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Control of Herbaceous Weeds in Allegheny Hardwood Forests with Herbicides[1]

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Abstract. Bromacil (5-bromo-3-*sec*-butyl-6-methyluracil), glyphosate (*N*-phosphonomethylglycine), picloram (4-amino-3,5,6-trichloropicolinic acid), simazine [2-chloro-4,6-bis (ethylamino)-*s*-triazine], and hexazinone [3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1*H*,3*H*)-dione] were evaluated at four application rates and five application dates, May 1, June 1, July 1, August 1, and September 1, for their ability to control seven herbaceous, forest ground covers, hayscented fern (*Dennstaedtia punctilobula* (Michx.) Moore), New York fern (*Thelypteris noveboracensis* L.), short husk grass (*Brachyelytrum erectum* Schreb.), bracken fern [*Pteridium aquilinum* (L.) Kuhn var. *latiusculum* (Desv.) Underw.], wild oat grass (*Danthonia compressa* Aust.), rough goldenrod (*Solidago rugosa* Mill.), and flattop aster (*Aster umbellatus* Mill.) without residual effects on black cherry (*Prunus serotina* Ehrh.) seed stored in the forest floor, or on survival and growth of natural or planted black cherry seedlings. Control of most of the target species depended on the date and rate of application. Simazine had no herbicidal effect on these extremely acid (pH 3.9 to 4.4) Allegheny Plateau sites. None of the herbicides interfered with germination of black cherry seed stored in the forest floor or with establishment of seedlings. Bromacil applied at 22.4 kg/ha, picloram, at 9.0 kg/ha, and hexazinone at 13.4 kg/ha reduced survival, or growth, or both, of black cherry seedlings planted in a forest opening. Glyphosate was the most economical herbicide that met the control criteria. Application of 1.1 kg/ha between August 1 and September 1 produced acceptable control of all target species for at least 3 yr.

Additional index words. Bromacil, glyphosate, picloram, simazine, hexazinone.

INTRODUCTION

The dense, herbaceous ground cover commonly found on many Allegheny Plateau forest sites in northwestern Pennsylvania interferes with the development of hardwood reproduction (1, 2). Small amounts of hayscented fern, New York fern, and short husk grass are found in most cherry-maple (*Prunus-Acer*) Allegheny hardwood stands. When these stands are thinned during intermediate stand culture, or when they are partially harvest-cut at the end of the stand rotation, the hayscented and New York fern and short husk grass spread rapidly from perennial rhizome systems or from seed.

These ground covers dramatically reduce seedling survival and growth of black cherry, red maple (*Acer rubrum* L.), sugar maple (*Acer saccharum* Marsh.), and other desirable hardwood species necessary for natural reproduction of these stands (2). If these herbaceous plants are removed by hand, seedling survival and growth are substantially increased[3]. Thus, weed control seems essential for satisfactory reproduction of some Allegheny hardwood stands.

Similar problems occurred after the virgin forests of Pennsylvania were cut earlier in the century. Slash fires and deer browsing combined to restrict reproduction in some stands. A dense, perennial ground cover dominated by bracken fern, wild oat grass, rough goldenrod, and flattop aster became established and spread from perennial rhizome systems (bracken fern, rough goldenrod, flattop aster) or seed (wild oat grass, rough goldenrod, flattop aster). Forest openings made in this way have not regenerated during the more than 50 yr that have elapsed since their creation, even where seed sources and small hardwood seedlings were present (1, 3). Most of these forest openings have few seedlings, so artificial regeneration will be necessary. Removal of weeds by hand around small, suppressed natural seedlings resulted in better growth. Weed control will be an essential step in preparing these areas for reforestation.

Herbicides offer one means of preparing sites for natural or artificial reproduction. There have been few studies of the use of herbicides in eastern hardwood forests, however, and no recent studies of their use in the Allegheny hardwood forest type. Presented here are results of field studies designed to evaluate (a) the control of the seven dominant, herbaceous ground covers in the Allegheny Plateau forest as a function of herbicide, rate, and date of application and (b) the potential for the herbicide to interfere with germination of natural black cherry seed stored in the forest floor, or with the survival and growth of black cherry seedlings planted after treatment.

MATERIALS AND METHODS

Herbicides. Field experiments were installed in 1976 and 1977 to evaluate control of the seven target forest ground covers. Herbicides and application rates tested included: the 80% wettable powder formulation of bromacil applied at 0, 5.6, 11.2, and 22.4 kg ai/ha, the 0.48 kg ai/L liquid formulation of glyphosate applied at 0, 1.1, 2.2, and 4.5 kg ai/ha, the 10% pelleted formulation of the potassium salt of picloram applied at 0, 2.2, 4.5, and 9.0 kg ai/ha, the 4% granular formulation of simazine applied at 0, 2.2, 4.5, and 9.0 kg ai/ha, and the 90% soluble powder formulation of hexazinone applied at 0, 3.8, 6.7, and 13.4 kg ai/ha. In 1976, each herbicide was applied on only one date. Bromacil and simazine were applied on May 1, glyphosate and hexazinone on June 1, and picloram on June 15. In 1977, simazine was deleted. Bromacil and picloram were applied at the same rates on five different dates – May 1, June 1,

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[3] Horsley, S. B., and D. A. Marquis. Unpublished research. Interference by weeds and deer with Allegheny hardwood reproduction.

July 1, August 1, and September 1. Glyphosate and hexazinone were applied at the same rates too, but not on May 1. Picloram was not applied to hayscented and New York fern or short husk grass.

Field layout utilized the split plot method in both experiments. In the 1976 experiment, herbicides were assigned to 7.6- by 7.6-m main plots that were split to receive four rates on 3.8- by 3.8-m subplots. In the 1977 experiment, times of herbicide application were assigned to 30.5- by 7.6-m main plots. These were split into four 7.6- by 7.6-m herbicide subplots, which were split further into 3.8- by 3.8-m rate subplots. Measurements were not taken within 0.3 m of plot boundaries to control possible effects of overspray. Both experiments were replicated three times.

Herbicide for each rate unit was premeasured before use in the field. All herbicides were applied using a double coverage technique. Half of the herbicide was distributed in several passes over the plot in a north-south direction; the remainder was applied in an east-west direction. Picloram pellets and simazine granules were distributed by hand; the other herbicides were dissolved and mixed in 0.8 L of water (551 L/ha) and sprayed on foliage from a small, compressed-air garden sprayer. All rates were within the high and low limits recommended by the manufacturers for other plants. No rain fell within 6 hr of herbicide application, but rain received within the first 4 weeks after application was adequate to move root-absorbed herbicides into the soil.

Study sites. Experiments to evaluate the control of hayscented and New York fern and short husk grass were installed in two forest stands on the Kane Experimental Forest near Kane, Pennsylvania. The overstory was black cherry and sugar maple, and ground coverage by fern or grass was 100%. Both hayscented and New York fern have similar growth habits and are frequently found together in the Allegheny hardwood forest. In these experiments they were not distinguished and there was no evidence that they responded differently to the chemicals applied. Soils at both locations were classified as somewhat poorly drained Cavode silt loam (Aeric Ochraguult). The pH of the A horizon ranged from 4.0 to 4.4; pH of the B horizon ranged from 4.2 to 4.4. Strong mottling was observed at a depth of 25 cm and a fragipan-like layer was present at 46 to 61 cm. Thickness of the F horizon ranged from 1 to 6 cm. A moderate amount of organic material was incorporated into the A horizon.

Control of bracken fern, wild oat grass, rough goldenrod, and flattop aster was evaluated at a third site located a short distance from the Kane sites in a 50-yr-old forest opening on the Ridgway (Pennsylvania) District of the Allegheny National Forest. These plants normally are found together in forest openings in mixtures of varying proportions, although all species are not always present at any particular site (1). On this site, all four species were on each plot. Soil was a moderately well drained Cookport sandy loam (Aquic Fragiudult). Mottling occurred at a depth of 46 to 76 cm and a fragipan was present at about 75 cm. The pH of the A horizon was 3.9. The F horizon ranged from about 0.3 cm on mounds and flats to 5 cm in mossy pits. There was little to moderate incorporation of organic material into the A horizon, depending on microsite characteristics.

Measurement of weed control. Percentage control of hayscented and New York fern and short husk grass in pure stands was estimated visually by two independent observers and an arbitrated value was recorded. In the forest opening there were variable numbers of each species on each measurement plot. Ten plants of each target species were marked on each rate subplot with color-coded metal pins. In post-treatment tallies, mortality at a pin represented 10% control. Pin counts were supplemented with visual estimates. Weed control was evaluated 1 and 3 yr after herbicide application.

Bioassay of herbicide residual effects. Forest openings usually lack adequate seed sources and must be regenerated artificially, such as by planting. Herbicide residues must not interfere with survival or growth of tree seedlings that may subsequently be planted on the site. Moreover, seed stored in the forest floor is a significant source of black cherry and other hardwood seedlings for regenerating Allegheny hardwood stands (5). It is important that herbicides not reduce this resource. Residual effects of the herbicides on planted seedlings were tested by planting 16 1-yr-old black cherry seedlings in the center of each herbicide-by-rate subplot in the 1976 experiment on April 14 to 19, 1977, almost 1 yr after herbicide application. Seedlings were grouped for uniformity of height and branch development before planting. Survival and seedling height growth were recorded annually. Herbicide residual effects on black cherry seed stored in the forest floor were tested using the hayscented and New York fern and short husk grass plots in the 1977 experiment. On each rate plot, 0.3- by 0.3-m sample points were covered with plastic window screen in the fall of 1977, before natural seedfall. A 0.3- by 0.3-m plot, 1 m to the right of each screened plot was marked, but not screened, so that it received natural seedfall. Differences in seedling emergence between screened and unscreened plots were used to test whether there was an affect of herbicide residues on black cherry seed stored in the forest floor. There were 312 screened and 312 unscreened observation points. Emergence counts were made on June 22 to 28, 1978.

RESULTS AND DISCUSSION

Adequacy of control. Allegheny hardwood stands normally are regenerated with natural seedlings that are present before the final harvest. Established regeneration guidelines for Allegheny hardwood stands prescribe that 70% of the stand must be free of herbaceous cover at the time of harvest cutting to obtain successful regeneration (6). Thus, 70% weed control is the minimum acceptable level. In stands where herbicide treatment is required, 2 to 3 additional yr are needed to replace desirable tree seedlings killed by the herbicide. Thus, there must be 70% control of the ground cover 2 to 3 yr after herbicide treatment to ensure that the stand will regenerate successfully after cutting.

There has been little work on regeneration of forest openings, so it is not possible to say with confidence what levels of weed control are satisfactory. Forest openings usually lack adequate seed sources; thus, artificial regeneration, such as planting, is required. Our experience with hardwood planting shows that seedlings must be free from interference for several years to become established and grow.[4] In this study, 70% weed control 3 yr after treatment was set as the standard against which satisfactory weed control was measured for both forest stands and forest openings. Regression analysis ($Y = 3.5472 + 0.87926X$; $R^2 = 83.0$) of data obtained in this study showed that treatments producing weed control of at least 85% 1 yr after treatment had at least 70% control 3 yr after treatment; thus, 85% control 1 yr after treatment was considered satisfactory, too.

Control 1 and 3 yr after application of bromacil. Seasonal trends in initial weed control were observed for all species except bracken fern and wild oat grass. Weed control was greatest when bromacil was applied in May and decreased at most rates with applications made later in the growing season (Table 1). Increasing the rate of bromacil increased the control of all species except wild oat grass; for the latter, all rates of application produced similar control.

For most weed species, the initial weed control fell far below the 85% minimum acceptable level. In forest stands, hayscented and New York fern were not controlled at satis-

[4] Horsley, S. B. Unpublished data.

Table 1. Percentage control of herbaceous plants 1 and 3 yr after application of bromacil at various rates and times[a].

Application rate	1 yr after application					3 yr after application				
	Application date					Application date				
	May[b]	June	July	August	September	May[b]	June	July	August	September
(kg/ha)	(%)									
	Hayscented and New York fern									
0	0(0)f	0f	0f	0f	0f	0(0)e	0e	0e	0e	0e
5.6	70(67)ab	45cd	8e	5ef	10e	23(5)b	7c-e	0e	0e	8c-e
11.2	75(70)ab	30d	42cd	30d	45cd	50(10)a	2de	15b-d	5c-e	18b
22.4	73(78)ab	78ab	62bc	68ab	85a	20(28)b	18b	15b-d	58a	70a
	Short husk grass									
0	0(0)h	0h	0h	0h	0h	0(0)c	0c	0c	0c	0c
5.6	23(23)e-g	12fg	15fg	25d-f	38c-e	10(8)c	0c	2c	8c	50b
11.2	70(80)b	18fg	12fg	45c	10g	40(30)b	2c	0c	10c	0c
22.4	90(87)a	47c	40cd	42cd	15fg	78(63)a	7c	7c	5c	10c
	Bracken fern									
0	0(0)f	0f	0f	0f	0f	0(0)d	0d	0d	0d	0d
5.6	23(60)e	20e	85cd	7f	30e	3(16)d	23cd	78a	7d	17cd
11.2	89(83)cd	91b-d	92b-d	80d	82cd	35(16)bc	15cd	68ab	80a	70a
22.4	98(88)ab	95a-c	94a-c	98ab	100a	85(51)a	33bc	88a	77a	80a
	Rough goldenrod									
0	0(0)f	0f	0f	0f	0f	0(0)d	0d	0d	0d	0d
5.6	93(88)ab	82bc	10e	0f	5f	53(51)ab	45c	38c	0d	0d
11.2	96(100)ab	92a-c	95ab	30d	20de	90(85)a	48c	88ab	0d	0d
22.4	97(100)a	93ab	94ab	87bc	77c	95(100)a	68a-c	83ab	67a-c	73a-c
	Wild oat grass[c]									
0	0(0)e	0e	0e	0e	0e	0(0)c	0c	0c	0c	0c
5.6	96(92)a-c	97a-c	91cd	88d	88d	55(16)ab	0c	0c	0c	0c
11.2	98(88)ab	94cd	95b-d	96a-c	98ab	65(16)ab	0c	50ab	50ab	83a
22.4	99(97)a	99a	98ab	98ab	99a	75(16)ab	10c	0c	0c	48b
	Flattop aster									
0	0(0)e	0e	0e	0e	0e	0(0)c	0c	0c	0c	0c
5.6	10(7)cd	0e	5de	0e	13cd	0(16)c	0c	13c	0c	10c
11.2	40(40)b	0e	92a	10cd	20c	5(16)c	0c	90a	13c	15c
22.4	90(95)a	94a	82a	88a	90a	83(85)a	55b	0c	40b	90a

[a]For 1977 experiment, month-by-rate interaction means within a species and year of evaluation followed by the same letter do not differ at the 0.05 level of probability using Duncan's new multiple range test.

[b]Numbers in parentheses are % control in the 1976 experiment.

[c]100% kill of wild oat grass was achieved the year of application; values presented are regrowth from seed stored in the litter.

factory levels at any rate or date. Control of short husk grass was above 85% only at 22.4 kg/ha applied May 1. Control of these species decreased substantially over the next 2 yr and was near zero at most rates and dates of application at the end of 3 yr. Only 22.4 kg/ha applied in May controlled short husk grass at the 70% minimum acceptable level; control of hayscented and New York fern remained at 70% 3 yr after treatment with only 22.4 kg/ha of bromacil applied in September.

Bromacil was more effective when applied to herbaceous weeds growing in the forest opening than when applied beneath the forest canopy. Wild oat grass was controlled easily at 5.6 kg/ha. Reinvasion of plots by wild oat grass from seed stored in the litter was delayed for more than 1 yr. Only May 1 applications of bromacil gave consistent wild oat grass control that lasted for 3 yr at levels above or near 70%. For bracken fern and rough goldenrod, 11.2 kg/ha was required between May 1 and July 1 to produce an initial control of 85%. After 3 yr, however, control of bracken fern was above 70% only for the July 1 application; 22.4 kg/ha was required to produce 3 yr of control over a wider span of application dates. The 22.4-kg/ha rate of bromacil con-

Table 2. Percentage control of herbaceous plants 1 and 3 yr after application of glyphosate at various rates and times[ab].

Application rate	1 yr after application				3 yr after application			
	Application date				Application date			
	June[c]	July	August	September	June[c]	July	August	September
(kg/ha)	(%)							
	Hayscented and New York fern							
0	0(0)d	0d	0d	0d	0(0)c	0c	0c	0c
1.1	93(68)c	99a	98ab	97a-c	81(18)b	96a	95a	93a
2.2	95(75)bc	98ab	98ab	97a-c	91(18)a	95a	96a	95a
4.5	97(73)a-c	98ab	98ab	99a	93(27)a	95a	92a	97a
	Short husk grass[d]							
0	0(0)e	0e	0e	0e	0(0)b	0b	0b	0b
1.1	88(68)cd	96ab	91cd	87cd	67(8)a	77a	68a	65a
2.2	88(83)cd	98a	93bc	85d	72(42)a	75a	63a	60a
4.5	90(92)cd	97ab	94a-c	85d	67(33)a	77a	60a	60a
	Bracken fern							
0	0(0)d	0d	0d	0d	0(0)c	0c	0c	0c
1.1	0(0)d	75c	93ab	95ab	0(0)c	63b	86a	87a
2.2	0(0)d	88b	95ab	95ab	0(0)c	88a	90a	88a
4.5	0(40)d	91b	98a	95ab	0(0)c	91a	94a	92a
	Rough goldenrod							
0	0(0)e	0e	0e	0e	0(0)e	0e	0e	0e
1.1	90(96)cd	90cd	95a-c	93b-d	75(85)b-d	73cd	91ab	85a-c
2.2	85(96)d	99a	99a	99a	63(85)d	96a	96a	96a
4.5	90(94)cd	97a-c	98ab	99a	82(85)a-d	95a	96a	95a
	Wild oat grass[d]							
0	0(0)c	0c	0c	0c	0(0)a	0a	0a	0a
1.1	95(80)a	87ab	91ab	97a	0(0)a	0a	0a	0a
2.2	88(77)ab	72b	90ab	92ab	0(0)a	0a	0a	0a
4.5	95(63)a	75b	90ab	95a	0(0)a	0a	0a	0a
	Flattop aster							
0	0(0)f	0f	0f	0f	0(0)d	0d	0d	0d
1.1	65(99)e	90cd	98ab	95bc	30(85)c	95a	85ab	90ab
2.2	82(99)d	99ab	100a	98ab	68(85)b	89ab	92a	92a
4.5	92(98)c	100a	99ab	99ab	37(85)c	92a	93a	95a

[a]For 1977 experiment, month-by-rate interaction means within a species and year of evaluation followed by the same letter do not differ at the 0.05 level of probability using Duncan's new multiple range test.

[b]Not applied in May.

[c]Numbers in parentheses are % control in the 1976 experiment.

[d]100% kill of short husk grass and wild oat grass was achieved the year of application; values presented are regrowth from seed stored in the litter.

sistently gave long-term control of rough goldenrod (Table 1). In the forest opening, flattop aster was the most difficult weed for bromacil to control. The 22.4-kg/ha rate yielded control above or near 85% throughout the initial growing season; however, only May and September applications produced control that was acceptable after 3 yr.

Control 1 and 3 yr after application of glyphosate. Response of all species except wild oat grass to glyphosate varied with date of application (Table 2). Wild oat grass was completely controlled by glyphosate, regardless of rate or date of application. Initial weed control following the June 1 application was substantially less than that obtained after later applications. Control of bracken fern was markedly seasonal; no control was obtained by the June 1 application, but it increased dramatically in July, averaging 93% or more at the August 1 and September 1 application dates. Seasonal trends were still observed for all fern species, rough goldenrod, and flattop aster 3 yr after application. The initial control of hayscented and New York fern for the June 1 application was less in 1976 than in 1977. These differences are attributed to slower plant development during the cooler spring of 1976.

Differences among rates were small for all species 1 yr after application (Tab! 2). Three y^ears after application, it was still apparent that date of application had an important effect on the control of bracken fern, rough goldenrod, and flattop aster at 1.1 kg/ha. Control equivalent to that for 2.2 and 4.5 kg/ha was produced only at the August 1 and September 1 application.

Among the target species in this study, wild oat grass is the only species that reproduces exclusively from seed. Large amounts of seed are produced annually, a portion of which remains dormant in the litter for at least several years. Initially, glyphosate controlled wild oat grass plants completely at all rates and dates of application; however, because glyphosate has no residual soil activity, germination and growth of dormant grass seeds in the following year were not impeded, particularly on portions of plots disturbed by the foot traffic that was necessary to make measurements. No control of wild oat grass was evident 3 yr after treatment (Table 2). Similarly, the initial control of short husk grass was nearly complete (Table 2), but reinvasion from seed stored in the litter began the same year glyphosate was applied. Control of short husk grass was 60 to 75% after 3 yr (Table 2).

The amount of grass regrowth appears to be partly an artifact of the small-plot experiment. In large-plot studies, in which forest stands were treated with glyphosate and then cut, skid trails left by the logging operation were quickly revegetated with grass from dormant seed in the litter. Thus far, this has not been a serious problem because skid trails cover a limited portion of the stand.

Considering both experiments, control of hayscented and New York fern in forest stands was satisfactory when glyphosate was applied at 1.1 kg/ha July 1 through September 1. Best control of short husk grass also occurred at the same rate and dates, although control was near or just below the minimum acceptable level. In the forest opening, control of bracken fern, rough goldenrod, and flattop aster was satis-

Table 3. Percentage control of herbaceous plants 1 and 3 yr after application of picloram at various rates and times[a].

Application rate	1 yr after applicaton					3 yr after application				
	Application date					Application date				
	May	June[b]	July	August	September	May	June[b]	July	August	September
(kg/ha)	(%)									
	Bracken fern									
0	0e	0(0)e	0e	0e	0e	0e	0(0)e	0e	0e	0e
2.2	92b-d	95(99)b-d	86d	90cd	99ab	95ab	86(51)bc	10d	72c	90bc
4.5	99ab	99(98)ab	93b-d	97a-c	98a-c	90a-c	93(51)ab	73c	88bc	90bc
9.0	100a	100(100)a	99ab	100a	100a	100a	97(85)ab	90bc	93ab	98ab
	Rough goldenrod									
0	0e	0(0)e	0e	0e	0e	0f	0(0)f	0f	0f	0f
2.2	97b	78(90)d	90c	90c	99ab	93bc	0(51)f	42e	78d	95bc
4.5	97b	99(97)ab	96bc	98ab	99ab	97a-c	98(85)a-c	90cd	95bc	98a-c
9.0	100a	99(100)ab	99ab	100a	100a	99ab	90(85)cd	93bc	99ab	100a
	Flattop aster									
0	0d	0(0)d	0d	0d	0d	0f	0(0)f	0f	0f	0f
2.2	92bc	30(87)d	80c	97ab	98ab	88b-d	0(51)f	0f	85c-e	95b
4.5	99ab	93(95)b	94b	93b	100a	92bc	83(51)c-e	93bc	83c-e	96b
9.0	98ab	96(100)ab	98ab	100a	100a	80de	73(100)e	85c-e	93bc	100a

[a]For 1977 experiment, month-by-rate interaction means within a species and year of evaluation followed by the same letter do not differ at the 0.05 level of probability using Duncan's new multiple range test.

[b]Numbers in parentheses are % control in the 1976 experiment.

factory at 1.1 kg/ha from August 1 to September 1. Satisfactory control could be extended to July 1 by applying 2.2 kg/ha.

Control 1 and 3 yr after application of picloram. Early- or late-season application of 2.2 kg/ha resulted in weed control exceeding 85% for bracken fern, rough goldenrod, and flattop aster (Table 3). Weed control had decreased little 3 yr after application and was considered satisfactory. Midsummer applications resulted in a reduced initial control and little or no residual control of these species after 3 yr.

The 4.5- and 9.0-kg/ha rates of application, and 2.2 kg/ha applied on June 1 and September 1, gave uniformly high initial control of bracken fern, rough goldenrod, and flattop aster, exceeding 90%. Control was 10 to 20% less for 4.5 or 9.0 kg/ha on most dates 3 yr after application of picloram. Regardless of the rate or date of application, no control of wild oat grass was observed.

Picloram was applied to hayscented and New York fern and short husk grass only in the 1976 study (data not shown). Some foliage burning occurred with 4.5 and 9.0 kg/ha, but the plants were not killed and no control was obtained.

Simazine. The use of simazine did not result in any notice-

Table 4. Percentage control of herbaceous plants 1 and 3 yr after application of hexazinone at various rates and times[ab].

Application rate	1 yr after application				3 yr after application			
	Application date				Application date			
	June[c]	July	August	September	June[c]	July	August	September
(kg/ha)	(%)							
	Hayscented and New York fern							
0	0(0)g	0g	0g	0g	0(0)e	0e	0e	0e
3.8	35(78)e	65d	12f	25e	0(15)e	43c	10d	15d
6.7	32(88)e	75cd	23ef	35e	5(63)d	50c	15d	12d
13.4	72(94)cd	97a	88b	82bc	47(77)c	87a	72b	55bc
	Short husk grass[d]							
0	0(0)g	0g	0g	0g	0(0)e	0e	0e	0e
3.8	68(78)b	62b	18f	20ef	45(10)a-c	0e	5de	10de
6.7	85(88)a	55bc	32d-f	40cd	62(37)a	18cd	7de	22b-d
13.4	85(95)a	87a	38c-e	62b	48(57)ab	67a	10de	45a-c
	Bracken fern							
0	0(0)e	0e	0e	0e	0(0)b	0b	0b	0b
3.8	83(80)d	90cd	98a-c	85d	75(16)a	82a	75a	77a
6.7	91(78)b-d	94b-d	99ab	95b-d	87(16)a	80a	85a	82a
13.4	98(98)a-c	98a-c	100a	100a	82(16)a	78a	82a	92a
	Rough goldenrod							
0	0(0)e	0e	0e	0e	0(0)g	0g	0g	0g
3.8	94(100)b	100ab	93ab	25d	50(100)e	97ab	65de	5fg
6.7	97(100)ab	96ab	96ab	63c	93(100)bc	96bc	93bc	15f
13.4	100(100)a	99ab	100a	96ab	98(100)ab	93bc	100a	83cd
	Wild oat grass[d]							
0	0(0)d	0d	0d	0d	0(0)d	0d	0d	0d
3.8	52(90)c	95b	96b	99ab	0(16)d	27bc	0d	75a
6.7	63(87)c	96b	93b	99ab	0(16)d	0d	0d	73a
13.4	70(94)c	98ab	99ab	100a	0(16)d	25c	50ab	58a
	Flattop aster							
0	0(0)f	0f	0f	0f	0(0)g	0g	0g	0g
3.8	88(100)c	99ab	92bc	5e	15(100)f	99a	40e	10f
6.7	95(100)bc	98ab	96bc	67d	78(100)cd	91a-c	72d	75cd
13.4	97(100)a-c	100a	93bc	92bc	80(100)cd	98ab	88a-d	82b-d

[a]For 1977 experiment, month-by-rate interaction means within a species and year of evaluation followed by the same letter do not differ at the 0.05 level of probability using Duncan's new multiple range test.

[b]Not applied in May.

[c]Numbers in parentheses are % control in the 1976 experiment.

[d]100% control of short husk grass and wild oat grass was achieved the year of application; values presented are regrowth from seed stored in the litter.

able damage or killing of the target species in either the year of application, 1976, or the following year. Under certain environmental conditions, the herbicidal activity of simazine is dissipated rapidly in the soil (4, 7). Acid hydrolysis, soil adsorption, and microbial metabolism are the major causes of reduced activity. Hydroxy-simazine, the major hydrolysis product of simazine, does not have herbicidal properties, and its formation is greatly increased as soils become more acidic (4, 7). Although no efforts have been made to determine the reasons for lack of herbicidal activity by simazine, it seems possible that extremely acid soil conditions and organic matter in the forest floor may contribute substantially. In any event, simazine was not useful for weed control on Allegheny hardwood forest sites and was not included in further experiments.

Control 1 and 3 yr after application of hexazinone. Date of application affected the control of all species except wild oat grass (100% control at all rates and dates). Early season applications resulted in substantially greater control than late season applications (Table 4). Measurements of control after 3 yr suggested that hexazinone had peak activity at the July 1 application.

Differences among rates of application of hexazinone were observed for most species and dates. In forest stands, control at all but 13.4 kg/ha was substantially less 3 yr after application than it had been 2 yr earlier. Only 13.4 kg/ha applied July 1 gave satisfactory control of hayscented and New York fern after 3 yr, and short husk grass was not controlled satisfactorily at any rate or date of application.

In the forest opening, bracken fern was satisfactorily controlled at 3.8 kg/ha applied from July 1 through September 1. The reappearance of wild oat grass was initially delayed by the residual activity of hexazinone, but 3 yr after application there was little control of grass. Control of rough goldenrod and flattop aster was greater than 85% after 1 yr with June 1 to August 1 applications, at all rates; control remained above 70% at 6.7 and 13.4 kg/ha for 3 yr.

Survival and growth of planted black cherry seedlings at 30 months. Application of herbicides increased seedling survival at all sites; however, these differences were statistically significant only in the forest stand at the hayscented and New York fern site (Table 5). Survival of black cherry seedlings was adversely affected by bromacil at 22.4 kg/ha, hexazinone at 13.4 kg/ha and picloram at 9.0 kg/ha when they were applied in the forest opening, although only hexazinone produced a statistically significant reduction in survival.

Little or no increase in black cherry seedling growth resulted from herbicide application on either of the forest stand sites, where overstory shading restricted growth (Table 6). In the forest opening, all rates of hexazinone reduced growth below that for control seedlings, and seedling growth was less on some simazine treated plots, although simazine had no herbicidal activity in this test. Most of these growth reductions were not statistically significant, even though they occurred consistently in the forest opening. The magnitude of some of the differences suggests that a lack of adequate numbers of observations prevented statistical detection. Glyphosate, which had no residual activity in the soil, had no detrimental effects on seedling survival or growth.

Germination of stored black cherry seed. About 60% (61% grass site; 63% fern site) of the black cherry seed emerging the year following application of herbicide was from seed stored in the forest floor. No differences in emergence attributable to herbicides, rates, or dates of application were noted, although there were twice as many germinants on treated as on control plots (treated, seven seedlings/m^2; control, three seedlings/m^2). Germinants were normal in appearance and there was no evidence of damage. Although most of the existing seedlings were killed by the herbicide applications, none of the treatments interfered with the ability of black cherry seed stored in the litter to germinate and develop into normal seedlings.

Table 5. Survival of black cherry seedlings 30 months after planting[a].

Site and species	Application rate	Bromacil	Glyphosate	Picloram	Simazine	Hexazinone
		(%)				
Forest stand	Control	78a	73a	87a	71a	88a
Short husk grass	Low	94a	98a	88a	77a	98a
	Medium	94a	93a	87a	64a	100a
	High	94a	98a	90a	75a	90a
Hayscented and	Control	18b	19b	19c	14a	12b
New York fern	Low	79a	88a	56b	8a	88a
	Medium	83a	92a	88a	29a	94a
	High	75a	92a	75a	31a	81a
Forest opening	Control	88a	81a	77a	90a	92a
	Low	88a	94a	88a	90a	81a
	Medium	90a	92a	90a	90a	73a
	High	69a	90a	77a	90a	58b

[a]Means within an herbicide by species by site interaction subclass followed by the same letter do not differ significantly at the 0.05 level of probability using Duncan's new multiple range test.

Table 6. Adjusted height of black cherry seedlings 30 months after planting[ab].

Site and species	Application rate	Bromacil	Glyphosate	Picloram	Simazine	Hexazinone
		(cm)				
Forest stand Short husk grass	Control	142a	135a	138a	119a	139a
	Low	122a	129a	131a	129a	121a
	Medium	122a	121a	137a	122a	128a
	High	122a	125a	150a	128a	115a
Hayscented and New York fern	Control	51a	74a	55a	67a	79a
	Low	60a	78a	72a	46c	72a
	Medium	68a	77a	110a	57b	74a
	High	67a	73a	95a	69a	80a
Forest opening	Control	112a	144a	136b	146a	158a
	Low	149a	174a	175a	120bc	116a
	Medium	202a	153a	187a	137ab	147a
	High	148a	174a	176a	113c	121a

[a]Means within an herbicide by species by site interaction subclass followed by the same letter do not differ significantly at the 0.05 level of probability using Duncan's new multiple range test.

[b]Seedling height adjusted for the regression of initial seedling height.

Comparison of treatments. Successful application of herbicides to control weeds in forest stands and forest openings on the Allegheny Plateau often requires that several weed species be controlled simultaneously. This is especially true in forest openings where wild oat grass is found in mixture with bracken fern, rough goldenrod, and flattop aster, either singly or in combination. In forest stands, hayscented and New York fern and short husk grass often are found in mixtures, although control of pure fern stands is by far the more important concern.

Clearly, cost has a great impact on the choice of herbicide. Glyphosate at 1.1 kg/ha is the most economical choice for treating herbaceous weeds in both forest stands and forest openings. Timing of herbicide application is essential with glyphosate. In forest stands, hayscented and New York fern and short husk grass were adequately controlled by applications made July 1 through September 1. In forest openings, glyphosate can be applied July 1 through September 1 to plant communities lacking bracken fern; however, if bracken fern is present, applications should be restricted to August 1 through September 1.

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