CHEMICAL CONTROL OF WEEDS IN CHRISTMAS TREE PLANTINGS

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Chemical treatment (at right) effectively controls sod in this planting.

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In this publication the authors summarize their research on the application of chemical and biological principles to specific problems in weed control. Their report shows the comparative performance of chemical compounds used in their experiments. Their goal is discovery of the least hazardous, least expensive, and most efficient method of accomplishing the desired control.

As of May 1969, the U. S. Department of Agriculture reported that materials mentioned in this Bulletin were registered for use in evergreen plantings used for Christmas trees, as follows:

Amitrole. For use on Arborvitae, balsam fir, Douglas fir, junipers, Norway spruce, red pine, Scotch pine, Tangier fir, white pine, yew (Taxus).

Atrazine. Douglas fir, grand fir, lodgepole pine, noble fir, ponderosa pine.

Dichlobenil. Arborvitae, eastern red cedar, fir, jack pine, junipers, pine, spruce, yew.

Paraquat. Arborvitae, pine.

Simazine. Balsam fir, Douglas fir, Fraser fir, junipers, Norway spruce, red pine, red spruce, Scotch pine, white pine, white spruce, yew (Taxus).

Dalapon was not registered for use on Christmas trees.

Because of changes in registered uses, these materials may be useful on additional species; check the product label.

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Most crops are grown on tilled fields kept weed-free by mechanical or chemical means. Christmas trees, largely for economic reasons, are grown on abandoned pastures and untilled hillsides. The typical vegetation in Christmas tree plantations is referred to as sod, a population of herbaceous plants in which perennial grasses usually dominate. Sod adversely affects both the growth and the quality of Christmas trees, especially when they are small.

Sod affects tree growth directly by competing for water, nutrients and light, and sometimes growing space. High mortality in young plantations often is associated with unchecked growth of sod, and those trees that do survive in sod often grow poorly the first few years. Heavy growth of grasses and other weeds mats down around trees during the winter, resulting in crooked stems and shaded and disfigured lower whorls. Fire hazards and rodent problems are increased by unchecked weed growth. Without question the sod environment lengthens the time required to produce a quality Christmas tree.

Mechanical methods of controlling sod are available but all have serious limitations, either in their effectiveness or for other undesirable features (13, 19, 23, 24). Planting on top of or in plowed furrows, for ex-

ample, leaves the land scarred and difficult, if not hazardous, to work with men or equipment. Disturbing the soil often encourages the rampant growth of annual weeds (13). Mowing reduces fire hazard in plantations but does not sufficiently reduce competition for moisture in critical periods, or control growth around the trees (20). To effectively control soil moisture loss, competing vegetation must be killed before moisture stress begins. Mowing usually is done after grasses and weeds have taken their toll of soil moisture. Mowing also is hazardous to small trees.

The use of chemicals to control herbaceous growth in Christmas trees gained impetus in the 1950's with the development of selective organic herbicides. Early work with simazine, an herbicide that could be safely applied directly over conifers, stimulated interest among Christmas tree growers in chemical control of sod (12, 13).

Our work with chemicals to control weeds in Christmas tree plantings began in 1962. In cooperative experiments with the University of Vermont, we have investigated the responses of conifers and native vegetation to herbicides. This bulletin discusses the findings of these experiments and those of others in relation to current cultural methods of growing Christmas trees in New England.

Methods

Several experiments were conducted in Connecticut and Vermont where herbicides were applied before or after planting conifers. In Connecticut the plants were three-year-old (3-0) seedlings of white spruce (*Picea glauca* [Moench] Voss), white pine (*Pinus strobus* L.), and Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco). In the Vermont trials, 2-0 seedlings of Scotch pine (*Pinus sylvestris* L.) and wildling transplants of balsam fir (*Abies balsamea* [L.] Mill.) were the principal test plants. However, additional work was done in Connecticut in established stands of white spruce and Colorado blue spruce (*Picea pungens* Engelm.) and in Vermont in established stands of balsam fir.

Six herbicides that have proven effective for weed control in conifers in other areas were included in our experiments (Table 1).

The herbicides were applied before planting or over rows after planting in bands varying from 20 inches to 36 inches, using calibrated knapsack sprayers, tractor-mounted sprayers, and tractor-mounted or hand-operated granular applicators (Fig. 1). With some herbicides, sprays were directed around the base of the trees to avoid hitting the needles, and granules were applied over trees by hand, using a tablespoon measure or a shaker jar.

Herbicide plots contained a minimum of 8 to 25 plants and the treatments were replicated three or more times, usually in randomized complete blocks. Control of the herbaceous vegetation was evaluated by estimating the percentage kill in plots at varying times after treatment. Plant response was evaluated in some trials by measuring the terminal

Table 1. Herbicides tested in Christmas tree plantings

Common Name	*Chemical Name*	*Trade Name(s)*	*Formulations*
simazine	2-chloro-4,6-bis(ethylamino)-*s*-triazine	Princep	80% wettable powder 4% granular
atrazine	2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine	AAtrex	80% wettable powder 8 and 10% granular
dichlobenil	2,6-dichlorobenzonitrile	Casoron	4% granular
dalapon	2,2-dichloropropionic acid	Dowpon	85% sodium salt
amitrole	3-amino-*s*-triazole	Weedazol Amino triazole	50% powder
amitrole-T	amitrole + ammonium thiocyanate mixture	Cytrol Amitrol-T	liquid-2 lb/gal
paraquat	1,1′-dimethyl-4,4′-bipyridinium salts	Paraquat CL	liquid-2 lb/gal

growth, height, and the number of lateral and internodal buds per leader.

Root dips of activated carbon were tested in trials in white spruce and Scotch pine. The roots of seedlings were dipped in the dry powder or a 15% water slurry (1¼ lb/gal water) of Aqua Nuchar "A"[1] before planting into herbicide-treated soil.

Details of these experiments, where pertinent, are given in the text or tables. All herbicide rates are given in terms of pounds of active ingredient per acre (lb/A). Trade names are used only to identify products and are not intended as an endorsement of any product.

Results and Discussion

Effects of herbicides on weeds and conifers

The herbicides that we tested for sod control in Christmas trees varied greatly in their effects on weeds and on Christmas trees. No single herbicide controlled all weeds or failed to injure conifers under some conditions. Rates of application, types of application, and timing of application greatly affect control of weeds and safety to conifers. Soil types also modify herbicide activity. Because each herbicide acts differently, the descriptions and a discussion of the results with the herbicides are given below. The effects of these herbicides on specific weeds are given in Table 2.

Simazine was included in all of our tests and has been widely tested elsewhere (6, 7, 8, 11, 12, 21, 24). It is widely used in nurseries, orchards and conifer plantations. Simazine kills weeds by entering the roots, moving to foliage, and interfering with photosynthesis. Its lack of absorption through leaves or needles allows it to be safely applied directly over

[1] Aqua Nuchar "A" from West Virginia Pulp and Paper Company.

Figure 1. Types of granular applicators: Top, a 2-ft lawn spreader with 24-inch wheels made from ¾-inch exterior plywood, bolted to the original wheels; bottom, commercial granular applicator mounted on the planter. The granules flow only as the machine moves forward.

woody plants. Simazine persists in the soil but is slowly broken down by plants, by soil microorganisms, and also on soil or plant surfaces by light and/or evaporation to the atmosphere. It is only slightly soluble in water and, therefore, must be activated by rainfall following application.

When applied before weed emergence, simazine controls most annuals and many perennials for periods of 2 months to 2 years, depending on the rate and timing of application and the soil type. In Connecticut, particularly on light soils, near cultivated lands, crabgrasses (*Digitaria* spp.) have invaded simazine-treated areas during mid-season. Reapplying

Table 2. Susceptibility of established perennial weeds to herbicides used in Christmas tree plantings[1]

	Atrazine 3-4 lb/A	*Simazine 4-6 lb/A*	*Dichlobenil (granular) 4-6 lb/A*	*Amitrole 2-4 lb/A*	*Paraquat ½-1 lb/A*[2]
bindweed (Convolvulus spp.)	R	R	I	R	I-R
bluegrass (Poa spp.)	S	S	S	S	S
brambles (Rubus spp.)	R	R	R	S-I	I
broomsedge (Andropogon virginicus L.)	R	R	I	I	I
buttercup (Ranunculus spp.)	R	R	R	S	S
carrot, wild (Daucus carota L.)	R	R	—	S	—
chickweed, mouseear (Cerastium vulgatum L.)	S	S	S	S	S
cinquefoil (Potentilla spp.)	S-I	I	S	S	S
clover (Trifolium spp.)	S-I	I-R	S	S	I-R
dandelion, common (Taraxacum officinale Weber)	R	R	S	S	S
dandelion, fall (Leontodon autumnalis L.)	R	R	S	S	I
fern, braken (Pteridium aquilinum [L.] Kuhn)	R	R	S	I	I
goldenrod (Solidago spp.)	I-R	I-R	S	S	S
horsenettle (Solanum carolinense L.)	R	R	S	S	I
horsetail, field (Equisetum arvense L.)	R	R	S	S	—
Joepyeweed (Eupatorium maculatum L.)	R	R	—	S	S
milkweed (Asclepias spp.)	R	R	—	I	—
orchardgrass (Dactylis glomerata L.)	I	I	S	S	S
poison ivy (Rhus toxicodendron)	R	R	R	S	I-R
quackgrass (Agropyron repens [L.] Beauv.)	S	I	S	I	I
redtop (Agrostis alba L.)	S	S	S	S	S
reed canarygrass (Phalaris arundinacea L.)	S	S	S	I	I
sedges (Cyperus spp. & Carex spp.)	I	I-R	S	I	I
sorrel, sheep (Rumex acetosella L.)	I	I-R	S	S	S
thistles (Cirsium spp.)	R	R	S	S-I	R
timothy (Phleum pratense L.)	S	S	S	S	S
toadflax, yellow (Linaria vulgaris Hill)	I	R	I	I	R
vernalgrass, sweet (Anthoxanthum odoratum L.)	S	S	R	S	S
vetch, wild (Vicia Cracca L.)	I	R	S	S-I	I-R
woody species	R	R	R	S-R	S-R

Table 3. Effect of timing of application and formulation on the control of sod with simazine and atrazine in Elmore, Vermont, 1968

Herbicide	*Formulation*[1]	*Rate*	*Date of Application*[2]	*Percentage control of sod July 6, 1968*
Untreated	....	....	....	0
simazine	G	6	4/28	83
	G	6	5/18	68
	G	9	5/18	85
	wp	6	4/28	87
	wp	6	5/18	88
atrazine	G	4	4/28	73
	G	6	4/28	95
	G	4	5/18	55
	G	6	5/18	93
	wp	4	4/28	95
	wp	4	5/18	95
	wp	6	5/18	95

[1] G = granules; wp = wettable powder in 50 gal spray per acre.
[2] On 4/28/68 growth of sod grasses was just beginning. On 5/18/68 growth of sod grasses was 4 to 6 inches tall.

a low rate of simazine in late May reduces crabgrass invasion. Seedlings of common dandelion (*Taraxacum officinale*) have been controlled at low rates (2 lb/A), but established dandelions have not been controlled by high rates of simazine. Established stands of Kentucky bluegrass, timothy, and redtop have been controlled with simazine at 4 to 6 lb/A, but quackgrass is only partially controlled at these rates. Perennial weeds such as horsenettle, bindweed, buttercups, vetches, broomsedge, true sedges, and many woody deciduous plants have been resistant to simazine (Table 2).

In Connecticut, simazine at 4 to 6 lb/A adequately controls susceptible sod grasses and annual weeds for one season. On some soils higher in organic matter, particularly in Vermont where lower temperatures also prevail, higher rates may be required. Organic matter and clays in soils adsorb simazine and increase the levels necessary to control weeds. Lower soil temperatures decrease herbicide activity and tend to increase the need for higher dosages. Poor results have been obtained with simazine in low pockets where standing water was present at the time of treatment.

Footnotes to Table 2, facing page.
[1] S = susceptible–plants usually controlled. I = intermediate–plants controlled under optimal conditions or for limited periods. R = resistant–plants not usually controlled. Two designations such as I-R indicate variable responses and inconclusive results. The responses to atrazine, simazine, and dichlobenil refer to applications during the late fall or early spring. The responses to amitrole and paraquat refer to sprays during active growth of the weeds. Most annual and many perennial weeds from seed are killed by preemergence applications of atrazine, simazine, or dichlobenil at the above rates.
[2] Paraquat kills the above ground parts of many weeds but their roots may survive.

Timing of application of simazine seems very important, especially for the granular formulation. To achieve maximum effectiveness against perennial grasses, simazine must be applied and become active before growth starts in the spring. Granular simazine is released slowly to the soil and requires more time and moisture for activity than wettable simazine. When applications of granular simazine were delayed until sod growth had started, higher rates were required for control (Table 3). With adequate rainfall soon after its application, wettable simazine controlled sod in its early stages of growth more effectively than granular simazine.

Our studies in nursery plantings and in Christmas trees have shown that granular simazine is more persistent in soil and provides weed control longer than wettable simazine. In a trial in which applications were made in September to control sod the next year, granular simazine was much more effective (Table 4). The application of wettable simazine on growing sod in early fall probably results in excessive losses of simazine by breakdown in plants and in the soil. However, applications of simazine alone in early fall have little basis in southern New England, because the sod grasses are not killed until the following spring. Applications very late in the fall or very early in the spring would minimize loss of simazine and maximize control. Applications on snow are not considered wise because of possible movement and poor distribution of the herbicide.

The persistence of simazine in the soil from one season to the next permits a reduced rate of application or no application the second year.

Table 4. Comparative effects of herbicide treatments applied on September 8, 1966

Treatment[1]	*Percentage control of weeds June 1967*	*Remarks—Weeds present*
Untreated	0	bluegrass, redtop, cinquefoil, sedges
simazine G, 4 lb/A in 3 ft bands over rows	80-90	good, some cinquefoil, sedges
simazine G, 6 lb/A in 3 ft bands over rows	95	excellent, some cinquefoil, sedges
simazine wp, 6 lb/A in 3 ft bands over rows	20-60	fair, much cinquefoil, sedges
simazine wp + paraquat, 3 lb + 1 lb/100 gal, directed spray in 3 ft circles around trees	50-75	fair—good, variable, sedges
simazine G, 6 lb/A 1 tablespoon per tree by hand, in 3 ft circles around trees	60-90	good, variable, because of distribution of granules

[1] Sprays applied in 50 gal solution per acre. wp = wettable powder in sprays, G = granules.

We have obtained satisfactory control of sod for two years, particularly in Vermont, where high rates were used the first year and control was excellent at the end of the first season. Breakdown or loss of simazine is greater with increasing soil temperature and on lighter as compared with heavier soils. On the light soils, particularly in southern New England, repeated applications of simazine at a reduced dosage have been necessary to maintain satisfactory control. Soils higher in organic matter, which require more simazine initially for sod control, are less likely to require an application the second year.

Conifers grown in plantations vary somewhat in their tolerance of simazine at dosages sufficient to control sod grasses (6, 12, 21). Established plants of all major Christmas tree species can be considered tolerant, but newly planted trees are more sensitive. Tolerance of conifers for simazine seems to increase with age and degree of establishment. For this reason the manufacturer recommends that simazine be applied only on trees at least 3 years old. Minor injury from simazine appears as a yellowing or bronzing of needle tips; severe injury can result in increased mortality. Reduced photosynthesis in conifers resulting from excessive uptake of simazine can occur without any observable effects on plant color (22). Plants usually recover from mild injury and may, in fact, demonstrate greater vigor the following year than untreated trees in sod.

We have observed no injurious effects of simazine in 3-0 seedlings of Scotch pine (Table 8) or Douglas-fir. Balsam fir wildlings, grown for an additional 2 years in nursery beds, appear to be very tolerant of simazine. In 1963 and 1964, survival of 3-0 seedlings of white pine was poorer in certain plots of sod treated with simazine than in plots of established sod, but the differences were not significant (Tables 5 and 6). In 1967, on a sandy loam soil, simazine at 8 lb/A increased the mortality of 3-0 seedlings of white pine, but 4 lb/A caused no injury.

Recent experiments demonstrate the importance of plant age and vigor as factors affecting the tolerance of white spruce to simazine. Transplants of white spruce (2-2 or older), with well developed root systems and good vigor, have been very tolerant of simazine. Seedlings (3-0), on the other hand, often survive poorly in sod without treatment and are also more sensitive to simazine than transplants. During 1968 we observed that seedlings formerly grown at close spacings in the nursery bed were more sensitive to applications of simazine than seedlings grown at wider spacings. The widely spaced plants had better color and larger, more fibrous root systems than the closely spaced plants. Possibly, shaded spruce seedlings from dense nursery beds are shocked by exposure to high light intensities when transplanted into dead sod (17).

The tolerance of Christmas trees to simazine is due partly to inherent tolerance of the plants and partly to escape (16). White pines are more tolerant than red pines, probably because they transport less simazine from roots to needles, where injury occurs (10). Seedlings and small

Table 5. Preplanting and postplanting treatments in seedlings (3-0) of white pine and white spruce (Experiment A)

Herbicide and rate of active ingredient per acre	*lb/A*	*Time applied*[1]	*Percentage control of* All weeds Aug. 1963	*Percentage control of* Redtop and bluegrass	*White pine* Leader growth inches '63	*White pine* Leader growth inches '64	*White pine* Percentage mortality '64	*White spruce* Leader growth inches '63	*White spruce* Leader growth inches '64	*White spruce* Percentage mortality '64
untreated			0	0	2.8	7.4	7	1.5	2.3	26
simazine wp	3	fall	8	43	2.7	8.4	3	1.9	3.9	31
	6	fall	43	99	2.1	8.5	10	1.6	4.1	17
	6	spr.-post.	67	96	2.6	8.7	7	1.7	3.2	27
simazine + amitrole	3+1	fall	23	97	2.5	7.4	12	1.5	4.6	39
	4.5+1.5	fall	22	97	2.3	7.7	19	1.4	3.2	17
	6+2	fall	53	99	2.4	7.4	13	1.7	3.1	42
	3+1	spr.-pre.	48	96	2.9	9.0	5	1.5	3.4	25
	6+2	spr.-pre.	72	97	2.3	7.8	6	1.5	3.9	19
simazine + dalapon	3+3	fall	15	96	2.4	7.9	16	1.7	2.9	42
	3+6	fall	37	93	2.2	7.0	8	1.7	2.8	33
	3+3	spr.-pre.	40	97	2.2	8.2	10	1.7	4.8	29
dichlobenil, G	4	spr.-post.	37	57	2.9	7.8	11	1.4	3.5	53
	8	spr.-post.	67	90	1.8	7.0	48	1.3	2.8	55

[1] Fall treatments were applied November 2, 1962 on sod mowed earlier. On April 23, spring preplanting treatments were applied (spr.-pre.) and the trees were planted. The postplanting treatments were applied on April 24. All treatments were sprayed with 50 gal of solution per acre except dichlobenil, which was applied in granular form.

Table 6. Preplanting and postplanting treatments in seedlings (3-0) of white pine and white spruce (Experiment B)

Herbicide & rate of active ingredient per acre	*lb/A*	*Time applied*[1]	*Percentage kill of sod* 6/64	*Percentage kill of sod* 12/64	*White pine* Leader growth inches '64	*White pine* Leader growth inches '65	*White pine* Leader growth inches '66	*White pine* Percentage mortality '65	*White spruce* Leader growth inches '64	*White spruce* Leader growth inches '65	*White spruce* Leader growth inches '66	*White spruce* Percentage mortality '65
untreated			0	0	2.7	4.8	10.8	8	1.5	1.1	3.3	51
simazine	4	fall	66	48	2.9	6.1	11.1	16	1.6	2.2	5.2	39
simazine	4	spr.-post.	0	33	2.8	5.5	10.4	15	1.6	2.4	4.8	50
simazine	6	fall	88	68	3.0	7.1	12.2	16	1.5	2.7	5.6	38
simazine	6	spr.-post.	16	45	3.3	7.1	11.4	20	1.5	2.6	4.9	51
simazine + amitrole	3+1	fall	46	25	3.1	5.9	13.5	23	1.5	2.0	5.0	39
simazine + amitrole	3+1	spr.-pre.	58	50	2.5	6.2	10.6	33	1.5	2.9	4.6	54
simazine + dalapon	3+3	fall	70	43	2.9	5.2	9.4	8	1.5	2.3	4.2	47
	3+3	spr.-pre.	84	51	2.5	6.0	12.2	31	1.5	2.8	5.9	74
simazine + paraquat	3+1	fall	66	30	3.0	6.5	13.0	10	1.7	2.6	4.8	43
dichlobenil, G	5	Nov. 1964	0	[2]	2.8	4.3	14.3	14	1.7	1.1	2.9	44

[1] Fall treatments were applied Oct. 31, 1963 on sod mowed earlier. On April 23, 1964 the spring preplanting treatments (spr.-pre.) were applied and three-year-old trees were transplanted. The postplanting treatments (spr.-post.) were applied on April 25, 1964 in 50 gal of solution per acre. Granular dichlobenil was applied on November 30, 1964.

[2] Control of sod including quackgrass was 75% in August 1965 with dichlobenil.

plants, in general, are less tolerant than large plants, probably because concentrations of simazine in smaller plants reach higher levels. Larger plants also have deeper root systems. Because of its low solubility and resistance to leaching, high concentrations of simazine do not contact the deeper roots of woody plants. Incorporating simazine into the root zone reduces this escape factor and allows greater uptake and subsequent injury (16). Excessive rainfall, especially on light soils, also can result in the leaching of simazine to the root zone to cause injury in conifers.

Atrazine is closely related to simazine. It has been widely tested and used in conifer plantations in the Pacific Northwest, where patterns of precipitation differ greatly from those in New England (5, 18, 19, 20). We have tested atrazine for many years in coniferous ornamental nursery stock, and have recently revaluated it for use in New England Christmas tree plantings (Tables 3 and 7).

Atrazine acts in the plant as simazine does but its water solubility is greater than that of simazine (33 ppm vs 5 ppm for simazine). It, therefore, requires less moisture for activation and it enters and kills plants more rapidly than simazine. It also is more susceptible to leaching and is less persistent in the soil than simazine. These qualities affect its selectivity on weeds and conifers.

Atrazine is more effective than simazine against certain perennial weeds such as quackgrass, cinquefoil, vetch, and sedges (Table 2). Four lb/A of atrazine seems equivalent to 5 to 6 lb/A of simazine in sod control. However, atrazine is less effective than simazine against certain

Table 7. Effects of herbicides on sod and balsam fir

Herbicide	*Rate of active ingredient (lb per acre)*		*Percentage control of sod*		*Leader growth in inches*		*Percentage mortality*
	1967	*1968*	*1967*	*1968*	*1967*	*1968*	*1968*
untreated	0	0	0	0	3.5	3.3	13
simazine, wp	6	6	90	90	3.0	6.1	7
	9	0	92	75	2.7	5.4	4
atrazine, wp	4	4	90	96	3.0	5.0	7
	6	0	95	80	2.8	4.4	13
simazine +	3+3	3+3	92	96	3.0	5.6	2
atrazine	4½+4½	0	92	65	2.8	5.7	13
dichlobenil, G	6	0	95	47	2.8	3.6	36
	9	0	98	62	2.9	3.1	62
Least significant difference	p = .05					1.9	

Balsam wildling transplants (grown 2 years in beds) were planted April 29, 1967. The herbicides were applied April 30, 1967 directly over the trees and some treatments were reapplied April 26, 1968. The soil was a gravelly loam in Vermont, with high organic matter content. The sod included quackgrass, sweet vernalgrass, timothy and orchardgrass.

annual grasses that invade some sites in southern New England, such as crabgrass, fall panicum, and barnyardgrass.

Although atrazine is currently available only in wettable powder form, we have tested both the wettable and experimental granular forms. With normal rainfall following application, wettable atrazine is effective against sod grasses and weeds in their early stages of growth in the spring. Our tests with granular forms of atrazine indicate that treatments on dormant sod are more effective than treatments on actively growing sod (Table 3). Therefore, like simazine, atrazine requires more time for activity when applied in the granular form.

Although more effective than simazine against perennial weeds, atrazine also appears to be more injurious to newly planted conifers in New England. We have observed more discoloration and defoliation in white pine, white spruce, and balsam fir with atrazine than with simazine. Severe injury to conifer transplants also has been reported in the Midwest and New York State (17, 26). In the Pacific Northwest, however, where most of the rainfall occurs in the dormant season, atrazine is reported to be the best herbicide currently available for conifer plantations (19).

Timing of application seems more important with atrazine than with simazine to avoid injury to Christmas trees. Applications of atrazine in late May during active growth of balsam fir have caused injury (9). On the other hand, applications on dormant balsam fir with atrazine at 4 to 6 lb/A gave no significant injury in 1967 or 1968 (Table 7). The application of atrazine before planting white spruce in 1968 caused less injury than application after planting.

Because of its effectiveness against perennial grasses, particularly quackgrass, atrazine deserves further investigation for use in Christmas trees in New England. Possibly it could be used to a greater advantage in established trees, rather than in transplants. Combinations of low rates of atrazine with simazine could also reduce the hazard of injury from atrazine and improve control of sod.

Dichlobenil has received attention for weed control in Christmas trees because of its broad uses in ornamental nurseries and orchard crops. We have tested it for use in Christmas tree plantings since 1963. Although the action of dichlobenil in plants is not fully known, it inhibits root growth in sensitive plants. It is a volatile herbicide and is rapidly lost to the atmosphere when sprayed on soil surfaces. However, when applied during the cool seasons in granular form, and carried into the soil by moisture, it is a very persistent herbicide.

At rates of 4 to 8 lb/A, dichlobenil has been very effective against most annual weeds and several of the perennial grasses and weeds not controlled by simazine. Among these are wild vetch, established dandelions, and orchardgrass. Sweet vernalgrass, on the other hand, is resistant to dichlobenil (Table 2).

Unfortunately, dichlobenil frequently injures newly planted conifers in sod. Dichlobenil has severely injured newly planted white spruce,

Table 8. Effects of simazine and dichlobenil on Scotch pine with and without root dips of activated carbon[1]

Herbicide and rate of active ingredient (lb per acre)		Percentage control of sod		1967 leader growth in inches		1968 plant height in inches		Percentage mortality Aug. 1968	
1967	1968	1967	1968	check	carbon	check	carbon	check	carbon
untreated	untreated	0	0	4.7	5.1	15.4	15.0	5	1
untreated	simazine 6	0	66	....	....	13.0	15.4	12	7
simazine 6	0	83	55	4.3	4.4	16.9	18.1	3	6
simazine 6	simazine 3	....	69	....	....	15.4	17.7	1	2
simazine 9	0	80	54	4.8	4.6	15.4	18.9	1	2
simazine 9	simazine 3	....	85	....	....	18.9	16.5	4	4
dichlobenil 6	0	88	35	3.3	5.4	11.8	20.5	12	7
dichlobenil 9	0	93	50	2.6	4.6	11.8	19.3	23	2

[1] Granular herbicides were applied in 2-ft bands on April 8, 1967, except simazine at 9 lb/A which was applied on April 27, 1967. Pine seedlings (3-0) were planted on April 27, 1967. Dead seedlings were replaced and granular simazine was reapplied on April 6, 1968. Sod control was evaluated in July 1967 and September 1968. Considerable mortality was observed in dichlobenil plots in April 1968. Statistical analysis of 1968 plant heights showed significant differences ($p = .01$) among herbicide treatments and between carbon and no carbon root dips. The interaction of herbicide treatments × root dips was significant at $p = .05$.

Table 9. Effect of simazine on bud and needle development in balsam fir

	Length of leader inches	No. of internodal buds per leader	Length of internodal buds inches	Length of needles in top whorl inches	Leader diameter 1 in. above 1st whorl inches
untreated	14.2	27.6	0.13	6.8	0.29
simazine	13.9	49.2	0.20	7.3	0.43

Simazine was applied in October 1965. Measurements were made in May 1967.

Scotch pine and balsam fir in our tests (Tables 5, 7, and 8). Injury also has been reported with dichlobenil in seedlings and transplants of Douglas-fir. The injury from dichlobenil is observed in poor root growth, poor foliage color, and subsequent high mortality. Surviving plants often grow poorly despite their release from sod competition (Table 7).

Injury from dichlobenil in conifer transplants undoubtedly is related to the leaching of dichlobenil into shallow root zones. In cultivated nurseries established plants of pines and spruces have seldom been injured by dichlobenil, but firs apparently are more sensitive. Established plants, with their deeper root systems, can escape serious root injury from dichlobenil. Because of its effectiveness against hard-to-kill perennial weeds, the use of dichlobenil in established conifers in sod should be investigated further. At the present, however, it seems too hazardous for use in transplants without protective root dips of activated carbon (see following section and Table 8).

Three herbicides that were tested alone or in combination with simàzine to improve the speed and spectrum of weed kill have certain merits for use in Christmas tree plantings. The herbicides are dalapon, amitrole and paraquat. These herbicides effectively kill growing vegetation but they persist for only short periods in the soil. None of these is safely applied over the tops of conifers.

Dalapon is a systemic herbicide, absorbed by leaves and roots and effective primarily against annual and perennial grasses. Although it may only depress growth of broadleafed weeds, it kills the tops and often the roots of perennial grasses within 2 to 3 weeks. The deep-rooted quackgrass often recovers, however, unless a residual herbicide such as simazine also is applied. Dalapon usually is dissipated in the soil within 3 to 4 weeks.

Dalapon has been successfully used to control quackgrass when sprayed on actively growing grass in the early fall at rates of 15 to 20 lb/A (26). Simazine is then applied in the spring after planting to provide residual control of weeds. When combined with simazine and sprayed on actively growing sod, lower rates of dalapon may be employed (13). In our tests, lower rates of dalapon (3-6 lb/A) in combination with simazine at 3 lb/A in the fall controlled sod about equally with simazine alone at higher rates (2, Tables 5 and 6).

Dalapon is a very soluble herbicide which can injure conifer transplants when sprayed on their foliage or when applied over their roots. The application of dalapon and simazine just before planting in the spring of 1964 caused injury to spruce and pine seedlings, probably because of uptake of dalapon by the roots. To avoid injury to conifers fall treatments with dalapon on sod land to be planted in the spring allow time for dalapon to dissipate in the soil (26).

Although results have varied, the application of dalapon around established conifers is somewhat hazardous unless care is taken to avoid heavy applications in the root zones of the trees or spray drift onto the foliage (11, 13, 26). The primary uses of dalapon in Christmas trees seem to be in the killing of sod ahead of planting and in the spot treating of troublesome perennial grasses such as broomsedge.

Amitrole is a systemic herbicide effective against a wide range of annual and perennial weeds. It enters plants through leaves and roots but does not penetrate the bark of woody plants. It is broken down by microorganisms in soil within several weeks. Amitrole inhibits growth and affects chlorophyl formation in plants, causing new shoots to turn white and die. Amitrole-T, a liquid formulation ("Amitrol-T" or "Cytrol") containing ammonium thiocyanate, is considered more effective against certain weeds than amitrole alone. Wetting agents also can improve weed kill with amitrole sprays.

Amitrole is effective against perennial grasses and weeds such as horsenettle, dandelion, and goldenrod and certain woody plants such as poison ivy when sprayed on their leaves during active growth. Like dalapon, amitrole kills weeds slowly and quackgrass incompletely unless it is combined with a residual herbicide such as simazine. Where applied alone, amitrole must be used at rates above 4 lb/A to control sod, but when combined with simazine, lower rates are effective.

Good results in Christmas trees have been obtained when amitrole was combined with simazine or applied before or after simazine applications. Combinations of amitrole at 1 to 2 lb/A plus simazine at 3 to 4 lb/A kill actively growing sod and provide long residual control of emerging seedlings. One combination of simazine and amitrole is commercially available (trade name—"Amizine") but the two herbicides can be mixed in the spray tank. A mixture of 2 lb of actual amitrole and 3 lb of actual simazine per 100 gallons of water has been very effective around established trees when the weeds are sprayed merely to wet. If applied in May before sod growth is excessively high, a gallon of this mixture is sufficient to treat a circle 3 ft in diameter around at least 40 trees.

Amitrole also injures conifers when applied on their foliage or at excessive rates which can leach to their root zones. Because it is broken down rapidly in soil, fall applications of amitrole, alone or in combination with simazine, have not injured conifers planted the following spring. However, when applied just before planting in 1964 a combination of amitrole and simazine injured white pine (Table 6). A delay between treatment with amitrole and planting, therefore, seems advisable to avoid injury to conifers.

When applied after planting or in established trees it is necessary to direct sprays of amitrole to avoid hitting the foliage and to avoid spraying excessively around the roots. However, where weed foliage is sprayed only to wet with low rates of amitrole and the soil is not drenched the chances of injury to trees from root uptake are minimized.

Paraquat is essentially a contact herbicide that is readily inactivated by soil clays and organic matter. It kills most green plants rapidly in sunlight, but has little effect on dormant, matted sods, or the mature bark of woody plants. On sunny days, effects of paraquat on herbaceous plants are noticed within a few hours of treatment. Because it is essentially immobile in plants, the roots of some perennial weeds survive when their foliage is killed with paraquat. Toadflax and vetches are resistant weeds. Non-ionic or cationic wetting agents increase the effectiveness of paraquat sprays.

Paraquat is most effective when combined with a residual herbicide such as simazine. We have tested it for use before and after planting Christmas trees with good results. When used in the fall or in the spring before planting, paraquat, like amitrole or dalapon, reduces the amount of simazine needed to control perennial grasses. Paraquat kills plants more rapidly than either amitrole or dalapon, however, and strips of sod sprayed with paraquat can be clearly identified for planting within two days of treatments, whereas strips sprayed with amitrole or dalapon may not be identified for 7 to 10 days. Effective combinations have been paraquat at ½ lb (1 qt) plus simazine at 3-5 lb/100 gal of spray. Applications with knapsack sprayers around established trees, using 1 tablespoon of paraquat plus 3-4 tablespoons of wettable simazine per gallon of water have been very effective.

Uptake of paraquat by conifer roots does not seem to occur. Conifers planted into sod soon after treatment with paraquat have never shown injury. When used after planting or in established trees, paraquat or paraquat-simazine sprays must be directed to prevent injury to tree foliage. However, since paraquat is essentially immobile in conifers, only sprayed foliage is injured and the rest of the plant remains unaffected.

Paraquat is a very poisonous herbicide and care should be exercised in its mixing and application to avoid absorption by skin or inhalation. Respirators and common sense in application greatly reduce the hazard. Under no circumstances should paraquat be applied as a mist that might be inhaled. Mists of paraquat sprays around established trees also are likely to cause severe injury to the trees. Low pressure sprays (25 psi or less) are much less hazardous.

Modifying the effects of herbicides with root dips of activated carbon

Herbicides can injure young conifers when applied to soil at excessive rates or if soil and weather conditions promote excessive leaching of herbicide to the root zone. In 1948 work with sweet potato slips showed that root dips of activated carbon could reduce herbicide injury (4). Several reports since have shown that activated carbon can adsorb and thereby counteract herbicides in soil around the roots of transplants (1, 3). In effect the root dips increase the tolerance of transplants to herbicides. Experiments continue in which root dips of activated carbon are being investigated for use in Christmas tree plantings to protect young transplants from herbicide injury.

In seedlings of Scotch pine (Table 8) root dips of activated carbon

Figure 2. Directed sprays of paraquat, amitrole, or combinations of these with simazine are effectively applied after sod and weeds are actively growing, but before they have overtopped the trees.

prevented the growth reduction and mortality caused by dichlobenil. In another experiment carbon root dips reduced the injury caused by dichlobenil in seedlings of white spruce (3). Thus carbon root dips may allow the use of dichlobenil where otherwise it is hazardous to transplants.

Other work indicates that carbon root dips can reduce the hazard of injury from atrazine and simazine in seedlings or transplants of white spruce. In the case of simazine, however, injury is minimized even without carbon root dips if transplants (2-2 or older) are used instead of seedlings (2-0 or 3-0). In the experiment with Scotch pine, simazine caused no apparent injury and carbon root dips, therefore, had no effect (Table 8).

The procedure found most practical in using the root dips was to make a 10 to 15% slurry of the carbon in water. A 15% slurry is 1¼ lb (approx. 3 qts of Aqua Nuchar "A") in 1 gallon of water. The roots are dipped into the slurry just before planting, *with care taken to prevent the heating and drying effects of sunlight on the blackened roots.*

Responses of weed populations to sod control with herbicides

Nature abhors a bare space. When an herbicide is used to control sod, the resistant weeds flourish as do the conifers. Examples of weeds resistant to individual herbicide treatments are given in Table 2. Whether or not these surviving weeds create problems that require repeated herbicide applications depends largely on the type of resistant weeds present on a given site. Quackgrass overtops small conifers and is considered a serious competitor, whereas low growing weeds such as cinquefoils, dandelions, and sheep sorrel probably are less competitive. Goldenrod, brambles, and brush can create special problems in plantations.

Often the invasion by plants resistant to herbicide treatments occurs gradually. Woody species may not invade until the second or third year after treatment. One thing is certain, however; plant populations change when herbicides eliminate the dominant sod grasses.

The answer to the problem of changing weed populations is to change the herbicide treatments as the situation demands. Few plants that invade following sod control present unsurmountable problems, if one is prepared to alternate or combine herbicides as required by the site. Directed sprays of amitrole and paraquat kill or suppress many of the plants that are resistant to simazine. Combinations of these herbicides with simazine greatly extend the spectrum of weeds that can be killed. Spot treatments with dichlobenil may prove useful in Christmas trees to control certain resistant perennials. Spot treatments with a brush killer (2,4,5-T) may be required when brambles and woody plants invade (14, 25).

Responses of conifers to sod control

Sod control can benefit Christmas tree production if it achieves better survival, growth or form (quality) of trees. Clearly, our goals in sod control are to promote optimal response of the trees and not necessarily to kill all competing vegetation. Optimal tree response may be achieved

Figure 3. Unchecked sod shades trees, creating fire hazards and reducing quality of lower branches and vigor of the whole tree: Left, unchecked growth; right, treated bands in white spruce.

with sod control practices that are less than perfect. The results show that young Christmas trees respond to partial release from sod. The higher levels of treatment required to control all vegetation may not necessarily improve tree response and may, in fact, be detrimental.

Survival of trees may be affected directly by toxic action of the herbicides on the trees or indirectly by the effects of herbicides on the weed population. Herbicide treatments that injure the trees sometimes increase mortality and should be avoided. These effects were discussed in a previous section.

Improved survival of conifers can result from sod control, especially during critical periods of moisture stress in the planting year (18). Largely because of differences in temperature and distribution of rainfall, moisture stress undoubtedly is more common in southern New England than in northern New England. However, even in northern Vermont, Kinerson found higher soil moisture contents in herbicide-treated sod than in untreated sod during dry periods (15). Dense sod on coarse-textured soil increases the potential for moisture stress. In 1966 survival of white spruce on a sandy soil was only about 7 percent in sod compared to 60 percent in plots treated with simazine (3).

During the dry season of 1964, the fall treatments with simazine that gave effective sod control early in the season gave survival of white spruce seedlings that was better than in untreated sod (Table 6).

During a dry period in July 1968 in Connecticut, we determined moisture contents in the upper four inches of a sandy loam soil in herbicide-treated and growing sod. The moisture content in the growing sod averaged 12 percent; whereas, the moisture content in sod killed by herbicide was 26 percent. Similar differences were found at other times during the dry period.

Sod control can improve survival in ways other than by conserving moisture. A heavy snow cover mats dead grasses down around trees and small seedlings often cannot find their way out of the mat. In Vermont, good survival of Scotch pine in heavy sod was achieved only by removing the sod thatch from seedlings in the spring. Seedlings in rows treated with simazine required no attention. Where mowing is practiced for fire prevention or other reasons, tree survival is often improved by sod control in the row. Mowing of heavy sod between the rows in young plantations is less hazardous because herbicide-treated rows are easily seen. Restocking of transplants and applying fertilizer also requires less time in herbicide-treated rows as compared with rows of trees in heavy sod.

In competing with conifers for soil nutrients, the herbaceous plants have a distinct advantage. Herbaceous plants grow over longer periods, produce more dry matter than young conifers, and withdraw more nutrients from the soil. Much of the poor color, vigor, and growth of conifers in sod results from this competition.

The application of fertilizer to conifers in sod may or may not produce a growth response in the conifers. In a Connecticut experiment, Stephens found that nitrogen fertilization stimulated the growth of sod more than the growth of white spruce (23). In Vermont experiments, however, probably because nutrients were more limiting than soil moisture, fertilization of balsam fir in sod increased tree growth and vigor (15).

When herbicides are used, however, the dying sod releases considerable nutrients to the soil. Soil tests commonly show higher levels of nitrogen and potassium in sod killed by herbicides than in unchecked growth. Improved growth and vigor of trees usually results, but not necessarily during the first season.

The growth and vigor of conifers in any given year seems to be determined long before buds break in the spring, and sod control usually has little effect on terminal growth during the first season. The nutrients and water made available by sod control contribute to the development of more vigorous buds, and better root systems which result in better growth the following season. Neither in transplants nor in established trees have we observed any marked improvement in terminal growth during the year of initial treatment. However, in heavy sods toward the end of the first season, improved bud development has been observed in white spruce and balsam fir and improved color has been observed in these species and in pines.

The effects of sod control on the growth of spruce and balsam fir are readily observed the second season following treatment. In balsam fir, sod control clearly increased the number of internodal buds, length of buds and the length of needles (Table 9). Increases in terminal growth of white spruce and balsam fir ranged from 30 percent to over 100 percent the year following treatment for sod control. In white spruce, with only partial control of vegetation from simazine in the planting year and with no additional herbicide treatments, increased terminal growth continued into the third year (Table 6).

Compared with spruce, terminal growth of white pine responded little to sod control treatments in 1963 and 1964 (Tables 5 and 6). In Scotch pine, terminal growth increases in 1968 also were modest from simazine applications in 1967. Nevertheless, pines grew straighter in the absence of heavy sod and their lower whorls were less deformed.

Data are lacking in New England on the response of Christmas trees to vegetation control after the first 3 or 4 years in the field. In the Northwest treatments of atrazine are reported effective on older trees to promote better color before harvest. As soon as trees overtop the competing vegetation and shade the soil, further herbicide treatments are not likely to produce a growth response, provided the trees receive adequate nutrition. Spot treatments may well be necessary, however, to control brush or certain herbaceous pests.

Types of herbicide application

In our work with Christmas tree plantings, we made many observations of the types of application that may be employed in sod control.

Treatments before, during, or after planting. With heavy sods of quackgrass or other grasses, treatment several months ahead of planting allows breakdown of the sod and easier planting, provided treated areas are clearly defined at planting time. Sod land to be planted in the spring can be treated in the fall and land to be planted in the fall can be treated in the spring, using simazine, dalapon, paraquat, amitrole-T, or combinations of these materials. Best results can be expected if tall sod growth is mowed before treatment.

Fall band treatments in northern New England are not practical where planting is done in the spring before sod growth has started in untreated areas, for greater effort is required to plant in the middle of treated bands that cannot be clearly seen. Similarly, treatments just prior to planting may not provide clearly defined bands (Fig. 4). If the sod is actively growing when treated with paraquat, visible strips result within a few days. The addition of colored dyes to herbicide sprays also has

Figure 4. Off-center planting, which often results from planting into treated bands before the sod has started to die. The sod was sprayed with simazine plus paraquat one day and planted the next. Had planting been delayed a day or two, the treated strips would have been clearly defined and planting in the center of the treated area would have been assured.

been suggested as a means of marking treated strips ahead of planting (26). Because of their slow action on sod, granular band treatments are best applied in the fall or after planting in the spring to insure treatment in the planting area.

Treatment during planting, by mounting a sprayer or granular applicator on the planting machine, has been used in practice and was investigated at the University of Vermont. Simultaneous spraying and planting has certain flaws for New England. Constant speed is difficult to maintain on the tree planter because of rocky soils and rough terrain. Changes of speed seriously affect the rate of application and result in poor distribution of herbicides. Time and attention is required during planting to apply sprays, and any equipment problems delay the planting operation. Furthermore, if treatments are delayed until after planting, several rows can be treated at once at a greater speed than is possible during the planting operation.

In contrast to sprays, the application of herbicide granules during planting has worked very well. A granular applicator, mounted on the planter, distributes material only while the planter moves and is not greatly affected by speed changes and rough terrain. Granular applicators mounted in this way require little attention and only occasional refilling which does not detract from the planting operation.

Granular versus spray applications. Sprays of simazine are less expensive than granules but require a water supply. Similarly, sprays of simazine act faster on weeds but granules last longer (see section on Effects of herbicides on weeds and conifers).

Band versus broadcast treatments. With the availability of chemical means of controlling sod some growers may consider broadcast treating, a common practice in the Northwest. Erosion can become a limiting factor in humid New England, when broadcast treatments are used without cultivation. At the present time we have no data to indicate whether broadcast treatments can improve conifer response on soils where erosion is not a problem. From the economic standpoint, however, band treatments or spot treatments require less herbicide per acre of trees than broadcast treatments.

Treated bands narrower than 24 inches or spots less than 27-30 inches in diameter allow the tall grasses that grow between rows to fall over small trees. If areas between rows in the plantation are mowed, however, narrower bands may prove effective.

Summary

Herbicides were evaluated for their effects on herbaceous plants and conifers in Christmas tree plantings in several experiments conducted in Connecticut and northern Vermont. Simazine was the most versatile herbicide tested and the one that is best adapted to the soil and climatic conditions in New England. Atrazine and dichlobenil are somewhat

more hazardous in planting stock but may have value in established plantings for the control of certain perennial weeds that are resistant to simazine. Amitrole, dalapon, and paraquat proved effective as supplements to simazine for the control of perennial weeds and grasses before or after planting Christmas trees.

Root dips of activated carbon proved effective in reducing injurious effects on transplants from herbicides in the root zone. In particular, carbon root dips counteracted the toxic effects of dichlobenil, allowing good survival and growth of Scotch pine and white spruce.

No herbicide controlled all herbaceous growth in plantations. Sod grasses, considered the most competitive herbaceous growth, were effectively controlled with all herbicides, alone or in combination. The encroachment of weeds and brush resistant to individual herbicides requires that herbicide treatments be changed as weed populations change.

Sod control results in higher soil moisture during dry periods, higher nutrient content in the soil and subsequent increases in growth and color in spruce and balsam the year following initial treatment. Spruces responded to control of the sod grasses even though resistant weeds flourished. Although sod control treatment did not accelerate the growth of white and Scotch pines as much as spruce and balsam fir, the treated pines had better color and lower whorls were less deformed than those in sod. Treatments in all species reduced losses from mowing and prevented the loss of small plants from the matting of sod during the winter and early spring.

A number of factors affecting the safe and effective use of herbicides in Christmas tree plantings are discussed.

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