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16. Abstract

Herbicides were applied by truck sprayers in the fall of 1991 and 1992 to woody plants encroaching on roadways near Garrison, Rusk, and Alto, Texas. Krenite®Arsenal®, and Escort®, either alone or in mixtures, were applied to evaluate spray effectiveness for trimming branches of various tree species. Krenite® and Arsenal® killed some trees less than 15 ft (4.6 m) tall that were completely covered by spray. Lower branches of most large trees either died or were growth inhibited for at least 1 year. The living branches treated with Krenite® or Arsenal® were either completely defoliated or had small, deformed leaves the year after spraying. Krenite® affected most hardwood species and pine. Arsenal® was effective on most hardwood species, but not pine. Addition of Escort® had little effect on woody plant response to Krenite® or Krenite® + Arsenal®. Krenite® and Arsenal® showed promise for for controlling encroaching woody plant growth along East Texas highways.

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CONTROLLING FOREST ENCROACHMENT ALONG EAST TEXAS ROADWAYS

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Sponsored by the
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TEXAS TRANSPORTATION INSTITUTE
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IMPLEMENTATION STATEMENT

This is a report of initial research progress to assess options of chemically trimming woody vegetation on roadsides. These tests may have application in areas of roadway user safety, maintenance, or economics that are yet to be determined.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation. This report does not constitute a standard, specification, or regulation.

Tradenames are used for convenience only, and do not constitute an endorsement of the materials named by either the Texas Department of Transportation or Texas Transportation Institute, nor is it a recommendation over comparable products not named.

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LIST OF ABBREVIATIONS/SYMBOLS

Abbreviation/Symbol	Item
ae	Acid equivalent
ai	Active ingredient
CR	County road
FM	Farm to market road
ft	Foot (feet)
g	Gram(s)
g/L	Gram(s) per liter
gal	Gallon(s)
gal/A	Gallon(s) per acre
>	Greater than
kg/ha	Kilogram(s) per hectare
km	Kilometer(s)
<	Less than
L	Liter(s)
L/ha	Liter(s) per hectare
lb/A	Pound(s) per acre
m	Meter(s)
ml	Milliliter(s)
oz	Ounce (fluid or solid)
oz/A	Ounce(s) per acre
®	Trademark

SUMMARY

Herbicides were applied by truck sprayers in the fall of 1991 and 1992 to woody plants encroaching on roadways in East Texas. Tests were established near Garrison, Rusk, and Alto, Texas. Krenite®, Arsenal®, and Escort®, either alone or in mixtures, were applied to evaluate spray effectiveness for trimming encroaching branches of various tree species.

Krenite® and Arsenal®, individually and in combination, tended to kill trees less than 15 ft (4.6 m) tall that were completely covered by spray. Lower branches of most large trees either died or had growth inhibited for at least 1 year. The living branches treated with Krenite® or Arsenal® either were completely defoliated or had small, deformed leaves the year after spraying.

Krenite® affected most deciduous hardwood species and pine, but it was generally ineffective on sassafras. Arsenal® was effective on most hardwood species, but not pine. Addition of Escort® had little effect on woody plant response to Krenite® or Krenite®+ Arsenal®.

CONTROLLING FOREST ENCROACHMENT ALONG EAST TEXAS ROADWAYS

INTRODUCTION

Unwanted woody vegetation readily encroaches on Texas highways, particularly in the eastern part of the state. This encroaching brush causes several problems along highways (Vernon et al., 1983). First, it causes a problem in line-of-sight distance at intersections, around curves, and at signs. This increases the chances of vehicular collisions. Second, overhanging limbs on narrow highways can cause physical damage to vehicles and injury to persons riding in open vehicles. Third, encroaching brush may cause a problem with minimum safety setback distance where vehicles leaving the pavement in an emergency could collide with a tree in the "Active Zone"[1]. Fourth, overhanging vegetation could cause a shading problem where a motorist might fail to see a pedestrian or large object on the pavement, or in the winter may allow buildup of ice and snow causing a slippery condition and possibly pavement deterioration.

At present, roadside woody vegetation is kept trimmed by crews with chain saws and other mechanical equipment. Increasing cost of labor and equipment for mechanical trimming on restricted budgets demand the development of less expensive methods to maintain the safety and maintenance standards of the Texas Department of Transportation (TxDOT). Several herbicides have been suggested for chemical trimming of these woody plant species in an effort to reduce cost both of trimming the present vegetation and in holding back future growth of the present vegetation.

The herbicide Krenite® [fosamine ammonium -- ethyl hydrogen (aminocarbonyl)phosphonate] is used on non-cropland areas such as highway, railroad, pipeline, and utility rights-of-way; drainage ditchbanks; storage areas; and industrial plant sites because of its foliar activity (Pritchard, 1979). Krenite® is highly water soluble,

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[1]The "Active Zone" is the roadside area from the pavement edge to the ditchline where intensive vegetation management occurs (Anonymous, 1993).

readily inactivated by soil, and has a low mammalian toxicity. Its effectiveness, however, is reduced by alkaline earth metals in the spray water and high concentrations of phosphorus in the plant tissue (Weigel and Riggleman, 1978).

Krenite® shows promise for controlling roadside brush since its mode of action is different from most other growth regulator herbicides (Hernandez et al., 1975). It causes little "brown out" which is often perceived by the public as unsightly. The woody vegetation is sprayed from July through September after the main flush of growth has matured. There is a slight foliage effect of premature fall coloring, but normal leaf drop occurs. The plants fail to refoliate the next spring. Leaf production is either prevented entirely, or the leaves are small and abnormal. The tree may eventually die if completely covered by spray. Krenite® treatments in the spring, when the leaves are expanding, usually prevent stem elongation and cause leaf death or chlorosis with some marginal puckering (Welch et al., 1974; Zoebisch et al., 1974). Many species will begin normal growth again the next year after spring or summer treatment. Pines, however, show a "brown out" response within 2 months after treatment.

Several characteristics of Krenite® have been suggested (Hernandez et al., 1974; Hernandez et al., 1975).

* Concentrated sprays are often more effective than diluted sprays.
* Thorough coverage of the foliage is imperative for good results; partial coverage results in only the sprayed vegetation being affected.
* Rain within 24 hours washes off the spray and reduces results.
* Vegetation suppression occurs at rates above 1.5 gal/A[2] (14 L/ha).
* Drift control agents generally reduce the effectiveness of Krenite®.
* Most non-coniferous evergreens are tolerant to Krenite®.
* Plants with glossy or very waxy leaves appear more resistant than species with less waxy leaves.

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[2]Quantities of liquid formulations are expressed in liquid units and solid formulations as product.

* An added nonionic surfactant or non-phytotoxic oil usually increases the effectiveness of Krenite® (Pritchard, 1979; Welch et al., 1974).

Gonzalez (1975) presented a list of woody species found in East Texas having varying susceptibilities to Krenite®. Susceptible species included birch[3], hawthorn, American hornbeam, honey locust, multiflora rose, white oak, water oak, loblolly pine, American sycamore, sumac, and sweetgum. Plants with intermediate susceptibility include white ash, black cherry, dogwood, elms, blackgum, hackberry, hickory, red maple, mulberry, osage-orange, common persimmon, poison-ivy, sassafras, smilax, and willow. Resistant species include boxelder, buckeye, buckthorn, eastern red cedar, honeysuckle, trumpetcreeper, and eastern redbud (Welch et al., 1974).

In Indiana, Holt and Seifert (1979) found excellent control of flowering dogwood, hickory, red maple, black cherry, and eastern hophornbeam with 1.5 gal/A (14 L/ha) of Krenite®. Chappell and Will (1974) in Virginia found 90 to 100% defoliation except for green stems and the presence of leaf buds on maple, oaks, sassafras, dogwood, hickory, black cherry, and American hornbeam at 1.5 gal/A (14 L/ha). Johnson (1988) in Pennsylvania found Krenite® at 2.0 gal/A (19 L/ha) gave equally good control of oaks, multiflora rose, and white ash at volumes of 25, 50, and 100 gal/A (234, 467, and 935 L/ha); whereas, boxelder and black cherry were controlled better at 25 gal/A (234 L/ha) than at 100 gal/A (935 L/ha). Morey and Dahl (1980) in Texas showed Krenite® suppressed stem and leaf growth of honey mesquite.

Arsenal® {imazapyr -- (±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-3-pyridinecarboxylic acid} is a broad-spectrum herbicide used for noncrop weed control for right-of-way and industrial use. It also has promise for site preparation and pine release applications in forestry. Arsenal® is absorbed by both roots and foliage for both preemergent and postemergent activity. It generally does not leach more than 6 inches (15 cm) into the soil (VanCantfort et al., 1985a).

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[3]Scientific names are given in the Appendix.

Arsenal® controls a wide variety of annuals, perennials, grasses, broadleaf weeds, vines, and deciduous trees. Arsenal® controls such troublesome broadleaf woody plants as multiflora rose, sweetgum, poplar, red maple, ash, oaks, hickory, and dogwood, as well as vines such as honeysuckle and trumpetcreeper (Dobson et al., 1985; Lowery and Troth, 1986; Muzyk et al., 1986; and VanWinkle et al., 1987). Yeiser and Gardiner (1990) in Arkansas found Arsenal® at 0.25 gal/A (2.3 L/ha) most readily controlled oaks and sweetgum, followed by red maple. Hickories, ash, common persimmon, and eastern hophornbeam were most difficult to control. VanCantfort et al. (1985b) indicated that red maple, black locust, willow, hawthorn, cherry, poplar, sweetgum, dogwood, hickory, oak, and ash can be controlled by 0.5 to 0.75 gal/A (4.7 to 7.0 L/ha) of Arsenal®.

Escort® {metsulfuron methyl -- methyl 2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino] sulfonyl]benzoate} has both foliar and soil activity and is usually applied with a nonionic surfactant. Escort® is widely used to control weeds in small grain crops because of their tolerance; however, it also controls some woody species. Woody species controlled at 0.83 to 3.3 oz/100 gal (24 to 94 g/378 L) include ash, cherry, elm, eastern cottonwood, multiflora rose, willow, eastern redbud, and dogwood (Rick et al., 1985). Escort® as a directed spray at 0.062 oz/gal (0.47 g/L) with 0.5% Cide-Kick® applied to runoff gave 80 to 100% control of red maple, blackgum, ash, flowering dogwood, and winged elm without injurying young loblolly pine plantings (Gonzalez, 1986). At 6.7 oz/A (467 g/ha) Meyer and Bovey (1990) found metsulfuron methyl effective for controlling Texas whitebrush, but ineffective on honey mesquite and huisache. Metsulfuron methyl has given marginal to excellent control of Macartney rose and multiflora rose (Derr, 1989; Meyer and Bovey, 1990).

In Pennsylvania, Lyman et al. (1990) found Krenite® had little activity on sassafras and only slightly injured hackberry at 1.5 gal/A (14 L/ha). All the contacted American elm branches were controlled; whereas, viburnum blackhaw and oaks were controlled beyond the contacted area. All treatments with Krenite® at 0.75 and 1.1 gal/A (7 and 10 L/ha)+Arsenal® at 2 to 4 oz/A (146 to 292 ml/ha) were more effective than Krenite® alone. Arsenal® gave effective control of sassafras. Krenite® 0.5 gal/A (4.7

L/ha)+Escort® at 1 oz/A (70 g/ha) gave complete control of black walnut and black cherry.

Also in Pennsylvania, Gover et al. (1993), found August treatments of Krenite® at 1.5 gal/A (14 L/ha)+Arsenal® at 4 oz/A (292 ml/ha) gave complete control of sprayed branches of black cherry, red maple, American elm, and flowering dogwood. Krenite® at 1.5 gal/A (14 L/ha)+Escort® at 0.5 oz/A (35 g/ha) controlled black cherry, and multiflora rose branches, but not sassafras. In a September test, Krenite® only gave good control of branches of mockernut hickory, moderate control of black cherry, red maple, and flowering dogwood, and poor control of sassafras.

The aim of this study was to evaluate the possibility of using herbicides to manage woody vegetation encroaching roadsides in East Texas. The objectives were to (1) evaluate species response to various herbicide combinations and (2) discover advantages and problems involved in such a program.

MATERIALS AND METHODS

Three tests were undertaken in East Texas. We established one test near Garrison on FM 1087 about 7.6 miles (12.2 km) east of the intersection with US 259 in TxDOT's Lufkin District. The second was located near Rusk on FM 1857 about 6.5 miles (10.5 kg) southwest from the intersection with Texas Highway 23 in the Tyler District. The third was established along FM 752 at CR 2325 about 7 miles (11.3 km) west of Alto.

All three test sites had typical woody vegetation characterized as the East Texas forest type designated by the Texas Forest Service (Haislet, 1971). The woody vegetation at time of treatment was encroaching into the critical area 15 ft (4.6 m) above and back 15 ft (4.6 m) from the pavement edge. The roadway grade undulated in elevation approximately 50 to 75 ft (15-23 m) at all sites.

At time of spraying, the plants near Garrison were sprayed near the end of the recommended treatment period. The sumacs were partially defoliated and mockernut hickory leaves were mostly brown and dying. The plants near Rusk and Alto were dark green and in healthy, mature condition.

In all tests, plots 24 x 260 ft (7.3 x 79 m) were established on both sides of the road. Three plots were designated per treatment and were randomly assigned within each of three groups (replicates). Names of individual trees by species nearest the roadway were recorded along the length of each plot prior to spraying to facilitate identification later. The plants near Garrison were also identified by numbered metal tags.

Herbicides were sprayed October 1, 1991, near Garrison, August 6, 1992, near Rusk, and September 15, 1992, near Alto. Untreated plots and five herbicide treatments were included at all sites as shown in Table 1. Krenite® rates are based on gallons of product. Arsenal® rates are based on fluid ounces of product, and Escort® rates are based on ounces of solid product. Krenite® herbicide was a 4 lb ai/gal (479 g/L) formulation of fosamine ammonium. Arsenal® was a 2 lb ae/gal (240 g/L) formulation of imazapyr. Escort® was a 60% active ingredient formulation of metsulfuron methyl.

Table 1. Herbicide treatments sprayed in three East Texas roadside vegetation control tests in 1991 and 1992.

Test site[1]	Treatment number	Herbicide[2]		
		Krenite®	Escort®	Arsenal®
		Gal/A	Ounce/A	Ounce/A
Garrison	1	0.67	0.45	---
	2	0.59	0.77	---
	3	---	---	6.18
	4	0.63	---	0.66
	5	0.63	---	1.98
	6	---	---	---
Rusk & Alto	1	2.0	---	---
	2	1.5	---	2.00
	3	1.5	---	4.00
	4	1.5	---	8.00
	5	1.5	1.00	4.00
	6	---	---	---

[1]Spray dates: Garrison = October 1, 1991; Rusk = August 6, 1992; Alto = September 15, 1992.

[2]Surfactant was added to all herbicide sprays at 0.25% by volume: DuPont WK® at Garrison and LI-700® at Rusk and Alto. English to metric conversions: Krenite® 0.59, 0.63, 0.67, 1.5, and 2.0 gal/A = 5.5, 5.9, 6.3, 14.0, and 18.7 L/ha. Escort® 0.45, 0.77, 1.00 oz/A = 31.5, 53.9, and 70.0 g/ha. Arsenal® 0.66, 1.98, 2.00, 4.00, 6.18, and 8.00 oz/A = 48, 145, 146, 292, 451, and 584 ml/ha.

The herbicides were sprayed as aqueous solutions using a boomless, off-center nozzle (OC® 40) from a pickup truck. At Garrison, the nozzle was mounted on the front bumper (Figure 1). Sprays at Rusk and Alto were applied using a nozzle in the truck bed. Herbicide solutions were sprayed at a volume of 42 gal/A (393 L/ha) near Garrison and 30 gal/A (280 L/ha) near Rusk and Alto. The spray was delivered in a swath 24 ft (7.3 m) wide. The spray truck was driven on the roadside shoulder near Garrison and Alto to allow the spray to arch about 15 ft (4.6 m) high and reach almost to the right-of-way boundry. Near Rusk, the truck was driven at the edge of the pavement with spray reaching the encroaching branches, but often not far enough to reach the main trunk of the trees.

Ratings were recorded for the sprayed portion of every tree by species in each plot the year following treatment on July 31, 1992, near Garrison and June 22, 1993, near Rusk and Alto. Percent defoliation of the stems and branches was recorded along with cutting of the bark to determine whether or not the tissue was still alive. Notes were made as to the leaf size and deformation. Also, the presence or absence of dead leaves or needles was recorded.

Where species occurred in sufficient numbers, data were analyzed statistically. Responses by species were analyzed across treatments in each test. Data were analyzed in an analysis of variance using a general linear model program which adjusts for unequal sample sizes in treatments. As an aid to help readers compare means, a Least Significant Difference test was calculated using a pooled standard deviation on an average number of trees per treatment.

Figure 1. Truck sprayer applying herbicides along a roadside near Garrison, Texas, October 1, 1991.

RESULTS

Garrison. Krenite®+Escort® (treatments 1 and 2) only effectively controlled (>79%) eastern hophornbeam, but the treatments also did kill one flowering dogwood, one sassafras, three shortleaf pines, five smooth sumacs, and two sweetgum plants (Table 2). Plants killed by herbicides were less than 15 ft (4.6 m) tall and had been completely covered by the herbicide spray.

Krenite®+Escort® moderately controlled (50-79%) flowering dogwood, post oak, bluejack oak, and shortleaf pine (Table 2). Most of the two oak species and shortleaf pine were more than 30 ft (9.1 m) tall; consequently, the spray probably failed to penetrate the foliage completely. Black hickory, black oak, flameleaf sumac, mockernut hickory, sassafras, smooth sumac, sugar hackberry, and sweetgum averaged less than 50% injury.

Arsenal® alone (treatment 3) effectively controlled (>79%) eastern hophornbeam, flameleaf sumac, flowering dogwood, and sassafras (Table 2). It moderately controlled (50-79%) post oak, smooth sumac, sugar maple, and sweetgum, but it failed to control (<50%) black hickory, black oak, bluejack oak, mockernut hickory, red maple, shortleaf pine, and sugar hackberry.

At least one of the Krenite®+Arsenal® treatments (treatments 4 and 5) effectively controlled (>79%) flameleaf sumac, flowering dogwood, post oak, red maple, sassafras, smooth sumac, and sugar maple (Table 2); moderately controlled (50-79%) bluejack oak, eastern hophornbeam, mockernut hickory, shortleaf pine, sugar hackberry, and sweetgum; but poorly controlled (<50%) black hickory and black oak.

The species varied widely in response to herbicide treatments which was due to the late season of application, plant size, and plant susceptibility. Mockernut hickory and the sumac species were already beginning fall dormancy. Mostly black hickory, black oak, bluejack oak, shortleaf pine, and sugar hackberry were much taller than the 15 ft (4.6 m) spray height. Sassafras was tolerant to Krenite®+Escort®, and shortleaf pine was resistant to Arsenal® (Table 2).

Table 2. Percent defoliation of East Texas forest trees near Garrison by six treatments applied October 1, 1991, and rated July 31, 1992.

Species	Treatment (Amount of product/A)[1]						LSD[2]
Herbicide[3]	1	2	3	4	5	6	
Krenite®	0.67 gal	0.59 gal	---	0.63 gal	0.63 gal	Untreated	
Escort®	0.45 oz	0.77 oz	---	---	---		
Arsenal®	---	---	6.18 oz	0.66 oz	1.98 oz		
Dogwood, flowering	36(10)1	50(7)	89(7)1	73(6)	83(6)1	6(7)	26
Hackberry, sugar	10(2)	22(12)	10(4)	55(4)	27(3)	10(6)	18
Hickory, black	5(3)	8(2)	8(2)	---	10(1)	6(4)	15
Hickory, mockernut	22(3)	18(10)	28(5)	49(15)	66(16)	9(15)	29
Hophornbeam, eastern	---	100(1)1	88(7)4	---	67(3)1	11(4)	41
Oak, black	5(1)	---	40(1)	---	20(1)	8(2)	59
Oak, bluejack	56(15)	28(8)	28(9)	46(5)	63(5)2	8(2)	34
Oak, post	63(2)	73(6)	64(5)2	91(8)4	63(9)4	13(6)	31
Pine, shortleaf	60(13)3	10(1)	13(7)	40(3)	65(2)1	25(4)	44
Maple, red	---	---	35(4)	82(4)	100(1)1	8(2)	24
Maple, sugar	---	---	78(2)	95(1)	75(9)	13(8)	27
Sassafras	20(30)1	13(23)	83(20)8	68(12)1	84(33)9	11(31)	15
Sumac, flameleaf	10(8)	33(7)	99(2)1	63(3)1	83(2)	10(7)	34
Sumac, smooth	16(11)	45(16)5	64(4)	90(14)7	5(1)	60(1)	57
Sweetgum	8(15)	36(13)2	56(6)1	62(22)3	37(4)	7(7)	30
Mean defoliation	28%	31%	58%	67%	70%	11%	6

[1]Numbers to the left of parentheses indicate mean percent defoliation by species. Numbers in parentheses are total numbers of plants in all three plots evaluated. Values to the right of the parentheses are numbers of dead plants in the three plots.

[2]Least Significant Difference at the 5% level by row for percent defoliation.

[3]Herbicides were applied as aqueous sprays at 42 gal/A (393 L/ha). Herbicides included: Krenite® = 4 lb ai/gal (479 g/L) fosamine ammonium; Escort® = 60% ai metsulfuron; Arsenal® = 2 lb ae/gal (240 g/L) imazapyr. Surfactant, DuPont WK®, was added at 0.25% v/v to all sprays. Krenite® at 0.59, 0.63, and 0.67 gal/A = 5.5, 5.9, and 6.3 L/ha. Escort® at 0.45 and 0.77 oz/A = 31.5 and 53.9 g/ha. Arsenal® at 0.66, 1.98, and 6.18 oz/A = 48, 145, and 451. ml/ha.

Rusk. Generally, the treatments were ineffective. Treatment 4 with Krenite® at 1.5 gal/A (14.0 L/ha)+Arsenal® at 8 oz/A (584 ml/ha) was most effective over all species by producing a mean defoliation of 40%; whereas, the other herbicide treatments were only slightly more effective than the untreated plots (Table 3). Treatment 4 tended to be the most effective because of the foliar activity of both herbicides and the soil effectiveness of the highest rate of Arsenal®.

Thirteen species occurred in sufficient numbers for statistical analysis. Herbicide treatments 3, 4, and 5 killed about half the flameleaf sumac and smooth sumac plants. Few other trees were killed in the test (Table 3). Krenite® alone (treatment 1) effectively controlled (>79%) eastern hophornbeam at 80%, but failed to control any other species, except winged elm, compared with the untreated plots.

One or more treatments of Krenite®+Arsenal® (treatments 2, 3, and 4) effectively controlled (>79%) flameleaf sumac and smooth sumac; moderately controlled (50-79%) cedar elm, eastern hophornbeam, and sugar maple; and ineffectively controlled (>50%) all other species (Table 3). Arsenal® at 8 oz/A (584 ml/ha) was only superior to the 2 or 4 oz/A (146-292 ml/ha) rates for smooth sumac and sugar maple. Krenite®+Arsenal® failed to control (<50%) loblolly pine, mockernut hickory, red maple, sassafras, shortleaf pine, southern red oak, sugar hackberry, sweetgum, water oak, willow oak, and winged elm. Addition of Escort® (treatment 5) failed to increase the activity of Krenite®+Arsenal® (treatment 3) alone.

Overall, the test was ineffective because much of the woody vegetation occurred at the distal fringe of the spray swath rather than next to the pavement. The spray truck was operated at the edge of the pavement. Consequently, most of the tree canopies were not deeply penetrated by the spray.

Alto. Figures 2A and 2B show the density and encroachment of problem woody vegetation along the roadside. The September 1992 herbicide treatments were highly effective by June 1993. Over all species, they resulted in 64 to 80% defoliation (Table 4). This means most stems either were completely defoliated or only had small,

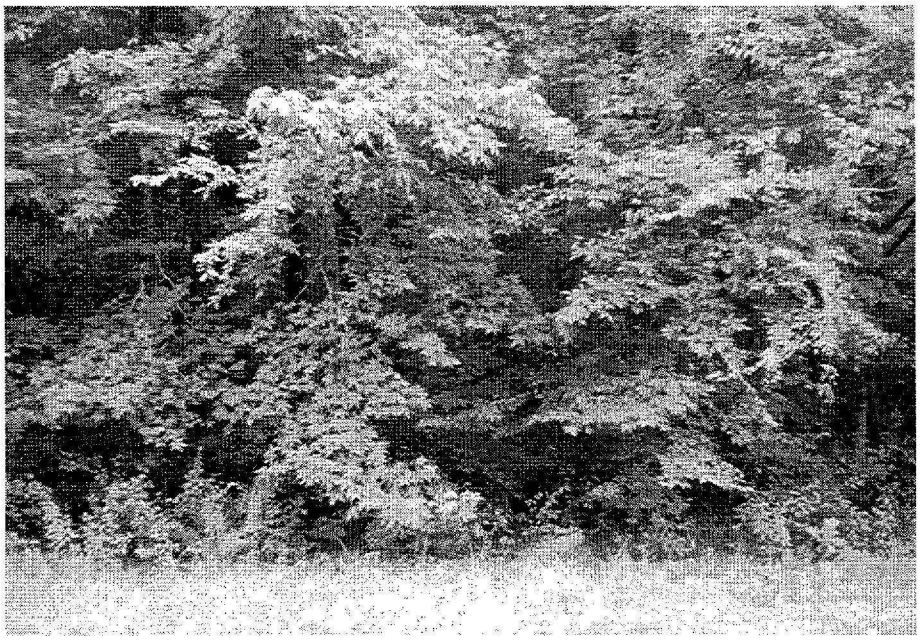
Table 3. Percent defoliation of East Texas forest trees near Rusk by six treatments applied August 6, 1992, and rated June 22, 1993.

Species	Treatment (Amt product/A)[1]						LSD[2]
Herbicide[3]	1	2	3	4	5	6	
Krenite® Arsenal® Escort®	2 gal	1.5 gal + 2 oz	1.5 gal + 4 oz	1.5 gal + 8 oz	1.5 gal + 4 oz + 1 oz	Untreated	
Elm, cedar	12(17)	52(4)	9(9)	43(20)	10(17)	1(20)	22
Elm, winged	30(7)	22(4)	33(3)	16(7)	0(1)	0(1)	25
Hackberry, sugar	0(1)	9(2)	0(2)	34(7)	5(3)	0(6)	36
Hickory, mockernut	---	0(2)	0(4)	---	0(3)	0(1)	25
Hophornbeam, eastern	80(9)	47(14)	57(3)	45(3)1	21(6)	0(1)	58
Maple, red	5(3)	8(4)	10(15)	0(1)	3(5)	---	28
Maple, sugar	0(2)	4(7)	1(12)	70(1)	---	0(1)	9
Oak, southern red	1(14)	0(1)	13(9)	0(1)	0(3)	5(2)	35
Oak, water	17(17)	11(8)	31(8)	45(4)	2(3)	1(8)	34
Oak, willow	0(1)	---	0(1)	35(2)	0(3)	0(1)	20
Pine, loblolly	5(2)	5(4)	26(5)1	27(5)	10(2)	0(1)	33
Pine, shortleaf	1(6)	5(6)	25(3)	45(6)	15(1)	0(2)	35
Sassafras	15(1)	16(5)	1(3)	---	14(5)	0(3)	34
Sumac, flameleaf	---	0(1)	100(2)2	100(1)1	0(1)	---	33
Sumac, smooth	---	0(4)	50(2)1	80(2)1	60(5)3	0(2)	16
Sweetgum	22(13)	20(10)2	12(4)	44(17)	3(9)	0(8)	30
Mean defoliation	19%	19%	17%	40%	11%	0.7%	7

[1]Numbers to the left of parentheses indicate mean percent defoliation by species. Numbers in parentheses are total numbers of plants in all three plots evaluated. Values to the right of the parentheses are numbers of dead plants in the three plots.

[2]Least Significant Difference at the 5% level by row for percent defoliation.

[3]Herbicides were applied as aqueous sprays at 30 gal/A (280 L/ha). Herbicides included: Krenite® = 4 lb ai/gal (479 g/L) fosamine ammonium; Arsenal® = 2 lb ae/gal (240 g/L) imazapyr; Escort® = 60% ai metsulfuron methyl. Surfactant, LI-700®, was added at 0.25% v/v to all sprays. Krenite® at 1.5 and 2.0 gal/A = 14.0 and 18.7 L/ha. Arsenal® at 2, 4, and 8 oz/A = 146, 292, and 584 ml/ha. Escort® at 1 oz/A = 70 g/ha.



A

B

Figure 2. Untreated woody vegetation near Alto, Texas, June 22, 1993. **A.** View perpendicular to the road showing density of vegetation. **B.** View almost parallel to the road showing encroachment.

Table 4. Percent defoliation of East Texas forest trees near Alto by six treatments applied September 15, 1992, and rated June 22, 1993.

Species	Treatment (Amt product/A)[1]						LSD[2]
Herbicide[3]	1	2	3	4	5	6	
Krenite® Arsenal® Escort®	2 gal	1.5 gal + 2 oz	1.5 gal + 4 oz	1.5 gal + 8 oz	1.5 gal + 4 oz + 1 oz	Untreated	
Dogwood, flowering	64(9)	90(5)	64(5)	60(3)	61(7)	5(8)	36
Elm, cedar	87(3)	90(5)	69(10)	59(8)	54(5)	2(6)	36
Elm, winged	86(9)	90(7)	77(22)1	87(3)	65(6)	4(7)	16
Hophornbeam, eastern	---	86(8)1	95(2)1	41(4)	73(3)1	5(2)	44
Hornbeam, American	64(23)	85(16)	52(2)	70(11)	69(36)4	4(11)	34
Maple, red	53(27)	69(14)	88(6)1	90(2)	49(6)	4(4)	36
Maple, sugar	63(30)	81(45)	45(2)	56(28)1	47(39)	2(58)	22
Oak, southern red	100(1)1	68(13)	66(8)	37(3)	80(2)	2(9)	59
Pine, loblolly	80(26)8	83(26)8	82(19)4	82(18)5	74(7)2	22(3)	20
Pine, shortleaf	74(15)3	93(3)2	75(23)2	85(15)7	80(3)	7(6)	21
Redbud, eastern	---	26(7)	85(1)	40(2)	5(2)	3(6)	54
Sumac, flameleaf	90(2)	96(7)4	90(2)	48(2)	95(2)1	12(4)	34
Sweetgum	75(41)7	84(49)	83(46)10	82(21)	76(39)2	2(42)	10
Yaupon	29(14)	60(1)	50(10)	50(4)	---	28(4)	44
Mean defoliation	67%	80%	76%	69%	64%	3.3%	6

[1]Numbers to the left of parentheses indicate mean percent defoliation by species. Numbers in parentheses are total numbers of plants in all three plots evaluated. Values to the right of the parentheses are numbers of dead plants in the three plots.

[2]Least Significant Difference at the 5% level by row for percent defoliation.

[3]Herbicides were applied as aqueous sprays at 30 gal/A (280 L/ha). Herbicides included: Krenite® = 4 lb ai/gal (479 g/L) fosamine ammonium; Arsenal® = 2 lb ae/gal (240 g/L) imazapyr; Escort® = 60% ai metsulfuron methyl. Surfactant, LI-700®, was added at 0.25% v/v to all sprays. Krenite® at 1.5 and 2 gal/A = 14.0 and 18.7 L/ha. Arsenal® at 2, 4, and 8 oz/A = 146, 292, and 584 ml/ha. Escort® at 1 oz/A = 70 g/ha.

deformed leaves. Fourteen species occurred in sufficient numbers to calculate statistical analyses.

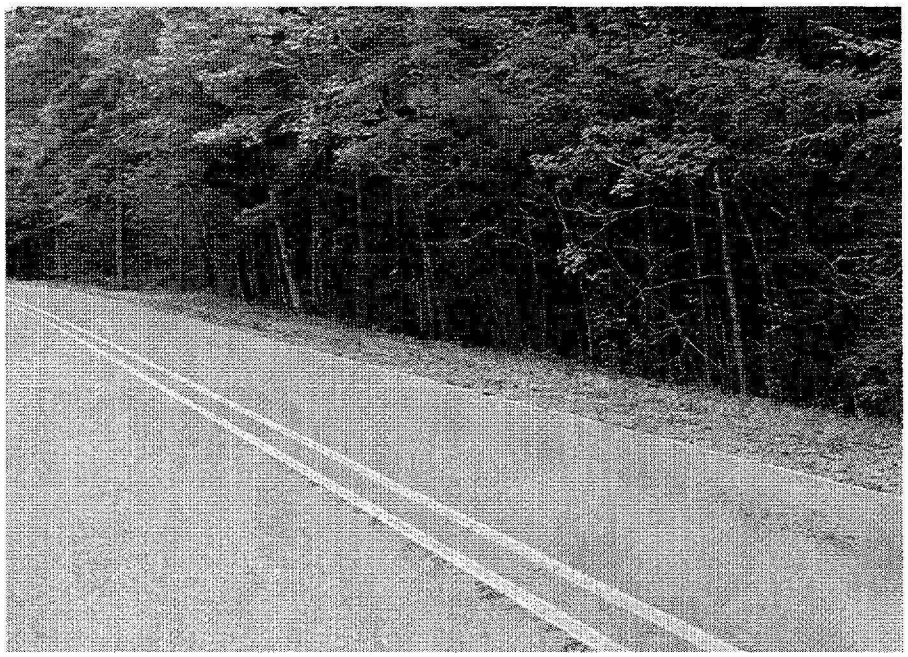
Numerous trees were killed by the herbicide treatments (Table 4). The following percentages of tree populations at 10% and above were killed in the herbicide treatments (not counting untreated plants): flameleaf sumac -- 33%, loblolly pine -- 28%, shortleaf pine -- 24%, eastern hophornbeam -- 18%, and sweetgum -- 10%. These trees were generally 15 ft (4.6 m) or less tall and were completely covered by the spray. Few trees taller than the spray pattern were killed.

Krenite® alone (treatment 1) effectively controlled (>79%) cedar elm, flameleaf sumac, loblolly pine, southern red oak, and winged elm; moderately controlled (50-79%) American hornbeam, flowering dogwood, red maple, shortleaf pine, sugar maple, and sweetgum; but failed to control yaupon (Table 4).

One or more treatments with Krenite®+Arsenal® (treatments 2, 3, and 4) effectively controlled (>79%) American hornbeam, cedar elm, eastern hophornbeam, eastern redbud, flameleaf sumac, flowering dogwood, loblolly pine, red maple, shortleaf pine, sugar maple, sweetgum, and winged elm; and moderately controlled southern red oak and yaupon (Figure 3)(Table 4). Increasing rates of Arsenal® did not increase the degree of vegetation control.

Krenite®+Arsenal®+Escort® effectively controlled (>79%) flameleaf sumac, shortleaf pine, and southern red oak; moderately controlled American hornbeam, cedar elm, eastern hophornbeam, flowering dogwood, loblolly pine, sweetgum, and winged elm; and ineffectively controlled (<50%) eastern redbud, red maple, and sugar maple. Addition of Escort® to Krenite® at 1.5 gal/A (14.0 L/ha)+Arsenal® at 4 oz/A (292 ml/ha) did not increase the effectiveness of the two-herbicide combination alone.

Thus, all herbicide treatments increased control of American hornbeam, cedar elm, flowering dogwood, loblolly pine, red maple, shortleaf pine, sweetgum, and winged elm. Krenite® alone at 2 gal/A (18.7 L/ha) was equally effective as any other treatment.



A

B

Figure 3. Woody vegetation near Alto, Texas, sprayed with herbicides September 15, 1992, and photographed June 22, 1993. **A.** Krenite® at 1.5 gal/A (14.0 L/ha)+Arsenal® at 2 oz/A (146 ml/ha). **B.** Krenite® at 1.5 gal/A (14.0 L/ha)+Arsenal® at 4 oz/A (292 ml/ha).

DISCUSSION

Results from the three tests varied widely. The treatments at Alto in September 1992 were most effective, followed by those near Garrison on October 1, 1991. Treatments at Rusk were least effective. Those at Alto were sprayed at the recommended time in September with the plants in good growing condition. Lower rates were used near Garrison and were applied past optimum time in a dry season. Those applied in August 1992 near Rusk probably were applied too far from the vegetation for maximum coverage.

None of the treatments were consistently superior across all three tests. However, those containing both Krenite® and Arsenal® tended to be more effective than those with Krenite® alone. Increasing the rate of Arsenal® did not always increase vegetation control. Escort® did not appear to enhance woody plant control at these East Texas sites.

The results varied widely among tests, but sprayed twigs and stems of the hardwood trees generally either died or remained alive with or without small, deformed leaves. The existing leaves 1 year after treatment were generally yellow-green, reduced in size, deformed, and usually narrow. No dead, brown leaves were present on the sprayed stems.

Pine response was different from the hardwood trees. The sprayed needles generally were dead and remained on the tree for at least 1 year after spraying. No rating was made in late fall of the spraying year to determine if a significant "brown out" occurred. Presumably, the broadleaf trees did not "brown out"; whereas, the pines probably did within 2 months after spraying.

Results of this study, particularly at Alto, supported data on species response to herbicides reported by other researchers. Krenite® has the potential to kill small trees where completely covered by the spray. Large trees only have branch growth inhibited or suspended by application of herbicides to the treated side of the lower canopy. Species in these tests responded similarly to Krenite® as those reported by others. Most deciduous tree branches either were killed or remained alive with small leaves. Krenite®

was effective on a number of hardwood species, except sassafras. Arsenal® also affected a number of species, but not pines, which confirms its potential use for conifer establishment and release from hardwood competition.

Results of these tests indicate that herbicide trimming of vegetation along East Texas highways has both benefits and problems. First, Krenite® either alone or with Arsenal® is promising for retarding woody plant growth when applied at the optimum time in September, as at Alto. These treatments did an effective job in preventing refoliation and growth of stems near or over the adjoining pavement the year following spraying. Second, mechanical removal of the defoliated stems is easier because of reduced stem growth and the absence of leaves. Third, these herbicides readily reduce dense stands of seedling woody plants. The long-term effect of these treatments, however, was not determined because the remaining stems were removed mechanically.

There are also problems involved with chemical trimming of roadside vegetation. First, the spray swath must be wide enough to give complete coverage of the encroaching vegetation. In the Alto test, the swath width was adequate; whereas, it was too narrow in the test at Rusk. Second, regardless of effective foliar control, the problem remains for removing the dead and living defoliated branches 1 year after treatment.

CONCLUSIONS

1. Krenite® and Arsenal® and mixtures of Krenite®, Arsenal®, and Escort® controlled woody plant stem and branch growth for at least 1 year.
2. Krenite® and Arsenal® killed some small woody plants when completely covered with spray, but, in most cases on large trees, they only inhibit growth of branches sprayed.
3. Herbicides can be sprayed in September that prevent woody vegetation from leafing out the following spring without causing foliage "brown out".
4. One vehicle can be used to treat many small, brush covered areas, such as inside curves, intersections, and concealed signs in a short period of time.

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APPENDIX

Woody species present in test areas near Garrison, Rusk, and Alto, Texas, sprayed with herbicides in October 1991 and August and September 1992.

Species[1]	Scientific name
Ash *	Fraxinus sp
Ash, white	Fraxinus americana L.
Beautyberry, American	Callicarpa americana L.
Birch *	Betula sp
Birch, river	Betula nigra L.
Blackgum	Nyssa sylvatica Marsh.
Blackhaw, viburnum *	Viburnum prunifolium L.
Boxelder	Acer negundo L.
Buckeye *	Aesculus sp
Buckeye, white	Aesculus arguta Buckl.
Buckthorn *	Rhamnus sp
Buckthorn, Carolina	Rhamnus caroliniana Walt.
Cedar, eastern red	Juniperus virginiana L.
Cherry, black	Prunus serotina Ehrh.
Chinkapin, allegheny	Castanea pumila (L.) Mill.
Cottonwood, eastern *	Populus deltoides (Bartr.)
Dogwood *	Cornus sp
Dogwood, flowering	Cornus, florida L.
Elm *	Ulmus sp
Elm, American	Ulmus americana L.
Elm, cedar	Ulmus crassifolia Nutt.
Elm, winged	Ulmus alata Michx.
Hackberry *	Celtis sp
Hackberry, sugar	Celtis laevigata Willd.

Hawthorn sp	Crataegus sp
Hickory *	Carya sp
Hickory, black	Carya texana Buckl.
Hickory, mockernut	Carya alba (Miller) K. Koch
Honeysuckle *	Lonicera japonica L.
Hophornbeam, eastern	Ostrya virginiana (Mill.) K. Koch
Hornbeam, American	Carpinus caroliniana Walt.
Huisache *	Acacia farnesiana (L.) Willd.
Locust, black	Robina pseudoacacia L.
Locust, honey	Gleditsia triacanthos L.
Maple, red	Acer rubrum L.
Maple, sugar	Acer saccharum Marsh.
Mesquite, honey *	Prosopis glandulosa Torr.
Mimosa	Albizia julibrissin Durazz.
Mulberry *	Morus sp
Mulberry, red	Morus rubra L.
Oak, black	Quercus velutina Lam.
Oak, bluejack	Quercus incana Bartr.
Oak, laurel	Quercus laurifolia Michx.
Oak, post	Quercus stellata Wang.
Oak, southern red	Quercus falcata Michx.
Oak, water	Quercus nigra L.
Oak, white	Quercus alba L.
Oak, willow	Quercus phellos L.
Osage-orange *	Maclura pomifera (Raf.) Schneid.
Persimmon, common	Diospyros virginiana L.
Pine, loblolly	Pinus taeda L.
Pine, shortleaf	Pinus echinata Mill.
Poison-ivy *	Toxicodendron radicans (L.) O. Ktze.

Poplar *	Populus sp
Redbud, eastern	Cercis canadensis L.
Rose, Macartney *	Rosa bracteata J.C. Wendl.
Rose, multiflora *	Rosa multiflora Thunb. ex Murr.
Sassafras	Sassafras albidum (Nutt.) Nees
Smilax *	Smilax sp
Sumac *	Rhus sp
Sumac, flameleaf	Rhus copallina L.
Sumac, smooth	Rhus glabra L.
Sweetgum	Liquidambar styraciflua L.
Sycamore, American	Platanus occidentalis L.
Trumpetcreeper *	Campsis radicans (L.) Seem. ex Bureau
Viburnum, rusty blackhaw	Viburnum rufidulum Raf.
Walnut, black	Juglans nigra L.
Waxmyrtle, southern	Myrica cerifera L.
Whitebrush, Texas *	Aloysia gratissima (Gilles & Hook.) Troncoso
Willow *	Salix sp
Yaupon	Ilex vomitoria Ait.

[1]Species or genera followed by * are named in the "Introduction", but they were not present in the sprayed areas.