

CONTROL OF CRABGRASS AND OTHER WEEDS IN TURF

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Control of Crabgrass and Other Weeds in Turf

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Turf grass represents one of the largest crops in the State of Connecticut. While many crops are decreasing in acreage, the acreage of turf grass is steadily on the increase. Weeds continue to pose a large problem in the maintenance of lawn turf. This bulletin has been prepared to report continued research on lawn weed control and to integrate new information with that reported previously in bulletins¹, circulars, and scientific journals. The information from other states was obtained in part at the Northeastern Weed Control Conference, established for the exchange of results of research.

Where herbicides are mentioned in this bulletin, rates of application are given in terms of pounds of active herbicide per acre. Percentages of active ingredient in herbicides differ for products with different brand names, and are given on the labels. Multiplying pounds per acre by 0.37 gives the rate of active ingredient in ounces per 1000 square feet. With dry materials, the desired amount of commercial product is obtained by multiplying the desired amount of active ingredient by 100 and dividing by the percentage active ingredient.

Herbicides vary in their toxicity to people and pets. Some are very poisonous if taken internally, while others are less so. Relative toxicities of the herbicides mentioned in this bulletin refer to the degree of danger if they are taken internally. Like other chemicals, herbicides should be handled with caution and stored in a safe place, out of reach of children.

CONTROL OF CRABGRASS

Of all the weeds in turf, crabgrass (*Digitaria* spp.) is the most widespread and troublesome. Both large crabgrass (*D. sanguinalis*) and small crabgrass (*D. ischaemum*) are annual in habit, arising from seed each spring. Small crabgrass has smooth stems and a prostrate habit of growth, whereas large crabgrass has hairy stems and a more erect habit of growth. Under favorable conditions both species root at the nodes and spread.

Emergence of crabgrass usually starts in early to mid-May, depending largely upon soil temperature, and continues throughout the summer as long as soil moisture is favorable. Crabgrass is killed by frost, but the numerous seeds live over to reinfest lawns each season. Crabgrass may be controlled in lawns to a large extent by management (cultural control) and with herbicides.

¹ Bulletin 642 of this Station reports results obtained on the control of crabgrass through 1960.

Cultural Control of Crabgrass

Crabgrass seeds require both light and moisture for germination and early growth. Practices that favor the development of dense turf discourage crabgrass and other weeds by shading the soil. Conversely, practices that result in thin stands of turf grasses often lead to crabgrass infestations.

Control of crabgrass begins with the first seeding of a lawn. Fertilization and liming at seeding, according to need, are essential to establish thick stands of turf grasses. Late summer and fall seedings almost invariably result in thicker stands of turf in the spring than do spring seedings. Seeding in the spring as soon as the frost leaves the ground is preferable to seeding later, both from the standpoint of soil moisture as well as that of crabgrass control.

On an established lawn, no single practice is more important in controlling crabgrass than the proper adjustment of mowing height. Not only do bluegrass and fescue grasses respond better at higher cutting heights, but crabgrass is shaded out to a large extent. This has been demonstrated in experiments and in practice. In a test at Mt. Carmel, with 11 different turf grasses, raising the mowing height from 1 to 2 inches reduced stands of crabgrass from 33 to 12 plants per square foot (Table 2).

Watering a lawn may encourage crabgrass if it is done frequently and lightly. Watering only when necessary for the benefit of the turf grasses, and then heavily, is less likely to encourage crabgrass.

Fertilizing, according to need and at the proper time, can greatly aid in control of crabgrass. Need can be determined by soil tests. The time to fertilize is when the turf grasses will be benefited, but crabgrass will not. Thus, fall and spring fertilization before crabgrass emerges tend to thicken the turf and so discourage crabgrass. Fertilization during periods when crabgrass is growing vigorously (June and July), and the turf grasses are relatively inactive, often encourages crabgrass.

Disease and insect controls also are important in crabgrass control because any damage to turf resulting from these pests often results in crabgrass invasion. The control of turf diseases is discussed in Circular 208 and of insects in Circular 212 of this Station.

Pre-emergence Control of Crabgrass With Herbicides

Pre-emergence control of crabgrass involves the application of a residual herbicide to the soil before crabgrass emerges in the spring. These herbicides kill crabgrass in its early stages of germination and growth. Excellent results with a few materials of this type were obtained at this Station and elsewhere during 1960. In 1961 at least seven different compounds, sold under many trade names, were on the market for the pre-emergence control of crabgrass. The number is expected to increase.

Our 1961 tests were designed to obtain additional information about the most promising pre-emergence materials. Several experiments at different locations in Connecticut involved the application of pre-emergence herbicides to newly seeded and established turf grasses. Most of the materials were applied with a lawn spreader calibrated for each material and rate. Low and high rates of application were commonly used. In some cases the low rates of application were those suggested by the herbicide manufacturers and correspond to amounts used by homeowners. Information was obtained on the control of crabgrass and other weeds; effects of

herbicides on turf grasses, certain nursery plantings, and earthworms; residual effects of herbicides during the second season after treatment; and effects of annual application of herbicides on crabgrass and turf.

Comparative effects of herbicides

Except for Pax, the rates of application are given in terms of active ingredient per acre, and except with dacthal and chlordane, the lowest rates given in Table 1 for each compound are the rates suggested on the herbicide label.

Three arsenicals were tested: (a) an arsenical complex containing arsenous oxide and lead arsenate, plus heptachlor for insect control and ammonium sulfate fertilizer (Pax), (b) tri-calcium arsenate, and (c) calcium propyl arsonate.

Table 1. Crabgrass control and injury to established turf with pre-emergence applications of herbicides in Connecticut, 1961

Herbicide	Rate active ingredient lbs./A	Percentage control of crabgrass at different locations and dates of application				Injury to stands of mixed turf grasses ²
		Windsor 5/4/61	Mt. Carmel 10/10/60	4/27/61	New Haven 4/29/61	
Tri-calcium arsenate	370	86	85	91	100	Moderate thinning of Colonial bentgrass
	740	95	98	99	....	"
Arsenical complex (Pax)	880 ¹	31	32	46	95	None
	1760 ¹	89	64	86	....	"
Calcium propyl arsonate	44	85	....	73	82	Slight thinning of fescue grasses
	88	80	....	80	....	"
Dacthal	7.5	66	87	96	....	None
	11.25	....	....	....	99	"
	15	93	97	98	....	Slight thinning of Colonial bentgrass
Diphenatril	30	99	....	....	90	"
	60	99	....	....	....	"
Chlordane	70	91	86	88	90	None
	140	98	89	95	....	"
Zytron	15	98	88	92	100	"
	30	99	93	96	....	Slight thinning of mixed turf

¹ Rate of Pax per acre.

² Turf mixtures including Kentucky bluegrass, creeping red and Chewings fescue, and Astoria Colonial bentgrass, established for one year or more.

Pax, referred to in this bulletin by its trade name because it is the only arsenical complex of its type that is commonly sold in Connecticut, provided poor control of crabgrass in our 1960 tests and excellent control at only one location in 1961. Variable results were obtained throughout the Northeast as well as in Connecticut.² Even where *Pax* has controlled crabgrass satisfactorily, the turf sometimes has been injured, albeit slightly in most cases. It would appear that rates of *Pax* over 1000 lbs. per acre are necessary for satisfactory control of crabgrass in many situations. Results from other states indicate that fall applications of *Pax* are as effective as spring applications, but the results from our test did not support this idea.

Residual control of crabgrass the year after treatment with *Pax* was negligible in our tests and those in Massachusetts. Treatment of turf for 2 years in succession, however, resulted in good control of crabgrass but caused significant injury to the turf (30 per cent thinning).

If turf grasses are seeded on the soil surface within 2 to 3 months after application of *Pax* germination may be poor. Applications of *Pax* a month after seeding also have been injurious to turf grasses.

Pax is effective against chickweed and annual bluegrass, and certain soil insects, including beetle grubs. It also reduced the earthworm population by 89 per cent in one test.

The effect of *Pax* on trees and ornamental plants is not known. Being an arsenical, it is poisonous to warm-blooded animals and should be watered in after application to eliminate the hazard.

Calcium propyl arsonate was included in our tests for the first time in 1961. Crabgrass control at the dosage suggested on the bag (44 lbs. per acre) ranged from 73 to 85 per cent when the material was applied before crabgrass emergence. Other tests in the Northeast indicate that calcium propyl arsonate is much more effective when applied while crabgrass is in its early stages of growth (1 to 4 leaves).

Calcium propyl arsonate caused 8 to 15 per cent thinning of fescue-bluegrass turf in our tests. In tests elsewhere, it occasionally has injured fescue grasses, but has not significantly injured bluegrass.

Calcium propyl arsonate has caused only slight thinning on newly seeded or seedling turf grasses. However, treatments at the time of seeding on bare ground did not control crabgrass, whereas treatments applied in May, a month after seeding, when crabgrass was emerging, provided good control of crabgrass.

The effects of calcium propyl arsonate on trees and ornamentals are not known. Unlike calcium arsenate, it is not highly toxic to warm-blooded animals, but because arsenic accumulates in the body over long periods, precautions should be taken in its storage and use.

Tri-calcium arsenate, often referred to as calcium arsenate, provided 85 to 100 per cent control of crabgrass in our 1960 and 1961 tests when applied at rates suggested on the herbicide label. In other areas crabgrass control varied from poor to excellent. Good control of crabgrass usually resulted when rates were 370 lbs. per acre or more. Spring applications of calcium arsenate have been slightly more effective than fall applications and March or April applications have been more effective than May appli-

cations. Applying a phosphorus fertilizer along with the calcium arsenate resulted in very poor control of crabgrass in a Pennsylvania test, presumably because phosphorus and arsenic substitute for each other to some extent in the plant.

In our tests, calcium arsenate thinned Colonial bentgrass in 1961 and Kentucky bluegrass in 1960. Occasionally these grasses and fescues are injured, usually only slightly but sometimes severely. In one experiment, a single application at 555 lbs. per acre in 1960 (1½ times the suggested rate) was still thinning turf moderately in 1961. Low soil fertility may increase the hazard of turf injury with this material.

Spring applications of calcium arsenate have provided control of crabgrass for a second season, the extent of control varying somewhat with the rate of application. An application of calcium arsenate at 555 lbs. per acre in 1960 controlled crabgrass perfectly during both 1960 and 1961 in one experiment. Repeat applications for 2 years in succession at normal rates, which does not appear necessary or advisable, resulted in slight thinning of turf. A lowered dosage the second year is more economical and safer for turf grasses.

In reseeding thin turf, the long residual effects of calcium arsenate must be considered. Although reseeding may be hazardous for 2 months after applying calcium arsenate, fall seeding after spring treatment is safe, especially if the soil is raked or otherwise disturbed.

Calcium arsenate also is injurious to turf grasses when applied at the time of seeding or shortly thereafter. Treatment, a month after seeding, thinned bluegrass, red fescue, and bentgrass about 15 per cent without providing good control of crabgrass.

In addition to crabgrass, calcium arsenate controls chickweed, henbit, and annual bluegrass (see *Weeds not controlled by 2,4-D*), and certain soil insects, including beetle grubs. Earthworms were reduced by about 82 per cent in our calcium arsenate plots.

At rates used for crabgrass control, calcium arsenate may be injurious to ornamental plants and trees when applied around their roots. Since it is poisonous to warm-blooded animals as well, care should be taken in its application, and watering into the turf should be considered.

Diphenatril (diphenyl acetonitrile) was tested in Connecticut for the first time during 1961. In our trials diphenatril provided 90 to 99 per cent control of crabgrass with slight injury only to Colonial bentgrass. At 30 lbs. per acre, the manufacturer's suggested rate, diphenatril has provided crabgrass control throughout the Northeast ranging from fair to excellent. Little or no injury to established turf grasses has been observed with this compound by other workers. Diphenatril seems to work best when applied soon before or at the time of crabgrass emergence. Applications in early May have been more effective in the Northeast than applications in March or early April.

Like most pre-emergence crabgrass killers, diphenatril is more injurious to turf seedlings if applied before, rather than after, seedling emergence. It is not safe to seed turf grasses for periods of 5 or more weeks following diphenatril application. Even with double applications in the spring, however, no effect was observed on turf seeded in September.

When diphenatril was applied in early May on emerged turf seedlings (30 days after seeding), Merion bluegrass and creeping red fescue were temporarily thinned about 25 per cent, but common Kentucky blue-

² Information obtained from the Northeastern Weed Control Conference. Copies of the Proceedings of the Northeastern Weed Control Conference are obtainable from Dr. John Meade, Department of Agronomy, University of Maryland, College Park, Md.

grass and Seaside bentgrass seedlings were uninjured. Almost 90 per cent control of crabgrass was obtained in that test. Other reports indicate that applications of diphenatril at 4 to 5 weeks after seeding have little effect on turf grasses. Diphenatril, therefore, may prove to be useful on spring seedlings, where very early seeding is possible.

Diphenatril is reported to be safe for use around trees, shrubs, and herbaceous flowering plants. It is also relatively non-toxic to warm-blooded animals. No effect of diphenatril on earthworms or beetle grubs in turf was observed even at the high rate of 60 lbs. per acre.

Chlordane, at a rate suggested by the manufacturer (60 lbs. per acre), has provided variable control of crabgrass in tests throughout the Northeast. At that dosage in 1960, we obtained only 55 per cent control of crabgrass. At 70 lbs. per acre in 1961, chlordane controlled 86 to 91 per cent of the crabgrass. Even higher rates may be required for consistent control of crabgrass. Fall applications of chlordane have been as effective as spring applications, but those in early spring have been more effective than those made just before crabgrass emergence.

Granular chlordane has not injured turf even at rates of 140 lbs. per acre. Emulsifiable chlordane has been less effective for crabgrass control and occasionally has injured turf.

At 60 lbs. per acre, spring applications of chlordane appear to have little effect on crabgrass populations the following season. At rates of 80 lbs. per acre in Massachusetts and 120 lbs. per acre in our tests, chlordane provided 60 to 70 per cent control of crabgrass for a second season. Repeated applications at 60 to 70 lbs. per acre, two seasons in a row, provided 86 per cent control of crabgrass and did not injure the turf.

Chlordane is less harmful to newly seeded and seedling turf grasses than most other crabgrass killers. Unfortunately applications on bare ground after seeding have not controlled crabgrass. However, reseeding thin turf before or after application of chlordane presents no problem.

Chlordane is effective against certain soil insects at a fraction of the dosages required for control of crabgrass. Earthworms also were reduced by 89 per cent in our chlordane plots. Chlordane is much less toxic to warm-blooded animals than the arsenicals and is not harmful to ornamental plants and trees.

Dacthal (dimethyl tetrachloro teraphthalate) continues to be one of the most effective pre-emergence crabgrass killers. In 1960 dacthal provided excellent control of crabgrass in our tests with no injury to turf. At rates of 7½ to 15 lbs. per acre in 1961, we obtained good to excellent control of crabgrass except at Windsor where the rate of 7½ lbs. per acre was insufficient to provide satisfactory seasonal control. However, at the manufacturer's suggested dosage of 11 lbs. per acre, most workers throughout the Northeast have obtained good to excellent control of crabgrass over the past three seasons. Fair or poor control of crabgrass was obtained in a few tests, substantiating the fact that no herbicide yet discovered works perfectly in every situation. Spring applications shortly before crabgrass emergence usually have been more effective than fall or early spring applications.

We have observed no severe injury with dacthal in 11 different established turf grasses. Colonial bentgrass was thinned in one test, and other workers have occasionally observed slight to moderate injury in fescue and bent grasses. This injury usually is not permanent, especially

in turf mixtures where bluegrass tends to fill in. The wettable powder form of dacthal appears to have the same effects on crabgrass and on turf as the granular form.

Dacthal may provide some residual control of crabgrass for a second season. Applied at 10 lbs. per acre in April 1960, dacthal provided about 70 per cent control of crabgrass in 1961. Repeating the treatments both years resulted in about 99 per cent control of crabgrass with no turf injury. Residual control of crabgrass a second season after dacthal application also was observed in Ontario, Canada, but not in Massachusetts, during 1961.

Dacthal is more toxic to newly seeded turf grasses if applied before seeding than if applied after the grasses have emerged. According to reports from Pennsylvania and Rhode Island, stands of turf grasses seeded within 2 months after application of dacthal may be moderately reduced. However, spring treatments of dacthal present no apparent hazard to turf grasses seeded in the fall.

Tests at this Station and elsewhere indicate that certain grasses are tolerant of dacthal applied a month or more after seeding. Dacthal applications a month after seeding, as crabgrass was germinating and the turf grasses were 1 to 2 inches high, provided 86 to 95 per cent control of crabgrass with only 10 to 12 per cent temporary thinning of Kentucky bluegrass and creeping red fescue and no thinning of Seaside creeping bentgrass. Such a treatment could be practical, however, only if the turf grasses are seeded early enough in the spring to allow seedling growth and treatment before crabgrass emerges.

In addition to crabgrass, dacthal controls certain other annual grasses and broadleafed weeds. It is safe for use on many woody and herbaceous plants and may prove to be useful as a general purpose weed killer in shrub and border plantings around the home. Some common weeds such as smartweed (*Polygonum* spp.) and ragweed (*Ambrosia artemisiifolia*) are, however, resistant to dacthal.

Dacthal has no known insecticidal value and has no apparent effect on earthworm populations in turf. It is relatively non-toxic to warm-blooded animals and constitutes no hazard in handling or storage.

Zytron (0-2,4 dichlorophenyl 0-methyl isopropylphosphoramidothioate), like dacthal, has provided consistently good control of crabgrass at several stations throughout the Northeast over the past few years. As with dacthal, unsatisfactory results were obtained in a few tests. We obtained excellent results with zytron in 1960. At 15 lbs. per acre (the rate suggested by the manufacturer) in 1961, we obtained 88 to 100 per cent control of crabgrass with no injury to 11 common turf grasses grown in pure stands.

Timing of application is less critical with zytron than with most other pre-emergence materials. Fall applications of zytron have been about as effective as spring applications, and applications during crabgrass emergence or early post-emergence (1 to 2 leaves) also have been effective. On seedling crabgrass, however, the emulsifiable form of zytron is more effective than the granular form.

Bluegrass turf and clover appear to be stimulated by zytron. Zytron-treated turf grasses often are darker green in color than untreated grasses. Although we have observed injury to established turf grasses only at high rates of zytron, other workers occasionally have observed slight to moderate

injury in bent and fescue grasses at normal rates of application. In stands of mixed grasses that include bluegrass, injury to the bents and fescues may go unnoticed because of the spreading habit of bluegrass.

Zytron at 15 to 20 lbs. per acre has provided some control of crabgrass for a second season. Applied at 20 lbs. per acre in April 1960, zytron provided 80 per cent control of crabgrass in 1961. Although applications at 20 lbs. per acre both years caused no injury to the stands of mixed turf, it is likely that a lower dosage would suffice the second year.

Although safe for established turf, zytron is toxic to germinating seed and small seedlings of turf grasses. It may not be safe to seed grasses on the surface of zytron-treated turf for 3 months after treatment. Fall seeding, following spring treatment, should present no problems, but spring seeding after fall treatment is questionable.

In tests at some Stations, zytron severely injured turf seedlings when applied 8 weeks or so after seeding. We found that seedling grasses (bent, fescue, and bluegrass), treated with zytron a month after seeding, were thinned from 10 to 20 per cent. Injury to seedling red fescue was more serious than injury to Merion and common Kentucky bluegrass, and Seaside bentgrass.

At rates required for the control of crabgrass, zytron also controls many other weeds including knotweed, spotted spurge, and chickweed (See *Weeds not controlled by 2,4-D*).

Zytron appears to be safe for use around certain woody and herbaceous ornamental plants. Iris is easily injured, however. Zytron at 15 lbs. per acre has some insecticidal value for the control of beetle grubs but appears to have no appreciable effect on earthworm populations. A dosage of 30 lbs. per acre reduced the earthworm population 52 per cent. Zytron also is relatively non-toxic to warm-blooded animals.

Dipropalin, *trifluralin*, and *bandane* are relatively new compounds that have shown promise for the pre-emergence control of crabgrass in turf both in our tests and those of others. Further investigation of these materials is necessary before they can be properly assessed for usefulness under conditions in Connecticut.

Dipropalin (N, N-di-n-propyl-2,6-dinitro-4 methyl aniline) provided 99 per cent control of crabgrass in our single 1961 trial at 5 and 10 lbs. per acre. About 15 per cent thinning of the turf was obtained with the higher rate. In tests throughout the Northeast, dipropalin at 8 lbs. per acre provided good control of crabgrass and little or no injury to turf. Crabgrass control was variable at lower rates.

Dipropalin is injurious to germinating seed of turf grasses but has been applied 4 weeks or more after seeding without serious injury to bluegrass.

Both dipropalin and trifluralin are reported to be safe for use around trees, shrubs, and many perennial and annual herbaceous plants. They are relatively non-toxic to warm-blooded animals.

Trifluralin (N, N-di-n-propyl-2,6-dinitro-4 trifluoromethylaniline) is closely related to dipropalin but is more active. In our test, trifluralin at 3 or 6 lbs. per acre provided 99 per cent control of crabgrass. It thinned the turf, however, 15 per cent at 3 lbs. per acre and 35 per cent at 6 lbs. per acre. Tests elsewhere indicate good to excellent control of crabgrass and little or no turf injury with trifluralin at 2 lbs. per acre.

Trifluralin treatment in the spring may injure turf grasses seeded 2 months or more after treatment, but fall seedings are possible on soil treated in the spring. Trifluralin also is reported to be injurious to turf grasses when applied 2 to 3 months after seeding.

Bandane (Polychlorodicylopentadiene isomers) is chemically similar to chlordane. In our tests it provided excellent control of crabgrass at 40 lbs. per acre with no injury to established turf. Most testing of bandane in the Northeast during 1961 was at lower rates (10 to 30 lbs. per acre). At 30 lbs. per acre crabgrass control ranged from 65 to 97 per cent (fair to excellent) with only slight discoloration or no turf injury observed. The granular form of bandane was more effective than the emulsifiable form in some tests.

Bandane is relatively harmless to seedling turf grasses. Applications 2 to 4 weeks after seeding did not severely injure turf grasses in Rhode Island and Pennsylvania. Treatments 2 to 4 weeks before seeding also had no severe effect on stands of turf. Whether bandane will control crabgrass when applied on bare soil remains to be determined.

Bandane, like chlordane, is relatively non-toxic to warm-blooded animals.

Factors affecting results with herbicides

Cultural practices can greatly influence the results obtained with pre-emergence herbicides. The influence of mowing height on the effectiveness of zytron and dacthal is shown in Table 2. Increasing the cutting height from 1 to 2 inches reduced the area covered by crabgrass and the number of crabgrass plants in the dacthal- and zytron-treated plots. Irrespective of the herbicide treatments, doubling the cutting height reduced the crabgrass by two-thirds. In some of the dacthal plots, especially, cutting height made the difference between satisfactory and unsatisfactory control of crabgrass. Evidence is given here that low cutting height not only encourages greater infestations of crabgrass, but also subjects certain pre-emergence killers to a more severe test. It can be expected that higher dosages of herbicide will be required for satisfactory control under more severe conditions.

Even distribution of herbicide over the soil surface is essential for best results with pre-emergence crabgrass killers. Failure to overlap

Table 2. Effects of mowing height on crabgrass control with herbicides

Herbicides	Rate active ingredient lbs./A	Mowing height in inches	Crabgrass plants per sq. ft.	Percentage control of crabgrass ¹
None	....	1	32.7	0
		2	12.4	62
Dacthal	11.25	1	3.8	84
		2	1.0	97
Zytron	15	1	0.9	94
		2	0.3	99

¹ Percentage control based on area covered by crabgrass in treated plots relative to untreated plots at 1-inch mowing height.

slightly with lawn spreaders often is responsible for poor results. Leaving only a 2-inch untreated strip allows crabgrass to escape action of the herbicide. Applying half the material in one direction and half in the other can provide good distribution.

The activity of pre-emergence herbicides may be decreased by soil disturbance that mixes the herbicide with the soil or changes the distribution of the herbicide on the soil surface. Thus, raking should be done before, not after, herbicide application. Spring raking of lawns treated in the fall for the control of crabgrass could be detrimental if the soil is disturbed.

Certain herbicides have provided good control of crabgrass when applied in the fall or winter (zytron, chlordane, calcium arsenate). Fall treatments are effective because the herbicide is held in the upper surface of soil and its breakdown is prevented by the low temperatures during the fall and winter. Applications late in the fall then, should prove to be more effective than applications early in the fall, but this has not been tested. Because of the long time between fall application and emergence of crabgrass, and the possible losses of herbicide activity, it would appear that fall applications offer a greater risk of failure and no particular advantage over spring applications.

The importance of watering pre-emergence herbicides into the soil after application has been difficult to demonstrate in Connecticut, where spring rains usually are frequent. Where granular materials are applied just prior to expected crabgrass emergence, however, it makes good sense to water the materials lightly into the soil so that they are activated. Heavy watering may be detrimental. With Pax and calcium arsenate, watering is a necessary precaution where children and pets abound.

Since most pre-emergence herbicides are toxic to germinating seeds of turf grasses, care must be taken in planning when to reseed. Reseeding may be important in thin turf where the mere control of crabgrass may leave sparse areas that other weeds tend to invade.

With spring-applied treatments, reseeding in the fall eliminates all of the problems encountered with spring seedlings, regardless of the herbicide used. Reseeding in the spring is hazardous for some time following the application of most herbicides except chlordane, bandane, and calcium propyl arsonate. However, treatments a month or so after reseeding look promising with materials such as dacthal, diphenatril, and calcium propyl arsonate, provided the treatments are timely with respect to crabgrass development (See *Comparative effects of herbicides*). Except with calcium propyl arsonate, this would require seeding as soon as the frost leaves the ground and perhaps no later than the first week in April.

Post-emergence Control of Crabgrass With Herbicides

Herbicides can be used to control crabgrass after it has emerged. The advantage of post-emergence treatment is that only infested areas are treated and not usually the whole lawn. The drawback, of course, is that crabgrass does not come up all at one time and, under favorable conditions, will emerge throughout the season.

Several of the herbicides that are used primarily for pre-emergence control of crabgrass also have looked promising when applied at crabgrass emergence and up to the 1- to 2-leaf stage. These include zytron, dacthal, diphenatril, and calcium propyl arsonate. The emulsifiable form of zytron

and calcium propyl arsonate appear particularly promising for this use. Calcium propyl arsonate is reported to be effective up to the 4- or 5-leaf stage of crabgrass development. These materials all were effective with a single application (See *Comparative effects of herbicides*).

Other herbicides that are effective against crabgrass in its seedling stages (2 to 5 leaves) include DMA (disodium methyl arsonate), AMA (ammonium methyl arsonate), CMA (calcium methyl arsonate), PMA (phenyl mercury acetate), and KOCN (potassium cyanate). At least one repeat application usually is required with all of these materials, and discoloration and turf injury sometimes result. Injury has been more frequent at high temperature (85°F.) or where three applications or high rates of application were used. PMA is especially injurious to Merion bluegrass. All of these materials are poisonous to warm-blooded animals and care should be taken in their storage and use.

CONTROL OF OTHER WEEDS

The numerous weeds that invade turf include those that are annual, biennial, or perennial in habit. Annuals and winter annuals complete their life cycle in one year, arising from seeds each year. Many of the annual weeds found in newly seeded turf will not be found the second year. Biennials take 2 years to complete their life cycle, storing food in their roots the first year and flowering the second. Perennials live over from year to year, reproducing from seeds and rootstocks. Perennial weeds, with their extensive root systems, often require repeated treatments for eradication.

Cultural Controls

The use of clean, high quality grass seed eliminates many of the annual and perennial weed problems in turf. Alta (or Kentucky 31) fescue, a desirable backyard grass, is often thoughtlessly sown in places where a fine-textured lawn is desired. Orchardgrass, another coarse bunch grass, clover, and numerous weed seeds are often found in less expensive grades of grass seed.

Cultural controls that are used against crabgrass also serve to control other weeds. Most weeds are discouraged by thick stands of turf. Clover is discouraged in turf by nitrogen fertilization, and sheep sorrel is discouraged by liming.

Topdressing a lawn with soil from weed-infested areas often is responsible for many perennial weed problems in turf. So called "bottom land" of supposedly rich loam often is infested with tubers of nutgrass (*Cyperus* spp.), a weed for which there is no practical control short of complete lawn renovation and expensive fumigation. Topsoil from cultivated cropland is more apt to be free of such pests. In many cases, however, the additional soil is negligible in amount and influence while the hazard of long-time weed problems associated with bringing in the soil is great. Screening of imported soil can be of some value, discarding all roots and tubers that are found.

Despite the best known management practices, weeds can be expected to recur in lawn and turf areas. Many of these are controlled by occasional hand weeding, but for some, herbicides may be the only practical means of control.

Control With Herbicides

Because weeds differ widely in their characteristics, no single herbicide or method of treatment is successful against all weeds.

From the standpoint of their effects on turf grasses, herbicides may be classified as selective or non-selective.

Selective herbicides

Selective herbicides are those herbicides that kill weeds in turf without killing the established turf grasses.

The best known member of this group is 2,4-D (2,4-dichlorophenoxy acetic acid), a relatively inexpensive and very effective killer of many annual and perennial broadleaved weeds. 2,4-D is commonly used at rates of 1/2 to 1 1/2 lbs. of acid equivalent per acre, but bentgrasses and clover often are injured at the higher rates. Best results are obtained with 2,4-D when the weeds are actively growing, but fall applications have the added advantage of allowing the turf to fill in before spring and crabgrass emergence.

Because of its high toxicity to plants at very low dosages, 2,4-D must be used with extreme caution. Many garden plants are ruined each year by misuse of 2,4-D. Flowers, vegetables, trees, and shrubs are sensitive to vapors and sprays of 2,4-D. For this reason, fall and spring applications are safer than applications during the summer.

To prevent injury to plants from vapor, non-volatile amine or low-volatile ester formulations of 2,4-D are preferred for home use. To prevent drift injury to desirable plants, spray applications of 2,4-D should be made when there is no wind, using a coarse spray, not a fine mist. Unless weeds are widespread throughout a lawn, spot treatments with a paint brush or other applicator are practical and less hazardous than broadcast spray treatment. Wax bars containing 2,4-D can be used behind the lawn mower and granular formulations of 2,4-D also are available. On hard-to-kill species, however, best results can be expected from liquid applications.

Equipment used for applying 2,4-D should be used only for lawns, and the compound should be stored in tight containers away from other garden materials. 2,4-D has a very low toxicity to warm-blooded animals.

Silvex (2,4,5-trichlorophenoxy propionic acid) is closely related to 2,4-D, but it controls many weeds that are resistant to 2,4-D. It is used at rates of 1/2 to 1 1/2 lbs. of acid equivalent per acre. *Silvex* is much more injurious to bentgrasses and clover than 2,4-D. Bluegrasses are more tolerant than bentgrasses, and fine-leaved fescues are intermediate in tolerance. *Silvex* should be used with the same precautions as 2,4-D.

Banvel D (2 methoxy-3,6 dichlorobenzoic acid), a new herbicide, looks very promising for the control of certain weeds in turf. It is effective at rates of 1 to 2 lbs. per acre. We, and others as well, have observed no injury to Colonial bentgrass, bluegrass, and red fescue with *Banvel D* in 1961 trials. However, it does kill clover. Since *Banvel D* has not been thoroughly investigated, it should be used with caution. It may injure trees and ornamental plants if carelessly applied.

Endothal (3,6 endohexahydrophthallic acid) is effective against certain weeds at rates of 1/2 to 4 lbs. per acre. Browning of turf grasses often occurs with *endothal*, especially at high rates and at temperatures over 85°F. Applications in the spring are less apt to injure the turf.

Other selective herbicides include a few of the materials that are used for the pre-emergence control of crabgrass (*zytron*, *dacthal*, calcium arsenate, *Pax*, etc.).

Non-selective herbicides

Non-selective herbicides include those materials that kill existing turf grasses as well as weeds.

Soil fumigants are a specialized type of non-selective herbicide. Fumigants are used to kill plants, weeds, seeds, tubers, and rootstocks in soil before a lawn is seeded. They also may be used to treat soil that is used for topdressing a lawn. Fumigation is expensive where the whole lawn is treated. Fumigants that are useful for turf areas include calcium cyanamide, *SMDC*, *DMTT*, and methyl bromide.

Calcium cyanamide is applied at a rate of 13 lbs. per cubic yard of soil to be used for topdressing. If kept moist, the soil can be spread and seeded within 6 weeks. As a pre-seeding treatment, calcium cyanamide is spread uniformly over the prepared seed bed at a rate of 50 to 75 lbs. per 1000 sq. ft. It is then worked into the top 2 or 3 inches and watered heavily. Seeding must be delayed for 4 to 6 weeks after treatment. Best results are obtained if the soil surface is kept moist after treatment.

When applied according to label directions, *SMDC* (sodium N-methyl dithiocarbamate dihydrate), *DMTT* (3,dimethyltetrahydro-1,3,5,2-4 thiaziazine-2-thione), and *methyl bromide* are effective in sterilizing soil of weeds, seeds, tubers, and rootstocks as well as insects and disease-producing organisms. *SMDC* and *DMTT* are drenched into the soil; methyl bromide, a poisonous gas, is released under a sealed plastic cover. With all three, the soil must be worked to a depth of at least 6 inches for best results. At soil temperatures of 60° F. or above, seeding is safe 1 to 3 weeks after treatment. Methyl bromide is poisonous and impractical for use around the home.

Other non-selective herbicides for weed control in turf include two materials, *dalapon* and *cacodylic acid*, that are applied on the existing weeds and turf. These herbicides may be used as spot treatments to avoid hand digging of weeds; they also are suitable for turf renovation, where the existing weeds and grass are killed and new grass is seeded in. A special use is the killing of grass in and along sidewalks.

Dalapon (2,2 dichloropropionic acid) kills annual and also many perennial grasses at rates of 5 to 8 lbs. per acre. To kill broadleaved weeds as well, it is necessary to apply 2,4-D with the *dalapon*. Actively growing plants are killed most easily. A period of at least 4 weeks must be allowed between *dalapon* treatment and reseeding.

Cacodylic acid (dimethyl arsenic acid), at rates of 10 to 15 lbs. per acre, kills many annual and some perennial weeds and grasses. Repeated applications are required for some weeds. Best results are obtained when the soil is moist and the weeds are actively growing. Since it is possible to reseed a few days following application of *cacodylic acid*, this herbicide

has shown promise for use in the renovation of weedy turf. Although it is a relatively non-toxic arsenical, care should be taken in its storage and use.

Weeds and Their Control

Some of the most common weeds in turf are readily controlled by 2,4-D, while others are resistant to this herbicide.

Weeds controlled by 2,4-D

Weeds controlled by 2,4-D in single or repeated applications include many broadleaved weeds as well as the following:

Common Name	Scientific Name	Habit of Growth
wild carrot	<i>Daucus carota</i>	biennial
cinquefoil	<i>Potentilla</i> spp.	perennial
fleabane	<i>Erigeron</i> spp.	annual
dandelion	<i>Taraxacum officinale</i>	perennial
plantain	<i>Plantago</i> spp.	perennial
ragweed	<i>Ambrosia artemisiifolia</i>	annual
wild onion and garlic	<i>Allium vineale</i> and <i>A. canadense</i>	perennial
shepherds purse	<i>Capsella bursa-pastoris</i>	winter annual
hawkweed	<i>Hieracium</i> spp.	perennial
round-leaved mallow	<i>Malva rotundifolia</i>	biennial

Weeds not controlled by 2,4-D

Weeds not controlled by 2,4-D require hand removal or treatments with other herbicides.

Knotweed (*Polygonum aviculare*), a creeping annual that thrives in compacted turf on edges of drives and walks, has been controlled by pre-emergence treatments in April with zytron for crabgrass control. Silvex, 2,4-D, banvel D, and the emulsifiable form of zytron also are reported to be effective against young knotweed seedlings.

Wood sorrel (*Oxalis* spp.), a perennial weed with leaves that closely resemble clover but are lighter in color, and spotted spurge (*Euphorbia maculata*), a creeping annual with reddish stems and milky sap, have been controlled by pre-emergence treatment with granular zytron or post-emergence treatment with emulsifiable zytron. Silvex also controls spotted spurge.

The chickweeds commonly occurring in turf include common chickweed (*Stellaria media*), an annual or winter annual; grass-leaved stitchwort (*Stellaria graminea*), a perennial; and mouse-eared chickweed (*Cerastium vulgatum*), also a perennial. Post-emergence sprays in late spring of zytron, banvel D, and silvex control all three species. Post-emergence granular applications of calcium arsenate and Pax in the spring or fall also provide some control. Pre-emergence applications in April of zytron and dacthal for crabgrass control have controlled common chickweed.

The speedwells (*Veronica* spp.) are creeping perennial weeds that are troublesome in lawns. Silvex, endothal, and emulsifiable zytron are reported to be effective against them.

Ground ivy or gill-over-the-ground (*Nepeta hederacea*), a perennial with creeping, 4-angled stems and purple flowers, has been controlled with banvel D or repeated applications of silvex.

Henbit (*Lamium amplexicaule*), a winter annual or biennial, also has 4-angled stems and purple flowers, but is more erect than ground ivy. It has been controlled by pre-emergence applications of zytron or calcium arsenate in the fall or post-emergence applications of banvel D or emulsifiable zytron in the spring.

Yarrow or milfoil (*Achillea millefolium*) is recognized by its hairy, finely-dissected leaves which resemble carrot tops and occur in clumps in turf. It is a perennial that is difficult to control with 2,4-D or silvex but may be controlled with banvel D.

Sheep sorrel (*Rumex acetosella*), a perennial with leaves shaped like arrowheads, has been controlled with 2,4-D or silvex plus liming, or banvel D. Calcium arsenate for crabgrass control or liming alone may reduce infestations of this weed.

Nimblewill (*Muhlenbergia schreberi*) is a creeping perennial grass that matures early in the fall, leaving ugly browned patches. Two applications of zytron at 15 lbs. per acre during a single growing season are needed to control this weed.

Annual bluegrass (*Poa annua*) looks very much like perennial bluegrass but has a lighter cast. It germinates in the late summer, fall, and spring, and usually dies out during hot, dry periods in the summer. Calcium arsenate and Pax, applied in the spring or fall for crabgrass control, are effective in lawn turf. Repeated applications of endothal at ½ lb. per acre in the spring also are reported to be effective. Pre-emergence applications of zytron at 15 lbs. per acre and dacthal at 10 lbs. per acre, in July or August, look promising for use on putting greens but require further investigation. Post-emergence sprays of zytron are reported to be effective against seedling annual bluegrass.

Certain other annual grasses that are occasionally troublesome in turf are controlled by pre-emergence crabgrass killers. Goosegrass (*Eleusine indica*) and foxtail (*Setaria* spp.) are controlled by zytron, dacthal, diphenatril, and dipropalin. Foxtail also is controlled by post-emergence application of DMA. Barnyard grass (*Echinochloa crusgalli*) is controlled by zytron, dacthal, dipropalin, trifluralin, and diphenatril. Bentgrasses (*Agrostis* spp.) are considered weeds in some lawns because they often crowd out other grasses, forming patches that are lighter in color and require different management. The only known selective control is silvex in repeated applications.

Tall fescue, better known as Alta or Kentucky 31 fescue (*Festuca arundinacea*) often is considered a weed in turf because it is a coarse bunch grass with wide leaf blades that grows faster than bluegrass and the red fescues, especially in early spring. It often is mistaken for quackgrass or wiregrass (*Agropyron repens*). It does not spread like quackgrass and it has a dark green shiny leaf, unlike the light green cast of quackgrass. The only way to eradicate tall fescue is by digging it out or treating it with non-selective grass killers such as dalapon or cacodylic acid.

Orchardgrass (*Dactylis glomerata*), also a perennial bunch grass, differs from tall fescue in having a coarser appearance and a lighter color. Control is the same as that for tall fescue.

Clover (*Trifolium* spp.) can be controlled with silvex or banvel D but also is discouraged by nitrogen fertilizer.

Certain perennial weeds cannot be successfully controlled in turf without destroying the existing grasses. Among these are quackgrass (*Agropyron repens*) and nutgrass (*Cyperus* spp.), a sedge. Quackgrass

has wide, flat leaf blades with a dull finish and spreads by underground stems. Nutgrass arises from small tubers, has shiny leaves and triangular stems, and usually grows faster than the turf grasses. Quackgrass can be held in check by good cultural practices. Nutgrass may be more difficult to live with. At the present eradication of these weeds is possible only with soil fumigants such as SMDC, DMTT, or methyl bromide, which require complete lawn renovation.

Lawn renovation where these persistent perennial weeds are not a problem has been accomplished by killing all vegetation with dalapon plus 2,4-D, or cacodylic acid, and reseeding in the dead turf.

SUMMARY

A positive approach to the control of weeds in turf calls for emphasis on practices that increase the vigor of the turf grasses. Although herbicides alone can be used to control many weeds, most effective weed control is achieved when herbicides are used to supplement good management practices.

Several pre-emergence crabgrass killers have provided good seasonal control of crabgrass in Connecticut with little or no injury to established turf grasses. Some of these herbicides have been widely tested; others have been tested for only a season or two in the Northeast. Each of the herbicides has its limitations; none has produced in all situations 100 per cent control of crabgrass with no injury to turf. Some (the arsenicals) are more hazardous for use around the home than others. At the present time zytron and dacthal look most promising, but good results also have been obtained with calcium arsenate, diphenatril, bandane, and dipropalin, the latter two in limited trials. Except at rates higher than those suggested on the herbicide labels, chlordane and Pax have not provided consistently good control of crabgrass.

Although a few pre-emergence herbicides are safe to use on seedling turf grasses, no herbicide has effectively controlled crabgrass when applied on bare ground at the time of seeding.

Some pre-emergence crabgrass killers, particularly zytron and calcium propyl arsonate, are effective when applied on crabgrass in its early seedling stages. Several other herbicides, which control only emerged crabgrass, must be applied two or three times during a season for good results. These include DMA, AMA, PMA, CMA, and KOCN. Turf discoloration usually is more of a problem and the timing of application more critical with the post-emergence crabgrass killers than with the better pre-emergence materials.

Some of the most common broadleaved weeds in turf are readily controlled with 2,4-D. Others also are selectively controlled with silvex, endothal, banvel D, or herbicides effective for pre-emergence control of crabgrass. Cautious use to avoid injury to turf and other plantings is required with all of these materials.

At the present time, quackgrass, nutgrass, and undesired perennial grasses, such as tall fescue and orchardgrass, can be eradicated only by non-selective herbicides which require spot reseeding or lawn renovation. In many instances it may be more practical to "learn to live" with these weeds in turf than to attempt to eradicate them. Thus for many weeds, prevention by good cultural practices still is the best cure.