NEW CONCEPTS IN TURF FERTILIZATION

Nitrogen is the most important element in a successful fertilization program. New concepts demonstrate when it is the best time to apply nitrogen, and how much is needed.

by John R. Street, Ph.D., Ohio State University

Late-season fertilization will extend the greening period and aesthetics of turf in fall and spring.

Turfgrass growth depends on an adequate supply of all essential plant nutrients, plus many other cultural and edaphic (soil-related) factors. Research in plant nutrition has shown that at least 16 elements are essential for plant growth and development (Table 1).

Those essential elements used in greatest quantities by the plant are referred to as macronutrients: nitrogen, phosphorus and potassium. Micronutrients, seldom deficient in most soils, are needed in relatively small quantities by the plant.

Nitrogen fertilization

Nitrogen receives the most attention in turfgrass fertilization programs for several reasons.

First, nitrogen is the essential element to which turfgrass is most responsive (Table 2). A key concept in turfgrass fertilization is that nitrogen is the "growth-control element." Supplies of other elements are maintained at adequate levels (maintenance fertilization). The turfgrass manager regulates growth and color by adding or withholding nitrogen.

Second, nitrogen plays a major role in turfgrass heat, drought and cold stress tolerances by its effect on rooting, plant carbohydrate levels and plant hydration.

Third, the turfgrass plant contains more nitrogen than any other element.

Fourth, nitrogen is a very dynamic element in the soil system. Its concentration is constantly changing, usually decreasing. The other essential elements are significantly more stable in soils. Nitrogen, therefore, must be routinely added to turfgrass to maintain a soil level sufficient for turfgrass growth.

An ideal nitrogen fertilization maintenance program on established turfgrass should provide for very slow to moderate uniform topgrowth throughout the growing season (Figure 1). The ideal program should supply enough nitrogen to stimulate some growth and green color to maintain turf quality and recuperative potential, where necessary. Rapid changes or surges in topgrowth, sometimes referred to as peak and valley growth or feeding, are undesirable from both an agronomic and maintenance standpoint.

Turfgrass shoot growth can be largely managed by the (1) amount of nitrogen applied; (2) type of nitrogen applied and (3) timing of the nitrogen application. Fast-release sources (e.g. urea) are readily available for the plant's use. They stimulate a relatively rapid plant/growth response.

Slow-release sources (e.g. methylene urea, sulfur-coated urea, IBDU) provide a time release of nitrogen to the plant. This results in a more uniform or controlled growth.

Fast-release/slow-release nitrogen combinations are typically used to control turfgrass growth and provide safety. Higher nitrogen rates generally stimulate greater turfgrass shoot growth.

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Nitrogen rates are usually limited to ½ to 1 pound per 1,000 sq. ft., especially with fast-release nitrogen sources. This avoids undesirable shoot growth surges during periods favorable for shoot growth (i.e. spring on cool-season grasses).

Recent nitrogen fertilization philosophy has been to limit nitrogen levels. This helps to avoid excessive topgrowth and adhere to a slow-to-moderate shoot growth concept.

This philosophy stems in part from the impact that nitrogen has on rooting and plant carbohydrate levels. Carbohydrates (sugars) support growth of plant parts (e.g. shoots and roots) and assist in recovery from injury. Carbohydrates are also the key source or energy for maintaining all the plant's growth and physiological processes.

Nitrogen applications favor turfgrass growth. As nitrogen rates are increased, more topgrowth is usually produced. More topgrowth results in more carbohydrate use to support this growth. *A key physiological principle is that under rapid growth, shoots take priority over roots, rhizomes and stolons for available carbohydrate.* Shoot growth will continue to respond to higher nitrogen levels, distinctly suppressing root growth and other growth processes.

These effects are well illustrated in a fertilization study evaluating the response of a Merion Kentucky bluegrass sod to incremental rates of nitrogen (topgrowth) and nitrogen content of clippings.

In contrast, sod strength, a reflection of root and rhizome growth, and rhizome weight decreased at higher nitrogen levels. Thus, when most of the plant's carbohydrate was directed toward shoot growth, root and rhizome growth suffered accordingly. Agronomists well recognize that a plant's stress tolerance is directly related to the depth and mass of the plant's root system.

Table 1:

Essential Plant Nutrients Required for Turfgrass Growth and Development

Macronutrients	Typical Percentage in Turfgrass Tissue[a]	Remarks
Nitrogen Phosphorus Potassium	3-6 0.2-0.5 2-3	Commonly used in maintenance fertilization at ratios of 3-1-2 to 5-1-2. Additional P and K (corrective) may be necessary where inherent soil levels are low.
Sulfur	0.2-0.3	Usually only applied where a specific deficiency has been diagnosed. Used in ratios similar to P.
Calcium Magnesium	0.4-0.6 0.2-0.4	Usually only applied where a soil pH adjustment is required or on alkali soils.
Micronutrients	Typical Parts per million (ppm) in Turfgrass Tissue	Remarks
Iron Zinc Molyldenum Manganese Copper Boron Chlorine	40-200 40-120 0.1-0.2 20-150 15-20 5-20 —	Iron is usually used to provide short term green color enhancement. Micronutrients primarily deficient on alkaline soils and/or soils with high phosphorus and/or high micronutrient levels (Mn, Zn, and Cu). Seldom deficient on fine-textured soils.

[a] Elemental percentages will vary to some extent depending on turfgrass species and cultivars, environmental conditions and other variables.

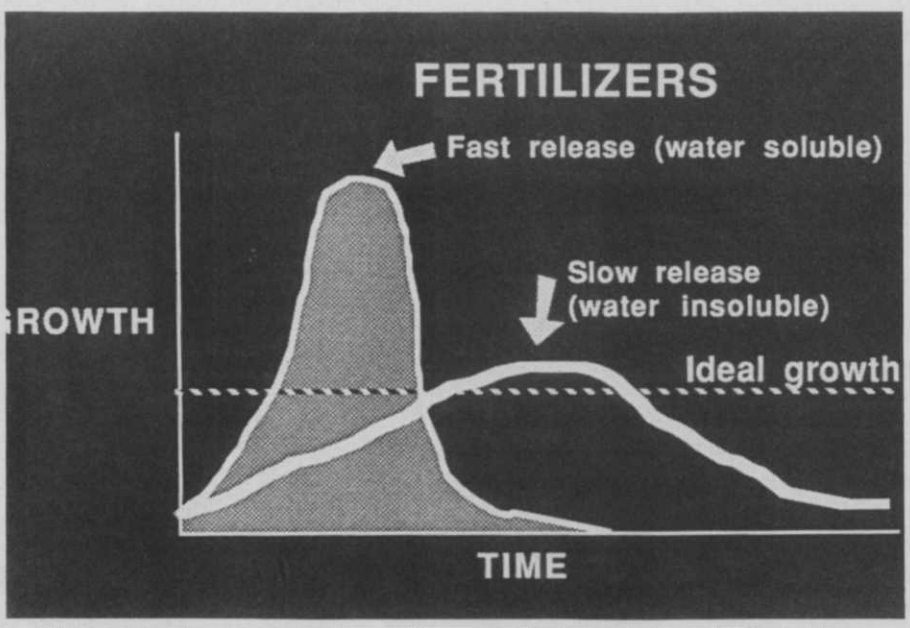

Figure 1. A slow to moderate, uniform growth is most desirable in turfgrass fertilization programs. Nitrogen is the "growth control" element.

Research at Ohio State University has shown that root initiation and root growth of cool-season grasses occurs in the spring and again in the fall (Figure 2). Liberal nitrogen fertilization in the spring will have a tendency to restrict root growth in favor of shoot growth. The turfgrass plant will go into the summer with a shorter root system than when low-to-moderate rates of nitrogen fertilizer are used.

Furthermore, high rates of nitrogen will increase topgrowth and increase the need for spring mowing. Rapid topgrowth may result in the removal of large amounts of clippings at each mowing. The removal of more than a third of the foliage at any one mowing retards both root and tiller development.

A reduction in root growth at this time is extremely critical since spring is an optimum time for root growth. A lot of "good root growth growing time" can be lost in the spring by heavy nitrogen applications.

Thus, mismanagement of nitrogen during the spring can have a dramatic effect on the root system under the turfgrass going into the summer. This, in turn, means a significant influence on stress tolerance.

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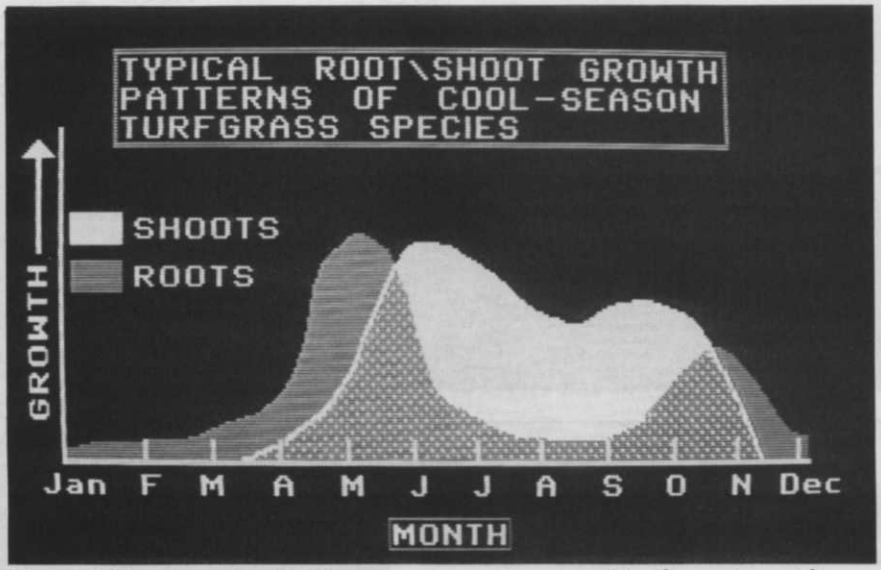


Figure 2. Root growth of cool-season grasses is greatest in the spring with a significant root growth surge again in the fall.

Timing of nitrogen applications is critical to a healthy turf with maximum stress tolerance. Heavy nitrogen fertilization during the spring and early summer is undesirable for cool-season turfgrasses. Environmental conditions are favorable for a rapid topgrowth surge at the expense of root growth. Lush, succulent growth is also produced from heavy nitrogen in the spring. This takes the turfgrass into the summer in a soft growth condition and more vulnerable to disease, heat and drought.

To avoid these latter disadvantages, late-season fertilization has been adopted for cool-season grasses. Late-season fertilization means application of nitrogen during that period of the year (late fall) that will favor root growth over shoot growth, and favor a positive carbohydrate balance in the turfgrass plant.

Cool-season turf shoot and root growth occur most readily in temperatures of 60 to 75 and 50 to 65 degrees Fahrenheit, respectively. Research at Ohio State University has shown that root growth of cool-season grasses will continue at soil temperatures close to freezing. Shoot growth will slow and eventually cease long before soil temperatures drop low enough to stop root growth. Roots can be actively growing while shoots above are brown and dormant. Late-season fertilization capitalizes on this differential in optimum temperatures and minimum temperatures for growth of shoots versus roots.

For the "late-season" concept to work successfully, turf must be green when the late-season nitrogen application is made.

On cool-season grasses, a late summer/early fall nitrogen application will ensure that the turf remains green before the late-season application.

Ideally, the late-season nitrogen application should be made when vertical shoot growth has stopped, but the turf is still green to produce carbohydrates via photosynthesis.

Air temperatures of 45 to 50 degrees Fahrenheit are usually necessary to ensure vertical shoot growth stoppage of cool-season grasses. Since temperatures will be at a point that stops roots, cool-season grass rhizomes and stolons will capitalize on any applied nitrogen and carbohydrate produced. The carbohydrate produced by the green turf will be more efficiently used for root, rhizome and stolon growth during the late fall, winter and spring.

Research at Ohio State University has shown a significant increase in both root growth rates and root numbers (Figures 3 and 4) from late-season nitrogen fertilization. A more positive carbohydrate balance also was provided from late-season fertilization compared to a spring/summer fertilization.

Nitrogen applications during the late season, if timed properly, will extend greening later into the fall and winter. Spring green-up will usually occur earlier.

In general, the turf's "greening period" from late-season fertilization can be extended four to eight weeks during late fall and early spring. This is a sound practice both agronomically and aesthetically.

Typically, spring color of late-season fertilized turf remains quite good until late May or early June. Then the effects of nitrogen applied the previous fall begin to wear off. Spring appli-

Poor fertilizer performance? It might be ammonia volitilization

Nitrogen loss from ammonia volatilization can result in poor fertilizer performance, according to David Kissel, researcher at Kansas State University.

Kissel says that as in leaching, losses of nitrogen by ammonia volatilization can make it necessary to re-apply fertilizer to restore the lawn to its original green color and vigorous growth.

Ammonia volatilization occurs when nitrogen is converted to a gas and released into the air. This nitrogen removal bypasses the turf and deprives a lawn of needed nutrition. Of the 16 elements needed for healthy turf development, nitrogen is by far the most important.

"Ammonia volatilization can take place when urea and urea-containing fertilizers are present on turfgrass surfaces, in the thatch layer, or very near the soil surface," he says. Non-urea fertilizers are also susceptible to nitrogen losses from ammonia volatilization, but only when applied to the surface of alkaline soils.

Along with heavy thatch, a lack of rainfall or irrigation will increase the chances for nitrogen loss from ammonia volatilization because movement of applied fertilizer into the soil will be reduced. Kissel says that substantial losses can be avoided if irrigation or rainfall occurs within a few hours after fertilizer application.

If irrigation is not possible, and conditions are favorable for loss, he recommended using non-urea nitrogen or slow-release fertilizer, such as sulfur-coated urea or some of the new products, like N-Sure nitrogen solution, in combination with the regular nitrogen source.

Kissel addressed the ammonia volatilization problem at the Kansas Turfgrass Foundation meeting in Wichita, Kan. □

Table 2:

Comparative Turfgrass Responses of Commonly Used Maintenance Nutrients — Nitrogen, Phosphorus and Potassium.

	Nutrient		
Turfgrass Response	Nitrogen	Phosphorus	Potassium
Shoot Growth	*		
Shoot Density	*		
Grass Color (Green)	*		
Root Growth	*	*	*
Establishment Rate	*	*	
Recuperative Rate	*		
Wear Tolerance	*		
Heat Stress	*		*
Drought Stress	*		*
Cold Stress	*		*
Disease Incidence	*		*

* Fairly strong relationship based on available research.

Table 3:

Nitrogen treatment effects on a Merion Kentucky bluegrass sod.

Nitrogen Rate	Annual Clipping Yield (dry wt.)	Nitrogen Content in Clippings	Sod Strength	Rhizomes
lb/A/month	lb/A	%	lb to tear	grams
0	463	3.0	146	99
15	1807	3.3	188	89
30	2555	3.6	130	120
60	5676	4.5	97	43
120	8447	5.4	67	14

Rieke, P. E. 1975. Turfgrass Fertilization - Nitrogen. 16th Illinois Turfgrass Conference Proceedings. 81-85.

Table 4:

A Comparison of Known Late-Season Fertilization Advantages on Cool- Versus Warm-Season Grasses.

Late-Season Effect	Cool-Season Grass Response	Warm-Season Grass Response
Winter hardiness	+−	−
Rooting	+	
Carbohydrate balance	+	
Fall color retention	+	+
Spring greenup	+	+
Spring mowing reduction	+	+
Turf density	+	+
Weed reduction	+	
Disease reduction	+	
Thatch accumulation	+	

Plus (+) denotes a positive response, negative (−) denotes a negative response, (+ −) denotes a limited response and a blank indicates research information limited.

cations of nitrogen should be delayed until the late-season fertility response dissipates.

The most efficient nitrogen sources for late-season fertilization programs are independent of temperature for nitrogen release. Soil temperatures and microbial activity are low at this time of the year, resulting in poor efficiency from temperature-dependent fertilizers like ureaformaldehyde.

Urea, IBDU, sulfur-coated urea and short chain methylene ureas will work effectively in this program. Recommended nitrogen rates are 1½ lbs. per 1,000 sq. ft.

In Ohio State University research, thatch has been found to be greater under late-season fertilization than under spring/summer fertilization. This has been the only disadvantage reported for late-season fertilization in cool-season grasses. The greater root growth occurring with late-season fertilization is considered the likely reason for more thatch. Thatch has been reported to consist of as much as 60 to 70 percent roots.

Management practices like late-season fertilization or high mowing that increase root depth and number will, more than likely, over time, increase thatch accumulation.

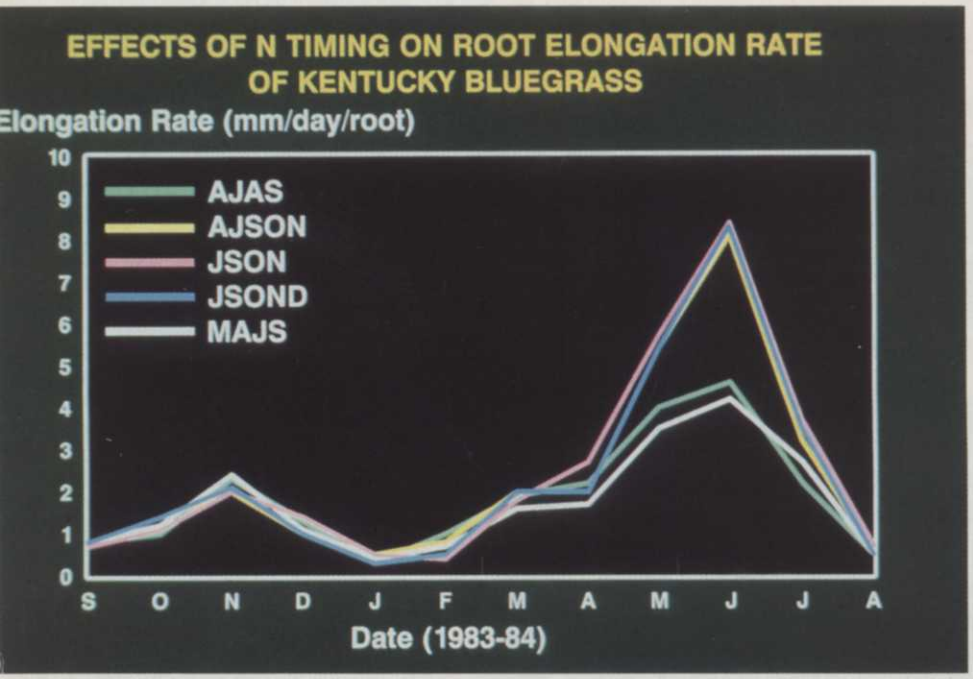
This implies that, in long-term management strategies where cultural practices maximize root growth, accompanying strategies like core cultivation must be used to control thatch.

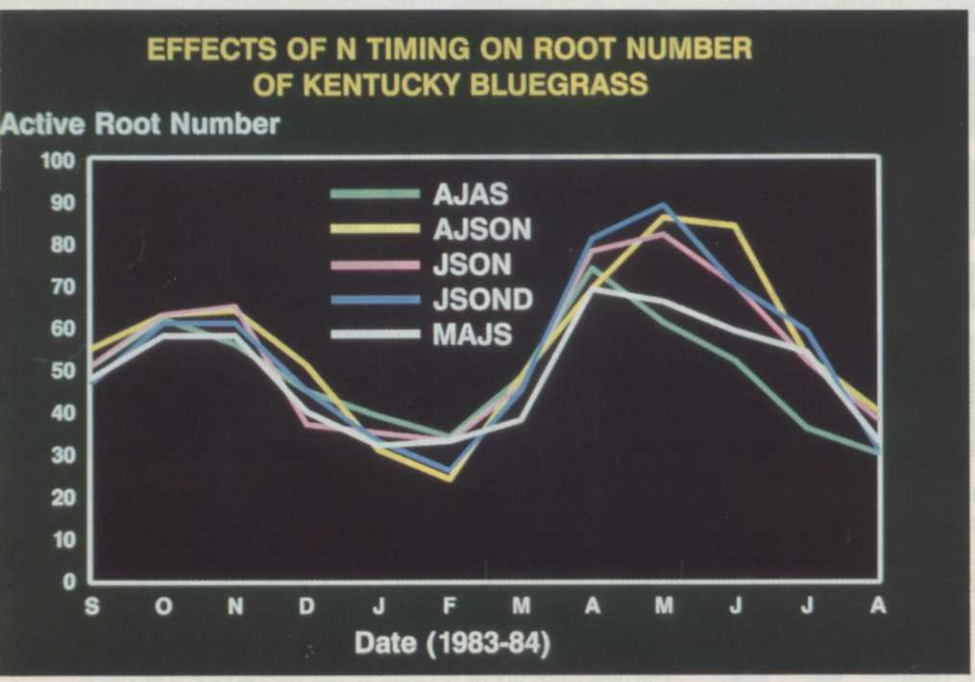
Limited information is available on the adaption of warm-season grasses to late-season fertilization. Some of the advantages claimed on cool-season grasses will provide similar benefits on warm-season grasses (Table 4), such as extended greening and earlier spring green up. Winter injury and winter hardiness are major concerns, however. In general, late-season fertilization will lower the winter hardiness of warm-season grasses by delaying or interfering with the hardening process.

This will result in a greater risk of injury, especially as in the northern limits of the transition zone. Turf managers must weigh the benefits against the risks.

Potassium fertilization

Turfgrasses need potassium in relatively large amounts, second only to nitrogen. The potassium content of properly fertilized turfgrasses normally ranges from two to three percent. Potassium in maintenance fertilization programs has generally been applied in a ratio of 3:1:2 to 5:1:2, nitrogen-to-phosphorus-to-





Figures 3 & 4. Late-season fertilization (O, N and/or D) significantly increased root elongation rates and root number during the following spring and early summer. Nitrogen was applied at one pound rates during the months indicated.

potassium. On low potassium soils, additional potassium may be necessary.

Recent research has demonstrated that increasing potassium levels result in improved root growth; an enhancement of heat, cold and drought tolerance; better wear tolerance and less chance of disease.

This research suggests a nitrogen-to-potassium ratio approaching 1:1. Higher analysis potassium fertilizers will be most beneficial before and during stress periods. Higher potassium levels prior to winter have been found to be extremely beneficial to warm-season grasses. They enhance winter hardiness and would certainly seem warranted in late-season fertilization of warm-season grasses.

Phosphorus fertilization

Phosporus usually enhances turfgrass establishment rate from seed or vegetative plantings and enhances root growth. In maintenance fertilization programs, phosphorus has generally been applied in ratios of 3:1:2 to 5:1:2 nitrogen-to-phosphorus-to-potassium.

Nitrogen-to-phosphorus ratios of 1:1 to 1:2 are recommended in establishing new turfgrass areas. Phosphorus deficiencies are, however, rarely observed in established turf areas unless their level in the soil is extremely low or an unfavorable pH exists.

Micronutrients

Micronutrient levels are usually adequate in most soils. In addition, these nutrients are needed in very small quantities. They are often supplied as impurities in commonly-used fertilizers, liming materials, top dressing, certain pesticides and irrigation water.

Sandiness increases the possibility for micronutrient deficiencies. However, most sands used for soil modification are not pure and are usually modified to some extent with soil or organic matter.

Thatch has been found to be greater under late-season fertilization than under spring/summer fertilization.

In general, micronutrient deficiencies are most likely to occur in alkaline soils (high pH). They are further aggravated by high soil phosphorus and high soil levels of other micronutrients. It is adviseable to use both soil and tissue testing to define a micronutrient deficiency.

Iron is the micronutrient most frequently supplemented in turfgrass fertilization programs. Its more frequent use among micronutrients is primarily due to its capability to enhance turfgrass color.

Iron application of 1 to 2 oz. of iron carrier per 1,000 sq. ft. produces a relatively rapid dark greening response with a short residual of one to three weeks. Iron has been known to have positive influence on plant carbohydrate reserves. It more recently has shown to have a positive effect on drought hardiness. **LM**

PRE-EMERGENCE WEED CONTROL IN COOL-SEASON TURF

Pre-emergence herbicides are generally safer to use on turf than post-emergence herbicides because they are being used to control seedlings rather than mature plants. Here are some tips.

by Prasanta C. Bhowmik, Ph.D., University of Massachusetts

Weeds are a fact of life. No turfgrass area or landscape will remain weed-free without intervention.

To establish and maintain an attractive, healthy lawn, weeds must be controlled. Maintenance practices such as mowing too low, over-irrigation, over-fertilization, using unnecessary heavy machinery, and poorly timed aerification can result in stress conditions that encourage weed infestations.

A good management program with both cultural and chemical program will help reduce these stress factors. A successful weed control program in cool-season turf results from integrating a recommended cultural practice program and a complete weed control program.

An effective weed control program uses herbicides only when necessary. Producing a dense, healthy stand of turfgrass is one way to control annual grassy weeds and other broadleaf weeds. Proper mowing height and frequency, fertilization and irrigation are part of the weed control program and should be practiced throughout the growing season.

This picture, taken 10 weeks after a pre-emergence herbicide application, shows the effective control of annual grassy weeds.

Turfgrass managers should be familiar with the following steps for a successful weed control program.

1. Knowing the specific weed problems: in relation to weed identification (grassy weeds vs. broadleaf weeds), life cycle of the weeds (annuals vs. perennials).

2. Selection of the right herbicide: in relation to effective weed control, turfgrass tolerance.

The most common annual grassy weeds include large crabgrass, small crabgrass, yellow foxtail, green foxtail, fall panicum, barnyardgrass and goosegrass. Crabgrass and goosegrass are the most troublesome weeds in turf. Crabgrass (*Digitaria spp.*) is among the most difficult weeds to control in turf.

In northern regions, seeds of crabgrasses (smooth and large) begin to germinate in late April to late May and continue to germinate throughout the summer. However, in transition regions, germination can occur as early as late March. Crabgrass germination is related to soil temperature. When the soil temperature reaches 65°F crabgrass begins to germinate.

This varies with the local conditions of soil type, rainfall, and weather in the spring. In general, most

crabgrass seeds germinate during a six- to eight-week period. And most other annual grassy weed seeds germinate during this germination period.

Selective weed control

The selective control of these grassy weeds and some broadleaf weeds can be obtained with pre-emergence herbicides. Pre-emergence herbicides provide effective control for several weeks or months, depending upon dosage and products.

The effectiveness of these compounds is based upon their ability to provide good weed control, turfgrass tolerance, and long residual control. The primary pre-emergence herbicides for grassy weed control in cool-season turfgrasses are benefin, bensulide, DCPA, oxadiazon, pendimethalin, and siduron (Table 1).

Benefin, Team (a pre-mix combination of benefin and trifluralin), DCPA is also effective in controlling common chickweed, carpetweed and common purslane.

In addition, pendimethalin controls goosegrass, barnyardgrass, fall panicum and some annual broadleaf weeds such as hop clover, yellow woodsorrel and prostrate spurge. Pendimethalin applied during the late summer to early fall can control common chickweed, mouseear chickweed, and henbit. Repeat application at the recommended rate eight weeks after the initial application may prevent goosegrass and heavy infestations of spurge. Oxadiazon controls hop clover, prostrate spurge and speedwell. Oxadiazon is more effective in goosegrass control than DCPA. Pendimethalin and DCPA control prostrate spurge, while benefin and bensulide are ineffective in controlling this weed.

Prodiamine (Blockade) is a new pre-emergence herbicide. It is expected to be in the market in the near future. It is very effective in controlling most annual grassy weeds such as crabgrass, goosegrass, bluegrass and several broadleaf weeds. It provides long residual control of weeds.

Timing applications

Timing is very important for herbicide applications. The best time for annual grassy weed control is to apply before weeds emerge. The key point is that pre-emergence herbicides need to be applied before grasses germinate in the spring. Treatments made too late (i.e after germination) will not control emerged grassy weeds.

If application timing does not coincide with the normal germination period of annual grassy weeds, weed control results may be erratic or poor. In general, pre-emergence herbicides should be applied two weeks prior to the expected weed seed germination period. Therefore, the application dates of pre-emergence herbicides will vary from one part of the country to another.

The herbicides should be watered-in so that the chemical can form a barrier in the soil prior to weed seed germination. The resulting chemical barrier should not be disturbed during key weed germination period.

Complementary effects

Post-emergence grass control can complement a pre-emergence weed control program when poor weed control results are obtained. The primary post-emergence herbicides for grassy weed control in cool-season turfgrass are the arsenates: MSMA, DSMA, and AMA. These compounds can be phytotoxic, especially when applied during hot weather. A new post-emergence herbicide, fenoxaprop (Acclaim) is now available for annual grassy weed control. Fenoxaprop is very effective in large crabgrass, goosegrass, fall panicum, giant foxtail, barnyardgrass and other grassy weed control. This compound offers a wider window of post-emergence control than the arsenates with less potential for turfgrass injury. Fenoxaprop is recommended for use on perennial ryegrass, fine fescue, tall fescue and Kentucky bluegrass turf.

Table 1.

Common name, trade names, formulations, and rate of pre-emergence herbicides.

Common Name	Trade Name(s)	Formulation	Recommended Rate (pound active per acre)	Company
Benefin	Balan	2.5G	2.0-3.0	Elanco
		2.5G	"	Lesco
Benefin & Trifluralin	Team (1:2)	2G	1.5-3.0	Elanco
		1G	"	Lesco
Bensulide	Betasan	4E, 7G, 12.5G	7.5-10.0	ICI
	Pre-san	4E, 7G, 12.5G	"	Mallinckrodt
	Lescosan	4E, 7G, 3.6G	"	Lesco
	Betamac Weedgrass	4E	"	PBI Gordon
	Preventer	8.5	12.5	Scotts
DCPA	Dacthal	75WP	10.5	Fermanta
	Dacthal	5G	"	Lesco
Oxadiazon	Ronstar	50WP, 2G	3.0-4.0	Rhone Poulenc
Oxadiazon + Bensulide	Goosegrass/ Crabgrass Control	6.56G	7.5	Scotts
Pendimethalin	Lesco Pre-M Weedgrass	60DG,	1.5-3.0	Lesco
	Control	60WDG	"	Scotts
	Halts Crabgrass	2.45G	"	Scotts
	Turf Weedgrass Control	1.71G	"	Scotts
Siduron	Tuperson	50WP	2.0-6.0	Du Pont

Longevity of pre-emergents

A complete weed control program aims at controlling weeds for the entire season. Season-long control of weed species is dependent upon the activity and longevity of the herbicide in use.

Oxadiazon, pendimethalin, Team and bensulide provide long residual weed control, while benefin is of short residual. On the other hand, DCPA is an intermediate type. Turfgrass managers should keep in mind that soil residual activity is also dependent upon the rate of herbicide being used.

In general, the higher the rate of application, the longer is the residual control over the growing season. Initial application determines the concentration in the soil for pre-emergence activity. It must maintain a critical soil residue level during the growing season for season-long weed control.

Turfgrass managers should keep in mind that application made early in the season may break in the soil to below the threshold level. When this occurs, one can expect less than desirable control following late germinating weeds. Repeat application of certain herbicides may be made 10 to

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12 weeks after the initial application for continued control of late germinating weeds over the entire season.

Turfgrass tolerance

Cool-season turfgrasses vary in their tolerance to pre-emergence herbicides. Siduron is the only pre-emergence herbicide that is recommended for newly-seeded turfgrass. All other pre-emergence herbicides are recommended for use on established fine fescues, Kentucky bluegrass, perennial ryegrass and tall fescue. However, bensulide and DCPA can be applied in the spring following a fall seeding of cool-season turfgrasses.

In general, the higher the rate of application, the longer is the residual control over the growing season.

Pendimethalin is not recommended for use on bentgrass or where annual bluegrass is the desired species. Benefin, DCPA and oxadiazon are not recommended for use on fine fescues or bentgrass turf. However, bensulide can be used on bentgrass. Team is recommended for use on most cool-season grasses. It may thin established annual bluegrass turf and fine fescues at rates above 1½ lbs. active ingredient per acre.

It should not be applied in the spring to turfgrass planted the previous fall. Team is not recommended for use on creeping bentgrass. However, it can be used on bentgrass fairways.

Reseeding time interval

Time for reseeding is very important in relation to the application date of pre-emergence herbicides. In general, pre-emergence herbicides persist in the soil for a length of time, allowing season-long weed control. Reseeding interval is dependent upon the herbicide and dosage used (Table 2).

For example, reseeding should be delayed at least six weeks after application of Team at the lower end of recommended rate. However, when using the highest recommended rate, reseeding should be delayed 12 to 16 weeks after the application. When reseeding, it is essential that proper cultural practices such as soil cultivation, irrigation and fertilization be followed.

In summary, a successful pre-emergence weed control program results from selecting the right herbicide and applying it uniformly at the proper time and appropriate dosage. The herbicide selection depends on the weeds to be controlled and the turfgrass to be treated.

Choose the most effective herbicide with maximum safety to the turfgrass. Changing the use of one class of herbicide to another class in a weed management program may provide a broad spectrum weed control in lawns. For crabgrass and other grassy weed control, turf managers and lawn care operators should emphasize a pre-emergence herbicide program along with a good management program. This approach will minimize the competitive advantage of efficient species like crabgrass.

Table 2.

Minimum time necessary for reseeding after various pre-emergence herbicide application.

Common Name	Trade Name(s)	Formulation	Recommended Rate (pound per acre)	Minimum Time Before Reseeding (Weeks)
Benefin	Balan	2.5G	2.0-3.0	6
Benefin & Trifluralin	Team (1:2)	2G	1.5-3.0	6
Bensulide	Betasan	4E, 7G, 12.5G	7.5-10.0	16
DCPA	Dacthal	75WP	10.5	8
Oxadiazon	Ronstar	50WP, 2G	3.0-4.0	16
Oxadiazon + Bensulide	Goosegrass/ Crabgrass Control	6.56G	7.5	16
Pendimethalin	Lesco Pre-M	60DG,	1.5-3.0	16
Siduron	Tuperson	50WP	2.0-6.0	N/A

PRE-EMERGENCE WEED CONTROL FOR WARM-SEASON TURF

by Clyde Elmore, Ph.D., University of California-Davis

Crabgrass will germinate in open areas of turf.

Pre-emergence weed control is more than applying the right herbicide at the right rate. It requires a knowledgeable turf manager. Often the manager must be able to manage the turf for multiple uses such as recreation, visual effects and athletic events.

Frequently, several species are involved. Knowing cultural practices needed to make the turf vigorous without inviting damage from diseases or other stresses is essential. Management practices are generalized about mowing height and frequency, fertilization amount, and frequency, time of aeration and irrigation. These practices need to be site-specific. Assuming all of the practices are correct, the manager must then think of tipping the balance against weeds.

Before beginning a weed control program, determine the weed species to be controlled using identification aids.

Local university advisors, nurserymen, industry representatives or people at the botanic gardens are available to assist. If there are many species or if perennial weeds are present, a single pre-emergence material will not be adequate.

Choosing a herbicide

Many herbicides are available for warm-season turf. They differ by the weeds controlled, their saftey to the vaious turf species and residual control. Some herbicides (atrazine, simazine and pronamide) also give some post-emergence control.

	Prostrate Spurge Control	Crabgrass Control
EXCELLENT	Pendimethalin	Bensulide, pendimethalin, oryzalin, trifluralin
GOOD	DCPA	Benefin, siduron, oxadiazon, DCPA, napropamide
FAIR	Oxadiazon, siduron	
POOR	Bensulide, napropamide	

(Based on consistance, length of control, and completeness of control)

Pre-emergence materials form the basis for controlling annual grass and many broadleaf weeds in turf. Once the weeds are controlled and the management practices have been changed to keep the weeds from re-invading, then good vigorously-growing turf can exclude most weeds.

Herbicides are applied in the spring to control summer annual grasses or broadleaves. They are applied in the fall for winter annuals. The germination times of large crabgrass, smooth crabgrass, prostrate spurge, goosegrass or foxtails all differ.

Timing applications

The manager must be able to time the application so the herbicide is in the germination zone at the first germination. One application may not be long enough to control the weeds for the full season, as is often the case in southern California, Texas, Florida, Georgia, etc.

These areas have an exceptionally long weed germination period. Since the soils are warmer and the temperature higher, herbicides degrade faster than in cooler climates. Greater amounts of water increase the loss of herbicides. A second application must be made to have enough herbicide in the germination zone to control all weeds.

The turf manager can affect timing of germination by turf quality. Areas that have bare soil warm up quicker in the spring and weeds germinate in these areas before cooler, tight-growing areas. With good quality turf, the herbicide can be applied later giving better control that lasts longer.

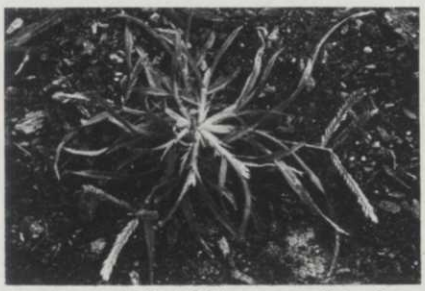
Pre-emergence herbicides are usually used in the early spring for crabgrass (large and smooth), goosegrass, sandbur, foxtails and prostrate spurge.

Knotweed can sometimes be a problem. In the fall of the year, materials are used for annual bluegrass, common chickweed, henbit and speedwells.

Table 1.

Directory of turfgrass pre-emergence herbicides.

Common Name	Trade Name	Formulations	Company
Atrazine	Aatrex	80W,90DG,4L	Ciba-Geigy
	Purge	4L	Security
Benefin	Balan	2.5G	Elanco
	2.5 Benefin Granular	2.5G	Lesco
Benefin + oryzalin	XL	2G	Elanco
Benefin + trifluralin	Team	2G	Elanco
Benefin + oxadiazon	Regalstar		
Bensulide	Betasan	2.9E,4E,7G,12.5G	Stauffer
	Iescosan	4E,7G,12.5G	Lesco
	Pre-san	4E,7G,12.5G	Mallinckrodt
	Bensumec 4LF	4E	
Bensulide + Oxadiazon	Goosegrass/Crabgrass Control	5.25G + 1.31G	Scotts
DCPA	Dacthal	75W	Fermenta
	Dacthal	5G	Lesco
Ethofumsate	Prograss	1.5E	Nor-Am
Fenarimol	Rubigan	50W	Elanco
Napropamide	Devrinol	50W,5G	Stauffer
Oryzalin	Surflan	4AS	Elanco
Pendimethalin	Southern Weedgrass Control	2.5G	Scotts
	Turf Weedgrass Control	1.71G	Scotts
	Weedgrass Control	60DG	Scotts
	Pre-M	60DG	Lesco
	Pendimethalin	60DG	Clean Crop
Pronamide	Kerb	50W	Rohm-Haas
Siduron	Tupersan	50W	Du Pont
Simazine	Princep	80W,90DG,4L,4G	Ciba-Geigy



Goosegrass should be treated in the early spring with a pre-emergence herbicide.

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Other weeds can be found locally, or are isolated problems. If perennial weeds have beed established in the turf and have seeded, then pre-emergence herbicides may be needed to control the germinating seeds of these weeds (Dallisgrass or Bermudagrass for example). The established plants must be controlled by post-emergence herbicides.

Overseeded turf

Overseeding of warm-season grasses is a concern when using herbicides. The pre-emergence material controlling crabgrass or goosegrass must be broken down so annual ryegrass can germinate and establish. Applications of herbicides for annual bluegrass control can be a problem.

Benefin has been used for annual bluegrass control. It can also be applied early in the season (August), giving early control. The ryegrass can be seeded about 45 days later. Bensulide has stunted overseeded ryegrass turf at 45 days. The residual of bensulide is usually two or three times longer than benefin in California turf.

Ethofumesate may be applied 20 to 30 days after overseeding. It should be applied to dormant Bermuda or suppression can occur in the spring.

Fenarimol, a fungicide, applied two weeks prior to overseeding, controls several turf diseases in addition to controlling the annual upright form of annual bluegrass. It has not controlled the low-growing perennial form in mild climate areas.

Careful water management going into the fall will help reduce annual bluegrass invasion. Conditions that allow alternate wetting (rainfall or irrigation) and drying, so the seedlings can dry out and die, will decrease weed populations.

Mechanical cultivation

Also, timing of aeration or other mechanical cultivations is important. Aeration or verticutting during annual bluegrass germination allows open spaces in the turf for weeds to invade.

Always aerate or verticut before—never after—an application of pre-emergence herbicide. These operations just before herbicide treatment will reduce the thatch and give the herbicide a better chance to get to the soil where it is effective.

Pre-emergence herbicides, when properly timed at the right rate, can effectively control most annual weeds and be a good tool to help manage turf. They generally are safer to use on turf than post-emergence herbicides because they are being used to control seedlings rather than mature plants. There are many good materials from which to select to control your weeds. **LM**

	Pre-emergence Herbicide Soil Longeviity
SHORT	benefin, DCPA, siduron
MEDIUM	oxadiazon, trifluralin
LONG	bensulide, pendimethalin, oryzalin

(Based on turf use and rates used in turf)

Table 2.

Tolerance of Warm-Season Turf to Pre-emergence Herbicides

Herbicide	Bahia	Bermuda	Centipede	St. Augustine	Zoysia
Atrazine	NR	I	T	T	I
Benefin	T	T	T	T	T
Benefin*oryzalin	T	T	T	T	T
Benefin*trifluralin	T	T	T	T	T
Bensulide	T	T	T	T	T
Bensulide*oxadiazon	NR	T	NR	NR	T
DCPA	T	T	T	T	T
Ethofumsate	NR	I	NR	NR	NR
Napropamide	T	T	T	T	TR
Oryzalin	T	T	T	T	T
Oxadiazon	NR	T	NR	T	T
Oxadiazon*benefin	NR	T	NR	NR	T
Pendimethalin	T	T	T	T	T
Pronamide	NR	T	NR	NR	NR
Siduron	NR	NR	NR	NR	NR
Simazine	NR	T	T	T	T

T= tolerant; I=Intermediate tolerance, apply only to dormant grass
NR=Not registered