Susceptibility Of Sugar Maple And Oak To Eleven Foliar-Applied Herbicides

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Abstract.--Eleven foliar-applied herbicides were tested for their effectiveness in controlling sugar maple and oak species. Picloram combined with 2,4-D (Tordon 101 M) applied at a rate of 757 ml/gallon of water proved to be the most effective. Three years after application, 100 percent of all sugar maple and 75 percent of all oak receiving this treatment were dead.

INTRODUCTION

A significant increase in the density of sugar maple (Acer saccharum Marsh.) in Missouri's oak-hickory forests has been reported (Nigh et al. 1985; Pallardy et al., 1988). Similar increases have occurred in other states (Schlesinger, 1976; Cottam, 1949; Lorimer, 1984).

Sugar maple encroachment is considered undesirable because it is associated with the failure of oak to regenerate under its subcanopy. Oak regeneration in Missouri has steadily declined since logging in oak-hickory forests peaked between 1890 and 1920. Early oak regeneration failure was largely independent of the more recent encroachment of sugar maple, but has been exacerbated by it. Dense shade, caused from the overlapping crowns of sugar maple saplings, prevents adequate light penetration for oak seedling growth and development. Seed germination may occur but the young oak seedlings soon die for lack of light. Without advanced oak regeneration, there are no saplings present to assume canopy positions as mature oaks die or are harvested. The problem is especially relevant to mesic sites which have the greatest potential for growing high quality oak, as sugar maple appearance and dominance is most rapid on these sites (Pallardy et al., 1988). Because of the potential for serious decline in oak wood supply, a future negative effect on the hardwood forest products industry of the affected states is possible. Further, as more oak falls from a position of dominance in the overstory and is replaced by sugar maple, the mast-producing capacity of oak-hickory forests will be reduced. Loss of this important food source could be detrimental to wildlife populations, particularly those of deer, turkey and squirrel.

This study was an initial step in developing herbicide recommendations for sugar maple in Missouri. It was designed to test the effectiveness of a number of chemicals applied to the foliage with a backpack mist blower. Several oak species were also treated to document the effect of foliar-applied herbicides on oak.

MATERIALS AND METHODS

Thirty-six, 0.02 ha (0.05 acre) circular plots were established on east-facing slopes at the Ashland Wildlife Area (Garrett and Cox, 1973) in late May and early June of 1984. The study employed a randomized complete block design with three replications of 12 plots each.

Thirty trees (15 sugar maple and 15 oak) were selected within each plot. Only trees that were healthy and growing vigorously were selected for treatment. There were 360 trees per replication or a total of 1080 trees, with 540 individuals each of sugar maple (Acer saccharum Marsh.) and oak species. Within the oak group, white (Quercus alba L.), chinquapin (Quercus muehlenbergii Engelm.), post (Quercus stellata Wangenh.), northern red (Quercus rubra L.), black (Quercus velutina Lam.) and blackjack (Quercus marilandica Muenchh.) oaks were included.

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The diameter of each tree was measured with Mishoto dial calipers calibrated to 0.02 mm accuracy. Seedlings less than 1.4 m (4.5') tall were measured approximately 15 cm (6") above the root collar. Saplings above 1.4 m (4.5') but less than 2.54 cm (1") in diameter were measured approximately 30 cm (12") above the root collar. Saplings over 2.54 cm (1") in diameter were measured at a height of 1.37 m (4.5').

Sugar maple study trees ranged from 3.54 to 117.24 mm (0.1-4.6") in diameter. The oak which grew under the subcanopy of sugar maple ranged from 2.22 to 117.34 mm (0.1-4.6") but averaged only 14 mm (0.6") bdh (basal diameter height) compared to 25 mm (1") dbh (diameter breast height) for the maple.

All herbicides were applied at label-recommended rates (Table 1); the highest rates were used when a range was provided. A Solo model 410 backpack mist blower mounted on an aluminum frame was used to apply all herbicides which were mixed the morning of application. Each of the 30 trees/plot was individually misted from at least two sides. Each tree was sprayed "to wet" but not to run-off. Replicate I was treated on May 21 and 22, replicate II on June 2 and 4 and replicate III over three days, June 11, 13 and 17, 1984. Defoliation data were recorded in September 1984, 1985 and 1986, one, two and three growing seasons after herbicide application, respectively.

Table 1.--Active ingredient(s) [AI] and application rate of herbicides applied to the foliage of sugar maple and oak.

Product (Manufacturer)	AI	%AI	Rate (ml/gal)
Roundup (Monsanto)	Glyphosate	41	79
Banvel 720 (Velsicol)	Dicamba	13	374
	Related acids	3	
	2,4-D	25	
Krenite (DuPont)	Fosamine ammonium	42	76
Tordon 101 M (Dow)	Picloram	10	757
	2,4-D	40	
Garlon 3A (Dow)	Triclopyr	44	123
Garlon 4 (Dow)	Triclopyr	62	95
Weedone 2,4-DP (Union Carbide)	2,4-DP	60	38
Weedone LV-4 (Union Carbide)	2,4-D	61	158
Weedone 170 (Union Carbide)	2,4-D	30	57
	2,4-DP	31	
Weedar 64 (Union Carbide)	2,4-D	47	30
Ethephon (Union Carbide)	Ethylene	4	95

All trees were classified according to topkill and mortality. "Topkill" referred only to those study plants in which 100 percent defoliation had occurred at the time of observation, with no sprouting along the upper stem or in the crown. Topkill was used to quantify the first- and second-year observations. Study trees sprouting at the base were recorded separately and expressed as a percentage of the total plants treated. The term "mortality" was applied only to data collected in the third year after spraying, and was applied to those study plants that were 100 percent defoliated (topkilled) and showed no basal sprouting.

ANOVA was applied only to the third year (1986) mortality data as the 1984 and 1985 data were preliminary in nature. Treatment means were compared with least significant difference tests (LSD) at the 95% confidence level. Additionally, linear correlations between mortality and diameter of sugar maple were calculated.

RESULTS

Sugar Maple Control

Most herbicides proved ineffective in controlling sugar maple when mist blown (Table 2). In September of 1984, at the end of the first growing season in which herbicides were applied, only two herbicides (Tordon 101 M and Garlon 3A) provided 100% topkill in 80% or more of the study plants. Tordon 101 M gave the best control at 98%. Garlon 4 and Banvel 720 induced complete topkill of sugar maple in 76 and 67% of the study plants, respectively, while Roundup gave 47% topkill. The 2,4-D/2,4DP ester herbicides proved to be among the least effective in controlling sugar maple. The ester formulation of 2,4-D (Weedone LV-4) yielded the highest control of the group (44%), while the combination of 2,4-D and 2,4-DP ester (Weedone 170) yielded only 13% control. The ester formulation of 2,4-DP (Weedone 2,4-DP) also exhibited poor results, with only 9% of the study plants completely topkilled. The amine formulation of 2,4-D (Weedar 64) induced complete topkill in only 7% of the sugar maple study plants. Krenite and Ethephon were also very ineffective.

Table 2.--Percentage of plants showing topkill (1984 and 1985) and whole-plant mortality (1986) of sugar maple mist blown with eleven herbicides in May/June of 1984.

Herbicide	Topkill 1984	Topkill 1985	Mortality 1986
	Percent		
Roundup	47	36	36c[1]
Banvel 720	67	27	38c
Krenite	7	24	29cd
Tordon 101 M	98	100	100a
Garlon 3A	80	42	40c
Garlon 4	76	40	60b
Weedone 2,4-DP	9	11	16d
Weedone LV-4	44	20	22d
Weedone 170	13	16	18d
Weedar 64	7	7	7de
Ethephon	2	4	9de
Control	0	0	0e

[1]Means with common letters are not significantly different at $P \leq 0.05$.

The resistance of sugar maple to most foliar-applied herbicides became even more evident in 1985 (Table 2). Most plants showed a reduced effect from the herbicide two growing seasons after application. Only one herbicide, Tordon 101 M, continued to provide good control, inducing or maintaining topkill in all sugar maple plants. Only two other herbicides (Garlon 3A and Garlon 4) provided at least 40% control. All other treatments proved much less effective by the second year after application.

Mortality percentages three growing seasons after herbicide application indicated that only Tordon 101 M provided 100% control (100% mortality) and was significantly more effective than all other herbicides tested. Most other herbicides yielded results similar to those reported in 1985, with the exception of Banvel 720 and Garlon 4. Application of both these herbicides resulted in improved control, although it was inadequate for a silvicultural prescription. Garlon 4 yielded the second highest level of control at 60% mortality.

Basal sprouting, for the most part, was not a problem in sugar maple. Most sprouts observed in 1985 (two growing seasons after application) had died by 1986. The two formulations of triclopyr (Garlon 3A [salt] and Garlon 4 [ester]) allowed the most sprouting -- 31% in 1985 and 19% in 1986. Krenite induced basal sprouting in 22% of the maple, while the remaining eight herbicides yielded sprouting of 11% or less.

Control of Oak Species

Although the primary objective of this study was to evaluate the effectiveness of herbicides in controlling sugar maple, oak species were also included for testing. Most herbicides proved to be more effective in their capacity to topkill oak than sugar maple, but oak appeared to be the more prolific sprouter, although this was not tested statistically. One growing season after herbicide application, four treatments had resulted in topkill in more than 82% of the oak study plants (Table 3). Banvel 720 and Garlon 4 gave 89% control, Krenite 84% and Tordon 101 M 82%. The ester formulations of 2,4-D/2,4-DP provided intermediate control, with Weedone 2,4-DP and Weedone 170 inducing 78% and Weedone LV-4 67% complete defoliation. Garlon 3A and Roundup provided 73 and 64% topkill, respectively. Weedar 64 and Ethephon provided poor control.

Table 3.--Percentage of plants showing topkill (1984 and 1985) and whole-plant mortality (1986) of oak (all species) mist blown with eleven herbicides in May/June of 1984.

Herbicide	Topkill 1984	Topkill 1985	Mortality 1986
	Percent		
Roundup	64	58	38bc[1]
Banvel 720	89	47	58abc
Krenite	84	69	67ab
Tordon 101 M	82	62	71a
Garlon 3A	73	47	53bc
Garlon 4	89	64	69ab
Weedone 2,4-DP	78	40	45bc
Weedone LV-4	67	44	60abc
Weedone 170	78	42	60abc
Weedar 64	36	20	22cd
Ethephon	11	4	11de
Control	0	0	0e

[1]Means with common letters are not significantly different at $P \leq 0.05$.

Data collected in 1985 revealed a reduction in effectiveness in every oak treatment, indicating that sprouting within the crowns was occurring. Only three treatments (Krenite [69%], Garlon 4 [64%] and Tordon 101 M [62%]) provided over 60% total defoliation in 1985.

As with sugar maple, changes in oak response data from 1984 to 1985 were much greater than between 1985 and 1986, indicating that the effects of the herbicides were stablizing and suggesting that first-year data in herbicide studies on woody vegetation may not be very

meaningful. In 1986, only Tordon 101M was found to result in mortality in excess of 70% (Table 3). However, Garlon 4 and Krenite yielded 69 and 67% mortality, respectively.

Basal sprouting was more prominent in oak than in sugar maple. In 1985, two treatments (Banvel 720 and Weedone 2,4-DP) resulted in basal sprouting in excess of 50%; two in over 40% (Weedone LV-4 and Weedone 170); two in over 30% (Garlon 3A and Weedar 64) and over 20% of Garlon 4 and Krenite-treated plants sprouted. Basal sprouting in 1986 was reduced for every herbicide except Roundup -- plants in four treatments sprouted in excess of 30% (Banvel 720, Weedone 2,4-DP, Roundup and Garlon 3A) and four induced between 20 and 30% plants with basal sprouts (Garlon 4, Weedone 170, Weedar 64 and Weedone LV-4).

The effectiveness of all herbicides on sugar maple, with the exception of Tordon 101 M (100% mortality), was significantly related to tree diameter (r^2 = 0.13 to 0.59). Significant regression slope coefficients indicated that larger diameter trees were more difficult to defoliate and, subsequently, harder to kill. Only three herbicide treatments, however, showed significant correlations between diameter and defoliation in oak (r^2 = 0.09 to 0.35). Defoliation with Roundup and the two triclopyr herbicides (Garlon 3A and Garlon 4) was significantly decreased as diameter increased.

DISCUSSION AND CONCLUSIONS

The amine salt formulations of picloram combined with 2,4-D (Tordon 101 M), applied at a rate of 757 ml/gallon water by a backpack mist blower, proved to be the most effective treatment for controlling sugar maple. These results are consistent with those reported in the literature. Coble et al. (1969) found high percentages of red maple topkill when applying picloram in a similar manner. Seventy four percent topkill was achieved at a 0.5 lb aehg rate while 1.0 and 2.0 lb aehg both produced 100% topkill with no sprouting two growing seasons after application. Schwartzbeck and Wiltse (1964) in their work with sugar and red maple, also reported 98-100% control when applying picloram alone and in combination with four rates of 2,4-D. Nine percent of the maple sprouted at the base at the highest rate of application (0.7 lb picloram plus 2.0 lb 2,4-D aehg).

The two triclopyr-based herbicides proved to be marginally effective in controlling sugar maple, with Garlon 4 being the second most effective chemical. Sixty percent mortality was realized three years after application of the ester formulation of triclopyr in this study. Haywood (1980) reported 63% mortality and McCormack et al. (1981) reported 64 to 74% control after applying Garlon 4 to red maple. Lichy (1978) reported from 44 to 100% control. In contrast to results for Garlon 4, a significant reduction to only 40% mortality was observed in our work with the salt formulation (Garlon 3A). However, between 65 and 90% defoliation and 100% mortality have been reported by Lichy (1978) when Garlon 3A was applied to red maple. Perala (1980) reported only 20% topkill of sugar maple with one-half of the trees sprouting at the base. In view of the differences observed between our study and Lichy's, sugar maple may be more resistant to the triclopyr salt than red and some other maple species.

The phenoxy compounds composed of 2,4-D, and 2,4-DP alone and in combination were the least effective herbicides tested and hence cannot be recommended for herbicidal control of sugar maple. Maple has also been shown to be resistant to these compounds in other studies. Stewart (1974) reported only 30% topkill of vine maple one year after application of 2,4-D/2,4-DP in a water carrier and no mortality after three years. When using diesel fuel as a carrier, control was only slightly better. Lichy (1978) reported 50% topkill of red maple after misting 2,4-D (ester) and only 10% with the salt formulation. Between five and 58% topkill was reported by Coble et al. (1969) for red maple when the ester formulation of 2,4-D was applied.

Timing of herbicide application is extremely important. Most herbicides should be applied when the plants are actively growing to be effective, and this criterion was generally met in our study. One herbicide used, however, was designed to be applied in late summer and early fall. This compound, Krenite, is a contact herbicide and prevents bud and shoot development the following spring. The poor control of sugar maple with Krenite in this study (29%) may have, in part, been a result of the early spring application. Inconsistent results have been reported, however, when using Krenite to control striped and red maple, even with proper fall application (Sprague and McCormack, 1981).

Roundup and Banvel 720 both proved ineffective for controlling sugar maple. Ethephon, included to determine its effect as a defoliator, was also ineffective.

Oak species employed in this study, for the most part, existed beneath the dense shade of the sugar maple understory, a condition which may have influenced the vigor and consequently the results of this study. The basal diameters (bdh) of the oak were quite small, averaging only 14 mm (0.6").

Mortality and basal sprouting among treated oak trees were generally higher than for sugar maple. Tordon 101 M, the most effective herb-

icide on sugar maple, was also responsible for the greatest oak mortality. However, it was not significantly more effective than Garlon 4, Krenite, Weedone LV-4, Weedone 170 or Banvel 720 (Table 3).

While, in general, a negative correlation was found between diameter and herbicide effectiveness, Tordon 101 M was found to be equally effective on large and small diameter sugar maple plants. Trees up to 96 mm (3.8") dbh were killed by foliar application of Tordon. Perala (1980) demonstrated similar results. In a study of Tordon 101 M applied at a rate of 2.5 lb ae/ac, 73% topkill of sugar maple up to 3.8" dbh with only 4% basal sprouting was reported.

In view of the increasing prominence of sugar maple in Missouri oak-hickory forests and related future management problems, some method to control sugar maple is desirable. Our study demonstrates that of 11 chemicals tested, only Tordon 101M, induced sufficient mortality to be recommended for foliar application. Furthermore, it is noted that in herbicide trials of this nature, a minimum of two, and preferably three, years are desirable to secure reliable data.

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