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16. Abstract

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# MANAGEMENT OF VEGETATION ON THE PAVEMENT EDGE AND ADJACENT SHOULDER

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# IMPLEMENTATION STATEMENT

The responses of bermudagrass [Cynodon dactylon (L.)] along highway pavement edges near Bellville and Nacogdoches to several rates of Roundup and Arsenal herbicides were documented and compared. The most promising treatments should be repeated with the possibility of improving the presently recommended treatment of Roundup alone.

# 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 these materials by either the Texas Department of Transportation or Texas Transportation Institute (TTI), nor is it a recommendation over comparable products not named.

# ACKNOWLEDGMENT

Texas Department of Transportation personnel at Bellville and Pearlie Bushong and Tony Perez of the Yoakum District and personnel at Nacogdoches and Bill Basham in the Lufkin District kindly assisted in locating test sites and furnished highway safety signs. Herbicides were supplied by American Cyanamid Co., E. I. Du Pont de Nemours and Co., and Monsanto Agricultural Products Co. Steven L. Hatch and Barron S. Rector assisted with plant identification. The Texas Department of Transportation financed the study.

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# LIST OF ABBREVIATIONS AND SYMBOLS

| Abbreviation/Symbol | Item |
|---|---|
| ae | Acid equivalent |
| ai | Active ingredient |
| ft | Foot (feet) |
| FM | Farm to market road |
| g/ha | Gram(s) per hectare |
| gal | Gallon(s) |
| kPa | Kilopascal(s) |
| km | Kilometer(s) |
| L | Liter(s) |
| L/ha | Liter(s) per hectare |
| lb/gal | Pound(s) per gallon |
| m | Meter(s) |
| mi | Mile(s) |
| ml | Milliliter(s) |
| mm | Millimeter(s) |
| oz | Ounce |
| % | Percent |
| psi | Pounds per square inch |
| qt | Quart(s) |
| qt/A | Quart(s) per acre |
| US | US highway |
| WAT | Weeks after treatment |

# SUMMARY

Herbicides were applied to the pavement edge and adjoining shoulder on two-lane highways FM 331 near Bellville on June 6, 1991, and on FM 1087 near Nacogdoches, Texas, on June 3, 1991, to evaluate their influence on vegetation control. Herbicides used included Arsenal (imazapyr), Oust (sulfometuron methyl), Roundup (glyphosate), and Velpar (hexazinone).

Arsenal, Roundup, and Velpar effectively controlled roadside vegetation for 10 or 11 weeks, especially on the sandy loam site near Nacogdoches. All herbicide treatments at Nacogdoches produced 94% or more control compared with 75% control near Bellville. Thus, a lower herbicide rate would be required to produce equal vegetation control on a sandy soil than on loam or clay soil.

Plant injury at both sites, particularly on the clay soil near Bellville, tended to be slightly more pronounced on the pavement edge than on the shoulder probably because of higher temperature and increased water runoff from the pavement. Roundup, and sometimes Velpar, were more rapid acting than Arsenal on most species at both sites. However, by 5 or 6 weeks after spraying, all three herbicides were usually equally effective for controlling bermudagrass, bahiagrass, bitter sneezeweed, ground spurge, prairietea croton, prickly sida, sawtooth fogfruit, slender vervain, and yellow woodsorrel.

Plant species responded about equally to the different rates of the same herbicide (i.e., Arsenal at 4.7 and 7.0 L/ha (2 and 3 qt/A) or Roundup at 7.0 to 11.7 L/ha (3 to 5 qt/A). The mixture of Arsenal+Roundup generally injured vegetation about equally as well as Roundup at 2 or 3 weeks, but did not extend or increase the effectiveness of Arsenal alone. The addition of Oust at 280 g/ha (4 oz product/A) did not enhance the activity of Roundup at 7.0 L/ha (3 qt/A) alone.

Arsenal, as well as Roundup, has potential for use as a practical pavement edge treatment. However, Arsenal and Velpar may be injurious to forest hardwood species if applied close enough for root uptake. This problem would most likely occur along narrow highways in East Texas.

# MANAGEMENT OF VEGETATION ON THE PAVEMENT EDGE AND ADJACENT SHOULDER

## INTRODUCTION

The Texas Department of Transportation (TxDOT) has the responsibility for providing attractive and safe driving conditions, including vegetation management, on the highways of Texas. Various procedures are used to manage vegetation including mechanical methods such as mowing, chemical methods with the use of herbicides, and propagation methods including planting of grass and broadleaf species. Vegetation along highways is desirable to provide a pleasing appearance and to minimize erosion.

Several relatively new herbicides have been considered for vegetation management on highways. Arsenal (imazapyr) is a nonselective herbicide that may be used either preemergence or postemergence to weeds because of its extended soil residual activity (Thomson, 1986; Weed Sci. Soc. Amer., 1989). Arsenal has demonstrated excellent control of a wide variety of annual and perennial weeds, deciduous trees, vines, and brambles in noncrop situations (VanCantfort et al., 1985; VanWinkle et al., 1987; Weed Sci. Soc. Amer., 1989; Yeiser and Gardiner, 1990). It also has promise for pine (Pinus sp) release applications in forestry (Watkins et al., 1989). Treatments of Arsenal alone and in combination with Oust (sulfometuron methyl) controlled bermudagrass effectively (Cargill et al., 1989). Both the foliage and roots absorb Arsenal, and it may persist in the soil 3 to 12 months depending on dosage and rainfall.

Oust is an effective broad-spectrum herbicide with both soil and foliar activity on many annual and perennial grass and broadleaf weeds (Weed Sci. Soc. Amer., 1989). It is effective on johnsongrass [Sorghum halepense (L.) Pers.] but not on bermudagrass [Cynodon dactylon (L.) Pers.]. Oust is used along Texas highways in combination with Roundup for control of vegetation around guardrails, sign posts, and delineator posts, and also for control of johnsongrass (Anonymous, 1993). Oust alone has controlled weeds along roadsides allowing bermudagrass, where desirable, to provide low-growing

vegetative cover (Boyd, 1985). Oust plus either Arsenal or Velpar has controlled perennial weeds effectively, including bermudagrass, in plantings of loblolly pine (Gardiner and Yelser, 1991).

Roundup (glyphosate) is a widely-used, broad-spectrum herbicide useful for crop and non-crop weed control (Weed Sci. Soc. Amer., 1989). It enters the plant primarily through the foliage and has very little soil activity. Roundup is used alone on Texas highways for total vegetation control from March through October on paved shoulders and medians, pavement edges and curbs, and around fixtures (Anonymous, 1993). Roundup is also used to control tall johnsongrass and other tall grass and broadleaf weeds from May through October (Anonymous, 1993). Roundup also can be used to kill wild oats (Avena fatua L.) and jointed goat-grass [Triticum cylindricum (Host) Ces.] in late March (Anonymous, 1993). Roundup plus Oust also controls undesirable vegetation around fixtures year around and tall johnsongrass in June or July. A rainfree period of 4 hours is sufficient for maximum johnsongrass control with Roundup (Barrett and Olson, 1985). Roundup is usually used to control actively growing bermudagrass, but it also can be used to kill only winter weeds when the bermudagrass is dormant (Johnson and Ware, 1978). Roundup has also controlled bahiagrass (Johnson, 1990).

Velpar (hexazinone) controls many annual, biennial, and perennial grasses (except johnsongrass), and broadleaf plants and woody vines on noncropland areas (Weed Sci. Soc. Amer., 1989). Welch (1991) recommends Velpar for the control of some woody plants, including honey mesquite (Prosopis glandulosa Torr.) on rangeland. The Texas Department of Transportation recommends Velpar for control of vegetation on pavement edges and curbs and around guardrails, sign posts, and delineator posts in November and December at the rate of 15.1 L/378 L (4 gal/100 gal) of water. At the same rate, Velpar controls grass and broadleaf species at stock piles in March through October. Velpar is also recommended for control of brush species near bridges and fences in April through October at the rate of either 4 ml/25.4 mm (0.14 oz/inch) of stem diameter with a spotgun or 15.1 L/378 L (4 gal/100 gal) of water around the base of the plant (Anonymous, 1993; Transportation Res. Board, 1988). Velpar tends to move laterally

after abundant rainfall when applied on a steep slope. Because it leaches readily through the soil, Velpar cannot be used safely near desirable herbaceous or woody vegetation.

The aim of this study was to evaluate several herbicide treatments for the control of herbaceous vegetation growing on the pavement edge and on the adjacent shoulder on a clay site in the Blackland Prairies and on a sandy site in the Pineywoods Vegetation Resource Areas of Texas.

# THE PROBLEM

Vegetation growing along highways controls erosion, but it may be a problem if it encroaches onto paved surfaces. Some plants encroach onto the pavement. Vehicles normally neutralize vegetation on the traffic lanes. However, vegetation generally remains on the pavement edges and is unsightly.

Species, like johnsongrass, produce underground stems (rhizomes) that turn upward and produce shoots through the pavement. Other species, like bermudagrass, produce both rhizomes and runners (stolons) which grow across the surface of the pavement and root down in joints and cracks. Seed of many species germinate and produce plants in the joints and cracks. Any vegetation growing in the joints and through cracks allows infiltration of water under the pavement which will lead to pavement destruction by either swelling of the soil underneath or by expansion of ice upon freezing.

Normally, some vegetation is desirable on the shoulder next to the pavement. Low-growing vegetation, whether grass or broadleaf flowering plants, is more desirable than a tall, coarse species such as johnsongrass. Long-term soil sterilization is not desirable because erosion is likely to occur forming a drop-off that results in a driving hazard and by providing an opening for water to accumulate underneath the pavement.

# MATERIALS AND METHODS

Researchers selected sites with a dense stand of bermudagrass growing on the pavement edges and adjoining shoulders for this study. One site was located on a clay soil on FM 331 about 3.2 km (2 mi) north of the junction with FM 529, about 11 km (7 mi) southeast of Bellville, Texas, in the Yoakum District. A second site was chosen on a sandy loam soil on FM 1087 about 8 km (5 mi) east of the junction with US 259, about 24 km (15 mi) north of Nacogdoches, Texas, in the Lufkin District. Both sites were two-lane roads without paved shoulders.

Species frequent enough for evaluation near Bellville were bermudagrass, ground spurge (Euphorbia prostrata Ait.), prickly sida (Sida spinosa L.), and sawtooth fogfruit [Phyla nodiflora var. incisa (Small) Moldenke] (Hatch et al., 1990, Weed Sci. Soc. Amer., 1984). At Nacogdoches, the principal grasses were bahiagrass (Paspalum notatum Fluegge), bermudagrass, and southern crabgrass [Digitaria ciliaris (Retz.) Koel.]. The most frequent broadleaf species were bitter sneezeweed [Helenium amarum (Raf.) H. Rock], ground spurge, prairietea croton (Croton monanthogynus Michx.), prickly sida, and slender vervain (Verbena officinale L.).

At both sites, 27 plots 0.8 by 18.6 m (2.5 by 61 ft) were established for three groups (replications) of nine treatments. Two complete sets of treatments were established together on the west side of FM 331 and the north side of 1087 and one set on the other side of each road to minimize variation among plots. Plants near Bellville were exposed to full sunlight during daylight hours; whereas, plots near Nacogdoches were shaded more than half the daylight hours by nearby tall shortleaf pine (Pinus echinata Mill.) trees.

Herbicides used included: the isopropylamine salt of Arsenal (±)-2-[4,5-dihydro-4-methyl-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-3-pyridinecarboxylic acid containing 907 g/3.78 L (2 lb/gal) ae of imazapyr; Oust {2-[[[[(4,6-dimethyl-2-pyrimidinyl)amino]carbonyl]amino]sulfonyl]benzoic acid} containing 75% ai of sulfometuron methyl; the isopropylamine salt of Roundup containing 1361 g/3.78 L (3

lb/gal) ae of glyphosate; and Velpar [3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazaine-2,4-(1H,3H)-dione] containing 908 g/3.78 L (2 lb/gal) ai of hexazinone. Herbicide treatments included: Arsenal at 4.7 and 7.0 L/ha (2 and 3 qt/A), Arsenal+Roundup at 4.7+2.3 L/ha (2 qt+1 qt/A), Roundup at 7.0, 9.4, and 11.7 L/ha (3, 4, and 5 qt/A), Roundup at 7.0 L/ha+Oust at 280 g/ha (3 qt+4 oz product/A), and Velpar at 14.0 L/ha (6 qt/A). Untreated plots were also included. Sprays were applied in 1991 near Bellville on June 6 and near Nacogdoches on June 3.

A wheel-mounted sprayer with a two-nozzle boom applied herbicides to a swath 0.76 m (2.5 ft) wide. The spray solutions were applied at the rate of 234 L/ha (25 gal/A) with a compressed air system held at 207 kPa (30 psi). Spray was applied 305 mm (1 ft) on the pavement and 457 mm (1.5 ft) on the soil shoulder.

Vegetation response ratings were made 3, 5, and 11 weeks after treatment (WAT) near Bellville and 2, 6, and 10 WAT near Nacogdoches. The presence and response to herbicides by all species were recorded in 20 quadrats 152 by 610 mm (0.5 by 2 ft) in each plot. Ten random quadrats 152 by 305 mm (6 by 12 inches) were sampled each in the middle of the swath on the pavement edge and off the pavement on the shoulder. Plant injury ratings varied from 0% being no injury to 100% being death of the plant. Also, a single overall visual whole plot rating was made averaging the response of all vegetation in each plot at each rating date.

Analyses of variance were calculated for treatment and replication variation. The Duncan multiple range test separated means at the 5% level.

# RESULTS

## BELLVILLE

**Pavement Edge.** Whole plot ratings indicated Velpar and Roundup either alone or with Oust injured the vegetation 75 to 86% 3 weeks after treatment (WAT) (Table 1). Arsenal alone or in combination with 2.3 L/ha (1 qt/A) of Roundup was slower acting. Five weeks after spraying, all treatments with either Arsenal or Roundup caused 85 to 95% control; whereas, Velpar caused only 63% injury. By 11 WAT, vegetation had begun returning in all herbicide treatments.

Bermudagrass, a perennial, low-growing grass that produces both rhizomes and stolons, was the most common invader of the pavement edge near Bellville. Bermudagrass response was similar to that of the whole plot ratings at 3 and 5 WAT (Table 1). However, at 11 WAT, Arsenal at 7.0 L/ha (3 qt/A) and Arsenal+Roundup continued to control bermudagrass more effectively than the other treatments.

Ground spurge, a spreading, prostrate annual, was not present at time of spraying or 3 WAT. At 5 WAT plant response was highly variable with no significant differences among treatments (Table 2). By 11 WAT, however, ground spurge plants had become established in all treatments and showed no appreciable injury in all treatments. Ground spurge seemed particularly tolerant to Arsenal because plants were present in 17 to 21 of 30 possible quadrat samples compared with no more than 12 in any other treatment (data not presented).

Sawtooth fogfruit is a perennial, low-growing plant 76 to 127 mm (3 to 5 inches) tall with creeping, prostrate stems and is a common invader of pavement edges. At 3 WAT, it was controlled 58 to 85% by Arsenal or Roundup (Table 2). Velpar was less effective. At 5 WAT, most sawtooth fogfruit plants were either dead or severely injured in the Arsenal treatments. At 11 WAT, however, this perennial plant had begun to grow back onto the pavement edge in all treatments without showing much injury.

Table 1. Influence of nine treatments on the response of whole plot vegetation and bermudagrass applied to a roadside pavement edge near Bellville, Texas, on June 6, 1991, and rated 3, 5, and 11 weeks later.

| Treatment[1] | Rate[2] | Percent plant injury by time after treatment[3] | | | | | |
|---|---|---|---|---|---|---|---|
| | | Whole plot | | | Bermudagrass | | |
| | | 3 Wk | 5 Wk | 11 Wk | 3 Wk | 5 Wk | 11 Wk |
| | (Amt/ha) | ---------- (0% = No injury, 100% = Dead Plant) ---------- | | | | | |
| Arsenal | 4.7 L | 60 c | 92 a | 60 ab | 58 d | 91 a | 66 bc |
| Arsenal | 7.0 L | 62 c | 92 a | 72 ab | 61 d | 91 a | 87 a |
| Arsenal+ Roundup | 4.7+ 2.3 L | 70 bc | 95 a | 75 a | 68 c | 95 a | 82 a |
| Roundup | 7.0 L | 86 a | 85 a | 40 ab | 85 ab | 85 b | 49 d |
| Roundup | 9.4 L | 84 ab | 92 a | 67 ab | 87 a | 92 a | 67 b |
| Roundup | 11.7 L | 86 a | 89 a | 53 ab | 89 a | 91 a | 59 c |
| Roundup+ Oust | 7.0 L + 280 g | 82 ab | 86 a | 37 ab | 81 b | 83 b | 35 e |
| Velpar | 14.0 L | 75 abc | 63 b | 32 b | 71 c | 64 c | 33 e |
| Untreated | | 28 d | 20 c | 35 ab | 26 e | 20 d | 38 e |

[1]Herbicides include: Arsenal = imazapyr, Oust = sulfometuron methyl, Roundup = glyphosate, and Velpar = hexazinone.

[2]Metric-English conversions; 2.3, 4.7, 7.0, 9.4, 11.7, and 14.0 L/ha = 1, 2, 3, 4, 5, and 6 qt/A, respectively; 280 g/ha = 4 oz product/A.

[3]Values in columns followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

Table 2. Influence of nine treatments on the response of ground spurge and sawtooth fogfruit applied to a roadside pavement edge near Bellville, Texas, on June 6, 1991, and rated 3, 5, and 11 weeks later.

| Treatment[1] | Rate[2] | Percent plant injury by time after treatment[3] | | | | |
|---|---|---|---|---|---|---|
| | | Ground spurge[4] | | Sawtooth fogfruit | | |
| | | 5 Wk | 11 Wk | 3 Wk | 5 Wk | 11 Wk |
| | (Amt/ha) | --------- (0% = No injury, 100% = Dead Plant) --------- | | | | |
| Arsenal | 4.7 L | 2 a | 11 a | 85 a | --- | 20 a |
| Arsenal | 7.0 L | 21 a | 11 a | 70 b | 100 a | 10 b |
| Arsenal+ Roundup | 4.7+ 2.3 L | 7 a | 16 a | 64 b | 90 ab | 13 ab |
| Roundup | 7.0 L | 8 a | 12 a | 58 b | 46 c | 10 b |
| Roundup | 9.4 L | 34 a | 10 a | 66 b | 83 b | 12 b |
| Roundup | 11.7 L | 4 a | 11 a | 65 b | 76 b | 12 b |
| Roundup+ Oust | 7.0 L + 280 g | --- | 10 a | --- | --- | 10 b |
| Velpar | 14.0 L | --- | 10 a | 40 c | --- | 10 b |
| Untreated | | 0 a | 10 a | 22 d | 16 d | 11 b |

[1]Herbicides include: Arsenal = imazapyr, Oust = sulfometuron methyl, Roundup = glyphosate, and Velpar = hexazinone.

[2]Metric-English conversions; 2.3, 4.7, 7.0, 9.4, 11.7, and 14.0 L/ha = 1, 2, 3, 4, 5, and 6 qt/A, respectively; 280 g/ha = 4 oz product/A.

[3]Values in columns followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

[4]Not enough plants were present 3 weeks after treatment to evaluate herbicide responses.

The stand of prickly sida, an erect annual was variable, but it was injured to some degree by herbicides where present at 3 WAT (data not shown). By 11 WAT, small uninjured prickly sida plants 101 to 203 mm (4 to 8 inches) tall were present in all treatments.

**Shoulder.** Results of the shoulder whole plot ratings were similar to those of the pavement edge near Bellville (Table 3). Treatments with Roundup alone or Roundup+Oust were more effective, giving 68 to 80% control than those with Arsenal at 3 WAT. By 5 WAT, all treatments with Arsenal and 9.4 or 11.7 L/ha (4 or 5 qt/A) of Roundup were more effective than Velpar. Results at 11 WAT were highly variable as vegetative cover started to return, but the Arsenal treatments tended to be the most effective.

Bermudagrass was controlled most effectively at 82 to 83% 3 WAT by 9.4 or 11.7 L/ha (4 or 5 qt/A) of Roundup (Table 3). At 5 WAT, Arsenal at 7.0 L/ha (3 qt/A), Arsenal+Roundup, and Roundup at 9.4 or 11.7 L/ha (4 or 5 qt/A) caused 87 to 92% injury. At 11 WAT, Arsenal at 7.0 L/ha (3 qt/A) and Arsenal+Roundup were most effective, causing 77 to 78% injury.

Prickly sida showed various responses at 3 WAT (Table 4). Most plants had been killed by herbicide sprays, but some new ones had germinated within 3 WAT. By 5 WAT, the plants showed very little injury.

Very few ground spurge were present at either time of spraying or 3 WAT. Only about two quadrats out of 30 per treatment had at least one ground spurge (data not shown). None of the plants that developed during the test showed much injury (Table 4). At 11 WAT, however, 21 to 26 quadrats of the 30 evaluated had ground spurge in the three Arsenal treatments and in the three Roundup-alone treatments at 7.0 to 11.7 L/ha (3 to 5 qt/A); whereas, only 4, 4, and 12 quadrats had ground spurge in the untreated areas and treatments of Roundup+Oust or Velpar, respectively.

All herbicide treatments caused some injury to sawtooth fogfruit 3 WAT that continued through 5 WAT (Table 4). Only Arsenal killed at least the above-ground tissue of all the plants at 4.7 and 7.0 L/ha (2 and 3 qt/A) rates 5 WAT. After 11 WAT, a few

Table 3. Influence of nine treatments on the response of whole plot vegetation and bermudagrass applied to a roadside shoulder near Bellville, Texas, on June 6, 1991, and rated 3, 5, and 11 weeks later.

| Treatment[1] | Rate[2] | Percent plant injury by time after treatment[3] | | | | | |
|---|---|---|---|---|---|---|---|
| | | Whole plot | | | Bermudagrass | | |
| | | 3 Wk | 5 Wk | 11 Wk | 3 Wk | 5 Wk | 11 Wk |
| | (Amt/ha) | ---------- (0% = No injury, 100% = Dead Plant) ---------- | | | | | |
| Arsenal | 4.7 L | 45 c | 87 ab | 50 a | 43 d | 85 b | 62 b |
| Arsenal | 7.0 L | 47 c | 87 ab | 60 a | 45 d | 87 ab | 77 a |
| Arsenal+ Roundup | 4.7+ 2.3 L | 60 bc | 92 a | 57 a | 58 c | 92 a | 78 a |
| Roundup | 7.0 L | 78 a | 70 bc | 33 a | 75 b | 72 c | 47 c |
| Roundup | 9.4 L | 77 ab | 90 a | 43 a | 82 a | 90 ab | 60 b |
| Roundup | 11.7 L | 80 a | 89 a | 43 a | 83 a | 87 ab | 54 bc |
| Roundup+ Oust | 7.0 L+ 280 g | 68 ab | 78 ab | 23 a | 64 c | 77 c | 25 d |
| Velpar | 14.0 L | 67 ab | 58 c | 19 a | 64 c | 57 d | 22 d |
| Untreated | | 15 d | 13 d | 22 a | 9 e | 11 e | 27 d |

[1]Herbicides include: Arsenal = imazapyr, Oust = sulfometuron methyl, Roundup = glyphosate, and Velpar = hexazinone.

[2]Metric-English conversions; 2.3, 4.7, 7.0, 9.4, 11.7, and 14.0 L/ha = 1, 2, 3, 4, 5, and 6 qt/A, respectively; 280 g/ha = 4 oz product/A.

[3]Values in columns followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

Table 4. Influence of nine treatments on the response of prickly sida, ground spurge, and sawtooth fogfruit applied to a roadside shoulder near Bellville, Texas, on June 6, 1991, and rated 3, 5, and 11 weeks later.

| Treatment[1] | Rate[2] | Percent plant injury by time after treatment[3] | | | | | |
|---|---|---|---|---|---|---|---|
| | | Prickly sida[4] | | Ground spurge[5] | | Sawtooth fogfruit[4] | |
| | | 3 Wk | 5 Wk | 5 Wk | 11 Wk | 3 Wk | 5 Wk |
| | (Amt/ha) | ---------- (0% = No injury, 100% = Dead Plant) ---------- | | | | | |
| Arsenal | 4.7 L | 46 b | 3 ab | 4 abc | 12 a | 72 a | 100 a |
| Arsenal | 7.0 L | 10 d | 0 b | 6 ab | 10 a | 70 a | 100 a |
| Arsenal+ Roundup | 4.7+ 2.3 L | 60 a | 3 ab | 3 abc | 11 a | 66 ab | 92 a |
| Roundup | 7.0 L | 23 c | 8 ab | 8 a | 7 b | 60 abc | 70 b |
| Roundup | 9.4 L | 13 cd | 5 ab | 3 bc | 11 a | 63 ab | 77 b |
| Roundup | 11.7 L | 42 b | 6 ab | 7 ab | 12 a | 60 abc | 71 b |
| Roundup+ Oust | 7.0 L +280 g | --- | 10 a | --- | 10 a | 52 bc | 48 c |
| Velpar | 14.0 L | 45 b | --- | --- | 10 a | 45 c | 20 d |
| Untreated | | 4 d | 4 ab | 1 c | 10 a | 23 d | 4 e |

[1]Herbicides include: Arsenal = imazapyr, Oust = sulfometuron methyl, Roundup = glyphosate, and Velpar = hexazinone.

[2]Metric-English conversions; 2.3, 4.7, 7.0, 9.4, 11.7, and 14.0 L/ha = 1, 2, 3, 4, 5, and 6 qt/A, respectively; 280 g/ha = 4 oz product/A.

[3]Values in columns followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

[4]No treatments were significantly different from the untreated plots 11 weeks after treatment.

[5]Not enough plants were present to rate 3 weeks after treatment to evaluate herbicide responses.

surviving plants out-grew the injury (data not presented). Only one plant was present with 10% injury at 11 WAT in each of the treatments with 4.7 L/ha (2 qt/A) of Arsenal.

## NACOGDOCHES

**Pavement Edge.** In whole plot ratings, all treatments with Roundup and Velpar caused more plant injury (84 to 100%) 2 WAT than the two treatments of Arsenal alone (65 to 67%) (Table 5). At 6 and 10 WAT, 95 to 100% of the vegetation was killed in all herbicide treatments. All the grasses present including bahiagrass, bermudagrass, and southern crabgrass responded similarly to the whole plot ratings (Table 5). Bahiagrass is a coarse, sod-forming perennial Paspalum. Southern crabgrass is a tufted annual often with creeping stems that root at the lower nodes.

Of the broadleaf species on the pavement edge 2 WAT, Arsenal alone was slightly less effective than Roundup for controlling bitter sneezeweed, prairietea croton, and at 4.7 L/ha (2 qt/A) yellow woodsorrel (Table 6). All herbicides essentially killed all ground spurge and prickly sida. Very few living broadleaf plants listed above were present 6 and 10 WAT.

**Shoulder.** Whole plot ratings showed 95 to 99% dead plant tissue 2 WAT with Roundup alone or Velpar (Table 7). The three Arsenal treatments were less effective. By 6 and 10 WAT, all herbicide treatments had caused 93 to 100% plant control.

At 2 WAT, bahiagrass and bermudagrass control followed the same pattern as the whole plot data, except that the Arsenal treatments tended to show slightly less injury than the whole plot ratings (Table 7). At 6 WAT, Roundup had killed most of the bahiagrass plants; the injured remaining few plants had grown back by 10 WAT. Arsenal caused severe bahiagrass injury at both 6 and 10 WAT. All herbicide treatments had killed most bermudagrass by 6 and 10 WAT.

Roundup killed southern crabgrass 2 WAT; whereas, Arsenal was less effective (Table 7). At 6 WAT, however, more southern crabgrass had become established in plots treated with Roundup alone; whereas, Arsenal and Velpar killed all

Table 5. Influence of nine treatments on the response of whole plot vegetation, bahiagrass, bermudagrass, and southern crabgrass applied to a roadside pavement edge near Nacogdoches, Texas, on June 3, 1991, and rated 2, 6, and 10 weeks later.

| Treatment[1] | Rate[2] | Percent plant injury by time after applications[3] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Whole plot | | | Bahiagrass[4] | | Bermudagrass | | | Southern crabgrass[4] | |
| | | 2 Wk | 6 Wk | 10 Wk | 2 Wk | 6 Wk | 2 Wk | 6 Wk | 10 Wk | 2 Wk | 6 Wk |
| | (Amt/ha) | ----------(0% = No Effect, 100% = Dead plant)---------- | | | | | | | | | |
| Arsenal | 4.7 L | 65 b | 97 b | 99 a | 58 c | 82 b | 49 c | 94 ab | 100 a | 59 c | 99 a |
| Arsenal | 7.0 L | 67 b | 97 b | 99 a | 56 c | 88 b | 61 bc | 90 b | 100 a | 77 b | 100 a |
| Arsenal+ Roundup | 4.7+ 2.3 L | 84 ab | 99 a | 95 a | 76 b | 97 a | 69 b | 100 a | 97 a | 100 a | 100 a |
| Roundup | 7.0 L | 96 a | 100 a | 99 a | 100 a | 100 a | 97 a | 100 a | 100 a | 100 a | 100 a |
| Roundup | 9.4 L | 100 a | 100 a | 98 a | 100 a | 100 a | 100 a | 100 a | 100 a | 100 a | 92 a |
| Roundup | 11.7 L | 98 a | 100 a | 98 a | 94 a | 100 a | 100 a | 99 a | 100 a | 100 a | 74 b |
| Roundup+ Oust | 7.0 L+ 280 g | 93 a | 100 a | 100 a | 79 b | 100 a | 97 a | 99 a | 100 a | 100 a | 100 a |
| Velpar | 14.0 L | 86 ab | 99 a | 99 a | 78 b | 96 a | 98 a | 100 a | 100 a | 100 a | 100 a |
| Untreated | | 12 c | 18 c | 18 b | 7 d | 17 c | 14 d | 19 c | 28 b | 3 d | 14 c |

[1]Herbicides include: Arsenal = imazapyr, Oust = sulfometuron methyl, Roundup = glyphosate, and Velpar = hexazinone.
[2]Metric-English conversions: 2.3, 4.7, 7.0, 9.4, 11.7, and 14.0 L/ha = 1, 2, 3, 4, 5, and 6 qt/A, respectively; 280 g/ha = 4 oz product/A.
[3]Values in columns followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.
[4]Not enough plants were present 10 weeks after treatment to evaluate herbicide responses.

Table 6. Influence of nine treatments on the response of bitter sneezeweed, ground spurge, prairietea croton, prickly sida, and yellow woodsorrel applied to a roadside pavement edge near Nacogdoches, Texas, on June 3, 1991, and rated 2, 6, and 10 weeks later.

| Treatment[1] | Rate[2] | Percent plant injury bytime after applications[3] | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Bitter sneezeweed[4] | | Ground spurge | | | Prairietea croton[4] | | Prickly sida[4] | | Yellow woodsorrel[4] | |
| | | 2 Wk | 6 Wk | 2 Wk | 6 Wk | 10 Wk | 2 Wk | 6 Wk | 2 Wk | 6 Wk | 2 Wk | 6 Wk |
| | (Amt/ha) | (0% = No Effect, 100% = Dead plant) | | | | | | | | | | |
| Arsenal | 4.7 L | 62 b | 100 a | 100 a | 97 a | 51 a | 91 ab | 94 a | 96 a | 96 a | 42 b | 94 a |
| Arsenal | 7.0 L | 35 c | 100 a | 100 a | 100 a | --- | 82 b | 99 a | 100 a | 100 a | 100 a | 100 a |
| Arsenal + Roundup | 4.7 + 2.3 L | --- | --- | 100 a | 100 a | 10 a | 100 a | 100 a | 100 a | 100 a | 100 a | 100 a |
| Roundup | 7.0 L | 100 a | 100 a | 100 a | 100 a | --- | 100 a | 100 a | 100 a | 100 a | 100 a | 100 a |
| Roundup | 9.4 L | 100 a | 100 a | 100 a | 100 a | 74 a | 100 a | 100 a | 100 a | 100 a | 100 a | 100 a |
| Roundup | 11.7 L | 100 a | 100 a | 100 a | 100 a | 55 a | 100 a | 100 a | 100 a | 100 a | 100 a | 100 a |
| Roundup + Oust | 7.0 L + 280 g | 100 a | 100 a | 100 a | 100 a | --- | 100 a | 100 a | 100 a | 100 a | 100 a | 100 a |
| Velpar | 14.0 L | 100 a | 100 a | 100 a | 100 a | --- | 100 a | 100 a | 100 a | 100 a | 100 a | 100 a |
| Untreated | | 0 d | 10 b | 0 b | 10 b | 10 a | 8 c | 18 b | 0 b | 12 b | 0 c | 20 b |

[1]Herbicides include: Arsenal = imazapyr, Oust = sulfometuron methyl, Roundup = glyphosate, and Velpar = hexazinone.
[2]Metric-English conversions: 2.3, 4.7, 7.0, 9.4, 11.7, and 14.0 L/ha = 1, 2, 3, 4, 5, and 6 qt/A, respectively; 280 g/ha = 4 oz product/A.
[3]Values in columns followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.
[4]Not enough plants were present 10 weeks after treatment to evaluate herbicide responses.

Table 7. Influence of nine treatments on the response of whole plot vegetation, bahiagrass, bermudagrass, and southern crabgrass applied to a roadside shoulder near Nacogdoches, Texas, on June 3, 1991, and rated 2, 6, and 10 weeks later.

| Treatment[1] | Rate[2] | Percent plant injury by time after application[3] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Whole plot | | | Bahiagrass | | | Bermudagrass | | | Southern crabgrass | | |
| | | 2 Wk | 6 Wk | 10 Wk | 2 Wk | 6 Wk | 10 Wk | 2 Wk | 6 Wk | 10 Wk | 2 Wk | 6 Wk | 10 Wk |
| | (Amt/ha) | (0% = No effect, 100% = Dead plant) | | | | | | | | | | | |
| Arsenal | 4.7 L | 72 c | 96 ab | 96 a | 58 c | 86 bc | 83 a | 48 c | 98 a | 89 a | 69 c | 100 a | 12 b |
| Arsenal | 7.0 L | 65 c | 93 b | 99 a | 56 c | 84 c | 90 a | 54 c | 87 b | 100 a | 83 b | 100 a | 10 b |
| Arsenal+ Roundup | 4.7+ 2.3 L | 88 b | 99 a | 96 a | 74 b | 94 ab | 70 a | 81 b | 100 a | 100 a | 100 a | 100 a | 13 b |
| Roundup | 7.0 L | 98 a | 98 a | 97 a | 99 a | 99 a | 15 b | 99 a | 100 a | 95 a | 100 a | 60 ab | 13 b |
| Roundup | 9.4 L | 99 a | 97 ab | 94 a | 97 a | 94 ab | --- | 100 a | 100 a | 100 a | --- | 57 ab | 14 b |
| Roundup | 11.7 L | 99 a | 99 a | 99 a | 93 a | 100 a | 10 b | 100 a | 100 a | 100 a | 100 a | 42 b | 25 ab |
| Roundup +Oust | 7.0 L+ 280 g | 95 ab | 100 a | 99 a | 92 a | 99 a | --- | 98 a | 99 a | 97 a | 100 a | 100 a | 30 a |
| Velpar | 14.0 L | 95 ab | 96 ab | 99 a | 78 b | 92 abc | 10 b | 91 ab | 98 a | 96 a | --- | 100 a | 15 b |
| Untreated | | 5 d | 15 c | 13 b | 5 d | 13 d | 8 d | 12 d | 13 c | 24 b | 3 d | 16 b | 11 b |

[1]Herbicides include: Arsenal = imazapyr, Oust = sulfometuron methyl, Roundup = glyphosate, and Velpar = hexazinone.
[2]Metric-English conversions: 2.3, 4.7, 7.0, 9.4, 11.7, and 14.0 L/ha = 1, 2, 3, 4, 5, and 6 qt/A, respectively; 280 g/ha = 4 oz product/A.
[3]Values in columns followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

existing southern crabgrass. At 10 WAT, some southern crabgrass had germinated and formed small plants in all plots.

Broadleaf plants on the shoulder varied slightly in their response to herbicides (Tables 8 and 9). Bitter sneezeweed, prairietea croton, slender vervain, and yellow woodsorrel were generally killed within 2 WAT by 7.0 to 11.7 L/ha (3 to 5 qt/A) of Roundup; whereas, Arsenal alone was less rapid acting. Almost all plants of these species, however, were killed by all herbicide treatments 6 WAT. All ground spurge plants present at spraying were killed by all herbicide treatments 2 WAT (Table 8); however, new seedlings appeared 6 WAT in plots treated with Roundup alone and in all treatments 10 WAT. Almost all prickly sida plants were killed by all treatments 2 WAT (Table 9), and only a few were present 10 WAT.

Table 8. Influence of nine treatments on the response of bitter sneezeweed, ground spurge, and prairietea croton applied to a roadside shoulder near Nacogdoches, Texas, on June 3, 1991, and rated 2, 6, and 10 weeks later.

| Treatment[1] | Rate[2] | Percent plant injury by time after treatment[3] | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Bitter sneezeweed[4] | | Ground spurge | | | Prairietea croton[4] | |
| | | 2 Wk | 6 Wk | 2 Wk | 6 Wk | 10 Wk | 2 Wk | 6 Wk |
| | (Amt/ha) | --------- (0% = No injury, 100% = Dead Plant) --------- | | | | | | |
| Arsenal | 4.7 L | 88 b | 100 a | 100 a | --- | 11 b | 74 b | 96 ab |
| Arsenal | 7.0 L | 46 c | 98 a | 100 a | --- | 32 ab | 74 b | 90 b |
| Arsenal+ Roundup | 4.7+ 2.3 L | 100 a | 100 a | 100 a | 100 a | 13 b | 96 a | 99 a |
| Roundup | 7.0 L | 100 a | 100 a | --- | 12 b | 25 ab | 100 a | 100 a |
| Roundup | 9.4 L | 100 a | 100 a | 100 a | 10 b | 33 ab | 100 a | 100 a |
| Roundup | 11.7 L | 100 a | 100 a | 100 a | 10 b | 34 ab | 100 a | 96 ab |
| Roundup+ Oust | 7.0 L +280 g | 100 a | 100 a | 100 a | 100 a | 28 ab | 100 a | 99 a |
| Velpar | 14.0 L | 100 a | 100 a | 100 a | 100 a | 55 a | 100 a | 96 ab |
| Untreated | | 0 d | 12 b | 0 b | 10 b | 9 b | 4 c | 16 c |

[1]Herbicides include: Arsenal = imazapyr, Oust = sulfometuron methyl, Roundup = glyphosate, and Velpar = hexazinone.

[2]Metric-English conversions; 2.3, 4.7, 7.0, 9.4, 11.7, and 14.0 L/ha = 1, 2, 3, 4, 5, and 6 qt/A, respectively; 280 g/ha = 4 oz product/A.

[3]Values in columns followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

[4]Not enough plants were present 10 weeks after treatment to evaluate herbicide responses.

Table 9. Influence of nine treatments on the response of prickly sida, slender vervain, and yellow woodsorrel applied to a roadside shoulder near Nacogdoches, Texas, on June 3, 1991, and rated 2, 6, and 10 weeks later.

| Treatment[1] | Rate[2] | Percent plant injury by time after treatment[3] | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Prickly sida[4] | | Slender vervain | | | Yellow woodsorrel[4] | |
| | | 2 Wk | 6 Wk | 2 Wk | 6 Wk | 10 Wk | 2 Wk | 6 Wk |
| | (Amt/ha) | --------- (0% = No injury, 100% = Dead Plant) ---------- | | | | | | |
| Arsenal | 4.7 L | 95 ab | 99 a | 52 b | 90 ab | 60 a | 55 b | 83 b |
| Arsenal | 7.0 L | 92 b | 100 a | 46 b | 100 a | 90 a | 47 b | 95 a |
| Arsenal+ Roundup | 4.7+ 2.3 L | 100 a | 100 a | 56 b | 84 b | 83 a | 100 a | 100 a |
| Roundup | 7.0 L | 100 a | 94 a | 85 a | 100 a | --- | 100 a | 100 a |
| Roundup | 9.4 L | 100 a | 79 b | --- | --- | --- | 100 a | 100 a |
| Roundup | 11.7 L | 100 a | 96 a | 92 a | 100 a | --- | 100 a | 100 a |
| Roundup+ Oust | 7.0 L +280 g | 100 a | 100 a | 85 a | 100 a | 90 a | 100 a | 100 a |
| Velpar | 14.0 L | 100 a | 100 a | 100 a | 100 a | --- | 100 a | 100 a |
| Untreated | | 2 c | 12 c | 12 c | 9 c | 10 b | 4 c | 10 c |

[1]Herbicides include: Arsenal = imazapyr, Oust = sulfometuron methyl, Roundup = glyphosate, and Velpar = hexazinone.

[2]Metric-English conversions; 2.3, 4.7, 7.0, 9.4, 11.7, and 14.0 L/ha = 1, 2, 3, 4, 5, and 6 qt/A, respectively; 280 g/ha = 4 oz product/A.

[3]Values in columns followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

[4]Not enough plants were present 10 weeks after treatment to evaluate herbicide responses.

# DISCUSSION

Vegetation at the two sites reacted differently to herbicides. Control generally occurred sooner and lasted longer on the Nacogdoches sandy loam site than on the clay site near Bellville. All treatments at Nacogdoches produced 94% or more control 10 WAT, at the end of the experiment, compared with 75% or less near Bellville. Both sites were rated about 17 WAT, and the vegetation control was similar to that at 10 or 11 WAT (data not presented). Thus, vegetation control was more effective near Nacogdoches than Bellville. However, fall germination of wild flowers, if desired, would more likely be successful near Bellville.

Plant injury at both sites, especially near Bellville, tended to be slightly more pronounced on the pavement edge than on the shoulder. There is a high probability that both higher temperature and more water runoff caused the increased control.

Roundup, and sometimes Velpar, was more rapid acting than Arsenal on most species at both sites. However, by 5 or 6 WAT, all herbicides were usually equally effective. Meaningful response ratings were often difficult to make 10 or 11 WAT because many of the plants had died, broken off, and left the plot area.

Vegetation responses to various rates of the same herbicide [Arsenal at 4.7 and 7.0 L/ha (2 and 3 qt/A) or Roundup at 7.0 to 11.7 L/ha (3 to 5 qt/A)] were generally similar. The mixture of Arsenal+Roundup usually injured vegetation equally well as Roundup alone at the first rating but did not provide superior control over Arsenal alone 10 or 11 WAT. The addition of Oust at 280 g/ha (4 oz/A) did not alter the effectiveness of Roundup alone at 7.0 L/ha (3 qt/A).

For individual species, bermudagrass was present on both the pavement edge and shoulder at both sites. Roundup and Velpar provided more effective control than Arsenal 2 WAT at both sites. By 5 or 6 WAT, however, all herbicides were about equally effective near Nacogdoches, but Velpar was less effective near Bellville. At 11 WAT, bermudagrass began reinvading all treatment areas at Bellville, but Arsenal allowed the least recovery.

Bahiagrass was present only at Nacogdoches, and it was controlled by Arsenal, Roundup, and Velpar through 6 WAT on both the pavement edge and shoulder. Some bahiagrass started coming back at 10 WAT in the Roundup plots.

Sufficient numbers of southern crabgrass to rate occurred only at Nacogdoches. Roundup killed the plants more rapidly than Arsenal. By 10 WAT, southern crabgrass had germinated and become established in all treatments on the shoulder, but not on the pavement edge.

Ground spurge occurred at both sites but did not occur at spraying or 3 WAT near Bellville. All treatments killed it at Nacogdoches 2 WAT. At 5 or 6 WAT, ground spurge at Nacogdoches was controlled by all treatments on the pavement edge and by Arsenal, Roundup+Oust, and Velpar on the shoulder, but it had begun germinating and becoming established on both the pavement edge and shoulder near Bellville. Ground spurge, however, was present at both sites 10 or 11 WAT showing little injury near Bellville and only moderate injury near Nacogdoches. Ground spurge was present in greater numbers in Arsenal plots than in plots treated with either Roundup or Velpar 10 or 11 WAT.

Prickly sida occurred on the shoulder at both sites, but only on the pavement edge at Nacogdoches. It was almost completely controlled on both the pavement edge and shoulder by all herbicide treatments near Nacogdoches 2 and 6 WAT, whereas plants showed almost no injury near Bellville by 5 WAT.

Sawtooth fogfruit occurred only near Bellville and was not readily killed. All herbicide treatments caused some injury 2 WAT on both the pavement edge and shoulder. Arsenal killed most plants by 5 WAT. However, the species recovered rapidly and occurred in stands similar to the untreated plots of both the pavement edge and shoulder 11 WAT.

Bitter sneezeweed occurred only near Nacogdoches on both the pavement edge and shoulder. Arsenal was slower acting on both roadside areas than the other herbicides 2 WAT. By 6 WAT though, all herbicide treatments had killed the bitter sneezeweed. Very few seedlings occurred at 10 WAT.

Prairietea croton occurred only on the shoulder near Nacogdoches and was readily killed by Roundup and Velpar within 2 WAT and by Arsenal at 6 weeks. Very few seedlings were present 10 WAT.

Slender vervain occurred only on the shoulder near Nacogdoches. It was killed at 2 WAT by Velpar and severely injured by Roundup. Arsenal, Roundup, and Velpar killed all or most plants 6 WAT and maintained control through 10 weeks.

Yellow woodsorrel occurred only near Nacogdoches on both the pavement edge and shoulder. Roundup and Velpar killed all plants at both roadside positions within 2 weeks. Arsenal killed almost all plants by 6 WAT.

Thus, Arsenal, Roundup, and Velpar were effective for controlling roadside vegetation in this study, especially near Nacogdoches. The addition of Oust to Roundup showed little advantage at either site. Arsenal should be investigated further for recommended use on pavement edges. However, both Arsenal and Velpar should be evaluated for possible injury to desirable herbaceous and woody vegetation growing adjacent to the right-of-way.

# REFERENCES


Anonymous. 1993. Roadside Vegetation Management Manual 93-1. Texas Dep. of Transportation. Austin, Tex.

Barrett, M., and G.L. Olson. 1985. Critical rainfree periods for postemergence johnsongrass control. Proc. South. Weed Sci. Soc. 38:453. (Abstract).

Boyd, J.W. 1985. Bermudagrass release on roadsides. Proc. South. Weed Sci. Soc. 38:358. (Abstract).

Cargill, L.M., M.P. Kenna, and D.P. Montgomery. 1989. Herbicide control of bermudagrass roadside encroachment. Proc. South. Weed Sci. Soc. 42:252. (Abstract).

Gardiner, E.S., and J.L. Yelser. 1991. Control of perennial weeds with sulfometuron plus imazapyr and hexazinone on old field plantings of loblolly pine. Proc. South. Weed Sci. Soc. 44:244-248.

Hatch, S.L., K.N. Gandhi, and L.E. Brown. 1990. Checklist of the vascular plants of Texas. Tex. Agric. Exp. Stn. Misc. Pub. 1655. 158 pp.

Johnson, B.J. 1990. Response of bahiagrass (Paspalum notatum) to plant growth regulators. Weed Technol. 4:895-899.

Johnson, B.J., and G.O. Ware., 1978. Dates of glyphosate treatments on weeds and bermudagrass (Cynodon dactylon). Weed Sci. 26:523-526.

Thomson, W.T. 1986. Agricultural Chemicals-Book II, Herbicides. Thomson Publ., Fresno, Cal. 301 pp.

Transportation Research Board. 1988. Use of herbicides in roadside maintenance. Prepared by W.D. Johnson, Chairman, Roadside Maintenance Comm. Trans Res. Circ. 342. 27 pp.

VanCantfort, A.M., J.C. Rabby, A.R. Hegman, and J.C. Dunn. 1985 Arsenal® herbicide update: new species controlled, forestry and grass release. Proc. South. Weed Sci. Soc. 38:356. (Abstract).

VanWinkle, D., J.D. Baum, J.B. Dobson, S. Hall, K. Muzyk, J.B. O'Neil, and F.R. Walls. 1987. Arsenal® herbicide 1985 forestry EUP results in southeastern United States. Proc. South. Weed Sci. Soc. 40:175. (Abstract).

Watkins, R.M., R.A. Beardmore, and M.H. Johnson. 1989. Arsenal applicators concentrate for loblolly pine release: three-year results of rates and timings on hardwood control and pine growth. Proc. South. Weed Sci. Soc. 42:225. (Abstract).

Weed Science Society of America. 1984. Composite list of weeds. Weed Sci. 323:1-137 (Suppl. 2). Prepared by D.T. Patterson, Chairman. Weed Sci. Soc. Amer., Champaign, IL.

Weed Science Society of America. 1989. Herbicide Handbook of the Weed Sci. Soc. Amer. (6th ed.). Prepared by N.E. Humburg, Chairman, Weed Sci. Soc. Amer., Champaign, IL. 301 pp.

Welch, T.G. 1991. Chemical weed and brush control suggestions for rangeland. Tex. Agr. Ext. Serv. Bul. 1466. 20 pp.

Yeiser, J.L. and E.S. Gardiner. 1990. Applying imazapyr at 5, 10, or 15 gallons of mixture per acre. Proc. South. Weed Sci. Soc. 43:251. (Abstract).