STATUS OF SOME NEW HERBICIDES

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SUMMARY

This paper reviews the past 15 years of research at Alexandria, Louisiana. on 10 of the newer herbicides that are in use or show promise. Only formulations with relatively high activity are included.

The report is based on more than 60 studies, including soil. foliar, and injection applications. The outlook is good for effective substitutes for herbicides now in use. and for new products that will control a broader array of species with greater consistency.

If* herbicides are handled, applied, or disposed of improperly they may be *injurious to humans, domestic animals, desirable plants, andpollinating insects, fish, or other wildlife, and may contaminate water supplies. Use herbicides only* when needed and handle them with *care. Follow the directions and heed all precautions on the container label.

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Status of Some New Herbicides

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Research to find more effective and less expensive methods of controlling cull hardwoods has been conducted continuously over the past three decades at Alexandria, Louisiana. Ammate in chopped cups, 2,4,5-T in frills, aerial spraying, and tree injection with undiluted herbicides are some of the innovations originating from this work that have saved landowners millions of dollars in site preparation, release, and stand improvement.

This paper summarizes the performance of 10 effective or promising herbicides that have been evaluated over the past 15 years at Alexandria. The information was obtained in about 60 studies, each of which tested two or more formulations. In all, about 30 formulations were evaluated, but many were ineffective or withdrawn by the manufacturer.

Only a few of the 10 herbicides are registered for specific uses in forestry: others are registered for nonforestry purposes, and several have no registration or only experimental registration. Data given here will aid in improving current practices and perhaps even in obtaining registrations.

Herbicides were tested for efficacy when applied to the foliage. to the soil, and injected into the base of trees. Some (such as pellets) were suitable only for soil application: most liquid formulations were tested by tree injection and foliar spraying. Procedures that were standard in tests are:

1. Tree injection incisions were made with a 1.75-inch bit within 2 inches of groundline. Spacing between incisions was measured from edge to edge.

2. Soil application consisted of uniformly distributing pellets, granules, or powders in a band 12 to 24 inches wide about 12 inches from tree base.

3. Foliar sprays were applied with backpack mist blower or garden sprayer.

4. Topkills were estimated two growing seasons after treatments were applied.

Herbicides are arranged alphabetically by common or trade names. The manufacturers of herbicides mentioned in this paper are listed in Appendix A. Since the text is restricted to highlights of the studies, detailed results of some of the more important studies are given in Appendix B. Publications emanating in whole or part from these studies are listed in Appendix C.

Many trials were made with mixtures of herbicides, of which only a few are mentioned. Also, about a dozen studies were conducted that attempted to combine soil and foliar herbicides (usually applied about 30 days apart). None of these are reported, although in several instances results obtained from application of one of the herbicides applied alone as a check have been used.

Throughout this paper the performance of herbicides is described in general terms like high or satisfactory, marginal, or unsatisfactory kills. Definitions for these terms vary by method of application. Generally, foliar sprays are satisfactory or effective if top defoliations are 75 percent or higher, marginal when between 60 and 74 percent, and unsatisfactory when below 60 percent. Criteria for kills with tree injection are slightly higher.

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Statistical tests were made in all comparisons, but they are not reported. Emphasis has been placed on overall efficacy rather than relative performance.

GLWHOSATE

Glyphosate is a new herbicide that shows considerable promise. It has been tested in two water-soluble liquid formulations: (1) MON 2139, now registered as Roundup, containing 3 pounds acid equivalent (ae) per gallon with a surfactant, and (2) MON 0139 containing 4 pounds ae per gallon without the surfactant. MON 2139 has experimental registration for foliar spraying and tree injection of unwanted hardwoods on forest sites.

Tree Injection

In **1973** both formulations were tested by tree injection with blackjack oak[1] and sweetgum, 5 to 7 inches d.b.h. A l-ml dose of undiluted herbicide was applied in May in three incisions about 6 inches apart. Topkills were 97 and 100 percent for the two formulations, an excellent result given the wide spacing of incisions. The control, 24-D amine: gave only 80-percent control.

Glyphosate (MON 0139) was compared with Tordon 101 on blackjack oak and sweetgum. Trees were injected with 2 ml of undiluted chemical in one and two incisions in winter and spring. Trees were grouped in two diameter classes-3.5 to 5.0 inches and 6.0 to 7.5 inches. Overall, glyphosate outperformed Tordon 101 and resulted in excellent kills with only four exceptions, three of which involved a single incision (Appendix B, table 1). A single injection of glyphosate was effective on all sizes of sweetgum in each season.

In another study, Glyphosate (MON 0139), Tordon 101, and Velpar were compared on sweetgum, blackjack oak, and hickory ranging from 5 to 9 inches d.b.h. Treatments were applied in May using 1 ml per incision with incisions spaced at 7-inch intervals. Glyphosate gave excellent kills, except with hickory, and was better overall than the other two herbicides (Appendix B, table 2). A 1:1 mixture of glyphosate and Tordon 101 gave higher kills than either herbicide alone, and was fairly effective on hickory.

In another injection study (Appendix B, table 3), 2 ml of undiluted glyphosate (MON 0139) injected in June with incisions 5 inches apart gave almost complete topkill of red and blackjack oaks. Glyphosate (MON 0139) mixed with equal parts of 2.4-D amine was superior to Tordon 101R and 2,4-D amine alone on sweetgum (Appendix B, table 4).

Glyphosate is an excellent herbicide for injection. More precise guidelines for use on upland species and prescriptions for bottomland species are needed. Mixtures of glyphosate and less costly herbicides should also be investigated.

Foliar Spray

As a foliar spray, Glyphosate (MON 0139) was initially tested on 4-year-old sweetgum, red oak, and green ash in a brush nursery. It was applied in May with 3 pounds ae in 10 gallons of water per acre. Topkills were satisfactory, except on red oak, and were comparable to or better than results with 2 pounds of 2,4,5-T[3] ester.

In a follow-up study in the brush nursery, 3 pounds ae of glyphosate (MON 0139) in 20 gallons of water killed sweetgum, red oak, and green ash more effectively than tebuthiuron (2 pounds active), 2,4,5-T (2 pounds active), or picloram (1 pound active)?

In the first field study, 2 pounds active of glyphosate (MON 0139) were compared with 2 pounds of 2,4,5-T ester, 2.54 pounds of Tordon 101, and 2.74 pounds of Tordon 101R in 20 gallons of water per acre. Treatments were applied in late May to mixed brush on an upland site. Topkills ranged from 73 to 79 percent for all formulations except Tordon 101R, which gave 65 percent control (Appendix B, table 5).

As a foliar spray glyphosate needs much more testing, particularly at different rates of application. Tests of this herbicide should use the MON 2139 formulation because it has an experimental registration. A defoamer is needed with glyphosate, especially when it is applied as a foliar spray.

KRENITE

Krenite is formulated as a liquid containing 4 pounds active ingredient (ai) per gallon that can be mixed with water. It is registered as a foliar spray for weed and brush control on industrial sites, tank farms, rights-of-way, and drainage ditches, and is reportedly safe to use around ponds and water supplies. The primay use of Krenite is to inhibit bud break in the spring. To inhibit bud break unwanted plants are drenched in the fall, 30 to 40 days before senescence. This method

‘Scientific names of species are given in Appendix D.

[2] 2,4-D is registered for control of broadleaf weeds and certain susceptible woody perennials on agricultural lands, rangelands and pastures as well as such noncrop areas as rights-of-way. drainage ditch banks and vacant lots.

32.4.5-T is registered for control of herbaceous and woody plants in forests. on rights-of-way. and on rangelands and pastures.

[4] Picloram is the active ingredient in Tordon 101. Tordon 101R. Tordon 10K. and Tordon 22K.

is especially good in recreational or scenic areas because aesthetically objectionable brownout of foliage is avoided. Fall-spray tests are underway, but results are not yet available.

One study of Krenite applied by tree injection has been completed (Appendix B, table 3) and another is in its second year. When 4 ml of undiluted Krenite was injected in June and incisions spaced 5 inches apart, high kills of red and blackjack oaks 5 to 7 inches d.b.h. were obtained. However, Tordon 101, glyphosate (MON 0139), Velpar, and Garlon 3A (Dow M-3724) were equally effective at only 2 ml per incision.

In a current study, Tordon 101, glyphosate (MON 0139), Velpar, and Garlon 3A (Dow M-3724) are being compared. Red oak, blackjack oak, sweetgum, and hickory were injected with 1 and 2 ml of undiluted herbicide per incision as follows: trees 3 to 5 inches d.b.h. received one incision, trees 6 to 8 inches two incisions, and trees 9 to 11 inches three incisions. First-year results (which are not always reliable) indicate Krenite performs satisfactorily on all but hickory and it is as effective as the other formulations in the test, but it is slower acting than most herbicides used for tree injection. Available information seems to show that Krenite has more promise in southern forestry when injected than when sprayed.

TEBUTHIURON

Tebuthiuron was formulated in a variety of ways during its development, including small pellets containing 10, 20, 30, and 40 percent active ingredient, an 80-percent wettable powder marketed under the trade name Spike, and large (lo-gram) pellets containing about 10. 20, and 30 percent active ingredient. Studies have been conducted with most of the formulations. Currently, only the 20-percent pellets and the 80-percent wettable powder are available. The wettable powder is registered for use around industrial sites, railway roadbeds, and tank farms. The 20-percent pellets have a permit for experimental use in controlling brush on range lands. Granules in 1- and 5-percent formulations are also registered for some industrial uses, but we have not tested them.

Tebuthiuron has been tested in 17 studies, starting in 1973, most often by soil application alone or in combination with foliar sprays. Several studies were conducted with the wettable powder. Because of the major changes in available formulations, only a few of the more important studies are summarized here.

Broadcast

Tebuthiuron showed promise from the first study in which it was included. Ten-percent ai pellets were compared with lo-percent bromacil (Hyvar X)[5] pellets in April when broadcast at 4, 8, and 12 pounds ai per acre. The 4-pound rate of tebuthiuron controlled a broad array of hardwoods (including oaks) well. The two high rates gave almost complete control. In contrast, all rates of bromacil achieved only marginal control, ranging from 63 to 81 percent, and several prevalent species were resistant (Appendix B, table 6).

When lo-percent pellets of tebuthiuron, Tordon 10K, and Velpar were broadcast in April, on an upland site, at 4 pounds per acre, tebuthiuron was most effective (Appendix B, table 7). Broadcast at 8 pounds per acre. Velpar and tebuthiuron were effective, and both were superior to Tordon 10K.

In another study, on an upland brushy site, tebuthiuron (lo-percent pellets) and Tordon 10K were compared by broadcasting 6, 8, and 10 pounds ai per acre in March. Contrary to early findings, the 6-pound rate of tebuthiuron was unsatisfactory, although the two higher rates were effective. Tordon 10K was effective at all rates.

Several other studies on upland sites showed that an 8-pound-per-acre rate of tebuthiuron is required for satisfactory control. Some variation in effectiveness probably was caused by differences in upland soils. Lower dosages were effective on the sandier soils and higher rates were needed on heavier. finer-textured soils.

A study conducted on a bottomland site that compared tebuthiuron and Tordon 10K broadcast at 4 and 8 pounds (active) per acre showed Tordon 10K was more effective at both rates, but only the 8-pound rate was satisfactory. Since the high rate of tebuthiuron gave only a 68-percent kill, the minimum rate on these sites should be at least 10 pounds per acre.

Tebuthiuron is a potent soil herbicide when broadcast, equal or superior to bromacil and Tordon 10K. But because its persistence in the soil limits its utility, no further broadcast studies are planned.

Banding

Tebuthiuron was also evaluated as 10- and 40-percent pellets. by banding individual trees on a sandy loam soil in May. It was compared with Tordon 10K, Velpar, and a combination of Tordon 10K and tebuthiuron at rates of 0.5 and 1.0 gram (active) per inch of trunk diameter (Appendix B, table 8). Concentration of tebuthiuron pellets had no important influence on kills. The l-gram rates gave 93 and 97 percent control of

[5] Hyvar X. whose active ingredient is bromacil. is registered for use on noncropland for nonselective weed and brush control and for selective control in certain crops.

post oak, but only 35 and 50 percent control of hickory.

Tebuthiuron does have merit for banding individual trees. Banding trials should be conducted at rates from 1 to 3 grams of active material per inch of diameter.

Tree Injection

Tebuthiuron was also evaluated by tree injection in three studies, but it was inferior to Tordon in all trials. The liquid for injection was made by adding 0.5 and 1.0 pound ai of the 80-percent wettable powder to 1 gallon of water, but since the powder does not dissolve in the carrier, its lethal action may be limited.

TORDON **101**

Tordon 101 is registered for application by injection and when mixed with 2,4,5-T for foliar spraying. It has been on the market for about 10 years. It is a liquid containing 2 pounds ae of 2,4-D amine and 0.54 pound ae of picloram per gallon.

Tree Injection

Over the past 15 years, Tordon 101 has been included in 18 individual injection studies. Initially, it was compared with 2,4-D amine, the standard chemical used for tree injection when testing began. Several comparisons of Tordon 101 and 2,4-D amine have been made (Appendix B, tables 9 and 10). Later Tordon 101 was used as a standard for evaluating other herbicides.

Tordon 101 has killed as much or more unwanted vegetation as 2,4-D amine in all comparisons, regardless of season, species, or site. It is effective on species that are difficult to kill with 2,4-D amine, including sweetgum, hickory, swamp privet, ironwood, pecan, and red maple. Tordon 101 is most effective when applied in late summer and winter, unlike 2,4-D which is most effective in spring and early summer.

Soon after Tordon 101's effectiveness was demonstrated, tests were conducted to determine if one-incision doses of 4 to 5 ml would kill several prevalent oak species, 2 to 8 inches d.b.h. Single incisions were not consistently satisfactory, although Tordon 101 again outperformed 2,4-D. Two incisions of 5 ml each gave acceptable kills of oaks up to 7 inches d.b.h.

When comparing Tordon 101 and 2,4-D amine it should be recognized that the acid equivalents are not the same. Tordon 101 contains 2.54 pounds ae per gallon, while 2,4-D has 4.0 pounds. However, Tordon 101 is about three times more costly than 2,4-D.

Since Tordon 101 is more viscous than many other herbicides, the liquid flows slowly from the injector. This may be a problem, especially in winter but it can be circumvented by mixing the herbicide with equal parts of water and increasing the dosage proportionately.

On upland sites, a l-ml dose of undiluted Tordon 101 in incisions spaced 5 inches apart is recommended in all seasons for trees 5 inches d.b.h. and larger. For smaller trees, a l-ml dose in two incisions is adequate. Local tests should be conducted to see if a wider spacing of incisions can be used in the dormant season. On bottomland sites, 1 ml in incisions 3 inches apart is recommended.

Foliar Spray

We have not adequately tested Tordon 101 as a foliar spray. In studies conducted in the brush nursery with high-volume applications, it showed no superiority over 2,4,5-T ester. In a field test with mixed species of brush, it gave marginal kills comparable to those achieved with 2,4,5-T. Little emphasis was placed on foliar-spray studies of Tordon 101 because early test results showed it had no superiority over 2,4,5-T alone and priority was given to a mixture of picloram and 2,4,5-T Newer, more promising foliar sprays that have been tested in the last few years have shown this to be a valid decision.

TORDON **101R**

Tordon 101R, also a liquid, has about one-half the concentration of each active ingredient as Tordon 101, a total of 1.37 pounds ae per gallon. It is registered for application by tree injection and frilling, but not as a foliar spray. The manufacturer states it is ready to use and gives no instructions for dilution. It is comparable to Tordon 101 mixed 1:1 with water, because it is less viscous, and flows quickly from an injector.

Tree Injection

In the first test of this formulation, May injection of 1 ml of undiluted chemical with incisions 5 inches apart resulted in 92 percent kill of red oaks 4 to 12 inches d.b.h. The same treatment with undiluted 2,4-D amine gave 99 percent kill. Defoliation of sweetgum with a l-ml dose in incisions at 3-inch intervals averaged 51 percent for Tordon 101R and 67 percent for 2,4-D amine. Apparently, the concentration of this material is too low for l-ml doses at wide spacing to be effective.

Until additional information is available from several studies that are underway, it seems advisable to rely on experience with Tordon 101 and use a 2-ml dose at 5-inch intervals.

Foliar Spray

Only one foliar spray study of Tordon 101R has been conducted. It compared 2.74 pounds ae or 2 gallons of Tordon 101R to 2 pounds ae of 2,4,5-T ester per acre. Both herbicides were mixed with water and applied in May at a rate of 20 gallons per acre. Topkill averaged 76 percent for 2,4,5-T and 65 percent for Tordon 101R. In the same study, Tordon 101 applied at 2.54 pounds per acre effected 75 percent topkill. It appears that both Tordon formulations are about as effective as the standard spray treatment with 2,4,5-T ester, and they may be adequate substitutes for 2,4,5-T But they should not be used for pine release because conifers are highly sensitive to picloram.

TORDON 155

This is a liquid, oil-soluble formulation containing 4.0 pounds ae of 2,4,5-T ester and 1.0 pound ae of picloram per gallon. It is registered as a basal-bark and dormant-season top spray. It has, however, been evaluated by tree injection and as a spring-applied foliar spray.

Foliar Spray

The first foliar-spray test was started in 1964. A locally mixed formulation of Tordon 155 was applied in May at 2.5 pounds (0.5 gallon) per acre in a drench spray to a stand of dense brush. A 2.0-pound-per-acre spray of 2.4.5-T ester was used for comparison. Both formulations used oil as the carrier and both were about equally effective, killing over 85 percent of the hardwoods.

In 1971; the manufacturer furnished several combinations of herbicides for test. A formulation equivalent to Tordon 155 was sprayed on small, mixed brush at 2.5 pounds per acre in 10 gallons of oil and compared to 4.0 pounds per acre of 2,4,5-T ester. Topkills averaged 74 and 72 percent, respectively. Tordon 155 excelled on red maple. 2.4.5-T was most effective on dogwood. and they were equally effective on the other species.

Included in the same trial was a mixture of 2,4.5-T and picloram that was similar to Tordon 155. It had 4.0 pounds of 2.4.5-T ester and 0.75 pound of picloram per gallon. not quite as much picloram as a gallon of Tordon 155. It was applied like the other formulations at a rate of 4.75 pounds per acre. Overall. topkills from this formulation were slightly higher than from 4.0 pounds of 2.4.5-T ester alone (Appendix B. table 11).

Another study compared Tordon 155 and 2.4.5-T ester as top sprays in January or foliar sprays in June at rates of 3.0 and 6.0 pounds in 30 gallons of diesel oil per acre. All treatments resulted in satisfactory topkills, ranging from 79 to 91 percent in winter and 87 to 94 percent in summer. Differences between the two herbicides were small and unimportant in both seasons. The high rate of 2.4.5-T was no more effective than the low one: doubling the rate of Tordon 155 increased topkills about 12 percentage points, which hardly justifies the added cost (Appendix B. table 12).

Studies conducted so far indicate that as a foliar spray, Tordon 155 may be slightly more effective than 2,4,5-T when total pounds of active ingredient are the same, but the higher cost (about double)[6] of Tordon 155 and the need for oil in the mixture may easily offset the small advantage Tordon 155 may have.

Tree Injection

Tordon 155 has been evaluated by tree injection in three studies. In the first. the Tordon formulation was mixed 1:1 with oil and injected in red maple and sweetbay with 1 and 2 ml in incisions at 1-, 3-, and 5-inch intervals. (Mixing with oil in this ratio reduced the acid equivalent from 5.0 to 2.5 pounds per gallon.) The control, 2,4-D amine, was injected undiluted. Treatments were applied in April to trees 4 to 8 inches d.b.h. Both herbicides gave excellent kills of sweetbay, even at the widest spacing of incisions. 2,4-D failed badly on red maple, but Tordon 155 gave an 89-percent kill even at the widest intervals. Adding a small amount of picloram to 2,4,5-T (as well as to 2,4-D) seems to increase its activity on hard-to-kill species,

The next study compared Tordon 155 mixed 1:1 with oil to Tordon 101 and oil-soluble 2,4-D amine (3 pounds ae/gallon), on 4- to 8-inch blackjack oak, post oak, and hickory. One-ml doses were applied in one and two incisions per tree in May and December. None of the May treatments were fully satisfactory. Tordon 101 and Tordon 155 gave comparable kills and both were better than 2.4-D. Winter applications of both Tordon 155 and 2,4-D were far inferior to Tordon 101. which effected satisfactory topkills with two incisions (Appendix B, table 10).

Finally, Tordon 155 and undiluted 2.4-D amine were compared on blackjack and red oaks ranging from 5 to 7 inches d.b.h. Treatments were applied in May with one incision per tree and dosages of 2, 3, and 5 ml. No treatment gave satisfactory topkills (41 to 72 percent) and differences between herbicides were small.

When injected, Tordon 155 seems less effective than Tordon 101, but slightly superior to 2.4-D amine.

TORDON 10K

Tordon 10K is a pelleted herbicide containing 11.6 percent picloram (or 10.0 percent ae) as the active ingredient. It is registered for use in forestry by banding individual trees and broadcasting.

[6] Costs vary by manufacturer and quantities purchased. making comparisons difficult.

Banding

Tests of Tordon 10K as a soil herbicide were started in **1962** by banding individual trees. The control was Hyvar X (as a wettable powder containing 80 percent ai), the most effective soil herbicide at that time. Test species were red and blackjack oaks on a sandy loam soil, and sweetgum and ironwood on a silt loam soil. 4 to 9 inches d.b.h. Both herbicides were applied in April at 0.25, 0.5, and 1 gram (active) per inch of trunk diameter. Tordon was satisfactory on ironwood at the two high rates and on sweetgum at all rates. Both oaks were resistant to Tordon 10K. Hyvar X was effective on blackjack oak and sweetgum at the lowest rate, but was unsatisfactory on the other two species at the highest rate. Overall. both herbicides were about equally effective.

Red oak, sweetgum, and ironwood from 4 to 12 inches d.b.h. were banded in March with the same two herbicides at 1.0, 1.5, and 2.0 grams per inch of diameter. The site was a low terrace with a silty clay soil. Kills, even at the 2-gram rate of Tordon. were very low on all species. In contrast, Hyvar X gave satisfactory kills of sweetgum and red oak at the 1.5-gram rate, but was ineffective with ironwood at all rates.

A study installed in May (ordinarily too late for maximum effectiveness) compared Tordon 10K, tebuthiuron pellets. and Velpar 90 percent water-soluble powder at 0.5- and l-gram rates for each inch of trunk diameter. Test species were post oak and hickory 4 to 10 inches d.b.h. Tordon 10K was unsatisfactory on post oak and gave satisfactory kills of hickory only at the l-gram rate. The other two herbicides were fully effective on post oak at the high rate. This study suggested Tordon may be a good candidate to mix with the other herbicides where hard-to-kill species like hickory are prevalent. Late application may have been a major factor in reducing Tordon's control of oak.

In a final banding study, Tordon 10K and lo-percent bromacil[7] pellets were compared on post and blackjack oaks 4 to 10 inches d.b.h. at 1 and 2 grams ai per inch of trunk diameter. Treatments were applied in March, April. May, and June. Tordon was unsatisfactory in all months at both rates, but bromacil was acceptable except at the l-gram rate in June. The high resistance of oaks to Tordon 10K was clearly demonstrated in this study.

Banding is ideally suited for small tracts where hardwoods are 4 inches d.b.h. or larger, especially when the landowner doesn't want to inject trees. In such cases, Tordon 10K is useful, especially on sandier soils. It should be applied at a minimum of 1.5 grams per inch of trunk diameter: more for oaks or when treating finer-textured soils. As with all soil herbicides, applications should be made in March or April when rainfall is high. Hyvar X is an excellent soil herbicide, but powder is difficult to apply.

Broadcasting

Tordon 10K was also tested for broadcasting, again using 10 percent bromacil pellets for comparison. Both herbicides were broadcast in March at rates of 2.5, 5.0, and 7.5 pounds per acre. Plots, located on a poorly drained upland site, had dense stands of small brush. Kills were marginal at the high rate, averaging 73 percent for Tordon 10K and 66 percent for bromacil.

In a study designed to determine effects of litter on herbicide effectiveness, 2, 4, and 10 pounds of Tordon 10K were broadcast in March on plots with mixed brush 2 to 12 feet tall. The lo-pound rate gave 93 percent kill, compared to 73 and 56 percent for the two lower rates, No other herbicide was tested. Removal of litter did not improve defoliation at any rate.

Tordon 10K and 10 percent tebuthiuron pellets were compared by broadcasting in March on a sandy loam soil at 2, 4, and 6 pounds per acre. At the 4-pound rate, Tordon 10K was satisfactory and more effective than tebuthiuron. At the high rates, both herbicides were comparable. Unlike tebuthiuron, Tordon gave marginal kills of resistant oak.

Tordon 10K and lo-percent tebuthiuron pellets were also evaluated at 4- and 8-pound rates on a creek-bottom site with small brush. Pellets were broadcast in May to avoid flooding. Kills averaged 89 percent for Tordon and 68 percent for tebuthiuron. Tordon was relatively ineffective on oaks, but was superior on most other species. the best performance of Tordon 10K to that time.

In a comparison of Tordon 10K and tebuthiuron pellets on an upland soil, pellets were broadcast in March at 6. 8. and 10 pounds (active) per acre. Tordon was satisfactory at all rates, as was tebuthiuron at the two higher rates (Appendix B, table 13). A 1:1 mix of the two herbicides was as effective as Tordon alone.

More recently, Tordon 10K, tebuthiuron. and Velpar pellets, all with 10 percent active material, were compared by broadcasting in April at 4 and 8 pounds per acre. The site had a sandy loam soil and dense hardwoods. Tordon ranked third in effectiveness at both rates: tebuthiuron gave the highest kills (Appendix B, table 7).

Tordon 10K is an effective soil herbicide when broadcast at 10 pounds (active) per acre. Like other soil herbicides. it should be applied in late winter or early spring when rains occur regularly. Why Tordon outperformed tebuthiuron in some studies and not in

[7] Bromacil is no longer available in pellet form

others is unclear; it may have been due partly to the prevalence of oaks. which are resistant to Tordon. Resistance of oaks is a major disadvantage of this herbicide. Its greatest value may be in mixing with other herbicides that are lethal to oaks.

TORDON 5K

This is a new. pelleted formulation that has about half as much picloram (the active ingredient) as Tordon 10K. The added weight is a decided drawback when broadcasting. If 10 pounds ai per acre is to be broadcast, 200 pounds of material must be distributed. But one potential advantage is rapid infiltration into the soil.

Tordon 5K and 10K have been compared in only one study. They were broadcast in May on an upland soil at a 6-pound rate. Topkills were 55 and 75 percent for the 5K and 10K formulations.

Additional studies are planned with Tordon 5K, but primarily as a banding treatment where weight is less critical than with broadcasting.

TRICLOPYR

Triclopyr. a relatively new herbicide, was initially made available for preliminary research in two formulations; M-3724. a water-soluble amine containing 3 pounds ae per gallon, and M-4021. an oil-soluble. water-emulsifiable ester containing 4 pounds ae per gallon, The amine formulation is now registered for foliar spraying and carries the trademark Garlon 3A Herbicide.

In our studies, the amine formulation has been used for tree injection and the ester formulation for foliar spraying, the same pattern that was followed with the phenoxy herbicides (2.4-D amine and 2.4.5-T ester).

Foliar Spray

Garlon 3A Herbicide was initially evaluated as a foliar spray in the hardwood brush nursery at 2 pounds ae in 20 gallons of water per acre. Trees were sprayed in May, Topkills of red oak were unacceptable and were marginal for sycamore and green ash. They were. however. comparable to those from 2 pounds per acre of 2,4,5-T ester.

As part of an evaluation of combined soil and foliar applications, Garlon 3A was sprayed on mixed brush in June at 1.5 pounds in 10 gallons of water per acre. Defoliation with Garlon 3A alone averaged 60 percent. which was promising, given the low concentration of the spray.

Triclopyr in its ester formulation (containing 4 pounds ae per gallon) was also appraised as a foliar spray on mixed brush. A rate of 2 pounds in 20 gallons of water per acre applied in May gave 79 percent topkill, comparable to that from 2 pounds of 2,4,5-T ester used as a check. When triclopyr (M-4021) was mixed 1:1 with 2,4,5-T ester (total 2 pounds active) or Tordon 101 (total 2.27 pounds active), defoliations were as high as with triclopyr alone (Appendix B, table 8).

Triclopyr (M-4021) was compared with 2,4,5-T estef as a foliar spray in January and June at 3 and 6 pounds in 30 gallons of oil per acre. Topkills from winter applications were excellent at both rates, and exceeded 2,4,5-T by 8 to 11 percentage points. Results from summer treatment were similar for both herbicides at the 3-pound rate. but triclopyr was more effective at the high rate (Appendix B, table 12).

Tree Injection

Triclopyr has not only shown promise as a foliar spray. but has given high kills when injected. A 2-ml dose of undiluted Garlon 3A (M-3724) applied in June with incisions 5 inches apart gave complete topkills of red and blackjack oaks. Undiluted Tordon 101, glyphosate. and Velpar at the same dosage were also highly effective (Appendix B, table 3).

In a follow-up study, a l-ml dose of a 1:1 mixture of undiluted Garlon 3A and 2,4-D amine (total 3.5 pounds active) injected in May gave perfect kills of red oak with incisions 5 inches apart and 95 percent kill of sweetgum with incisions 3 inches apart. Tordon 101R and 2,4-D amine were about equally effective in l-ml doses on red oak, and less effective on sweetgum, a species resistant to tree injection (Appendix B. table 4). Garlon 3A shows exceptional promise for application by tree injection.

Undiluted Garlon 3A is included in a comprehensive injection study still underway with red oak, blackjack oak. sweetgum, and hickory. Doses were. applied in July at 1 and 2 ml of undiluted material per incision. Number of incisions varied with tree size: hardwoods 3 to 5 inches d.b.h. have one incision, trees 6 to 8 inches have two incisions, and trees 9 to 11 inches have three incisions. At the end of the first growing season, Garlon 3A and Tordon 101 both gave high kills of all species. Both triclophyr formulations show enough promise to merit additional research by tree injection and foliar spraying.

VELPAR

Tests have been conducted with hexazinone (the trade name of which is Velpar) formulated as a 90-percent ai water-soluble powder. 10 and 15 percent ai pellets, and a liquid containing 2 pounds ai per gallon. Only the powder is registered. and it is limited to spraying around industrial sites, rights-of-way, tank farms and for weeding in Christmas tree and established conifer plantations.

Banding

In its initial evaluation, the 90-percent, water-soluble powder was compared to Tordon 10K, tebuthiuron, and a 1:1 mixture of Tordon 10K and tebuthiuron. In May, 4- to lo-inch d.b.h. post oak and hickory trees on a sandy loam soil were banded at rates of 0.5 and 1.0 gram ai per inch of tree diameter. Both rates of Velpar were effective on post oak, but gave low kills of hickory (Appendix B, table 8). No formulation was as effective as Velpar on post oak only the high rate of Tordon 10K alone or the Tordon-tebuthiuron mixture controlled hickory satisfactorily.

In a banding study on a sandy loam soil, Velpar applied in May at 1 gram active per inch of trunk diameter gave excellent results with blackjack oak but marginal results with red oak. Tebuthiuron and bromacil in the same study were as effective as Velpar on blackjack oak but unsatisfactory on red oak. Low kills overall were attributed to late applications.

Velpar appears to be an excellent herbicide for banding hardwoods. Ten-percent pellets are available for trials, and studies should be conducted using rates higher than 1 gram per inch of diameter.

Broadcasting

Broadcasting Velpar pellets has also given encouraging results. In a comparison of 10 percent pellets of Velpar, tebuthiuron, and Tordon 10K applied in April on an upland site at 4 and 8 pounds ai per acre, tebuthiuron was most effective at both rates and Velpar ranked second (Appendix B, table 7). Both herbicides controlled hardwoods satisfactorily, while Tordon 10K gave marginal kills.

Additional studies of soil-applied Velpar are needed on upland and bottomland sites to determine optimum rates and the minimum interval that must elapse between application and planting. Currently available data indicate Velpar does not persist in the soil long enough to affect planting survival when used for site preparation. Moreover, it controls herbaceous vegetation as well as woody plants.

Tree Injection

Velpar was evaluated for tree injection as the 90-percent powder before the liquid formulation became available. Four pounds (active) per gallon were mixed in water and injected in May at 1 ml in incisions 7 inches apart. Study trees were sweetgum, blackjack oak, and hickory, 5 to 9 inches d.b.h. Topkills were excellent with oak, intermediate with sweetgum, and very low with hickory. Undiluted Tordon 101 and glyphosate (MON 0139) were more effective than Velpar, especially on hickory (Appendix B, table 2). Spacing of incisions was wide, however, a severe test that probably contributed to the relatively low kills from all herbicides.

When the liquid formulation of Velpar (DPX-3674-L) became available it was compared with five other herbicides applied in June on red and blackjack oaks, 5 to 7 inches d.b.h. (Appendix B, table 3). All formulations effected high kills, except tebuthiuron. which was in wettable powder form.

A 1:1 mixture of Velpar and 2,4-D amine outperformed 2,4-D alone and Tordon 101R on sweetgum and did as well on red oak (Appendix B, table 4). Several other herbicide mixtures in the study gave kills of red oak in excess of 90 percent. On sweetgum, a resistant species, glyphosate (MON 0139), Velpar, tebuthiuron, and triclopyr (Garlon 3A) each mixed 1:1 by volume with 2,4-D amine gave satisfactory kills.

Liquid Velpar is an excellent candidate for tree injection. Its major drawback is ineffectiveness on hickory. Studies are underway to determine optimum dosages and incision spacing for upland and bottomland species.

Evaluations of Velpar for foliar spraying are not completed because the liquid formulation for such studies only became available during the last year. However, we intend to give high priority to foliar-spray studies.

DISCUSSION

Herbicides play a key role in managing pines and hardwoods in the South. As mechanical site preparation declines and more owners of small tracts intensify management practices, herbicides will probably grow in importance. The time is critical. Herbicides and other pesticides are under careful scrutiny for their impact on the environment and all of its living organisms.

The cost of developing, testing, and registering a new herbicide cannot be justified by forestry use alone. Ordinarily, most new formulations tested in our research have large anticipated or actual agricultural or other nonforesty uses. This means the basic toxological evaluations are completed, so registration for forestry is relatively easy after data on efficacy are obtained, provided there are no unique environmental problems and the manufacturer judges forestry use will be profitable.

Forest managers are now in a fairly good position regarding tree injection and site preparation. Substitute herbicides are available in the event one is withdrawn from the market. A substitute for 2,4,5-T or Silvex for pine release is needed, but there are new herbicides being tested that seem likely to be adequate.

Certainly new herbicides will be more costly than the phenoxy compounds in wide use today. This should not be an obstacle to conducting research. We can often expect greater efficiency for the higher price, and nonchemical alternatives to phenoxy herbicides are also very expensive.

2,4.5-T and Silvex,[8] both primarily used as foliar sprays, are being examined by environmental officials. If they are banned, Tordon 101 may be used for site preparation: it is too toxic to pines for release application. Garlon 3A, triclopyr (M-4021), glyphosate, and possibly Velpar will be suitable for foliar spray once they are registered. Tests of these herbicides should be intensified to support any applications the manufacturers may submit.

2.4-D. like 2.4,5-T and Silvex, is a phenoxy herbicide, but it has not been suspected of containing a dangerous contaminant. A few years ago. it was the primary herbicide for tree injection. Recently, however, many landowners switched to Tordon 101 and Tordon 101R, both highly effective on a broad array of species. including those resistant to 2,4-D. Krenite. Velpar, glyphosate. and Garlon 3A also seem to be good candidates for tree injection. and will be given priority in future studies.

[8] Silvex is currently registered for use in forests for control of woody. herbaceous and aquatic plants. It is also registered for use on industrial sites. rights-of-way. in ponds. farmyards. pastures. rangeland. and in rice and sugar cane.

Soil herbicides are not used extensively in southern forestry because most products are expensive and their effectiveness is closely related to soil properties. Moreover, they must be applied in early spring when rainfall is high and trees are growing actively. Tordon 10K is effective on many hardwood species (excluding oaks) and dissipates fast enough for use in site preparation. Many of the other soil herbicides tested have persistence problems. Velpar is an exception: preliminary data indicate pines can be planted in the first winter after its application. It has an added advantage in that it kills many herbaceous plants that compete with pines in the first few years.

Applying soil herbicides in bands around individual trees shows promise, theoretically. Our tests have probably been too conservative: higher rates of application are needed for greater consistency.

Mixtures of herbicides to control a broader array of unwanted trees is an important approach to the hardwood problem that cannot be overlooked. Testing mixtures must be given high'priority, even though it greatly expands the research workload, because early results have shown great potential benefits.

The prospect for more effective herbicides is good. Development of new formulations should be accelerated and registration should be coordinated more closely among manufacturers, researchers, and users.

APPENDIX A

Manufacturers Furnishing Mentioned Herbicides

Glyphosate	Monsanto Company
Hyvar X (Bromacil)	E. I. DuPont DeNemours & Co.
Krenite	E. I. DuPont DeNemours & Co.
Tebuthiuron	Elanco Products Company
Tordon 101	Dow Chemical Company
Tordon 101R	Dow Chemical Company
Tordon 10K	Dow Chemical Company
Tordon 5K	Dow Chemical Company
Tordon 155	Dow Chemical Company
Triclopyr or Garlon 3A Herbicide	Dow Chemical Company
2,4-D and 2,4,5-T	Experimental samples obtained from a number of companies
Velpar	E. I. DuPont DeNemours & Co.

APPENDIX B

Tables

Table 1.—*Topkill of blackjack oak and sweetgum when* injected with 2 *ml of* undiluted *Tordon 101 and glyphosate in two seasons*

Herbicide	Active material per gallon	Incisions per tree	Tree size	Blackjack oak		Sweetgum	
				Winter	Spring	Winter	Spring
	Pounds	*Number*	*D.b.h.*	*Percent*			
Tordon 101	2.54	1	x.5-5.0	41	40	87	35
		2	3.5-5.0	64	85	98	90
		1	6.0-7.5	12	34	47	25
		2	6.0-7.5	31	57	73	42
Glyphosate (MON 0139)	4.0	1	x.5-5.0	55	92	100	100
		2	3.5-5.0	89	99	100	100
		1	6.0-7.5	45	61	94	98
		2	6.0-7.5	69	94	97	100

Table 2.—*Topkill* of *three common* hardwoods *when* injected *in* May with 1 ml of undiluted herbicide *in incisions 7 inches apart*

Herbicide	Active material per gallon	Species		
		Sweetgum	Blackjack oak	Hickory
	Pounds	*Percent*		
Tordon 101	2.54	79	97	76
Glyphosate (MON 0139)	4.0	100	99	63
Velpar	4.0	73	97	6
1:1 mix of Tordon 101 and glyphosate	1.27+2.0	100	98	82

Table 3. —*Topkill of two oak species* 5 to 7 *inches d.b.h.* injected undiluted at *5-inch* intervals *in* June

Herbicide	Active material per gallon	Dose per incision	Topkill	
			Red oak	Blackjack oak
	Pounds	Ml	. . . . . . *percent.*	
Tordon 101	2.54	2	100	98
Glyphosate (MON 0139)	4.0	2	100	98
Krenite	4.0	4	89	99
Velpar (DPX-3674-L)	2.0	2	100	99
Triclopyr (Garlon 3A)	3.0	2	99	100
Tebuthiuron (80% WP)	3.0	4	86	90

Table 4. —*Topkill of red oak* and *sweetgum* 4 to 12 inches d.b.h. injected with *1* ml *per* incision in May with several herbicides *and mixtures*

Species and herbicide	Active material per gallon	Spacing of incisions	Topkill
	Pounds	*Inches*	Percent
Red oak			
2,4-D amine	4.0	5	99
Tordon 101R	1.37	5	92
1:1 mix of triclopyr (Garlon 3A) and 2,4-D amine	1.5+2.0	5	100
1:1 mix of Velpar DPX-3674-L and 2,4-D amine	1.0+2.0	5	100
1:1 mix of tebuthiuron and 2,4-D amine	1.5+2.0	5	97
1:1 mix of glyphosate (M-0139) and 2,4-D amine	2.0+2.0	5	100
Sweetgum			
2,4-D amine	4.0	3	67
Tordon 101R	1.37	3	51
1:1 mix of triclopyr (Garlon 3A) and 2,4-D amine	1.5+2.0	3	95
1:1 mix of Velpar DPX-3674-L and and 2,4-D amine	1.0+2.0	3	89
1:1 mix of tebuthiuron and 2,4-D amine	1.5+2.0	3	94
1:1 mix of glyphosate (M-0139) and 2,4-D amine	2.0+2.0	3	91

Table 5. —*Topkill* of small hardwoods *by foliar* spraying nine herbicides and *mixtures* applied in *water at 20 gallons per acre* in May

Herbicide	Active material per acre	Average topkill
	Pounds	*Percent*
2,4,5-T ester	2.0	76
Triclopyr M-4021	2.0	79
Tordon 101	2.54	75
Tordon 101R	2.74	65
Glyphosate (0139)	2.0	73
1:1 mix of 2,4,5-T ester + triclopyr (M-4021)	1.0+1.0	75
1:1 mix of 2,4,5-T ester + Tordon 101R	1.0+1.37	78
1:1 mix of 2,4,5-T ester + glyphosate (0139)	1.0+1.0	62
1:1 mix of triclopyr (M-4021) + Tordon 101	1.0+ 1.27	78

Table 6 .-Comparison of pelleted tebuthiuron *and bromacil when broadcast* **in** *April at three rates on an* upland *site*

Herbicide and rates'	Topkill					
	Post oak	Blackjack oak	Sumac	Tree sparklebery	Dogwood	All species
	Percent					
Tebuthiuron						
4 pounds	99	Xl	98	–	100	91
8 pounds	–	98	100	100	100	98
12 pounds	100	100	100	–	100	99
Bromacil						
4 pounds	99	76	36	10	100	81
8 pounds	96	7.5	50	6	100	63
12 nounds	100	100	43	9	100	77

'Pellets contained 10 percent active material: rates based on active material per acre

Table 7.—*Topkill of mixed* hardwoods by *broadcasting Tordon 10K,* tebuthiuron. and Velpar pellets' on an upland soil *at two* rates in April

Herbicide	Topkill	
	4 pounds	8 pounds
	Percent	
Tebuthiuron	91	96
Tordon 10K	70	78
Velpar	83	92

[1]All pellets contained 10 percent active material: rates are active material per acre.

Table 8.—*Topkill of post oak and hickory* when four soil herbicides were applied **in bands in** May

Herbicide	Active material per pound	Rate per inch of d.b.h.[1]	Topkill	
			Post oak	Hickory
	Percent	Grams	percent	
Tordon 10K— 10% pellets	10	0.5	27	79
		1.0	30	90
Tebuthiuron — 10% pellets	10	0.5	45	15
		1.0	97	35
Tebuthiuron — 40% pellets	40	0.5	66	30
		1.0	93	50
Velpar — 90% powder	90	0.5	91	12
		1.0	100	42
1: 1 mix of Tordon 10K and 10% tebuthiuron pellets	10	0.5	11	33
		1.0	11	87

'Active **material**

Table 9. -Selected comparisons of undiluted 2.4-D amine and Tordon *101* for controlling hardwoods 5 to 9 inches d.b.h. by tree injectron

Herbicide	Concen-tration (a.e./gal.)	Dosage/ incision	Spacing of incisions	Season applied	Topkill		
					Oak	Sweetaum	Hickorv
	Lb.	MI.	Inches			Percent----	
2.4-D amine	4.0	1	5	Winter	83	—	42
		2	5	Winter	90		33
		1	7	Winter	66		18
		2	7	Winter	88		51
Tordon 101	2.54	1	5	Winter	100		92
		2	5	Winter	98	–	100
		1	7	Winter	99	–	100
		2	7	Winter	100	–	96
2.4-D amine	4 0	1	7	Winter	54	46	0
Tordon 101	2.54	1	7	Winter	97	100	94
		1	9	Winter	95	90	97
2.4-D amine	4.0	0.5	7	Spring	74	38	—
Tordon 101	2.54	0.5	7	Spring	92	81	
2,4-D amine	4.0	2	Two incisions	Summer	99	–	—
		4	One incision	Summer	74		—
Tordon 101	2.54	2	Two incisions	Summer	100		
		4	One Incision	Summer	88		
2.4-D amine	4.0	1	Two incisions	Summer	70	11	42
Tordon 101	2.54	1	Two incisions	Summer	100	74	54

Table 10. —*Topkill of three common upland hardwoods injected with 1 ml of undiluted 2,4-D* **amine, Tordon 101, and** diluted Tordon 155 in May and December

Season and herbicide	Active material per gallon	Incisions	Post oak	Blackjack oak	Hickory
	Lb.	*Number*		*Percent*	
***May* injection**					
2.4-D amine[1]	3.0	1	28	37	21
		2	49	44	45
Tordon 101	2.54	1	28	45	35
		2	76	82	70
Tordon 155[2]	2.5	1	23	16	71
		2	75	57	76
December injection					
2.4-D amine[1]	3.0	1	11	31	18
		2	45	49	34
Tordon 101	2.54	1	78	64	66
		2	87	93	97
Tordon 155[2]	2.5	1	10	24	61
		2	26	66	90

[1]Oil-soluble formulation that has been as effective as water-soluble 2,4-D amine with 4 pounds (ae) per gallon.

[2]Tordon 155 diluted 1:1 with oil to reduce active ingredient per gallon.

Table 11. —*Topkill of six prevalent brush species when sprayed in* May *with 2,4,5-T ester, Tordon 155, and a mixture similar to Tordon 155 with 10 gallons of* oil per acre

Herbicide	Rate per acre (ae)	Blackjack oak	Sweet-gum	Black-gum	Huckle-berry	Dog wood	Red maple	Avg.
	Pounds				*Percent*			
2,4,5-T ester	4.0	50	97	93	55	91	60	74
Tordon 155	2.5	48	99	93	45	67	78	72
Formulation similar to Tordon 155	4.75	76	100	99	74	90	76	86

Table 12. — *Topkill* ***of mixed hardwood*** brush ***with three*** herbicides applied at *two* ***rates in winter and summer*** **using 30** ***gallons*** **of oil** ***per*** acre

Season and herbicide	Active material per acre	Topkill
	Pounds	***Percent***
January		
2,4,5-T ester	***3.0***	***a4***
	6.0	***85***
Triclopyr (M-4021)	3.0	92
	6.0	96
Tordon 155	3.0	79
	6.0	91
June		
2,4,5-T ester	3.0	87
	6.0	87
Triclopyr (M-4021)	3.0	85
	6.0	98
Tordon 155	3.0	83
	6.0	94

Table 13. — *Topkill* ***of mixed, small hardwoods by broadcasting pellets of*** *Tordon 10K*, ***tebuthiuron, and an equal*** *mixture* ***of the two at three rates on an upland soil***

Herbicides	Active ingredient	Pounds (ai) per acre 6	8	10
	Percent			
Tordon 10K	10	86	95	92
Tebuthiuron	10	66	91	89
1:1 mix of Tordon 10K and tebuthiuron	10	83	94	94

APPENDIX C

Publications Emanating from Herbicide Studies in Alexandria, Louisiana

Brady. Homer A.

1969. Herbicide mixtures promising for hardwood control by foliar spraying. Proc. South. Weed Sci. Soc. 22: 245-250.

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Fitzgerald. Charles H.. Fred A. Peevy. and Darwin E. Fender.

1973 The Southern Region. J. For. 71: 148-153.

McLemore. B. F.

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1969. Several herbicides and mixtures show promise for injection of cull hardwoods. Proc. South. Weed Sci. Soc. 22: 251-256.

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1970. Banding soil herbicides not promising for hardwood control. Proc. South. Weed Sci. Soc. 23: 225-229.

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1976. Injected oil- and water-soluble herbicides give similar kills. Proc. South. Weed Sci. Soc. 29: 291-294.

——. and H. A. Brady.

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APPENDIX D

Common and Scientific Names of Listed Species

Common name	Scientific name
Blackgum	Nyssa sylvatica Marsh.
Blackjack oak	Quercus marilandica Muenchh.
Dogwood	*Cornus florida* L.
Green ash	*Fraxinus pennsylvanica* Marsh.
Hickory	*Carya* sp.
Huckleberry	Vaccinium sp.
Ironwood	Osty virginiana (Mill.) K. Koch
Pecan	*Carya illinoensis* (Wangenh.) K. Koch
Post oak	*Quercus* stellata Wangenh.
Red maple	*Acer rubrum* L.
Red oak	Quercus *falcata*
Sumac	*Rhus* sp.
Swamp privet	*Ligustrum* sp.
Sweetbay	Magnolia virginiana L.
Sweetgum	Liquidambar *styraciflua* L.
Sycamore	Platanus *occiden* talis L.
Tree sparkleberry	Vaccinium arboreum Marsh.

Mann, W. F., Jr. and M. J. Haynes.

1978. Status of some new herbicides. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. SO-21, 18 p. South. For. Exp. Stn., New Orleans, La.

Summarizes 15 years of research on 10 herbicides that are now in use or show promise. The report is based on more than 60 studies, including soil, foliar, and injection applications.

Additional keywords: Hardwood control, tree injection, foliar spraying, soil application, banding herbicides, site preparation, release, weeding, stand improvement.

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