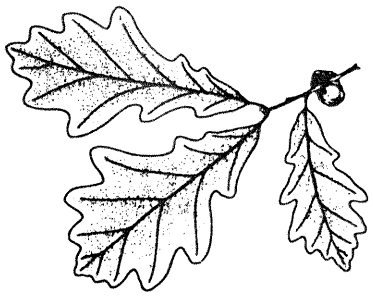
PREEMERGENCE HERBICIDE PERFORMANCE ON FOREST SOIL[1]

Alan W. Sam, Todd W. Bowersox and Larry H. McCormick[2]



ABSTRACT

A greenhouse study was conducted to evaluate the ability of selected preemergence herbicides to control herbaceous vegetation on forest soils. Northern red oak and two species of grass (annual ryegrass and 'Kentucky 31' tall fescue) were grown from seed in forest soil cores separated into two litter treatments. Half of the soil cores had the litter and unincorporated humus layer removed while the other half were left intact. Seven preemergence herbicides; metolachlor, napropamide, oryzalin, oxadiazon, oxyfluorfen, simazine and sulfometuron methyl, were applied at three rates to soil cores of both litter treatments. Oven dry weights of the grass after 16 weeks were used to measure herbicide effectiveness. Herbicide effects on northern red oak seed germination and growth were also noted. Sulfometuron methyl, simazine and oxyfluorfen were the most effective in controlling the seeded grass at all rates, with and without surface organic material. Sulfometuron methyl was the only herbicide to adversely affect red oak germination and growth.

INTRODUCTION

Forest land managers have successfully regenerated northern red oak where adequate numbers of seedlings have been present before harvest cuts. However, many Pennsylvania oak stands do not have sufficient numbers of red oak seedlings present to insure desirable stocking levels following their harvest. The absence of sufficient advanced red oak reproduction can be caused by many factors: stress from woody and/or herbaceous vegetation, predation by herbivores, unfavorable physical environment, insects and diseases. Each of these factors can be important, but when compounded they can create very unfavorable conditions for the establishment and growth of northern red oak seedlings.

Stress from herbaceous vegetation has been frequently cited as a critical factor in determining the establishment and growth of natural or planted red oak seedlings (Beck 1970, Merritt 1979, McGee 1979, Rietveld 1979). Nonselective postemergence herbicides, such as glyphosate, have proven effective in controlling competing fern and grass vegetation found on Allegheny Plateau forest sites (Horsley 1981), but such control is often short-lived since grasses can reinvade treated areas from seed the following year. Four years of weed-free conditions may be necessary to allow establishment of natural reproduction or to accumulate adequate numbers of vigorous tree seedlings for successful regeneration (Horsley 1981). Needed are selective, preemergence herbicides capable of providing residual control of herbaceous vegetation, but which are not phytotoxic to the desirable tree species.

Most preemergence herbicides currently available for forest use have been developed for agronomic soil conditions. The effectiveness of these agronomic herbicides may be greatly reduced when applied to forested soils. Low pH, abundant organic matter, large amounts

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[2]The authors are Graduate Assistant, Associate Professor of Silviculture and Assistant Professor of Forest Resources, respectively, School of Forest Resources, The Pennsylvania State University. This research was supported by funds from McIntire-Stennis allotments.

of surface litter and an active microbial community of the forested conditions all may alter herbicide effectiveness and phytotoxicity (Smith 1982). These soil properties are known to affect herbicide volatilization, adsorption, leachability and eventual degradation (Harris and Warren 1964, Norris 1975, Stark 1982). Soil applied herbicides can become so tightly adsorbed to clay and organic matter that they are inactivated and have little or no control on germinating grasses and broadleaves (Norris 1975). The objective of this research was to find suitable preemergence herbicides for controlling herbaceous vegetation under these limiting conditions which would not be phytotoxic to northern red oaks developing from seed.

MATERIALS AND METHODS

A greenhouse study was conducted to evaluate the effectiveness of selected preemergence herbicides in controlling annual grass vegetation on forested soils. Seven herbicides; metolachlor (2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl) acetamide), napropamide (2-(a-naphthoxy)-N, N-diethylpropionamide), oxadiazon (2-tert-butyl-4-(2,4-dichloro-5-isopropoxyphenyl^2-Δ^2-1,3,4-oxadiazolin-5 -one), oxyfluorfen(2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl) benzene), simazine (2-chloro-4,6-bis (ethylamino)-s-triazine) and sulfometuron methyl (methyl 2-((((4,6-dimethyl -2-pyrimidinze) amino)-carbonyl) amino) sulfonyl) benzoate) were applied at one, two and four times the recommended rates to forest soil cores separated into two litter treatments (Table 1). Prior to herbicide application, the soil cores were sown with northern red oak (Quercus rubra L.) acorns and two species of grasses: annual ryegrass (Lolium multiflorum) and 'Kentucky 31' tall fescue (Festuca arundinacea, Selection Ky-31). The experiment was replicated three times and treatments were arranged in a completely randomized block design with 22 soil cores per treatment, per replication.

TABLE 1.--Characteristics and descriptions of preemergence herbicides used in the experiment.[1]/

Common Name (Product Name Formulation)[3]/	Normally Applied	Target Vegetation	Mode of Action	Major Cause of Reduced Phototoxicity	1X Rate of Application[2]/ (kg ai/ha)
Sulfometuron methyl (Oust 75% WG)	Preemergence to early Postemergence	Annual grasses and Broadleaves	Stops cell division in growing tips	Low pH and microbial degradation	0.19
Simazine (Princep 4L)	Preemergence or Postemergence	Annual grasses and Broadleaves	Photosynthetic inhibitor	Adsorption to OM and microbial degradation	3.94
Metolachlor (Dual 8E)	Preemergence	Annual grasses	Root inhibitor	Photodecomposition and adsorption to organic matter	2.93
Oxadiazon (Ronstar 2% G)	Preemergence and some Postemergence	Annual grasses and Broadleaves	Contact	Adsorption to soil OM and clay particles	1.69
Oxyfluorfen (Goal 1.6E)	Preemergence to early Postemergence	Annual grasses and Broadleaves	Contact	Strongly adsorbed to OM and clay particles	1.01
Oryzalin (Surflan 75% WP)	Preemergence	Annual grasses and Broadleaves	Mitotic poison	Adsorption to soil OM and clay particles	1.97
Napropamide (Devrinol 50% WP)	Preemergence	Primarily annual grasses	Inhibits Root development	Photodecomposition and microbial degradation	3.91

[1]/ Information summarized from the Herbicide Handbook (1983) and Anderson (1983).

[2]/ The amount of herbicide required for 1X rate applications determined from recommendations made for non-crop use by herbicide experts and the literature.

[3]/ The trade names are supplied with the understanding that no discrimination is intended, and no endorsement by the authors is implied. Furthermore, in some instances, the same compound may be sold under different trade names, which may carry different label clearences. It is the users responsibility to follow the label.

The forest soil cores used in this study were taken from a central Pennsylvania oak forest stand containing northern red oak, white oak (Q. alba L.) and black oak (Q. velutina Lam.) in the overstory and hayscented fern (Dennstaedtia punctilobula L.) and poverty oat grass (Danthonia spicata) in the understory. The cores were obtained by using a 15 cm diameter soil extractor. The top 10 cm of the soil, a Typic Dystrochrept, were removed and later potted with the soil horizons intact. The thickness of the O1-O2, A1 and A2 horizons of the cores averaged 2.5, 1.3 and 3.8 to 6.3 cm respectively; pH of the O2, A1 and A2 horizons averaged 4.7, 4.7 and 4.9, respectively.

Litter and the unincorporated humus (O1-O2 horizons) was removed from one half of the soil cores (scalped) while the other half were left intact (non-scalped). Each core was sown with three northern red oak acorns and equal amounts of grass seed. Applications of all herbicides, except oxadiazon, were made 24 hrs after seeding with a hand-held, carbon dioxide sprayer using a single, even flat-fan nozzle calibrated to provide an even discharge of 150 ml of carrier plus herbicide over a 1.2 m x 4.8 m plot (248.7 L/ha). Oxadiazon was applied as a granular formulation and sprinkled over the designated soil cores placed randomly in a .6 m x 1.1 m plot. Treated pots were watered 24 hours after application and subsequently watered as needed.

Ocular estimates of percentage grass inhibition for each soil core were made periodically (every 2 to 3 days) for a period of 16 weeks by comparing the amount of grass vegetation present on the herbicide soil cores with the amount of grass present on the control soil cores. Herbicide effects on timing and the number of germinating red oaks were recorded as well as suspected red oak phytotoxicity.

The grass vegetation was harvested following the final observation (16 weeks) by clipping the stems 1 cm from the soil surface. The clippings were then dried at 85° C for 36 hours or until weight stabilized. Red oak seedling height was measured to the nearest 0.1 cm and numbers of live seedlings per pot recorded. Seedlings were then extracted from the soil medium and separated into root and stem portions, oven dried and weighed. The data were analyzed using standard analysis of variance procedures.

RESULTS

Vegetation Control

Analysis of the amount of grass growing in the soil cores 16 weeks after treatment indicated no significant difference in control among the three rates of application for any of the herbicides. Therefore, data for all three application rates for each herbicide were combined for further analysis.

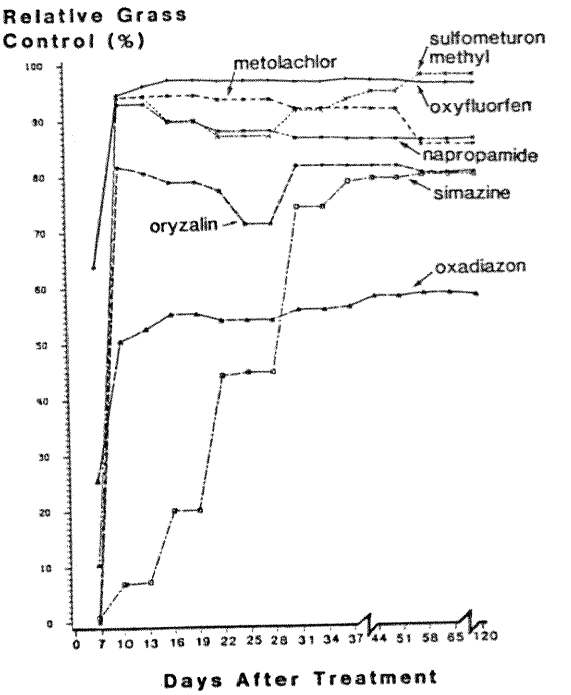

FIGURE 1.--Relative amount of grass inhibition, as compared to control treatment, for the selected herbicides, by days after treatment. Values for each observation time are based on ocular estimates and averaged over scalped and non-scalped soil cores.

Herbicide influence on grass germination was first noted one week after application (Figure 1). Seed germination and growth inhibition attained within the first two weeks of evaluation remained relatively constant throughout the experiment for all herbicides, except simazine. Simazine's initial control was poor, but slowly improved to a level comparable to the other herbicides. The simazine results were expected because it is a photosynthetic inhibitor, and is most effective when the target species reaches a stage mature enough to sustain active photosynthesis. Mode of action for the other six herbicides is such that control should be expected soon after application. Elapsed time before effective control is attained, may be a critical feature in selecting a herbicide, particularly if immediate control is necessary to obtain maximum growth potential of the desirable vegetation.

The organic layer had a very significant effect on the preemergence herbicides' ability to control herbaceous vegetation (Figure 2). Over all applications and rates, the herbicides were five times more efficient in controlling the grasses when applied to scalped soils than when applied to non-scalped soils. At the end of the 16 week growth period, all herbicides, except sulfometuron methyl, were more effective

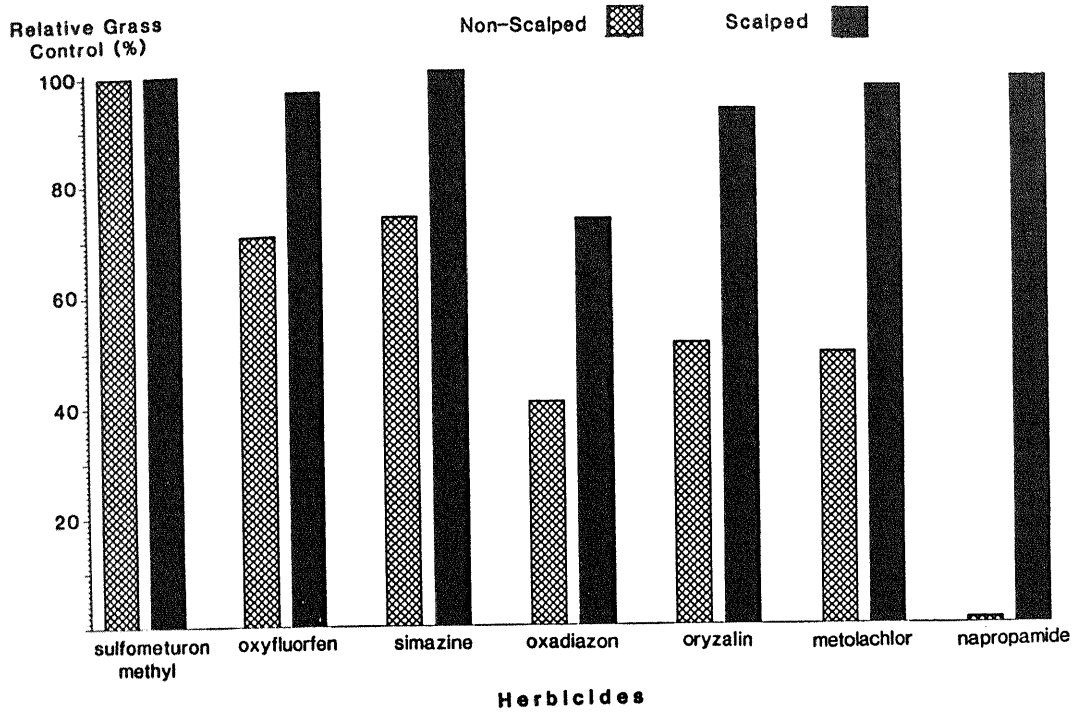

FIGURE 2.--Comparison of relative amount of grass inhibition on non-scalped and scalped soil cores for each herbicide. Percentage grass control based on dry weight comparisons of harvested grass of herbicide treatments with control treatments.

TABLE 2.--Effects of herbicide treatment on grass grown in scalped and non-scalped soils cores.

Herbicide	Grass Per Soil Core[1]/ Scalped	Non-Scalped
	(- - -Oven dry grams- - -)	
Sulfometuron methyl	0.0 a	0.0 a
Simazine	0.0 a	1.5 abc
Oxyfluorfen	0.2 ab	1.7 bc
Metolachlor	0.2 ab	2.9 cde
Oryzalin	0.4 ab	2.8 cd
Oxadiazon	1.5 abc	3.4 de
Napropamide	0.1 ab	5.6 f
Control[2]/	3.3 de	4.4 ef

[1]/ Weights averaged over replications, and rates (N = 9). Means followed by the same letter within and between soil treatments are not significantly different at the $\alpha = 0.05$ level based on Duncan's Multiple Range Test.

[2]/ Control treatment received no herbicide application.

on scalped soils than non-scalped soils (Table 2). Sulfometuron methyl was equally effective on both soil treatments. The other six herbicides averaged 27% to 98% better grass control on scalped soils. These differences were statistically significant only for metolachlor, napropamide, oryzalin and oxadiazon (Table 2).

Metolachlor, napropamide and oryzalin, which are most effective when they form a complete chemical barrier on the soil surface, were rendered somewhat ineffective by the abundance of surface litter present on the non-scalped soils. Napropamide resulted in the poorest control among the seven herbicides when applied to the non-scalped soils with virtually 0% grass control. However, when napropamide was applied on the scalped soils it was 98% effective in controlling the grass. Leaf and twig litter appeared to shield the germinating grass seed from napropamide, enabling the grass to grow through the litter. The poor grass control attained from oxadiazon applied to non-scalped soils was probably also a result of the surface litter. The litter may have caused an uneven distribution of the granular herbicide on the non-scalped cores which resulted in poor and spotty control.

The three herbicides least affected by the litter and unincorporated organic material were oxyfluorfen, simazine and sulfometuron methyl. All three attained greater than 70% grass control on both scalped and non-scalped soils. These results with our litter conditions suggest that oxyfluorfen, simazine and

sulfometuron methyl may not be adsorbed by the surface litter and can readily wash off and leach into the zone where they can inhibit the germinating grass.

Northern Red Oak Seedlings

Germination of the northern red oak acorns was about 90% or greater for all treatments except metolachlor and sulfometuron methyl (Table 3). Percentage of successful germinates averaged about 80% for metolachlor and 50% for the sulfometuron methyl treatments. Germination was also delayed by as much as 4 weeks for the sulfometuron methyl treatments and most germinates were multistemed and initially deformed. However, seedlings that did emerge, recovered and grew rapidly in the absence of competing vegetation. Observations over a longer time would be needed to determine if the apparent sulfometuron methyl phytotoxicity to the emerging northern red oak seedlings could be overcome.

After 16 weeks, the northern red oak seedlings varied in height and oven dry weight according to soil treatment (Table 3). Seedling size was significantly reduced only on the sulfometuron methyl treated cores. Northern red oak seedlings growing in sulfometuron methyl, scalped soils were 50% smaller than those growing in non-scalped soils. Apparently the surface organic material of the non-scalped soils buffered the potential phytotoxicity of sulfometuron methyl to germinating northern red oak seedlings. Seedlings grown on forest soil cores treated with the other six herbicides averaged slightly larger for the scalped soils than the non-scalped soils.

DISCUSSION

Of the seven preemergence herbicides evaluated in this experiment, sulfometuron methyl, oxyfluorfen and simazine were most

TABLE 3.--Effects of herbicide treatment on the germination and average[1]/ growth of northern red oak (*Quercus rubra*) seedlings grown in scalped and non-scalped soil cores.

Herbicide and Soil Treatment	Root Weight	Stem Weight	Seedling Height	Germination
	(- - - - - - g - - - - - -)		(cm)	(%)
Sulfometuron methyl				
Scalped	4.6 e	2.4 f	5.3 c	51.9 c
Non-Scalped	7.2 cde	7.1 abcde	10.5 b	55.6 bc
Simazine				
Scalped	11.8 ab	7.6 abcd	13.5 ab	96.3 a
Non-Scalped	11.3 abc	7.1 abcde	13.8 ab	96.3 a
Metolachor				
Scalped	10.6 abcd	8.4 ab	16.5 a	81.5 ab
Non-Scalped	9.1 abcd	6.4 abcde	12.0 ab	81.5 ab
Oxadiazon				
Scalped	10.8 abcd	7.2 abcde	12.0 ab	96.3 a
Non-Scalped	7.7 bcde	5.0 def	10.8 b	81.5 ab
Oxyfluorfen				
Scalped	13.2 a	9.1 a	15.0 ab	100.0 a
Non-Scalped	10.2 abcd	8.1 abc	14.0 ab	96.3 a
Oryzalin				
Scalped	12.8 a	8.0 abcd	13.8 ab	96.3 a
Non-Scalped	11.3 abc	6.8 abcde	13.8 ab	96.3 a
Napropamide				
Scalped	10.7 abcd	8.1 abcd	14.8 ab	88.9 a
Non-Scalped	6.6 de	5.7 bcde	12.8 ab	96.3 a
Control[2]/				
Scalped	11.6 ab	5.2 cde	11.5 ab	88.9 a
Non-Scalped	9.3 abcd	4.4 ef	10.8 b	88.9 a

1/ Averaged over replications and rates, and presented as averages per soil core. (N = 9). Numbers followed by the same letter between herbicide treatments for each seedling variable are not significantly different at the $\alpha = 0.05$ level based on Duncan's Multiple Range Test.

2/ Control treatment received no herbicide application.

effective, with an average control of 75% or better of the herbaceous vegetation over both soil treatments. Sulfometuron methyl did not appear to be affected by the surface litter or organic matter, since no distinction in control could be made between the scalped and non-scalped soils. Oxyfluorfen and simazine control was reduced on the non-scalped soils, but not by a significant amount. Immediate and long-lasting control was attainable with applications of sulfometuron methyl or oxyfluorfen but good control from simazine was reached only after minimal control was sustained for several weeks (Figure 1).

Oxadiazon and napropamide were considered the least effective in controlling grass grown on the forested soil of this study (Figure 2). Oxadiazon's control was inconsistant and varied considerably among replications and soil treatments. Napropamide's control of the vegetation was good to excellent on scalped soils but on non-scalped soils had virtually no affect on the vegetation, resulting in poor control.

Oryzalin and metolachlor were marginal in their ability to control germinating grass vegetation in this study. Both were adversely affected by the presence of surface organic matter but not to the same degree as napropamide. These herbicides may have forest applications where organic matter and surface litter is minimal. Further evaluations may be needed to determine their potential use in regeneration of oak stands.

Only sulfometuron methyl when applied to scalped soils significantly reduced red oak germination and initial growth. Red oak seedling height, weight and acorn germination were not significantly reduced when the herbicide was applied to non-scalped soils. This may indicate that sulfometuron methyl applications to forest soils having average amounts of surface organic material should not adversely affect red oak germination and growth. The potential phytotoxicity under low organic matter conditions should receive additional study.

SUMMARY AND CONCLUSIONS

Based on the results of this preliminary study, preemergent herbicides can provide effective herbaceous vegetation control on forest soils without adversely affecting the growth of red oak seedlings. However, the degree and timing of this control can vary with herbicide treatment and surface organic matter. Surface organic matter was shown to influence herbicide effectiveness and could be expected to alter herbicide performance in field applications. The amount of influence which the organic matter had on vegetation control varied with the specific herbicide being used.

The next step in the process would be to test the promising and marginally promising herbicides under field conditions to determine the effectiveness on native vegetation. Also, field evaluation of these herbicides, particularly of sulfometuron methyl, as to their phytotoxic affects on red oak seedlings from seed, bare root and naturally occurring stems must be conducted before final determinations can be made.

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