lansing, MI. Reprinted from Tom Dudek. January 1987. "Greenhouse Newsletter."
2 Northeast Regional Agricultural Engineering Service. May 1996. Water and Nutrient Management for Greenhouses. NRAES-56. Ithaca, NY: Cooperative Extension.

If you think you need to acidify your irrigation water because of high pH or alkalinity, request an alkalinity test from the water-testing laboratory. If testing indicates your water requires more acidity, the lab can recommend the proper amount of acid to add. NRAES-56, "Water and Nutrient Management for Greenhouses," listed as a reference, explains how to mix acid into water to deal with pH or alkalinity. Water quality and nutrient issues discussed below are covered.

To avoid crop damage, hold water used in greenhouses, including on plugs or small pots, to higher water quality standards than water used for landscape plants; the substrate is small in volume and some substrate has little buffering. Also, crops vary in their sensitivity to nutrient elements.

Alkalinity And pH

Alkalinity and pH are not the same. pH is a measure of the acidity or basicity of water or soil. Alkalinity is the buffering capacity. A buffer solution has the capacity to resist change in pH (usually a decrease). The greater the alkalinity of water, the greater the water's buffering capacity. The higher the alkalinity reading (in milligrams of calcium carbonate per liter of water), the greater the amount of acid is needed to neutralize the alkalinity. If the alkalinity levels get too high, inject acid (phosphoric, sulfuric, or nitric acid) to reduce the bicarbonate level. Phosphoric acid is generally used.

Water Hardness

Hard water is high in calcium and/or magnesium. Tests for water hardness do not help much for determining water suitability for plants. Water hardness is either noncarbonate or carbonate. Noncarbonate hardness or permanent hardness results from polyvalent cations (Ca++, Mg++, Fe++), which can only be removed through water treatment. Most hard water ions are useful as fertilizer for crops but reduce the activity of oil-type pesticides. Carbonate, or temporary, hardness results from bicarbonates present in higher-pH water, particularly above 7.4. Injecting acids into irrigation water neutralizes high levels of bicarbonate. For trickle irrigation, precipitation of calcium and magnesium carbonate causes lime deposits and plugging problems. Bicarbonate levels under 100 ppm are preferred to lessen plugging problems. Two conversions may be useful while reading water test reports. To convert bicarbonates reported as "ppm calcium carbonate equivalent" to bicarbonate, multiply by 0.61. Convert grains per gallon to ppm by multiplying by 17.118.

Calcium (Ca)

A good level of Ca for plants is between 40 ppm and 120 ppm. High-alkalinity water usually contains high amounts of Ca. Ca levels of 250 ppm are very high and water treatment should be considered. You can use acid to lower the Ca. Low Ca is definitely a problem for plants. Improve Ca levels below 40 ppm. Use limestone (CaCO3) if the pH is low; use gypsum (CaSO4) if pH does not need to be changed. Do not mix a phosphorus- or sulfate-containing fertilizer with a calcium-containing fertilizer in the liquid fertilizer stock solution tank. Precipitates will form.

Magnesium (Mg)

The desired level of Mg is between 6 ppm and 24 ppm. Low Mg can be a problem and is often associated with a lack of calcium. The deficiency shows up as interveinal yellowing on midplant and lower leaves. Dolomitic limestone is a source of both magnesium and calcium during crop production.

Ammonium Toxicity

Ammonium is toxic to roots and can accumulate in the substrate if changes are not favorable for microorganism action to convert the ammonium to nitrate. Ammonia gas can form to burn roots and leaves if any of the following conditions are present: pH near or above 7, low cation exchange capacity, warm temperatures, fertilizer surface application, or drying of the substrate surface.

Water Management

Monitoring Soil Moisture

Once an irrigation system is in place, it is time to practice water management. Plants need oxygen and water, but they do not want flooded or saturated soils. Monitor soil moisture by using a soil moisture sensor, such as a tensiometer. For field plantings, monitor at two depths—for example, at 6 to 9 inches deep and at 15 to 18 inches deep. Adjust these depths for crops that have rooting depths shallower or deeper than 24 inches. For container plants, monitor at one depth only. Place the bottom of the tensiometer about three-fourths of the way down into the container. Good contact between the tensiometer and the substrate is necessary for accurate readings. For further details about rooting depths and using the tensiometer and other moisture sensors, obtain University of Maryland Extension Bulletin 312, "Soil Moisture Sensors for Irrigation Management," available from county Extension offices.

A tensiometer responds to the moisture tension in the soil to indicate how easy or difficult it is for a root to get water. A vacuum gauge on the tensiometer tells how tightly water is held by soil particles. A low gauge reading indicates water is readily available. A high reading means soil particles are tightly holding water and plants cannot remove it. The tensiometer is a water-filled tube with a porous tip. Water can pass into and out of the porous tip based on the attractive forces of the soil particles. As plants use moisture, the plant root tries to remove more water from the soil particles. As the attractive force (binding force) of the soil particles increases, the vacuum of the tensiometer gauge increases until the attractive force and the vacuum are at equilibrium. Water is held in the tensiometer with the same force as the soil particles are attracting water. The vacuum gauge on the tensiometer indicates water availability to plants. The tensiometer's tension reading varies according to type of soil and soilless substrate. At 50 percent field capacity—when half of the water is used—irrigation should begin to replenish soil moisture (Table 16.2). A "low tension" tensiometer was developed to monitor soil moisture in organic soilless substrates, which hold very little water. The gauge of a low-tension tensiometer ranges from 0–40 centibars (cb) pressure.

Table 16.2 Irrigation Guidelines For Using Tensiometers

Soil/Substrate Texture	**Moisture and Irrigation Status (in centimeters)**	
	Field capacity— no irrigation	50% field capacity— irrigation needed
Organic substrate[1]	0–5	5–15
Sand, loamy soil	5–10	20–40
Sandy loam, loam, silt loam	10–20	40–60
Clay loam, clay	20–40	50–100

[1] Substrates are composed of a variety of materials with different water-holding capacities. Values given are estimates.

Tensiometer Maintenance

Tensiometers need maintenance from time to time. New or dry tensiometers are placed overnight in a bucket—filled with distilled water,with green dye dissolved in it—to wet the porous tip. The dye makes it easier to see the liquid in the tensiometer. For installation, use a piece of 1⁄2-inch black steel pipe to make a tight-fitting hole in the soil or substrate. Push the tensiometer firmly but gently down into the soil or substrate. Be careful not to put too much pressure on the tip.

- Tensiometers must maintain tight contact with the substrate; press the substrate in close to the tip of the device. Check this contact frequently during the season.
- When filling the tensiometer, use an ordinary drinking straw. Carefully hold the straw in the tube. The straw should be slightly smaller than the hole so water can flow in outside the straw while air escapes

through the straw itself. The hand pump purchased with the tensiometer helps to pull air out from the tube and gauge. Remove all air. Seal the top of the tube with the cap. Establish a gauge reading to indicate when the substrate needs to be watered. If the soil or substrate dries out and the tensiometer reading approaches the limit of the gauge, the column of water in the tensiometer "breaks" and allows air into the device. After breaking tension, the device does not operate correctly until it is serviced. Open the cap and repeat the water-filling and air-evacuation steps used for filling the device.

- Periodically check the tube for air bubbles or missing water below the seal. Open the top and allow water to fill the bottom area when necessary. Use the hand pump to remove air bubbles. Store the tensiometers dry and indoors in winter. Do not let water freeze inside them.

New Irrigation Technology

The use of moisture sensors to determine moisture content in mineral and potting soils is not new, although technological advances have improved accuracy and precision of these instruments. Older devices like tensiometers and gypsum blocks function well in mineral soils, however, this is dependent upon these devices having good physical contact with the soil particles. Most potting soils are very porous by design. The high porosity decreases the probes contact with the soil and lessens their performance and reliability. However, electromagnetic probes are not dependent on physical contact with soil particles and are much more reliable in these porous substrates. This form of technology is not new and has been evolving for decades. The most current probes have overcome most of the problems associated with them, including compensation for temperature or electric conductivity in the substrate. In particular are capacitance probes, which can determine the substrate's water content by emitting an electric field. Together with a datalogger, an irrigation manager can visualize what is happening inside the containers. Presently, a number of companies offer these systems which can operate in real-time, giving the irrigation manager minute by minute knowledge of plant water use, allowing for precision irrigation – that is to say, the irrigation manager will know when the plants need irrigation and when the irrigation should be turned off to limit leaching. The benefits of these irrigation monitoring systems include less water wasted, less nutrients leached, and less energy used in delivering the water to the plants which translates into increased efficiency and less dollars spent.

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Chapter 17
Water And Nutrient Management Planning

David Ross, Professor Emeritus and Extension Specialist, Agricultural Engineering
John D. Lea-Cox, Extension Specilaist, Nursery Research

Introduction

The Maryland Water Quality Improvement Act of 1998 introduced a new set of regulations for Maryland horticultural industries. To reduce the quantity of nutrients reaching public waters, the law requires producers to document their use of nitrogen and phosphorus fertilizer nutrients and to assess the risk of the nutrients reaching public waters. A water management component of the law also applies to horticultural container crops. In fact, water management is the most critical factor in growing container crops, as nitrate and orthophosphate are both highly soluble, and soilless substrates do not hold these anions. In-ground crops do not present as much of a problem because the soil has the capacity to hold the anions and water to a greater degree. In-ground growers, however, must also account for nutrient use.

Collecting data on your management practices enables you to examine the information and make informed decisions. Keeping records is becoming more and more important as a way to make growers aware of the effects of their management decisions on both their pocketbooks and the environment.

For specific information about Maryland's nutrient management requirements, go to Maryland's Department of Agriculture website at http://www.mda.state.md.us/ and search for Office of Resource Conservation.

Management Units

One of the problems of keeping information about nursery and greenhouse crops is the large number of different plant species and cultivars in production. Therefore, the first and perhaps most important task is to simplify the planning process by developing a set of management units. This requires that you group your herbaceous perennial plants (or other crops you are producing) into the least possible number of units. First, group out-of-ground containers by size and spacing. Plants in similar-size containers are often similarly spaced and watered and may be fertilized at the same rates. They also may take the same amount of time to produce. If they are fertilized the same and watered the same, then they likely can fit together into a management unit. Three container-size groupings, such as a) less than 1 gallon, b) 1 to 3 gallons, and c) greater than 3 gallons, are enough to handle common production practices. Thus, many different species are treated the same for practical purposes and can fit into a management unit which simplifies your planning. The most important consideration is whether the plants are watered and fertilized in a similar way. Your objectives are to make sure that you are applying fertilizer efficiently to ensure maximum plant uptake and that you are watering practices enable plants to maintain available moisture without causing excessive leaching. Excess runoff will carry nutrients from the production area. Documenting the efficiency of these production factors is the key to determining whether fertilizer and water is being used efficiently and to developing best management practices. So, for each management unit, you should document the number of plants, the square footage of the growing areas, the container size and spacing, and the length of the production cycle. For in-ground production, note the type of growing area, not the size of container. You might want to develop a chart or spreadsheet for recording this information.

For in-ground crops, focus management units on similar soils and fertilization practices, including the use of organic mulches or manures or cover crops. In-ground crops may have various different production cycles

which may be a reason to separate the crops into different management units. If different species or soils require different fertilization rates, then use separate management units based on each fertility practice. The goal is to group the total production into as few management units as possible to simplify the process.

In some small operations, crops may be mixed in a growing area, making it difficult to separate out different container sizes or fertilizer practices. If only a few bags of fertilizer are used annually, document the details on the types and amounts of fertilizer and the total growing area. Use the total pounds of fertilizer and the total growing area to calculate the average pounds of fertilizer applied per acre of growing space. The calculation may show that you are at low risk of applying too much fertilizer and more detailed calculations are not needed. The risk criteria are based on pounds of nutrient per acre.

Production Operation Maps And Sketches

A more complete documentation of production activities requires that you collect additional information on each management unit. Identify growing areas, water application, and paths of runoff, and then describe your operation, using pictures, sketches, and written text. This exercise will help you with your planning and will enable an outside plan reviewer to understand your operation.

First, map or sketch the production property location relative to highways and surface water located off-site. Second, sketch the production area: show the growing areas and drainage pathways; use arrows to show the direction of water flow from growing areas through drain pathways; identify the water source; locate main irrigation lines; and show any other details that make the operation clear to a stranger. This exercize not only helps the business owner, it is a legal requirement of submitting nutrient management plans.

Recordkeeping—Fertilizer Usage

For each management unit, prepare a separate chart with data on the type of fertilizer, its application method, and the amounts applied as well as the total amount applied in terms of pounds per acre per year (or per cycle, if in a given year you produce more than one crop from the same area). Records on fertilizer usage are most critical to this project. Try to be accurate: save all receipts for fertilizer purchased and note where and when the fertilizer is applied. Compile this record each year; include fertilizer purchased in advance, purchased during that year, and carried over from the previous year. For small operations this is the easiest way to document fertilizer used.

For each management unit, keep records on the fertilizer applications, including any pre-incorporation (rate in pounds per cubic yard and volume of substrate), any soluble fertilizer applied (parts per million, amount of water applied, and date applied), and any amounts of topdressed controlled-release fertilizer. For each management unit, you must be able to sum up the total amount of fertilizer applied during the production cycle in terms of nitrogen, phosphoric acid, and potash. Where possible, figure out the "per plant application rate" used. Record the number of containers or plants and measure and record the size of the growing area.

For pre-incorporation, determine the number of containers filled by a cubic yard of substrate. Then, knowing the amount of fertilizer added per cubic yard of substrate, calculate the amount of fertilizer applied per container. The number of containers used for a crop times the amount of fertilizer added per container gives the amount of fertilizer used for the crop.

Soluble application is more difficult to calculate, but, it can be done. The equation for calculating the pounds of soluble nutrient applied via irrigation water is to multiply the concentration in parts per million (ppm) times the flow rate of irrigation water, in gallons per minute, times the duration of irrigation, in minutes, times 7.5 pounds per gallon. Multiplying these together gives the amount of fertilizer applied.

Pounds of fertilizer applied = ppm applied X flow (gpm) x duration (minutes) x 7.5 lb/gal

Site Risk Assessment And Management

For out-of-ground or container production, water management is the most important factor in nutrient management because the soluble nutrients are carried in the water. Good irrigation efficiency and management of runoff water is essential.

Site risk assessment is the process of observing the water flow paths from the growing areas to the boundary of the property and determining the risk of soluble nutrients leaving the property in that water. Water should move slowly without erosion through grass waterways or other pathways. As water reaches the boundary of the property it should pass through a grass buffer 50 feet wide or more, moving in a spread-out uniform thin layer called sheet flow. Or the water should be contained for recycling. The goal is to control the water flow so that sediments and soluble nutrients can be removed before the water reaches a stream or other public surface water.

Site risk management is the process of making any changes needed to reduce risk of water and nutrient runoff. Reducing risk in your fertilizer or irrigation practices or in how runoff water is conveyed on the ground may require change. Implement best management practices to reduce the risk of runoff. From a management viewpoint, a grower must take an active role in monitoring the nutrient levels in the container and in watching to prevent the application of excessive water. The nutrient must be soluble for the plant to take it up. Excess water applied to the container flushes or leaches some of the soluble nutrient out the bottom of the container onto the ground along with the excess water. Leaching may be a good management practice if excess fertilizer salts in the container are raising the EC (electrical conductivity) values to excessive levels. However, unless the EC levels are monitored or sampled frequently, a grower has no knowledge of the nutrient level in the container.

The irrigation system can be a source of problems. The time it takes to apply water should match the time required to deliver the volume of water necessary to wet the substrate to its moisture-holding capacity. The goal is to replace the water used from the container without much leaching taking place. This length of time will vary over the season as the crop grows. Uniformity of water application is a factor for the irrigation system. Check the water discharge of the first sprinkler on a lateral compared to the last sprinkler; the difference should be no more than 20 percent. Pressures should vary only 10 percent. Check the depth of water applied under a lateral, using straight-sided cans placed on the beds. Sprinkler spacing should achieve fairly uniform coverage. For trickle irrigation, check that the emitters are discharging uniformly.

For in-ground production, water management is not an issue unless soils have excessive phosphorus levels; then the slope of the land and potential water runoff becomes a factor. The soil binds anions and holds water in storage much better than the substrates used in containers. Maintain and use grass waterways and buffer strips as best management practices to reduce runoff velocity and soil erosion.

Best Management Practices (BMPs)

Best management practices are mostly common sense kinds of ideas once you think about them. BMPs represent ways to reduce the risk of nutrients leaving the property. Many BMPs may cost little to implement; some of them, in fact, may save more money than they will cost.

Soluble fertilizer applied by overhead irrigation to large, wide-spaced containers can result in a lot of fertilizer falling onto the ground. You can reduce fertilizer loss in a number of ways: reduce the concentration of fertilizer; reduce the frequency and duration of nutrient application; adopt slow-release formulations of fertilizer; or, ultimately, contain the leachate and runoff in containment basins and recycle the water.

Chapter 18
General Nutrient Deficiency Key

John D. Lea-Cox, Extension Specilaist, Nursery Research

This key is designed to assist in diagnosing suspected nutrient deficiencies. Determining actual nutrient deficiencies (or toxicity) requires substrate and leaf tissue analysis. To use this key, read and pick the description most closely matching the problem. Each description, lettered A through M, ends in either a bold word—the suspected nutrient deficiency—or a bold letter. For letters, advance to the designated lettered description.

A. Symptoms on leaves, stems, or petioles B

Flowering or fruiting affected M, B

B. Youngest leaves affected first C

Entire plant affected or oldest leaves affected first I

C. Chlorosis appears on youngest leaves D

Chlorosis is not a dominant symptom. Growing points eventually die and storage organs are affected H

D. Leaves uniformly light green, followed by yellowing and poor, spindly growth **Sulfur**

Uniform chlorosis does not occur E

E. Leaves wilt, become chlorotic, then necrotic **Copper**

Wilting and necrosis are not dominant symptoms F

F. Distinct yellow or white area appears between veins; eventually veins become chlorotic. Symptoms rare on mature leaves. Necrosis usually absent **Iron**

Yellow or white areas are not so distinct; veins remain green G

G. Chlorosis is less marked near veins. Some mottling occurs in interveinal areas. Chlorotic areas eventually turn brown, transparent, or necrotic. Symptoms may appear later on older leaves **Manganese**

Leaves are abnormally thick, small, necrotic, and curl downward **Zinc**

H. Brittle tissues. Young, expanding leaves may be necrotic or distorted, followed by death of growing points. Internodes may be short, especially at shoot terminals. Stems may be rough or cracked **Boron**
Brittle tissues not a dominant symptom. Growing points usually damaged or dead. Margins of leaves developing from the growing point are first to turn brown or necrotic; old leaves remain green **Calcium**

I. Plants exhibit chlorosis J

Chlorosis is not the dominant symptom L

J. Interveinal or marginal chlorosis K

General chlorosis. Chlorosis of older leaves progresses from light green to yellow. Entire plant becomes yellow under prolonged stress. Growth is immediately restricted; plants soon become spindly and drop older leaves **Nitrogen**

K. Marginal chlorosis or chlorotic blotches that later merge. Leaves show yellow chlorotic interveinal tissue progressing to necrosis. Younger leaves affected with continued stress. Chlorotic area may turn necrotic and brittle, curl upward. Symptoms usually occur late in the growing season **Magnesium**

Interveinal chlorosis, with early symptoms resembling nitrogen deficiency; older leaves chlorotic or blotchy, with veins remaining pale green. Leaf margins turn necrotic and may roll or curl. Symptoms appear on younger leaves as deficiency progresses **Molybdenum**

L. Leaf margins are tanned or scorched or have necrotic spots (may be small black dots, which later coalesce). Margins turn brown and cup downward. Growth is restricted, and dieback may occur. Mild symptoms appear first on recently matured leaves, then become pronounced on older leaves and finally on younger leaves. Symptoms may be more common late in the growing season **Potassium**

Leaves appear dull, dark green, blue-green, or red-purple, especially on the underside and at the midrib and veins. Petioles may also exhibit purpling.

Restriction in growth may be noticed **Phosphorus**

Terminal leaflets wilt with slight water stress. Wilted areas later turn bronze and, finally, necrotic. Very infrequently observed **Chlorine**

M. Fruit appears rough, cracked, or spotted. Flowering is greatly reduced. Fruit shows internal browning, blotchy ripening, or stem-end russeting **Boron**

Fruit cracking and roughness are not dominant symptoms. Fruit exhibits water-soaked lesions at blossom end, which later grow sunken, dark, or leathery **Calcium**

Chapter 19
Plant Growth Regulators For Containerized Herbaceous Perennials

Joyce G. Latimer, Professor, Horticulture
Holly Scoggins, Associate Professor, Horticulture

Production Of Herbaceous Perennials

There is a tremendous diversity of herbaceous perennial plant species being grown for both the retail and landscaping sectors of the industry. Because of the diversity in species grown, there is much more unknown about perennials production than is known. Growth regulation is of particular concern. In production settings, as well as in retail locations, herbaceous perennials grown in pots tend to stretch and become leggy or simply overgrow their pots before their scheduled market date. These plants are less marketable and harder to maintain. Many growers resort to pruning, which is not only costly in terms of labor, but also delays plant production two to four weeks.

Plant growth regulators (PGRs) are chemicals that are designed to affect plant growth and/or development. They are applied for specific purposes to affect specific plant responses. Although there is much scientific information on using PGRs in the greenhouse, it is not an exact science. Achieving the best results with PGRs is a combination of art and science – science tempered with a lot of trial and error and a good understanding of plant growth and development.

Availability of chemical plant growth regulators (PGRs) for perennials is not a problem. All of the primary floriculture growth retardants are labeled for use on perennials. The issues are 1) lack of knowledge about rates; and 2) the wide disparity of plant responses to these PGRs. Even after years of research, many of the herbaceous perennials in the market have never been evaluated for response to any of these chemicals. This chapter provides basic information on selecting and applying PGRs to affect growth, branching, and flowering with an emphasis on their use on perennials, followed by a discussion of specific growth regulators used on herbaceous perennials. This discussion references a table that summarizes the results of research trials using PGRs on over 175 perennial species/cultivars Table 19.3).

Choosing The Correct PGR

For best results, PGRs should be handled as production tools like water and fertilizer. They should not be used as crutches for poor management of other cultural practices. PGRs should be an integrated part of your crop production cycle. The selection of PGRs and their application rates will be affected by how your crop is grown. Especially with very vigorous plants, as are many of the herbaceous perennials, higher fertility and irrigation levels will increase the amounts of growth regulator required to prevent excessive growth. Shading, lower light levels or tight plant spacing, especially under higher growing temperatures, also will increase plant stretch and reduce lateral branching. For the highest quality plants, the use of PGRs must be integrated into your production plan.

PGRs are most effective when applied at the appropriate times to regulate plant growth or development. In other words, growth retardants cannot “shrink” an overgrown plant. They must be applied before the plant is overgrown to avoid plant stretch. When planning PGRs in your production schedule, consider what you want to accomplish with the treatment.

- Do you want to regulate shoot growth of the plant, resulting in a sturdier, more compact plant with improved color? If so, you probably want a growth retardant.

- Do you want to increase plant branching for enhanced cutting production or for a more bushy potted plant or hanging basket? If so, you probably want to use a branching agent or "chemical pincher."

- Do you want to enhance flower initiation or synchronize flowering? If so, you probably want to use chlormequat chloride or gibberellic acid.

- Do you want to remove flowers from stock plants to increase the number of vegetative cuttings? If so, you probably want to use an ethylene-generating compound.

Answering these questions will indicate which type of PGR you need to use to accomplish your goal and the most appropriate timing of the application. Then, you will need to select a specific PGR in that class and determine the appropriate dosage and the appropriate application method to attain the desired response.

Regulating Shoot Growth

Most of the PGRs used in the greenhouse or nursery are used to regulate shoot growth of containerized crops. These PGRs are referred to as "growth retardants". Typical growth retardants are daminozide (B-Nine, Compress or Dazide), chlormequat chloride (Chlormequat E-Pro, Citadel or Cycocel), ancymidol (Abide or A-Rest), flurprimidol (Topflor), paclobutrazol (Bonzi, Downsize, Florazol, Paczol, or Piccolo) and uniconazole (Concise or Sumagic). Now that most of the PGR chemistries are off patent, there are several options available (Table 19.1). These PGRs reduce plant height by inhibiting the production of gibberellins, the primary plant hormones responsible for cell elongation. Therefore, these growth retardant effects are primarily seen in stem, petiole and flower stalk tissues. Lesser effects are seen in reductions of leaf expansion, resulting in thicker leaves with darker green color. Other benefits of using these PGRs in plant production include improved plant appearance by maintaining plant size and shape in proportion with the pot. Plant growth retardants also increase the tolerance of plants to the stresses of shipping and handling as well as retail marketing, thereby improving shelf-life and extending plant marketability.

Generally, growth retarding PGRs should be applied just prior to rapid shoot growth. This is generally one to two weeks after transplanting a plug, after the roots are established and as the plant resumes active growth; on pinched plants, it is after the new shoots are visible, just starting to elongate. This is where the art of plant growth regulation is most important. You must learn how your crop grows and when to intervene to obtain the desired results. Remember to note details of crop development in your records of PGR treatments. For example, due to the weather conditions, next year you may need to treat at seven days after transplanting instead of at the ten days after transplanting that you used this year. You must gauge when rapid elongation will likely occur and treat to counter it.

Enhancing Lateral Branching

Another group of PGRs used in floricultural crops are those that enhance branching, including ethephon (Florel), BA (benzyladenine, Configure), dikegulac sodium (Atrimmec or Augeo), and methyl esters (Off-Shoot-O) (Table 19.2). These PGRs are frequently called "chemical pinchers" because they generally inhibit the growth of the terminal shoots or enhance the growth of lateral buds, thereby increasing the development of lateral branches. They can be used to replace mechanical pinching of many crops like vinca vine, verbena, lantana, and English ivy (*Hedera*). Often this increased branching also will reduce the overall height of the plant. The ethylene released inside the plant by Florel inhibits internode elongation, keeping treated plants more compact than untreated plants. Florel also affects flowering (see below). Configure is a synthetic cytokinin (6-benzyladenine) which is a plant hormone that stimulates lateral branching. If you are looking for enhanced branching, you must have sufficient growth on the plant to allow for sites of lateral

development. They cannot enhance lateral branching if there are no laterals on the plant. Timing of the application is critical to a good branching response. Again, read the label for details of when to apply for optimum response. Always consider the side effects of treatments. Some of these PGRs reduce or eliminate flowering (Tables 19.1 and 19.2).

Enhancing Plant Flowering

Plant growth regulators can be used to enhance flowering (GA3 products). To improve flowering, FlorGib or ProGibb, which contains the growth promoter gibberellic acid (GA3), can be used to substitute for all or part of the chilling requirement of some woody and herbaceous ornamentals typically forced in the greenhouse, including azalea for florist crops and asters for cut flowers. These compounds also can improve flowering and/or bloom size of camellia, baby's breath (*Gypsophila*), and statice (*Limonium*). Gibberellic acid also is used to promote growth and increase stem length of other cut flowers like stock (*Matthiola*), *Delphinium*, and Sweet William (*Dianthus*). See product labels for specific uses and recommended rates. Again, timing is critical since late applications or excessive rates may cause excessive plant stretching resulting in weak, spindly stems. Chlormequat chloride (a plant growth retardant) used to control stem height of hibiscus and geranium also improves early flowering of these crops.

Removal of Flowers

Flower removal is especially desirable for stock plants maintained for cuttings of vegetatively propagated ornamentals like verbena or lantana. Florel (ethephon) is the primary compound used for flower removal. Once ethephon is absorbed by the plant it is converted to gaseous ethylene, a natural plant hormone effective in many plant processes. Ethylene is the primary hormone responsible for flower senescence and fruit ripening. It is the "postharvest" hormone. With proper rates and timing, it will remove unwanted flowers from stock plants, cuttings, or plugs. Flower removal diverts more energy into vegetative growth increasing the number of laterals available for cuttings on stock plants and promotes increased branching of plugs and finished plants which increases fullness in the container. Since initiation and development of flowers requires time, Florel should not be used on crops within six to eight weeks of marketing.

Read The Label!

Plant growth regulators are classified as pesticides and are subject to all of the same USDA recordkeeping and Worker Protection Standard (WPS) rules as all other pesticides. Their use is governed by the manufacturer's label as with other pesticides. The label contains information on restrictions and information on how to use the product effectively. Before spending time and money applying PGRs, answer these questions:

- Is the chemical labeled for the crop you wish to treat? Most of the PGR labels have undergone revisions that apply to a broad range of similar crops not specifically listed on the label with the user taking responsibility for determining appropriate rates. This provides label permission to use the compound on these crops without the manufacturer accepting the responsibility for the rate selection.

- Is the chemical labeled for the area you wish to treat? Many of the PGRs are only labeled for use inside a greenhouse or other growing structure.

- Are there any potential side effects such as phytotoxicity? Note that you may need to look elsewhere for this information for your specific crop.

- Are there label warnings regarding the PGR's effect on plant flowering? For example, many branching enhancers delay flowering. Florel causes flower bud abscission prior to enhancing branching. Therefore, it is not recommended within six to eight weeks of marketing. Side effects are often affected by application timing; e.g., late applications of growth retardants may delay flowering.

Application Guidelines

Spray Applications

Plants to be treated with PGRs should be healthy, turgid and unstressed – never wilted. The label will identify the target tissue for that PGR. For example, daminozide is only effective as a foliar spray whereas paclobutrazol and uniconazole sprays must reach the stems. When making spray applications, look at the growth and development of the plant to see that there is sufficient development to make the treatment effective. Generally, there should be sufficient foliage or stems to absorb the PGR.

Uptake and effectiveness of a PGR also depend on selecting the application technique that will ensure proper coverage of the target tissue. Daminozide is not soil. Therefore, a foliar spray application, wetting most of the foliage, is necessary to provide a uniform reduction in growth. Leaf surfaces should be dry for foliar applications and the best uptake of PGRs from spray applications will occur under low stress, low drying conditions. This is more critical for daminozide and ethephon than for some of the newer chemistries like the triazoles. Overhead irrigation after treatment with daminozide or ethephon should be delayed for 18 to 24 hours to avoid washing the material off of the leaves.

The triazoles, paclobutrazol and uniconazole, are absorbed primarily by stem tissue and then translocated upwards in the plant. Therefore, consistent and complete coverage of the stems is necessary for uniform effects. In other words, if the stem of one lateral receives an inadequate amount of spray, it will grow faster than the others, resulting in a poorly shaped plant. Ancymidol and flurprimidol are taken up by both foliage and stems. In addition, all four of these compounds are very "soil active" which means they may be adsorbed to particles in the media and become available to the plant through root uptake. Therefore, drenching is a very effective application method for these chemicals in crops where it is economically feasible.

The label will provide a recommended application volume for sprays, especially for chemicals that are soil active. All foliar applications of PGRs should be applied on an area basis, i.e., uniformly spray the area where the plants are located with the recommended volume of solution. Do NOT spray individual plants or spray to reach a subjective target like "spray to glistening." Since every applicator will have a slightly different definition of these goals, there will be no way of recommending appropriate rates or obtaining predictable results. For soil active PGRs, dosage is dependant on both concentration of the solution and the volume of that solution applied in the treated area. Therefore, to improve predictability, the label-recommended spray application rates are generally set at 2 qt. finished spray per 100 sq. ft., which is sufficient to cover the plant and permit a small amount of runoff onto the medium. It also is considered to be a comfortable walking pace for applicators with hand-held sprayers. This is the same application volume recommended for daminozide which is not soil-active.

With the soil active PGRs, precautions should be taken to avoid over-application with sprays. Spray applications require more attention to detail, because overspray material lands or drips onto the medium. The overspray from a 2 qt. per 100 sq. ft. application is a part of the recommended dosage. However, if your application volume exceeds that recommendation, then your application dosage also exceeds the recommendation.

Recognizing that stem coverage is necessary for the triazoles, you may need to apply a higher than recommended volume to large or dense plants to obtain adequate coverage. In fact, the paclobutrazol label recommends 3 qt. per 100 sq. ft. for "larger plants with a well developed canopy." Adjust the concentration you apply accordingly. Record-keeping is very important when evaluating these adjustments. Always consider the rates presented in Table 19.3, or from any other resource, to be a guideline to assist you in developing your own rates based on your growing conditions and application methods.

The relationship of rate and volume can be exploited when treating multiple crops with different PGR needs. With a single solution of PGR in the spray tank, you can apply the label recommended volume to attain your basic application dosage or you can apply additional volume to crops that need additional growth regulation to attain a higher dosage. Application volume is another tool that you can use to maximize your efforts and reduce time mixing or reloading higher concentrations of PGR solutions.

Spray Equipment

To assure proper spray volumes, your compressed air sprayer should be equipped with a pressure gauge and regulator and you should consistently use the same nozzle for all PGR applications. Calibrate your sprayer by determining the output of the chemical with the selected nozzle at the selected pressure within a specified time period. Using this information, you can apply a known amount of material to a known area. Spray droplet size also affects response with smaller droplet sizes providing better coverage, but only up to a point. Mist or fog type applicators do not provide adequate volume for coverage of plant stems and the medium, and therefore, have not been effective when used with compounds like paclobutrazol and uniconazole. PGR applicators should be trained to uniformly apply a given amount of clear water in the greenhouse before they make PGR applications. Uniformity of the application is critical to the uniformity of the crop response.

Applying Drenches

Although a drench application has several advantages over sprays, traditional drenches are seldom used on perennials due to the higher application costs of handling individual pots. Drenches generally have less effect on flowering or flower size and tend to provide longer lasting growth regulation than sprays. Drenches are easier to apply uniformly than sprays because the drench volume is easily measured, and when applied to moist media, it is easy to obtain good distribution of the PGR in the media. Therefore, the resulting growth regulation is frequently more uniform. Product labels specify the recommended volumes for drench applications to different size pots or types of media. In general, 4 fl. oz. of drench solution is applied to a six-inch "azalea" pot, and that volume is adjusted up or down with pot size to obtain a volume where about 10% of the solution runs out the bottom of the pot when the media is moist. Remember, the amount of active ingredient applied to plants depends on both the concentration (ppm) of the solution and volume applied.

Alternative methods of applying PGRs directly to the media have been developed and are described on the label. For example, ancymidol, flurprimidol, and paclobutrazol are labeled for application through the irrigation system ("chemigation"). These PGRs are generally labeled for flood (sub-irrigation), drip irrigation and overhead sprinkler systems. Again, rates vary with the volumes used and method of application. Paclobutrazol applied once by sub-irrigation requires 50% to 75% of the amount of paclobutrazol that is applied in a typical drench application. Pressure compensated drippers are recommended for use with PGRs to more accurately regulate the volume of solution applied to each pot. Read and exactly follow the label for chemigation applications, especially with regard to safety of municipal water supplies.

Three other methods of providing a drench type application of soil-active PGRs on a more economical scale are being used by growers. One is media surface application sprays. These are spray applications made to the surface of the media of filled flats or pots. The treatment is applied at normal to high spray volumes but since it is applied to the media surface it is activated by irrigation and is available to the plant in the root zone. Both paclobutrazol and uniconazole are labeled for this method of application. Rates are lower than used for sprays, but higher than used for drench applications. A second method is called "sprenches" which is a high volume foliar spray that results in additional runoff into the media, providing a drench effect. Rates are lower than what is for recommended for spray rates. A third technique, called "watering in", is a type of chemigation where the PGR is injected into the irrigation water and applied at each irrigation at very low rates of active ingredient. Only PGRs labeled for chemigation can be used for watering-in. All of these application methods use the relationship between rate and volume to provide the desired control. Again, you must develop techniques that fit your production methods and your growth management preferences.

Liner dips or drenches are another specialized way to use soil active growth retardants. Although many of the soil active PGRs have been tested, only Paczol (paclobutrazol) is labeled for this application (Table 19.1). The root system of rooted liners or plugs is dipped into a solution of the PGR (or they may be thoroughly drenched in the plug tray). Extensive work has been conducted at the University of Florida on this application method.

Liners should "dry" which is defined as the root ball being ready for irrigation, but not under drought stress. Time in the solution is not critical; 30 sec to 2 minutes is sufficient for saturation of the rootball. Liners may be planted immediately or held up to 10 days without loss of PGR effect. There is no loss of effectiveness of the dip solution during treatment.

Advantages of the liner dip include early control of very vigorous crops and flexibility of the treatment with respect to not having to handle plants during the restricted entry interval (REI). The liner dip is especially useful in combination plantings where the more vigorous plants can be treated prior to planting without reducing the growth of the slower plants in the group. The liner dip rates should be selected to provide early control of plant growth. Additional applications can be made as necessary for longer term crops.

Be Aware of Bark
For many years, the adage in PGR drenches has been "Bark ties up soil-active PGRs." However, new research shows that this is not necessarily true. As long as the bark is properly aged before the media is mixed, it has little effect on the availability of these soil active PGRs to the plant roots.

Growing Conditions
Look for label recommendations on time of day or condition of the plant for optimum treatment response. Generally, a healthy, unstressed plant growing under low evaporative conditions, e.g., early in the morning or late in the afternoon, is most responsive to treatment. To maximize uptake, the chemical must remain in contact with the leaf long enough to be absorbed. This time varies for the different PGRs, but generally foliar uptake is enhanced with slower drying conditions which in turn increases the effectiveness of the treatment. Plants treated with daminozide or Florel should not be overhead irrigated for at least 18 to 24 hours after treatment, but plants treated with flurprimidol, paclobutrazol or uniconazole may be irrigated one hour after treatment. Read the label for any warnings on how irrigation or environmental conditions will affect plant response to the PGR treatment.

Specific Plant Growth Regulators

The following discussion of the effects of specific growth retarding PGRs on perennials references Table 19.3 which summarizes the results of research trials using PGRs on over 175 perennial species/cultivars. This summary includes rates found effective in reducing plant height in published articles, as well as many of our own research results. Foliar spray applications are tested more often than drenches, presumably due to the higher labor costs involved in applying drenches in large scale production areas. All of these research results are from the Mid-Atlantic and Southern parts of the U.S. which means that they should be adjusted down for growers further north (see Summary).

Daminozide (B-Nine Compress, or Dazide; Re-entry Interval (REI) = 24 hrs) was one of the first PGRs labeled for use in the floriculture industry and is still widely used. In general, it is not phytotoxic and has a short-term effect that seldom results in over-stunting of treated plants. The low activity of daminozide and its lack of soil activity make it easier to get consistent, predictable responses than with the newer, more potent PGR chemistries. Plants should be well-irrigated prior to treatment but foliage should be dry at the time of treatment. Do not irrigate overhead for 18 to 24 hours after treatment. The low activity also means that daminozide must be applied more frequently to maintain control over vigorous crops. Nearly one-half of the perennial species tested have shown some response to multiple applications of daminozide (Table 19.3).

Generally, perennial foliar sprays of 5000 ppm are applied every 10 to 14 days as necessary. Daminozide is labeled for use on containerized or bed-grown crops in the greenhouse, and on containerized plants grown outdoors under nursery conditions. Frequency of application may need to be increased to weekly for more vigorous cultivars grown outdoors.

Chlormequat chloride (Chlormequat E-Pro, Citadel or Cycocel; REI = 12 hr) is another PGR with a long history in floriculture. Note that the product use labels for these three chlormequat chloride products vary in application limits. See the label for your product for the specific rates and sites of application (Table 19.1). Chlormequat chloride is generally applied as a foliar spray at 200 to 3000 ppm with a maximum of three to six applications per crop cycle depending on which product you use. Although rates above 1500 ppm often cause chlorosis on young treated leaves of other floricultural crops, we have seen few examples of phytotoxicity on perennials. However, chlormequat chloride alone has not been tested on a wide variety of perennials. Rose mallow (*Hibiscus moscheutos*), like the tropical *Hibiscus*, is responsive to chlormequat chloride, responding well to multiple applications of 500 ppm Cycocel (Table 19.3). Chlormequat chloride also promotes earlier flowering and greater flower numbers on *Hibiscus*. First application should be made when the laterals are 0.5 to 1 inch long. Chlormequat chloride is also labeled for drench applications at rates of 2000 to 4000 ppm when applied inside a greenhouse depending on the specific product label. Again, rose mallow was very responsive to a 2000 ppm Cycocel drench (4 fl.oz. per 6" pot).

Of these three chlormequat chloride products, only Cycocel is labeled for use on containerized plants in the outdoor nursery where it may be applied at a maximum spray rate of 3000 ppm up to three times in any crop production cycle. This limit includes any applications of Cycocel combined with daminozide. Drench applications of Cycocel are not permitted in the outdoor nursery, even on containerized plants. Read the pesticide label for your product. It is the law for application sites and rates. Chlormequat chloride is not labeled for application through the irrigation system.

A daminozide/chloremequat chloride tank mix has more PGR activity than either daminozide or chloremequat chloride alone and generally causes less phytotoxicity than chlormequat chloride applied by itself. Both the daminozide and chlormequat chloride labels have approved tank mix instructions. This combination has been tested on a wide variety of perennials. For example, three-lobed coneflower (*Rudbeckia triloba*) was very responsive to B-Nine applied twice at 5000 ppm, but not responsive to Cycocel at rates up to 4000 ppm. However, a tank mix of 5000 ppm B-Nine with increasing rates of Cycocel resulted in height control similar to the B-Nine treatments but with a single application. The "high activity" rate generally used for the tank mix is 5000 ppm daminozide plus 1500 ppm chlormequat chloride. Although the rate of daminozide is usually adjusted to increase or decrease activity, changing the chlormequat chloride rate also affects activity. Shoot height of more than 50 of the perennials listed in Table 19.3 was effectively controlled by this tank mix including blanket flower (*Gaillardia grandiflora* 'Burgundy') and Russian sage (*Perovskia atriplicifolia*) along with two of the ornamental grasses, *Sorghastrum* 'Indian Steel' and *Calamagrostis* 'Karl Foerster.' Single applications of the tank mix are frequently more effective than multiple applications of daminozide alone. In other crops in Table 19.3 where the tank mix is listed as non-responsive (NR) with one application, the effects may have been too short term for the research evaluation. Multiple applications of the tank mix may provide control on these species.

Ancymidol (Abide or A-Rest; REI = 12 hrs) is a more active compound than daminozide or chlormequat chloride. Ancymidol is active as a spray or a drench so application volume affects plant response. In addition, ancymidol is labeled for chemigation, i.e., distribution through the irrigation system via flood, sprinkler or drip systems. Follow all label directions. Abide is not labeled for spray applications in shadehouses or nurseries, but drench applications can be made indoors and outdoors. A-Rest is labeled for use as a spray or drench on containerized plants in greenhouses, nurseries, shadehouses and interiorscapes.

Although ancymidol has not been evaluated for effectiveness on a large number of perennial species, the labels specifically list foliar sprays on bleeding heart (*Dicentra*) and columbine (*Aquilegia*) at 65 to 132 ppm, gayfeather (*Liatris*) (25 to132 ppm) and hybrid bee delphinium (*Delphinium*) (35 to 132 ppm). Ancymidol also can be applied as a drench at 2 to 4 ppm for these crops. For best results, treatments should be applied to well-rooted plants in active growth, prior to the initiation of flowering. The higher rates necessary for foliar applications to some crops may not be economically feasible. The use of ancymidol as a drench or as a treatment of plants in the plug stage is more economical than foliar applications on finished plants. In our studies on finished plants, we had excellent control of *Veronica* 'Icicle' and *Hemerocallis* 'Happy Returns' with 2 ppm drenches of Abide (2 fl.oz. per quart pot and 10 fl.oz. per trade gallon pot, respectively) and *Delphinium* 'Blue Bird' at 4 ppm Abide (10 fl.oz. per trade gallon pot) (Table 19.3).

Flurprimidol (Topflor; REI = 12 hrs) is similar in chemistry to ancymidol but much more potent. Its activity is similar to that of the triazoles. Herbaceous perennials have proved very responsive to flurprimidol. With spray applications, Topflor rates are similar to those used with paclobutrazol. However, in soil applications, its activity is more similar to that of uniconazole. It is labeled for use as a spray or drench on containerized ornamental plants grown in nurseries, greenhouses, and shadehouses. Topflor is labeled for chemigation. Test spray rates around 15 to 40 ppm. We have not researched drench applications on perennials but reports on other bedding plants suggest drench rates about 0.25 to 4 ppm.

The triazole class of PGRs includes paclobutrazol (Bonzi, Downsize, Florazol, Paczol, or Piccolo,; REI = 12 hrs) and uniconazole (Concise or Sumagic; REI = 12). These compounds are much more active than most of the previous compounds. Uniconazole is more potent than paclobutrazol. As mentioned above, the activity of flurprimidol (Topflor) is between these two triazoles depending on application method. For perennials in the South and Mid-Atlantic, paclobutrazol is generally applied at spray rates of 30 to 100 ppm and uniconazole at 15 to 45 ppm. These PGRs are rapidly absorbed by plant stems and petioles or through the roots. Excess spray dripping off treated plants acts as a drench to the substrate, increasing the activity of the treatment. For foliar sprays of triazoles, uniform application of a consistent volume per unit area is critical to uniform and consistent crop response (Table 19.1). Both compounds are labeled for application to the media surface prior to planting plugs. In this case, the PGR is applied as a spray to the surface of the medium in filled pots. The PGR moves into the medium with subsequent irrigations and effectively behaves as a drench. Effectiveness also is reduced by bark in the medium, as with drenches.

Neither paclobutrazol nor uniconazole has resulted in any specific phyotoxicity symptoms on perennials, but care must be taken with application on sensitive plants. In some cases, excessive stunting can be very persistent, e.g., goldenrod (*Solidago sphacelata*) treated with higher rates of Bonzi (240 ppm) or Sumagic (60 ppm) did not recover normal size at five months after planting into the landscape. Growth of velvet sage (*Salvia leucantha*) was excessively reduced by 45 or 60 ppm Sumagic in the greenhouse. Furthermore, 60 ppm Sumagic caused a significant delay in landscape growth of the *Salvia*. These compounds must be used carefully and appropriately. Especially when working with the triazoles, thoroughly test your application methods and rates on a small number of plants before treating your entire crop.

Avoid late applications of the triazoles. They should be applied prior to flower initiation when possible. The persistence of these compounds in plant stems and petioles can have significant effects on the flower display as well. As with many of the growth retardants, the triazoles inhibit gibberellin synthesis. Generally, the most rapidly elongating tissues have the highest production of gibberellins and, therefore, are most affected by reductions in gibberellin production. For example, elongation of flowering stems of gaura (*Gaura lindheimeri*) was much more affected by PGR application than the leafy stems. Usually this is acceptable because it keeps the flower height in better proportion to the plant height. However, differences in response vary, and in some yarrow (*Achillea*) cultivars, flower height has been excessively stunted at moderate application rates. We have also seen significant height suppression of flower stalks with drench applications

of paclobutrazol or uniconazole on daylily (*Hemerocallis*). These plants were deemed acceptable by nursery producers because of their improved ship-ability.

Paclobutrazol has a broad label for ornamentals that includes use on greenhouse or outdoor-grown containerized crops. See Table 19.1 for label restrictions for the different products. All of the paclobutrazol products are labeled for application through the irrigation system, including ebb/flow or flooded floor systems. Paclobutrazol has been tested on a wide variety of perennials with species ranging from extremely sensitive to low rates to non-responsive to very high rates. To establish rates for plants not listed in Table 19.3 or on the product label, treat a small number of plants with 30 to 100 ppm as a foliar spray or up to 10 ppm as a drench. In many cases, multiple treatments with lower rates have been more effective, with less chance of over-stunting, than a single application at a higher rate.

Uniconazole also has a broad label for ornamentals, but its use is limited to containerized plants grown in greenhouses, overwintering structures, shadehouses, or lathhouses. It is not labeled for outdoor nursery use. Uniconazole also is not labeled for application through any irrigation system. Uniconazole has been very effective on a large number of perennials with spray rates in the 15 to 45 ppm range in the south and mid-Atlantic areas. We have done less research on drench rates on perennials. However, we have found them to be very sensitive to uniconazole with good growth control using 0.5 to 2 ppm drenches. Since it is very potent, pay special attention to uniform application and proper volumes. Use caution in the higher rates or on more sensitive species since uniconazole can be very persistent in the landscape.

NOTE: Ancymidol, flurprimidol, paclobutrazol and uniconazole are persistent on plastic surfaces and in soil. Do not reuse flats, pots or soil from treated plants, especially for plug production of sensitive crops.
Ethephon (Florel Brand Growth Regulator; REI = 48 hrs) is a compound that breaks down in plant tissue after application to release ethylene, a natural plant hormone. As with ethylene, its effects can vary depending upon the species and the stage of growth at time of application. It has a broad use label (EPA Reg. No. 54705-8) for increasing lateral branching of floricultural crops. Florel also inhibits internode elongation of many plants, however, research with perennials has been limited (Table 19.3). Florel has controlled runner elongation of clump verbena (*Verbena* 'Homestead Purple') and increased inflorescence numbers of sage (*Salvia* 'May Night') and yarrow (*Achillea* 'Coronation Gold'). Florel should be applied to actively growing plants prior to flower development. If flowers are present at the time of application, they are likely to abort. Florel may delay flowering about one to two weeks, particularly if applied close to the time of flower initiation. Florel should not be applied to plants that are heat or drought stressed. The pH of the water used for the spray solution can be important. If the pH is too high, the ethephon will convert to ethylene before it gets to the plant and activity will be reduced. Florel contains sufficient acidifiers and buffers to maintain a pH of 5.0 or lower when mixed with most greenhouse water supplies. In general, water that has sufficient quality for irrigation of greenhouse crops (moderate pH and alkalinity) is suitable for mixing Florel. However, if you are acidifying your water prior to irrigation, use the acidified water for mixing the Florel as well. The solution should be applied within 4 hours of mixing.

Benzyladenine (6-BA, Configure; REI = 12 hrs). Configure is a synthetic cytokinin (6-benzyladenine) which is a plant hormone that stimulates lateral branching. It is a relatively inexpensive PGR and has been very effective in enhancing the branching of a wide variety of perennials. Configure stimulates, but does not cause, an increase in branching. Therefore, application timing is important. Treated plants must have sufficient lateral buds formed to respond to the treatment. BA has a short period of activity and has no residual in the plant. So, multiple applications may be useful with many of the perennial crops. Furthermore, it is not translocated in the plant so thorough coverage is required.

Initial work on herbaceous perennials focused on *Hosta* and *Echinacea* which are very responsive to Configure. In our trials, multiple *Echinace*a cultivars have shown two to four times the number of basal

branches versus untreated plants when treated about two weeks after potting. Other researchers have reported similar results with a number of other *Echinacea* cultivars. Further screening trials with other herbaceous perennials have identified a large number of crops that showed increased basal or lateral branching in response to a 600 ppm spray of Configure (Table 19.3). We have found little incidence of phytotoxicity with Configure. Successful use of Configure to increase the number of shoots on perennial plugs/liners has been reported by several growers. We found that Configure had little effect on root growth of plugs treated after the cuttings were moderately rooted whereas branching was significantly increased for many crops. Although the primary objective with Configure is to increase branching, it has resulted in growth reduction in some crops. However, if additional growth control is necessary, we have found that growth retardants may be used following the Configure treatment without reducing the branching response.

Dikegulac sodium (Atrimmec, Augeo; REI = 12 hr) is a compound that interferes with terminal growth by inhibiting deoxyribonucleic acid (DNA) synthesis which is required for new growth. By primarily inhibiting terminals, apical dominance is reduced which enhances the production of lateral branches. Note that this mode of action tends to cause a delay in the resumption of plant growth and may add 2 to 4 weeks to production time. Atrimmec is labeled for use on containerized and landscape woody ornamentals but also is labeled for use on some hanging basket plants and groundcovers. Of particular interest to perennial growers is its label for lantana (*Lantana camara*) (750 to 1500 ppm) and butterfly bush (*Buddleia*) (530 to 1500 ppm). Augeo was labeled in 2010 with an REI of 4 hrs for use on container-grown and landscape ornamentals and trees, including Christmas tree farms. Dikegulac sodium should be applied to actively growing plants with at least two nodes to provide sufficient lateral development. In addition to creating a fuller plant, enhancing the number of laterals in a pot generally reduces the overall height of the plant due to the greater distribution of resources. Responses are very species-specific so test several rates under your growing conditions. Dikegulac sodium usually causes leaf chlorosis which can be very persistent at higher rates (above 1500 ppm). Other phytotoxic responses, including malformed flowers, have been noted at higher rates on perennials such as gayfeather (*Liatris spicata*). Research suggests that dikegulac sodium can increase branching of big-flowered hybrids of *Clematis*. We are still testing Augeo on a variety of herbaceous perennials. Foliar spray rates in 400 to 800 ppm range improved branching without excessive phytotoxicity or growth inhibition. Check our searchable database (see Resources) for updates.

Recordkeeping

Keeping notes on your application methods and the results of your PGR treatments will allow you to improve the consistency of your own application methods and establish rates and volumes appropriate to your production system. Note the concentration and the volume applied, the stage of development of the crop (number of leaves, approximate height, presence of flowers), and the environmental conditions under which the PGR was applied. It is always recommended to keep a few untreated plants for comparison, especially if you are new to using PGRs.

Summary

The degree of growth regulation by PGRs is impacted by all other phases of plant culture. Remember that you have to fit PGRs into your own production program. Plan ahead to achieve the best results from PGRs; do not use them as an afterthought when the plants are out of control. You cannot "shrink" an overgrown plant!

The multitude of variations possible in application methods, cultivar and species grown, and growing conditions make it impossible to recommend specific rates for all operations. Table 3 provides a resource for the use of PGRs on herbaceous perennials. In the Mid-Atlantic and South, use the lower of suggested effective rates for starting your own trials.

There are a couple of general rules for using rate recommendations from other sources:

1) Southern growers use higher rates and more frequent applications than Northern growers. Rates for Virginia/Maryland tend be closer to the Southern rates.
2) Outdoor applications usually require higher rates or more frequent applications than for plants grown under cover.

Always consider any rate recommendation as a starting point for your own trials and keep records of your successes and failures with PGRs. Whenever you treat your crop, hold back a few untreated plants so that you can judge the effectiveness of your treatment. Remember that methods of application have significant effects on results. Develop your own program, then test and refine it. Watch for PGR compounds new to the floriculture market and for expanded labeling of current products as we develop more guidelines for their use on perennials.

Recommended Resources

PGR Calculator

For a ready resource on preparing PGR solutions, download the Plant Growth Regulator Calculator developed by floriculture specialists from North Carolina State University and the University of New Hampshire: http://www.nhfloriculture.com. This Microsoft Excel spreadsheet allows you to enter your own PGR costs and calculate solutions based on the rate desired and the amount of area to be treated. The spreadsheet includes information on both spray and drench applications. It not only gives you the amount of PGR to mix per gallon or liter of water, but also provides the cost of the application based on the area or number of containers treated.

PGR Searchable Database

The data in Table 19.3 have been entered into an expanded searchable database of PGR use on herbaceous perennials that GPN magazine hosts on their website. This table is updated annually with new research information from the Virginia Tech Herbaceous Perennials Program.
http://www.gpnmag.com/index.cfm/fa-showPGRSearchForm

Table 19.1 Plant Growth Regulators Used To Reduce Plant Height During The Production Of Floricultural Crops

Common Name/ Trade Name	Application Methods	Comments	Concerns
Ancymidol Abide (Fine Americas, Inc.) A-Rest (SePRO Corp.)	Foliar spray Bulb dip Drench Chemigation Injection	Broad spectrum label. Very active on many bedding plants; commonly used on plugs. Abide label prohibits spray applications in shadehouses or nurseries. Drench applications can be made indoors or outdoors. A-Rest labeled for use as spray or drench on containerized ornamentals grown in nurseries, greenhouses, shadehouses and interiorscapes.	Very safe. Relatively expensive for many crops. Maximum spray rate is 132 ppm. Do not add wetting agent. Follow all label directions for all chemigation uses. Do not reuse pots, trays or media previously treated with ancymidol.
Daminozide B-Nine 85WSG (OHP, Inc.) Compress WSG (PROKoZ, Inc.) Dazide 85WSG (Fine Americas, Inc.)	Foliar spray Cutting dip	Apply uniformly to all foliage. No soil activity. Effective on a broad list of species, but low level activity and short residual; multiple applications generally required. Increased activity when tank mixed with chlormequat chloride. Labeled for use on beds and containers in greenhouses, shadehouses and nurseries. Limited to containerized plants in uncovered production areas.	Safe, few incidences of phytotoxicity or overstunting. Do not overhead irrigate within 24 hrs after treatment.
Chlormequat chloride Chlormequat E-Pro (Etigra LLC) Citadel (Fine Americas, Inc.) Cycocel (OHP, Inc.)	Foliar spray Drench	Standard for geraniums, poinsettias, and hibiscus; enhances flowering of geranium and hibiscus. Label allows use on a broad spectrum of crops in the greenhouse. Activity is low, multiple applications generally required. Increased activity when tank mixed with daminozide. Only Cycocel is labeled for use as a spray on containerized plants in the outdoor nursery (max 3000 ppm three times in any crop production cycle).	Causes discoloration of leaves especially with rates above 1500 ppm; phytotoxicity reduced in tank mix with daminozide. Less effective under high temperature conditions.

Table 19.1 Plant Growth Regulators Used To Reduce Plant Height During The Production Of Floricultural Crops (continued)

Common Name/ Trade Name	Application Methods	Comments	Concerns
Flurprimidol Topflor (SePRO Corp.)	Spray Drench Chemigation Subirrigation	Labeled for use as spray or drench on containerized ornamental plants grown in nurseries, greenhouses, and shadehouses.	Applications not to exceed 3.0 lbs ai/A/year. Do not use wetting agents. Do not reuse pots, trays or media previously treated with flurprimidol.
Paclobutrazol Bonzi (Syngenta Crop Protection) Downsize (Greenleaf Chemical, LLC) Downsize is labeled only for drench applications indoors or outdoors, manually or through chemigation. Florazol (PROKoZ, Inc.) Paczol (OHP, Inc.) Piccolo (Fine Americas, Inc.)	Spray Media spray (Paczol only) Drench Bulb dip Liner dip (Piccolo only) Chemigation Subirrigation	Labeled for use as spray or drench on containerized ornamental plants grown in nurseries, greenhouses, shadehouses and interiorscapes. Apply uniformly to cover stems (not absorbed by leaves). Much more active than above PGRs; measure accurately. Spray procedure and uniformity greatly affects results. Sprays are limited to enclosed areas (greenhouses) to eliminate drift. Very soil active as a drench. Piccolo is also available as a 10x clear concentrate (Piccolo 10XC, 4% a.i.) which requires less agitation. Fine Americas is also developing a granule formulation.	Spray volume critical to establishing rates due to drench effect of runoff. Use higher rates under high temperature conditions. Late applications can reduce flowering. Phytotoxicity includes overstunting. Avoid drift onto non-target plants. Agitate spray solution often for uniform concentration. Do not reuse pots, trays or media previously treated with paclobutrazol.
Uniconazole Concise (Fine Americas, Inc.) Sumagic (Valent USA Corp.)	Spray Media spray Drench Bulb dip Liner dip (mums)	Labeled for use as spray or drench on containerized ornamental plants grown in greenhouses, lathhouses, and shadehouses. Sumagic also is labeled for greenhouse grown vegetable transplants (see Supplemental Label). Apply uniformly to cover stems (not absorbed by leaves). Spray procedure and uniformity greatly affects results. Very soil active as a drench. Fine Americas is also developing a granule formulation of Concise.	Spray volume critical to establishing rates due to drench effect of runoff. Use higher rates under high temperature conditions. Do not add wetting agents. Late applications can reduce flowering. Phytotoxicity includes overstunting. Avoid drift to non-target plants. High leaching potential. Do not apply to pots on dirt floors. Do not reuse pots, trays or media previously treated with uniconazole.

Table 19.2 Other Plant Growth Regulators Used To Reduce Plant Height During The Production Of Floricultural Crops

Common Name/ Trade Name	Application Methods	Comments	Concerns
Ethephon Florel® Brand Growth Regulator (Monterey Lawn and Garden Products, Inc.)	Foliar spray	Promotes lateral branching, thereby reducing stem elongation. Also aborts flowers; improves stock plant branching and cutting yield. Use early in crop cycle to increase branching and remove early flowers (6-8 wk before flowering).	The pH of spray solution should be below 5.0. Has no drench activity. Use within 4 hours of mixing. Results less predictable under high temperature conditions. Do not treat plants under environmental stress conditions.
Benzyladenine Configure (Fine Americas, Inc.)	Foliar spray	Enhances lateral branching of greenhouse grown containerized ornamentals. Not labeled for chemigation.	May need to add wetting agent for waxy crops. Not translocated in the plant so thorough plant coverage required. Short residual. Multiple applications may improve response.
Benzyladenine/ GA_{4+7} Fascination (Valent USA) Fresco (Fine Americas, Inc)	Foliar spray	Growth promoter and reduced yellowing of lily leaves. Fascination is labeled for growth promotion to overcome growth retardant effects on containerized and field grown ornamentals.	Effective dose strongly affected by volume (soil active). Thorough coverage required. Avoid application to plants under conditions of environmental stress. For perennials, start with low rates, 1 to 3 ppm. Repeat in five days if necessary.
Gibberellic acid (GA3) FlorGib 4L (Fine Americas, Inc.) GA3 4% (Greenleaf Chemical, LLC) ProGibb T&O (Valent USA)	Folair spray	Growth promoter. Broad use label. Labeled for growth promotion to overcome growth retardant effects on containerized and field grown ornamentals.	Over application or incorrect timing can cause weak stems and excessive stem elongation. Very potent growth promoter. Start with 1 ppm on most crops.

Table 19.2 Other Plant Growth Regulators Used To Reduce Plant Height During The Production Of Floricultural Crops (continued)

Common Name/ Trade Name	Application Methods	Comments	Concerns
Dikegulac sodium Atrimmec (PBI Gordon) Augeo (OHP, Inc.)		Broad label lists greenhouse, nursery and field sites. Inhibits terminal growth, thereby promoting lateral development. Apply to actively growing plants with at least two nodes to provide sufficient lateral development. Atrimmec labeled for several perennials including lantana, buddleia, ivies. Augeo has proposed a broad use label for greenhouse crops.	May significantly delay plant development, especially at higher rates. Causes leaf chlorosis which may be persistent at high rates. Do not pinch or prune soon after treatment. Do not add wetting agents.
Methyl esters of fatty acids Off-Shoot-O (Cochran Corp.)		Labeled for chemical pinching of actively growing azalea, cotoneaster, juniper, ligustrum, *Rhamnus*, and *Taxus*.	Ensure coverage of growing points. Do not spray more than once.

Table 19.3 Use Of PGRs On Herbaceous Perennials: Research Results And Precautions

This table is a summary of research results on the use of plant growth regulators (PGRs) on containerized herbaceous perennials. Rates listed were tested as spray applications at the label-recommended volumes unless otherwise stated. Use the rates listed as starting points for your own PGR trials. Multiple applications are generally applied 10 to 14 days apart. These rates are from research conducted in the Southern and Mid-Atlantic regions of the U.S. Growers in the north should test lower rates. See text. NOTE: "NR" means that the plants were not responsive to the rates tested.

Crop	Product	Spray Rate of Application (ppm) x Number of Applications	Precautions or Remarks
Achillea 'Coronation Gold' Yarrow	B-Nine	7650 x 1	Apply at 10-14 day intervals.
	Bonzi	30 to 40 x 1	
	Cycocel	NR @ 4000 x 1	
	Florel	500 x 1	Delayed flowering. Apply before visible bud.
	Sumagic	Less than 15 x 1	Persistent reductions in plant growth continue in the landscape.
Achillea 'Moonshine' Yarrow	B-Nine	NR @ 5000 x 2	
	Bonzi	Less than 240 x 1	This rate caused excessive height reduction. Test rates much lower than 240 ppm.
	Sumagic	NR @ 60 x 1	
Achillea 'Paprika' Yarrow	B-Nine	5000 x 2	Apply at 10-14 day intervals. May delay flowering.
	B-Nine/ Cycocel	5000/1500 x 1	
	Sumagic	15 x 1	Plant width also reduced.
Achillea 'Summer Pastels' Yarrow	B-Nine	5000 x 2	Apply at 10-14 day intervals.
	Bonzi	120 x 1	
	Cycocel	NR @ 3000 x 1	
	Sumagic	NR @ 60 x 1	
Achillea millefolium 'Red Beauty' Yarrow	B-Nine	5000 x 2	Apply at 10-14 day intervals.
	B-Nine/ Cycocel	NR @ 5000/1500 x 1	
	Bonzi	NR @ 160 x 1	
	Cycocel	NR @ 1500 x 1	
	Sumagic	NR @ 60 x 1	
Agastache x 'Blue Fortune'[z] Anise Hyssop	B-Nine	5000 x 3	Apply at 10-14 day intervals.
	B-Nine/ Cycocel	5000/1500 x 1	
	Sumagic	Less than 15 x 1	Very sensitive to Sumagic. Test rates less than 15 ppm.
Alcea rosea 'Powder Puff Mix' 'Chater's Double Mix' Hollyhock	B-Nine	5000 x 4	Apply at 10-14 day intervals.
	Bonzi	30 to 50 x 1	
	Sumagic	Much less than 15 x 1	Very sensitive to Sumagic. Test rates less than 15 ppm.

Table 19.3 Use Of PGRs On Herbaceous Perennials: Research Results And Precautions (continued)

Crop	Product	Spray Rate of Application (ppm) x Number of Applications	Precautions or Remarks
Alcea rosea 'Chater's Mix' Hollyhock	Bonzi	80 x 1	
Alcea rosea 'The Watchman' Hollyhock	Piccolo	80 x 1	
	Bonzi	NR @ 50 x 1	Drench applied at 10 fl.oz. per trade gallon pot.
	Sumagic	NR @ 2 x 1 (drench) 30 x 1	
Alchemilla mollis Lady's Mantle	B-Nine	NR @ 5000 x 2	
	B-Nine/ Cycocel	5000/1500 x 1	Multiple applications at 10-14 day intervals may be necessary.
	Bonzi	NR @ 200 x 1	
	Sumagic	NR @ 90 x 1	
Amsonia Blue Star	Bonzi	30 x 1	
Aquilegia x *hybrida* 'McKana Giants' Hybrid Columbine	B-Nine	5000 x 2	Apply at 10-14 day intervals.
	Bonzi	NR @ 240 x 1	
	Sumagic	NR @ 120 x 1	
Aquilegia vulgaris 'Winky Purple White' Winky columbine	Configure	NR @ 600 x 1	This was our screening rate. Test multiple applications or higher rates.
Artemisia schmidtiana 'Silver Mound' Silvermound Artemisia	B-Nine	5000 x 2	Moderate control. Apply at 10-14 day intervals.
	B-Nine/ Cycocel	5000/1500 x 1	
	Bonzi	200 x 1	Moderate control. May require multiple applications.
	Sumagic	45 x 1	
Artemisia x 'Oriental Limelight' Wormwood	Sumagic	30 x 1	
Artemisia x 'Powis Castle' Wormwood	Sumagic	60 x 1	Multiple applications may be required.
Asclepias incarnata Swamp Milkweed	B-Nine	5000 x 2	Good control. Apply at 10-14 day intervals.
	B-Nine/ Cycocel	5000/1500 x 1	Good control.
	Bonzi	NR @ 160 x 1	
	Florel	500 x 2	
	Sumagic	NR @ 60 x 1	
Asclepias tuberosa Butterfly Weed	Configure	NR @ 600 x 1	This rate was our screening rate. Higher rates may be effective.

Table 19.3 Use Of PGRs On Herbaceous Perennials: Research Results And Precautions (continued)

Crop	Product	Spray Rate of Application (ppm) x Number of Applications	Precautions or Remarks
Asclepias tuberosa 'Hello Yellow' Butterfly Weed *Aster dumosa* 'Sapphire' Sapphire Aster	Bonzi Dazide	NR @ 50 x 1 NR @ 2 x 1 (drench) NR @ 5000 x 2	Rates reduced width 10% to 18%. Drenches applied at 2 fl.oz. per quart pot.
	Dazide/ Cycocel	NR @ 5000/1500 x 1	
	Piccolo	80 x 1	Width control; little effect on height.
	Sumagic	30 x 1	Moderate width control; little effect on height.
	Topflor	NR @ 60 x 1	Fall trial.
Aster x *frikartii* 'Alpine Mix' Frikart's Aster	Sumagic	NR @ 60 x 1	
Aster x *frikartii* 'Monarch', 'Monch' Frikart's Aster	B-Nine	5000 x 2	Apply at 10-14 day intervals.
	Bonzi	NR @ 240 x 1 2 to 16 x 1 (drench)	Drench applied at 2 fl.oz. per quart pot.
	Sumagic	NR @ 60 x 1 NR @ 4 x 1 (drench)	Drench applied at 2 fl.oz. per quart pot.
Astilbe chinensis 'Purpurkerze' Chinese Astilbe	B-Nine	5000 x 2	Excessive height reduction. Use lower rate and/or fewer applications.
	B-Nine/ Cycocel	Less than 5000/1500 x 1	Reduce both B-Nine and Cycocel rates.
	Bonzi	40 x 1	
	Cycocel	1500 x 1	Moderate control.
	Sumagic	35 x 1	
Astilbe x *arendsii* 'Elizabeth Bloom' Hybrid Astilbe	B-Nine	NR @ 5000 x 2	
	Bonzi	80 x 1	Short term response, plan on multiple applications.
	Sumagic	30 x 1	Short term response, plan on multiple applications.
Baptisia australis False Indigo	Sumagic	NR @ 60 x 1 NR @ 1.5 x 1 (drench)	Drench applied at 2 fl.oz. per quart pot.
Barleria cristata Phillipine Violet	B-Nine	5000 x 3	Apply at 10-14 day intervals.
	Bonzi	Greater than 45 x 1	
Buddleia fallowiana 'Lochinch' Butterfly bush	Sumagic	60 x 1 1.5 x 1 (drench)	Drench applied at 10 fl.oz. per trade gallon pot. Short term height control with sprays and drenches. Multiple applications required.

Table 19.3 Use Of PGRs On Herbaceous Perennials: Research Results And Precautions (continued)

Crop	Product	Spray Rate of Application (ppm) x Number of Applications	Precautions or Remarks
Buddleia weyeriana 'Honeycomb' Butterfly bush	Paczol	4 x 1 (liner dip)	Moderate control.
	Sumagic	2 x 1 (liner dip)	Moderate control.
Calamagrostis x *acutifolia* 'Karl Foerster' Feather Reed Grass	B-Nine	NR @ 5000 x 2	
	B-Nine/ Cycocel	5000/1500 x 2	Good response.
	Piccolo	NR @ 160 x 1	
	Topflor	NR @ 120 x 1	
	Sumagic	NR @ 60 x 1	
	Concise	1 x 1 (liner dip)	
Canna x *generalis* 'Florence Vaughan' Hybrid Canna	B-Nine	NR @ 7500 x 1	
	Bonzi	66 x 1	
	Florel	NR @ 1000 x 1	
Canna x *orchiodes* Hybrid Canna	B-Nine	NR @ 7500 x 1	Delayed flowering.
	Bonzi	66 to 99 x 1	
	Florel	NR @ 1000 x 1	
Caryopteris x *clandonensis* 'Dark Knight' Bluebeard	B-Nine	NR @ 5000 x 2	
	B-Nine/ Cycocel	NR @ 5000/1500 x 1	
	Paczol	NR @ 160 x 1	
	Concise	30 x 1	
Chrysanthemum parthenium Feverfew	Bonzi	Much less than 40 x 1	Very sensitive to Bonzi. Test rates much less than 40 ppm.
	Cycocel	750 x 1	
	Sumagic	Much less than 15 x 1	Very sensitive to Sumagic. Test rates much lower than 15 ppm.
Coleus (*Solenostemon scutelleroides*) 'Burgundy Sun' Coleus	Bonzi	NR @ 80 x 2	
	Sumagic	32 x 1	
Coleus (*Solenostemon scutelleroides*) 'Solar Storm' Coleus	B-Nine	Greater than 5000 x 1	Apply at 10-14 day intervals.
	B-Nine/ Cycocel	2500/1500 x 1	
	Bonzi	NR @ 80 x 2	
	Sumagic	16 x 1	
Coreopsis grandiflora 'Sunray' Tickseed	B-Nine	NR @ 5000 x 2	May delay flowering.
	B-Nine/ Bonzi	2500/20 to 40 x 1	
	B-Nine/ Cycocel	5000/1500 x 1	Multiple applications may be required.
	Bonzi	80 to 100 x 1 5 to 10 x 1 (drench)	Drench applied at 2 fl.oz. per quart pot.
	Sumagic	40 x 1	May delay flowering.

Table 19.3 Use Of PGRs On Herbaceous Perennials: Research Results And Precautions (continued)

Crop	Product	Spray Rate of Application (ppm) x Number of Applications	Precautions or Remarks
Coreopsis grandiflora 'Baby Sun' Tickseed	B-Nine/ Bonzi	2500/ 20 to 40 x 1	
	B-Nine/ Cycocel	Greater than 2500/1500 x 1	
	Bonzi	80 to 100 x 1 5 to 10 x 1 (drench)	Drench applied at 2 fl.oz. per quart pot.
	Sumagic	40 x 1 15 x 2	May delay flowering.
Coreopsis rosea 'American Dream' Pink coreopsis	B-Nine	5000 to 7500 x 1	
	Bonzi	NR @ 100 x 1 Greater than 4 x 1 (drench)	Drench applied at 2 fl.oz. per 4-inch pot.
	Sumagic	40 x 1	
Coreopsis rosea 'Sweet Dreams' Pink coreopsis	B-Nine	2500 x 2	Excellent response.
	Paczol	3 to 4 x 1 (liner dip)	
	Sumagic	0.5 x 1 (liner dip)	
Coreopsis verticillata 'Moonbeam' Thread Leaf Coreopsis	A-Rest	6 x 1 (drench)	Drench applied at 2 fl.oz. per 4-inch pot.
	B-Nine	5000 x 2	Some flower delay. Apply at 10-14 day intervals.
	Bonzi	NR @ 160 x 1 Less than 6 x 1 (drench)	Drench applied at 2 fl.oz. per 4-inch pot. Some distortion of laterals with this drench rate.
	Concise	15 to 20 x 1 Less than 1 x 1 (drench)	Applied drench at 2 fl.oz. per quart pot. Test rates ~0.5 ppm.
	Sumagic	15 to 20 x 1 Less than1 x 1 (drench)	Applied drench as 2 fl.oz. per quart pot. Test rates ~0.5 ppm.
Coreopsis verticillata 'Zagreb' Thread Leaf Coreopsis	B-Nine	5000 x 2	Apply at 10-14 day intervals.
	B-Nine/ Cycocel	1500/5000 x 2	
	Configure	600 x 1	Increased number of early branches. Difference did not persist. Multiple applications may improve response.
	Florel	NR @ 500 x 2	
	Sumagic	20 x 1	
Coreopsis verticillata 'Golden Gain' Thread leaf Tickseed	B-Nine	5000 x 3	Good control with applications at 14 day intervals.
	B-Nine/ Cycocel	5000/1500 x 1	
	Bonzi	NR @ 160 x 1	
	Cycocel	NR @ 1500 x 1	
	Sumagic	NR @ 60 x 1	

Table 19.3 Use Of PGRs On Herbaceous Perennials: Research Results And Precautions (continued)

Crop	Product	Spray Rate of Application (ppm) x Number of Applications	Precautions or Remarks
Cortaderia selloana Pampas Grass	A-Rest	15 x 1 (drench)	Drench applied at 4.5 fl.oz. per 6-inch pot.
	Bonzi	15 x 1 (drench)	Drench applied at 4.5 fl.oz. per 6-inch pot.
	Sumagic	Less than 2 x 1 (drench)	Very sensitive to Sumagic. Test rates below 1 ppm. Drench at 4.5 fl.oz. per 6-inch pot.
Delphinium x *elatum* 'Astolat' Hybrid Bee Delphinium	B-Nine	NR @ 5000 x 2	
	B-Nine/ Cycocel	NR @ 5000/1500 x 1	
	Bonzi	40 to 60 x 1	Moderate control; multiple applications may be necessary.
	Sumagic	30 to 45 x 1	Multiple applications may be required.
Delphinium x *elatum* 'Black Knight' Delphinium	Piccolo	100 x 1	Multiple applications required.
Delphinium x *elatum* 'Blue Bird' Hybrid Bee Delphinium	Abide	4 x 1 (drench)	Drench applied at 10 fl.oz. per trade gallon pot.
	Bonzi	NR @ 60 x 1 Less than 1 x 1 (drench)	Slight reduction in plant width with spray. Very sensitive to Bonzi drenches. Drench applied at 2 fl.oz. per quart pot.
	Piccolo	Less than 2 x 1 (drench)	Drench applied at 10 fl.oz. per trade gallon pot.
	Concise	1 x 1 (drench)	Drench at 10 fl.oz. per trade gallon pot. Very short term response. Multiple applications or higher rate required.
	Topflor	15 x 1	
Delphinium x *elatum* 'Galahad' Hybrid Bee Delphinium	Configure	NR @ 600 x 1	This rate was our screening rate. Higher rates may be effective.
Dendranthema zawadskii 'Clara Curtis' Garden Mum	B-Nine	Multiple at 5000	Apply at 10-14 day intervals.
	B-Nine/ Cycocel	5000/1500 x 1	Multiple applications required.
	Bonzi	Less than 40 x 1	Sensitive to Bonzi. Test rates less than 40 ppm.
	Sumagic	Less than 15 x 1	Sensitive to Sumagic. Test rates less than 15 ppm.
Dicentra spectabilis Common Bleeding Heart	A-Rest	50 x 2	Phytotoxic, leaf tip chlorosis.
	B-Nine	3000 x 2	Slight delay in flowering.
	Cycocel	NR @ 2000 x 2	

Table 19.3 Use Of PGRs On Herbaceous Perennials: Research Results And Precautions (continued)

Crop	Product	Spray Rate of Application (ppm) x Number of Applications	Precautions or Remarks
Digitalis mertonensis Strawberry Foxglove	Bonzi	60 x 1	Moderate height and width control.
Digitalis purpurea 'Foxy' Foxglove	B-Nine	NR @ 5000 x 4	
	B-Nine/ Cycocel	NR @ 5000/1500 x 1	
	Bonzi	80 to 160 x 1	
	Sumagic	30 to 45 x 1	
Duranta repens Golden Dewdrop	Bonzi	Greater than 100 x 1	
Echinacea hybrids 'Fragrant Angel', ' Merlot', 'Tiki Torch' Hybrid Coneflower	Configure	600 x 1	Increased basal branching. This rate was our screening rate. Lower rates may be effective.
Echinacea purpurea 'Bravado' Purple Coneflower	B-Nine	5000 x 2	Apply at 10-14 day intervals.
	Sumagic	Much less than 40 x 1	Sensitive to Sumagic. Test rates below 30 ppm.
Echinacea purpurea 'Magnus' Purple Coneflower	B-Nine	5000 x 2	Apply at 10-14 day intervals.
	B-Nine/ Cycocel	5000/1500 x 1	May require multiple applications at 10-14 day intervals.
	Configure	300 x 1	Increased basal branching.
	Florel	500 x 2	
Echinacea purpurea 'Doubledecker' Purple Coneflower	Configure	600 x 1	Increased basal branching. This rate was our screening rate. Lower rates may be effective.
	Piccolo	120 x 1	Multiple applications required.
Echinacea purpurea 'Ruby Star' Purple Coneflower	Bonzi Configure	NR @ 60 x 1 300 x 1	Increased basal branching. No significant effect on height.
	Florel	NR @ 500 x 2	No effect on basal branching.
	Sumagic	30 x 1	Multiple applications may be required.
	Topflor	45 x 1	Multiple applications may be required.
Echinacea purpurea 'Sombrero Hot Pink' Purple Coneflower	Augeo	800 x 1	Increased lateral branching.
	Configure	600 x 1	Moderate increase in branching. Multiple applications may be required.
Echinacea purpurea 'White Swan' Purple Coneflower	Configure	300 x 1	Increased basal branching. No significant effect on height.

Table 19.3 Use Of PGRs On Herbaceous Perennials: Research Results And Precautions (continued)

Crop	Product	Spray Rate of Application (ppm) x Number of Applications	Precautions or Remarks
Erysimum linifolium Wallflower	B-Nine	5000 x 2	Apply at 10-14 day intervals.
	B-Nine/ Cycocel	5000/1500 x 1	May require multiple applications.
	Bonzi	80 to 120 x 1	
	Piccolo	80 to 120 x 1	
	Sumagic	15 x 1	
	Topflor	30 x 1	
Eupatorium coelestinum Hardy Ageratum	B-Nine	NR @ 5000 x 2	
	Bonzi	NR @ 240 x 1 8 to 10 x 1 (drench)	Drenches applied at 2 fl.oz. per quart pot.
	Sumagic	60 x 1 NR @ 1 x 1 (drench)	Drench applied at 4 fl.oz. per quart pot.
Eupatorium rugosum 'Chocolate' Chocolate boneset, white snakeroot	Concise	60 x 1 4 x 1 drench 2 x 1 liner dip	Moderate growth control. Multiple applications may be required. Drench applied at 2 fl.oz. per quart pot.
Euphorbia dulcis 'Chameleon' Purple spurge	Configure	600 x 1	This rate was our screening rate. Lower rates may be effective.
Euphorbia hybrid 'Efanthia', 'Despina' Wood Spurge	B-Nine	NR @ 5000 x 3	
	B-Nine/ Cycocel	NR @ 5000/1500 x 2	
	Bonzi	40 to 80 x 1	
	Piccolo	80 to 120 x 1	
	Sumagic	30 x 1	
	Topflor	30 x 1	
Filipendula rubra 'Venusta' Queen of the Prairie	Sumagic	60 x 1	Very short term growth reduction. Test multiple applications.
Gaillardia arista 'Dazzler' Blanket flower	Configure	Less than 600 x 1	This rate was our screening rate. Use much lower rates for this crop. Excessive branching.
Gaillardia x *grandiflora* 'Burgundy' Blanket flower	B-Nine	5000 x 3	Apply at 10-14 day intervals.
	B-Nine/ Cycocel	5000/1500 x 1	
	Sumagic	60 x 1	Moderate control. May require multiple applications.
Gaillardia x *grandiflora* 'Gallo Yellow' Blanket flower	Augeo	400 x 1	Increased lateral branching.
	Configure	600 x 1	Increased branching and number of flowers. Resulted in more upright growth habit.

Table 19.3 Use Of PGRs On Herbaceous Perennials: Research Results And Precautions (continued)

Crop	Product	Spray Rate of Application (ppm) x Number of Applications	Precautions or Remarks
Gaillardia x *grandiflora* 'Goblin' Blanket flower	B-Nine	NR @ 5000 x 2	
	Bonzi	NR @ 160 x 1 NR @ 5 x 1 (drench)	
	Concise	NR @ 5 x 1 (liner dip)	
	Sumagic	NR @ 60 x 1 NR @ 2 x 1 (drench)	Drench applied at 4 fl.oz. per quart pot.
Gaillardia x *grandiflora* 'Gold Kobold' Blanket flower	B-Nine	NR @ 5000 x 2	
	B-Nine/ Cycocel	NR @ 5000/1500 x 1	
	Bonzi	NR @ 160 x 1	
	Sumagic	NR @ 60 x 1	
Gaura lindheimeri 'Corrie's Gold' White gaura	B-Nine	5000 x 2	Apply at 10-14 day intervals.
	B-Nine/ Cycocel	5000/1500 x 1	
	Bonzi	80 x 1	
	Florel	500 to 1000 x 1	May delay flowering.
	Piccolo	40 to 80 x 1	
	Sumagic	30 x 1	May require multiple applications.
Gaura lindheimeri 'Dauphin' Wandflower	Bonzi	NR @ 40 x 1 Less than 30 x 1 (drench)	Drenches applied at 2 fl.oz. per quart pot.
	Sumagic	60 x 1	Moderate control.
Gaura lindheimeri 'Siskiyou Pink' White gaura	B-Nine	5000 x 2	Apply at 10-14 day intervals.
	B-Nine/ Bonzi	2500/8 x 1	
	B-Nine/ Cycocel	5000/1500 x 1	
	Bonzi	Greater than 100 x 1 15 x 1 (drench)	Moderate growth control with 100 ppm spray; test multiple applications or higher rate. Drenched at 2 fl.oz. per quart pot.
	Configure	600 x 1 300 x 1 on plugs	Test screening rate; lower rates may be effective. Increased branches and shoots, nos. of flower stalks. Plugs: single or multiple sprays applied ~27 days after sticking increased lateral and basal branching w/ no adverse effects on rooting.
	Piccolo	Greater than 100 x 1 15 x 1 (drench)	Moderate growth control with 100 ppm spray; test multiple applications or higher rate. Drenched at 2 fl.oz. per quart pot.
	Sumagic	NR @ 60 x 1	Plant width reduced.

Table 19.3 Use Of PGRs On Herbaceous Perennials: Research Results And Precautions (continued)

Crop	Product	Spray Rate of Application (ppm) x Number of Applications	Precautions or Remarks
Gaura lindheimeri 'Whirling Butterflies' White gaura	B-Nine	5000 x 2	Apply at 10-14 day intervals.
	B-Nine/ Cycocel	5000/1500 x 1	Moderate control; multiple applications may be required.
	Sumagic	15 x 1	Test rates below 15 ppm.
Geranium 'Rozanne' Cranesbill geranium	Configure	NR @ 600 x 1	This rate was our screening rate. Higher rates or multiple applications may be effective.
Helenium autumnale 'Coppelia' Sneezeweed	B-Nine	2500 x 2	Apply at 10-14 day intervals.
	B-Nine/ Cycocel	NR @ 5000/1500 x 1	Reduced width.
	Concise	NR @ 60 x 1	
	Configure	NR @ 600 x 1	This rate was our screening rate. Higher rates may be effective.
	Paczol	NR @ 160 x 1	
Heliopsis helianthoides 'Summer Sun' False sunflower, Sunflower Heliopsis	B-Nine	Less than 5000 x 2	Sensitive to B-Nine. Test at lower rates.
	B-Nine/ Cycocel	5000/1500 x 1	
	Bonzi	NR @ 160 x 1	
	Florel	500 x 2	Moderate control.
	Sumagic	NR @ 60 x 1	
Heliotropium arborescens 'Fragrant Blue' Heliotrope	B-Nine	5000 x 3	Apply at 10-14 day intervals.
	B-Nine/ Cycocel	5000/1500 x 1	
	Sumagic	60 x 1	
Hemerocallis 'Black eyed Stella' Daylily	Piccolo	NR @ 160 x 1	
Hemerocallis 'Butter Pat' Daylily	Sumagic	0.75 x 1 (drench)	Applied at 10 fl.oz. per trade gallon pot. Moderate control of height. Avoid higher rates. Significant reduction of flower stalk height.
Hemerocallis 'Frankly Scarlet', 'Sammy Russell' Daylily	Sumagic	0.5 x 1 (drench)	Applied at 10 fl.oz. per trade gallon pot. Moderate control of height. Avoid higher rates. Significant reduction of flower stalk height.

Table 19.3 Use Of PGRs On Herbaceous Perennials: Research Results And Precautions (continued)

Crop	Product	Spray Rate of Application (ppm) x Number of Applications	Precautions or Remarks
Hemerocallis 'Happy Returns' Daylily	Abide	2 x 1 (drench)	Applied at 10 fl.oz. per trade gallon pot. Significant reduction of flower stalk at higher rates.
	Piccolo	2 x 1 (drench)	Applied at 10 fl.oz. per trade gallon pot. Significant reduction of flower stalk at higher rates.
	Concise	1 x 1 (drench)	Applied at 10 fl.oz. per trade gallon pot. Significant reduction of flower stalk at higher rates.
Hemerocallis 'Hyperion' Daylily	Bonzi	180 x 1	Moderate control of height.
Hemerocallis 'Hyperion', 'Prairie Blue Eyes' Daylily	Bonzi	Less than 2 x 1 (drench)	Applied at 10 fl.oz. per trade gallon pot. Significant reduction of flower stalk height.
Hemerocallis 'Mary Todd' Daylily	Piccolo	160 x 1	Moderate response.
Hemerocallis 'Pink Song'	Concise	NR 60 x 1 NR 1 x 1 drench NR 2 x 1 liner dip	Bare root liners. Drench applied at 2 fl.oz. per quart pot.
Hemerocallis 'Prairie Blue Eyes' Daylily	Bonzi	NR @ 180 x 1	
Hemerocallis 'Strutters Ball'	Configure	NR @ 600 x 1	This rate was our screening rate. Higher rates or multiple applications may be effective.
Heuchera 'Raspberry Ice' Coral bells	Configure	600 x 1	This rate was our screening rate. Lower rates may be effective.
Heuchera 'Silver Lode' Coral bells	Configure	600 x 1	This rate was our screening rate. Lower rates may be effective.
	Piccolo	NR @ 120 x 1	
Hibiscus moscheutos 'Grenache' Rose Mallow	Sumagic	20 x 1 0.5 x 1 (drench)	Drench applied at 10 fl.oz. per trade gallon pot.

Table 19.3 Use Of PGRs On Herbaceous Perennials: Research Results And Precautions (continued)

Crop	Product	Spray Rate of Application (ppm) x Number of Applications	Precautions or Remarks
Hibiscus moscheutos 'Lord Baltimore' Rose Mallow	Cycocel	500 x 2 Less than 2000 x 1 (drench)	Good control. Drenches applied at 4 fl.oz. per 6-inch pot.
Hosta 'Ginko Craig' Liberty Hosta	Configure	1000 x 1	Increased basal branching.
Hosta 'Great Expectations' Great Expectations Hosta	Configure	3000 x 1	Increased basal branching.
Hosta 'Liberty' Liberty Hosta	Configure	Less than 6000 x 1 (see remarks)	Increased basal branching. Significant phytotoxicity at this rate. Test multiple applications of a lower rate.
Hypericum calycinum Aaron's Beard, St. John's Wort	B-Nine	NR @ 5000 x 2	
	B-Nine/ Cycocel	NR @ 5000/1500 x 1	
	Bonzi	NR @ 160 x 1	
	Sumagic	30 x 1	
Iris siberica 'Caesar's Brother' Siberian Iris	Bonzi	90 x 1 Less than 2 x 1 (drench)	Drench applied at 10 fl.oz. per trade gallon pot.
Iris siberica 'Chilled Wine' Siberian Iris	Bonzi	NR @ 180 x 1 4 x 1 (drench)	Drench applied at 10 fl.oz. per trade gallon pot.
Iris x *germanica* Bearded Iris	Bonzi	Greater than 160 x 1	
Kniphofia uvaria 'Bressingham Comet' Red Hot Poker, Torchlily	B-Nine	NR @ 5000 x 2	
	B-Nine/ Cycocel	NR @ 5000/1500 x 1	
	Bonzi	NR @ 160 x 1	
	Cycocel	NR @ 4000 x 1	
	Sumagic	45 x 1	
Lamiastrum galeobdolon 'Hermann's Pride' Yellow archangel, golden dead nettle	Dazide	5000 x 2	Excellent control of runners. Apply at 10-14 day intervals.
	Dazide/ Cycocel	2500/1500 x 1	Excellent control of runners.
	Piccolo	80 x 1	Moderate width control.
	Sumagic	15 x 1	Moderate width control.
	Topflor	45 x 1	Moderate width control. May need multiple applications.

Table 19.3 Use Of PGRs On Herbaceous Perennials: Research Results And Precautions (continued)

Crop	Product	Spray Rate of Application (ppm) x Number of Applications	Precautions or Remarks
Lamium maculatum 'Beacon Silver' Spotted Nettle	B-Nine	NR @ 5000 x 2	
	B-Nine/ Cycocel	NR @ 5000/1500 x 1	
	Bonzi	NR @ 160 x 1	
	Sumagic	NR @ 60 x 1	
Lamium maculatum 'Pink Pewter' Spotted Nettle	B-Nine	5000 x 2	Moderate control.
	B-Nine/ Cycocel	5000/1500 x 1	Moderate control. Multiple applications may be required.
	Bonzi	40 x 1	
	Sumagic	30 x 1	Multiple applications may be necessary.
Lantana camara 'Confetti' Lantana	B-Nine	5000 x 3	Moderate control with slight delay in flowering. Apply at 10-14 day intervals.
	B-Nine/ Cycocel	NR @ 5000/1500 x 1	
	Sumagic	30 x 1	Moderate control.
Lantana camara 'New Gold' Lantana	B-Nine/ Cycocel	5000/1500 x 1	Good control.
	Bonzi	40 x 1	Good control.
Lantana camara 'Professor Raoux' Lantana	B-Nine/ Cycocel	5000/1500 x 1	Good control.
	Sumagic	20 x 1	Good control.
Lavandula x *intermedia* 'Provence' Lavandula	Configure	300 x 2 for plugs	Two foliar sprays applied, first at ~34 days after sticking and again 2 weeks later; increased lateral and basal branching with slight reduction in root growth. Apply after plugs are well rooted.
Lavandula x *intermedia* 'Silver Edge' ('Walvera') Silver Edge Lavender	B-Nine	5000 x 2	Apply at 10-14 day intervals.
	B-Nine/ Cycocel	5000/1500 x 1	
	Concise	NR @ 60 x 1	
	Paczol	NR @ 160 x 1	
Leucanthemum x *superbum* 'Snow Lady' Shasta Daisy	Bonzi	Greater than 40 x 1	

Table 19.3 Use Of PGRs On Herbaceous Perennials: Research Results And Precautions (continued)

Crop	Product	Spray Rate of Application (ppm) x Number of Applications	Precautions or Remarks
Leucanthemum x *superbum* 'Alaska' Shasta Daisy	B-Nine	NR @ 5000 x2	
	Bonzi	Less than 40 x 1	Sensitive to Bonzi. Test rates below 40 ppm.
	Configure	600 x 1	Increased branching short term, doubled nos. of flowers. This rate was screening rate. Higher rates or multiple applications may be more effective.
	Cycocel	NR @ 4000 x 1	
	Sumagic	Less than 15 x 1	Sensitive to Sumagic. Test rates below 15 ppm.
Leucanthemum x *superbum* 'Becky' Shasta Daisy	B-Nine	NR @ 5000 x 2	
Leucanthemum x *superbum* 'Becky' Shasta Daisy	B-Nine/ Cycocel	NR @ 5000/1500 x 1	
	Bonzi	NR @ 100 x 1	
	Configure	600 x 1	Increased basal branching. This was our screening rate. Lower rates may be effective.
	Cycocel	NR @ 4000 x 1	
	Piccolo	120 x 1	Moderate short-term response. Multiple applications or higher rates required.
	Sumagic	NR @ 60 x 1	
Leucanthemum x *superbum* 'Snowcap' Shasta Daisy	Configure	300 x 1 for plugs	Single or multiple foliar sprays applied ~27 days after sticking increased basal branching but slightly reduced root growth. Apply after plugs are well rooted.
Leucanthemum x *superbum* 'Thomas Killen' Shasta Daisy	Florel	500 x 3	Flower size and plant quality reduced.
Liatris spicata 'Floristan Violet' Spike Gayfeather	Bonzi	NR @ 160 x 1	
	Sumagic	NR @ 60 x 1	
Liatris spicata 'Kobold' Spike Gayfeather	Florel	1000 x 3	Response small and inconsistent: flowering delayed.

Table 19.3 Use Of PGRs On Herbaceous Perennials: Research Results And Precautions (continued)

Crop	Product	Spray Rate of Application (ppm) x Number of Applications	Precautions or Remarks
Lilium x *aurelianense* 'Pink Perfection' Trumpet Lily	Concise	8 x 1 (drench) 16 x 1 (bulb dip)	Dips or drenches at 4 or 8 ppm reduced height at 6 weeks after planting but control did not persist through flowering. Drenched at 10 fl.oz. per trade gal. pot. Bulb dipped for one min. the day before potting reduced height by ~50% at flowering.
	Piccolo	NR @ 40 x 1 (drench) NR @ 40 x 1 (bulb dip)	Drenches applied at 10 fl.oz. per trade gal. pot. Bulbs dipped for 15 min. day before potting.
Lilium lancifolium 'Red Twinkle' Tiger Lily	Concise	8 x 1 (drench) 4 x 1 (bulb dip)	Drenched at 10 fl.oz. per trade gallon pot. Bulbs dipped for one minute the day before potting. Growth control: ~40% height reduction at flowering.
	Piccolo	10 x 1 (drench) 20 x 1 (bulb dip)	Bulbs dipped for 15 minutes day before potting. Drenches applied at 10 fl.oz. per trade gallon pot. Results: ~25% height reduction at flowering.
Lobelia cardinalis Cardinal flower	B-Nine	NR @ 5000 x 2	
	B-Nine/ Cycocel	NR @ 5000/4000 x 1	
	Bonzi	NR @ 60 x 1	
	Configure	600 x 1	This was our screening rate. Lower rates may be effective.
	Sumagic	30 x 1	
Lobelia x *speciosa* 'Fan Deep Rose' Hybrid Lobelia	Configure	600 x 1	Increased number of shoots not branches. Moderate response. Was screening rate. Higher rates may be more effective.
	Piccolo	120 x 1	Moderate response. Multiple applications required.
Lychnis x *arkwrightii* 'Vesuvius' Arkwright's Campion	B-Nine	NR @ 5000 x 2	
	B-Nine/ Cycocel	NR @ 5000/1500 x 1	
	Concise	NR @ 60 x 1	
	Configure	600 x 1	This was our screening rate. Lower rates may be effective.
	Paczol	120 x 1	

Table 19.3 Use Of PGRs On Herbaceous Perennials: Research Results And Precautions (continued)

Crop	Product	Spray Rate of Application (ppm) x Number of Applications	Precautions or Remarks
Lysimachia 'Snow Candles' Loosestrife	Dazide	5000 x 2	Moderate control. Apply at 10-14 day intervals.
	Dazide/ Cycocel	2500/ 1500 x 1	Moderate control of height and width.
	Piccolo	120 x 1	Moderate height and width control.
	Topflor	30 x 1	Moderate height and width control.
Malva alcea Hollyhock	B-Nine	NR @ 5000 x 2	
	Bonzi	Much less than 40 ppm x 1	Very sensitive to Bonzi. Test rates around 10 to 20 ppm.
	Cycocel	750 to 1500 x 1	
	Sumagic	Much less than 15 ppm x 1	Very sensitive to Sumagic. Test rates around 2 to 5 ppm.
Mazus reptans	Atrimmec	800 x 1	Reduced shoot length.
	Florel	500 x 1	Reduced shoot length.
Miscanthus sinensis 'Gracillimus' Maiden grass	B-Nine	NR @ 5000 x 2	
	B-Nine/ Cycocel	NR @ 5000/1500 x 2	
	Piccolo	NR @ 160 x 1	
	Topflor	NR @ 120 x 1	
	Sumagic	NR @ 60 x 1	
	Concise	2 x 1 (liner dip)	
Monarda citriodora Bee balm	Bonzi	60 to 100 x 1 Greater than 4 x 1 (drench)	
Monarda didyma 'Beauty of Cobham' Bee balm	Atrimmec	NR @ 1600 x 1	Limited height control; no increased branching.
	Florel	500 x 2	Some phytotoxicity. Good height control and increased number of shoots.
Monarda didyma 'Blue Stocking' Bee balm	B-Nine	NR @ 5000 x 2	
	Bonzi	NR @ 160 x 1	
	Cycocel	NR @ 4000 x 1	
	Florel	500 x 3	Phytotoxic at 1000 ppm; reduced number of flowers.
	Sumagic	15 to 30 x 1	

Table 19.3 Use Of PGRs On Herbaceous Perennials: Research Results And Precautions (continued)

Crop	Product	Spray Rate of Application (ppm) x Number of Applications	Precautions or Remarks
Monarda didyma 'Jacob Cline' Bee balm	Bonzi	Less than 120 x 1 Less than 60 x 2	
	Concise	Less than 30 x 1 0.025 x 1 (drench)	Drenched at 10 fl.oz. per trade gallon pot. Moderate control.
	Piccolo	NR @ 160 x 1 NR @ 10 x 1 (drench)	Drench applied at 10 fl.oz. per trade gallon pot.
	Sumagic	15 x 1 1 x 1 (drench)	Drenched at 4 fl.oz. per quart pot.
	Topflor	Less than 37 x 1	
Monarda didyma 'Mahogany' Bee balm	B-Nine	5000 x 3	Excellent control.
	B-Nine/ Cycocel	5000/1500 x 1	Multiple applications required.
	Bonzi	NR @ 200 x 1	
	Sumagic	30 - 45 x 1	
Monarda didyma 'Marshall's Delight' Bee balm	B-Nine	5000 x 2	Apply at 10-14 day intervals.
	B-Nine/ Cycocel	5000/1500 x 1	
	Sumagic	30 x 1	
Monarda didyma 'Raspberry Wine' Bee balm	B-Nine	5000 x 2	Good control. Apply at 10-14 day intervals.
	Bonzi	100 x 1 6 x 1 (drench)	Drenches applied at 2 fl.oz. per quart pot. May require multiple applications.
	Dazide	5000 x 2	Good control. Apply at 10-14 day intervals.
Nepeta x *faassenii* 'Six Hills Giant' Faassen Nepeta, Catmint	B-Nine	5000 x 2	
	B-Nine/ Cycocel	5000/1500 x 1	Good response; multiple applications.
	Bonzi	30 x 2	May require multiple applications.
	Cycocel	NR @ 1500 x 2	
	Florel	500 x 2	May require multiple applications.
	Sumagic	15 x 2	
Oenothera speciosa Showy Evening Primrose	B-Nine	5000 x 2	Apply at 10-14 day intervals.
	B-Nine/ Cycocel	NR @ 5000/1500 x 1	
	Bonzi	NR @ 200 x 1	
	Sumagic	45 x 1	Multiple applications may be required.

Table 19.3 Use Of PGRs On Herbaceous Perennials: Research Results And Precautions (continued)

Crop	Product	Spray Rate of Application (ppm) x Number of Applications	Precautions or Remarks
Panicum virgatum 'Shenanadoah' Switchgrass	B-Nine	NR @ 5000 x 2	
	B-Nine/ Cycocel	5000/1500 x 2	Moderate response.
	Piccolo	80 x 1	Moderate response.
	Topflor	60 x 1	Moderate response.
	Sumagic	NR @ 60 x 1	
Papaver orientale 'Princess Victoria' Oriental Poppy	Bonzi	NR @ 160 x 1	
	Sumagic	45 x 1	Growth reduction moderate.
Papaver orientale 'Royal Wedding' Oriental Poppy	Bonzi	160 x 1	Growth reduction moderate and short term.
	Sumagic	30 to 45 x 1	Growth reduction moderate.
Penstemon digitalis 'Husker Red' Smooth White Penstemon	B-Nine	NR @ 5000 x 3	
	B-Nine/ Cycocel	5000/1500 x 1	Moderate control. Multiple applications may be necessary.
	Bonzi	40 to 80 x 1 15 x 1 drench	May need multiple sprays. Drenched at 2 fl.oz. per qt. pot.
	Concise	10 x 1 0.5 x 1 drench 1 x 1 liner dip	Moderate growth control. Drenched at 2 fl.oz. per qt. pot.
	Configure	600 x 1	Small increase in number of laterals but increased pot fill. This was our screening rate. Lower rates may be effective.
	Cycocel	NR @ 1500 x 1	
	Piccolo	40 to 80 x 1 15 x 1 drench	Multiple spray applications may be necessary. Drench applied at 2 fl.oz. per quart pot.
	Sumagic	Less than 15 x 1	Excessive height reduction at 15 ppm. Reduce rate.
Perovskia atriplicifolia Russian Sage	B-Nine	5000 x 2	Delayed flowering. Apply at 10-14 day intervals.
	B-Nine/ Cycocel	5000/1500 x 1	
	Bonzi	30 to 40 x 1 2 x 1 (liner dip)	
	Florel	500 x 2	Delayed flowering.
	Sumagic	15 to 30 x 1 1 x 1 (liner dip)	
	Topflor	35 to 45 x 1 Less than 2 x 1 (liner dip)	This liner dip rate gave excessive early height reduction but grew out by 7 weeks after treatment.

Table 19.3 Use Of PGRs On Herbaceous Perennials: Research Results And Precautions (continued)

Crop	Product	Spray Rate of Application (ppm) x Number of Applications	Precautions or Remarks
Perovskia atriplicifolia 'Longin' Russian Sage	Bonzi	80 x 1	May require multiple applications.
	Piccolo	80 x 1	May require multiple applications.
Persicaria microcephala 'Red Dragon' Knotweed, Fleece Flower	Sumagic	45 x 1 0.5 x 1 (drench)	Drench applied as 10 fl.oz. per trade gallon pot.
Phlox paniculata 'Blue Boy' Garden Phlox	B-Nine	5000 x 2	Moderate response.
	Paczol	4 x 1 (liner dip)	Moderate response.
	Piccolo	NR @ 160 x 1	
Phlox paniculata 'Blue Boy', 'Charles Curtis' Garden Phlox	B-Nine	NR @ 5000 x 2	
	B-Nine/ Cycocel	5000/4000 x 1	Multiple applications required.
	Bonzi	NR @ 160 x 1	
	Cycocel	NR @ 4000 x 1	
	Sumagic	NR @ 60 x 1	
Phlox paniculata 'Bright Eyes' Garden Phlox	B-Nine	5000 x 2	Apply at 10-14 day intervals.
	Paczol	4 x 1 (liner dip)	Moderate response.
	Sumagic	2 x 1 (liner dip)	Moderate response.
Phlox paniculata 'David' Garden Phlox	B-Nine	5000 x 2	Moderate control. Apply at 10-14 day intervals.
	B-Nine/ Cycocel	NR @ 5000/1500 x 1	
	Concise	Less than 2 x 1 (liner dip)	Response saturated at 2 ppm but little height response at 1 ppm. Test rates ~1.25 to 1.5 ppm for liner dip.
	Configure	NR @ 600 x 1	This rate was our screening rate. Higher rates or multiple applications may be effective.
	Sumagic	60 x 1	
Phlox paniculata 'Franz Schubert' Garden Phlox	Atrimmec	NR @ 1600 x 1	
	Configure	600 x 1	Increased number of shoots. No effect on height.
	Florel	NR @ 1000 x 2	No increased branching. No effect on height.
Phlox paniculata 'Juliet' Garden Phlox	B-Nine	NR @ 5000 x 2	
	Bonzi	NR @ 240 x 1	
	Sumagic	Greater than 80 x 1	Persistent reductions in plant growth in landscape at 80 ppm.

Table 19.3 Use Of PGRs On Herbaceous Perennials: Research Results And Precautions (continued)

Crop	Product	Spray Rate of Application (ppm) x Number of Applications	Precautions or Remarks
Phlox paniculata 'Laura' Garden Phlox	Augeo	1600 x 1	Transient increase in lateral branching.
	Configure	NR @ 600 x 1	This rate was our screening rate. Higher rates or multiple applications may be effective.
Phlox paniculata 'Mt. Fuji' Garden Phlox	Florel	NR @ 1000 x 3	
Phlox subulata 'Apple Blossom' Thirft, Moss Pink, Creeping Phlox	B-Nine	NR @ 5000 x 2	
	B-Nine/ Cycocel	5000 x 1	Moderate control.
	Piccolo	120 x 1	Moderate response, multiple applications may be required.
	Sumagic	15 x 1	
	Topflor	30 x 1	
Platycodon grandiflorus 'Fuji White' Balloon Flower	Bonzi	Greater than 50 x 1	
Polemonium caeruleum Jacob's Ladder	B-Nine	Greater than 2500 x 1	Apply at 10-14 day intervals.
	B-Nine/ Bonzi	2500/15 x 1	
	B-Nine/ Cycocel	2500/1500 x 1	
	Bonzi	Greater than 15 x 1	
Rosa 'Knockout' Knockout Rose	Sumagic	60 x 1 0.25 x 1 (drench)	Drench applied at 10 fl.oz. per trade gallon pot. Multiple applications required.
Rudbeckia fulgida var. *sullivantii* 'Goldsturm' Orange Coneflower, Black-eyed Susan	Bonzi	80 to 120 x 1	Multiple applications may be necessary.
	Concise	30 x 1 1 x 1 (liner dip) 2 x 1 (drench)	Good control. Applied drench as 2 fl.oz. per quart pot.
	Cycocel	NR @ 4000 x 1	
	Piccolo	80 to 120 x 1	Multiple applications may be necessary.
	Sumagic	30 x 1 2 x 1 (drench)	Applied drench as 2 fl.oz. per quart pot.
Rudbeckia hirta 'Indian Summer' Gloriosa daisy, Black-eyed Susan	Piccolo	NR @ 160 x 1	

Table 19.3 Use Of PGRs On Herbaceous Perennials: Research Results And Precautions (continued)

Crop	Product	Spray Rate of Application (ppm) x Number of Applications	Precautions or Remarks
Rudbeckia triloba Three-lobed Coneflower	B-Nine	5000 x 2	Apply at 10-14 day intervals.
	B-Nine/ Cycocel	5000/1500 x 1	
	Bonzi	80 x 1	Multiple applications required.
	Cycocel	2000 x 1	No phytotoxicity; multiple applications may be required.
	Paczol	2 x 1 (liner dip)	Moderate control.
	Sumagic	30 x 1 0.5 x 1 (liner dip)	
	Topflor	0.5 x 1 (liner dip)	Moderate control.
Salvia greggii Texas Sage	B-Nine	5000 x 2	Apply at 10-14 day intervals.
	B-Nine/ Cycocel	5000/1500 x 1	
	Sumagic	Less than 15 x 1	No landscape persistence at 15 ppm.
Salvia x 'Indigo Spires' Hybrid Sage	B-Nine	NR @ 5000 x 2	
	Bonzi	NR @ 60 x 1	
	Dazide	NR @ 5000 x 2	
	Sumagic	15 x 1	Very responsive. May require multiple applications.
Salvia leucantha Velvet Sage; Mexican Sage	B-Nine	5000 x 3	Apply at 10-14 day intervals.
	B-Nine/ Cycocel	5000/1500 x 1	
	Bonzi	60 x 1	
	Cycocel	2250 x 1	
	Florel	500 x 1	
	Sumagic	30 x 1	No landscape persistence at 30 ppm.
	Topflor	30 x 1	
Salvia nemorosa 'May Night' Meadow Sage	Configure	300 x 1 on plugs	Single or multiple foliar sprays applied ~34 days after sticking increased basal branching but slightly reduced root growth. Apply after plugs well rooted.
Salvia x *sylvestris* 'Blue Hill' Hybrid Sage	Bonzi	NR @ 160 x 1	
	Piccolo	NR @ 160 x 1	
Salvia x *sylvestris* 'Blue Queen' Hybrid Sage	B-Nine	5000 x 2	Excessive control and delayed flowering. Test lower rate or single application.
	Bonzi	80 x 1	
	Sumagic	60 x 1	Multiple applications may be required.

Table 19.3 Use Of PGRs On Herbaceous Perennials: Research Results And Precautions (continued)

Crop	Product	Spray Rate of Application (ppm) x Number of Applications	Precautions or Remarks
Salvia x *sylvestris* 'May Night' Hybrid Sage	B-Nine	5000 x 2	Apply at 10-14 day intervals.
	Bonzi	NR @ 160 x 1	
	Florel	250 to 1000 x 1	Some delay in flowering with eventual increase in inflorescence numbers.
	Sumagic	NR @ 20 x 1	
Saponaria ocymoides Rock Soapwort	B-Nine/ Cycocel	NR @ 5000/1500 x 1	
	Bonzi	NR @ 160 x 1	
	Sumagic	NR @ 60 x 1	
Scabiosa caucasica 'Butterfly Blue' Pincushion Flower	B-Nine	NR @ 5000 x 2	
	B-Nine/ Cycocel	NR @ 5000/1500 x 1	Multiple applications may be effective.
	Florel	250 to 750 x 1	Higher rates may delay flowering.
	Sumagic	20 x 1	
Scabiosa caucasica 'House Hybrids' Pincushion Flower	B-Nine	NR @ 5000 x 2	
	B-Nine/ Cycocel	NR @ 5000/1500 x 1	
	Bonzi	NR @ 160 x 1	
	Cycocel	NR @ 4000 x 1	
	Sumagic	NR @ 60 x 1	
Scabiosa columbaria 'Pink Mist' Pincushion Flower	B-Nine	NR @ 5000 x 3	
	B-Nine/ Cycocel	5000/1500 x 1	Moderate control; multiple applications may be required.
	Bonzi	40 to 80 x 1	Under nursery conditions higher rates may be necessary.
	Cycocel	NR @ 1500 x 1	
	Sumagic	45 x 1	
	Topflor	15 x 1	
Sedum x 'Autumn Joy' Autumn Joy Sedum	B-Nine	5000 x 2	Moderate control. Apply at 10-14 day intervals.
	B-Nine/ Bonzi	Greater than 2500/40 x 1	
	B-Nine/ Cycocel	5000/1500 x 1	Moderate control. Multiple applications may be required.
	Bonzi	80 x 1	
	Cycocel	NR @ 4000 x 1	
	Sumagic	15 to 30 x 1	Persistent reductions in growth continue in the landscape.
	Topflor	37 x 1	May require multiple applications.

Table 19.3 Use Of PGRs On Herbaceous Perennials: Research Results And Precautions (continued)

Crop	Product	Spray Rate of Application (ppm) x Number of Applications	Precautions or Remarks
Sedum x 'Matrona' Matrona Sedum	Bonzi	160 x 1	May require multiple applications.
	Piccolo	160 x 1	May require multiple applications.
	Sumagic	45 x 1	May require multiple applications.
	Topflor	NR @ 120 x 1	Width was reduced at 60 x 1.
Solidago sphacelata 'Golden Fleece' Golden Rod	B-Nine	5000 x 2	Apply at 10-14 day intervals.
	Bonzi	80 to 100 x 1	Persistent reductions in plant growth continue in the landscape with rates above 100 ppm.
	Sumagic	Less than 30 x 1	Persistent reductions in plant growth continue in the landscape with 30 ppm.
Sorghastrum nutans 'Indian Steel' Indiangrass	B-Nine	5000 x 2	Moderate response.
	B-Nine/ Cycocel	5000/1500 x 2	Good response.
	Piccolo	160 x 1	Moderate response.
	Topflor	NR @ 120 x 1	
	Sumagic	45 x 1	Moderate response. May require multiple applications.
Stokesia laevis 'Purple Parasols' Stoke's Aster	B-Nine	5000 x 2	Apply at 10-14 day intervals.
	B-Nine/ Cycocel	5000/2250 x 1	
	Bonzi	40 to 80 x 1	
	Cycocel	NR @ 4000 x 1	
	Sumagic	NR @ 60 x 1	
Stokesia laevis 'Klaus Jelitto' Stoke's Aster	B-Nine	5000 x 2	Apply at 10-14 day intervals.
	B-Nine/ Cycocel	5000/1500 x 1	Moderate control. Apply at 10-14 day intervals.
	Bonzi	NR @ 80 x 1 NR @ 2 x 1 (drench)	Drench applied at 2 fl.oz. per quart pot.
	Sumagic	NR @ 60 x 1	
Stokesia laevis 'Silver Moon' Stoke's Aster	Concise	Less than 60 x 1 Greater than 2 x 1 (drench)	
	Configure	NR @ 600 x 1	This rate was our screening rate. Higher rates may be effective.

Table 19.3 Use Of PGRs On Herbaceous Perennials: Research Results And Precautions (continued)

Crop	Product	Spray Rate of Application (ppm) x Number of Applications	Precautions or Remarks
Tradescantia virginiana 'Blue Stone' Virginia spiderwort	B-Nine	5000 x 2	Moderate growth control.
	B-Nine/ Cycocel	NR @ 5000/1500 x 1	
	Bonzi	40 x 1	
	Sumagic	15 x 1	
	Topflor	45 x 1	
Tradescantia virginiana 'Red Cloud' Virginia spiderwort	B-Nine	5000 x 2	Moderate control. Multiple applications necessary.
	B-Nine/ Cycocel	5000/1500 x 2	Moderate control. Multiple applications may be necessary.
	Bonzi	80 - 120 x 1	
	Sumagic	30 x 1	
	Topflor	15 x 1	
Verbena bonariensis South American Verbena, Tall Verbena	B-Nine	5000 x 2	Apply at 10-14 day intervals.
	Bonzi	120 to 160 x 1	
	Cycocel	NR @ 4000 x 1	
	Sumagic	30 to 45 x 1	Persistent reductions in plant growth continued in landscape.
Verbena canadensis 'Homestead Purple' Clump Verbena	B-Nine	NR @ 5000 x 2	
	B-Nine/ Cycocel	5000/1500 x 1	Multiple applications may be required.
	Florel	500 to 1000 x 1	High rates (1000 ppm) delay flowering.
	Sumagic	15 x 1 NR @ 1 x 1 (drench)	Effects on width reported. Sprays had very short term effect. Multiple applications required. Drench applied at 10 fl.oz. per trade gallon pot.
Verbena rigida	Atrimmec	800 x 1	Increased branching; little height reduction.
	Configure	600 x 1	Increased number of shoots and branching.
	Florel	NR @ 500 x 2	Higher rates reduced height slightly but there was no increased branching.

Table 19.3 Use Of PGRs On Herbaceous Perennials: Research Results And Precautions (continued)

Crop	Product	Spray Rate of Application (ppm) x Number of Applications	Precautions or Remarks
Veronica alpina 'Goodness Grows' Alpine Speedwell	B-Nine	5000 x 2	Apply at 10-14 day intervals.
	B-Nine/ Cycocel	5000/1500 x 1	
	Bonzi	Less than 240 x 1	Test rates below 240 ppm.
	Sumagic	Less than 15 x 1	Persistent reductions in plant growth continue in the landscape at 15 ppm.
	Abide	2 x 1 (drench)	Drench applied at 2 fl.oz. per quart pot. Excellent response.
	Bonzi	80 x 1	
	Configure	1 x 1 (drench)	Sprays yielded moderate control. May need multiple applications. Drench was very effective but may reduce number of flowers. Drench applied at 2 fl.oz. per quart pot.
	Concise	Less than 0.5 x 1 (drench)	Drench applied at 2 fl.oz. per quart pot.
	Piccolo	80 x 1 1 x 1 (drench)	Drench (2 fl.oz. per quart pot) was very effective but may reduce number of flowers. Excessive growth reductions at 2 ppm drench.
Veronica peduncularis 'Georgia Blue' Veronica Speedwell	B-Nine	Greater than 2500 x 1	Apply at 10-14 day intervals.
	B-Nine/ Bonzi	2500/7.5 x 2	
	Bonzi	Greater than 15 x 1	
Veronica repens 'Sunshine' Creeping Speedwell	B-Nine	5000 x 1	Multiple applications at this rate resulted in excessive growth reduction. Test lower rates or limit to a single application.
	B-Nine/ Cycocel	5000/1500 x 1	Test lower rates or limit to a single application.
	Piccolo	Much less than 40 x 1	Excessive width reduction. Test lower rates, ~10 to 20 ppm.
	Sumagic	Much less than 15 x 1	Excessive width reduction. Test lower rates, ~5 ppm.
	Topflor	Much less than 15 x 1	Excessive width reduction. Test lower rates, ~2 to 5 ppm.

Table 19.3 Use Of PGRs On Herbaceous Perennials: Research Results And Precautions (continued)

Crop	Product	Spray Rate of Application (ppm) x Number of Applications	Precautions or Remarks
Veronica spicata 'Blue' Spike Speedwell	B-Nine	5000 x 4	Apply at 10-14 day intervals.
Veronica spicata 'Red Fox' Spike Speedwell	B-Nine	5000 x 2	Apply at 10-14 day intervals.
	B-Nine/ Cycocel	5000/1500 x 2	
	Bonzi	Less than 40 x 1	
	Cycocel	NR @ 4000 x 1	
	Sumagic	Less than 15 x 1	
Veronica x 'Sunny Border Blue' Hybrid Speedwell	B-Nine	5000 x 2	Apply at 10-14 day intervals.
	B-Nine/ Cycocel	5000/1500 x 1	Multiple applications may be required.
	Bonzi	Much less than 40 x 1	Very sensitive to Bonzi. Test rates below 20 ppm.
	Cycocel	750 to 1500 x 1	
	Sumagic	Less than 15 x 1 Less than 1 x 1 (drench)	Very sensitive. Drench applied at 4 fl.oz. per quart pot. Persistent reductions in plant growth continue in the landscape at 15 ppm.

NR = Non-responsive at rates listed.
* Rates given are for spray applications at label recommended volumes unless stated otherwise. Not all uses listed are on the label. Check product label before using.
Note: PGRs are not labeled for use on edible herbs. Specify for ornamental use only.