

tions may be necessary to provide control over the entire germination period. Contact your local university or industry turf specialist for germination times of primary weeds.

The differences

Turfgrass pre-emergence herbicides differ in soil longevity, weed control efficacy, and potential turfgrass injury. Benfen is generally considered to be shorter-lived in soils than bensulide or pendimethalin; while DCPA is considered to be intermediate. Concentration of the initial application is important in terms of maintaining pre-emergence herbicide soil concentrations.

Pre-emergence herbicides must maintain a critical soil residual level (threshold value) during the growing season that is conducive for germination of the target weed (i.e., annual bluegrass, crabgrass, foxtail, goosegrass or spurge). Applications made too early in the season may break down in the soil to levels below the threshold value. If this occurs and conditions remain favorable for weed germination, less than desirable control will be obtained.

Maintaining levels

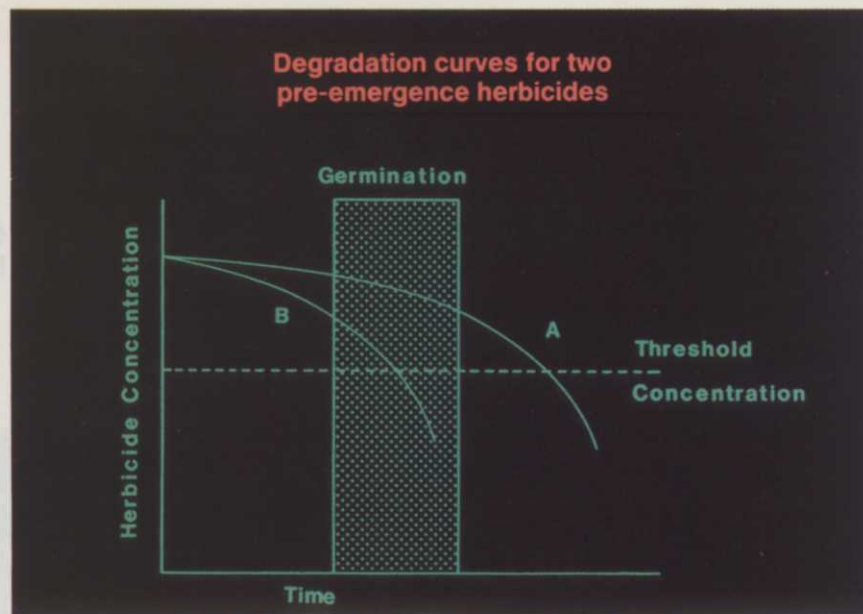
To obtain critical threshold values for the pre-emergence herbicide, adequate application rates must be made or repeat applications must be applied to maintain the threshold level. Initial applications will be dictated by label directions, turfgrass safety, efficacy and economics. In cases where potential turfgrass injury is a concern, light, frequent or split applications may be used to obtain control and minimize potential turfgrass injury.

Consult your local turfgrass specialist for specific information regarding the need for split applications of pre-emergence herbicides in your area. This information should increase its effectiveness and safety of your pre-emergence herbicide program.

Most turfgrass pre-emergence herbicides are effective in controlling crabgrass. These herbicides may differ somewhat in percent of control. It is wise to check with turf specialists in your region for the most efficacious materials.

Other annuals

Pre-emergence herbicides differ in their ability to control other annual weed problems. For example, DCPA and pendimethalin effectively control prostrate spurge; while benfen and bensulide are ineffective in controlling this troublesome weed. Bensulide, at concentrations normally ap-



Pre-emergence herbicides differ in their ability to maintain effective soil residual concentrations (i.e., Herbicide A vs. Herbicide B). When values drop below the "threshold" level, effective weed control is lost. In this case, Herbicide B requires a second application to maintain effective weed control.

plied for crabgrass control, is not as effective in controlling foxtail as is DCPA or pendimethalin. Oxadiazon is more effective for goosegrass control than DCPA. Pendimethalin has good to excellent efficacy for all the annual warm-season species.

It is essential to apply pre-emergence herbicides uniformly to the area. These herbicides are bound in the soil by clay and organic matter and have limited lateral movement. Skips in application allow the target weed to escape, germinate and produce addi-

tional seed, thus disrupting turf quality. Careful application is important, making sure to follow label directions and to calibrate application equipment prior to treatment. This will give the safest, most efficacious control from the herbicide selected at the most economic rate.

Turfgrass managers should keep in mind that successful pre-emergence herbicide programs result from selecting the appropriate herbicide, and applying it uniformly at the appropriate rate and time. **WT&T**

PRE-EMERGENCE HERBICIDES FOR WARM-SEASON TURF

by Tim R. Murphy

Successful weed control programs in warm-season turf depend on the development of a two-phase control strategy by the professional turf manager.

The first phase involves the use of cultural practices and insect and disease control programs that promote a dense, vigorous turf cover. Adequately maintained turf is less susceptible to a high level of a weed

infestation than poorly maintained turf.

Prior to the use of any herbicide, cultural practices—adequate fertilization, irrigation, cultivation and correct mowing height and interval—should be matched to the needs of a particular turfgrass species. Addition-

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ally, insect and disease problems should be eliminated. Strict reliance on herbicides without regard for the contribution of other management practices to the total weed control program does not result in a high-quality, aesthetically appealing turf.

The second phase of a weed control strategy involves the use of pre-emergence and post-emergence herbicides. Pre-emergence herbicides are applied prior to weed seed germination and generally have little, if any, activity on emerged weeds. In contrast, post-emergence herbicides are applied directly to the foliage of emerged weeds and have no or minimal residual activity on non-emerged weeds. Although the majority of herbicides may be classified as either pre-emergence or post-emergence, atrazine and simazine are exceptions. These herbicides have both pre-emergence and post-emergence activity on a wide variety of winter annual weeds.

Pre-emergence herbicides form the base of the chemical weed control program and are used primarily to control annual grasses and certain annual broadleaf weeds. This group of weeds can be controlled with post-emergence herbicides; however, two or more applications are usually necessary and a possibility exists that the turf may be discolored or injured for a short time after application.

Generally, pre-emergence herbicides are safer to apply to warm-season turf, and often only one application is necessary. Therefore, pre-emergence herbicides are the preferred method for controlling annual grass and certain annual broadleaf weeds. Post-emergence herbicides should be relied upon to control perennial grass and broadleaf weeds that are not controlled by pre-emergence herbicides.

Pre-emergence herbicides are applied in the spring for crabgrass and goosegrass control and in the fall months primarily for annual bluegrass control.

Since most pre-emergence herbicides are not effective against emerged weeds, applications must be made prior to weed seed germination. Late February to early March applications generally provide better crabgrass control than later applications. However, in the cooler, mountainous regions of the South, the spring application may be delayed until late March.

For annual bluegrass, late August to early October applications are used, depending on the geographical location. Pre-emergence herbicides require rainfall or irrigation water to

Table 1. Directory of turfgrass pre-emergence herbicides.

Common Name	Trade Name(s)	Formulations ¹	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
Bensulide	Betasan	2.9E, 4E, 3.6G, 7G, 12.5G	Stauffer
	Lescosan	4E, 7G, 12.5G	Lesco
	Weedgrass Preventer	8.5G	Scotts
	Pre-San	4E, 7G, 12.5G	Mallinckrodt
Bensulide + Oxadiazon	Bensumec 4LF	4E	PBI Gordon
	Goosegrass/Crabgrass Control	5.25G + 1.31G	Scotts
DCPA	Dacthal	75W	Fermenta
	Dacthal	5G	Lesco
Ethofumesate	Prograss	1.5E	Nor-Am
Fenarimol	Rubigan	50W	Elanco
Napropamide	Devrinol	50W, 5G	Stauffer
Oryzalin	Surflan	4AS	Elanco
Oxadiazon	Ronstar	50W, 2G	Rhone-Poulenc
Pendimethalin	Southern Weedgrass Control	2.45G	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

¹W = Wettable powder; DG = Water dispersible granule; L = Liquid; E = Emulsifiable concentrate; G = Granule.

Table 2. Tolerance of warm-season turfgrasses and tall fescue to pre-emergence herbicides.

Herbicide	Turfgrasses					
	Bahia	Bermuda	Centipede	St. Augustine	Tall Fescue	Zoysia
Atrazine	NR	I	T	T	NR	I
Benefin	T	T	T	T	T	T
Benefin + Oryzalin	T	T	T	T	T	T
Benefin + Trifluralin	T	T	T	T	T	T
Bensulide	T	T	T	T	T	T
Bensulide + Oxadiazon	NR	T	NR	NR	T	T
DCPA	T	T	T	T	T	T
Ethofumesate	NR	I	NR	NR	NR	NR
Napropamide	T	T	T	T	T	NR
Oryzalin	T	T	T	T	T	T
Oxadiazon	NR	T	NR	T	T	T
Pendimethalin	T	T	T	T	T	T
Pronamide	NR	T	NR	NR	NR	NR
Siduron	NR	NR	NR	NR	T	NR
Simazine	NR	T	T	T	NR	T

T = Tolerant; I = Intermediate tolerance, apply to dormant grass; NR = Not Registered for use.

move them into the zone of maximum weed seed germination (e.g. the upper one to two inches of the soil profile). Recommendations vary slightly among the different pre-emergence herbicides, but unless one-fourth to one-half inch of rainfall occurs within seven days, the herbicide should be irrigated in the top two inches of the soil profile.

Removal of heavy thatch by

cultivation (aerification, verticutting, etc.) prior to herbicide application will improve spray penetration through the turf canopy and increase herbicide contact with the soil. Cultivation after a pre-emergence herbicide application is not recommended since it may decrease the effectiveness of the herbicide.

In past years, there were only about four or five pre-emergence her-

bicides available for use on warm-season turf. However, 16 are now registered for use on Southern turf (Table 1).

The selection of which to use should be based on (a) turfgrass tolerance and (b) the weed species composition of a particular site. Herbicide selection based solely on cost may result in possible turf injury and/or the additional expense of a follow-up post-emergence herbicide treatment.

Turfgrass tolerance

Warm-season turfgrasses and tall fescue vary in their tolerance to pre-emergence herbicides (Table 2). For example, with the exception of spring greenup, centipede and St. Augustine have excellent tolerance to atrazine at all times of the year. Zoysia and bermudagrass are tolerant to atrazine when dormant, but may be discolored or injured if applications are made at other times of the year. Tall fescue is highly susceptible to severe injury from atrazine. Also, bahiagrass will be injured from pre-emergence applications of this herbicide.

Summer annual weed control

Crabgrass (large, smooth, Southern) and goosegrass are commonly found in Southern turf. With the exception of atrazine, pre-emergence herbicides applied in the spring months provide good to excellent crabgrass control (Table 3).

Goosegrass tends to sporadically germinate during the long growing season of the South and is more difficult to control than crabgrass. Oxadiazon, napropamide and bensulide + oxadiazon have provided high levels of goosegrass control in tests conducted in Georgia. Benfenin + oryzalin, oryzalin and the various formulations of pendimethalin have also provided fair to good control of goosegrass with a single application at recommended rates.

Split applications of oryzalin and pendimethalin are being evaluated in Georgia and usually have provided better goosegrass control than a single application.

Sandbur is an occasional problem in warm-season turf. It can be controlled with spring applications of benfenin + oryzalin, bensulide, napropamide, oryzalin, and pendimethalin.

Certain pre-emergence herbicides can also be selected that provide control of prostrate spurge and prostrate knotweed.

Winter annual weed control

Similar to summer annual weed control, pre-emergence herbicides vary

in their effectiveness on winter annual weeds. Bensulide has generally not provided the high level of annual bluegrass control that has been observed with other pre-emergence herbicides (Table 4).

Common chickweed and henbit are easily controlled by pre-emergence applications of benfenin, benfenin + oryzalin, oryzalin, or pendimethalin. Additionally, common chickweed can be controlled with DCPA, ethofumesate, napropamide, and pronamide. Herbicides that have effectively controlled parsley-piert are bensulide and oxadiazon. Napropamide is effective for spurweed control. Good to excellent corn

speedwell control can be obtained with benfenin, DCPA, napropamide, oxadiazon and pronamide. Atrazine and simazine provide effective pre-emergence or post-emergence annual bluegrass and winter annual broadleaf weed control (Table 4).

The wide time period of application for these herbicides offers tremendous scheduling flexibility for the professional warm-season turf manager.

Overseeded bermudagrass

On bermudagrass that is overseeded with annual or perennial ryegrass, fenarimol or ethofumesate may be used for annual bluegrass con-

Table 3. Summer annual weed control ratings for pre-emergence herbicides.

Herbicide	Crabgrass spp.	Goosegrass	Sandbur	Prostrate Spurge	Prostrate Knotweed
Atrazine	P	P	P	E	E
Benfenin	E	F	F	P	P
Benfenin + Oryzalin	E	F-G	G	L	L
Benfenin + Trifluralin	L	L	—	—	—
Bensulide	E	P	G	P	G
Bensulide + Oxadiazon	E	G	—	—	—
DCPA	E	F	F	P	G
Napropamide	E	G	G	—	L
Oryzalin	E	F-G	G	L	L
Oxadiazon	G	E	F	P	G
Pendimethalin	E	F-G	G	L	—
Siduron	G	P	—	P	P
Simazine	G	P	—	G	G

E = Excellent, $\geq 90\%$ control.

G = Good, 80 to 89% control.

F = Fair, 70 to 79% control.

P = Poor, <70% control.

L = Weed species is listed on the herbicide label, but has not been evaluated by the University of Georgia.

— = Weed response is not known.

Table 4. Winter annual weed control ratings for pre-emergence herbicides.

Herbicide	Annual Bluegrass	Common Chickweed	Henbit	Parsley-Piert	Spurweed	Corn Speedwell
Atrazine	E	E	E	E	E	E
Benfenin	E	G	G	P	P	E
Benfenin + Oryzalin	E	L	L	—	—	—
Benfenin + Trifluralin	L	—	—	—	—	—
Bensulide	F	P	P	E	P	P
DCPA	G	E	F	P	P	E
Ethofumesate	G	L	—	—	—	—
Fenarimol	G	—	—	—	—	—
Napropamide	G	E	P	P	E	E
Oryzalin	G	L	L	—	—	—
Oxadiazon	G	P	P	E	P	G
Pronamide	E	E	P	P	P	E
Pendimethalin	G	L	L	—	—	—
Simazine	E	E	E	G	E	E

E = Excellent, $\geq 90\%$ control.

G = Good, 80 to 89% control.

F = Fair, 70 to 79% control.

P = Poor, <70% control.

L = Weed species is listed on the herbicide label, but has not been evaluated by the University of Georgia.

— = Weed response is not known.

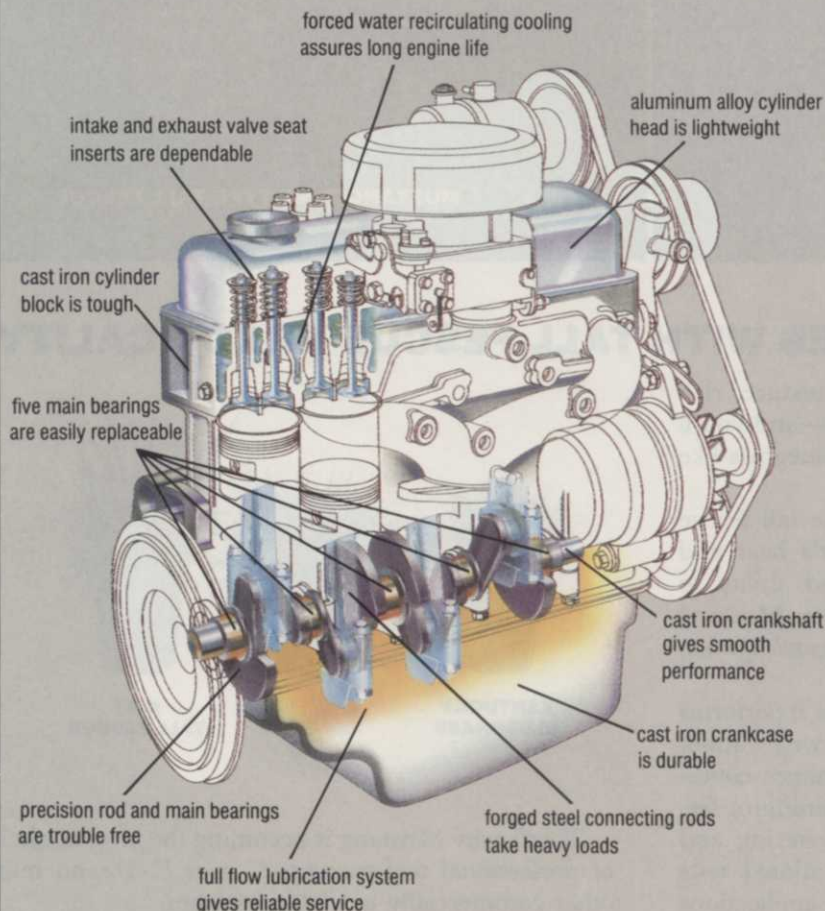
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tol. Ethofumesate should only be applied to bermudagrass that is completely dormant. Ethofumesate applications to bermudagrass that is not completely dormant have shown to delay greenup the following spring.

Spring applications of oryzalin, oryzalin + benefin and pendimethalin have shown to decrease the stand of overseeded ryegrass. In some years, overseeded ryegrass may persist for longer than the desired time period and provide competition to bermudagrass that is breaking dormancy. These herbicides are currently being evaluated for their possible role in improving the transition of a cool-season to a warm-season grass in overseeded golf course fairways.

Summary

Pre-emergence herbicides represent the backbone of the chemical weed control program. Post-emergence herbicide use will be necessary if perennial grass or perennial broadleaf weeds infest the site. However, pre-emergence herbicides offer the professional turf manager more than crabgrass, goosegrass and annual bluegrass control. Careful study of weed response charts or the herbicide label will enable the selection of a pre-emergence herbicide to control these annual grasses and certain annual broadleaf weeds.

WT&T

PRE-EMERGENCE HERBICIDE SOIL LONGEVITY

Short

benefin
DCPA
oxadiazon
pendimethalin
bensulide

Long

PROSTRATE AND SPOTTED SPURGE CONTROL

Poor

benefin
bensulide

Variable

oxadiazon
siduron

Excellent

DCPA
pendimethalin

CRABGRASS CONTROL

Good

benefin
bensulide
DCPA
oxadiazon
pendimethalin

FACTORS INFLUENCING PESTICIDE CONCENTRATIONS IN SOIL

- *photodecomposition
- *volatilization
- *leaching
- *microbial breakdown
- *insoluble complexes
- *absorption
- *dilution
- *mechanical removal