ROADSIDE VEGETATION MANAGEMENT

FINAL REPORT

for the Period
December 1991 to September 1996

by

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16. ABSTRACT

The information contained within this report addresses: (1) Research -- involving the use of experimental, newly labeled and traditionally available herbicides in combination with mowing for roadside vegetation management; (2) Maintenance -- implementation of research results into an operational phase of the Oklahoma Department of Transportation's (ODOT) maintenance program, as well as performing on-site visits, telephone and written consultation to ODOT personnel; and (3) Training -- conducting pesticide applicator certification programs, and providing continuing education programs for these certified applicators.

The following are conclusions based on our research: (1) Campaign herbicide or Roundup plus 2,4-D may be used post-emergence in place of atrazine or diuron applied pre-emergence for the control of winter annual grasses and broadleaf weeds. Timing of herbicide application is critical. (2) Ammonium sulfate may be added to either Campaign herbicide or the combination treatment of Roundup + 2,4-D amine to improve control of winter annual weeds. This product addition may allow end users to reduce use rates of these herbicides. (3) Primo plus Oust may be used for temporary growth and seedhead suppression of common bermudagrass on roadsides; additional product labeling will be required to implement this treatment into the maintenance phase of ODOT's vegetation management program. (4) The product Plateau, when combined with Roundup, will provide an acceptable level of both seedling and rhizome johnsongrass control (minimum of 80% control) in common bermudagrass roadsides with potential to reduce phytotoxicity as compared to the traditional Oust plus Roundup herbicide treatment.

Several research plot tours, meetings, sprayer calibration workshops, musk thistle head weevil collection/release days as well as herbicide/fertilizer demonstrations were conducted throughout the duration of this project in order to implement current research information into an operational phase of ODOT's roadside vegetation management program.

Training achievements included the execution of 12 pesticide applicator certification schools resulting in 146 new herbicide applicators becoming certified. A total of 68 continuing education programs were conducted with 2,795 ODOT certified applicators attending over a 5 year period. Numerous training information sheets were developed and provided to applicators during workshops.

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DISCLAIMER

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Oklahoma Department of Transportation and the Federal Highway Administration.

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As pesticide labels change frequently, it is inevitable that the legality of using a certain pesticide on a site and the legal use rates of pesticides will change over time. Therefore, it is the responsibility of the end user to read and follow all pesticide label directions. The Oklahoma Department of Transportation, the Federal Highway Administration, the Oklahoma State University, the Oklahoma Cooperative Extension Service, the Dept. of Horticulture and Landscape Architecture and the Authors will not assume liability for any pesticide purchase, transportation, storage or use decisions made by any individuals or entities referencing this document.

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SI (METRIC) CONVERSION FACTORS

Approximate Conversions to SI Units

Symbol	When you know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	25.40	millimeters	mm
ft	feet	0.3048	meters	m
yd	yards	0.9144	meters	m
mi	miles	1.609	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm
ft^2	square feet	0.0929	square meters	m^2
yd^2	square yards	0.8361	square meters	m^2
ac	acres	0.4047	hectares	ha
mi^2	square miles	2.590	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.0283	cubic meters	m^3
yd^3	cubic yards	0.7645	cubic meters	m^3
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.4536	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
ºF	degrees Fahrenheit	(ºF-32)/1.8	degrees Celsius	ºC
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.448	Newtons	N
lbf/in^2	poundforce per square inch	6.895	kilopascals	kPa

Approximate Conversions from SI Units

Symbol	When you know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.0394	inches	in
m	meters	3.281	feet	ft
m	meters	1.094	yards	yd
km	kilometers	0.6214	miles	mi
		AREA		
mm^2	square millimeters	0.00155	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.196	square yards	yd^2
ha	hectares	2.471	acres	ac
km^2	square kilometers	0.3861	square miles	mi^2
		VOLUME		
mL	milliliters	0.0338	fluid ounces	fl oz
L	liters	0.2642	gallons	gal
m^3	cubic meters	35.315	cubic feet	ft^3
m^3	cubic meters	1.308	cubic yards	yd^3
		MASS		
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.1023	short tons (2000 lb)	T
		TEMPERATURE (exact)		
ºC	degrees Celsius	9/5+32	degrees Fahrenheit	ºF
		FORCE and PRESSURE or STRESS		
N	Newtons	0.2248	poundforce	lbf
kPa	kilopascals	0.1450	poundforce per square inch	lbf/in^2

Oklahoma Project No. AG-91-EX-037

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EXECUTIVE SUMMARY OF THE FINAL REPORT CONCERNING ROADSIDE VEGETATION MANAGEMENT

In 1991, a "Roadside Vegetation Management" project was initiated as a cooperative agreement between Oklahoma State University and the Oklahoma Department of Transportation (ODOT). The objectives of this project were to optimize the expenditure of maintenance resources and enhance the environment by investigations or education in the following three areas:

(1) Research -- initiate research involving the use of herbicides and plant growth regulators for the most effective and economical means of managing roadside vegetation;

(2) Maintenance -- implement research results into an operation phase of ODOT's maintenance program by initiating large-scale demonstration areas and attend statewide meetings of concern to ODOT roadside interests; and

(3) Training -- conduct pesticide applicator certification programs and provide continuing educational programs for certified applicators.

The results of each of the three subject matter areas are summarized below:

1. **RESEARCH**

a. Campaign herbicide may be used post-emergence in place of a pre-emergent application of atrazine or diuron for the control of winter annual grasses and broadleaf weeds. Campaign should be applied postemergence to actively growing weeds at 1.2 to 2.4 ℓ of product ha^{-1} in 144 to 288 ℓ of water ha^{-1} (2.0 to 4.0 pints of product per acre in 15 to 30 gallons of water per acre). Use the lower rate where treating annual weeds below 15.2 cm (6 inches) in height. Use the higher rate on weeds taller than 15.2 cm (6 inches) or as they approach flower or seedhead formation. Using 1.2 ℓ of product ha^{-1} (2.0 pint per acre) will result in suppression of biennial and perennial weeds as opposed to control. Timing of application is critical with Campaign. For best results, treat when plants are in early stages of growth but after most have germinated as Campaign has no soil activity. In Oklahoma the time of application will be between February 15 and March 31 as you move from the south to the north. Applications should be made prior to bermudagrass green-up. Applications made to bermudagrass which is beginning to green-up will result in a short temporary green-up delay. Precautions should be taken to avoid drift to susceptible off-target plants. These recommendations were in full compliance with the federal Campaign label on July 1, 1996. It is the responsibility of the end user to verify labeled use rates at the time of each herbicide application.

b. Ammonium sulfate (AMS) may be added to either Campaign herbicide or the combination treatment of Roundup + 2,4-D amine to improve control of winter annual weeds. Adding 20.4 g of sprayable grade AMS per ℓ (17.0 pounds of AMS per 100 gallons of water) has been shown to improve weed control when added to the lower labeled use rates of either Campaign (1.2 ℓ ha^{-1} or 2.0 pints per acre) or the combination treatment of Roundup + 2,4-D amine (Refer to respective Roundup and 2,4-D amine labels for specific use rates). AMS must be added to water (carrier) first, followed by the addition of herbicide(s) and drift control product. If a treatment of Roundup + 2,4-D amine is used for winter annual weed control, then the time of application will be the same as for using Campaign herbicide.

c. The plant growth regulator Primo, when applied at 500 to 750 g ai ha^{-1} (7.0 to 10.6 oz ai per acre) and combined with Oust at 50 g ai ha^{-1} (0.7 oz ai per acre) will produce significant growth suppression of common bermudagrass to reduce mowing frequencies on high mowing frequency areas. This treatment has shown the ability to reduce mowing frequencies in areas that receive at least 4 to 6 mowings per year. This treatment should be made in May to actively growing bermudagrass. Being a foliar absorbed treatment, good coverage is important so carrier at 383 ℓ ha^{-1} (40 gallons per acre) minimum should be used. This treatment will produce a minimum of 50% growth and seedhead suppression of common bermudagrass for a six to eight week period with only a slight temporary discoloration. As Primo has shown little ability to control weeds it is important that the treated areas be free of perennial grasses and broadleaf weeds. The addition of Oust will give short term summer pre-emergence control of many annual roadside weeds. In 1993, Primo became commercially available and was labeled for use on a number of turfgrass areas. Although Primo became legal to use on roadside right-of-way, the principal targeted market for Primo was the fine turf market and not the industrial turf market. As a result of this target market, Primo was not labeled at a rate that would be effective on roadside common bermudagrass and also, the product was not priced so that it would be affordable for the roadside manager. We recommend that the ODOT, OSU, CIBA and the Oklahoma Dept. of Agriculture work together to develop a 24C label for use of Primo by the ODOT and that the ODOT pursue a special bid agreement with CIBA for this very useful proprietary product.

d. Plateau when combined with Roundup will provide an acceptable level of both seedling and rhizome johnsongrass control (minimum of 80%

control) in common bermudagrass roadsides. At 70 to 140 g ai ha^{-1} (4 to 8 fluid ounces of product per acre) Plateau combined with Roundup at 280 to 430 g ai ha^{-1} (8 to 12 fluid ounces of product per acre) will provide acceptable johnsongrass control. Using lower rates will provide less johnsongrass control than the higher rate combinations. This treatment should be mixed with 187 to 374 ℓ water ha^{-1} (20 to 40 gallons of water per acre) and be applied in May or early June to actively growing bermudagrass and johnsongrass.

2. MAINTENANCE

Several research plot tours, meetings, workshops, and demonstrations were initiated throughout the duration of this project in an effort to obtain information and implement current research information into an operational phase of ODOT's roadside vegetation management program. The following are brief descriptions of the many events attended or conducted statewide:

a. Conducted Annual Summer Research plot tours for ODOT roadside steering committee.

b. Participated in Annual December Roadside Research Steering Committee Meeting in Oklahoma City.

c. Conducted 15 calibration workshops statewide at 6 of 8 Field Divisions.

d. Attended various statewide legislative meetings/hearings on ODOT's behalf.

e. Conducted Musk Thistle Weevil Collection and Release Tours in 1995 and 1996 for statewide ODOT personnel that resulted in over 60 releases around the state.

f. Monitored the "Lucas 64" demonstration during the summer of 1995 in Division 1.

g. Conducted 3 Bermudagrass Fertilizer Demonstrations in 1994 in Division 1,4, and 8, using current fertilizer recommendations for bermudagrass roadsides east of US-81.

h. Conducted the 1995 ODOT/OSU Roadside Research Bus Tour demonstrating numerous vegetation management products and techniques.

3. <u>TRAINING</u>

Applicator training for ODOT continues to be an important component of their roadside vegetation management program. Initial training and certification provides employees with information needed to be a good applicator and the continuing education workshops keep each applicator informed on current products, regulations, and other useful tips that allow them to make confident herbicide applications. The new ODOT Herbicide Policy of 1995 reflects the importance and significance of the herbicide training efforts that ODOT has implemented since the mid-1980s.

The following is a summary of highlights for the training programs:

a. A total of 12 pesticide applicator certification schools were conducted resulting in 146 new herbicide applicators being certified.

b. A total of 68 continuing education programs have been conducted with 2,795 ODOT certified applicators attending over a 5-year period.

c. Updated "Suggested Herbicides for Roadside Weed Problems" (OSU Extension publication number CR-6424).

d. Demonstrated and implemented the use of the boomless "Boom Buster" Nozzle tip in 1995.

1. INTRODUCTION

The Oklahoma Department of Transportation's (ODOT) commitment to progressive roadside vegetation management is evidenced by the funding of and cooperation in joint research, implementation and training projects with Oklahoma State University beginning in 1963. ODOT's continued commitment and understanding of the importance of sound roadside vegetation management practices will allow them to continue to have one of the most advanced programs in the nation.

The full purpose of roadside vegetation management is to provide the citizens of Oklahoma and the nation with a roadside cover that has the following attributes: 1) a low growing cover, allowing proper and safe site distances to motorists; 2) a recuperative cover, having the ability to recover from damage caused by insects, diseases, fires, floods, construction changes to roadsides and off-shoulder vehicular activity by motorists; and 3) a dense cover, reducing wind and water erosion and thus stabilizing the roadway as well as allowing proper surface drainage.

In managing this living roadside groundcover, the roadside manager continually battles the process of succession. Succession is the continued introduction of more and more plant species both by nature and man. Succession results in the introduction of a number of plant species (weeds) which are unsuitable for providing the attributes required on the roadside. While diverse plant communities can be beautiful and appropriate for backslopes on roadsides, this same diversity can have deadly consequences to motorist when tall plant materials block site distances, dramatically reducing the amount of reaction time that a motorist has available to make proper driving decisions.

ODOT roadside vegetation managers currently manage roadside groundcovers using an integrated program of mechanical (mowing), chemical (herbicides) and biological (musk thistle head weevils) tools. The integrated approach also dictates that the roadside manager maintain the cover in the most cost effective manor possible, complying with all state and federal regulations and using methods and tools that minimize risks to humans as well as to the environment at large.

The purpose of this five-year project was to investigate several roadside vegetation management tools that were of interest to ODOT research, maintenance and training personnel. Research was conducted to provide ODOT information on the performance of experimental and newly commercialized herbicides for vegetation management as well as refine existing herbicide recommendations. This research was conducted with a watchful eye towards costs to ODOT and taxpayers of implementing any new alternatives as well as examining alternatives that allowed managers to minimize risks to humans and the environment. Through our research efforts, new recommendations for johnsongrass control in common bermudagrass roadsides were developed. Control alternatives were also investigated for managing the tall native invasive prairiegrass know as switchgrass, on common bermudagrass roadsides. Additionally, herbicide rates were refined for control of the legally declared noxious weed called musk thistle. Drift control additives were screened so that ODOT personnel could use appropriate adjuvants that would not cause tank mix incompatibility. While common bermudagrass is a desirable roadside cover, it can at times become too invasive, and thus research was required to examine new products that held potential for use by ODOT in managing this problem. Work with Ammonium Sulfate as a spray additive was necessary to determine if herbicide rates could be reduced while providing continued acceptable levels of post-emergent winter annual weed control in dormant bermudagrass. Alternatives to the herbicide product Atrazine were also evaluated in our work.

Without an effort to transfer and integrate our research findings into the everyday operations of ODOT's roadside managers, neither ODOT nor our citizens would have received the full benefit of having funded this project and prior projects. Therefore, an integral part of this project was to conduct large and small scale plot demonstrations, sprayer calibration workshops, beneficial predatory insect collection/release days, on-site visits and phone consultations for/with ODOT field personnel.

A vital part of this project was also the education of ODOT pesticide applicators through initial pesticide application training schools as well as continuing education workshops. These programs helped ODOT personnel comply with the ODOT Herbicide Application Policy, the ODOT Equipment Operators Certification Program as well as with state and federal laws regulating the purchase, transportation, storage and use of pesticides.

2. Development of Plateau in Combination with Selective Herbicides for Johnsongrass Control

D. P. Montgomery, L. M. Cargill, and D. L. Martin

2.1 INTRODUCTION

Johnsongrass (*Sorghum halepense*) continues to be a troublesome weed along Oklahoma's state highway system. Johnsongrass is a warm season, perennial grass that spreads by seed and by extensive rhizomes (1). It can grow to a height of 91 to 183 cm, well above the recommended maximum vegetation height of 30.5 cm on "maintained" highway areas (2). Maintenance activities such as ditch cleaning, brush removal, shoulder construction, shouldering-up operations, scalping due to low mowing heights and any other operation that requires heavy machinery to traverse the roadside can cause temporary damage to roadside bermudagrass. Even something as common as a vehicle driving off the road surface for a second can damage bermudagrass and create an opening in the turf canopy, favoring johnsongrass seed germination. These small damaged areas are ideal for a plant such as johnsongrass to quickly reestablish if the opportunity arises.

Since the mid-1970s ODOT has made great strides in managing johnsongrass growing in the maintained portion of bermudagrass roadsides. These strides were made because of the implementation of a sound selective herbicide program to compliment their existing mowing program. For the first five to ten years of the johnsongrass control program, herbicide treatments consisting of two to three annual applications of MSMA or DSMA were practiced. This program, while effective and very safe to bermudagrass, was time consuming and thus, alternatives were sought. In the mid-1980s ODOT started using selective rates of Roundup plus Oust for johnsongrass control. This single annual treatment was effective

(3, 5, 7) if used properly and was not as forgiving in terms of phytotoxicity to bermudagrass as the past MSMA treatments. Proper rate of application with Roundup plus Oust applications was critical. Even if applied accurately this treatment created a temporary yellowing of bermudagrass (7, 9). If over applied, this yellowing became severe and caused a thinning of the bermudagrass.

In 1993, American Cyanamid introduced a new herbicide, Plateau, into the roadside management area. Early research results on Plateau indicated that it might have the potential to be a good johnsongrass control product (6, 8) yet having little injurious effect on bermudagrass (4). These promising attributes plus ODOT's and American Cyanamid's interest in developing a roadside and industrial label lead our program into a three year research effort with Plateau.

The objectives of this research were to 1) evaluate Plateau applied alone and with selected combinations of other herbicides and adjuvants for the control of johnsongrass and 2) evaluate the tolerance of common bermudagrass to Plateau.

2.2.0 MATERIALS AND METHODS

A total of seven experiments were conducted from 1993 to 1995, primarily in north central Oklahoma. All treatments were applied to actively growing bermudagrass and johnsongrass. During the span of years this research was conducted, Plateau went through several name changes. For reference to this final report and other interim reports on this project the following are all synonyms: AC-263,222, Cadre, Contend and Plateau (active ingredient imazameth). For ease of reporting, the latter trade name will be used exclusively in this chapter.

A separate analysis of variance was conducted on data from each experiment. Because treatment rating date effects were always significant, mean separation was conducted within rating dates using the Least Significant Difference Test at the 5% significance level.

2.2.1 Experiments 4-H-68-93 and 4-H-69-93

Experiments 4-H-68-93 and 4-H-69-93 included identical treatments in 1993 but were located at different sites on roadsides in Oklahoma. A total of 15 treatments were applied at two different johnsongrass growth stages. Plateau application rates in these studies remained constant at 0.14 kg ai ha^{-1} whether applied alone or in combination with other herbicides. Plateau was combined with Arsenal at 0.07, 0.10 or 0.14 kg ai ha^{-1}, Roundup at 0.28 or 0.42 kg ai ha^{-1} or Pursuit at 0.07 kg ai ha^{-1}. Arsenal at 0.07, 0.10 and 0.14 kg ai ha^{-1} was combined with Pursuit at 0.05 or 0.07 kg ai ha^{-1}. Treatments of Arsenal at 0.14 plus Roundup at 0.42 kg ai ha^{-1} and Oust at 0.11 plus Roundup at 0.84 kg ai ha^{-1} were also evaluated. All treatments received X-77 non-ionic surfactant at 0.25% v/v. The treatments were applied at two different johnsongrass growth stages to evaluate the effects of early versus late timing of applications. The early growth stage treatments (30 to 46 cm tall johnsongrass at the whorl) were applied on 21 May 1993 (Experiment 4-H-68-93) and 25 May 1993 (Experiment 4-H-69-93). The late growth stage treatments (61 to 91 cm tall johnsongrass in boot to seedhead) were applied on 10 June 1993 (Experiment 4-H-68-93) and 11 June 1993 (Experiment 4-H-69-93). The treatments were applied using a CO_2-powered hand-held boom sprayer calibrated to deliver 187 ℓ ha^{-1}. The treatments were arranged in a randomized complete block design with three replications of treatments. The individual plot size was 1.5 x 3 m. Treatments were evaluated 50 and 100 days after treatment (DAT) along with an evaluation 1 year after treatment (YAT). Treatments were visually evaluated for percent johnsongrass control where 0 = no control and 100 = complete control and percent bermudagrass injury where 0 = no injury and 100 = complete brownout. Experiment 4-H-68-93 was conducted on a fine sandy loam soil located along side SR 33, 1.1 km west of the junction of SR 33 and SR 108 in Payne County in ODOT Division 4. Experiment 4-H-69-93 was conducted on a loam soil along side SR 51, 3.2 km east of Stillwater in Payne County in ODOT Division 4.

2.2.2 Experiment 4-H-75-94

The purpose of this experiment was to evaluate herbicide treatments that had been applied on the same plots for two consecutive years (Experiment 4-H-68-93 in 1993 and Experiment 4-H-75-94 in 1994). A total of nine herbicide treatments were applied at two different johnsongrass growth stages. Herbicide treatments, rates and methods of application were the same as in Experiment 4-H-68-93. The treatments were again applied at two different johnsongrass growth stages to evaluate the effects of early versus late timing of applications. The early growth stage treatments (30 to 46 cm tall johnsongrass at the whorl) were applied on 20 May 1994. The late growth stage treatments (91 to 152 cm tall johnsongrass in boot to seedhead) were applied on 7 June 1994. The experimental design, parameter evaluation and analysis were as previously discussed for Experiment 4-H-68-93.

2.2.3 Experiment 4-H-76-94

During the course of our research on Plateau, it became apparent from the efforts of other researchers that the activity of Plateau and other imidazolinone herbicides could be increased with the addition of various adjuvants. Therefore, the objective of this experiment was to evaluate the effectiveness of a surfactant/fertilizer blend (Squire) and a methylated seed oil (Sunrise) in increasing johnsongrass control while minimizing bermudagrass injury.

Experiment 4-H-76-94 was conducted on a loam soil located along side SR 33, 0.8 km east of the junction with SR 108 in Payne County in ODOT Division 4. Herbicide treatments evaluated included Plateau at 0.14 kg ai ha^{-1}, alone and combined with Pursuit at 0.07 kg ai ha^{-1} or Roundup at 0.28 kg ai ha^{-1} or Arsenal at 0.10 kg ai ha^{-1}. Each herbicide treatment was combined with Squire at 0.25% v/v or Sunrise at 1.25% v/v. As with earlier experiments, each of these treatments were applied at two different johnsongrass growth stages. The early growth stage treatments (30 to 46 cm tall johnsongrass at the whorl) were applied on 24 May 1994. The late growth stage treatments (61 to 102 cm tall johnsongrass in boot to seedhead) were applied on 15 June 1994. The method of treatment application, experimental design, parameter evaluation and analysis were identical to those discussed in Section 2.2.1. Additionally, bermudagrass canopy heights were also taken by randomly measuring three areas in each plot and taking an average.

2.2.4 Experiment 4-H-77-94

The objective of this experiment was to further refine Plateau rates and treatment combinations and to evaluate single versus sequential applications and to determine if there were control advantages in having two annual applications versus a single application. It included additional combinations of Plateau plus Roundup over other experiments because the combination of Plateau plus Roundup was beginning to show some promise as a johnsongrass control treatment.

Herbicide treatments that were evaluated included Plateau at 0.07, 0.14 and 0.21 kg ai ha^{-1} combined with Roundup at 0.28 or 0.42 kg ai ha^{-1}. Plateau at 0.14 kg ai ha^{-1} was also combined with Arsenal at 0.07, 0.10 or 0.14 kg ai ha^{-1}. Plateau was applied alone at 0.21 kg ai ha^{-1} and combined with Arsenal at 0.70 kg ai ha^{-1}. Plateau was also applied alone at

0.14 kg ai ha^{-1} and combined with Pursuit at 0.07 kg ai ha^{-1}. Other treatments included Arsenal at 0.14 kg ai ha^{-1} plus Roundup at 0.42 kg ai ha^{-1} and Oust at 0.11 plus Roundup at 0.56 kg ai ha^{-1}. All treatments received X-77 non-ionic surfactant at 0.25% v/v.

Each of our 15 treatments were applied as initial (single/whole plot) and sequential (two/subplot) applications. Initial applications were made at two different johnsongrass growth stages to evaluate the effects of early versus late timing of applications. The early growth stage treatments for initial applications were made on 30 to 46 cm tall johnsongrass on 25 May 1994. The late growth stage treatments for initial applications were made on 91 to 152 cm tall johnsongrass on 16 June 1994. All initial treatments were made to whole plots that measured 3 x 3 m. The sequential applications involved reapplying like herbicide treatments over one-half of the whole plot (subplot/1.5 x 3 m). These applications were made when the johnsongrass regrowth reached 30 to 46 cm in height. The sequential applications were made on 7 July 1994 (early growth stage treatments) and 15 July 1994 (late growth stage treatments). Experiment 4-H-76-94 was conducted on a loam soil located along side SR 33, 0.8 km east of the junction with SR 108 in Payne County in ODOT Division 4. Application method, study design, ratings and data analysis were conducted as previously discussed in Section 2.2.1.

2.2.5 Experiment 4-H-80-95

The objective of this experiment was to evaluate herbicide treatments in the third year on plots that had received two consecutive years (Experiment 4-H-68-93 in 1993 and Experiment 4-H-75-94 in 1994) of treatment. A total of nine herbicide treatments, identical to those applied in 1993 and 1994, were made at two different johnsongrass growth stages. The treatments were also applied at two different johnsongrass growth stages as in the two previous years, in order to evaluate the effects of early versus late timing of applications. The early growth stage treatments (46 to 61 cm tall johnsongrass at the whorl) were applied on 1 June 1995. The late growth stage treatments (76 to 91 cm tall johnsongrass in boot to seedhead) were applied on 15 June 1995. Experimental design, data collection and analysis were as previously discussed.

2.2.6 Experiment 4-H-81-95

The objectives of this final experiment were to further refine Plateau plus Roundup rates and combine them with a surfactant or methylated seed oil. This experiment had a total of 11 treatments all of which were applied at a single early growth stage in late May. The treatments that were evaluated included Plateau at 0.10, 0.14, 0.17 and 0.21 kg ai ha^{-1}, applied alone or in combination with Roundup at 0.42 kg ai ha^{-1} plus X-77 non-ionic surfactant at 0.25% v/v. Also evaluated were treatments of Plateau at 0.17 kg ai ha^{-1}, applied alone and combined with Roundup at 0.84 kg ai ha^{-1} plus Sunrise methylated seed oil at 1.25% v/v and the standard treatment of Oust at 0.11 plus Roundup at 0.56 kg ai ha^{-1} plus X-77. The treatments were applied on 22 May 1995 using a CO_2-powered bicycle sprayer calibrated to deliver 187 ℓ ha^{-1}. The treatments were arranged in a randomized complete block design with three replications of treatments. The individual plot size was 1.5 x 4.5 m.

Treatments were evaluated 2, 4, 8, 12 and 16 weeks after treatment (WAT). Treatments were visually evaluated for percent johnsongrass control where 0 = no control and 100 = complete control; percent bermudagrass seedhead suppression where 0 = no suppression and 100 = complete suppression; and percent bermudagrass injury where 0 = no injury and 100 = complete brownout. Bermudagrass canopy heights were also taken by randomly measuring three areas in each plot and taking an average.

2.3.0 RESULTS AND DISCUSSION

For a johnsongrass control treatment to be considered successful or satisfactory, the treatment must provide 90% control or greater for the duration of the growing season or through 100 DAT in the case of our research. Injury or discoloration of bermudagrass in the range of 40 to 45% that did not persist for more than 4 to 6 weeks or 50 DAT in this experiment would be considered acceptable for roadsides in Oklahoma.

2.3.1 Experiment 4-H-68-93

The treatments in Experiments 4-H-68-93 and 4-H-69-93 (identical experiments in 1993) were generally very consistent in activity between the two experiments; however, in Experiment 4-H-68-93, there was more weed control activity from the late treatments (treatments 17-31) applied to the more mature johnsongrass. Even though there were instances of increased control from some of the later treatments in this experiment, only the treatments of Roundup (0.84 kg ai ha^{-1}) plus Oust (treatment 18) and Plateau (0.11 kg ai ha^{-1}) plus Roundup (treatment 24) produced acceptable (≥90%) control of johnsongrass among the late treatments at 100 DAT (Table 1).

The remainder of this discussion will pertain to the early treatments applied to johnsongrass in the less mature (treatments 1-15), vegetative stage of growth. All treatments of Arsenal plus Pursuit did not provide an acceptable level of johnsongrass control (Table 1). Johnsongrass control from Arsenal plus Pursuit treatments ranged from 47 to 87% (50 DAT), 38 to 72% (100 DAT), and 23 to 63% (1 YAT). Plateau alone produced moderate johnsongrass control of 70% (50 DAT), 78% (100 DAT) and 67% (1 YAT). Treatments of Plateau which included either Arsenal or Roundup did produce better johnsongrass control. Treatments of Plateau plus Arsenal produced good to excellent johnsongrass control which ranged from 70 to 88% (50 DAT) and 78 to 92% (100 DAT). Treatments of Plateau plus Roundup also produced good johnsongrass control which ranged from 73 to 78% (50 DAT), 83 to 88% (100 DAT) and 68 to 78% (1 YAT). The current industry standard treatment of Roundup plus Oust (0.56 plus 0.11 kg ai ha^{-1}) produced excellent johnsongrass control of 94% (50 DAT), 93% (100 DAT) and 85% (1 YAT). Arsenal plus Roundup produced good to moderate control of johnsongrass at 50 DAT (85%), 100 DAT (75%) and 1 YAT (57%). Overall it appears that many of these imidazolinone herbicide combinations show promise in controlling johnsongrass.

All of the products in this experiment have the potential to cause temporary injury or discoloration to bermudagrass. Just like the injury from Roundup plus Oust treatments that roadside managers currently manage, the amount of discoloration from the products tested appears to depend greatly on the specific combinations and rate of application. Injury or discoloration of bermudagrass in the range of 40 to 45% that did not persist for more than 4 to 6 weeks was considered acceptable for roadsides in this experiment. Bermudagrass injury from Roundup plus Oust was 38% (50 DAT), 17% (100 DAT) and 7% (1 YAT). Treatments which produced an unacceptable level of injury at 50 DAT included all treatments of Plateau plus Arsenal, Arsenal plus Roundup, and higher rates of Arsenal plus Pursuit. Injury from these treatments ranged from 47% to 83%. At 100 DAT only the high rate of Plateau plus Arsenal provided unacceptable bermudagrass injury (57%).

2.3.2 Experiment 4-H-69-93

All late treatments (treatments 17-31) applied on 11 June to the more mature johnsongrass (boot) provided poor johnsongrass control (<70% control) (Table 2). Therefore, our discussion will focus on results from the earlier application date (treatments 1-15) of 25 May. All treatments of Arsenal combined with Pursuit did not provide an acceptable level of johnsongrass control at 50 or 100 DAT (Table 2). Johnsongrass control from Arsenal plus Pursuit treatments ranged from 56 to 73% (50 DAT) and 30 to 56% (100 DAT). Plateau alone produced good to moderate johnsongrass control at 50 DAT (80%) and 100 DAT (75%). Treatments of Plateau and Arsenal produced good johnsongrass control at 50 DAT (86%) and ranged from 75 to 80% at 100 DAT. Plateau and Pursuit produced good johnsongrass control at 50 DAT (87%) and 100 DAT (82%). Treatments of Plateau and Roundup also produced good to excellent johnsongrass control which ranged from 85 to 92% (50 DAT) and 83 to 92% (100 DAT). Roundup and Oust, the standard treatment for a bermudagrass release program in Oklahoma, provided 97% (50 DAT) and 93% (100 DAT) johnsongrass control. Arsenal and Roundup produced good to moderate control of johnsongrass at 50 DAT (83%) and 100 DAT (77%).

Bermudagrass injury observed from the Roundup plus Oust treatment was 30% (50 DAT) and 18% (100 DAT) (Table 2). All treatment combinations which contained Arsenal at 0.14 kg ai ha^{-1} produced an unacceptable level of bermudagrass injury. Injury from these treatments ranged from 52 to 70% (50 DAT). All other treatments produced moderate to low levels of temporary bermudagrass injury, which was deemed acceptable.

2.3.3 Experiment 4-H-75-94

The data from this experiment suggest that most herbicide treatments applied to johnsongrass that was 30 to 61 cm in height (early treatments or treatments 1-9) appear to offer better johnsongrass control when compared to like treatments applied to taller and more mature johnsongrass that was 91 to 152 cm in height (late treatments or treatments 10-18) (Table 3). The combination treatments of Roundup plus Oust provided the best overall (and acceptable) control for either johnsongrass growth stage. With the one exception of the combination treatment of Plateau plus Pursuit (applied late to the taller johnsongrass), Roundup plus Plateau exhibited 87 to 88% johnsongrass control. Combination treatments of Arsenal plus Roundup provided 72 to 85% control of johnsongrass at 100 DAT and 1 YAT with Plateau plus Arsenal combination treatments providing slightly less control at 100 DAT (67 to 80%) and 75 to 88% control at 1 YAT. Plateau alone did not effectively control johnsongrass at 100 DAT (62 to 70%) and at 1 YAT (73 to 85%).

Substantial bermudagrass phytotoxicity was observed at 100 DAT from combination treatments of Plateau plus Arsenal (50 to 88%) which in most cases would not be acceptable for roadside situations. Bermudagrass phytotoxicity in plots treated with Roundup plus Oust ranged from 53 to 65% injury (100 DAT) which also would be on the borderline of being unacceptable as well. Visual observations of bermudagrass phytotoxicity from Plateau plus Roundup treatments ranged from 12 to 20% (very acceptable) with the least amount of injury (8%) observed in the plots treated with Plateau alone.

All herbicide treatments, with exception of Plateau alone, Roundup plus Oust and all Plateau plus Roundup treatments applied during June, significantly reduced bermudagrass height at 100 DAT. The greatest amount of height reduction was observed in plots treated with Roundup plus Arsenal which ranged from 8 to 10 cm in plots treated in May.

2.3.4 Experiment 4-H-76-94

All of the 16 treatments produced unacceptable johnsongrass control throughout the duration of this experiment (Table 4). Johnsongrass control from the 24 May treatments (treatments 1-8) could have been reduced by a short light rain which fell immediately after the application. At 50 DAT all of the early herbicide treatments when combined with the surfactant/fertilizer provided 53% johnsongrass control or less. Johnsongrass control was noticeably improved when herbicides were combined with the methylated seed oil. By 50 DAT control of johnsongrass increased from 25 to 47% for Plateau alone, 35 to 75% for Plateau plus Arsenal, 38 to 58% for Plateau plus Roundup and 25 to 50% for Plateau plus Pursuit. At 100 DAT johnsongrass control decreased for all treatments, except for the Plateau/Arsenal combination plus methylated seed oil at the 15 June application date. When evaluated 1 YAT the level of johnsongrass control remained relatively unchanged from the 100 DAT evaluations. Most treatments had either decreased or remained the same with only four treatments showing a slight increase in control.

At 50 DAT all herbicide treatments, except Plateau alone, when combined with the methylated seed oil produced unacceptable bermudagrass injury. Early treatments of Plateau/Roundup plus surfactant/fertilizer and Plateau/Arsenal plus surfactant/fertilizer also produced unacceptable injury. At 100 DAT the treatments of Plateau/Arsenal plus methylated seed oil applied early or late continued to produce unacceptable bermudagrass injury. All other treatments produced moderate to low levels of injury which was acceptable.

2.3.5 Experiment 4-H-77-94

All initial herbicide treatments evaluated 50 and 100 DAT indicated a reduction (not statistically significant) in bermudagrass height (Table 5).

All sequential herbicide treatments except for Plateau plus Roundup at 0.07 plus 0.42 kg ai ha^{-1}, also resulted in some bermudagrass height suppression, although not significant, when evaluated 50 DAT (Table 6). This same trend was observed when plots were evaluated 100 DAT with the addition of Plateau plus Roundup at 0.14 plus

0.28 kg ai ha^{-1}. Overall, the data from this experiment suggests no significant differences among herbicide treatments for bermudagrass height reduction or suppression.

Statistically significant bermudagrass injury resulted from the following initial herbicide treatments (applied to the earlier, less mature, johnsongrass growth stage - treatments 1-15) over that occurring on the control at 50 DAT (Table 5): all Arsenal combination treatments, except Plateau plus Arsenal at 0.14 plus 0.07 kg ai ha^{-1}, and the high rate of Plateau alone at 0.21 kg ai ha^{-1}. Initial treatments causing significant bermudagrass injury at 50 DAT when applied to the taller more mature johnsongrass included Arsenal plus Roundup at 0.14 plus 0.42 kg ai ha^{-1}, Oust plus Roundup at 0.11 plus 0.56 kg ai ha^{-1}, Plateau plus Arsenal at 0.14 plus 0.14 kg ai ha^{-1} and at 0.21 plus 0.07 kg ai ha^{-1}. When plots were evaluated 100 DAT, the same trend was evident for those treatments applied to the earlier johnsongrass growth stage except for the Plateau plus Arsenal treatment at 0.21 plus 0.07 kg ai ha^{-1} respectively. Only one treatment, Plateau plus Arsenal at 0.14 plus 0.14 kg ai ha^{-1}, was exhibiting significant bermudagrass injury in the more mature johnsongrass (second growth stage) plots following the initial application, when ratings were made at 100 DAT.

All sequential herbicide treatments applied to the early, less mature, johnsongrass growth stage (treatments 1-15) caused statistically significant bermudagrass injury over the check when evaluations were made 50 DAT (Table 6). The following sequential treatments also caused significant bermudagrass injury when applied to the late, more mature johnsongrass growth stage at 50 DAT: Plateau plus Arsenal at 0.14 plus 0.14 kg ai ha^{-1}, and at 0.21 plus 0.07 kg ai ha^{-1}; Plateau plus Roundup at 0.07 plus 0.28 kg ai ha^{-1}, and at 0.21 plus 0.42 kg ai ha^{-1}; Plateau at 0.21 kg ai ha^{-1}; and Plateau plus Pursuit at 0.14 plus 0.07 kg ai ha^{-1}. When evaluations were made 100 DAT, the following sequential treatments were still causing significant bermudagrass injury: Arsenal plus Roundup at 0.14 plus 0.42 kg ai ha^{-1} (for both johnsongrass growth stages); Plateau plus Arsenal at 0.14 plus 0.07 kg ai ha^{-1}, at 0.14 plus 0.10 kg ai ha^{-1} (both johnsongrass growth stages), at 0.14 plus 0.14 kg ai ha^{-1} (both johnsongrass growth stages), at 0.21 plus 0.07 kg ai ha^{-1}; Plateau at 0.14 kg ai ha^{-1}; Plateau plus Pursuit at 0.14 plus 0.07 kg ai ha^{-1}; and Plateau plus Arsenal at 0.21 plus 0.07 kg ai ha^{-1}. Results of this experiment indicate the least amount of bermudagrass injury occurred in the Plateau plus Roundup treated plots.

When plots were evaluated at 50 and 100 DAT, unacceptable johnsongrass control was observed from all of the initial herbicide treatments applied to the earlier, less mature johnsongrass growth stage (Table 5). This may be due largely to the fact that very little, if any rainfall occurred for 6 to 7 weeks after these treatments were applied. However, the following treatments provided marginally acceptable (≥85%) johnsongrass control when applied to the more mature johnsongrass growth stage at 100 DAT: Oust plus Roundup at 0.11 plus 0.56 kg ai ha^{-1}; Plateau plus Roundup at 0.14 plus 0.42 kg ai ha^{-1}, 0.07 plus 0.42 kg ai ha^{-1}, 0.07 plus 0.28 kg ai ha^{-1}, 0.21 plus 0.42 kg ai ha^{-1}, and 0.21 plus 0.28 kg ai ha^{-1}; Plateau plus Arsenal at 0.21 plus 0.07 kg ai ha^{-1} and Plateau plus Pursuit at 0.14 plus 0.07 kg ai ha^{-1}. When evaluated 1 YAT, the level of johnsongrass control remained relatively unchanged from the 100 DAT evaluations. Efficacy of most treatments had either decreased or remained the same with only eight of the initial treatments and eight of the sequential treatments exhibiting a slight increase in the level of control. Although many of these herbicides applied as sequential treatments provided acceptable johnsongrass control, it is questionable as to whether ODOT would be able to afford the additional expenditure for sequential treatments.

With ODOT's current emphasis on cost effective treatments, more emphasis and consideration should be placed on those johnsongrass control treatments that are successful after only a single application.

2.3.6 Experiment 4-H-80-95

After three consecutive years of herbicide treatment application, few significant differences in johnsongrass control appeared between identical herbicide treatments when applied to either johnsongrass at 30 to 61 cm in height (treatments 1-9) as compared to taller and more mature johnsongrass at 91 to 152 cm in height (treatments 10-18) (Table 7). Exceptions were significantly better control with Arsenal plus Roundup at 50 and 100 DAT when applied to larger johnsongrass and with Plateau plus Pursuit at 100 DAT when applied to larger johnsongrass. Treatments providing the best overall and acceptable control for either johnsongrass growth stage with minimal bermudagrass injury were combination treatments of Roundup plus Oust (96 to 98% control), Roundup plus Plateau at 0.28 plus 0.14 kg ai ha^{-1} (88 to 93% control), and Roundup plus Plateau at 0.42 plus 0.14 kg ai ha^{-1} (93 to 99% control). Combination treatments of Arsenal plus Roundup provided 70 to 86% johnsongrass control at 100 DAT while Plateau plus Arsenal combinations exhibited 86 to 96% control. Plateau alone resulted in 83 to 89% control of johnsongrass while combination treatments of Plateau plus Pursuit exhibited 77 to 99% control.

Significant bermudagrass injury was observed at 100 DAT from combination treatments of Plateau plus Arsenal (33 to 50% injury) and Roundup plus Arsenal (57 to 58% injury). This level of phytotoxicity is on the borderline of being unacceptable this late in the growing season in roadside situations. Plots treated with Roundup plus Oust ranged from 0 to 10% bermudagrass injury which was very acceptable. The least amount of bermudagrass injury was observed in plots treated with a combination of Roundup plus Plateau (0 to 3% injury).

All herbicide treatments caused significant bermudagrass height reduction when evaluations were made 50 DAT. Observations 100 DAT indicated all Plateau plus Arsenal combination treatments applied to the earlier growth stage were causing significant bermudagrass height reduction. In addition, the high rate of Plateau plus Arsenal (0.14 plus 0.14 kg ai ha^{-1}) applied to the more mature, taller johnsongrass caused a significant reduction in bermudagrass height 100 DAT. The remainder of the treatments resulted in no significant bermudagrass height reduction.

2.3.7 Experiment 4-H-81-95

Significant bermudagrass phytotoxicity was observed 2 WAT and 4 WAT in all herbicide treatments except in the three lowest rates of Plateau (0.10, 0.14 and 0.17) plus X-77, alone when compared to the untreated check (Table 8). By 8 WAT the untreated check plot was exhibiting phytotoxicity due to the hot, dry summertime conditions. No bermudagrass phytotoxicity was observed for any treatment when evaluations were made 12 WAT and 16 WAT.

Bermudagrass seedhead formation was significantly suppressed by all herbicide treatments when evaluations were made 4 WAT and 8 WAT. By 12 WAT the high rate of Plateau plus Roundup plus X-77 (0.21 plus 0.42 kg ai ha^{-1} plus 0.25% v/v) was the only treatment continuing to significantly suppress bermudagrass seedhead formation. All herbicide effects had completely diminished by 16 WAT.

Bermudagrass canopy heights were significantly reduced by all herbicide treatments when ratings were made 4 WAT and 8 WAT. By 12 WAT no significant differences among all treatments (including the untreated check plot) were detected.

Johnsongrass control at 4 WAT for Plateau plus X-77 treatments ranged from 36.7 to 71.7%. The treatment with the lowest rate of Plateau plus X-77 (0.11 kg ai ha^{-1} plus 0.25% v/v) exhibited significantly less control than all other herbicide treatments. Plots treated with Roundup plus Plateau plus X-77 varied from 76.7 to 81.7% johnsongrass control. Some increase in percent johnsongrass control by 8 WAT was observed in the Plateau plus X-77 treatments (51.7 to 95.7%), however, by 16 WAT control had diminished to 38.3 to 81.7%. Plateau plus Roundup plus X-77 treatments also showed an increase in activity for johnsongrass control by 8 WAT (94.0 to 97.3%) but decreased somewhat at 16 WAT (76.0 to 96.0%). Plateau plus Roundup plus MSO provided an acceptable level of johnsongrass control (78.3 to 92.7%) throughout the duration of this experiment. The standard treatment of Roundup plus Oust plus X-77 used in this experiment exhibited 81.7% johnsongrass control 4 WAT which increased to a level of 94.3% 8 WAT then decreased to 89.3% when the last evaluations were made 16 WAT. Plateau (0.17 kg ai ha^{-1}) plus MSO provided 76.7% johnsongrass control 4 WAT, 94.3% at 8 WAT, but dropped to a marginal level of 83.3% at 16 WAT.

2.4 CONCLUSIONS

The data from these experiments indicate that Plateau at 0.07 to 0.14 kg ai ha^{-1} when combined with Roundup at 0.28 to 0.42 kg ai ha^{-1} will provide good to excellent control of johnsongrass that is comparable to today's industry standard treatment of Oust at 0.05 kg ai ha^{-1} plus Roundup at 0.56 kg ai ha^{-1}. The data also indicates that common bermudagrass is more tolerant to the Plateau/Roundup treatment than to the Oust/Roundup treatment at these rates. The greater tolerance of bermudagrass to the Plateau/Roundup treatment is evident as less yellowing of bermudagrass occurs following applications and bermudagrass recovers more quickly following the slight phytotoxicity effect. In areas of Oklahoma where roadside managers have been concerned about past Oust/Roundup phytotoxicity to bermudagrass, the use of Plateau/Roundup may lessen the phytotoxicity visible to the public while still providing acceptable control of johnsongrass. Under Oklahoma growing conditions it appears that earlier treatments of Plateau/Roundup applied during May will provide better more consistent control than applications made in June. Treatments should be made when bermudagrass is green and actively growing and when johnsongrass reaches heights of 30 to 61 cm. While the data indicate that the addition of certain adjuvants can produce good to excellent johnsongrass control, it doesn't appear that these adjuvants produce a significant increase in weed control over like treatments without the adjuvant.

Future research with Plateau/Roundup should determine the spectrum of weed species controlled with this treatment. Past observations indicate that this treatment may have a narrower spectrum of weed control than the standard Oust/Roundup treatment.

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Table 1. Johnsongrass control and bermudagrass phytotoxicity of 31 post-emergent herbicide treatments in ODOT Division 4 near Stillwater, Oklahoma in 1993 (Experiment 4-H-68-93).

Treatments[1,2]	Rate (kg ai ha^{-1})	Percent Johnsongrass Control			Percent Bermudagrass Injury		
		50 DAT[3]	100 DAT	1 YAT[4]	50 DAT	100 DAT	1 YAT
		--------30 to 45 cm height--------					
1. Arsenal + Roundup	0.14 0.42	85	75	57	77	27	10
2. Oust + Roundup	0.11 0.84	94	93	85	38	17	7
3. Plateau	0.14	70	78	67	10	10	7
4. Plateau + Arsenal	0.14 0.07	70	78	68	47	32	13
5. Plateau + Arsenal	0.14 0.10	88	92	78	70	37	12
6. Plateau + Arsenal	0.14 0.14	82	88	68	65	57	15
7. Plateau + Pursuit	0.14 0.07	68	70	48	28	20	17
8. Plateau + Roundup	0.14 0.42	78	88	72	33	20	20
9. Plateau + Roundup	0.14 0.28	73	83	62	22	13	7
10. Arsenal + Pursuit	0.07 0.07	50	55	42	27	15	8
11. Arsenal + Pursuit	0.10 0.07	77	72	63	67	33	8
12. Arsenal + Pursuit	0.14 0.07	87	70	38	83	43	18
13. Arsenal + Pursuit	0.07 0.05	47	38	35	42	7	7
14. Arsenal + Pursuit	0.10 0.05	60	37	23	50	22	10
15. Arsenal + Pursuit	0.14 0.05	77	55	33	40	27	8
$LSD_{0.05}$		23	31	40	33	27	15

[1]All herbicide treatments had X-77 added at 0.25% v/v.
[2]Treatments 1-15 were applied on 21 May to 30 to 45 cm tall johnsongrass; treatments 17-31 were applied on 10 June to 61 to 91 cm tall johnsongrass.
[3]DAT = Days After Treatment.
[4]YAT = Years After Treatment.

Table 1. Continued. (Experiment 4-H-68-93).

Treatments[1,2]	Rate (kg ai ha^{-1})	Percent Johnsongrass Control 50 DAT[3]	100 DAT	1 YAT[4]	Percent Bermudagrass Injury 50 DAT	100 DAT	1 YAT
		----61 to 91 cm height----					
16. Check	------	0	0	0	0	0	0
17. Arsenal + Roundup	0.14 0.42	67	43	33	57	53	27
18. Oust + Roundup	0.11 0.84	93	90	88	12	13	13
19. Plateau	0.14	75	65	67	12	7	5
20. Plateau + Arsenal	0.14 0.07	88	82	57	75	47	12
21. Plateau + Arsenal	0.14 0.10	89	80	57	65	62	17
22. Plateau + Arsenal	0.14 0.14	87	78	60	83	70	17
23. Plateau + Pursuit	0.14 0.07	80	70	63	42	38	20
24. Plateau + Roundup	0.14 0.42	87	91	84	25	22	12
25. Plateau + Roundup	0.14 0.28	77	83	83	33	18	10
26. Arsenal + Pursuit	0.07 0.07	55	50	43	35	17	7
27. Arsenal + Pursuit	0.10 0.07	62	60	50	48	23	8
28. Arsenal + Pursuit	0.14 0.07	85	62	40	65	58	28
29. Arsenal + Pursuit	0.07 0.05	53	47	43	35	20	10
30. Arsenal + Pursuit	0.10 0.05	37	22	17	67	45	13
31. Arsenal + Pursuit	0.14 0.05	78	62	43	63	52	20
$LSD_{0.05}$		23	31	40	33	27	15

[1]All herbicide treatments had X-77 added at 0.25% v/v.
[2]Treatments 1-15 were applied on 21 May to 30 to 45 cm tall johnsongrass; treatments 17-31 were applied on 10 June to 61 to 91 cm tall johnsongrass.
[3]DAT = Days After Treatment.
[4]YAT = Years After Treatment.

Table 2. Johnsongrass control and bermudagrass phytotoxicity of 31 post-emergent herbicide treatments in ODOT Division 4 in northeast Payne County in 1993 (Experiment 4-H-69-93).

Treatments[1,2]	Rate (kg ai ha^{-1})	Percent Johnsongrass Control 50 DAT[3]	100 DAT	Percent Bermudagrass Injury 50 DAT	100 DAT
		-----30 to 45 cm height-----			
1. Arsenal + Roundup	0.14 0.42	83	77	52	50
2. Oust + Roundup	0.11 0.84	97	93	30	18
3. Plateau	0.14	80	75	23	12
4. Plateau + Arsenal	0.14 0.07	88	75	23	9
5. Plateau + Arsenal	0.14 0.10	87	80	35	17
6. Plateau + Arsenal	0.14 0.14	87	80	70	53
7. Plateau + Pursuit	0.14 0.07	87	82	18	3
8. Plateau + Roundup	0.14 0.42	85	83	10	5
9. Plateau + Roundup	0.14 0.28	92	92	22	17
10. Arsenal + Pursuit	0.07 0.07	57	30	22	12
11. Arsenal + Pursuit	0.10 0.07	62	30	18	3
12. Arsenal + Pursuit	0.14 0.07	73	57	60	37
13. Arsenal + Pursuit	0.07 0.05	48	30	12	2
14. Arsenal + Pursuit	0.10 0.05	65	38	37	8
15. Arsenal + Pursuit	0.14 0.05	68	57	52	12
$LSD_{0.05}$		20	26	27	21

[1]All herbicide treatments had X-77 added at 0.25% v/v.
[2]Treatments 1-15 were applied on 25 May to 30 to 45 cm tall johnsongrass; treatments 17-31 were applied on 11 June to 61 to 102 cm tall johnsongrass.
[3]DAT = Days After Treatment.

Table 2. Continued. (Experiment 4-H-69-93).

Treatments[1,2]	Rate (kg ai ha^{-1})	Percent Johnsongrass Control 50 DAT[3]	100 DAT	Percent Bermudagrass Injury 50 DAT	100 DAT
		-----------------------------61 to 102 cm height		-----------------------------	
16. Check	-------	0	0	0	0
17. Arsenal + Roundup	0.14 0.42	43	33	37	15
18. Oust + Roundup	0.11 0.84	65	52	28	17
19. Plateau	0.14	27	23	12	8
20. Plateau + Arsenal	0.14 0.07	67	52	55	30
21. Plateau + Arsenal	0.14 0.10	70	55	63	35
22. Plateau + Arsenal	0.14 0.14	77	67	32	25
23. Plateau + Pursuit	0.14 0.07	30	32	22	7
24. Plateau + Roundup	0.14 0.42	68	63	10	7
25. Plateau + Roundup	0.14 0.28	40	35	15	5
26. Arsenal + Pursuit	0.07 0.07	37	42	28	8
27. Arsenal + Pursuit	0.10 0.07	55	32	48	22
28. Arsenal + Pursuit	0.14 0.07	55	37	52	30
29. Arsenal + Pursuit	0.07 0.05	23	13	20	5
30. Arsenal + Pursuit	0.10 0.05	35	32	50	12
31. Arsenal + Pursuit	0.14 0.05	35	20	50	22
$LSD_{0.05}$		20	26	27	21

[1]All herbicide treatments had X-77 added at 0.25% v/v.
[2]Treatments 1-15 were applied on 25 May to 30 to 45 cm tall johnsongrass; treatments 17-31 were applied on 11 June to 61 to 102 cm tall johnsongrass.
[3]DAT = Days After Treatment.

Table 3. Effect of 18 herbicide treatments on johnsongrass control, bermudagrass injury and bermudagrass height in ODOT Division 4 in 1994. (Experiment 4-H-75-94).

Treatments[1,2]	Rate	Percent Johnsongrass Control			Percent Bermudagrass Injury		Bermudagrass Height (cm)	
	(kg ai ha^{-1})	50 DAT[3]	100 DAT	1 YAT[4]	50 DAT	100 DAT	50 DAT	100 DAT
1. Arsenal + Roundup	0.14 + 0.42	92	85	77	65	43	6	12
2. Oust + Roundup	0.11 + 0.84	97	97	94	70	53	8	12
3. Plateau	0.14	58	62	73	35	17	10	13
4. Plateau + Arsenal	0.14 + 0.07	62	73	83	50	32	8	10
5. Plateau + Arsenal	0.14 + 0.10	82	80	88	83	73	7	10
6. Plateau + Arsenal	0.14 + 0.14	73	70	83	88	83	7	8
7. Plateau + Roundup	0.14 + 0.28	90	87	85	22	12	10	13
8. Plateau + Pursuit	0.14 + 0.07	58	47	60	38	28	10	14
9. Plateau + Roundup	0.14 + 0.42	75	76	80	54	50	11	11
10. Arsenal + Roundup	0.14 + 0.42	53	72	72	77	57	10	15
11. Oust + Roundup	0.11 + 0.84	93	93	93	82	65	10	17
12. Plateau	0.14	53	70	85	28	8	13	20
13. Plateau + Arsenal	0.14 + 0.07	57	67	78	58	47	11	14
14. Plateau + Arsenal	0.14 + 0.10	60	77	80	73	53	9	18
15. Plateau + Arsenal	0.14 + 0.14	68	70	75	78	67	10	14
16. Plateau + Roundup	0.14 + 0.42	85	88	93	50	25	9	17
17. Plateau + Roundup	0.14 + 0.28	47	53	77	40	20	12	21
18. Plateau + Pursuit	0.14 + 0.07	88	92	93	47	35	10	15
19. Check	-----	0	0	0	0	0	21	24
$LSD_{0.05}$		28	25	24	29	36	6	7

[1]All herbicide treatments had X-77 surfactant added at 0.25% v/v.

[2]Treatments 1-9 were applied on 20 May to 30 to 45 cm tall johnsongrass; treatments 10-18 were applied on 7 June to 91 to 152 cm tall johnsongrass.

[3]DAT = Days After Treatment.

[4]YAT = Years After Treatment.

Table 4. Effect of herbicide/adjuvant combinations on bermudagrass height, bermudagrass phytotoxicity and johnsongrass control in ODOT Division 4 in 1994 (Experiment 4-H-76-94).

Treatments[1]	Rate (kg ai ha^{-1})	Bermuda Height (cm)		Bermudagrass Phytotoxicity		Percent Johnsongrass Control		
		50 DAT[4]	100 DAT	50 DAT	100 DAT	50 DAT	100 DAT	1 YAT[5]
1. Plateau + (surf. + fert.)[2]	0.14 + 0.25% v/v	14	20	5	0	15	9	6
2. Plateau + Pursuit + (surf. + fert.)	0.14 + 0.07 + 0.25% v/v	14	19	7	0	25	15	16
3. Plateau + Roundup + (surf. + fert.)	0.14 + 0.28 + 0.25% v/v	13	20	12	2	48	40	37
4. Plateau + Arsenal + (surf. + fert.)	0.14 + 0.10 + 0.25% v/v	11	19	20	0	53	28	23
5. Plateau + MSO[3]	0.14 + 1.25% v/v	14	23	2	0	42	20	18
6. Plateau + Arsenal + MSO	0.14 + 0.10 + 1.25% v/v	10	14	68	27	77	55	40
7. Plateau + Roundup + MSO	0.14 + 0.28 + 1.25% v/v	14	19	9	1	62	43	42
8. Plateau + Pursuit + MSO	0.14 + 0.07 + 1.25% v/v	15	21	4	1	48	23	17
9. Plateau + (surf. + fert.)	0.14 + 0.25% v/v	21	27	2	0	25	17	17
10. Plateau + Arsenal + (surf. + fert.)	0.14 + 0.10 + 0.25% v/v	19	28	35	10	35	27	33
11. Plateau + Roundup + (surf. + fert.)	0.14 + 0.28 + 0.25% v/v	18	27	3	2	38	33	29
12. Plateau + Pursuit + (surf. + fert.)	0.14 + 0.07 + 0.25% v/v	21	27	7	0	25	10	10
13. Plateau + MSO	0.14 + 1.25% v/v	20	24	4	0	47	35	35
14. Plateau + Arsenal + MSO	0.14 + 0.10 + 1.25% v/v	17	23	72	45	75	82	82
15. Plateau + Roundup + MSO	0.14 + 0.28 + 1.25% v/v	19	23	9	2	58	48	50
16. Plateau + Pursuit + MSO	0.14 + 0.07 + 1.25% v/v	20	25	6	0	50	43	47
17. Check	----------	29	30	0	0	0	0	0
$LSD_{0.05}$		4	7	14	17	30	33	35

[1]Treatments 1-8 were applied on 24 May to 30 to 45 cm tall johnsongrass; treatments 9-16 were applied on 15 June to 61 to 102 cm tall johnsongrass.
[2]surf. + fert. = a combination of a surfactant + fertilizer (adjuvant).
[3]MSO = Methylated Seed Oil.
[4]DAT = Days After Treatment.
[5]YAT = Years After Treatment.

Table 5. Effect of initial applications of 15 herbicide treatments at 2 johnsongrass growth stages on bermudagrass height, bermudagrass injury and johnsongrass control in ODOT Division 4 in 1994 (Experiment 4-H-77-94, initial applications).

Treatments[1,2]		Rate (kg ai ha^{-1})	Bermuda Height (cm) 50 DAT[5]	Bermuda Height (cm) 100 DAT	Percent Bermuda Injury[3] 50 DAT	Percent Bermuda Injury[3] 100 DAT	Percent Johnsongrass Control[4] 50 DAT	Percent Johnsongrass Control[4] 100 DAT	Percent Johnsongrass Control[4] 1 YAT[6]
			20 to 46 cm height						
1.	Arsenal +	0.14							
	Roundup	0.42	8	8	23	43	63	75	72
2.	Oust +	0.11							
	Roundup	0.56	9	11	4	5	67	68	68
3.	Plateau +	0.14							
	Arsenal	0.07	7	11	9	6	56	40	25
4.	Plateau +	0.14							
	Arsenal	0.10	7	8	20	13	65	43	43
5.	Plateau +	0.14							
	Arsenal	0.14	11	10	15	13	58	45	45
6.	Plateau +	0.14							
	Roundup	0.42	8	10	7	10	65	60	67
7.	Plateau +	0.14							
	Roundup	0.28	11	12	7	8	68	52	60
8.	Plateau +	0.07							
	Roundup	0.42	12	10	5	5	55	65	75
9.	Plateau +	0.07							
	Roundup	0.28	13	14	7	3	52	40	57
10.	Plateau +	0.21							
	Roundup	0.42	9	9	6	7	83	68	58
11.	Plateau +	0.21							
	Roundup	0.28	12	12	8	7	65	35	25
12.	Plateau	0.21	10	12	23	15	50	50	58
13.	Plateau	0.14	11	12	12	7	65	47	50
14.	Plateau +	0.21							
	Arsenal	0.07	7	8	27	12	62	43	43
15.	Plateau +	0.14							
	Pursuit	0.07	10	11	27	13	53	35	22
16.	Check		19	16	0	0	0	0	0
$LSD_{0.05}$			NS	NS	12	13	22	27	32

[1]All herbicide treatments had X-77 surfactant added at 0.25% v/v.
[2]Treatments 1-15 were applied on 25 May to 20 to 46 cm tall johnsongrass; treatments 17-31 were applied on 16 June to 61 to 91 cm tall johnsongrass.
[3]Bermudagrass injury was rated on a 0 to 100 scale were 0 = no injury and 100 = complete brownout.
[4]Johnsongrass control was rated on a 0 to 100 scale where 0 = no control and 100 = complete control.
[5]DAT = Days After Treatment.
[6]YAT = Years After Treatment.

Table 5. Continued. (Experiment 4-H-77-94, initial applications)

Treatments[1,2]	Rate (kg ai ha^{-1})	Bermuda Height (cm) 50 DAT[5]	Bermuda Height (cm) 100 DAT	Percent Bermuda Injury[3] 50 DAT	Percent Bermuda Injury[3] 100 DAT	Percent Johnsongrass Control[4] 50 DAT	Percent Johnsongrass Control[4] 100 DAT	Percent Johnsongrass Control[4] 1 YAT[6]
		-61 to 91 cm height-						
17. Arsenal +	0.14							
Roundup	0.42	10	15	13	5	90	82	72
18. Oust +	0.11							
Roundup	0.56	11	16	15	0	95	93	88
19. Plateau +	0.14							
Arsenal	0.07	13	15	10	8	58	60	57
20. Plateau +	0.14							
Arsenal	0.01	13	14	10	8	75	75	85
21. Plateau +	0.14							
Arsenal	0.14	10	9	33	30	79	78	88
22. Plateau +	0.14							
Roundup	0.42	14	16	5	0	95	85	78
23. Plateau +	0.14							
Roundup	0.28	12	14	6	0	96	81	77
24. Plateau +	0.07							
Roundup	0.42	15	18	5	0	96	95	93
25. Plateau +	0.07							
Roundup	0.28	15	19	4	0	85	85	80
26. Plateau +	0.21							
Roundup	0.42	12	13	10	3	98	98	93
27. Plateau +	0.21							
Roundup	0.28	13	17	4	0	96	96	94
28. Plateau	0.21	14	15	11	6	40	40	50
29. Plateau	0.14	12	12	5	3	78	68	68
30. Plateau +	0.21							
Arsenal	0.07	14	15	15	8	78	85	80
31. Plateau +	0.14							
Pursuit	0.07	14	14	10	5	88	93	90
$LSD_{0.05}$		NS	NS	12	13	22	27	32

[1]All herbicide treatments had X-77 surfactant added at 0.25% v/v.
[2]Treatments 1-15 were applied on 25 May to 20 to 46 cm tall johnsongrass; treatments 17-31 were applied on 16 June to 61 to 91 cm tall johnsongrass.
[3]Bermudagrass injury was rated on a 0 to 100 scale where 0 = no injury and 100 = complete brownout.
[4]Johnsongrass control was rated on a 0 to 100 scale where 0 = no control and 100 = complete control.
[5]DAT = Days After Treatment.
[6]YAT = Years After Treatment.

Table 6. Effect of sequential applications of 15 herbicide treatments at 2 johnsongrass growth stages on bermudagrass height, bermudagrass injury and johnsongrass control in ODOT Division 4 in 1994. (Experiment 4-H-77-94, sequential applications).

Treatments[1,2]	Rate (kg ai ha^{-1})	Bermuda Height (cm) 50 DAT[5]	Bermuda Height (cm) 100 DAT	Percent Bermuda Injury[3] 50 DAT	Percent Bermuda Injury[3] 100 DAT	Percent Johnsongrass Control[4] 50 DAT	Percent Johnsongrass Control[4] 100 DAT	Percent Johnsongrass Control[4] 1 YAT[6]
		-30 to 41 cm height-						
1. Arsenal +	0.14							
Roundup	0.42	6	8	91	67	96	82	77
2. Oust +	0.11							
Roundup	0.56	10	11	25	13	89	95	91
3. Plateau +	0.14							
Arsenal	0.07	6	8	73	42	88	68	68
4. Plateau +	0.14							
Arsenal	0.10	8	7	77	57	86	83	81
5. Plateau +	0.14							
Arsenal	0.14	10	11	75	45	84	83	89
6. Plateau +	0.14							
Roundup	0.42	10	14	22	9	92	81	81
7. Plateau +	0.14							
Roundup	0.28	9	15	25	13	80	78	77
8. Plateau +	0.07							
Roundup	0.42	11	10	27	11	79	92	94
9. Plateau +	0.07							
Roundup	0.28	9	13	22	11	78	78	78
10. Plateau +	0.21							
Roundup	0.42	9	12	25	7	95	97	95
11. Plateau +	0.21							
Roundup	0.28	12	13	40	17	90	85	90
12. Plateau	0.21	10	12	37	12	90	80	80
13. Plateau	0.14	10	12	40	30	70	62	63
14. Plateau +	0.21							
Arsenal	0.07	6	9	73	47	87	77	77
15. Plateau +	0.14							
Pursuit	0.07	10	10	32	20	70	50	53
16. Check		14	15	0	0	0	0	0
$LSD_{0.05}$		NS	NS	19	20	16	29	29

[1]All herbicide treatments had X-77 surfactant added at 0.25% v/v.
[2]Sequential treatments 1-15 were applied on 7 July to 30 to 41 cm tall johnsongrass; sequential treatments 17-31 were applied on 15 July to 30 to 45 cm tall johnsongrass.
[3]Bermudagrass injury was rated on a 0 to 100 scale where 0 = no injury and 100 = complete brownout.
[4]Johnsongrass control was rated on a 0 to 100 scale where 0 = no control and 100 = complete control.
[5]DAT = Days After Treatment.
[6]YAT = Years After Treatment.

Table 6. Continued. (Experiment 4-H-77-94, sequential applications)

Treatments[1,2]	Rate (kg ai ha^{-1})	Bermuda Height (cm) 50 DAT[5]	Bermuda Height (cm) 100 DAT	Percent Bermuda Injury[3] 50 DAT	Percent Bermuda Injury[3] 100 DAT	Percent Johnsongrass Control[4] 50 DAT	Percent Johnsongrass Control[4] 100 DAT	Percent Johnsongrass Control[4] 1 YAT[6]
		---30 to 46 cm height---						
17. Arsenal +	0.14							
Roundup	0.42	10	11	25	27	93	88	83
18. Oust +	0.11							
Roundup	0.56	12	14	12	2	94	93	91
19. Plateau +	0.14							
Arsenal	0.07	9	11	13	7	87	68	63
20. Plateau +	0.14							
Arsenal	0.01	10	12	18	20	88	91	90
21. Plateau +	0.14							
Arsenal	0.14	9	8	78	70	95	96	96
22. Plateau +	0.14							
Roundup	0.42	9	12	13	10	97	81	77
23. Plateau +	0.14							
Roundup	0.28	11	15	10	8	98	77	73
24. Plateau +	0.07							
Roundup	0.42	15	18	8	3	95	92	90
25. Plateau +	0.07							
Roundup	0.28	10	12	23	15	94	95	95
26. Plateau +	0.21							
Roundup	0.42	10	10	35	14	98	97	97
27. Plateau +	0.21							
Roundup	0.28	11	15	8	2	97	96	96
28. Plateau	0.21	13	11	30	18	97	90	93
29. Plateau	0.14	10	11	18	13	60	40	40
30. Plateau +	0.21							
Arsenal	0.07	10	10	55	50	94	69	88
31. Plateau +	0.14							
Pursuit	0.07	12	12	30	4	94	88	93
$LSD_{0.05}$		NS	NS	19	20	16	29	29

[1]All herbicide treatments had X-77 surfactant added at 0.25% v/v.
[2]Sequential treatments 1-15 were applied on 7 July to 30 to 46 cm tall johnsongrass; sequential treatments 17-31 were applied on 15 July to 30 to 46 cm tall johnsongrass.
[3]Bermudagrass injury was rated on a 0 to 100 scale where 0 = no injury and 100 = complete brownout.
[4]Johnsongrass control was rated on a 0 to 100 scale where 0 = no control and 100 = complete control.
[5]DAT = Days After Treatment.
[6]YAT = Years After Treatment.

Table 7. Effect of 9 herbicide treatments at 2 johnsongrass growth stages on johnsongrass control, bermudagrass injury ratings and bermudagrass heights in ODOT Division 4 in 1995 (Experiment 4-H-80-95).

Treatments[1,2]	Rate (kg ai ha^{-1})	Percent Johnsongrass Control[3] 50 DAT[5]	Percent Johnsongrass Control[3] 100 DAT	Percent Bermudagrass Injury[4] 50 DAT	Percent Bermudagrass Injury[4] 100 DAT	Bermudagrass Height 50 DAT	Bermudagrass Height 100 DAT
1. Arsenal + Roundup	0.14 + 0.42	77	70	43	58	10	15
2. Oust +Roundup	0.11 + 0.84	98	96	22	2	12	18
3. Plateau	0.14	88	83	63	57	10	16
4. Plateau + Arsenal	0.14 + 0.07	92	92	53	45	9	14
5. Plateau + Arsenal	0.14 + 0.1	93	96	65	50	7	13
6. Plateau + Arsenal	0.14 + 0.14	93	90	62	48	8	12
7. Plateau + Roundup	0.14 + 0.28	93	88	18	0	15	19
8. Plateau + Pursuit	0.14 + 0.07	87	77	50	30	15	20
9. Plateau + Roundup	0.14 + 0.42	95	93	25	3	16	22
10. Arsenal + Roundup	0.14 + 0.42	97	86	60	57	11	16
11. Oust + Roundup	0.11 + 0.84	96	98	25	10	15	19
12. Plateau	0.14	90	89	37	38	15	18
13. Plateau + Arsenal	0.14 + 0.07	88	88	38	38	12	15
14. Plateau + Arsenal	0.14 + 0.1	86	86	33	33	11	15
15. Plateau + Arsenal	0.14 + 0.14	84	86	43	50	11	13
16. Plateau + Roundup	0.14 + 0.42	99	99	8	0	15	21
17. Plateau + Roundup	0.14 + 0.28	96	93	10	0	17	22
18. Plateau + Pursuit	0.14 + 0.07	99	99	6	0	16	17
19. Check	-----	0	0	0	0	24	22
$LSD_{0.05}$		11	15	31	37	5	7

[1]All herbicide treatments had X-77 surfactant added at 0.25% v/v.
[2]Treatments 1-9 were applied on 1 June to 46 to 61 cm tall johnsongrass; treatments 10-18 were applied on 15 June to 76 to 91 cm tall johnsongrass.
[3]Johnsongrass control was rated on a 0 to 100 scale where 0 = no control and 100 = complete control.
[4]Bermudgrass injury was rated on a 0 to 100 scale where 0 = no injury and 100 = complete brownout.
[5]DAT = Days After Treatment.

Table 8. Effect of Plateau/Roundup combinations with adjuvants on bermudagrass and johnsongrass in ODOT Division 4 in 1995 (Experiment 4-H-81-95).

Treatments[1]	Rate (kg ai ha^{-1})	Percent Bermudagrass Phytotoxicity[2] 2 WAT[4]	4 WAT	8 WAT	12 WAT	16 WAT	Percent Bermudagrass Seedhead Suppression[3] 4 WAT	8 WAT	12 WAT	16 WAT
1. Check	-----	0	0	43	0	0	0	0	0	0
2. Plateau +	0.11									
X-77	0.25% v/v	4	2	43	0	0	32	25	3	0
3. Plateau +	0.14									
X-77	0.25% v/v	10	6	27	0	0	68	50	5	0
4. Plateau +	0.17									
X-77	0.25% v/v	10	8	28	0	0	77	57	17	0
5. Plateau +	0.21									
X-77	0.25% v/v	15	12	42	0	0	82	65	2	0
6. Plateau +	0.11									
Roundup +	0.42									
X-77	0.25% v/v	18	15	37	0	0	93	73	7	0
7. Plateau +	0.14									
Roundup +	0.42									
X-77	0.25% v/v	17	12	23	0	0	78	43	2	0
8. Plateau +	0.17									
Roundup +	0.42									
X-77	0.25% v/v	25	18	37	0	0	90	60	13	0
9. Plateau +	0.21									
Roundup +	0.42									
X-77	0.25% v/v	27	23	50	0	0	92	47	27	0
10. Plateau +	0.17									
MSO	1.25% v/v	18	15	48	0	0	85	83	20	0
11. Plateau +	0.17									
Roundup +	0.42									
MSO	1.25% v/v	17	13	32	0	0	80	78	18	0
12. Roundup +	0.56									
Oust +	0.11									
X-77	0.25% v/v	20	12	35	0	0	80	42	8	0
$LSD_{0.05}$		10	9	21	NA	NA	30	21	24	NA

[1]Treatments were applied on 22 May to 46 to 61 cm tall johnsongrass.
[2]Bermudagrass phytotoxicity was rated on a 0 to 100 scale where 0 = no phtotoxicity and 100 = completely brown.
[3]Seedhead suppression was rated on a 0 to 100 scale where 0 = no seedhead suppression and 100 = complete suppression.
[4]WAT = Weeks After Treatment.

Table 8. Continued. (Experiment 4-H-81-95).

Treatments[1]	Rate (kg ai ha^{-1})	Bermudagrass Height (cm) 4 WAT[3]	8 WAT	12 WAT	16 WAT	Percent Johnsongrass Control[2] 4 WAT	8 WAT	12 WAT	16 WAT
1. Check	-----	31	33	28	23	0	0	0	0
2. Plateau +	0.11								
X-77	0.25% v/v	20	24	25	19	37	52	40	38
3. Plateau +	0.14								
X-77	0.25% v/v	15	18	27	18	60	92	52	50
4. Plateau +	0.17								
X-77	0.25% v/v	16	18	24	19	62	89	67	63
5. Plateau +	0.21								
X-77	0.25% v/v	14	16	21	18	72	96	82	82
6. Plateau +	0.11								
Roundup +	0.42								
X-77	0.25% v/v	14	15	20	17	82	97	93	93
7. Plateau +	0.14								
Roundup +	0.42								
X-77	0.25% v/v	14	17	25	20	80	94	82	76
8. Plateau +	0.17								
Roundup +	0.42								
X-77	0.25% v/v	12	17	23	18	77	94	88	88
9. Plateau +	0.21								
Roundup +	0.42								
X-77	0.25% v/v	14	17	23	21	78	96	96	96
10. Plateau +	0.17								
MSO	1.25% v/v	15	19	28	17	77	93	85	83
11. Plateau +	0.17								
Roundup +	0.42								
MSO	1.25% v/v	17	19	28	21	78	95	89	93
12. Roundup +	0.56								
Oust +	0.11								
X-77	0.25% v/v	14	16	23	18	82	94	91	89
$LSD_{0.05}$		7	6	8	4	18	19	21	25

[1]Treatments were applied on 22 May to 46 to 61 cm tall johnsongrass.

[2]Johnsongrass control was rated on a 0 to 100 scale where 0 = no control and 100 = complete control.

[3]WAT = Weeks After Treatment.

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3. Management of Switchgrass with Selective Herbicides and Mowing/Herbicide Combinations

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3.1 INTRODUCTION

The Oklahoma Department of Transportation's current roadside vegetation management program utilizing selective weed control practices has allowed switchgrass (*Panicum virgatum* L.) to proliferate and become a major weed problem in the western two-thirds of the state. Switchgrass is a native, perennial, warm-season, bunch-type tall grass which reproduces from underground stems and seeds (3). Its tall upright growth habit enables it to successfully compete with the desirable common bermudagrass (*Cynodon dactylon* L.) along highway roadsides. As a result, serious problems with sight distance have occurred along roadsides necessitating additional mowings and thus increasing ODOT's roadside maintenance expenditures.

In a review of the literature, no information was found concerning herbicides effective in the control of switchgrass. However, experiments conducted in an earlier ODOT/OSU Joint Project indicated significant switchgrass growth suppression could be achieved with the use of plant growth regulators/herbicides including Oust (2).

The objective of these experiments was to screen a number of herbicide compounds for their efficacy in controlling switchgrass ($\geq$90% control was satisfactory) while providing an acceptable level of phytotoxicity (rating of 4.6 to 5.1 not exceeding a duration of 4 to 6 weeks) or injury to common bermudagrass.

3.2.0 MATERIALS AND METHODS

3.2.1 Preliminary Greenhouse Experiment 4-H-61-92

Due to a lack of research data available for switchgrass efficacy from herbicide applications, a preliminary greenhouse study (Experiment 4-H-61-92) was initiated during the winter of 1992. This method enabled the authors to investigate the efficacy of 32 treatments and 16 actual herbicides during a relatively short period of time. This work was conducted with the intent that the most promising herbicide treatments could be included in a field efficacy trial during the spring of 1992.

On 6 January 1992, 10 cm dia. x 20 cm deep plugs were collected from the crowns of dormant, lowland switchgrass plants growing on a fine sandy loam soil along SR 51, 13.7 km west of Stillwater in Payne County in ODOT Division 4. Plants were placed in 10 cm x 20 cm deep plastic pots and placed into a greenhouse at the OSU Turfgrass Research Center. Greenhouse conditions were maintained at a 29°C ± 4°C maximum and a 21.1°C ± 4°C minimum temperature under a 12-hour photoperiod. Lamps used in the experiment were of the metal halide 1000 W type. Plants were allowed to break dormancy and grow to a height of approximately 46 cm. They were then removed from the greenhouse and placed onto a gravel surface for treatment 28 February 1992. Ambient temperatures ranged from 12.8 to 18.3°C during the herbicide treatment/air drying period. The experimental design was a randomized complete block with four replications. Plot size was one 10.2 cm dia. pot per replication. Treatments were applied using a CO_2 hand-held boom sprayer equipped with TeeJet 80015 flat fan spray tips that were calibrated to deliver 374 ℓ ha^{-1} utilizing a pressure of 207 kPa. Herbicides treatments included Poast at 0.31 and 0.45 kg ai ha^{-1}; Fusilade at 0.21 and 0.43 kg ai ha^{-1}; Vision at 0.56 and 1.12 kg ai ha^{-1}; Select at 0.11 and 0.22 kg ai ha^{-1};

Asulox at 3.74 and 7.48 kg ai ha^{-1}; Whip 1 EC at 0.20 and 0.39 kg ai ha^{-1}; Verdict at 0.28 and 0.56 kg ai ha^{-1}; Arsenal at 0.28 and 0.56 kg ai ha^{-1}; Scepter at 0.14 and 0.28 kg ai ha^{-1}; Pursuit at 0.07 and 0.14 kg ai ha^{-1}; Assure at 0.11 and 0.22 kg ai ha^{-1}; Hoelon at 0.84 and 1.26 kg ai ha^{-1}; Prograss at 1.68 and 3.36 kg ai ha^{-1}; Roundup at 1.12 and 1.68 kg ai ha^{-1}; Whip Super at 0.20 and 0.39 kg ai ha^{-1}; and Oust at 0.10 and 0.21 kg ai ha^{-1}. These herbicides were included in this experiment because a review of their respective labels revealed they had herbicidal activity on C-4 grass species. The rates of products used were the highest and lowest labeled rates on their 1992 commercial labels. Plants were allowed to air dry for several hours before being placed back into the greenhouse.

Visual evaluations were made at 30, 60 and 90 days after treatment (DAT) for switchgrass phytotoxicity. The ANOVA for a split plot in time design was performed on the data. Main plots were herbicide treatments with rating dates as subplots. As a significant treatment date interaction was present, an LSD was used to separate treatment means within sampling dates.

3.2.2 Switchgrass Control Experiment 4-H-64-92

Based on the results generated in the preliminary greenhouse study (Experiment 4-H-61-92), the nine herbicides which exhibited the most phytotoxicity to switchgrass were evaluated in a roadside field study. Experiment 4-H-64-92 was conducted on a sandy clay loam along side SR 51, 2.4 km east of the junction of SR 48 in Creek County in ODOT Division 4. Treatments were applied on 26 May 1992 using a CO_2-pressurized bicycle sprayer calibrated to deliver 374 ℓ ha^{-1} at 193 kPa equipped with TeeJet 8003 stainless steel, flat-fan spray tips. Plots measured 2.4 x 6.0 m and were replicated three times in a randomized complete block design. Application was made to actively growing switchgrass plants measuring 61 to 76 cm in height.

Herbicide treatments included Poast at 0.31 and 0.45 kg ai ha^{-1}; Fusilade at 0.21 and 0.43 kg ai ha^{-1}; Select at 0.11 and 0.22 kg ai ha^{-1}; Asulox at 3.74 and 7.48 kg ai ha^{-1}; Verdict at 0.28 and 0.56 kg ai ha^{-1}; Arsenal at 0.28 and 0.56 kg ai ha^{-1}; Assure at 0.11 and 0.22 kg ai ha^{-1}; Roundup at 1.12 and 1.68 kg ai ha^{-1}; and Oust at 0.10 and 0.21 kg ai ha^{-1}. All herbicide treatments except Roundup had a crop oil added at 0.5% v/v.

Treatments were evaluated on 26 June 1992 at 1 month after treatment (MAT); 27 July 1992 (2 MAT); 27 August 1992 (3 MAT); 3 June 1993 (12 MAT); and 26 July 1993 (14 MAT). Visual ratings were made for bermudagrass phytotoxicity, switchgrass phytotoxicity, switchgrass height and switchgrass seedhead suppression. Bermudagrass phytotoxicity was visually rated on a scale of 1 to 10 where 1 = no effect and 10 = complete yellowing. Switchgrass phytotoxicity was visually rated on a scale of 1 to 10 where 1 = no effect and 10 = complete yellowing. Switchgrass heights were taken by measuring plant height (cm) in three randomly selected samples from each plot. Switchgrass seedhead suppression was visually rated on a scale of 0 to 100 where 0 = no seedhead suppression and 100 = complete seedhead suppression. Data analysis was conducted as in Section 3.2.1.

3.2.3 Switchgrass Control Experiment 8-H-33-92

This experiment was identical to Experiment 4-H-64-92 with the same herbicides, rates, experimental design, carrier rates and application method except treatments were applied to actively growing mature switchgrass plants approximately one month before dormancy on 4 September 1992. The hypothesis was made that mature switchgrass plants may be more susceptible to herbicide applications made in the fall of the year as compared to late spring or early summer applications. Experiment 8-H-33-92 was conducted on a fine sandy loam along side SR 51, 5.8 km west of the junction of SR 48 in Creek County in ODOT Division 8.

Evaluations were made at 9 and 10 months after treatment (MAT) for switchgrass control and switchgrass height using the method discussed in Section 3.2.2 and analyzed as described in Section 3.2.1.

3.2.4 Switchgrass Control Experiment 8-H-36-93 (lst year applications)

This experiment was a nearby identical duplication of Experiment 4-H-64-92 having the same herbicide treatments, application rates, replications and method of application. Experiment 8-H-36-93 was conducted on a fine sandy loam soil along side SR 51, 6.0 km west of the junction of SR 48 in Creek County in ODOT Division 8. Herbicide treatments were applied on 28 May 1993 to actively growing switchgrass plants approximately 38 to 48 cm in height.

Evaluations were made at 1, 2 and 3 MAT for bermudagrass phytotoxicity, switchgrass phytotoxicity and switchgrass heights as previously described in Section 3.2.2 with analysis conducted as described in Section 3.2.1.

3.2.5 Switchgrass Control Experiment 8-H-38-94 (2nd year applications)

This experiment was conducted to evaluate the efficacy of several herbicide treatments when applied in two consecutive years (Year 1 = Experiment 8-H-36-93) for the selective control of switchgrass growing in bermudagrass roadsides. Repeat treatments utilizing the same herbicides and rates were applied to plots of actively growing switchgrass plants 30 to 61 cm in height on 27 May 1994, in the experimental area previously designated as Experiment 8-H-36-93.

Methods of evaluation and analysis were the same as given in the previous discussion in Section 3.2.4. Additionally, switchgrass seedhead suppression was visually rated as described in Section 3.2.2

3.2.6 Switchgrass Mowing/Herbicide Interaction Experiment 8-H-39-94 (1st year applications)

Although six treatments provided a consistent level of switchgrass control in Experiment 8-H-38-93, the level of switchgrass control achieved through single, yearly herbicide applications alone was unsatisfactory. Therefore, the objective of this experiment was to evaluate the efficacy of six herbicide treatments (three herbicides at two rates each) followed by timely mowing cycles for the selective control of switchgrass in bermudagrass roadsides.

This experiment was located adjacent to Experiment 8-H-38-94. Treatments were applied 2 June 1994 to actively growing switchgrass plants measuring 27 to 76 cm in height. Herbicide treatments evaluated included Fusilade at 0.21 and 0.43 kg ai ha^{-1}; Verdict at 0.28 and 0.56 kg ai ha^{-1}; and Assure at 0.11 and 0.22 kg ai ha^{-1}. All herbicide treatments were combined with a crop oil at 0.5% v/v. Herbicide treatments were applied to 4.8 x 6.0 m main plots using a CO_2 powered, bicycle boom sprayer calibrated to deliver 374 ℓ ha^{-1}. Mowing cycles were initiated on 1 July and 22 August 1994 just as switchgrass seedhead formation began. Plots were mowed at a height of 10 cm during each mowing cycle. The experimental design was a randomized complete block with three replications, using a split plot arrangement of treatments split in time. Visual observations were made for bermudagrass phytotoxicity, switchgrass height, percent switchgrass seedhead suppression, percent switchgrass density (percentage of plot covered with switchgrass), percent bermudagrass density and switchgrass control. Percent switchgrass density and bermudagrass density were visually rated for each plot. Other parameters were measured as described in Section 3.2.2.

3.2.7 Switchgrass Mowing/Herbicide Interaction Experiment 8-H-40-95 (2nd year applications)

This experiment was conducted to evaluate the efficacy of six herbicide treatments followed by timely mowing cycles after two consecutive years for the selective control of switchgrass in bermudagrass roadsides. Repeat treatments utilizing the same herbicides, rates and number of mowing cycles were initiated in the same plots within the experimental area previously designated as Experiment 8-H-39-94. Herbicides were applied on 7 June 1995 to actively growing switchgrass plants 30 to 76 cm in height. Methods of herbicide application, mowing and experimental design were the same as previously described in the above text in Section 3.2.6. Mowing treatments consisted of 0, 1 or 2 mowings per year. Mowing at a 10 cm height with a rotary mower was conducted on 7 July and again on 24 August 1995 as switchgrass seedhead emergence began. Visual observations were made for herbicide phytotoxicity to bermudagrass, percent bermudagrass cover, percent switchgrass cover and switchgrass control as described in Sections 3.2.2 and 3.2.6. Plots were evaluated at 1, 2, 3 and 4 MAT.

3.3.0 RESULTS AND DISCUSSION

3.3.1 Preliminary Greenhouse Experiment 4-H-61-92

Based upon data presented in Table 9, the most effective herbicide treatments included Poast, Fusilade, Select, Asulox, Verdict, Arsenal, Assure, Roundup and Oust.

Research data collected from this experiment was utilized to formulate the field experiments along roadsides from 1992 through 1995.

3.3.2 Switchgrass Control Experiment 4-H-64-92

Significant bermudagrass phytotoxicity was observed during all three evaluation dates (Table 10). All treatments exhibited significant bermudagrass phytotoxicity at 1 MAT with the only exception being the treatment of the lowest rate of Roundup (1.12 kg ai ha^{-1}). When rated at 2 MAT, the following treatments had caused significant bermudagrass phytotoxicity: the high rate of Fusilade, both rates of Verdict, both rates of Arsenal and the higher rate of Assure. The remaining treatments were showing some symptoms of discoloration but were acceptable. The only treatments exhibiting significant bermudagrass phytotoxicity when evaluations were made 3 MAT were the higher rate of Verdict and both rates of Arsenal. The phytotoxicity observed in the plots treated with Verdict would probably be acceptable for most roadside managers, however, the amount of injury observed from both treatments of Arsenal would not be acceptable.

Significant phytotoxicity was present on switchgrass during all three evaluation dates. All treatments except Oust exhibited significant phytotoxicity on switchgrass 1 MAT. When evaluations were made 2 MAT, the only treatment not showing significant phytotoxicity was the lower rate of Oust. This same trend was observed 3 MAT, with the addition of the lower rate of Asulox. The following treatments in this experiment appear to exhibit the greatest amount of switchgrass phytotoxicity: the higher rate of Fusilade, both rates of Verdict, and the higher rate of Assure.

Switchgrass height was significantly reduced by all herbicide treatments as compared to that of the control plots except for the lower rate of Asulox 1 and 2 MAT. By 3 MAT the mean height of switchgrass in all treated plots was significantly less than in the control plots. The greatest amount of suppression in overall switchgrass height in this experiment appeared to be from the following treatments: the higher rate of Fusilade, both rates of Verdict and both rates of Arsenal.

At 2 MAT, switchgrass seedhead suppression was significantly reduced by all herbicide treatments except both rates of Asulox. This same trend was observed 3 MAT with the addition of the lower rate of Oust. The better treatments in this experiment for reducing switchgrass seedhead production appear to be the following: the higher rate of Fusilade, both rates of Verdict, both rates of Arsenal and both rates of Assure.

It was important to monitor the effectiveness of the various herbicide treatments during the growing season following application. Therefore, the following data represent the level of long-term switchgrass control and/or growth suppression.

As of August 1992 many of the treatments in this experiment were maintaining a significant level of switchgrass phytotoxicity. Even though numerous treatments provided statistically significant switchgrass control at 12 MAT, no treatment was providing an acceptable level of switchgrass control (Table 11). Based on the results of this trial, the herbicides which show the most promise from strictly an efficacy standpoint were Verdict, Assure, Fusilade and Roundup.

Switchgrass heights were effectively reduced by all herbicides during the 1992 growing season. However, one year after application, the switchgrass plants that survived the herbicide application seemed to be healthy and resumed normal growth patterns.

3.3.3 Switchgrass Control Experiment 8-H-33-92

Because of seasonal physiological changes occurring in the switchgrass plant it was hypothesized that the plant may be more susceptible to herbicides in the fall of the year. In the fall, movement of sugars in switchgrass (and most perennials) is primarily downward from the foliage to the crown. The application of the correct herbicide during this translocation period would possibly be moved to the growing point (crown) and effectively control the plant. All treatments in this experiment were applied to actively growing mature switchgrass plants approximately one month before fall dormancy.

No herbicide treatment provided an acceptable level of switchgrass control at 9 and 10 MAT. While the low rate of Roundup at 9 MAT and the high rate of Arsenal at 9 and 10 MAT provided significant reduction in switchgrass plant height, these plants were still substantially taller than the recommended (1) 30.5 cm maximum plant height for roadsides. Based on the poor efficacy results obtained with fall applications of herbicide treatments in this experiment, no additional fall switchgrass control trials were conducted.

3.3.4 Switchgrass Control Experiment 8-H-36-93 (1st year applications)

When plots were rated 1 MAT, all herbicide treatments were exhibiting significant bermudagrass phytotoxicity except the following treatments: both rates of Select, the lower rate of Asulox and the lower rate of Roundup (Table 13). At 2 MAT, all plots continued showing significant bermudagrass phytotoxicity except those treated with the high rate of Poast, the low rate of Fusilade and both rates of Select and Asulox. At 3 MAT, all plots treated with either Arsenal or Oust were the only treatments still exhibiting significant bermudagrass phytotoxicity.

Significant switchgrass phytotoxicity was observed from all herbicide treatments when ratings were made 1 and 2 MAT. By 3 MAT, those treatments which appeared to have the most phytotoxic effects on switchgrass were the higher rate of Fusilade, both rates of Verdict and the higher rates of both Arsenal and Assure.

Switchgrass height was significantly reduced by all herbicide treatments when evaluations were made 1 and 2 MAT. This same trend was observed when ratings were made 3 MAT, with the only exception being the lower rate of Asulox (which was the only treatment not exhibiting significant switchgrass height reduction). Those treatments which provided the greatest reduction in switchgrass height in this experiment were the higher rate of Fusliade, both rates of Verdict and both rates of Arsenal.

3.3.5 Switchgrass Control Experiment 8-H-38-94 (2nd year applications)

After three years of screening herbicides and rates including those in this experiment, it became apparent that there would not be a simple method consisting of a single application that provided an acceptable level of switchgrass control (≥90%). One of the goals of this experiment was to reapply similar herbicide treatments over the same plots in Experiment 8-H-36-93 in two successive years. As it had appeared in the past that after one year of applications some plots were showing reductions in switchgrass crowns, a question arose as to whether a second year of applications would continue this reduction, eventually leading to acceptable control of switchgrass in the plots.

Switchgrass phytotoxicity ratings indicated an increase in activity from several of the treatments as compared to the previous year's experiment. During the second year, many treatments maintained or increased their level of control compared to the first year. Treatments of Fusilade (higher rate) and Verdict produced excellent switchgrass control

3 MAT evaluation (Table 14). Other treatments producing good control were Poast (higher rate), Fusilade (lower rate), Select (higher rate), Assure and Roundup (higher rate).

The treatments of Fusilade (higher rate), Asulox (higher rate), Verdict, Arsenal and Assure were all producing significant bermudagrass injury 1 MAT. At 2 MAT and 3 MAT, only the Arsenal treatments were producing significant injury to the bermudagrass.

All treatments, except Oust, Asulox, and Roundup (lower rate), were producing excellent switchgrass seedhead suppression 2 MAT. Treatments of Poast, Fusilade, Select, Verdict, and Assure were able to maintain good to excellent suppression throughout the growing season. These treatments could potentially reduce the number of seeds produced by the switchgrass plant, and thus reduce its ability to spread. However, to verify this, a sampling for seed production would be required to assess the number, quality and viability of the seeds produced.

Many of the herbicide treatments demonstrated the ability to reduce the overall canopy height of switchgrass. At 1 MAT and 2 MAT all treatments were significantly reducing switchgrass canopy heights. By 3 MAT, all treatments were maintaining significant height reduction which ranged from 22 to 69% of the untreated check.

3.3.6 Switchgrass Mowing/Herbicide Interaction Experiment 8-H-39-94 (1st year applications)

All herbicide treatments caused significant bermudagrass injury (Table 15) 1 MAT. By 2 MAT, only the higher rates of Fusilade and Assure caused bermudagrass phytotoxicity, however, these effects were not statistically significant. No bermudagrass phytotoxicity was observed from any herbicide treatment when evaluations were made 3 and 4 MAT. Due to the large amount of data generated from this experiment, our remaining discussion in this section is based upon the 4 MAT evaluations. All herbicide treatments resulted in lower switchgrass heights in the unmowed subplots when compared to the untreated check, however, no significant differences among herbicide treatments were observed (Table 16). No significant differences in switchgrass heights were observed among any of the herbicide subplot treatments which had been mowed either once or twice.

Significant switchgrass seedhead suppression occurred with all herbicide treatments in the unmowed subplots when compared to the untreated check, however, no significant differences among herbicide treatments were observed (Table 17). In subplots mowed once, only treatments of the higher rate of Fusilade and the lower rate of Verdict were significantly different from the higher rate of Verdict for switchgrass seedhead suppression. No significant differences among any herbicide treatments were observed in any subplot mowed twice.

Switchgrass cover was significantly reduced by all herbicide treatments (Table 18). No significant differences among herbicide treatments were observed for percent switchgrass cover.

Plots treated with the higher rate of Fusilade contained significantly greater amounts of bermudagrass cover than plots treated with the higher rate of Assure or the untreated check. There were no significant differences among the remainder of the herbicide treatments for percent bermudagrass cover.

Significant switchgrass control was exhibited by all herbicide treatments in the unmowed subplots (Table 19). The higher rate of Fusilade provided significantly better switchgrass control than both rates of Assure in the unmowed subplots. There were no significant differences among the remainder of the herbicide treatments. With the exception of the higher rate of Verdict, no treatment was significantly different from the untreated check plot when subplots were mowed once. At 4 MAT all treatments consisting of a herbicide plus two mowings provided significant control of switchgrass as compared to treatments that contained no herbicide plus two mowings. However, when either one or two mowing cycles were combined with a selective herbicide during the first year of this experiment, switchgrass control efficacy was not improved as compared to the use of a selective herbicide alone 4 MAT.

3.3.7 Switchgrass Mowing/Herbicide Interaction Experiment 8-H-40-95 (2nd year applications)

At 1 MAT, all herbicide treatments were causing significant bermudagrass injury (Table 20). All rates of Assure and Verdict were significantly more phytotoxic to bermudgrass than the other treatments. No herbicide phytotoxicity was observed on bermudagrass 2, 3 and 4 MAT.

Due to the amount of data generated from this experiment and the fact that any treatment implemented into an actual operations phase would need to provide at least 4 months of weed control, the following information is based on the 4 MAT evaluations. No significant difference in percent bermudagrass plot cover was evident due to herbicide treatments (data not shown). Mowing either 1 or 2 times per year resulted in significantly more bermudagrass coverage compared to no mowing, with no statistical differences between 1 or 2 mowings (Table 21). Percent bermudagrass coverage was 37, 51 and 54% for 0, 1 and 2 mowings, respectively, after two years.

Switchgrass plot cover was significantly affected by the number of mowings practiced (Table 21). Mowing 2 times per year produced significantly less switchgrass coverage than 0 or 1 mowings per year. Mowing 1 time per year also resulted in significantly less switchgrass coverage as compared to no mowing. Percent switchgrass cover was 20, 15 and 6% for 0, 1 and 2 mowings per year, respectively. Herbicides had a significant effect on switchgrass cover (Table 22). In plots which received no mowing, the higher rate of Verdict (0.56 kg ai ha^{-1}) resulted in significantly less switchgrass cover than all other treatments except the lower rate of Verdict (0.28 kg ai ha^{-1}). Significantly less switchgrass cover was present in plots mowed 1 time per year when treated with the higher rate of Verdict (0.56 kg ai ha^{-1}) and Assure (0.11 kg ai ha^{-1}). In plots mowed twice per year, percent switchgrass coverage was significantly higher in plots treated with the lower rate of Fusilade (0.21 kg ai ha^{-1}) or the check (control) when compared to all other treatments.

Herbicide control ratings for switchgrass were averaged over mowing treatments to provide a significance ranking of: control < Fusilade (0.21 kg ai ha^{-1}) = Assure (0.22 kg ai ha^{-1}) = Fusilade (0.43 kg ai ha^{-1}) = Assure (0.11 kg ai ha^{-1}) = Verdict (0.28 kg ai ha^{-1}) = Verdict (0.56 kg ai ha^{-1}) (Table 22). A significant mowing frequency X herbicide interaction was found. Overall, mowing 1 or 2 times per year provided better control of switchgrass than no mowing (Table 21).

3.4 CONCLUSIONS

Based upon the research data from the preliminary greenhouse experiment and subsequent field experiments, it became apparent that switchgrass was going to be a very difficult plant to control with a single herbicide application during the late spring. Since the spring application didn't work as well as expected, it was hypothesized that a fall application of similar herbicide treatments and rates might possibly be the answer to this problem. Results from Experiment 8-H-33-92 indicated quite the opposite to be true. The approach was then taken to apply the same herbicide treatments and rates for two consecutive years to possibly control switchgrass (Experiments 8-H-36-93 and 8-H-38-94). When results from this multi-year approach indicated this method was still not the desired answer for controlling switchgrass, another approach that integrated mowing with herbicide applications was tested. Herbicides were applied either alone or in combination with timely mowing cycles to improve switchgrass efficacy for not only one year (Experiment 8-H-39-94) but for two consecutive years (Experiment 8-H-40-95). Verdict at 0.28 and 0.56 kg ai ha^{-1}; Assure at 0.11 and 0.21 kg ai ha^{-1}; and Fusilade at 0.43 kg ai ha^{-1} consistently provided the best switchgrass control and an acceptable level of bermudagrass phytotoxicity when integrated with 1 or 2 timely mowing cycles. Presently, only Assure and Fusilade are labeled for use on highway rights-of-way. Verdict, the herbicide which consistently provided the best switchgrass control, is not currently labeled for any herbicidal use in the United States. After visiting with DowElanco representatives it appears that no effort will be underway in the near future to pursue federal registration of the product Verdict due to the cost of registration of the product relative to the potential sales income from the product.

Future research is planned that will focus on changing from a conventional broadcast method of herbicide application to one with a pipe-wick or rope-wick method of applying herbicides. Hopefully, this method will prove to be the answer to a very difficult plant to selectively control in bermudagrass roadsides.

Table 9. Effect of 32 herbicide treatments on switchgrass growing in a greenhouse in 1992 (Experiment 4-H-61-92).

Treatments[2]		Rate (kg ai ha^{-1})	Switchgrass Phytotoxicity[1]		
			1 MAT[3]	2 MAT	3 MAT
1.	Poast	0.31	3.8	4.5	4.8
2.	Poast	0.45	3.8	5.0	5.0
3.	Fusilade	0.21	3.8	5.0	4.8
4.	Fusilade	0.43	4.3	6.3	6.3
5.	Vision	0.56	1.3	2.5	3.5
6.	Vision	1.12	2.0	2.5	4.0
7.	Select	0.11	2.3	2.8	3.5
8.	Select	0.22	5.5	5.8	5.8
9.	Asulox	3.74	1.8	5.8	5.8
10.	Asulox	7.48	3.0	8.5	7.8
11.	Whip 1 EC	0.20	2.8	3.8	4.8
12.	Whip 1 EC	0.39	2.3	3.5	4.0
13.	Verdict	0.28	4.5	7.5	8.0
14.	Verdict	0.56	8.0	8.8	7.5
15.	Arsenal	0.28	5.0	6.3	5.3
16.	Arsenal	0.56	4.0	7.3	5.8
17.	Scepter	0.14	4.0	4.0	3.3
18.	Scepter	0.28	2.3	2.8	3.0
19.	Pursuit	0.07	2.8	3.3	3.8
20.	Pursuit	0.14	2.5	3.5	4.0
21.	Assure	0.11	5.8	6.3	6.3
22.	Assure	0.22	4.3	5.0	5.0
23.	Hoelon	0.84	1.3	3.0	3.5
24.	Hoelon	1.26	2.0	3.3	4.5
25.	Prograss	1.68	1.5	2.3	3.3
26.	Prograss	3.36	1.5	4.0	5.5
27.	Roundup	1.12	2.8	2.5	3.5
28.	Roundup	1.68	4.3	4.3	4.0
29.	Whip Super	0.20	2.0	3.3	4.0
30.	Whip Super	0.39	2.0	4.3	4.8
31.	Oust	0.10	3.3	4.3	3.3
32.	Oust	0.21	4.3	6.3	4.3
33.	Check	-----	1.5	1.3	2.3
$LSD_{0.05}$			1.8	2.0	1.8

[1]Switchgrass phytotoxicity was visually rated on a scale of 1 to 10 where 1 = no effect and 10 = complete yellowing.
[2]All treatments except Vision, Prograss and Roundup had a crop oil added at 0.5% v/v.
[3]MAT = Months After Treatment.

Table 10. Effect of 18 spring applied post-emergent herbicide treatments on switchgrass in ODOT Division 4 during 1992 (Experiment 4-H-64-92).

Treatments[1]	Rate (kg ai ha^{-1})	Bermudagrass Phytotoxicity[2]			Switchgrass Phytotoxicity[3]			Switchgrass Height (cm)[4]			Percent Switchgrass Seedhead Suppression	
		1 MAT[5]	2 MAT	3 MAT	1 MAT	2 MAT	3 MAT	1 MAT	2 MAT	3 MAT	2 MAT	3 MAT
1. Poast	0.31	4.0	2.3	1.0	3.7	4.7	5.3	54	55	55	75	57
2. Poast	0.45	4.3	2.7	1.7	5.0	7.3	7.7	54	52	54	95	82
3. Fusilade	0.21	4.0	2.3	1.3	5.7	8.3	7.7	47	45	52	100	80
4. Fusilade	0.43	5.7	3.3	1.7	7.3	9.5	9.5	46	43	38	100	98
5. Select	0.11	2.7	2.0	1.0	4.3	4.7	4.7	52	56	58	65	60
6. Select	0.22	3.0	2.3	1.7	5.0	5.8	6.0	50	55	53	83	73
7. Asulox	3.74	2.0	2.0	1.0	4.0	2.3	2.0	74	89	83	5	3
8. Asulox	7.48	2.7	2.0	1.0	5.0	4.3	4.0	64	75	84	20	13
9. Verdict	0.28	5.3	4.0	2.3	7.3	9.4	9.3	44	47	44	100	100
10. Verdict	0.56	6.0	5.3	3.7	7.0	9.3	9.7	52	50	39	100	100
11. Arsenal	0.28	4.7	8.0	5.7	4.7	8.2	8.0	49	52	49	100	90
12. Arsenal	0.56	5.3	9.0	7.7	4.0	7.0	7.0	52	50	45	100	90
13. Assure	0.11	7.0	2.0	1.0	7.7	8.8	8.0	47	49	49	95	88
14. Assure	0.22	7.0	4.0	1.7	7.7	9.5	9.2	55	49	54	98	92
15. Roundup	1.12	2.0	1.7	1.0	3.7	3.7	4.0	57	76	65	38	37
16. Roundup	1.68	3.7	2.7	1.3	4.3	6.3	7.0	57	63	62	60	60
17. Oust	0.10	2.3	2.7	1.3	2.3	2.0	1.7	60	73	66	30	22
18. Oust	0.21	2.3	2.3	1.0	2.7	4.0	3.7	52	62	64	30	28
19. Check	-----	1.0	1.0	1.0	1.0	1.0	1.0	84	93	104	0	0
$LSD_{0.05}$		1.2	1.8	1.4	1.8	1.9	2.1	13	17	15	23	23

[1]All treatments except Roundup had a crop oil added at 0.5% v/v.
[2]Phytotoxicity to bermudagrass was rated on a 1 to 10 scale where 1 = no effect and 10 = complete yellowing.
[3]Phytotoxicity to switchgrass was rated on a 1 to 10 scale where 1 = no effect and 10 = complete yellowing.
[4]Mean switchgrass plant height in cm.
[5]MAT = Months After Treatment.

Table 11. Effect of 1992 spring applied post-emergent herbicide treatments on switchgrass in ODOT Division 4 in 1993 (Experiment 4-H-64-92).

Treatments[1,2]		Rate ($kg\ ai\ ha^{-1}$)	Switchgrass Control[3] 12 MAT[4]	Switchgrass Control[3] 14 MAT	Switchgrass Height (cm) 12 MAT	Switchgrass Height (cm) 14 MAT
1.	Poast	0.31	2.0	2.0	49	83
2.	Poast	0.45	2.0	2.0	52	88
3.	Fusilade	0.21	2.3	2.0	47	75
4.	Fusilade	0.43	4.0	3.7	42	71
5.	Select	0.11	3.3	2.7	45	68
6.	Select	0.22	3.0	2.7	48	75
7.	Asulox	3.74	2.7	2.3	50	80
8.	Asulox	7.48	3.3	3.0	50	79
9.	Verdict	0.28	6.0	5.0	44	69
10.	Verdict	0.56	7.3	7.0	39	71
11.	Arsenal	0.28	4.0	3.7	52	82
12.	Arsenal	0.56	3.7	3.3	48	78
13.	Assure	0.11	3.3	3.0	45	78
14.	Assure	0.22	4.0	3.3	47	77
15.	Roundup	1.12	3.0	2.7	47	72
16.	Roundup	1.68	3.3	3.0	51	81
17.	Oust	0.10	2.3	2.0	47	72
18.	Oust	0.21	2.3	2.0	48	76
19.	Check	-----	1.0	1.0	53	83
$LSD_{0.05}$			1.9	1.9	7	14

[1]All treatments except Roundup had a crop oil added at 0.5% v/v.
[2]Treatments were applied on 26 May 1992.
[3]Switchgrass control was visually rated on a 1 to 10 scale where 1 = no control and 10 = complete control.
[4]MAT = Months After Treatment.

Table 12. Effect of fall applied post-emergent herbicide treatments on switchgrass in ODOT Division 8 (Experiment 8-H-33-92).

Treatments[1,2]		Rate (kg ai ha^{-1})	Switchgrass Control[3]		Switchgrass Height (cm)	
			9 MAT[4]	10 MAT	9 MAT	10 MAT
1.	Poast	0.31	2.0	1.0	45	73
2.	Poast	0.45	2.7	1.0	43	73
3.	Fusilade	0.21	2.3	1.0	40	66
4.	Fusilade	0.43	3.0	1.0	39	63
5.	Select	0.11	2.0	1.0	40	65
6.	Select	0.22	2.0	1.0	41	67
7.	Asulox	3.74	2.0	1.0	41	66
8.	Asulox	7.48	2.7	1.0	42	66
9.	Verdict	0.28	2.7	1.3	38	65
10.	Verdict	0.56	4.0	2.3	38	68
11.	Arsenal	0.28	2.3	1.0	39	63
12.	Arsenal	0.56	6.3	4.0	34	56
13.	Assure	0.11	2.0	1.0	41	62
14.	Assure	0.22	2.0	1.0	42	68
15.	Roundup	1.12	2.7	1.0	36	60
16.	Roundup	1.68	2.7	1.0	39	67
17.	Oust	0.10	2.0	1.0	49	73
18.	Oust	0.21	2.3	1.0	41	69
19.	Check	-----	1.0	1.0	45	67
$LSD_{0.05}$			1.1	0.9	7	10

[1]All treatments except Roundup had a crop oil added at 0.5% v/v.
[2]Treatments were applied on 4 September 1992.
[3]Switchgrass control was visually rated on a 1 to 10 scale where 1 = no control and 10 = complete control.
[4]MAT = Months After Treatment.

Table 13. Effect of spring applied post-emergent herbicide treatments on switchgrass in ODOT Division 8 (Experiment 8-H-36-93).

Treatments[1]	Rate	Bermudagrass Phytotoxicity[2]			Switchgrass Phytotoxicity[3]			Switchgrass Height (cm)			
	(kg ai ha^{-1})	1 MAT[4]	2 MAT	3 MAT	1 MAT	2 MAT	3 MAT	0 MAT	1 MAT	2 MAT	3 MAT
1. Poast	0.31	3.3	2.7	1.0	5.0	4.0	3.3	39	40	42	52
2. Poast	0.45	3.0	2.3	1.0	5.7	4.0	3.0	40	38	45	58
3. Fusilade	0.21	3.7	2.3	1.0	5.7	5.3	5.0	41	35	38	42
4. Fusilade	0.43	4.0	2.7	1.0	7.0	8.0	7.7	40	34	36	34
5. Select	0.11	2.3	1.7	1.0	4.0	3.0	2.0	40	40	46	55
6. Select	0.22	2.0	2.3	1.0	4.0	4.0	3.0	37	36	37	47
7. Asulox	3.74	2.0	1.3	1.0	4.0	3.0	2.3	40	50	69	71
8. Asulox	7.48	3.0	2.3	1.0	5.7	4.3	3.3	42	47	57	61
9. Verdict	0.28	3.3	3.0	1.3	7.3	7.3	7.3	40	35	35	39
10. Verdict	0.56	5.7	3.3	1.0	8.0	9.0	9.0	42	37	38	32
11. Arsenal	0.28	6.3	9.9	8.7	5.0	5.7	6.3	42	41	40	37
12. Arsenal	0.56	8.3	9.9	9.0	5.0	5.7	7.3	40	39	38	39
13. Assure	0.11	4.3	2.0	1.0	7.3	6.7	5.3	44	45	46	53
14. Assure	0.22	5.3	3.0	1.0	8.7	8.3	7.0	48	42	40	51
15. Roundup	1.12	2.3	1.7	1.0	4.0	3.3	2.7	39	36	54	53
16. Roundup	1.68	3.7	2.7	1.0	7.3	6.7	5.7	43	37	38	49
17. Oust	0.10	6.0	3.7	2.0	3.3	3.3	2.0	40	42	51	54
18. Oust	0.21	7.0	5.0	3.7	3.3	3.7	3.0	44	40	44	50
19. Check	-----	1.0	1.0	1.0	1.0	1.0	1.0	43	68	82	75
$LSD_{0.05}$		1.5	1.5	0.8	1.7	1.8	1.7	8	8	9	10

[1]All treatments except Roundup had a crop oil added at 0.5% v/v.
[2]Phytotoxicity to bermudagrass was rated on a 1 to 10 scale where 1 = no effect and 10 = complete yellowing.
[3]Phytotoxicity to switchgrass was rated on a 1 to 10 scale where 1 = no effect and 10 = complete yellowing.
[4]MAT = Months After Treatment.

Table 14. Post-Emergent Control of Switchgrass in ODOT Division 8 (Experiment 8-H-38-94).

Treatments[1]	Rate (kg ai ha^{-1})	Bermudagrass Phytotoxicity[2]			Switchgrass Phytotoxicity[3]			Switchgrass Seedhead Suppression (%)		Switchgrass Height (cm)		
		1 MAT[4]	2 MAT	3 MAT	1 MAT	2 MAT	3 MAT	2 MAT	3 MAT	1 MAT	2 MAT	3 MAT
1. Poast	0.31	2.3	1.3	1.0	5.0	5.7	6.0	93	53	38	38	45
2. Poast	0.45	3.3	1.7	1.0	5.0	5.7	7.0	99	60	38	36	44
3. Fusilade	0.21	3.3	1.7	1.0	5.0	5.7	7.3	99	75	35	33	40
4. Fusilade	0.43	5.0	2.0	1.0	6.3	8.3	9.2	100	98	29	28	24
5. Select	0.11	2.3	1.3	1.0	4.3	5.0	6.3	88	57	39	41	49
6. Select	0.22	2.7	1.7	1.0	4.7	6.0	7.3	99	72	32	32	42
7. Asulox	3.74	4.3	1.3	1.0	7.0	4.7	4.7	16	7	46	60	62
8. Asulox	7.48	5.0	1.7	1.0	7.7	6.0	6.7	33	32	43	61	59
9. Verdict	0.28	6.0	1.7	1.0	8.0	8.3	9.5	100	100	32	30	26
10. Verdict	0.56	8.0	3.0	1.0	9.0	9.0	9.7	100	100	29	26	23
11. Arsenal	0.28	6.7	9.9	8.7	4.3	2.7	3.3	100	47	38	37	47
12. Arsenal	0.56	7.7	9.9	9.9	5.0	3.0	3.0	97	37	36	35	47
13. Assure	0.11	6.0	1.3	1.0	6.3	7.0	7.0	87	47	41	40	56
14. Assure	0.22	7.7	3.0	1.0	6.7	7.0	7.0	100	68	38	39	46
15. Roundup	1.12	2.3	1.3	1.0	3.7	3.0	5.7	35	30	38	40	48
16. Roundup	1.68	3.0	2.0	1.0	6.3	6.0	7.0	88	48	32	31	41
17. Oust	0.10	2.3	1.3	1.0	3.0	2.3	3.3	7	3	46	59	56
18. Oust	0.21	3.0	1.3	1.0	3.0	2.0	3.0	7	5	42	51	53
19. Check	____	1.0	1.3	1.0	1.0	1.0	1.0	0	0	65	75	76
$LSD_{0.05}$		1.2	0.6	0.2	1.5	1.3	1.2	20	28	9	10	13

[1]All treatments except Roundup had a crop oil added at 0.5% v/v.
[2]Phytotoxicity to bermudagrass was rated on a 1 to 10 scale where 1 = no effect and 10 = complete yellowing.
[3]Phytotoxicity to switchgrass was rated on a 1 to 10 scale where 1 = no effect and 10 = complete yellowing.
[4]MAT = Months After Treatment.

Table 15. Effect of herbicide treatments and mowing cycles on bermudagrass in ODOT Division 8 during 1994 (Experiment 8-H-39-94).

		Bermudagrass Phytotoxicity[2]											
	Rate	MOW = 0				MOW = 1				MOW = 2			
Treatments[1]	(kg ai ha^{-1})	1 MAT[3]	2 MAT	3 MAT	4 MAT	1 MAT	2 MAT	3 MAT	4 MAT	1 MAT	2 MAT	3 MAT	4 MAT
1. Fusilade[2]	0.21	2.7	1.0	1.0	1.0	2.7	1.0	1.0	1.0	2.7	1.0	1.0	1.0
2. Fusilade	0.43	4.7	1.7	1.0	1.0	4.7	1.0	1.0	1.0	4.7	1.0	1.0	1.0
3. Verdict	0.28	4.3	1.0	1.0	1.0	4.3	1.0	1.0	1.0	4.3	1.0	1.0	1.0
4. Verdict	0.56	6.3	1.7	1.0	1.0	6.3	1.7	1.0	1.0	6.3	1.7	1.0	1.0
5. Assure	0.11	6.7	1.0	1.0	1.0	6.7	1.0	1.0	1.0	6.7	1.0	1.0	1.0
6. Assure	0.22	7.7	2.0	1.0	1.0	7.7	2.0	1.0	1.0	7.7	1.7	1.0	1.0
7. Check	-----	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
$LSD_{0.05}$		1.2	1.0	NS	NS	1.2	1.2	NS	NS	1.2	0.7	NS	NS

[1]Each herbicide treatment (main plot) had a crop oil added at 0.5% v/v.
[2]Phytotoxicity was rated on a 1 to 10 scale where 1 = no phytotoxicity and 10 = complete brownout.
[3]MAT = Months After Treatment.

Table 16. Effect of herbicide treatments and mowing cycles on switchgrass in ODOT Division 8 during 1994 (Experiment 8-H-39-94).

		Switchgrass Height (cm)											
	Rate	MOW = 0				MOW = 1				MOW = 2			
Treatments[1]	(kg ai ha^{-1})	1 MAT[2]	2 MAT	3 MAT	4 MAT	1 MAT	2 MAT	3 MAT	4 MAT	1 MAT	2 MAT	3 MAT	4 MAT
1. Fusilade	0.21	38	34	35	34	39	24	41	39	42	24	8	16
2. Fusilade	0.43	42	41	38	35	44	21	38	41	37	20	9	14
3. Verdict	0.28	41	42	35	36	37	22	38	41	42	21	12	15
4. Verdict	0.56	40	38	37	34	40	13	29	31	35	13	11	14
5. Assure	0.11	35	33	39	36	32	19	33	35	38	19	9	15
6. Assure	0.22	37	34	34	36	36	20	30	34	36	16	11	15
7. Check	-----	49	60	54	58	53	21	40	37	51	19	9	13
$\text{LSD}^{0.05}$		5	12	10	7	9	7	12	14	9	8	3	4

[1]Each herbicide treatment had a crop oil added at 0.5% v/v.
[2]MAT = Months After Treatment.

Table 17. Effect of herbicide treatments and mowing cycles on switchgrass flowering in ODOT Division 8 during 1994 (Experiment 8-H-39-94).

			Percent Switchgrass Seedhead Suppression								
			MOW = 0			MOW = 1			MOW = 2		
Treatments[1]		Rate (kg ai ha^{-1})	2 MAT[2]	3 MAT	4 MAT	2 MAT	3 MAT	4 MAT	2 MAT	3 MAT	4 MAT
1.	Fusilade	0.21	95	90	88	95	52	33	100	100	100
2.	Fusilade	0.43	100	100	100	100	27	8	100	100	100
3.	Verdict	0.28	100	93	95	100	40	22	100	100	98
4.	Verdict	0.56	100	97	95	100	73	67	100	100	100
5.	Assure	0.11	100	88	78	100	55	47	100	100	100
6.	Assure	0.22	100	93	81	100	47	40	100	100	98
7.	Check	-----	0	0	0	0	57	30	100	100	98
$LSD_{0.05}$			6	12	22	6	36	40	NS	NS	8

[1]Each herbicide treatment had a crop oil added at 0.5% v/v.
[2]MAT = Months After Treatment.

Table 18. Effect of herbicide treatments and mowing cycles on switchgrass and bermudagrass cover in ODOT Division 8 during 1994 (Experiment 8-H-39-94).

			Percent Switchgrass Cover						Percent Bermudagrass Cover					
		Rate	MOW = 0		MOW = 1		MOW = 2		MOW = 0		MOW = 1		MOW = 2	
Treatments[1]		(kg ai ha^{-1})	0 MAT[2]	4 MAT	0 MAT	4 MAT	0 MAT	4 MAT	0 MAT	4 MAT	0 MAT	4 MAT	0 MAT	4 MAT
1.	Fusilade	0.21	38	8	30	27	57	15	43	38	45	42	28	43
2.	Fusilade	0.43	37	4	42	25	42	7	47	35	40	42	38	47
3.	Verdict	0.28	50	6	37	19	35	9	33	40	45	45	43	62
4.	Verdict	0.56	43	9	33	15	37	5	37	45	35	43	42	45
5.	Assure	0.11	40	12	27	18	28	12	43	33	42	37	45	43
6.	Assure	0.22	47	13	50	23	48	10	40	27	37	32	38	28
7.	Check	-----	60	52	55	33	60	28	23	23	30	28	28	37

[1]Each herbicide treatment had a crop oil added at 0.5% v/v.
[2]MAT = Months After Treatment.

Table 19. Effect of herbicide treatments and mowing cycles on control of switchgrass in ODOT Division 8 during 1994 (Experiment 8-H-39-94).

		Switchgrass Control Rating[3]											
	Rate	1 MAT[4]			2 MAT			3 MAT			4 MAT		
Treatments[1]	(kg ai ha^{-1})	MOW=0	MOW=1	MOW=2	MOW=0	MOW=1	MOW=2	MOW=0	MOW=1	MOW=2	MOW=0	MOW=1	MOW=2
1. Fusilade[2]	0.21	4.7	2.7	4.7	5.3	1.0	1.0	8.0	1.0	1.0	8.0	4.0	5.7
2. Fusilade	0.43	6.3	4.7	6.3	6.7	1.0	1.0	9.0	1.0	1.0	9.3	4.7	7.5
3. Verdict	0.28	7.0	4.3	7.0	8.3	1.0	1.0	9.1	1.0	1.0	8.7	4.5	6.3
4. Verdict	0.56	8.0	6.3	8.0	8.7	7.7	8.0	9.8	1.0	1.0	8.8	7.0	8.8
5. Assure	0.11	7.7	6.7	7.7	7.7	1.0	1.0	8.0	1.0	1.0	7.7	5.0	6.7
6. Assure	0.22	8.0	7.7	8.0	8.7	1.7	1.7	8.8	1.0	1.0	7.3	4.3	6.7
7. Check	-----	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
LSD$_{0.05}$		1.1	1.2	1.1	1.5	0.9	1.5	1.5	NS	NS	1.5	4.4	4.1

[1]Each herbicide treatment (main plot) had a crop oil added at 0.5% v/v.
[2]Each main plot (herbicide treatment) was divided into three (3) subplots (mowing treatments).
[3]Switchgrass control was rated on a 1 to 10 scale where 1 = no control and 10 = complete control.
[4]MAT = Months After Treatment.

Table 20. Effect of herbicide treatments and mowing cycles on bermudagrass and switchgrass in ODOT Division 8 in 1995 (Experiment 8-H-40-95).

Treatments[1]	Rate (kg ai ha^{-1})	Bermudagrass Injury[3] 1 MAT[5]	2 MAT	3 MAT	4 MAT	Switchgrass Control[4] 4 MAT
1. Fusilade[2]	0.21	3.1	1.0	1.0	1.0	7.1
2. Fusilade	0.43	3.0	1.0	1.0	1.0	8.0
3. Verdict	0.28	3.7	1.0	1.0	1.0	9.1
4. Verdict	0.56	4.0	1.0	1.0	1.0	9.7
5. Assure	0.11	4.0	1.0	1.0	1.0	8.6
6. Assure	0.22	4.0	1.0	1.0	1.0	7.6
7. Check	-----	1.0	1.0	1.0	1.0	3.8
$LSD_{0.05}$		0.4	NA	NA	NA	1.5

[1]Each herbicide treatment (main plot) had a crop oil added at 0.5% v/v.
[2]Each main plot (herbicide treatment) was divided into three (3) subplots (mowing treatments).
[3]Bermudagrass injury ratings were averaged over mowing cycles, 1 = no injury and 10 = complete brownout.
[4]Switchgrass control was rated on a 1 to 10 scale where 1 = no control and 10 = complete control.
[5]MAT = Months After Treatment.

Table 21. Effect of mowing cycles on bermudagrass cover, switchgrass cover and control of switchgrass in ODOT Division 8 in 1995 (Experiment 8-H-40-95).

Mowing Cycles	Percent Bermudagrass Cover	Percent Switchgrass Cover	Switchgrass Control Rating[1]
0	37	20	7.0
1	51	15	7.3
2	54	6	8.8
$LSD_{0.05}$	6	2	0.3

[1]Switchgrass control ratings were taken on a 1 to 10 scale where 1 = no control and 10 = complete control. All ratings are at 4 months after herbicide treatments.

Table 22. Effect of herbicide applications on switchgrass cover in ODOT Division 8 in 1995 (Experiment 8-H-40-95).

Treatments[1]	Rate (kg ai ha^{-1})	Percent Switchgrass Plot Cover (4 MAT)[3]		
		Mow=0	Mow=1	Mow=2
1. Fusilade[2]	0.21	18	22	12
2. Fusilade	0.43	13	13	4
3. Verdict	0.28	7	6	4
4. Verdict	0.56	1	1	0
5. Assure	0.11	12	12	1
6. Assure	0.22	12	17	5
7. Check	-----	77	37	17
$LSD_{0.05}$		9	13	6

[1]Each herbicide treatment (main plot) had a crop oil added at 0.5% v/v.
[2]Each main plot (herbicide treatment) was divided into three (3) subplots (mowing treatments).
[3]MAT = Month After Treatment.

3.5 LITERATURE CITED

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4. Control of Musk Thistle with Selective Herbicides

L. M. Cargill, D. P. Montgomery, and D. L. Martin

4.1 INTRODUCTION

Musk thistle or nodding thistle (*Carduus nutans* L.) is a native of Europe. It was first recorded in the United States in 1852 at Harrisburg, Pennsylvania. It has since spread throughout most of North America where it has become a weed of considerable economic importance. Previously considered primarily a pasture and rangeland weed in 40 states (2), musk thistle now hinders agricultural production (3) and the maintenance of roadways (4). Musk thistle grows in many areas that are inaccessible and typically uneconomical for herbicide use (3). The successful use of herbicides for musk thistle control has been reported on rangeland pasture sites in Nebraska (7, 8) and in Colorado (1). Timely mowings have also been reported as a method of significantly reducing the amount of viable seed being produced (7).

Musk thistle is primarily considered a biennial plant, however, it can behave as an annual, particularly in early planted wheat (9). Musk thistle reproduces only from seed. Each seed has a set of parachute-like hairs which allow for the seed dispersal downwind. Each musk thistle plant can produce more than 10,000 seeds. The plants usually produce a rosette during the first year of their life cycle. The leaves are deeply-lobed, hairless and are dark green with a light green or white mid-rib. A silver-gray leaf margin is characteristic of each spiny tipped lobe. In its second year of life, the musk thistle plant will transform from the rosette stage into a mature, flowering plant, which may reach heights in excess of two meters. Flowering begins usually in May-June. Flowers range in color from rose (reddish-pink) to purple.

Musk thistle has been declared a noxious weed in the states of Missouri and Kansas. In recent years, this plant has steadily moved southward out of those two states into the northern parts of Oklahoma. It is currently a major weed problem in north central, east central and northeast Oklahoma. As a result of its rapid and widespread movement into these areas in a relatively short time span, the Oklahoma State Legislature enacted a new noxious weed law in 1994. This law designated musk thistle, Scotch thistle (*Onopordum acanthium* L.) and Canada thistle (*Cirsium arvense* L.) as noxious weeds in Craig, Delaware, Ottawa and Mayes Counties. The law basically stated "it shall be the duty of every landowner (including ODOT) in such counties to eradicate all Canada, musk or Scotch thistles growing thereon so often in each and every year as shall be sufficient to prevent said thistles from going to seed."

Prior to this action, OSU and ODOT had recognized the potential problem that musk thistle may pose along roadsides. Research had already been formulated in the late 1980s and early 1990s to screen potential herbicides which would selectively control musk thistle along bermudagrass roadsides (5). At the conclusion of that five-year project (1986-1991), research results were reported for all but the 1991 growing season. As a result, the objective of the following research, which was initiated at the beginning of the current five-year project (1991-1996), was to complete these research efforts and make a formal recommendation to ODOT as to what herbicide(s) and rate(s) should be utilized to selectively control musk thistle along roadsides.

4.20 METHODS AND MATERIALS

4.21 Musk Thistle Control Experiment 8-H-29-91

A field experiment (Experiment 8-H-29-91) was initiated on 22 March 1991 to compare the efficacy of 13 herbicide treatments for the selective control of musk thistle in a bermudagrass roadside (Table 23). Experiment 8-H-29-91 was conducted on a silt loam soil along side the junction of SR 66 and SR 266 in Rogers County in ODOT Division 8. Treatments were applied using a CO_2 pressurized, hand-held boom sprayer calibrated to deliver 187 ℓ ha^{-1} at a pressure of 207 kPa equipped with TeeJet 80015 stainless steel, flat-fan spray tips. Plots measured 1.5 x 3.0 m and were replicated three times in a randomized complete block experimental design. Application was made to actively growing musk thistle plants in a rosette stage of growth 2.5 to 7.6 cm in height.

Herbicide treatments included Escort at 0.12 kg ai ha^{-1}; Telar at 0.09 kg ai ha^{-1}; Banvel at 1.12 kg ai ha^{-1}; Transline at 0.14, 0.28 and 0.56 kg ai ha^{-1}; Tordon K at 0.56 kg ai ha^{-1}; Garlon 4 at 1.12 kg ai ha^{-1}; Garlon 3A at 1.12 kg ai ha^{-1}; and XRM-4950 at 0.07, 0.14 and 0.28 kg ai ha^{-1}. All herbicide treatments had the surfactant X-77 added at 0.25 % v/v.

Treatments were evaluated on 23 April 1991 (1 MAT), 22 May 1991 (2 MAT) and 21 June 1991 (3 MAT). Visual ratings were made for musk thistle control and bermudagrass phytotoxicity. Musk thistle control was rated on a scale of 0 to 100 percent where 0 = no control and 100 = complete control. Bermudagrass phytotoxicity was visually rated on a scale of 1 to 10 where 1 = no effect and 10 = complete yellowing. Data were analyzed using Statistical Analysis Systems Software. An analysis of variance was conducted. Because treatment and treatment by rating date effects were significant, treatment means within sampling dates were separated using the LSD test at $p = 0.05$.

4.3 RESULTS AND DISCUSSION

4.31 Musk Thistle Control Experiment 8-H-29-91

Bermudagrass phytotoxicity was observed 1 MAT in all herbicide treated plots, however, all treatments provided an acceptable level of phytotoxicity (Table 23). By 2 MAT no phytotoxic effects on the bermudagrass remained. When the experiment was rated at 1 MAT, the best treatments for musk thistle control were Tordon K and the two higher rates of Transline (0.28 and 0.56 kg ai ha^{-1}). At 2 MAT these same herbicides as well as treatments of Escort and Garlon 4 were providing excellent control (>90%). When the last evaluation was made at 3 MAT the following treatments provided excellent musk thistle control: Escort, Banvel, all three rates of Transline, Tordon K, Garlon 4 and Garlon 3A. Telar and all rates of XRM-4950 did not provide an acceptable level of musk thistle control throughout the duration of this experiment.

4.4 CONCLUSIONS

Results of our 1991 musk thistle control trial indicated that the following treatments provided excellent control of musk thistle with acceptable levels of phytotoxicity to bermudagrass: Escort at 0.12 kg ai ha^{-1}; Banvel at 1.12 kg ai ha^{-1}; Transline at 0.14, 0.28 or 0.56 kg ai ha^{-1}; Tordon K at 0.56 kg ai ha^{-1}; Garlon 4 at 1.12 kg ai ha^{-1} and Garlon 3A at 1.12 kg ai ha^{-1}.

After conducting three years of roadside research (1989-1991), the following herbicides consistently provided excellent control of musk thistle: Transline, Banvel, Tordon K and Garlon 4. Escort exhibited excellent results in two of three years tested. Based upon these research results and the economics associated with each of these respective products, a formal recommendation was made to ODOT in 1991 to use Transline at 0.14 to 0.28 kg ai ha^{-1} in 234 to 468 ℓ ha^{-1} total spray volume (6). It was suggested that ODOT make herbicide application anytime during March through April when the musk thistle plants were actively growing and prior to bolting (flowering).

Table 23. Effect of 12 herbicide treatments on bermudagrass and musk thistle (Experiment 8-H-29-91).

Treatments[1]	Rate (kg ai ha^{-1})	Bermudagrass Phytotoxicity[2] 1 MAT[3]	Bermudagrass Phytotoxicity[2] 2 MAT	Percent Musk Thistle Control 1 MAT	Percent Musk Thistle Control 2 MAT	Percent Musk Thistle Control 3 MAT
Check	------	1.0	1.0	0	0	0
Escort	0.12	2.3	1.0	72	98	100
Telar	0.09	2.0	1.0	71	76	89
Banvel	1.12	2.3	1.0	72	75	95
Transline	0.14	2.3	1.0	75	89	100
Transline	0.28	2.3	1.0	94	100	100
Transline	0.56	2.0	1.0	96	100	100
Tordon K	0.56	3.0	1.0	98	100	100
Garlon 4	1.12	3.0	1.0	75	94	98
Garlon 3A	1.12	2.3	1.0	67	78	90
XRM-4950	0.07	2.0	1.0	17	23	31
XRM-4950	0.14	2.0	1.0	11	32	49
XRM-4950	0.28	2.3	1.0	30	40	44
$LSD_{0.05}$		0.8	NA	30	30	24
C.V. %		20.0	NA	30	26	19

[1]All herbicide treatments received X-77 surfactant at 0.25% v/v.
[2]Bermudagrass phytotoxicity was rated on a 1 to 10 scale where 1 = no phytotoxicity and 10 = complete brownout.
[3]MAT = Months After Treatment.

4.50 LITERATURE CITED

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5. Suppression of Common Bermudagrass Growth and Development on Roadside Right-of-Ways

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5.1 INTRODUCTION

The ability to efficiently manage roadside vegetation is critical to today's Oklahoma Department of Transportation (ODOT) roadside vegetation manager. Today ODOT uses mechanical (mowers, chainsaws, weedhooks), chemical (herbicides), and biological (musk thistle head weevil) controls to manage their roadside vegetation. Each of these tools are very interdependent upon each other. To insure the greatest benefit from each control effort, detail should be paid to how, where, and when to implement each program. Unquestionably, mowing roadsides takes the lions share of both time and monies. Herbicides help reduce these inputs by controlling tall undesirable weeds and promoting low-growing desirable bermudagrass. By lowering the overall canopy of roadside plants one has successfully reduced the mowing requirements of the roadside. After several years of integrating mowing/herbicide programs, and after a thick solid stand of desirable bermudagrass has been established, herbicide inputs can be reduced to an "as-needed" basis. It is at this point that an annual application of a plant growth regulator (PGR) could reduce mowing frequency. This could be a great benefit to managers of urban roadsides and interstates that typically receive 4 to 6 mowings per year and present traffic hazards to the equipment operator.

In the previous Roadside Vegetation Management Project it was found during preliminary screening studies that Vision/Primo (trinexapac ethyl) had the ability to significantly reduce common bermudagrass (*Cynodon dactylon*) canopy heights (by 50%) for a period of 2 to 3 months (4). Primo, as noted by other researchers, is a Type II bermudagrass growth regulator (5). Primo has shown the ability to reduce common bermudagrass canopy heights (2, 3) and mowing cycles on medium to high maintenance turf areas while maintaining an acceptable level of turf quality. One weak point found with a Primo treatment applied alone is that it has proven to be very selective in which plants it will suppress (4). Primo, while suppressing bermudagrass, does not suppress annual broadleaf weeds, silver bluestem (*Andropogon saccharoides*) or johnsongrass (*Sorghum halepense* L. Pers.). To get the full benefit from a Primo application alone, the roadside will need to be void of both perennial and annual weeds.

With the previous information in mind the search for a suitable PGR to incorporate into ODOT's vegetation management program continued into the current project. Our new PGR related objectives were: 1) to continue to evaluate several herbicides and PGRs for their ability to suppress the growth and development of common bermudagrass, 2) to determine if the level of bermudagrass suppression obtained from promising PGRs could reduce mowing frequency and 3) to evaluate the weed control ability of these herbicide/PGR treatments.

5.2.0 MATERIALS AND METHODS

Four field experiments were conducted in 1991 (Experiments 4-PGR-60-91 and 8-PGR-30-91) and 1992 (Experiments 3-PGR-3-92 and 8-PGR-32-92) at four locations in Oklahoma. All treatments were applied to nonmowed plots in late May or early June to actively growing roadside bermudagrass stands. Treatments at all locations were evaluated on a monthly basis for bermudagrass canopy height suppression, bermudagrass seedhead suppression, bermudagrass phytotoxicity, annual weed control, and silver bluestem control (Experiment 8-PGR-32-92 only). Bermudagrass canopy heights were evaluated by randomly measuring three areas in each plot and producing a mean height. Bermudagrass seedhead suppression was visually rated on a 0 to 100 scale where 0 = no seedhead suppression and 100 = complete seedhead suppression as compared to the untreated check. Bermudagrass phytotoxicity was visually rated on a scale of 1 to 10 where 1 = no effect and 10 = complete brownout of bermudagrass. Phytotoxicity ratings that did not exceed a value of 4.6 at 2 MAT were considered satisfactory. Annual weed control and silver bluestem control was visually rated on a 1 to 10 scale where 1 = no control and 10 = complete control.

During the developmental stages of a new product, the product can go through several name changes. For this report and other interim reports, the following are synonyms for the same product having the active ingredient of Cimectacarb or Trinexapac Ethyl: CGA-163935, Vision, and Primo. For uniformity purposes this report will use the product's current trade name of Primo.

Data were analyzed using an analysis of variance procedure where PGR and rating dates were main effects (split plot in time). As the PGR x rating date interaction was always significant, mean performance parameters were compared with an LSD test within each rating date.

5.2.1 Experiments 4-PGR-60-91 and 8-PGR-30-91

Experiment 4-PGR-60-91 was conducted on a silt loam soil along side the junction of SR 51 and SR 86 in Payne County in ODOT Division 4. Experiment 8-PGR-30-91 was conducted on a silt loam soil along side the junction of SR 20 and US 169 in Tulsa County in ODOT Division 8. Treatments included Primo at 0.70 and 0.90 kg ai ha^{-1}, Poast at 0.31 and 0.38 kg ai ha^{-1}, alone, and in combination with Oust at 0.05 kg ai ha^{-1}. As noted in previous research and in current ODOT applications, Roundup plus Oust combinations for johnsongrass control also produced noticeable bermudagrass growth suppression. For comparison, treatments of Roundup at 0.69 plus Oust at 0.05 kg ai ha^{-1} and Roundup at 0.56 plus Oust at 0.05 kg ai ha^{-1} plus Frigate (surfactant) at 0.5% v/v were included. All treatments of Poast also included a crop oil at 0.5% v/v.

Treatments were applied to the entire plot using a CO_2 pressurized hand-held boom sprayer calibrated to deliver 374 ℓ ha^{-1} at 179 kPa. Treatments were applied on 30 May 1991 (Experiment 4-PGR-60-91) and 3 June 1991 (Experiment 8-PGR-30-91). Plots measured 1.5 x 3 m and were replicated three times in a randomized complete block design.

5.2.2 Experiments 3-PGR-3-92 and 8-PGR-32-92

Experiment 3-PGR-3-92 was conducted on a silt loam soil along side US 62, 0.6 km east of the junction with US 177 in Lincoln County in ODOT Division 3. Experiment 8-PGR-32-92 was conducted on a loam soil along side SR 48, 5.5 km south of the junction of SR 33 in Creek County in ODOT Division 8. Treatments included Primo at 0.70 and 0.90 kg ai ha^{-1}, alone, and combined with Oust at 0.05 kg ai ha^{-1}. Also included were treatments of Roundup at 0.84 plus Oust at 0.11 kg ai ha^{-1}, and Roundup at 0.56 plus Oust at 0.05 kg ai ha^{-1} plus Frigate at 0.5% v/v.

Treatments were applied to the entire plot using a single OC-80 off-center nozzle (Experiment 8-PGR-32-92) and a multiple nozzle solid-stream spray head (Experiment 3-PGR-3-92). The sprayer was calibrated to deliver 374 ℓ ha^{-1} while operating at 207 kPa. Treatments were applied on 4 June 1992 (Experiment 3-PGR-3-92) and 11 June 1992 (Experiment 8-PGR-32-92). Plots measured 5.5 x 30 m and were replicated three times in a randomized complete block design.

5.3.0 RESULTS AND DISCUSSION

5.3.1 Experiments 4-PGR-60-91 and 8-PGR-30-91

Analysis of bermudagrass canopy heights indicated that all treatments significantly reduced bermudagrass growth 1 MAT as compared to the untreated control (Table 24 and 25). In Experiment 4-PGR-60-91, all treatments actually resulted in a reduction in bermudagrass canopy heights from their initial starting height of 63 mm. This would be due to the chemical suppression followed by subsequent warm, dry environmental conditions. In Experiment 8-PGR-30-91, no reductions were evident but all treatments of Primo maintained initial canopy heights through 3 MAT (Table 25). Treatments of Primo and Primo plus Oust maintained this reduction throughout the entire growing season. Treatments of Roundup plus Oust alone, and in combination with Frigate, provided similar suppression to Primo treatments for one month (Experiment 8-PGR-30-91) and two months (Experiment 4-PGR-60-91).

Primo alone and in combination with Oust provided the best bermudagrass seedhead suppression. All treatments in both experiments provided significant seedhead suppression 1 MAT ratings (Table 24 and 25). At 2 MAT, treatments of Primo and Poast did show early trends of increasing annual weed control, however, its total effect was somewhat masked in 1991 because of the hot dry summer. As evidenced by weed control values for the untreated check, even plots which were not treated showed signs of annual weed necrosis and decline 2 MAT. This made evaluations for annual weed control difficult in treated plots.

Phytotoxicity was again evident in 1991 from all PGR and PGR plus herbicide treatments. All treatments produced similar phytotoxicity 1 MAT (Table 24 and 25) for both locations. Only treatments of Primo alone, and in combination with Oust, maintained any noticeable bermudagrass seedhead suppression through 2 MAT. Only a small amount of yellowing of bermudagrass was noticed and would be acceptable for roadside situations. No phytotoxicity was noticed at later rating dates.

5.3.2 Experiments 3-PGR-3-92 and 8-PGR-32-92

Both 1992 plant growth regulator experiments had identical treatments, however, Experiment 3-PGR-3-92 was treated using the solid-stream sprayer and Experiment 8-PGR-32-92 was treated using the off-center equipped sprayer. From the data presented and personal observations there were no differences in performance of the two sprayers in these two experiments as indicated by the similar trends in data.

Analysis of canopy heights revealed that all treatments maintained initial canopy heights (Experiment 8-PGR-32-92) for three months as compared to a 41% increase in the untreated plots (Table 27). In Experiment 3-PGR-3-92 all treatments which included Primo maintained initial canopy heights for two months and allowed nominal growth three months after application (Table 26). Treatments that included Roundup and Oust maintained their initial canopy heights for one month with significant increases by three months after application.

Phytotoxicity was evident on bermudagrass from all treatments 1 MAT in both experiments. The addition of Oust to Primo in a tank mix significantly increased bermudagrass phytotoxicity. The only treatment which produced an unacceptable level of phytotoxicity was the Roundup/Oust/Frigate combination in Experiment 8-PGR-32-92 (Table 27). There was no visible phytotoxicity 2 MAT for any of the treatments.

Primo alone has little or no ability to control or suppress weeds. The addition of Oust does provide the necessary weed control of most annual weeds with only limited effect on perennial species. Excellent control of marestail (*Conyza canadensis* L. Crona)

(Experiment 8-PGR-32-92) and temporary suppression of crabgrass (*Digitaria* spps.) (Experiment 3-PGR-3-92) was evident from the Oust plus Primo treatments. All treatments of Roundup and Oust provided excellent long term control of annual weeds in both experiments and moderate control of silver bluestem (Experiment 8-PGR-32-92).

5.4 CONCLUSIONS

A total of 12 PGR studies were conducted during 1987-1992 in ODOT/OSU Project 2147 and Project 2187 examining herbicides and PGRs for their ability to suppress roadside bermudagrass. During this time Uniconazole and Select showed promise but their respective manufacturers discontinued pursuit of federally labelled use. The product Primo, after many evaluations, appeared to have the greatest potential as a satisfactory bermudagrass PGR.

Primo applied between 0.7 and 0.9 kg ai ha^{-1} has demonstrated a consistent ability to suppress vertical bermudagrass growth by at least 50% for 2 to 3 months while also suppressing bermudagrass seedhead formation. Primo applications would by no means maintain a mowed appearance, but there is no doubt it has the ability to reduce mowing frequencies on roadsides which receive at least four mowings annually.

If perennial weeds such as silver bluestem and johnsongrass are problems on bermudagrass roadsides targeted for PGR programs, it would be best to maintain the roadsides with a Roundup plus Oust program until these weeds have been removed from the spray zone. If annual weeds are a concern, then 0.05 to 0.11 kg ai ha^{-1} of Oust should be added to the Primo treatment.

In 1992, prior to federal registration, Ciba Geigy (the manufacturer of Primo/Vision) decided to change their marketing strategy with the Primo product. In this change the Experimental Use Permit product Vision (labelled for roadside or industrial use and priced accordingly) was discontinued and replaced with the Primo product which received its label primarily for fine turf areas in early 1993. While the Primo label does not prohibit the product's use on roadsides, the cost of the fine turf labelled product prevented its economical use on roadsides by ODOT.

Table 24. Effects of plant growth regulators on bermudagrass in ODOT Division 4 in 1991 (Experiment 4-PGR-60-91).

Treatments[1,2]	Rate (kg ai ha^{-1})	Bermudagrass Canopy Height 1 MAT[3]	2 MAT	3 MAT	Bermudagrass Seedhead Suppression 1 MAT	2 MAT	3 MAT	Bermudagrass Phytotoxicity 1 MAT	2 MAT	Annual Weed Control 1 MAT	2 MAT	3 MAT
		-------------mm-------------			--------------%--------------							
Check	-----	74	83	92	0	0	0	1.0	2.0	1.0	5.5	8.8
Primo	0.7	43	39	49	98	85	88	1.7	2.7	2.0	8.0	8.7
Primo +	0.7											
Oust	0.05	39	41	50	99	90	77	2.0	2.7	3.7	9.0	8.3
Primo	0.9	45	41	47	99	93	92	2.0	3.3	4.0	8.3	9.3
Primo +	0.9											
Oust	0.05	40	36	40	99	98	87	2.2	2.8	5.0	9.5	9.8
Poast[1]	0.31	44	52	67	99	90	58	1.8	1.7	7.0	9.3	9.2
Poast +	0.31											
Oust	0.05	47	51	63	99	82	35	2.2	1.0	6.0	9.3	9.6
Poast	0.38	48	59	66	99	93	55	2.3	1.8	7.0	9.5	9.2
Poast +	0.38											
Oust	0.05	47	47	60	98	90	43	2.0	1.3	5.7	9.5	9.5
Roundup +	0.69											
Oust	0.05	46	51	66	99	72	20	2.3	1.8	7.5	9.3	9.6
Roundup +	0.56											
Oust +	0.05											
Frigate	0.5% v/v	47	50	69	99	82	32	3.5	1.0	9.2	9.3	9.3
$LSD_{0.05}$		13	15	18	2	13	32	0.8	1.0	3.0	2.3	1.1

[1]All treatments of Poast also included a crop oil at 0.5% v/v.
[2]Treatments were applied on 30 May 1991.
[3]MAT = Months After Treatment.

Table 25. Effects of plant growth regulators on bermudagrass in ODOT Division 8 in 1991 (Experiment 8-PGR-30-91).

Treatments[1,2]	Rate (kg ai ha^{-1})	Bermudagrass Canopy Height 1 MAT[3]	2 MAT	3 MAT	Bermudagrass Seedhead Suppression 1 MAT	2 MAT	3 MAT	Bermudagrass Phytotoxicity 1 MAT	2 MAT	Annual Weed Control 1 MAT	2 MAT
		-------------	mm	-------------	-------------	%	-------------				
Check	-----	100	104	114	0	0	0	1.0	1.3	1.0	9.9
Primo	0.7	60	66	71	96	83	43	2.3	2.7	1.0	9.9
Primo +	0.7										
Oust	0.05	57	65	68	99	80	65	3.0	2.7	8.0	9.9
Primo	0.9	58	64	65	99	87	67	3.0	2.7	2.3	9.9
Primo +	0.9										
Oust	0.05	63	66	65	99	91	88	3.2	3.2	7.7	9.9
Poast	0.31	71	92	97	99	67	37	2.0	1.5	8.3	9.9
Poast[1] +	0.31										
Oust	0.05	63	78	97	99	58	60	2.3	1.8	9.2	9.9
Poast	0.38	85	101	115	99	68	37	1.0	1.7	8.7	9.9
Poast +	0.38										
Oust	0.05	63	92	105	99	60	22	2.3	1.0	6.7	9.9
Roundup +	0.69										
Oust	0.05	67	76	96	99	52	35	2.2	1.3	9.3	9.9
Roundup +	0.56										
Oust +	0.05										
Frigate	0.5% v/v	65	78	93	99	57	33	2.5	1.2	8.8	9.9
$LSD_{0.05}$		13	12	22	3	25	29	1.0	1.1	2.1	NA

[1]All treatments of Poast also included a crop oil at 0.5% v/v.
[2]Treatments were applied on 3 June 1991.
[3]MAT = Months After Treatment.

Table 26. Effects of plant growth regulators on bermudagrass in ODOT Division 3 in 1992 (Experiment 3-PGR-3-92).

Treatments[1]	Rate (kg ai ha^{-1})	Bermudagrass Canopy Height				Bermudagrass Seedhead Suppression			Bermudagrass Phytotoxicity		Annual Weed Control		
		0 DAT[2]	1 MAT[3]	2 MAT	3 MAT	1 MAT	2 MAT	3 MAT	1 MAT	2 MAT	1 MAT	2 MAT	3 MAT
		----------------mm----------------				------------%------------							
Primo	0.7	78	47	52	89	93	85	27	1.8	2.7	1.7	1.7	1.0
Primo + Oust	0.7 0.05	83	60	64	84	95	82	72	3.2	4.0	4.8	3.8	3.3
Primo	0.9	53	44	51	84	97	82	47	1.5	2.8	2.0	2.3	1.0
Primo + Oust	0.9 0.05	67	51	61	88	97	87	58	2.3	4.0	4.7	4.7	2.7
Roundup + Oust	0.84 0.11	79	68	97	135	88	70	48	1.8	2.8	9.0	9.5	8.3
Roundup + Oust + Frigate	0.56 0.05 0.5% v/v	97	82	125	159	88	92	77	2.2	3.5	9.5	9.3	8.9
Check	------	107	130	162	169	0	60	27	1.0	1.0	1.0	1.7	1.0
$LSD_{0.05}$		25	30	28	48	15	51	29	0.7	0.7	3.3	4.2	2.9

[1]Treatments were applied on 4 June 1992 using a multiple solid-stream nozzle (Estes Chemical Co.) equipped sprayer.
[2]DAT = Day After Treatment.
[3]MAT = Months After Treatment.

Table 27. Effect of plant growth regulators on bermudagrass in ODOT Division 8 in 1992 (Experiment 8-PGR-32-92).

Treatments[1]	Rate (kg ai ha^{-1})	Bermudagrass Canopy Height				Bermudagrass Seedhead Suppression			Bermudagrass Phytotoxicity		Annual Weed Control			Silver Bluestem Control		
		0 DAT[2]	1 MAT[3]	2 MAT	3 MAT	1 MAT	2 MAT	3 MAT	1 MAT	2 MAT	1 MAT	2 MAT	3 MAT	1 MAT	2 MAT	3 MAT
		mm				%										
Primo	0.7	146	134	107	152	70	45	28	1.5	2.5	1.0	1.0	1.7	1.0	1.0	1.0
Primo + Oust	0.7 0.05	134	113	117	131	87	83	15	2.3	3.5	9.6	5.3	8.5	3.7	3.7	3.7
Primo	0.9	125	114	99	114	67	63	23	1.8	2.5	1.0	1.0	1.7	1.0	1.0	1.0
Primo + Oust	0.9 0.05	137	111	104	126	88	75	15	2.5	3.7	9.8	5.8	8.0	4.3	3.3	3.3
Roundup + Oust	0.84 0.11	143	125	151	158	93	68	0	3.0	4.5	9.9	9.5	9.6	6.8	5.7	5.7
Roundup + Oust Frigate	0.56 0.05 0.5% v/v	162	142	158	167	93	77	0	3.5	6.5	9.9	9.0	9.3	8.0	6.3	6.3
Check	------	135	196	234	229	0	0	0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
$LSD_{0.05}$		27	31	47	51	16	28	22	0.6	0.6	0.4	2.0	1.3	0.8	4.0	4.0

[1]Treatments were applied on 11 June 1992 using a single OC-80 (Spray Systems, Inc.) nozzle equipped sprayer.
[2]DAT = Day After Treatment.
[3]MAT = Months After Treatment.

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6. Effects of Ammonium Sulfate on Herbicides Used for Control of Winter Annual Weeds

L. M. Cargill, D. P. Montgomery, and D. L. Martin

6.0 INTRODUCTION

Controlling winter annual weeds with herbicides along highway right-of-way is a major component of the Oklahoma Department of Transportation's (ODOT) roadside vegetation management program. If left untreated, winter annual plants not only become an eyesore, but necessitate mowing early in the growing season to minimize seed production and further competition to the desirable roadside turf. For the past several years, atrazine has been the most commonly used herbicide by ODOT for winter annual weed control. Environmental and ground water concerns resulted in a temporary loss of atrazine for roadside use (enacted by the Environmental Protection Agency) during the winter of 1991-1992. During that time, research efforts of our program were immediately focused on finding a replacement herbicide which would be an economical alternative having a similar spectrum of weed control.

In a review of the literature it was found that some of the herbicides which would be tested as atrazine alternatives had improved efficacy on some weed species when ammonium sulfate (AMS) was added to the tank mix. AMS is considered to be an adjuvant. An adjuvant is a product that when added to other compounds will enhance or improve their performance (efficacy). AMS does not exhibit herbicidal properties when used alone. AMS appears to act as a buffering agent when combined with water. This allows less quantities of products such as glyphosate to be chemically tied up, particularly with higher pH water, or the AMS allows more of the glyphosate to be available for uptake by susceptible plants, thereby increasing potential activity (4). The use of AMS has been shown to enhance the activity of herbicides such as Pursuit on *Ipomoea lacunosa* (2) and Roundup (glyphosate) or SC-0224 (sulfosate) on johnsongrass (*Sorghum halepense*) (3). When AMS was combined with Poast an increase in activity was observed for the control of large crabgrass and maize (6). In greenhouse experiments, the activity of 2,4-D at 1 kg ai ha^{-1} against *Cyperus rotundus* was significantly enhanced by the addition of AMS at 10 kg ai ha^{-1} (5). The activity of Roundup at 0.5 and 1.0 ℓ ha^{-1} against *Elymus repens* under greenhouse and field conditions was enhanced by the addition of AMS at 2.5 kg ai ha^{-1} (1). From this data it was assumed that AMS, when combined with specific herbicides, may allow for a quicker kill of undesirable vegetation. Based upon these assumptions, it may be possible to use lower labeled rates of specific herbicides by adding AMS and achieving the same results as compared to using higher labeled rates. This in turn may allow for a more economical means of applying less herbicides into roadside situations. The end result would be application of less herbicide into the environment, a big plus in any right-of-way vegetation management program.

The objectives of the following research was to focus on combining AMS with lowered labeled rates of specific herbicides for the control of winter annual weeds in dormant bermudagrass.

6.2.0 MATERIALS AND METHODS

6.2.1 Ammonium Sulfate Experiment 4-H-66-93

A field experiment (Experiment 4-H-66-93) was initiated 16 March 1993 (treatments 8 and 16 in Table 28) and 5 April 1993 (treatments 1-7 and 9-15 in Table 28) on a roadside right-of-way consisting of an intermix of both common bermudagrass and several species of both winter annual broadleaves and annual grassy weeds. The objective of this study was to compare labeled rates of Campaign (glyphosate plus 2,4-D) herbicide with equivalent rates of Roundup (glyphosate) combined with 2,4-D amine, with or without the addition of AMS to control winter annual weeds in dormant bermudagrass. Weed species included hairy vetch (*Vicia villosa* Roth), plantain spp. (*Plautago* spp.), speedwell spp. (*Veronica* spp.), catchweed bedstraw (*Galium aparine* L.) and bromes (*Bromus* spp.).

Experiment 4-H-66-93 was conducted on a fine sandy loam soil along side SR 51, 5.6 km west of Stillwater in Payne County in ODOT Division 4. Treatments were applied with a CO_2 pressurized, hand-held boom sprayer equipped with TeeJet 80015 stainless steel, flat-fan spray tips calibrated to deliver 187 ℓ ha^{-1} at a pressure of 207 kPa. Plots measured 1.5 x 3 m and were replicated 3 times in a randomized complete block experimental design.

Herbicide treatments included Campaign at 0.94, 1.41 and 1.88 ℓ (product) ha^{-1}, alone, and in combination with AMS at 3.81 kg (product) ha^{-1}; Roundup plus 2,4-D amine at 0.28 plus 0.56 kg ai ha^{-1}, 0.43 plus 0.84 kg ai ha^{-1}, 0.56 plus 1.12 kg ai ha^{-1}, respectively, alone, and in combination with AMS at 3.81 kg (product) ha^{-1}; and Aatrex 4L at 2.24 kg ai ha^{-1}, alone, and in combination with AMS at 3.81 kg product ha^{-1}. Combination treatments of Roundup plus 2,4-D amine had X-77 surfactant added at 0.5% v/v.

Treatments were evaluated on 5 May 1993 (1 MAT), 4 June 1993 (2 MAT) and 6 July 1993 (3 MAT). Visual ratings were made for winter annual broadleaf weed control, winter annual grass control and bermudagrass phytotoxicity. Weed control ratings were made on a scale of 1 to 10 where 1 = no control and 10 = complete control. Bermudagrass phytotoxicity was visually rated on a scale of 1 to 10 where 1 = no effect and 10 = complete yellowing.

6.2.2 Ammonium Sulfate Experiment 4-H-67-93

This experiment was a duplication of Experiment 4-H-66-93 as previously discussed in Section 6.2.1. All herbicide treatments, rates of application, carrier rates, plot size and methods of application were identical. Herbicides were applied 16 March 1993 (treatments 8 and 16 in Table 29) and 26 March 1993 (treatments 1-7 and 9-15 in Table 29). Experiment 4-H-67-93 was conducted on a silty clay loam soil at the Oklahoma State University Turfgrass Research Center, 1.6 km west of Stillwater, Oklahoma. The experimental site was a low-maintenance area consisting of Guymon common bermudagrass (*Cynodon dactylon* 'Guymon') intermixed with several species of winter annual broadleaves and annual grassy weeds. Weed species present in the experimental area included wild carrot (*Daucus carota* L.), hairy vetch, chickweed (*Stellaria media* L. Vill.), speedwell spp., henbit (*Lamium amplexicaule* L.) and bromes.

Treatments were evaluated 27 April 1993 (1 MAT), 28 May 1993 (2 MAT) and 28 June 1993 (3 MAT). Visual ratings were made for winter annual broadleaf control, winter annual grass control and bermudagrass phytotoxicity using the rating scales discussed in Section 6.2.1.

6.2.3 Ammonium Sulfate Experiment 4-H-73-94

A roadside field study (Experiment 4-H-73-94) was initiated 10 February 1994 (treatments 8 and 16 in Table 30) and 29 March 1994 (treatments 1-7 and 9-15 in Table 30). The purpose of the experiment was to compare labeled rates of Campaign herbicide with Roundup combined with 2,4-D amine, with or without the addition of AMS, to control winter annual weeds in dormant bermudagrass. This experiment was a duplicate of the two experiments conducted during 1993 (Experiments 4-H-66-93 and 4-H-67-93). The same herbicide treatments, rates of application, plot size, carrier rates and method of application were utilized. Experiment 4-H-73-94 was conducted on a silty clay loam soil along side SR 51, 8.0 km west of Stillwater in Payne County in ODOT Division 4. Within the experimental site, weed species included wild carrot, bromes and hairy vetch. Treatments were evaluated 29 April 1994 (1 MAT), 27 May 1994 (2 MAT) and 29 June 1994 (3 MAT). Evaluations were made by visual ratings for control of wild carrot, hairy vetch, broadleaves, brome spp. and bermudagrass phytotoxicity based on the scales discussed in Section 6.2.1.

6.2.4 Ammonium Sulfate Experiment 5-H-12-94

Experiment 5-H-12-94 was a duplicate of Experiment 4-H-73-94 as discussed earlier in the previous section 6.2.3. Experiment 5-H-12-94 was conducted on a silt loam soil along side the junction of SR 51 and US 183 in Dewey County in ODOT Division 5. Herbicide treatments were applied 16 February 1994 (treatments 8 and 16 in Table 31) and 30 March 1994 (treatments 1-7 and 9-15 in Table 31). Weeds species present within the experimental site included henbit and brome. Evaluation of herbicide treatments were made 29 April 1994 (1 MAT), 31 May 1994 (2 MAT) and 30 June 1994 (3 MAT). Visual ratings were made for henbit control, brome control and bermudagrass phytotoxicity using the rating scales discussed in Section 6.2.1.

6.2.5 Ammonium Sulfate Experiment 8-H-37-94

This experiment was a duplicate of Experiments 4-H-73-94 and 5-H-12-94 as previously discussed in sections 6.2.3 and 6.2.4. Herbicide treatments were applied 11 February 1994 (treatments 8 and 16 in Table 32) and 22 March 1994 (treatments 1-7 and 9-15 in Table 32). Experiment 8-H-37-94 was conducted on a silt loam soil along side US 169, 1.6 km north of Owasso in Tulsa County in ODOT Division 8. Weed species present within the experimental area included hairy vetch, chickweed, bromes and tall fescue (*Festuca arundinacea* Schreb.). Herbicide treatments were evaluated 22 April 1994 (1 MAT) and 23 May 1994 (2 MAT). Visual evaluations were made for control of hairy vetch, chickweed, broadleaf weeds, brome, tall fescue and bermudagrass phytotoxicity using methods described earlier.

6.3.0 RESULTS AND DISCUSSION

6.3.1 Ammonium Sulfate Experiment 4-H-66-93

Winter annual broadleaf weed control was improved by the addition of AMS to Campaign treatments when compared to equivalent treatments of Campaign alone, however, this effect was not statistically significant (Table 28). The greatest increase in control was found at the low rate of Campaign (0.94 ℓ product ha^{-1}) for all three evaluation dates. Likewise, AMS added to combination treatments of Roundup plus 2,4-D amine also increased the level of broadleaf weed control when compared to similar treatments without AMS. The addition of AMS to Aatrex did not improve the level of broadleaf weed control when compared to using Aatrex alone.

The greatest increase in the performance (efficacy) from the addition of AMS to a particular herbicide treatment was noted in the ratings for winter annual grass control. The addition of AMS to the low rate of Campaign (0.94 ℓ product ha^{-1}) resulted in significantly better winter annual grass control than the same rate of Campaign alone. Also, the lowest rate of Roundup combined with 2,4-D plus AMS was significantly better when compared to the same treatment without AMS.

Throughout the duration of this experiment no bermudagrass phytotoxicity was visually observed in any plot.

From this data it appears AMS will definitely improve the performance of both Campaign or the combination treatment of Roundup plus 2,4-D amine, especially at the lower labeled use rates. As the labeled herbicide rates are increased, the effect from the addition of AMS appears to become less visually noticeable.

6.3.2 Ammonium Sulfate Experiment 4-H-67-93

The addition of AMS to all three treatments of Campaign did improve the control of both winter annual grasses and broadleaf weeds when compared to the same Campaign treatments without AMS, however, this difference was not statistically significant (Table 29). When AMS was added to the two lower rates of Roundup combined with 2,4-D amine, the control of winter annual broadleaf and grassy weeds was significantly increased as compared with the same combination treatments without the addition of AMS. An increase in the level of winter annual weed control was observed when AMS was added to the higher rate of Roundup combined with 2,4-D amine as compared with the same treatment without AMS. However, this effect was not statistically significant. Little, if any, improvement was observed by the addition of AMS to the treatment of Aatrex 4L.

No bermudagrass phytotoxicity was observed in any plot throughout the duration of this experiment.

It appears from these data that AMS will definitely improve the performance of both Campaign or the combination treatment of Roundup plus 2,4-D amine, especially at the lower labeled use rates. As the herbicide rates are increased, the effect from the addition of AMS appears to become less visually noticeable.

6.3.3 Ammonium Sulfate Experiment 4-H-73-94

The following discussion will focus on the final visual observations made on 29 June 1994 at 3 MAT. Wild carrot control was improved by the addition of AMS to the two lower rates of Campaign (0.94 and 1.41 ℓ product ha^{-1}) as compared to equivalent treatments of Campaign alone, however, this effect was not statistically significant (Table 30). No differences in control of wild carrot were observed when comparing the two treatments with the highest rate of Campaign (1.88 ℓ product ha^{-1}) either with or without AMS. Also, the addition of AMS to the combination treatments of Roundup plus 2,4-D amine also increased the level of wild carrot control at the two lower rates as compared to equivalent treatments without AMS. No differences in wild carrot efficacy were observed when comparing the highest rate of the two combination treatments of Roundup plus 2,4-D amine (0.56 plus 1.12 kg ai ha^{-1}) with or without AMS. Adding AMS to Aatrex 4L also significantly increased the level of wild carrot control as compared to the treatment of Aatrex 4L alone.

The level of hairy vetch control was unaffected by the addition of AMS to all Campaign treatments, all combination treatments of Roundup plus 2,4-D amine, and Aatrex 4L. One interesting observation in this experiment was that all Campaign treatments, with or without AMS, performed significantly better than both Aatrex 4L treatments for control of hairy vetch.

Overall, broadleaf weed control observations from this experiment indicate no significant differences among all Campaign treatments and combination treatments of Roundup plus 2,4-D amine, with or without AMS. However, all of these treatments performed significantly better than both Aatrex 4L treatments (with or without AMS) for broadleaf weed control.

The only herbicide treatment which was significantly improved by the addition of AMS for *Bromus* spp. control was the lowest rate of Campaign (0.94 ℓ product ha^{-1}). All remaining herbicide treatments were not significantly affected by the addition of AMS. All herbicide treatments used in this experiment provided an acceptable level of *Bromus* spp. control.

No bermudagrass phytotoxicity was observed for any herbicide treatment throughout the duration of this experiment.

6.3.4 Ammonium Sulfate Experiment 5-H-12-94

The following discussion will focus on the final visual observations made on 30 June 1994 at 3 MAT.

Treatments of Campaign, Roundup plus 2,4-D amine and Aatrex 4L provided good to excellent control of henbit. The addition of AMS to each of the treatments did increase henbit control, however, the increase was not statistically significant (Table 31).

The two lower rates of Campaign and Roundup plus 2,4-D amine did not produce acceptable levels of *Bromus* spp. control. The addition of AMS significantly increased *Bromus* spp. control from these same treatments. *Bromus* spp. control was acceptable from the two higher rates of Campaign and Roundup plus 2,4-D amine when combined with AMS. All treatments including Aatrex 4L produced excellent *Bromus* spp. control. The two lower rates of Campaign did produce significantly better *Bromus* spp. control when compared to equivalent rates of Roundup plus 2,4-D amine. This increase in control was not evident when AMS was added to these treatments.

No bermudagrass phytotoxicity was observed for any treatment throughout the duration of this experiment.

6.3.5 Ammonium Sulfate Experiment 8-H-37-94

The following discussion will focus primarily on the last visual evaluations made on 23 May 1994 2 MAT. The addition of AMS to all herbicide treatments used in this experiment did not improve the level of hairy vetch control (Table 32). All treatments of Campaign and Roundup plus 2,4-D amine combinations with or without the addition of AMS exhibited significantly better control of hairy vetch than Aatrex 4L alone or in combination with AMS.

Chickweed control was improved significantly when AMS was added to the lower rate of Campaign (0.94 ℓ product ha^{-1}) as compared to the treatment of Campaign at 0.94 ℓ product ha^{-1} alone. The addition of AMS to the remaining Campaign treatments, all combination treatments of Roundup plus 2,4-D amine, and Aatrex 4L, did not improve the level of chickweed control as compared to equivalent treatments without AMS.

Overall, broadleaf weed control did improve by the addition of AMS to most of the herbicide treatments used in this experiment, however, the improvement was not statistically significant. The treatment which had the greatest increase in broadleaf weed control by the addition of AMS was the lowest rate of Campaign (0.94 ℓ product ha^{-1}).

The level of *Bromus* spp. control was significantly improved when AMS was added to Campaign at 0.94 ℓ product ha^{-1} as compared to the equivalent treatment without AMS. Although the addition of AMS to both treatments of Campaign at 1.41 and 1.88 ℓ product ha^{-1} did improve the control of *Bromus* spp. as compared to the respective equivalent treatments without AMS, this effect was not statistically significant. The addition of AMS to the lowest rate of Roundup plus 2,4-D amine (0.28 plus 0.56 kg ai ha^{-1}) significantly improved the level of *Bromus* spp. control as compared to the same treatment without AMS. No significant differences were observed with the other two rates of Roundup plus 2,4-D amine with or without the addition of AMS for *Bromus* spp. control.

Evaluations for tall fescue control indicated some initial control by some of the herbicide treatments, however, this effect soon diminished with none of them providing an acceptable level of control.

No bermudagrass phytotoxicity was observed from any of the herbicide treatments throughout the duration of this experiment.

6.4 CONCLUSIONS

Five experiments were conducted over a two-year period (1993-1994) to evaluate lower labeled use rates of specific herbicides combined with AMS for efficacy on winter annual weeds. Based upon the research data from these experiments, recommendations on AMS use were made to ODOT in the September 1994 Semi-Annual Progress Report. It was recommended that AMS could be added to either Campaign herbicide or the combination treatment of Roundup plus 2,4-D amine to improve control of winter annual weeds. A rate of 7.65 kg of sprayable grade AMS per 380 liters of water has been shown to improve weed control when added to the lower labeled use rates of either Campaign (0.94 ℓ product ha^{-1}) or the combination treatment of Roundup plus 2,4-D amine (refer to the respective Roundup and 2,4-D amine labels for specific use rates). AMS must be added to water (carrier) first, followed by the addition of herbicide(s) and drift control product. If a treatment of Roundup plus 2,4-D amine is used for winter annual weed control, then the time of application will be the same as for using Campaign herbicide.

Table 28. Effect of herbicide/ammonium sulfate treatments on annual broadleaves and grasses in a dormant bermudagrass roadside in ODOT Division 4 west of Stillwater in 1993 (Experiment 4-H-66-93).

Treatments[1]	Rate (kg ai ha^{-1})	Annual Broadleaf Control[4] 1 MAT[3]	2 MAT	3 MAT	Annual Grass Control[4] 1 MAT	2 MAT	3 MAT	Bermudagrass Phytotoxicity[5] 1 MAT	2 MAT
1. Check	-----	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2. Campaign	0.94 ℓ (product rate)	8.6	8.6	8.0	9.1	7.3	7.0	1.0	1.0
3. Campaign	1.41 ℓ (product rate)	9.7	9.6	9.3	9.6	9.2	9.3	1.0	1.0
4. Campaign	1.88 ℓ (product rate)	9.8	9.8	9.3	9.9	9.3	9.3	1.0	1.0
5. Roundup +	0.28								
2,4-D amine	0.56	8.5	8.5	8.3	7.2	7.0	6.8	1.0	1.0
6. Roundup +	0.43								
2,4-D amine	0.84	9.0	9.0	9.2	9.1	9.0	9.0	1.0	1.0
7. Roundup +	0.56								
2,4-D amine	1.12	9.5	9.6	9.5	9.6	9.5	9.3	1.0	1.0
8. Aatrex 4L	2.24	9.0	9.3	9.3	9.6	9.5	9.3	1.0	1.0
9. Check +	-----								
AMS[2]	3.81 (product)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
10. Campaign +	0.94 ℓ (product rate)								
AMS	3.81	9.9	9.9	9.3	9.9	9.6	9.5	1.0	1.0
11. Campaign +	1.41 ℓ (product rate)								
AMS	3.81	9.9	9.9	9.3	9.9	9.9	9.3	1.0	1.0
12. Campaign +	1.88 ℓ (product rate)								
AMS	3.81	9.9	9.9	9.5	9.9	9.8	9.3	1.0	1.0
13. Roundup +	0.28								
2,4-D amine +	0.56								
AMS	3.81	9.9	9.9	9.5	9.8	9.8	9.3	1.0	1.0
14. Roundup +	0.43								
2,4-D amine +	0.84								
AMS	3.81	9.9	9.9	9.5	9.9	9.8	9.3	1.0	1.0
15. Roundup +	0.56								
2,4-D amine +	1.12								
AMS	3.81	9.9	9.9	9.5	9.9	9.9	9.3	1.0	1.0
16. Aatrex 4L +	2.24								
AMS	3.81	7.6	7.6	7.5	7.6	7.6	7.5	1.0	1.0
$LSD_{0.05}$		1.5	1.5	1.4	1.8	2.0	2.1	NA	NA

[1]Combination treatments of Roundup plus 2,4-D amine had X-77 added at 0.5% v/v.
[2]AMS = Ammonium Sulfate.
[3]MAT = Months After Treatment.
[4]Weed control was rated on a 1 to 10 scale where 1 = no control and 10 = complete control.
[5]Bermudagrass phytotoxicity was rated on a 1 to 10 scale where 1 = no phytotoxicity and 10 = complete brownout.

Table 29. Effect of herbicide/ammonium sulfate treatments on annual broadleaves and grasses in a dormant bermudagrass roadside in ODOT Division 4 at Stillwater in 1993 (Experiment 4-H-67-93).

Treatments[1]		Rate ($kg\ ai\ ha^{-1}$)	Annual Broadleaf Control[4]			Annual Grass Control[4]			Bermudagrass Phytotoxicity[5]	
			1 MAT[3]	2 MAT	3 MAT	1 MAT	2 MAT	3 MAT	1 MAT	2 MAT
1.	Check	-----	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2.	Campaign	0.94 ℓ (product rate)	7.5	7.2	7.0	8.8	8.0	7.7	1.0	1.0
3.	Campaign	1.41 ℓ (product rate)	8.0	8.3	8.3	9.2	9.2	9.0	1.0	1.0
4.	Campaign	1.88 ℓ (product rate)	8.3	8.3	8.3	9.3	9.3	9.3	1.0	1.0
5.	Roundup +	0.28								
	2,4-D amine	0.56	2.0	3.0	3.0	3.7	5.0	5.0	1.0	1.0
6.	Roundup +	0.43								
	2,4-D amine	0.84	5.0	5.3	5.3	6.8	6.3	6.0	1.0	1.0
7.	Roundup +	0.56								
	2,4-D amine	1.12	7.8	8.0	7.7	8.5	8.8	8.7	1.0	1.0
8.	Aatrex 4L	2.24	9.3	9.2	8.3	8.6	8.8	8.7	1.0	1.0
9.	Check +	-----								
	AMS[2]	3.81 (product)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
10.	Campaign +	0.94 ℓ (product rate)								
	AMS	3.81	9.0	8.7	8.3	9.3	9.3	9.3	1.0	1.0
11.	Campaign +	1.41 ℓ (product rate)								
	AMS	3.81	9.3	9.3	9.2	9.6	9.5	9.5	1.0	1.0
12.	Campaign +	1.88 ℓ (product rate)								
	AMS	3.81	9.2	9.2	9.2	9.8	9.5	9.5	1.0	1.0
13.	Roundup +	0.28								
	2,4-D amine +	0.56								
	AMS	3.81	8.7	8.7	8.3	9.5	9.5	9.5	1.0	1.0
14.	Roundup +	0.43								
	2,4-D amine +	0.84								
	AMS	3.81	9.3	9.2	9.2	9.8	9.5	9.5	1.0	1.0
15.	Roundup +	0.56								
	2,4-D amine +	1.12								
	AMS	3.81	9.0	9.2	8.8	9.6	9.5	9.5	1.0	1.0
16.	Aatrex 4L +	2.24								
	AMS	3.81	9.3	9.3	9.3	8.7	9.3	9.0	1.0	1.0
$LSD_{0.05}$			1.6	1.9	1.8	1.8	1.8	1.9	NA	NA

[1]Combination treatments of Roundup plus 2,4-D amine had X-77 added at 0.5% v/v.
[2]AMS = Ammonium Sulfate.
[3]MAT = Months After Treatment.
[4]Weed control was rated on a 1 to 10 scale where 1 = no control and 10 = complete control.
[5]Bermudagrass phytotoxicity was rated on a 1 to 10 scale where 1 = no phytotoxicity and 10 = complete brownout.

Table 30. Effect of herbicide/ammonium sulfate treatments on winter annual weeds in ODOT Division 4 in 1994 (Experiment 4-H-73-94).

	Treatments[1]	Rate (kg ai ha^{-1})	Wild Carrot Control[4]			Hairy Vetch Control[4]			Broadleaf Control[4]			Bromus Control[4]			Bermudagrass Phytotoxicity[5]		
			1 MAT[6]	2 MAT	3 MAT	1 MAT	2 MAT	3 MAT	1 MAT	2 MAT	3 MAT	1 MAT	2 MAT	3 MAT	1 MAT	2 MAT	3 MAT
1.	Check	-----	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2.	Campaign	0.94 ℓ (prod. rate)	9.1	8.9	9.5	9.9	9.6	9.8	9.5	9.3	9.6	9.8	9.1	9.0	1.0	1.0	1.0
3.	Campaign	1.41 ℓ (prod. rate)	9.7	9.3	9.3	9.9	9.9	9.9	9.8	9.6	9.6	9.8	9.5	9.6	1.0	1.0	1.0
4.	Campaign	1.88 ℓ (prod. rate)	9.3	9.6	9.5	9.9	9.9	9.9	9.6	9.8	9.7	9.9	9.5	9.5	1.0	1.0	1.0
5.	Roundup +	0.28															
	2,4-D amine[2]	0.56	9.1	9.6	9.5	9.9	9.9	9.9	9.6	9.8	9.7	9.9	9.3	9.3	1.0	1.0	1.0
6.	Roundup +	0.43															
	2,4-D amine	0.84	8.7	9.6	9.5	9.9	9.9	9.9	9.4	9.8	9.7	9.9	9.6	9.6	1.0	1.0	1.0
7.	Roundup +	0.56															
	2,4-D amine	1.12	9.5	9.6	9.5	9.9	9.9	9.9	9.7	9.8	9.7	9.9	9.5	9.8	1.0	1.0	1.0
8.	Aatrex 4L	2.24	8.3	7.6	6.8	9.0	9.3	8.3	8.7	8.5	7.6	9.9	9.9	9.9	1.0	1.0	1.0
9.	Check +	-----															
	AMS[3]	3.81 (product)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
10.	Campaign +	0.94 ℓ (prod. rate)															
	AMS	3.81	9.6	9.9	9.8	9.9	9.9	9.9	9.8	9.9	9.8	9.9	9.6	9.8	1.0	1.0	1.0
11.	Campaign +	1.41 ℓ (prod. rate)															
	AMS	3.81	9.8	9.8	9.6	9.9	9.9	9.9	9.9	9.8	9.8	9.9	9.8	9.6	1.0	1.0	1.0
12.	Campaign +	1.88 ℓ (prod. rate)															
	AMS	3.81	9.8	9.6	9.3	9.9	9.9	9.9	9.9	9.8	9.6	9.9	9.8	9.5	1.0	1.0	1.0
13.	Roundup +	0.28															
	2,4-D amine +	0.56															
	AMS	3.81	9.1	9.4	9.1	9.7	9.9	9.9	9.4	9.8	9.5	9.9	9.8	9.5	1.0	1.0	1.0
14.	Roundup +	0.43															
	2,4-D amine +	0.84															
	AMS	3.81	9.1	9.6	9.3	9.9	9.9	9.9	9.5	9.8	9.6	9.9	9.8	9.8	1.0	1.0	1.0
15.	Roundup +	0.56															
	2,4-D amine +	1.12															
	AMS	3.81	8.9	9.6	9.5	9.9	9.9	9.9	9.4	9.8	9.7	9.9	9.9	9.8	1.0	1.0	1.0
16.	Aatrex 4L +	2.24															
	AMS	3.81	8.5	9.3	8.6	8.8	6.7	7.7	8.7	8.0	8.2	9.9	9.9	9.9	1.0	1.0	1.0
$LSD_{0.05}$			1.4	1.3	1.2	0.4	0.8	1.1	0.8	0.7	1.0	0.1	0.5	0.6	NS	NS	NS

[1]Treatments 8 and 16 applied 2-10-94; treatments 1-7 and 9-15 applied 3-29-94.
[2]Combination treatments of Roundup plus 2,4-D amine had X-77 added at 0.5% v/v.
[3]AMS = Ammonium Sulfate.
[4]Weed control was rated on a 1 to 10 scale where 1 = no control and 10 = complete control.
[5]Bermudagrass phytotoxicity was rated on a 1 to 10 scale where 1 = no phytotoxicity and 10 = complete brownout.
[6]MAT = Months After Treatment.

Table 31. Effect of herbicide/ammonium sulfate treatments on winter annual weeds in ODOT Division 5 in 1994 (Experiment 5-H-12-94).

Treatments[1]	Rate (kg ai ha^{-1})	Henbit Control[4]			Bromus spp. Control[4]			Bermudagrass Phytotoxicity[5]		
		1 MAT[6]	2 MAT	3 MAT	1 MAT	2 MAT	3 MAT	1 MAT	2 MAT	3 MAT
1. Check	-----	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2. Campaign	0.94 ℓ (product rate)	5.0	8.3	8.3	8.8	6.5	5.3	1.0	1.0	1.0
3. Campaign	1.41 ℓ (product rate)	6.0	8.7	8.7	9.5	7.8	7.8	1.0	1.0	1.0
4. Campaign	1.88 ℓ (product rate)	8.0	9.0	9.0	9.8	9.2	8.7	1.0	1.0	1.0
5. Roundup +	0.28									
2,4-D amine[2]	0.56	4.3	8.0	8.0	6.7	4.7	3.7	1.0	1.0	1.0
6. Roundup +	0.43									
2,4-D amine	0.84	5.3	8.3	8.3	8.7	7.3	6.3	1.0	1.0	1.0
7. Roundup +	0.56									
2,4-D amine	1.12	7.0	8.7	8.7	9.8	8.0	8.0	1.0	1.0	1.0
8. Aatrex 4L	2.24	9.9	9.6	9.6	9.9	9.9	9.9	1.0	1.0	1.0
9. Check +	-----									
AMS[3]	3.81 (product)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
10. Campaign +	0.94 ℓ (product rate)									
AMS	3.81	7.0	8.7	8.7	9.6	9.0	7.7	1.0	1.0	1.0
11. Campaign +	1.41 ℓ (product rate)									
AMS	3.81	7.8	8.7	8.7	9.9	9.3	9.2	1.0	1.0	1.0
12. Campaign +	1.88 ℓ (product rate)									
AMS	3.81	9.3	8.7	8.7	9.9	9.8	9.8	1.0	1.0	1.0
13. Roundup +	0.28									
2,4-D amine +	0.56									
AMS	3.81	7.0	8.5	8.5	9.9	8.5	8.3	1.0	1.0	1.0
14. Roundup +	0.43									
2,4-D amine +	0.84									
AMS	3.81	7.7	9.0	9.0	9.9	9.6	9.1	1.0	1.0	1.0
15. Roundup +	0.56									
2,4-D amine +	1.12									
AMS	3.81	8.8	9.2	9.2	9.9	9.8	9.6	1.0	1.0	1.0
16. Aatrex 4L +	2.24									
AMS	3.81	9.9	9.6	9.6	9.9	9.9	9.8	1.0	1.0	1.0
$LSD_{0.05}$		1.2	0.9	0.9	1.0	1.2	1.4	NS	NS	NS

[1]Treatments 8 and 16 applied 2-16-94; treatments 1-7 and 9-15 applied 3-30-94.
[2]Combination treatments of Roundup plus 2,4-D amine had X-77 added at 0.5% v/v.
[3]AMS = Ammonium Sulfate.
[4]Weed control was rated on a 1 to 10 scale where 1 = no control and 10 = complete control.
[5]Bermudagrass phytotoxicity was rated on a 1 to 10 scale where 1 = no phytotoxicity and 10 = complete control.
[6]MAT = Months After Treatment.

Table 32. Effect of herbicide/ammonium sulfate treatments on winter annual weeds in ODOT Division 8 in 1994 (Experiment 8-H-37-94).

Treatments[1]	Rate (kg ai ha^{-1})	Hairy Vetch Control[4] 1 MAT[6]	Hairy Vetch Control[4] 2 MAT	Chickweed Control[4] 1 MAT	Chickweed Control[4] 2 MAT	Broadleaf Control[4] 1 MAT	Broadleaf Control[4] 2 MAT	Bromus spp. Control[4] 1 MAT	Bromus spp. Control[4] 2 MAT	Tall Fescue Control[4] 1 MAT	Tall Fescue Control[4] 2 MAT	Bermudagrass Phytoxicity[5] 1 MAT	Bermudagrass Phytoxicity[5] 2 MAT
1. Check	-----	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2. Campaign	0.94 ℓ (prod. rate)	8.3	9.9	5.3	7.7	6.3	8.7	7.3	7.0	1.0	1.3	1.0	1.0
3. Campaign	1.41 ℓ (prod. rate)	9.8	9.9	9.6	8.7	9.6	9.3	9.6	9.3	2.7	1.7	1.0	1.0
4. Campaign	1.88 ℓ (prod. rate)	9.9	9.9	9.3	8.8	9.6	9.4	9.8	9.0	2.7	1.7	1.0	1.0
5. Roundup +	1.28												
2,4-D amine[2]	0.56	9.6	9.9	8.0	8.3	8.5	9.2	8.7	8.0	2.0	1.0	1.0	1.0
6. Roundup +	0.43												
2,4-D amine	0.84	9.8	9.9	9.3	8.7	9.3	9.3	9.3	9.5	2.7	2.3	1.0	1.0
7. Roundup +	0.56												
2,4-D amine	1.12	9.9	9.9	9.8	9.6	9.8	9.8	9.8	9.9	4.0	2.0	1.0	1.0
8. Aatrex 4L	2.24	9.3	7.0	9.8	9.9	9.6	8.5	9.9	9.9	1.0	1.3	1.0	1.0
9. Check +	-----												
AMS[3]	3.81 (product)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
10. Campaign +	0.94 ℓ (prod. rate)												
AMS	3.81	9.9	9.9	9.3	8.8	9.6	9.3	9.8	9.3	2.7	2.3	1.0	1.0
11. Campaign +	1.41 ℓ (prod. rate)												
AMS	3.81	9.9	9.9	9.4	9.6	9.7	9.8	9.9	9.9	3.3	1.3	1.0	1.0
12. Campaign +	1.88 ℓ (prod. rate)												
AMS	3.81	9.9	9.9	9.4	9.0	9.7	9.5	9.8	9.8	4.7	2.0	1.0	1.0
13. Roundup +	0.28												
2,4-D amine +	0.56												
AMS	3.81	9.6	9.9	8.2	8.3	8.9	9.2	9.6	9.8	3.3	2.7	1.0	1.0
14. Roundup +	0.43												
2,4-D amine +	0.84												
AMS	3.81	9.9	9.9	9.6	9.0	9.7	9.5	9.9	9.9	4.7	1.3	1.0	1.0
15. Roundup +	0.56												
2,4-D amine +	1.12												
AMS	3.81	9.9	9.9	9.6	9.6	9.8	9.8	9.9	9.9	4.0	3.0	1.0	1.0
16. Aatrex 4L +	2.24												
AMS	3.81	9.0	8.3	9.6	9.9	9.3	9.1	9.9	9.9	1.0	1.3	1.0	1.0
$LSD_{0.05}$		0.8	1.5	1.9	0.9	1.3	0.9	1.2	1.0	1.7	1.0	NS	NS

[1]Treatments 8 and 16 applied 2-11-94; treatments 1-7 and 9-15 applied 3-22-94.
[2]Combination treatments of Roundup plus 2,4-D amine had X-77 added at 0.5% v/v.
[3]AMS = Ammonium Sulfate.
[4]Weed control was rated on a 1 to 10 scale where 1 = no control and 10 = complete control.
[5]Bermudagrass phytotoxicity was rated on a 1 to 10 scale where 1 = no phytotoxicity and 10 = complete brownout.
[5]MAT = Months After Treatment.

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7. Effects of Selective Herbicides as Atrazine Alternatives for Control of Winter Annual Weeds

D. P. Montgomery, L. M. Cargill, and D. L. Martin

7.1 INTRODUCTION

Atrazine was first examined for roadside weed control in Oklahoma during the mid-1960s. Even though atrazine was economical and performed well in research experiments, it was not implemented into wide-scale use along the state highway system until 1980. Atrazine was the first selective preemergent herbicide used to any extent on Oklahoma roadsides. For the first time, state transportation personnel were controlling weeds such as cheat (*Bromus secalinus* L.), downy brome (*Bromus tectorum* L.), hairy vetch (*Vicia villosa*), and sweet clovers (*Melilotus officinalis* L. and M. alba). Roadsides having these winter weeds traditionally required an early spring safety mowing which was eliminated with the use of atrazine.

In November of 1988 all registrants of atrazine voluntarily submitted an atrazine management program to EPA. The program, accepted in 1990, resulted in benefits of having reduced applicator exposure; reduced potential groundwater and surface water contamination; and a reduction in the number of use sites. The program resulted in the withdrawal of the State-of-Oklahoma issued 24-C (Special Local Needs Permit) which amended the federal label. It was this 24-C label that had allowed vegetation managers to use atrazine along Oklahoma roadsides. As a result, atrazine was unavailable for ODOT applicators to use for winter weed control applications in spring of 1992.

In spring of 1992 there was again interest by registrants in obtaining a new 24-C label for use on Oklahoma roadsides. However, with the new interest came many proposed changes. First, atrazine would only be available for use by ODOT and Oklahoma Turnpike Authority (OTA) personnel. This was primarily due to ODOT and OTA's familiarity with atrazine use and the cooperative project with OSU which provided training on atrazine use. Secondly, application rates were limited to a maximum of 2.2 kg ai ha^{-1} (2 lbs ai A^{-1} yr^{-1}). Lastly, a voluntary educational program for ODOT was to be performed before use of atrazine was continued. The fall 1992 program implemented county maps with designated no-spray areas and it reinforced the 1990 label changes.

Even with atrazine's new 24-C label (effective fall 1992) most researchers and industry personnel agreed that with the scrutiny the triazine family was/is receiving, the 24C label allowing atrazine use on roadsides would remain in jeopardy. While this loss may or may not again come about, it was imperative to find alternatives to atrazine use for winter annual weed control in dormant bermudagrass roadsides. Many agronomic herbicides have the ability to control winter annual grasses and broadleaf weeds. The challenge was to find a single or combination treatment that would be economical in a non-crop situation.

Experiments completed on earlier Joint Projects have shown several treatments will produce winter annual weed control comparable to atrazine (1). A literature review (2) also shows other products that are currently labeled for right-of-way use should produce annual weed control in bermudagrass roadsides. With this in mind the objective of these experiments was to find an economical replacement for atrazine by screening several herbicides and combinations for their ability to control winter annual grasses and broadleaf weeds common to Oklahoma roadsides.

7.2 MATERIALS AND METHODS

7.2.1 Experiments 4-H-57-91, 5-H-10-91 and 8-H-28-91

It was evident from experiments completed on the ODOT/OSU Joint Project 2147 that many of the herbicides that could potentially serve as a replacement for atrazine have limited postemergence activity. Therefore, in the 1991 experiments each plot treated with a herbicide or combination of herbicides had one-half of the plot also treated with Roundup at 0.56 kg ai ha^{-1}. Each of these experiments had identical treatments but were conducted on different sites in western, central and eastern Oklahoma. Experiment 4-H-57-91 was conducted on a loam soil along side the junction of SR 33 and SR 108 in Payne County in ODOT Division 4 while Experiment 5-H-10-91 was conducted on a silt loam soil along side I-40 at Exit 65-A in Clinton in Custer County in ODOT Division 5. Experiment 8-H-28-91 was conducted on a silt loam soil along side US 169, 1.6 km north of Owasso in Tulsa County in ODOT Division 8. The herbicide treatments evaluated in these experiments included Solicam at 0.45, 0.90 and 1.80 kg ai ha^{-1}; atrazine at 2.20 kg ai ha^{-1}; Rifle at 0.17 kg ai ha^{-1}; Karmex at 2.70 kg ai ha^{-1}; Oust at 0.027 kg ai ha^{-1} combined with Karmex at 1.12 kg ai ha^{-1}, or Lexone at 0.21 kg ai ha^{-1}, or Telar at 0.05 kg ai ha^{-1}, or Escort at 0.043 kg ai ha^{-1}. Also, treatments of XRM-4950 at 0.07, 0.14, and 0.28 kg ai ha^{-1}; Stomp at 1.12 kg ai ha^{-1}; and Surflan at 2.24 kg ai ha^{-1} were evaluated. All treatments excluding Solicam, Stomp, and Surflan received X-77 surfactant at 0.25% v/v.

Treatments were applied on 8 March (Experiment 4-H-57-91), 14 March (Experiment 8-H-28-91) and 20 March 1991 (Experiment 5-H-10-91) to dormant bermudagrass and actively growing weeds. Treatments were applied to the entire plot (split block fashion) using a CO_2 powered backpack sprayer equipped with a three nozzle hand held boom calibrated to deliver 187 ℓ ha^{-1}. Treatments were repeated three times in a randomized complete block design. After the herbicide treatments were applied, they were allowed to dry at which point Roundup at 0.56 kg ai ha^{-1} was applied to the back one-half of the 1.5 x 3 m plots.

The plots were evaluated at 1, 2 and 3 months after treatment (MAT) for annual grass and annual broadleaf weed control where 1 = no effect and 10 = complete control. A control value of 9.5 or above was considered acceptable. Bermudagrass phytotoxicity was evaluated on a scale of 1 to 10 where 1 = no effect and 10 = complete browning. A phytotoxicity level of 4.6 or less at 2 MAT was considered acceptable.

Data were analyzed using an analysis of variance procedure. The experimental design was a split block (Roundup applied in strips across herbicide treatments within blocks) split in time (due to rating dates). Because of significant location x treatment x rating date effect, treatment means within rating dates within locations were separated with an LSD test.

7.2.2 Experiments 4-H-62-92, 5-H-11-92 and 8-H-31-92

Three experiments were initiated in 1992 to further refine herbicide products and rates as potential replacements for atrazine even though a new 24-C label was granted. The 1992 experiments consisted of identical treatments but each experiment was conducted at different sites in Oklahoma. Experiment 4-H-62-92 was conducted on a loam soil along side the junction of SR 33 and SR 108 in Payne County in ODOT Division 4 while Experiment 5-H-11-92 was conducted on a silt loam soil along side I-40 at Exit 65-A in Clinton in Custer County in ODOT Division 5. Experiment 8-H-31-92 was conducted on a silt loam soil along side US 169, 1.6 km north of Owasso in Tulsa County in ODOT Division 8. The 20 treatments evaluated included Solicam at 0.45, 0.9, 1.8, and 4.48 kg ai ha^{-1}; atrazine at

2.2 kg ai ha^{-1}; Rifle at 0.17 kg ai ha^{-1}; Karmex at 2.7 kg ai ha^{-1}; or Oust at 0.027 kg ai ha^{-1} combined with Karmex at 1.12 kg ai ha^{-1}; or Lexone at 0.21 kg ai ha^{-1}; or Telar at 0.05 kg ai ha^{-1}; or Escort at 0.043 kg ai ha^{-1}. Also evaluated were treatments of Stomp at 1.12 kg ai ha^{-1}; Surflan, Princep, or Bladex at 2.24 kg ai ha^{-1}; Lexone alone at 1.12 and 2.24 kg ai ha^{-1}; Campaign at 0.5 and 0.67 kg ai ha^{-1}; and Corn Gluten Meal at 976 kg product per hectare. All treatments excluding Solicam, Stomp, Surflan, Campaign, and Corn Gluten Meal received X-77 surfactant at 0.25% v/v. Treatments were applied to dormant bermudagrass and actively growing weeds on 2 March (Experiment 4-H-62-92), 3 March (Experiment 8-H-31-92) and 5 March (Experiment 5-H-11-92) using the same technique as used on 1991 experiments. Roundup was also applied to one-half of the plot in the same manner as 1991 experiments. Treatments were evaluated on a monthly basis for annual grass control, broadleaf weed control, and bermudagrass phytotoxicity as discussed in Section 7.2.1.

7.3 RESULTS AND DISCUSSION

7.3.1 Experiments 4-H-57-91, 5-H-10-91 and 8-H-28-91

Products which did not exhibit postemergent activity, such as Solicam, Stomp, Surflan, and XRM-4950, benefited significantly from the addition of Roundup for both annual grass and broadleaf weed control (data not shown). Roundup appeared to enhance the level of annual grass control more so than the amount of broadleaf weed control, when it was added to other products. Atrazine, alone, continued to provide better annual grass and broadleaf weed control than any of the other products tested in these experiments. Closely following atrazine in efficacy were two treatments, Rifle and the combination treatment of Karmex plus Oust, which provided an acceptable level of both annual grass and broadleaf weed control (without the addition of Roundup). The combination treatments of Oust with other products (no Roundup added) provided only marginal control of both annual grasses and broadleaf weeds, but with the addition of Roundup, control of annual weeds was acceptable. Treatments of Solicam, Stomp, Surflan, and XRM-4950, with and without Roundup, did not exhibit an acceptable level of either annual grass or broadleaf weed control.

Bermudagrass phytotoxicity was observed initially (1 MAT), however, no significant bermudagrass phytotoxicity was observed 2 MAT evaluations.

7.3.2 Experiment 4-H-62-92

No significant bermudagrass phytotoxicity was observed 1 MAT in any treatments alone or with the addition of Roundup. At 2 MAT, significant bermudagrass phytotoxicity was evident with the following treatments, alone or in a combination with Roundup: the highest rate of Solicam (4.48 kg ai ha^{-1}), Karmex plus Oust, Lexone plus Oust, and Telar plus Oust. By 3 MAT, no significant differences in bermudagrass phytotoxicity was observed (Table 33).

The level of broadleaf weed control for all treatments combined with Roundup was acceptable and significantly better than the plots treated with Corn Gluten Meal 1 MAT (Table 34). Roundup significantly enhanced the level of broadleaf weed control in plots treated with all rates of Solicam, Surflan, Stomp and Corn Gluten Meal 1, 2 and 3 MAT evaluations.

At 1 MAT, the level of annual grass control for all treatments combined with Roundup was acceptable and significantly better than plots treated with Corn Gluten Meal (Table 35). The amount of annual grass control was enhanced significantly by the addition of Roundup in plots treated with all rates of Solicam, Surflan, Stomp and Corn Gluten Meal for all three evaluation dates. Addition of Roundup slightly increased the performance of Princep 2 and 3 MAT evaluations.

It appears from data in this experiment that Roundup will enhance both annual grass and broadleaf weed control to an acceptable level for some herbicide treatments which would otherwise not produce a desirable level of annual weed control. The better treatments (without Roundup) in this experiment appeared to be atrazine; Rifle; Karmex; all combination treatments of Oust with Karmex, Lexone, Telar, Escort; Bladex; both rates of Lexone; and the high rate of Campaign.

7.3.3 Experiment 5-H-11-92

Bermudagrass phytotoxicity was not present 1 and 3 MAT evaluations for all treatments alone or combined with Roundup. Significant differences in bermudagrass phytotoxicity were observed when evaluated 2 MAT (Table 33). Roundup significantly increased bermudagrass phytotoxicity in plots treated with Telar plus Oust and Escort plus Oust, however, phytotoxicity was at an acceptable level.

No significant differences in the level of annual broadleaf control 1, 2 and 3 MAT were observed for all treatments combined with Roundup (Table 36). However, there were significant differences for all three rating dates among treatments which contained no Roundup. Roundup significantly enhanced the level of annual broadleaf control in plots treated with all rates of Solicam, Karmex, Stomp, Surflan, Princep, Bladex, the lowest rate of Lexone and Corn Gluten Meal.

When evaluations were made 1, 2 and 3 MAT, no significant differences in annual grass control were evident for all treatments combined with Roundup (Table 37). Significant differences were observed during all three evaluation dates for annual grass control for treatments which had no Roundup added. The level of annual grass control was significantly enhanced with the addition of Roundup in plots treated with all rates of Solicam, Rifle, Karmex, Karmex plus Oust, Telar plus Oust, Stomp, Surflan, Princep, Bladex, the lower rate of Lexone and Corn Gluten Meal.

From the data in this experiment, it appears that Roundup will enhance both annual grass and broadleaf weed control to an acceptable level for some herbicide treatments which would otherwise not produce a desirable level of annual weed control alone. The better treatments (without Roundup) in this experiment for both annual grass and broadleaf weed control appeared to be atrazine, the higher rate of Lexone and both rates of Campaign.

7.3.4 Experiment 8-H-31-92

No bermudagrass phytotoxicity was observed for any treatments when evaluations were made 1 MAT. Significant differences in bermudagrass phytotoxicity were evident when ratings were made 2 MAT (Table 33). Treatments with the two higher rates of Solicam, Karmex plus Oust, Lexone plus Oust, Telar plus Oust and Escort plus Oust when combined with Roundup exhibited significantly more bermudagrass phytotoxicity than the remainder of the treatments combined with Roundup. Treatments including the highest rate of Solicam, Lexone plus Oust, Telar plus Oust and Escort plus Oust without addition of Roundup were those exhibiting significantly more bermudagrass phytotoxicity than the remaining treatments with no Roundup added. By 3 MAT the level of bermudagrass phytotoxicity was acceptable in all plots and no significant differences were present.

When evaluations were made 1 MAT, no significant differences in annual broadleaf control were present in plots which had Roundup applied, however, there were significant differences in ratings for plots which had no Roundup present (Table 38). All rates of

Solicam, Stomp, Surflan and Corn Gluten Meal without Roundup provided significantly less control of annual broadleaf weeds than the remaining treatments. Roundup significantly enhanced the level of annual broadleaf control for all three evaluation dates. Greatest effects were observed when Roundup was added to all rates of Solicam, Stomp, Surflan and Corn Gluten Meal.

Ratings made 1 and 3 MAT for annual grass control indicated no significant differences among herbicide treatments when combined with Roundup (Table 39). The level of annual grass control was enhanced significantly by the addition of Roundup in plots treated with all rates of Solicam, Rifle, Stomp, Surflan and Corn Gluten Meal.

From the data in this experiment, it appears that Roundup will enhance both annual grass and broadleaf weed control to an acceptable level for some herbicide treatments which would otherwise not produce a desirable level of annual weed control. The better treatments (without Roundup) in this experiment for both annual grass and broadleaf weed control appear to be atrazine; the combination of Oust with Karmex, Lexone, Telar, Escort; and the higher rate of Lexone.

7.4 CONCLUSIONS

Data from earlier experiments in Joint Project 2147 (1) (Experiments 4-H-53-90, 5-H-1-88, 4-H-42-88 and 4-H-43-88) along with data presented in this chapter indicate that a replacement for atrazine is possible but it will come at a price. Atrazine has provided effective control of both annual grass and broadleaf weeds for product cost of about $11.40 - $13.90 per hectare. Few, if any, single products today have this broad spectrum of weed control for such an economical price. The modern herbicides are very selective such that it is now necessary to mix two or more together to maintain the desirable level of weed control. This trend has become apparent in these experiments as the most effective treatments are all combination treatments. The most efficacious treatments in these experiments included Oust combined with Karmex, Lexone, Telar or Escort and higher rates of Campaign (a premix of glyphosate plus 2,4-D). These treatments would cost a minimum of two to three times as much as a single treatment of atrazine. Data also indicates that adding Roundup at 0.56 kg ai ha^{-1} to many of these products will both increase weed control and lower chemical costs by allowing herbicide use rate reductions.

Table 33. Phytotoxicity to bermudagrass of herbicide treatments applied to bermudagrass roadsides in 1992 (Experiments 4-H-62-92, 5-H-11-92, and 8-H-31-92).

		Bermudagrass Phytotoxicity[3] 2 MAT[4]					
		Experiment 5-H-11-92		Experiment 4-H-62-92		Experiment 8-H-31-92	
Treatments[1]	Rate[2] (kg ai ha^{-1})	With Roundup[5]	No Roundup	With Roundup	No Roundup	With Roundup	No Roundup
Solicam	0.45	1.0	1.0	1.3	1.0	1.0	1.0
Solicam	0.9	1.0	1.0	1.3	1.7	1.0	1.0
Solicam	1.8	1.0	1.0	2.0	1.7	3.3	1.7
Solicam	4.48	2.0	1.7	5.3	3.7	5.3	4.0
Atrazine	2.24	1.0	1.0	1.7	1.7	1.0	1.0
Rifle	0.17	1.7	1.0	2.7	2.3	1.0	1.0
Karmex	2.7	1.3	1.0	1.3	1.0	1.3	1.0
Karmex + Oust	1.12 + 0.027	2.0	1.0	3.7	2.7	2.7	2.7
Lexone + Oust	0.21 + 0.027	1.7	1.0	4.0	3.3	3.0	3.7
Telar + Oust	0.05 + 0.027	2.3	1.3	4.0	3.3	4.0	4.0
Escort + Oust	0.043 + 0.027	3.3	1.3	2.7	2.0	4.0	5.0
Stomp	1.12	1.3	1.0	1.3	1.0	1.0	1.0
Surflan	2.24	1.0	1.0	1.7	1.3	1.3	1.0
Princep	2.24	1.0	1.0	1.7	1.7	1.0	1.0
Bladex	2.24	1.0	1.0	1.3	1.3	1.0	1.0
Lexone	1.12	1.0	1.0	1.3	1.0	1.0	1.0
Lexone	2.24	1.0	1.0	1.3	1.0	1.0	1.0
Campaign	0.5	1.3	1.0	2.0	1.7	1.0	1.0
Campaign	0.67	1.7	1.0	2.0	1.3	1.0	1.0
Corn Gluten Meal	976 (prod. rate)	1.0	1.0	1.3	1.7	1.0	1.0
Check	------	1.0	1.0	1.3	1.0	1.3	1.0

[1]The adjuvant X-77 was added at 0.25% v/v to all treatments except Solicam, Stomp, Surflan, Campaign and Corn Gluten Meal.
[2]Corn Gluten Meal rate is in kg of product per hectare.
[3]Bermudagrass phytotoxicity was rated on a 1 to 10 scale where 1 = no phytotoxicity and 10 = complete brownout. Statistical comparison may be made between treatments and columns within experiments using the following LSD values: 0.85 (Experiment 5-H-11-92), 1.53 (Experiment 4-H-62-92) and 1.76 (Experiment 8-H-31-92).
[4]MAT = Months After Treatment.
[5]Roundup was applied at 0.56 kg ai ha^{-1}.

Table 34. Control of annual broadleaf weeds in bermudagrass roadsides in ODOT Division 4 in 1992 (Experiment 4-H-62-92).

		Annual Broadleaf Control[3]					
		1 MAT[4]		2 MAT		3 MAT	
Treatments[1]	Rate[2] (kg ai ha^{-1})	With Roundup[5]	No Roundup	With Roundup	No Roundup	With Roundup	No Roundup
Solicam	0.45	9.5	1.0	9.3	1.0	8.2	1.0
Solicam	0.9	9.6	1.0	9.3	1.7	9.3	1.7
Solicam	1.8	9.6	1.0	9.5	1.0	9.6	1.0
Solicam	4.48	9.8	2.3	9.6	4.0	9.5	4.0
Atrazine	2.24	9.9	9.9	9.8	9.9	9.8	9.8
Rifle	0.17	9.9	9.5	9.8	9.8	9.8	9.8
Karmex	2.7	9.8	9.6	9.6	9.6	9.6	9.5
Karmex + Oust	1.12 + 0.027	9.9	9.9	9.9	9.9	9.8	9.8
Lexone + Oust	0.21 + 0.027	9.9	9.8	9.8	9.6	9.5	9.5
Telar + Oust	0.05 + 0.027	9.9	9.9	9.9	9.9	9.9	9.9
Escort + Oust	0.043 + 0.027	9.9	9.9	9.9	9.9	9.9	9.9
Stomp	1.12	9.2	2.7	9.3	2.7	9.3	2.7
Surflan	2.24	9.2	1.7	6.8	1.3	6.7	1.3
Princep	2.24	9.3	8.2	9.2	7.8	9.2	7.3
Bladex	2.24	9.9	9.9	9.9	9.9	9.9	9.9
Lexone	1.12	9.9	9.9	9.9	9.9	9.8	9.8
Lexone	2.24	9.9	9.9	9.8	9.8	9.8	9.8
Campaign	0.5	9.9	9.3	9.8	8.8	9.8	8.8
Campaign	0.67	9.9	9.6	9.6	9.4	8.9	8.9
Corn Gluten Meal	976 (prod. rate)	8.5	1.0	7.5	1.0	7.8	1.0
Check	------	9.2	1.0	8.5	1.0	8.5	1.0

[1]The adjuvant X-77 was added at 0.25% v/v to all treatments except Solicam, Stomp, Surflan, Campaign and Corn Gluten Meal.
[2]Corn Gluten Meal rate is in kg of product per hectare.
[3]Bermudagrass phytotoxicity was rated on a 1 to 10 scale where 1 = no phytotoxicity and 10 = complete brownout. Statistical comparison may be made between treatments and columns within rating dates using the following LSD values: 0.99 (1 MAT), 1.36 (2 MAT) and 1.46 (3 MAT).
[4]MAT = Months After Treatment.
[5]Roundup was applied at 0.56 kg ai ha^{-1}.

Table 35. Control of annual grasses in bermudagrass roadsides in ODOT Division 4 in 1992 (Experiment 4-H-62-92).

Treatments[1]	Rate[2] (kg ai ha^{-1})	Annual Grass Control[3] 1 MAT[4] With Roundup[5]	1 MAT No Roundup	2 MAT With Roundup	2 MAT No Roundup	3 MAT With Roundup	3 MAT No Roundup
Solicam	0.45	9.3	1.0	9.0	1.0	7.2	1.0
Solicam	0.9	9.6	1.0	8.3	1.7	7.8	1.7
Solicam	1.8	9.9	1.0	9.8	1.0	9.5	1.0
Solicam	4.48	9.8	4.7	9.6	4.3	9.3	4.3
Atrazine	2.24	9.9	9.9	9.9	9.9	9.8	9.8
Rifle	0.17	9.9	9.6	9.8	9.8	9.8	9.8
Karmex	2.7	9.8	9.8	9.8	9.8	9.6	9.5
Karmex + Oust	1.12 + 0.027	9.9	9.9	9.9	9.9	9.9	9.9
Lexone + Oust	0.21 + 0.027	9.9	9.9	9.8	9.8	9.5	9.5
Telar + Oust	0.05 + 0.027	9.9	9.9	9.9	9.9	9.9	9.9
Escort + Oust	0.043 + 0.027	9.9	9.9	9.9	9.9	9.9	9.9
Stomp	1.12	9.3	3.3	9.6	4.0	9.0	3.7
Surflan	2.24	9.2	1.7	7.0	2.7	6.0	2.3
Princep	2.24	9.3	8.3	9.3	8.1	9.2	7.5
Bladex	2.24	9.9	9.9	9.9	9.9	9.9	9.9
Lexone	1.12	9.9	9.9	9.9	9.9	9.8	9.8
Lexone	2.24	9.9	9.9	9.9	9.9	9.9	9.9
Campaign	0.5	9.9	9.4	9.8	8.8	9.6	9.3
Campaign	0.67	9.9	9.6	9.6	9.4	8.9	8.9
Corn Gluten Meal	976 (prod. rate)	8.5	1.0	7.0	1.0	7.0	1.0
Check	------	9.2	1.0	7.5	1.0	7.7	1.0

[1]The adjuvant X-77 was added at 0.25% v/v to all treatments except Solicam, Stomp, Surflan, Campaign and Corn Gluten Meal.
[2]Corn Gluten Meal rate is in kg of product per hectare.
[3]Bermudagrass phytotoxicity was rated on a 1 to 10 scale where 1 = no phytotoxicity and 10 = complete brownout. Statistical comparison may be made between treatments and columns within rating dates using the following LSD values: 1.34 (1 MAT), 1.72 (2 MAT) and 1.95 (3 MAT).
[4]MAT = Months After Treatment.
[5]Roundup was applied at 0.56 kg ai ha^{-1}.

Table 36. Control of annual broadleaf weeds in bermudagrass roadsides in ODOT Division 5 in 1992 (Experiment 5-H-11-92).

		Annual Broadleaf Control[3]					
		1 MAT[4]		2 MAT		3 MAT	
Treatments[1]	Rate[2] (kg ai ha^{-1})	With Roundup[5]	No Roundup	With Roundup	No Roundup	With Roundup	No Roundup
Solicam	0.45	9.6	1.3	8.7	1.3	8.7	1.0
Solicam	0.9	9.5	1.7	8.8	1.7	8.5	1.3
Solicam	1.8	9.5	2.7	8.5	1.3	8.5	1.3
Solicam	4.48	9.5	6.7	9.0	6.7	9.0	5.3
Atrazine	2.24	9.8	9.8	9.7	9.7	9.5	9.5
Rifle	0.17	9.8	8.5	9.7	7.9	9.6	7.8
Karmex	2.7	9.7	7.0	9.1	6.2	8.3	4.3
Karmex + Oust	1.12 + 0.027	9.8	9.3	9.7	9.3	9.5	9.0
Lexone + Oust	0.21 + 0.027	9.7	9.6	9.6	9.5	9.5	9.5
Telar + Oust	0.05 + 0.027	9.8	9.4	9.7	9.5	9.5	9.3
Escort + Oust	0.043 + 0.027	9.8	9.7	9.7	9.6	9.5	9.5
Stomp	1.12	9.7	5.2	9.7	4.8	9.5	4.3
Surflan	2.24	9.7	2.3	9.6	2.3	9.5	2.0
Princep	2.24	9.7	6.7	9.5	5.7	9.5	5.3
Bladex	2.24	9.5	4.7	9.4	4.0	9.3	3.0
Lexone	1.12	9.7	9.1	9.6	8.3	9.3	7.5
Lexone	2.24	9.7	9.7	9.7	9.7	9.5	9.5
Campaign	0.5	9.7	9.7	9.7	9.5	9.5	9.3
Campaign	0.67	9.8	9.7	9.5	9.7	9.3	9.5
Corn Gluten Meal	976 (prod. rate)	9.6	1.0	9.5	1.0	9.3	1.0
Check	------	9.5	1.0	9.5	1.0	9.3	1.0

[1]The adjuvant X-77 was added at 0.25% v/v to all treatments except Solicam, Stomp, Surflan, Campaign and Corn Gluten Meal.
[2]Corn Gluten Meal rate is in kg of product per hectare.
[3]Bermudagrass phytotoxicity was rated on a 1 to 10 scale where 1 = no phytotoxicity and 10 = complete brownout. Statistical comparison may be made between treatments and columns within rating dates using the following LSD values: 1.79 (1 MAT), 2.00 (2 MAT) and 2.04 (3 MAT).
[4]MAT = Months After Treatment.
[5]Roundup was applied at 0.56 kg ai ha^{-1}.

Table 37. Control of annual grassy weeds in bermudagrass roadsides in ODOT Division 5 in 1992 (Experiment 5-H-11-92).

		Annual Grass Control[3]					
		1 MAT[4]		2 MAT		3 MAT	
Treatments[1]	Rate[2] (kg ai ha^{-1})	With Roundup[5]	No Roundup	With Roundup	No Roundup	With Roundup	No Roundup
Solicam	0.45	9.7	1.3	9.6	1.3	9.3	1.0
Solicam	0.9	9.6	1.7	8.5	2.0	7.5	1.3
Solicam	1.8	9.4	2.7	9.4	3.7	9.0	3.3
Solicam	4.48	9.7	5.0	9.6	5.0	9.3	3.7
Atrazine	2.24	9.8	9.7	9.8	9.7	9.5	9.3
Rifle	0.17	9.7	7.4	9.8	7.3	9.6	6.8
Karmex	2.7	9.4	3.3	9.4	2.7	9.3	1.7
Karmex + Oust	1.12 + 0.027	9.8	9.0	9.8	6.7	9.2	5.7
Lexone + Oust	0.21 + 0.027	9.7	9.6	9.8	8.0	9.5	8.0
Telar + Oust	0.05 + 0.027	9.8	9.0	9.8	7.7	9.5	7.0
Escort + Oust	0.043 + 0.027	9.8	9.0	9.8	8.0	9.5	8.0
Stomp	1.12	9.8	4.5	9.8	3.7	9.5	2.0
Surflan	2.24	9.7	2.0	9.6	1.3	9.5	1.0
Princep	2.24	9.6	3.3	9.5	2.7	9.5	2.3
Bladex	2.24	9.6	3.3	9.6	3.3	9.5	1.7
Lexone	1.12	9.6	8.3	9.6	5.9	9.5	5.2
Lexone	2.24	9.7	9.7	9.7	9.7	9.5	9.5
Campaign	0.5	9.7	9.7	9.7	9.5	9.3	8.8
Campaign	0.67	9.8	9.7	9.8	9.5	9.5	9.0
Corn Gluten Meal	976 (prod. rate)	9.5	1.0	9.5	1.0	9.5	1.0
Check	------	9.6	1.0	9.6	1.0	9.3	1.0

[1]The adjuvant X-77 was added at 0.25% v/v to all treatments except Solicam, Stomp, Surflan, Campaign and Corn Gluten Meal.
[2]Corn Gluten Meal rate is in kg of product per hectare.
[3]Bermudagrass phytotoxicity was rated on a 1 to 10 scale where 1 = no phytotoxicity and 10 = complete brownout. Statistical comparison may be made between treatments and columns within rating dates using the following LSD values: 2.17 (1 MAT), 2.39 (2 MAT) and 2.36 (3 MAT).
[4]MAT = Months after Treatment.
[5]Roundup was applied at 0.56 kg ai ha^{-1}.

Table 38. Control of annual broadleaf weeds in bermudagrass roadsides in ODOT Division 8 in 1992 (Experiment 8-H-31-92).

Treatments[1]	Rate[2] (kg ai ha^{-1})	Annual Broadleaf Control[3] 1 MAT[4] With Roundup[5]	1 MAT No Roundup	2 MAT With Roundup	2 MAT No Roundup	3 MAT With Roundup	3 MAT No Roundup
Solicam	0.45	9.8	1.0	8.5	1.0	6.7	1.3
Solicam	0.9	9.5	2.0	8.5	1.3	7.3	1.3
Solicam	1.8	9.3	5.0	8.3	4.2	7.5	3.7
Solicam	4.48	9.3	3.0	8.5	3.0	7.7	3.7
Atrazine	2.24	9.9	9.9	9.9	9.9	9.6	9.6
Rifle	0.17	9.5	8.8	9.5	8.7	8.7	6.7
Karmex	2.7	9.6	9.3	9.5	9.0	9.5	8.8
Karmex + Oust	1.12 + 0.027	9.9	9.8	9.8	9.5	9.6	9.4
Lexone + Oust	0.21 + 0.027	9.9	9.9	9.9	9.9	9.9	9.9
Telar + Oust	0.05 + 0.027	9.9	9.8	9.9	9.9	9.9	9.9
Escort + Oust	0.043 + 0.027	9.8	9.8	9.9	9.9	9.9	9.9
Stomp	1.12	9.6	1.0	8.8	1.0	7.2	1.0
Surflan	2.24	9.3	2.0	8.7	2.0	8.3	3.3
Princep	2.24	9.6	7.8	9.3	8.1	9.1	8.1
Bladex	2.24	9.8	9.8	9.6	9.6	9.3	8.2
Lexone	1.12	9.9	9.9	9.8	9.5	9.6	9.5
Lexone	2.24	9.9	9.9	9.9	9.9	9.9	9.9
Campaign	0.5	9.9	9.9	9.8	9.1	9.8	9.0
Campaign	0.67	9.9	8.0	9.6	7.3	9.3	6.8
Corn Gluten Meal	976 (prod. rate)	9.6	1.0	7.7	1.0	7.3	1.0
Check	------	9.5	1.0	8.8	1.0	7.3	1.0

[1]The adjuvant X-77 was added at 0.25% v/v to all treatments except Solicam, Stomp, Surflan, Campaign and Corn Gluten Meal.
[2]Corn Gluten Meal rate is in kg of product per hectare.
[3]Bermudagrass phytotoxicity was rated on a 1 to 10 scale where 1 = no phytotoxicity and 10 = complete brownout. Statistical comparison may be made between treatments and columns within rating dates using the following LSD values: 1.72 (1 MAT), 1.87 (2 MAT) and 2.49 (3 MAT).
[4]MAT = Months After Treatment.
[5]Roundup was applied at 0.56 kg ai ha^{-1}.

Table 39. Control of annual grassy weeds in bermudagrass roadsides in ODOT Division 8 in 1992 (Experiment 8-H-31-92).

		Annual Grass Control[3]					
		1 MAT[4]		2 MAT		3 MAT	
Treatments[1]	Rate[2] (kg ai ha^{-1})	With Roundup[5]	No Roundup	With Roundup	No Roundup	With Roundup	No Roundup
Solicam	0.45	9.1	1.3	6.8	1.0	6.0	1.0
Solicam	0.9	9.5	3.3	8.5	3.7	7.2	3.3
Solicam	1.8	9.3	5.3	8.7	4.7	7.5	3.8
Solicam	4.48	8.2	3.3	8.0	3.7	7.0	2.7
Atrazine	2.24	9.9	9.9	9.9	9.9	9.6	9.6
Rifle	0.17	9.5	8.0	8.8	5.7	8.5	3.0
Karmex	2.7	9.6	9.0	9.5	8.5	9.3	8.0
Karmex + Oust	1.12 + 0.027	9.9	9.8	9.6	9.6	9.3	9.0
Lexone + Oust	0.21 + 0.027	9.9	9.9	9.8	9.6	9.3	8.9
Telar + Oust	0.05 + 0.027	9.9	9.3	9.9	9.5	9.8	8.7
Escort + Oust	0.043 + 0.027	9.8	9.6	9.6	9.6	9.6	9.2
Stomp	1.12	8.6	2.0	7.8	1.0	6.7	1.0
Surflan	2.24	8.6	2.0	8.2	2.0	7.8	3.3
Princep	2.24	9.5	8.0	9.1	7.6	9.1	7.3
Bladex	2.24	9.5	9.0	9.2	8.7	8.7	8.0
Lexone	1.12	9.9	9.8	9.8	9.3	9.3	8.3
Lexone	2.24	9.9	9.9	9.9	9.9	9.9	9.9
Campaign	0.5	9.6	9.0	9.5	8.2	8.8	1.0
Campaign	0.67	9.9	8.3	9.6	7.1	9.0	6.8
Corn Gluten Meal	976 (prod. rate)	8.0	1.0	8.0	1.0	7.0	1.0
Check	------	8.6	1.0	8.3	1.0	7.8	1.0

[1]The adjuvant X-77 was added at 0.25% v/v to all treatments except Solicam, Stomp, Surflan, Campaign and Corn Gluten Meal.
[2]Corn Gluten Meal rate is in kg of product per hectare.
[3]Bermudagrass phytotoxicity was rated on a 1 to 10 scale where 1 = no phytotoxicity and 10 = complete brownout. Statistical comparison may be made between treatments and columns within rating dates using the following LSD values: 1.99 (1 MAT), 2.31 (2 MAT) and 2.86 (3 MAT).
[4]MAT = Months After Treatment.
[5]Roundup was applied at 0.56 kg ai ha^{-1}.

7.0 LITERATURE CITED

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8. Compatibility of Several Drift Control Products with Selected Herbicides

L. M. Cargill, D. P. Montgomery, and D. L. Martin

8.1 INTRODUCTION

Today, there is a heightened public concern about environmental effects arising from pesticide use. A major concern is the control of off-target drift of herbicides applied to roadside right-of-way. Windy conditions in Oklahoma make complete on-target deposition of all spray droplets very difficult for ODOT herbicide applicators. Drift problems arising from windy conditions can be minimized with quality drift control additives. With the 1994 ODOT Herbicide Policy in full effect, drift control agents must be added to all tanks of herbicides to be applied by ODOT personnel.

In the past, ODOT personnel have had problems with some drift control products settling out in spray tanks. These problems may have resulted from poor mixing procedures (adding product too fast) or possibly using drift control adjuvants past their effective shelf life in addition to true tank mix incompatibility. Review of the literature as well as product labels revealed very little practical information regarding what drift control products are compatible with specific herbicides. Manufacturers/marketers of drift control products are not regulated as strictly as those who manufacture/market pesticides. In addition, they are not currently required to supply information on the label pertaining to the compatibility of their product with specific pesticides, namely herbicides. As a result, the end user of such products is unaware as to whether a specific drift control product is compatible with a certain herbicide. In cases where compatibility problems arise, precipitates may form resulting in a potential for clogged strainers or filters. This creates a situation where valuable time may be wasted due to the "down-time" involved to remedy the problem.

In a review of the literature, no sources of information were discovered dealing with compatibility of drift control adjuvants with specific herbicides. However, there was information available pertaining to aerial application of pesticides in regards to selection of equipment for drift control (2, 3). In addition, most other information found during the literature review dealt with the methods of measuring drift during pesticide application (4, 5).

The research to be discussed was conducted over a two-year period (1994-1995) with an objective of determining the compatibility of certain drift control adjuvants with specific herbicides currently recommended for roadside vegetation management in Oklahoma.

8.2.0 MATERIALS AND METHODS

8.2.1 Herbicide/Drift Additive Laboratory Compatibility Experiment 4-H-78-94

This experiment was conducted at the Oklahoma State University Turfgrass Research Center Laboratory on 7 September 1994 (Rep 1), 9 September 1994 (Rep 2) and 12 September 1994 (Rep 3). The objectives of this experiment were to determine the compatibility of 11 herbicides when combined with 7 drift control additives. The procedure to perform this experiment was accomplished by adapting an industry standard compatibility jar test (1).

Herbicide/drift additive mixture compatibility was evaluated in one liter clear plastic bottles containing 500 ml of deionized water. After all products were added to bottles, the experiment proceeded as follows: 1) the jar was inverted ten times followed immediately by visual evaluation, 2) the jar sat undisturbed for 30 minutes followed by visual evaluation and

3) then the jar was reinverted ten times followed immediately by visual evaluation. Methods of visual observations were made by answering yes or no to the following questions: 1) Were separate layers formed?, 2) Were precipitates formed (i.e. flakes, sludge, gel, other)?, 3) Did the chemical rise or settle? and 4) Was there excess foaming?. Visual observations and comments were collected, where applicable, for each of the aforementioned questions. Herbicide x drift control additives were recorded as being incompatible if layers, flakes, sludges or gels failed to resuspend following the second of the two inversions.

A list of the treatments and rates of application are provided in Table 40. The experimental design used in this experiment was a factorial design (11 herbicides x 7 drift control additives x 3 replications).

8.2.2 Herbicide/Drift Additive Laboratory Compatibility Experiment 4-H-84-95

This experiment was initiated at the Oklahoma State University Turfgrass Research Center Laboratory on 28 July 1995 (Rep 1), 31 July 1995 (Rep 2) and 1 August 1995 (Rep 3). The objectives of this experiment were to evaluate the compatibility of 14 herbicide treatments (alone or in combination with other herbicides) combined with 7 drift control additives when using the industry standard jar test procedure. This experiment was similar to Experiment 4-H-78-94 as previously described in the aforementioned section 8.2.1, in that the same experimental procedure was used as well as the same methods of evaluation were utilized.

A list of treatments and rates of application are provided in Table 41 with results of compatibility testing reported in Table 43.

A factorial experimental design (14 herbicides x 7 drift control additives x 3 replications) was utilized for this experiment.

8.3 RESULTS AND DISCUSSION

8.3.1 Herbicide/Drift Additive Laboratory Compatibility Experiment 4-H-78-94

No variation was present among replications within treatments for compatibility. Therefore, compatibility tables were developed for each experiment. Atrazine, Garlon 4 plus Tordon K and Roundup plus AMS combined well with all additives except 41-A and Get-Down (Table 42). Campaign was compatible only with Nalco-Trol, all other additives presented tank mix problems. Roundup alone and when combined with Oust was compatible with Nalco-Trol II, Polycontrol II and Exactrol. Transline plus X-77 surfactant was compatible with MORE, Polycontrol II and Nalco-Trol. Arsenal plus X-77 surfactant and MSMA was compatible with Nalco-Trol II, MORE, Polycontrol II and Nalco-Trol. Banvel was compatible with all products except Get-Down. Karmex plus X-77 surfactant was compatible with MORE, Exactrol and Nalco-Trol. Preliminary results are summarized in Table 42 as far as overall performances are concerned.

8.3.2 Herbicide/Drift Additive Laboratory Compatibility Experiment 4-H-84-95

With the 1994 Herbicide Policy in effect, which required the use of a drift control adjuvant with all herbicide applications, there remained several unanswered questions concerning the compatibilities of different herbicides when tank mixed with these products. This experiment was initiated to build an additional database of information to the previously initiated Experiment 4-H-78-94 by 1) evaluating additional herbicide treatments, 2) changing the mixing procedure to follow directions as outlined and described by each respective drift control adjuvant label and 3) retesting of several drift control products used previously using "fresh samples" due to manufacturers' concerns regarding products used before in Experiment 4-H-78-94 which may have had "problems" in quality.

A complete set of results for all herbicide treatments combined with the different drift control products are summarized in Table 43. Treatments of atrazine, Roundup plus AMS, Arsenal plus X-77 surfactant and Krenite plus Crop Oil combined well (were compatible) with all drift control products used in this experiment (Table 43). Campaign was compatible with 41-A, Get-Down, Nalco-Trol II, Polycontrol II and Nalco-Trol. Roundup alone and when combined with Oust was compatible with 41-A, Get-Down, Nalco-Trol II, MORE and Nalco-Trol. MSMA was compatible with MORE, Polycontrol II, Exactrol and Nalco-Trol. Banvel was compatible with 41-A, Nalco-Trol II, MORE, Polycontrol II and Nalco-Trol. The combination treatment of Garlon 4 plus Tordon K was compatible with Nalco-Trol II, MORE, Polycontrol II, Exactrol and Nalco-Trol. Karmex plus X-77 surfactant was compatible with MORE, Exactrol and Nalco-Trol. The combination treatment of Roundup plus Plateau was compatible with Nalco-Trol II, MORE, Polycontrol II and Nalco-Trol. Rodeo plus X-77 surfactant was compatible with 41-A, Nalco-Trol II, MORE, Polycontrol II, Exactrol and Nalco-Trol.

8.4 CONCLUSIONS

Experiments 4-H-78-94 and 4-H-84-95 were conducted over a two-year period (1994-1995) to determine the tank mix compatibility of several herbicides that are currently recommended to ODOT for roadside vegetation management purposes with selected drift control additives. Based upon this research data, a summary was developed (Table 43) to provide ODOT personnel with a reference to select compatible drift control additives to tank mix with specific herbicide treatments. While use of this table should help ODOT applicators in selecting drift control additives all applicators should perform a jar test prior to creating a tank mix of 2 or more products.

Table 40. Herbicide Treatments and Drift Additives Used in Laboratory Compatibility Experiment 4-H-78-94.

Herbicide Treatment	Product Rate (ℓ ha^{-1})	Drift Additive	Product Rate/935 Liters	Manufacturer
1. Atrazine	2.1	1. 41-A (dry)	199 g	Sanag
2. Campaign	2.1	2. Get-Down (dry)	284 g	Exacto
3. Roundup	0.53	3. Nalco-Trol II	443 ml	Nalco
4. Transline + X-77	0.35 + 0.25% v/v	4. MORE	296 ml	Exacto
5. Arsenal + X-77	2.1 + 0.25% v/v	5 Polycontrol II	237 ml	Brewer Int.
6. MSMA	2.1	6. Exactrol	473 ml	Exacto
7. Banvel	1.1	7. Nalco-Trol	296 ml	Nalco
8. Garlon 4 + Tordon K	4.3 + 4.3	8. Check		
9. Roundup + Oust	0.8 + 63.6 g			
10. Karmex + X-77	1.53 kg + 0.25% v/v			
11. Roundup + AMS	0.53 + 3.81 kg			

Table 41. Herbicide Treatments and Drift Control Products Used in Laboratory Compatibility Experiment 4-H-84-95.

Herbicide Treatment	Product Rate (ℓ ha^{-1})	Carrier Rate (ℓ ha^{-1})	Drift Control Product	Product Rate/935 Liters	Manufacturer
1. Atrazine	2.1	187	1. 41-A (dry)	199 g	Sanag
2. Campaign	2.1	187	2. Get-Down (dry)	284 g	Exacto
3. Roundup	0.53	187	3. Exactrol	473 ml	Exacto
4. Roundup + AMS	0.53 + 3.81 kg	187	4. Nalco-Trol II	443 ml	Nalco
5. Transline + X-77	0.35 + 0.25% v/v	234	5 Nalco-Trol	296 ml	Nalco
6. Arsenal + X-77	2.1 + 0.25% v/v	374	6. Polycontrol II	237 ml	Brewer Int.
7. MSMA	2.1	187	7. MORE	296 ml	Exacto
8. Banvel	1.1	234	8. Check (herbicide/water only)		
9. Garlon 4 + Tordon K	4.3 + 4.3	468			
10. Roundup + Oust	0.8 + 63.6 g	187			
11. Karmex + X-77	1.53 kg + 0.25% v/v	234			
12. Roundup + Plateau	0.4 + 0.27	187			
13. Rodeo + X-77	6.45 + 0.5% v/v	935			
14. Krenite + Crop Oil	12.9 + 1.65	468			

Table 42. Compatibility (by Jar Method) of drift control additives with commonly used herbicides for weed control in Oklahoma.

		Drift Control Additive (rate/935 liters)						
		C = Compatible[1] I = Incompatible[2]						
Herbicide	Product Rate (ℓ ha^{-1})	41-A 199g	Get-Down 284 g	Nalco-Trol II 443 mls	MORE 296 mls	Polycontrol II 237 mls	Exactrol 473 mls	Nalco-Trol 296 mls
Atrazine	2.1	I	I	C	C	C	C	C
Campaign	2.1	I	I	I	I	I	I	C
Roundup	0.53	I	I	C	I	C	C	I
Roundup + AMS	0.53 + 3.81 kg	I	I	C	C	C	C	C
Transline + X-77	0.35 + 0.25% v/v	I	I	I	C	C	I	C
Arsenal + X-77	2.1 + 0.25% v/v	I	I	C	C	C	I	C
MSMA	2.1	I	I	C	C	C	I	C
Banvel	1.1	C	I	C	C	C	C	C
Garlon 4 + Tordon K	4.3 + 4.3	I	I	C	C	C	C	C
Roundup + Oust	0.8 + 63.6 g	I	I	C	I	C	C	I
Karmex + X-77	1.53 kg + 0.25% v/v	I	I	I	C	I	C	C

[1]Compatible based on visual observations where no apparent change in appearance occurred when compared to a check.
[2]Incompatible based on visual observations which may include the following descriptions: white flakes formed, suspended; large white gel globules, suspended or settled; clear gel globules, settling, etc.

Table 43. 1995 Table of Herbicide/Drift Control Additive Compatibility.

		Drift Control Additive (rate/935 liters) C = Compatible[1] I = Incompatible[2]						
Herbicide	Product Rate (ℓ ha^{-1})	41-A 199g	Get-Down[3] 284 g	Nalco-Trol II 443 mls	MORE 296 mls	Polycontrol II 237 mls	Exactrol 473 mls	Nalco-Trol 296 mls
Atrazine	2.1	C	C	C	C (1994)	C	C	C (1994)
Campaign	2.1	C	C	C	I (1994)	C	I	C (1994)
Roundup	0.53	I	I	C	I (1994)	C	C	I (1994)
Roundup + AMS	0.53 + 3.81 kg	C	C	C	C (1994)	C	C	C (1994)
Transline + X-77	0.35 + 0.25% v/v	C	C	C	C (1994)	I	I	C (1994)
Arsenal + X-77	2.1 + 0.25% v/v	C	C	C	C (1994)	C	C	C (1994)
MSMA	2.1	I	I	I	C (1994)	C	C	C (1994)
Banvel	1.1	C	I	C	C (1994)	C	I	C (1994)
Garlon 4 + Tordon K	4.3 + 4.3	I	I	C	C (1994)	C	C	C (1994)
Roundup + Oust	0.8 + 63.6 g	I	I	C	I (1994)	C	C	I (1994)
Karmex + X-77	1.53 kg + 0.25% v/v	I	I	I	C (1994)	I	C	C (1994)
Roundup + Plateau	0.4 + 0.27	I	I	C	C	C	I	C
Rodeo + X-77	6.45 + 0.5% v/v	C	I	C	C	C	C	C
Krenite + Crop Oil	12.9 + 0.94% v/v	C	C	C	C	C	C	C

[1]Compatible based on visual observations where no apparent change in appearance occurred when compared to a check.
[2]Incompatible based on visual observations which may include the following descriptions: white flakes formed, suspended or settled; large white gel globules, suspended or settled; clear gel globules, settling, etc.
[3]Mixing order as per drift control additive label was as follows: drift control additive, herbicide, then other adjuvants. All other mixing orders were as follows: herbicide, adjuvants, then drift control additive.

8.5 LITERATURE CITED

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9.0 MAINTENANCE PROGRAM DEMONSTRATIONS AND ACTIVITIES

9.1 ANNUAL SUMMER ROADSIDE RESEARCH TOURS

Each summer, usually in late June or July, a tour is held to view the many roadside weed control trials conducted by the Roadside Vegetation Management Program at OSU. The tours are attended by six to twelve ODOT and OSU personnel and the attendees are provided with an opportunity to discuss product performance in the field. Over the years, many future research trials were formulated based on discussions that occurred during these tours. There is no replacement for being on site and evaluating trials firsthand. During Joint Project 2187 a total of five summer tours were conducted in cooperation with the ODOT Research Division.

9.2 ANNUAL YEAR-END ROADSIDE RESEARCH SUMMARY MEETINGS

Near the end of each calendar year during 1991-1995, a Year-End Roadside Research Summary Meeting was held in Oklahoma City at ODOT Division 9 headquarters. The purpose of each one-half day meeting was to summarize the calendar year field research, maintenance, and training activities on Joint Project 2187. During the course of this project, a total of five Year-End Roadside Research Summary meetings were conducted in cooperation with the ODOT Research Division. The summary meeting was attended by the ODOT project liaison, Curtis Hayes, a majority of the Project 2187 Research Steering Committee and the three principle OSU representatives to the project.

9.3 PARTICIPATION IN VARIOUS ODOT MEETINGS

An important component of this project was the availability of OSU personnel for year round consultation in various meetings that were of concern to ODOT roadside vegetation management programs and managers. It was impossible to predict very far in advance when meetings of this nature were to occur but it was important that both ODOT and OSU personnel were present to provide both guidance and scientifically based information at these meetings. Meetings of this nature may be as small as ODOT personnel and a concerned citizen or as large as State Senate or House Committee meetings. During this current project, many meetings of this nature have been attended by OSU personnel at the request of both maintenance and research personnel (data not shown).

9.4 SPRAYER CALIBRATION WORKSHOPS

Proper herbicide sprayer calibration and sprayer performance are critical to ODOT's roadside vegetation management program. A properly tuned sprayer is essential to ensure the desired results. Since 1993 many of the field divisions have begun upgrading their spray equipment while some have even purchased new sprayers. Calibration procedures and mathematics were covered in regular continuing education workshops, however, the best way to learn is to educate ODOT crews on their own rigs. While we did not specifically propose conducting calibration workshops in this project, 15 calibration workshops were conducted in ODOT Divisions 1, 3, 5, 6, 7 and 8.

During each workshop, the ODOT vegetation management crew is "walked" through the calibration procedure and they complete a sprayer calibration worksheet. Each spray rig is evaluated and fine-tuned to make certain that it is working as efficiently as possible given the age and condition of the equipment. If there are problems with design or function they are fixed before calibration continues. Each field Division has been very cooperative in both having mechanics on hand and fixing whatever problems arise.

9.5 MUSK THISTLE WEEVIL COLLECTION AND RELEASE DAYS

On 11-12 May 1994, OSU project personnel were part of an OSU contingency that went on a musk thistle weevil collection tour in southwestern Missouri. The two-day collection took place on a private farm outside of Springfield. Approximately 10,000 musk thistle head (MTH) and rosette weevils were collected. As part of the arrangements, some of the MTH weevil were to be released at designated sites along Oklahoma's state highway system. MTH Weevil were released in Wagoner County on SH-51 east of Coweta; in Rogers County on SH-266 and SH-66; and at the OSU Turfgrass Research Center in Stillwater. Approximately 500-750 MTH weevil were released at each site. Sites in Wagoner and Rogers County showed no previous activity from MTH weevil before the release. The sites were revisited during May 1995 to evaluate whether any MTH weevil had reproduced. MTH weevil were found at both sites.

One of the positive aspects of introducing a biological control agent such as the musk thistle weevil is that of public relations. On 22 May 1994 ODOT's Public Affairs filmed video and interviewed OSU and ODOT personnel about the MTH weevil release program. This interview/video was subsequently used in issues of "Access" and "Centerline," both ODOT publications. OSU's Sunup program, Channel 4 (NBC) in Oklahoma City, and Channel 8 (ABC) in Tulsa also conducted interviews with OSU personnel about ODOT's MTH weevil release program. There was tremendous interest in the MTH weevil and the ODOT MTH weevil release program.

On 4 May 1995 and 16 May 1996 OSU hosted a one-day MTH weevil collection day around the Stillwater area. Interest and curiosity were high for this event as it was attended by 21 and 19 ODOT personnel in 1994 and 1995, respectively. It was estimated that between 10,000 to 15,000 weevils (1994) and 9,000 (1995) were collected and subsequently redistributed in musk thistle infested areas around the state. We have requested the field Divisions keep records on the release dates and sites and notify OSU personnel so we can monitor ODOT's effort. Following the 1995 and 1996 collections, the MTH weevil were released in over 20 and 30 sites, respectively, on both private and public right-of-way.

9.6 LUCAS 64 SPRAYER DEMONSTRATION

In May of 1995 we were contacted by ODOT Research personnel and asked if we would inspect and evaluate a Division 1 roadside vegetation management demonstration. The demonstration included the Lucas 64 system which injects a herbicide/water mixture beneath the deck of a mower. This particular system uses the centrifugal air currents under the mower deck to apply the herbicide. There is currently no public domain information available on the weed control efficacy of this system.

Treatments 1-7 (Table 44) were applied using the Lucas 64 system on 20-21 June 1994. These treatments were applied to roadsides that had not been previously mowed and did not receive any additional mowings other than the Lucas 64 mowing. Treatment 8 was an untreated mowed check that received an early June mowing and then remained unmowed for the duration of the evaluations. Treatment 9 received a mid-May mowing followed by a

5 June conventional herbicide treatment followed by an early July mowing. Because of an over abundance of rain in May, treatment 9 had to receive an unplanned mid-May mowing. Traditionally, this mowing would be replaced by the herbicide treatment. Evaluations were made 1, 2, and 3 MAT for bermudagrass height, percent bermudagrass injury, percent johnsongrass injury, johnsongrass height, and percent tall fescue injury.

Bermudagrass canopy heights were unaffected by any of the treatments as compared to the untreated check 1, 2, and 3 MAT evaluations (Table 44). Some of the treatments did produce bermudagrass injury 1 MAT, however, the injury diminished as the summer progressed and it was always at an acceptable level.

Percent johnsongrass injury evaluations indicated that treatment 9 (conventional broadcast application of Roundup plus Oust) produced 88% johnsongrass control 1 MAT evaluations (Table 45). Johnsongrass control from this treatment fell slightly 2 MAT with 73% control and was unavailable 3 MAT due to an untimely mowing. All Lucas 64 treatments produced unacceptable levels of johnsongrass control throughout the duration of evaluations.

One of the more promising observations was that tall fescue suffered substantial injury (phytotoxicity) from several treatments (Table 46). Lucas 64 treatments 6 and 7 have demonstrated an increased amount of injury to tall fescue as compared to the mowed check and to the conventional herbicide treatment. This increased activity on tall fescue would be useful in removing unwanted tall fescue from roadsides that were in a "bermudagrass release" program.

9.7 BERMUDAGRASS FERTILIZER DEMONSTRATIONS

During the summer of 1994 fertilizer demonstrations were conducted in Division 1 (Table 47), 4 (Table 48), and 8 (Table 49). A single application of 112, 19, and 18 kg per hectare of actual nitrogen, phosphorus, and potassium were applied respectively. The fertilizer consisted of a blend of two commercially available fertilizers, a 13-13-13 and a 46-0-0. The fertilizer was applied using a Spyker rotary spreader.

While it is unlikely that ODOT will ever fertilize roadsides that already contain solid stands of bermudagrass, some of the responses during the 1994 fertilizer demonstrations indicate an advantage in fertilizing thin or disturbed stands of roadside bermudagrass. Even areas of solid bermudagrass where maintenance personnel are harvesting sprigs or sod should be fertilized because of the removal of nutrients from that area. Data from Tables 47, 48, and 49 indicate that fertilization definitely produced a more healthy bermudagrass. This is indicated by the consistently darker green color in each of the demonstration areas. Even though it was not monitored, one would also expect a positive response of the bermudagrass roots and rhizomes.

9.8 1995 ROADSIDE RESEARCH BUS TOUR

A significant effort went into the production of the 1995 ODOT/OSU Roadside Research Bus Tour that was conducted on 20 June 1995. The latest techniques in brush control, musk thistle control, bermudagrass encroachment control and johnsongrass control were demonstrated on the tour. Additionally, a demonstration on roadside research spray equipment was conducted. The tour was attended by 52 people, 31 of which were ODOT personnel, with the remainder being industry and OSU personnel. Along with the bus tour, a 29-minute video documentary of the tour was produced in cooperation with ODOT's video productions staff. The video recorded the days events and was shown during the 1995 ODOT Continuing Education Pesticide Applicator Workshops to over 500 certified applicators across the state.

Table 44. Effect of the Lucas 64 system applied herbicide treatments on bermudagrass in ODOT Division 1 in 1994.

Treatment	Rate (kg ai ha^{-1})	Bermudagrass Height[1] 1 MAT	2 MAT	3 MAT	Bermudagrass Phytotoxicity[2] 1 MAT	2 MAT	3 MAT
		-------------	cm	-------------	-------------	%	-------------
1. Roundup + Oust	0.56 0.05	15	23	28	5	7	0
2. Velpar L + Oust	0.17 0.05	15	20	18	8	8	0
3. Velpar L + Oust	0.17 0.08	15	16	19	13	8	5
4. Escort + Oust	0.011 0.08	13	15	22	18	10	0
5. Velpar L + Oust	0.17 0.11	22	24	22	3	3	0
6. Roundup + Content	0.56 0.28	14	19	17	2	7	0
7. Escort + Oust	0.011 0.11	19	21	18	15	5	0
8. Mowed Check	-----	19	21	21	0	0	0
9. Roundup + Oust (conventional)	0.56 0.05	16	20	20	5	0	0
$LSD_{0.05}$		7	6	4	8	7	3

[1]All height measurements are an average of three measurements/treatment (cm).
[2]Phytotoxicity evaluations were made using a 0 to 100 scale where 0 = no injury and 100 = completely brown vegetation as compared to the untreated check. A value of 45% or less at 2 MAT was considered acceptable.

Table 45. Effect of the Lucas 64 system applied herbicide treatments on johnsongrass in ODOT Division 1 in 1994.

Treatment	Rate (kg ai ha^{-1})	Johnsongrass Height[1] 1 MAT	2 MAT	3 MAT	Johnsongrass Phytotoxicity[2] 1 MAT	2 MAT	3 MAT
		---------------cm-------------			---------------%---------------		
1. Roundup + Oust	0.56 0.05	43	78	78	2	2	5
2. Velpar L + Oust	0.17 0.05	39	77	77	3	3	5
3. Velpar L + Oust	0.17 0.08	39	68	68	12	8	2
4. Escort + Oust	0.011 0.08	35	70	70	17	10	8
5. Velpar L + Oust	0.17 0.11	52	104	104	0	0	0
6. Roundup + Content	0.56 0.28	59	112	112	0	0	0
7. Escort + Oust	0.011 0.11	47	90	90	7	8	2
8. Mowed Check	-----	47	80	80	0	0	0
9. Roundup + Oust (conventional)	0.56 0.05	23	46	46	88	73	NA
$LSD_{0.05}$		12	17	17	10	14	4

[1]All height measurements are an average of three measurements/treatment (cm).
[2]Phytotoxicity evaluations were made using a 0 to 100 scale where 0 = no injury and 100 = completely brown vegetation as compared to the untreated check. A value of 45% or less at 2 MAT was considered acceptable.

Table 46. Effect of Lucas 64 system applied herbicides on tall fescue in ODOT Division 1 in 1994.

Treatment	Rate (kg ai ha^{-1})	Tall Fescue Phytotoxicity[1] 1 MAT	2 MAT	3 MAT
		-----%-----		
1. Roundup + Oust	0.56 0.05	47	55	28
2. Velpar L + Oust	0.17 0.05	60	55	10
3. Velpar L + Oust	0.17 0.08	50	62	32
4. Escort + Oust	0.011 0.08	47	80	22
5. Velpar L + Oust	0.17 0.11	50	47	10
6. Roundup + Content	0.56 0.28	40	70	73
7. Escort + Oust	0.011 0.11	65	70	67
8. Mowed Check	-----	0	0	0
9. Roundup + Oust (conventional)	0.56 0.05	65	55	NA
$LSD_{0.05}$		20	32	24

[1]Phytotoxicity evaluations were made using a 0 to 100 scale where 0 = no injury and 100 = completely brown vegetation as compared to the untreated check. A value of 45% or less at 2 MAT was considered acceptable.

Table 47. Bermudagrass response to fertilizer applied in Division 1 in 1994.[1,2]

Plot Number	Fertilizer Yes (Y) or No (N)	Percent Bermudagrass Cover			
		8 June	21 July	19 August	28 September
1	Y	75	75	85	95
2	N	65	65	70	87
3	Y	80	88	90	98
4	N	75	75	75	85
5	Y	90	90	95	98
6	N	50	40	45	60
7	Y	55	60	65	75

[1]Fertilizer was applied on 8 June 1994. Fertilized plots were treated with 112, 19, and 18 kg ha^{-1} of N, P and K in a single application.
[2]The demonstration was located on I-40, 0.81 km west of Ross Road (Exit #284) on the outside shoulder.

Table 48. Visual observation of bermudagrass response to the Division 4 fertilizer demonstration in 1994.[1,2]

Fertilizer Yes (Y) or No (N)	Bermudagrass Response: 6 June	6 July	10 August	14 October
yes	15% bermuda	not available	35% bermuda	80% bermuda
	-middle very sparse bermuda	-darker green bermuda	-lost some of the dark green contrast	-new stolon growth
		-new stolon	-stolons continuing to spread	-some color difference
no	not available	not available	not available	not available

[1]Fertilizer was applied on 6 June 1994. Fertilized plots were treated with 112, 19 and 18 kg ha^{-1} of N, P and K in a single application.
[2]The demonstration was located at the northwest corner of the junction of SR-51 and SR-51C west of Stillwater.

Table 49. Visual observation of the bermudagrass response at the Division 8 fertilizer demonstration in 1994.[1,2]

Plot Number	Fertilizer Yes (Y) or No (N)	Percent Bermudagrass Cover 8 June	20 July	19 August	14 October
1	Y	60	80 -darker green bermuda	90	92%-bermuda 3%-tall fescue -no color -difference
2	N	25	35	45	55%-bermuda 25%-tall fescue
3	Y	40	65 -darker green	75	80%-bermuda 15%-tall fescue -no color differences

[1]Fertilizer was applied on 8 June 1994. Fertilized plots were treated with 112, 19 and 18 kg ha^{-1} of N, P and K in a single application.
[2]The demonstration was located on SR-151, 0.81 km north of SR-51 on the west side of the road.

10. TRAINING PROGRAM

10.1 PESTICIDE APPLICATOR CERTIFICATION

The initial training of an ODOT pesticide applicator or someone who will be supervising applications is usually just the beginning of their understanding of basic principles vital to today's roadside vegetation manager. Knowledge of basic plant, soil, and environmental relationships is a valuable foundation on which an applicator builds with his/her personnel experiences in handling and applying herbicides. Basic training allows those personnel to make confident decisions on what, where, when, and how to apply herbicides along the state highway rights-of-way.

On February 22, 1994, ODOT drafted its first formal Herbicide Program Policy (amended August 1, 1995). Even though the requirements in this policy were for the most part already being practiced, it formalized these procedures into a very useful policy. The policy stated that "All herbicides used by the Department shall be properly labeled for use on public rights-of-way, and shall be applied by a certified applicator." The policy definition, as well as implementation specifics, and application specifics are scientifically and agriculturally sound and should give the citizens of the Oklahoma peace of mind that ODOT intends to be a good steward of the environment.

During the past five years, the personnel of the Roadside Vegetation Management program have conducted 12 pesticide applicator certification schools to help prepare ODOT employees for their pesticide applicator certification exams (Table 50) which are administered by the Oklahoma Department of Agriculture (ODA). The schools have directly assisted in the certification of 146 ODOT employees and helped each Division to comply with ODOT's new Herbicide Policy. During this five-year period, the two-day certification schools have continued to be an effective means of providing initial training. Most schools yielded a 70 to 80% success rate in applicator certification. The certification standards continue to require the successful completion of both the General Category and Rights-of-Way Category Exams. Each examination featured 100 questions where passing required ≥70% correct.

In 1995 it was brought to our attention by the ODA that ODOT makes aquatic applications on a routine basis and it would be in ODOT's best interest to certify personnel in the Aquatic Herbicide Applicator category. ODOT applicators are not allowed to make any herbicide applications to standing water on a roadside under their current Category 6 (Rights-of-Way) certification. In 1996, Certification Schools offered aquatic vegetation management information. The Aquatic exam (50 questions) was passed by 36 ODOT personnel from ODOT field Divisions 1, 4, 5, 6 and 8.

10.2 CONTINUING EDUCATION PESTICIDE APPLICATOR WORKSHOPS

The second phase of applicator training involves continuing education of certified applicators and other key ODOT personnel involved in the roadside vegetation management program. A continuing education workshop offered to pesticide applicators on a yearly basis has three major benefits. First, the yearly program is designed to provide new and precise information to ODOT applicators; second, certified applicators who attend the yearly workshop receive continuing education credits toward recertification; and finally, it helps ODOT personnel comply with the new ODOT Herbicide Policy. The policy states "All employees involved with the application of herbicides are to attend yearly continuing education courses..."

The goal of each year's Continuing Education Workshops was to provide ODOT personnel with roadside vegetation management information that would assist them in making decisions and caring out their duties. Each year the topics presented were carefully chosen and were generated from numerous sources. Topics were solicited from ODOT pesticide applicators, generated from research results from this project, or developed from various other sources. Each year it was a goal of our program that one-half of the information presented should be new to attendees with the other half being more of an update or continuation of previous training efforts. Our programs continue to receive very positive comments from both ODOT personnel and non-ODOT personnel who attend training workshops in other states.

Our program conducted 68 ODA approved pesticide applicator continuing education workshops for ODOT applicators during this current project. Attendance of the Continuing Education Workshops over the last five years has reflected the downsizing trend that ODOT has experienced in recent years (Table 51). Attendance of these sessions peaked in 1992 with over 600 certified ODOT employees attending. ODOT employee attendance has decreased from peak by around 18% according to the 1996 attendance figures. Some recent ODOT hirings and subsequent increases in Certification School attendance should bring this number up slightly in the future.

For both Pesticide Applicator Certification Schools and Pesticide Applicator Continuing Education Workshops all records of attendance and exam scores are maintained at OSU and are sent to the appropriate entities on a timely basis. Copies of all workshop attendance are sent to the ODA, field divisions, and ODOT Training Division to assure proper credit and updating of records. Exam scores are sent to field divisions and the ODOT Training Division.

Table 50. Summary of Attendance Figures at ODOT Pesticide Applicator Certification Schools.

ODOT Division		New Applicators in Category 6 (Rights-of-Way)					
Location	Number	1992	1993	1994	1995	1996	Total
Muskogee	1	0	5	0	7	18	30
Antlers	2	0	0	3	5	0	8
Ada	3	12	3	0	2	7	24
Perry	4	0	1	2	0	8	11
Clinton	5	13	0	13	2	13	41
Buffalo	6	1	5	1	3	2	12
Duncan	7	0	6	0	0	1	7
Tulsa	8	10	0	0	0	3	13
Total		36	20	19	19	52	146

Table 51. Summary of Attendance at ODOT Continuing Education Pesticide Applicator Workshops.

ODOT Division		Number of Certified Applicators Attending[1]					
Location	Number	1992	1993	1994	1995	1996	Total
Muskogee	1	73	69	80	68	67	357
Antlers	2	38	32	28	35	34	167
Ada	3	98	100	90	83	79	450
Perry	4	92	80	83	71	66	392
Clinton	5	91	91	90	83	79	434
Buffalo	6	55	37	56	53	53	254
Duncan	7	67	64	58	63	51	303
Tulsa	8	102	86	83	89	78	438
Total		616	559	568	545	507	2,795

[1]Each certified applicator received continuing education credit towards automatic recertification.

APPENDIX A

Johnsongrass Control Experiment 4-H-59-91

Experiment: Johnsongrass Control Experiment 4-H-59-91.

Objective: To compare the efficacy of nine herbicide treatments for the selective control of Johnsongrass.

Cosponsor: Dow Chemical

Date of Treatment: 10 May 1991

Plot Size: 1.5 x 3 m

Dates Scored: 28 May or 2 weeks after treatment (2 WAT), 10 June or 1 month after treatment (1 MAT), 10 July (2 MAT), 9 August (3 MAT), and 11 September 1991 (4 MAT).

Methods of Scoring: Johnsongrass control - where 1 = no effect and 10 = complete control; Bermudagrass Phytotoxicity - where 1 = no effect and 10 = complete yellowing.

Discussion: At 2 WAT, significant bermudagrass phytotoxicity was observed for all herbicide treatments (Table 52). At 1 MAT, these same effects were observed. By 2 MAT, no phytotoxic effects were present. When johnsongrass control was rated at 1 MAT, all treatments were providing significant johnsongrass control. At 1 MAT the treatments of Roundup at 0.84 kg ai ha^{-1} plus Oust at 0.11 kg ai ha^{-1} and Roundup at 0.84 kg ai ha^{-1} plus Rifle at 0.16 kg ai ha^{-1} combined with X-77 were performing better than all other treatments for control of johnsongrass. Although this same trend was again observed at the time of 3 and 4 MAT ratings, Roundup at 0.84 kg ai ha^{-1} plus 0.05 kg ai ha^{-1} of Oust also exhibited an acceptable level of johnsongrass control throughout the duration of this experiment. The remainder of the treatments did not perform at an acceptable level.

No additional work was performed on Rifle due to the insistance by the cosponsor that the product would not be labeled in the very near future for use on bermudagrass roadsides.

Table 52. Effect of Roundup and Roundup tank mix combinations on johnsongrass control and bermudagrass phytotoxicity in 1991 (Experiment 4-H-59-91).

Treatments	Rate (kg ai ha^{-1})	Bermudagrass Phytotoxicity[1]			Johnsongrass Control[4]			
		2 WAT[2]	1 MAT[3]	2 MAT	1 MAT	2 MAT	3 MAT	4 MAT
Check	-----	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Roundup	0.84	4.0	4.7	1.0	9.0	8.3	8.0	7.0
Roundup + Oust	0.84 + 0.053	4.7	5.3	1.0	9.3	9.0	9.0	9.0
Roundup + Oust	0.84 + 0.11	4.7	5.7	1.0	9.6	9.3	9.6	9.6
Roundup + XRM-4950	0.84 + 0.07	4.7	4.7	1.0	9.2	8.7	7.8	7.3
Roundup + XRM-4950	0.84 + 0.14	5.0	5.3	1.0	9.3	8.2	7.0	5.7
Roundup + XRM-4950	0.84 + 0.28	4.7	5.0	1.0	8.7	8.2	7.7	6.7
Roundup + XRM-4950 + X-77	0.84 + 0.28 + 0.25% v/v	4.0	4.3	1.0	9.2	8.3	7.8	7.3
Roundup + Rifle + X-77	0.84 + 0.16 + 0.25% v/v	4.3	5.0	1.0	9.6	9.6	9.5	9.5
$LSD_{0.05}$		1.0	1.3	NA	0.5	0.8	1.3	1.0
C.V.%		14.6	16.6	NA	3.4	5.7	9.7	8.3

[1]Bermudagrass phytotoxicity was measured on a 1 to 10 scale where 1 = no phytotoxicity and 10 = complete brownout.
[2]WAT = Weeks After Treatment.
[3]MAT = Months After Treatment.
[4]Johnsongrass control was evaluated on a 1 to 10 scale where 1 = no control and 10 = complete control.

APPENDIX B

Johnsongrass Control Experiment 4-H-65-92

Experiment: Johnsongrass Control Experiment 4-H-65-92.

Objective: To evaluate the efficacy of eight herbicide treatments for postemergent control of johnsongrass and their phytotoxicity to bermudagrass.

Cosponsor: Hoechst-Roussel

Date of Treatment: 9 July 1992

Plot Size: 1.5 x 3 m

Dates Scored: 24 July or 2 weeks after treatment (2 WAT), 7 August (4 WAT), 20 August (6 WAT) and 3 September 1992 (8 WAT).

Methods of Scoring: Bermudagrass Phytotoxicity - where 1 = no effect and 10 = complete yellowing; Johnsongrass control - where 1 = no effect and 10 = complete yellowing.

Discussion: This experiment was initiated on a roadside right-of-way site containing an intermix of both common bermudagrass and johnsongrass (near Ripley) in north central Oklahoma. Treatments were applied 9 July 1992 with a CO_2 hand held sprayer equipped with 80015 stainless steel flat fan spray tips spraying at a pressure of 187 kPa. A 187 ℓ ha^{-1} carrier rate was utilized. All treatments had a crop oil added at 0.5% v/v. Air temperature was 24.4°C at the time of treatment. The site had been mowed approximately 6 weeks prior to herbicide treatment and the johnsongrass regrowth was 46 to 61 cm in height at the time of application.

Bermudagrass phytotoxicity was evident from all herbicide treatments 2 WAT, however, phytotoxicity was acceptable at this time (Table 53). By 4 WAT, Assure was exhibiting an unacceptable level of bermudagrass phytotoxicity. Treatments of Roundup plus Oust and the higher rate of Horizon 2000 showed significant bermudagrass phytotoxicity at 4 WAT. This level of phytotoxicity was marginally acceptable. When ratings were made at 6 and 8 WAT, the level of bermudagrass phytotoxicity was acceptable for all treatments except Assure. It appears from this experiment that Assure will exhibit an unacceptable amount of bermudagrass phytotoxicity for at least 8 WAT.

Evaluations made 2 WAT for johnsongrass control indicated good initial burndown by all treatments. At 4 WAT the better treatments appeared to be Assure, MSMA and Roundup plus Oust. By 6 WAT all activity on the johnsongrass was diminishing and regrowth was beginning to occur in all plots. It appears that most of these treatments may be effective for a quick, initial burndown of johnsongrass, however, for longer term control the best treatment appears to be the combination treatment of Roundup plus Oust at 0.84 plus 0.11 kg ai ha^{-1} respectively.

Table 53. Effect of post-emergent applications of Horizon 2000 herbicide treatments on johnsongrass in a bermudagrass roadside in 1992 (Experiment 4-H-65-92).

Treatments[1]	Rate[2] (kg ai ha^{-1})	Bermudagrass Phytotoxicity[3]				Johnsongrass Control[5]			
		2 WAT[4]	4 WAT	6 WAT	8 WAT	2 WAT	4 WAT	6 WAT	8 WAT
Check	-----	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Horizon 2000	0.14	2.0	2.0	2.0	1.0	7.8	6.3	3.7	2.7
Horizon 2000	0.16	1.7	2.7	1.7	1.3	5.8	6.3	4.7	3.7
Horizon 2000	0.19	2.3	2.7	2.0	1.0	8.7	7.0	4.3	3.3
Horizon 2000	0.21	2.3	3.3	2.3	1.3	8.7	7.7	4.7	4.0
Horizon 2000 + Iron	0.21 + 9.0	2.0	2.7	2.0	1.3	8.0	6.7	4.7	3.7
Assure	0.14	3.3	6.7	6.7	6.0	8.5	8.7	7.7	6.0
MSMA	4.5	1.3	1.0	1.0	1.0	9.0	8.3	6.3	5.3
Roundup + Oust	0.84 + 0.11	1.7	3.7	2.0	1.3	9.3	9.0	8.7	8.7
$LSD_{0.05}$		1.0	0.8	0.6	0.8	2.5	2.1	2.8	3.0

[1]Treatments were applied on 9 July 1992.
[2]All treatments (except MSMA and Roundup plus Oust) included a crop oil at 0.5% v/v.
[3]Bermudagrass phytotoxicity was measured on a 1 to 10 scale where 1 = no phytotoxicity and 10 = complete brownout.
[4]WAT = Weeks After Treatment.
[5]Johnsongrass control was evaluated on a 1 to 10 scale where 1 = no control and 10 = complete control.

APPENDIX C

Johnsongrass Control Experiment 4-H-71-93

Experiment: Johnsongrass Control Experiment 4-H-71-93.

Objective: To assess potential antagonism from several compounds tank-mixed with Horizon 2000 by rating the subsequent johnsongrass efficacy and to determine if any bermudagrass injury (phytotoxicity) may occur.

Cosponsor: Hoescht-Roussel

Date of Treatment: 24 May 1993

Plot Size: 1.5 x 3 m

Dates Scored: 7 June or 14 days after treatment (DAT), 14 June (21 DAT), 21 June (28 DAT), 6 July (42 DAT) and 19 July 1993 (56 DAT).

Methods of Scoring: Percent Johnsongrass Control - where 0 = no control and 100 = complete control; Bermudagrass Phytotoxicity (Injury) - where 1 = no effect and 10 = complete yellowing.

Discussion: This experiment was initiated east of Stillwater on a roadside right-of-way consisting of predominantly an intermix of both common bermudagrass and johnsongrass. Treatments were applied with a hand-held CO_2-powered boom sprayer equipped with 80015 stainless steel flat fan spray tips operating at a pressure of 207 kPa. A 187 ℓ ha^{-1} carrier rate was utilized. Each herbicide treatment had a crop oil added at 0.25% v/v. The johnsongrass plants ranged in height from 38 to 46 cm tall at the time of application.

When Horizon 2000 is tank-mixed with Banvel, Embark or Transline, a significant amount of antagonism occurs (a decrease in the percent control of johnsongrass) when compared with the treatment of Horizon 2000 plus Crop Oil alone (Table 54). However, when Horizon 2000 is tank-mixed with Oust, no antagonism is apparent and the percent control of johnsongrass is increased. These observations were noted for each of the five rating dates throughout the duration of this experiment.

The most antagonism appears to be when Horizon 2000 is combined with either Embark or Banvel followed by Transline. Horizon 2000 combined with Oust provided significantly better (and acceptable) johnsongrass control than all other treatments.

Bermudagrass phytotoxicity (injury) was observed from all herbicide treatments, with the most occurring in plots with the combination of Horizon 2000 and Oust. However, this effect had totally diminished in all plots when the last evaluation was made 56 DAT.

Table 54. Evaluation of Horizon 2000 tank mixes for post-emergent johnsongrass control in 1993 (Experiment 4-H-71-93).

Treatments[1]	Rate (kg ai ha^{-1})	Percent Johnsongrass Control[2]					Bermudagrass Phytotoxicity[3]				
		14 DAT[4]	21 DAT	28 DAT	42 DAT	56 DAT	14 DAT	21 DAT	28 DAT	42 DAT	56 DAT
Check	-----	0	0	0	0	0	1.0	1.0	1.0	1.0	1.0
Horizon 2000	0.21	87	78	68	62	62	3.3	3.3	3.3	2.0	1.0
Horizon 2000 + Banvel	0.21 1.12	55	40	28	17	12	3.0	3.0	3.3	2.0	1.0
Horizon 2000 + Oust	0.21 0.11	92	88	88	85	85	3.3	4.3	4.3	2.3	1.0
Horizon 2000 + Embark	0.21 1.22	22	12	12	12	12	2.7	2.7	2.7	2.0	1.0
Horizon 2000 + Transline	0.21 0.21	68	68	57	40	40	3.3	3.3	3.3	2.0	1.0
LSD$_{0.05}$		12	16	18	21	21	0.6	1.2	1.0	0.4	NA

[1]All treatments had a crop oil added at 0.25% v/v.
[2]Johnsongrass control was evaluated on a 1 to 10 scale where 1 = no control and 10 = complete control.
[3]Bermudagrass phytotoxicity was measured on a 1 to 10 scale where 1 = no phytotoxicity and 10 = complete brownout.
[4]DAT = Days After Treatment.

APPENDIX D

Roundup Formulation Experiment 4-H-82-95

Experiment: Roundup Formulation Experiment 4-H-82-95.

Objective: To evaluate the efficacy of two experimental herbicides (MON 60696 and MON 65005) compared to Roundup for the selective control of johnsongrass and bermudagrass tolerance along roadsides.

Cosponsor: Monsanto Company

Date of Treatment: 6 June 1995

Plot Size: 1.5 x 3 m

Dates Scored: 9 June or 3 days after treatment (DAT), 13 June (7 DAT), 5 July (30 DAT), 4 August (60 DAT) and 5 September 1995 (90 DAT).

Methods of Scoring: Visual observations of percent bermudagrass phytotoxicity where 0 = no effect and 100 = complete brownout and percent johnsongrass phytotoxicity where 0 = no effect and 100 = complete control.

Discussion: Significant bermudagrass phytotoxicity was observed 3 DAT in plots treated with the higher rates of MON 65005 (1.12 kg ai ha^{-1}) alone and MON 60696 (1.12 kg ai ha^{-1}) alone, when compared to the untreated check plot (however, these amounts would be acceptable) (Table 55). Within 7 DAT these same two treatments continued to exhibit a significant level of bermudagrass phytotoxicity along with the addition of two other treatments, the higher rate of Roundup at 1.12 kg ai ha^{-1} (alone) and the lower rate of MON 60696 (0.56 kg ai ha^{-1}) alone. With one exception being the lower rate of Roundup (0.56 kg ai ha^{-1}) alone, all herbicide treatments were causing a significant amount of bermudagrass phytotoxicity when evaluations were made 30 DAT. By 60 DAT these effects had diminished to an acceptable level for all herbicide treatments with three exceptions, the higher rate of MON 65005 (1.12 kg ai ha^{-1}) alone and both rates of MON 60696 (0.56 and 1.12 kg ai ha^{-1}) alone. A similar trend was observed again when evaluations were made 90 DAT with these same treatments causing an unacceptable level of bermudagrass phytotoxicity.

Significant johnsongrass phytotoxicity was observed 3 DAT from all herbicide treatments except Roundup at 0.56 kg ai ha^{-1}, alone, MON 65005 at 0.56 kg ai ha^{-1} combined with either X-77 or Methylated Seed Oil (MSO). All herbicide treatments were exhibiting significant johnsongrass phytotoxicity by 7 DAT with the higher rate of MON 60696 (1.12 kg ai ha^{-1}) showing the greatest amount at 91.7% followed closely by the highest rate of MON 65005 (1.12 kg ai ha^{-1}) alone (90%). When ratings were made 30 DAT these same two treatments continued to provide the most johnsongrass phytotoxicity

(96% to 98.3%). All herbicide treatments were exhibiting 80% or greater johnsongrass phytotoxicity when the experiment was evaluated 60 DAT. Treatments of MON 65005 at 0.56 kg ai ha^{-1} plus MSO and MON 60696 at 0.56 kg ai ha^{-1} alone were causing 90% and 91.7% johnsongrass phytotoxicity, respectively. When the last ratings were made 90 DAT treatments of Roundup alone ranged from 75% to 81.7%. The addition of either X-77 or MSO to Roundup increased activity to 86.7%. MON 65005 treatments alone or with the addition of either X-77 or MSO provided 75% to 85% johnsongrass phytotoxicity. Treatments of MON 60696 ranged from 78.3% to 85%. No significant differences in the levels of johnsongrass phytotoxicity were observed among all herbicide treatments when evaluations were made from both 60 DAT and 90 DAT.

Table 55. Effect of Roundup, MON 65005 and MON 60696 on bermudagrass and johnsongrass in 1995 (Experiment 4-H-82-95).

Treatments[1]	Rates (kg ai ha^{-1})	Percent Bermudagrass Phytotoxicity[2]					Percent Johnsongrass Phytotoxicity[3]				
		3 DAT[4]	7 DAT	30 DAT	60 DAT	90 DAT	3 DAT	7 DAT	30 DAT	60 DAT	90 DAT
1. Roundup	0.56	1	8	13	1	0	17	72	78	83	82
2. Roundup	1.12	4	32	62	20	10	30	87	88	80	75
3. Roundup + X-77	0.56 0.25% v/v	1	10	25	3	0	22	82	89	88	87
4. Roundup + MSO	0.56 1.25% v/v	1	10	18	2	0	23	80	92	87	87
5. MON 65005	0.56	1	10	20	2	0	22	67	83	85	82
6. MON 65005	1.12	6	47	78	62	47	42	90	96	88	75
7. MON 65005 + X-77	0.56 0.25% v/v	2	8	33	8	0	18	75	92	87	85
8. MON 65005 + MSO	0.56 1.25% v/v	0	10	20	0	0	17	72	85	90	83
9. MON 60696	0.56	4	35	72	40	32	23	83	93	92	85
10. MON 60696	1.12	5	40	85	58	48	40	92	98	83	78
11. Check	------	0	0	0	0	0	0	0	0	0	0
$LSD_{0.05}$		5	20	18	28	29	19	15	12	13	17

[1]Treatments were applied on 6 June 1995.
[2]Bermudagrass phytotoxicity was measured on a 1 to 10 scale where 1 = no phytotoxicity and 10 = complete brownout.
[3]Johnsongrass control was evaluated on a 1 to 10 scale where 1 = no control and 10 = complete control.
[4]DAT = Days After Treatment.

APPENDIX E

Winter Annual Grass and Broadleaf Weed Control Experiment 4-H-63-92

Experiment: Winter Annual Grass and Broadleaf Weed Control Experiment 4-H-63-92.

Objective: To evaluate Roundup and Campaign for their effectiveness in controlling winter annual weeds and their phytotoxicity to bermudagrass.

Cosponsor: Monsanto Company

Date of Treatment: 25 March 1992 (Treatments 1-5), 15 April 1992 (Treatments 6-10).

Plot Size: 1.5 x 3 m

Dates Scored: 24 April, 15 May, 16 June and 17 July 1992.

Methods of Scoring: Visual ratings of annual grass and annual broadleaf control where 1 = no control and 10 = complete control. Bermudagrass phytotoxicity was visually rated on a 1 to 10 scale where 1 = no effect, 5 = yellow bermudagrass and 10 = completely brown bermudagrass.

Discussion: With Atrazine having been unavailable for use on roadsides in spring of 1992, many herbicide applicators utilized Campaign for roadside weed control. The objective of this experiment was to evaluate winter annual weed control achieved with treatments of Roundup and Campaign (Glyphosate plus 2,4-D). Identical treatments (Table 56) were applied to completely dormant bermudagrass and to bermudagrass at approximately 30% green-up. This later treatment was used to evaluate the potential for bermudagrass injury from these products if they were applied after green-up. Annual weeds present in this study included Bromus spp. (downy brome and cheat), hairy vetch and wild carrot.

With no preemergent activity from Roundup or Campaign, the timing of application is critical. These treatments must be applied late enough (late March or early April) to assure that the majority of target weeds are emerged but early enough to minimize injury (phytotoxicity) to bermudagrass. No injury was observed from treatments applied to completely dormant bermudagrass (25 March treatment date) for all rating dates. All treatments, excluding Campaign at 0.5 kg ai ha^{-1}, applied at 30% bermudagrass green-up (15 April treatment date) produced significant amounts of bermudagrass phytotoxicity. The injury was a yellowing of leaves and delay in green-up. The level of injury from all treatments was acceptable for roadside turf.

Visual observations of 24 April 1992 indicated excellent control of annual grasses and broadleaf weeds with treatments 1-5 which were applied on 25 March 1992 (Table 56). Treatments 6-10, which were applied two weeks previously on 15 April 1992, had just begun to exhibit annual weed control on 24 April 1992. Although some differences in the level of annual weed control were noted when ratings were made on 15 May 1992, all treatments provided an acceptable level of control of annual weeds on this date. This same trend continued throughout the duration of this experiment.

Table 56. Effect of timing of application of Roundup and Campaign on control of winter annual weeds and bermudagrass phytotoxicity (Experiment 4-H-63-92).

Treatments[1]	Rate	Annual Grass Control[2]				Annual Broadleaf Control[3]				Bermudagrass Phytotoxicity[4]		
	(ℓ/ha^{-1})	4/24	5/15	6/16	7/17	4/24	5/15	6/16	7/17	4/24	5/15	6/16
1. Campaign	3.51	9.8	9.5	9.2	9.2	9.8	9.8	9.8	9.8	1.0	1.0	1.0
2. Campaign	4.68	9.9	9.8	9.4	9.4	9.9	9.8	9.8	9.8	1.0	1.0	1.0
3. Roundup	1.75	9.9	9.6	9.2	9.2	9.9	9.8	9.6	9.6	1.0	1.0	1.0
4. Roundup	2.34	9.9	9.6	9.5	9.5	9.9	9.8	9.3	9.5	1.0	1.0	1.0
5. Roundup	3.51	9.9	9.8	9.6	9.6	9.9	9.8	9.6	9.6	1.0	1.0	1.0
6. Campaign	3.51	5.7	9.8	9.5	9.5	4.7	9.9	9.5	9.5	1.0	1.3	1.0
7. Campaign	4.68	6.0	9.9	9.6	9.6	5.3	9.9	9.5	9.5	1.0	1.7	1.0
8. Roundup	1.75	5.7	9.8	9.5	9.5	5.0	9.8	9.8	9.8	1.0	2.3	1.0
9. Roundup	2.34	5.7	9.8	9.5	9.5	5.3	9.9	9.9	9.9	1.0	3.0	1.0
10. Roundup	3.51	5.7	9.9	9.8	9.8	5.0	9.9	9.7	9.6	1.7	3.3	1.0
11. Check	-----	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
$LSD_{0.05}$		0.5	0.3	0.5	0.5	0.7	0.2	0.4	0.4	0.3	0.9	NA
C.V.%		4.3	1.8	3.2	3.3	5.8	1.3	2.5	2.8	16.4	34.3	NA

[1]Treatments 1-5 were applied on 25 March 1992 (bermudagrass completely dormant); treatments 6-10 were applied on 15 April 1992 (bermudagrass 25% green-up).
[2]Annual Grass Control was rated on a visual scale of 1 to 10 where 1 = no effect and 10 = complete control of Bromus spp.
[3]Annual Broadleaf Control was rated on a visual scale of 1 to 10 where 1 = no effect and 10 = complete control of wild carrot and/or hairy vetch.
[4]Bermudagrass Phytotoxicity was rated on a visual scale of 1 to 10 where 1 = no effect and 10 = complete browning.

APPENDIX F

Winter Weed Control Experiment 4-H-74-94

Experiment: Winter Weed Control Experiment 4-H-74-94.

Objective: Evaluate the efficacy of several imidazolinone herbicides on winter annual weeds.

Cosponsor: American Cyanamid

Date of Treatment: 18 April 1994

Plot Size: 1.5 x 3 m

Dates Scored: 3 May, 17 May, and 14 June 1994

Methods of Scoring: Visual ratings (percent control) of prickly lettuce (LACSE), wild carrot (DAUCA), common speedwell (VEROF), cheat (BROSE) and johnsongrass (SORHA) where 0 = no control and 100 = complete control; and percent decrease in turfgrass (bermudagrass) color where 0 = no effect and 100 = complete brownout.

Discussion: The following discussion will center on the final visual ratings conducted on 14 June, approximately two months after herbicide treatments were applied (Table 57). The highest rate of Plateau (0.14 kg ai ha^{-1}) provided significantly better control of prickly lettuce than the two lowest rates of Plateau (0.036 and 0.07 kg ai ha^{-1}); however, none of these treatments exhibited an acceptable level of control. Combination treatments of Scepter plus Plateau appeared to enhance (increase) the efficacy of prickly lettuce when compared to either Scepter or Plateau treatments alone. However, no treatment of Scepter, alone or in combination with Plateau, nor the treatment of Pursuit alone, provided an acceptable level of prickly lettuce control. Oust was the only product tested in this experiment which exhibited acceptable control of prickly lettuce.

The best control of wild carrot (which was acceptable) was achieved with Oust. This treatment was significantly better than all those tested in this experiment. None of the imidazolinone herbicides, alone or in combination, provided an acceptable level of wild carrot control.

Visual observations for common speedwell control indicated that none of the herbicide treatments tested in this experiment exhibited an acceptable level of control.

The highest rates of Plateau (0.14 kg ai ha^{-1}) exhibited significantly better but unacceptable control of cheat than any of the imidazolinone herbicides tested in this experiment. Oust provided acceptable and significantly better cheat control than all other herbicides screened in this experiment.

Minimal effects were visually observed for control of johnsongrass from any of the imidazolinone herbicides and rates used in this experiment. Oust was the only product tested which demonstrated initial control of johnsongrass. Control with Oust diminished considerably by the time the experiment was terminated.

Initially, some bermudagrass phytotoxicity was observed (percent decrease in color ratings) in all plots treated with herbicides. However, these effects had totally diminished when the last ratings were made during June.

Table 57. Effect of imidazolinone herbicides on several winter annual weeds in 1994 (Experiment 4-H-74-94).

Treatments[1]	Rate (kg ai ha^{-1})	% LACSE Control[2]			% DAUCA Control[3]			% VEROF Control[4]			% BROSE Control[5]			% SORHA Control[6]			% Decrease in Color[7]		
		5/3	5/17	6/14	5/3	5/17	6/14	5/3	5/17	6/14	5/3	5/17	6/14	5/3	5/17	6/14	5/3	5/17	6/14
1. Check	-----	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Plateau	0.036	10	5	8	55	35	35	10	15	15	10	8	8	5	7	3	7	3	0
3. Plateau	0.07	18	22	22	70	50	50	30	10	10	13	13	13	8	5	0	8	3	0
4. Plateau	0.11	18	25	27	70	53	53	12	8	8	13	22	20	8	10	7	8	8	0
5. Plateau	0.14	22	47	43	75	65	65	17	15	13	10	55	55	8	17	13	8	7	0
6. Scepter	0.43	20	8	10	75	57	57	17	2	2	10	2	1	7	2	0	8	2	0
7. Scepter	0.56	15	18	18	70	50	50	10	4	3	10	5	7	7	3	2	8	2	0
8. Plateau + Scepter	0.036 0.43	23	20	23	73	60	60	17	3	3	10	8	12	10	9	7	12	2	0
9. Plateau + Scepter	0.036 0.56	20	30	30	70	57	57	13	10	10	10	17	22	8	10	5	10	5	0
10. Pursuit	0.07	8	3	3	37	26	27	8	1	1	13	1	1	7	1	0	10	0	0
11. Oust	0.05	45	87	87	70	95	93	37	33	33	23	77	87	5	82	58	5	7	0
$LSD_{0.05}$		11	22	22	NS[8]	30	29	15	10	10	3	NS	3	5	7	10	5	4	NS

[1]All herbicide treatments had X-77 surfactant added at 0.25% v/v and were applied on 18 April 1994.
[2]LACSE Control = prickly lettuce control and was rated on a 0 to 100 scale where 100 = complete control.
[3]DAUCA Control = wild carrot control and was rated on a 0 to 100 scale where 100 = complete control.
[4]VEROF Control = common speedwell control and was rated on a 0 to 100 scale where 100 = complete control.
[5]BROSE Control = cheat control and was rated on a 0 to 100 scale where 100 = complete control.
[6]SORHA Control = johnsongrass control and was rated on a 0 to 100 scale where 100 = complete control.
[7]Decrease in color was rated on a 0 to 100 scale where 0 = no effect and 100 = complete brownout.
[8]NS=Nonsignificant.

APPENDIX G

Evaluation of Herbicides for Post-Emergent Control of Kochia
(Experiment 4-H-58-91)

Experiment:	Evaluation of herbicides for post-emergent control of Kochia (Experiment 4-H-58-91).
Objective:	To compare the efficacy of seven herbicide treatments applied at two growth stages for the selective control of Kochia.
Cosponsor:	Dow Chemical
Date of Treatment:	28 March (treatments 2-8; Kochia plants 1.9 to 5.1 cm in height), 16 April (treatments 9-15; Kochia plants 5 to 15 cm in height).
Plot Size:	1.5 x 3 m
Dates Scored:	16 April, 2 May, 4 June, 18 June, 28 June, 29 July and 16 August 1991.
Methods of Scoring:	Kochia control where 1 = no effect and 10 = complete control; Bermudagrass phytotoxicity where 1 = no effect and 10 = complete yellowing.
Discussion:	Approximately three weeks after herbicide treatments were applied, no bermudagrass phytotoxicity was observed (Table 58). A slight discoloration of the bermudagrass was noted when ratings were made during May, however, this was possibly due to an ODOT application of Roundup nearby. When the last phytotoxicity rating was made in June, none was observed to be present for any of the treatments.

The best treatments which were applied in March (treatments 2-8) the 1 MAT ratings were the two treatments of Garlon 4 combined with either 0.07 or 0.14 kg ai ha^{-1} of XRM-4950. This trend was observed throughout the duration of the experiment for all remaining evaluations. When evaluations were made during May for treatments of Transline at 0.56 kg ai ha^{-1} applied alone or in combination with either 0.07 or 0.14 kg ai ha^{-1} of XRM-4950, were providing significantly less control of Kochia than the remaining treatments. However, for the duration of this experiment, the only treatment which did not provide satisfactory Kochia control was Transline applied alone at 0.56 kg ai ha^{-1}. The remainder of the treatments did exhibit excellent control of Kochia when evaluations were made during the month of August.

Table 58. Effect of post-emergent applications of Transline, Garlon and XRM-4950 tank mixes on bermudagrass and Kochia (Experiment 4-H-58-91).

Treatments[1]	Rate (kg ai ha^{-1})	Treatment Date	Bermudagrass Phytotoxicity[2] 4/16	5/2	6/18	Kochia Control[3] 4/16	5/2	6/4	6/18	6/28	7/29	8/16
Check	----	-----	1.0	1.0	1.0	1.0	1.0	3.7	1.0	1.0	1.0	1.0
Transline	0.56	3/28	1.0	1.0	1.0	1.3	1.0	6.3	6.7	6.0	5.7	5.0
Transline + XRM-4950	0.56 + 0.07	3/28	1.0	1.3	1.0	7.7	1.3	9.2	9.4	9.0	7.7	7.7
Transline + XRM-4950	0.56 + 0.14	3/28	1.0	1.0	1.0	6.0	1.0	9.6	9.5	9.2	8.9	8.5
Garlon 4 + XRM-4950	1.12 + 0.07	3/28	1.0	1.0	1.0	9.0	1.0	9.9	9.8	9.8	9.4	9.2
Garlon 4 + XRM-4950	1.12 + 0.14	3/28	1.0	1.3	1.0	9.0	1.3	9.9	9.8	9.8	9.8	9.8
Garlon 3A + XRM-4950	1.12 + 0.07	3/28	1.0	1.0	1.0	8.7	1.0	9.9	9.9	9.7	9.3	8.7
Garlon 3A + XRM-4950	1.12 + 0.14	3/28	1.0	1.3	1.0	8.3	1.3	9.6	9.0	9.0	8.1	8.1
Transline	0.56	4/16	NA	1.0	1.0	NA	1.0	7.3	9.0	8.3	7.4	6.7
Transline + XRM-4950	0.56 + 0.07	4/16	NA	1.0	1.0	NA	1.0	9.3	9.8	9.6	9.5	9.4
Transline + XRM-4950	0.56 + 0.14	4/16	NA	1.0	1.0	NA	1.0	9.5	9.8	9.8	9.7	9.6
Garlon 4 + XRM-4950	1.12 + 0.07	4/16	NA	1.0	1.0	NA	1.0	9.8	9.9	9.9	9.4	9.4
Garlon 4 + XRM-4950	1.12 + 0.14	4/16	NA	1.0	1.0	NA	1.0	9.9	9.9	9.9	9.9	9.9
Garlon 3A + XRM-4950	1.12 + 0.07	4/16	NA	1.0	1.0	NA	1.0	9.9	9.9	9.9	9.7	9.6
Garlon 3A + XRM-4950	1.12 + 0.14	4/16	NA	1.0	1.0	NA	1.0	9.9	9.9	9.9	9.8	9.8
$LSD_{0.05}$			NA	0.4	NA	1.3	1.8	1.1	0.6	1.0	1.7	1.9
C.V.%			NA	24.2	NA	22.6	16.5	7.6	4.4	6.9	12.1	13.6

[1]All treatments received X-77 surfactant at 0.25% v/v.
[2]Bermudagrass phytotoxicity was measured on a 1 to 10 scale where 1 = no phytotoxicity and 10 = complete brownout.
[3]Kochia control was evaluated on a 1 to 10 scale where 1 = no control and 10 = complete control.

APPENDIX H

Evaluation of Herbicide Treatments for Complete Vegetation Control along Highway Shoulders (Experiments 4-H-70-93 and 8-H-34-93)

Experiment: Evaluation of herbicide treatments for complete vegetation control along highway shoulders (Experiments 4-H-70-93 and 8-H-34-93).

Objective: To evaluate the efficacy of Arsenal plus Diuron tank-mixes versus competitive bareground treatments for total vegetation control along highway roadside shoulders.

Cosponsor: American Cyanamid

Date of Treatment: 27 May 1993 (4-H-70-93) and 2 June 1993 (8-H-34-93)

Plot Size: 0.6 x 15 m

Dates Scored: 25 August or 90 days after treatment (DAT) and 22 October 1993 (180 DAT) for Experiment 4-H-70-93; 31 August (90 DAT) and 22 October 1993 (180 DAT) for Experiment 8-H-34-93. October evaluations were made prior to first killing frost.

Methods of Scoring: Percent control by specific species where 0 = no control and 100 = complete control; and percent bareground where 0 = no bareground present (no control) and 100 = complete bareground (total vegetation control).

Discussion: The following are observations based upon evaluations from Experiment 4-H-70-93 and were made approximately five months after treatments were applied (Table 59). The better treatments for controlling bermudagrass were Oust plus Krovar (treatment 7), Hyvar (treatment 8) and Arsenal plus Oust (treatment 11). Treatments which performed best for silver bluestem control were Krovar (treatment 5), Hyvar (treatment 8) and Arsenal plus Oust (treatment 11). All treatments evaluated in this experiment provided excellent virginia pepperweed (100%). Switchgrass control was achieved best with Hyvar (treatment 8) and Arsenal plus Oust (treatment 11). The better treatments for obtaining total bareground effects were Hyvar (treatment 8) and Arsenal plus Oust (treatment 11).

The following are observations from 8-H-34-93 and are based upon evaluations made approximately five months after treatments were applied (Table 60). The best treatment for controlling bermudagrass was Arsenal plus Oust (treatment 11). The better treatment for switchgrass control was Arsenal plus Cadre plus Karmex (treatment 9). All treatments evaluated in this experiment had excellent control of common ragweed and broom snakeweed (100%). The better treatments for obtaining total bareground effects were Hyvar (treatment 8) and Arsenal plus Oust (treatment 11).

Table 59. Effect of 11 herbicide treatments on complete control of vegetation along a highway shoulder in ODOT Division 4 in Oklahoma (Experiment 4-H-70-93).

Treatment	Rate (kg ai ha^{-1})	Percent Bermudagrass Control[2]		Percent Silver Bluestem Control		Percent Virginia Pepperweed Control		Percent Switchgrass Control		Percent Bareground[3]	
		8/25/93	10/22/93	8/25/93	10/22/93	8/25/93	10/22/93	8/25/93	10/22/93	8/25/93	10/22/93
1. Arsenal + Karmex	0.56 5.38	40	47	63	27	100	100	30	35	50	45
2. Arsenal + Karmex	0.56 7.17	68	68	83	57	100	100	60	45	75	67
3. Arsenal + Karmex	0.56 8.96	60	68	78	52	100	100	75	25	72	65
4. Oust + Karmex	0.21 5.38	37	63	60	33	100	100	70	50	45	55
5. Krovar	7.17	94	63	100	82	100	100	100	50	94	68
6. Krovar	10.75	96	58	100	67	100	100	95	55	97	68
7. Oust + Krovar	0.16 7.17	91	83	97	73	100	100	90	50	90	77
8. Hyvar	8.96	99	90	100	95	100	100	100	83	99	90
9. Arsenal + Cadre + Karmex	0.42 0.14 5.38	48	70	47	63	100	100	37	28	48	63
10. Arsenal + Cadre + Karmex	0.42 0.14 7.17	52	63	57	60	100	100	35	50	53	68
11. Arsenal + Oust	1.12 0.11	99	95	100	92	100	100	100	80	99	93
12. Check	-----	0	0	0	0	0	0	0	0	0	0
$LSD_{0.05}$		25	19	33	28	NS	NS	16	13	22	15

[1]All herbicide treatments had X-77 added at 0.25% v/v.

[2]Weed percent control was rated on a 0 to 100 scale for all species where 0 = no control and 100 = complete control.

[3]Percent bareground was rated on a 0 to 100 scale where 0 = no vegetation control and 100 = complete total vegetation control.

Table 60. Effect of 11 herbicide treatments on complete control of vegetation along a highway shoulder in ODOT Division 8 in Oklahoma (Experiment 8-H-34-93).

Treatment[1]	Rate (kg ai ha^{-1})	Percent Bermudagrass Control[2]		Percent Switchgrass Control		Percent Common Ragweed Control		Percent Broom Snakeweed Control		Percent Bareground[3]	
		8/31/93	10/22/93	8/31/93	10/22/93	8/31/93	10/22/93	8/31/93	10/22/93	8/31/93	10/22/93
1. Arsenal + Karmex	0.56 5.38	58	57	43	43	100	100	100	100	65	57
2. Arsenal + Karmex	0.56 7.17	67	38	30	20	100	100	100	100	72	38
3. Arsenal + Karmex	0.56 8.96	68	60	62	47	100	100	100	100	73	57
4. Oust + Karmex	0.21 5.38	55	57	47	30	100	100	100	100	63	53
5. Krovar	7.17	70	48	47	40	100	100	100	100	73	47
6. Krovar	10.75	85	58	93	53	100	100	100	100	90	62
7. Oust + Krovar	0.16 7.17	86	47	67	40	100	100	100	100	83	45
8. Hyvar	8.96	96	67	100	55	100	100	100	100	98	70
9. Arsenal + Cadre + Karmex	0.42 0.14 5.38	55	57	90	70	100	100	100	100	62	60
10. Arsenal + Cadre + Karmex	0.42 0.14 7.17	58	57	55	35	100	100	100	100	63	57
11. Arsenal + Oust	1.12 0.11	96	83	85	55	100	100	100	100	96	82
12. Check	------	0	0	0	0	0	0	0	0	0	0
$LSD_{0.05}$		30	21	NS	23	NS	NS	NS	NS	27	27

[1]All herbicide treatments had X-77 added at 0.25% v/v.
[2]Weed percent control was rated on a 0 to 100 scale for all species where 0 = no control and 100 = complete control.
[3]Percent bareground was rated on a 0 to 100 scale where 0 = no vegetation control and 100 = complete total vegetation control.

APPENDIX I

Evaluation of an Experimental Herbicide for Complete Control of Vegetation on Roadside Shoulders in ODOT Division 4 (Experiment 4-H-72-93)

Experiment:	Evaluation of an experimental herbicide for complete control of vegetation on roadside shoulders in ODOT Division 4 (Experiment 4-H-72-93).
Objective:	To determine if the quick action of UCC-C4243 (experimental herbicide) reduces translocation and therefore control of grasses with Roundup and evaluate UCC-C4243 for maintaining bareground in Roundup combinations under field conditions in ODOT Division 4.
Cosponsor:	Uniroyal
Date of Treatment:	27 May 1993
Plot Size:	0.54 x 15 m
Dates Scored:	10 June or 14 days after treatment (DAT), 28 June (30 DAT), 27 July (60 DAT) and 26 August 1993 (90 DAT).
Methods of Scoring:	Percent control by specific species where 0 = no control and 100 = complete control; percent total vegetation control (percent bareground) where 0 = no control and 100 = complete control (complete bareground).
Discussion:	The addition of UCC-C4243 to Roundup appears to enhance the initial burndown (Table 61) of bermudagrass (14 DAT), however, the effect seems to diminish with time (1 to 3 MAT). There appears to be no advantage in combining UCC-C4243. The treatment of Arsenal plus Oust (treatment 10) provided significantly better bermudagrass control than any other treatment.

The best silver bluestem control observed 3 MAT was achieved with Arsenal plus Oust (treatment 10), followed by the combination treatment of the highest rates of UCC-C4243 plus Roundup (treatment 6). With one exception (lowest rate of UCC-C4243 plus Roundup - treatment 3), Roundup alone or combined with UCC-C4243 provided 80% or more silver bluestem control 3 MAT.

All herbicide treatments, except the two rates of UCC-C4243 alone and the combination treatment using the lowest rate of UCC-C4243 plus Roundup (treatment 3) provided excellent control of Italian ryegrass at 1 MAT (Table 62).

The treatment in this experiment which provided the best total vegetation control was the standard treatment of Arsenal plus Oust (treatment 10).

Additional information (raw data) for switchgrass and common pepperweed control is provided in Tables 63 and 64 respectively. UCC-C4243 alone and the combination treatment of the lowest rate of UCC-C4243 plus Roundup (treatment 3) appear to effectively control common pepperweed.

Table 61. Effect of UCC-C4243 and Roundup herbicides on bermudagrass in ODOT Division 4 (Experiment 4-H-72-93).

Treatments[1,2]	Rate ($kg\ ai\ ha^{-1}$)	Percent Bermudagrass Control[3]				Percent Total Vegetation Control			
		14 DAT[4]	1 MAT[5]	2 MAT	3 MAT	14 DAT	1 MAT	2 MAT	3 MAT
1. UCC-C4243	0.28	7	4	2	2	7	4	2	2
2. UCC-C4243	0.56	17	8	3	3	15	8	3	3
3. UCC-C4243 + Roundup	0.28 + 2.8	86	42	30	28	86	42	38	35
4. UCC-C4243 + Roundup	0.28 + 5.6	97	88	73	65	94	88	80	70
5. UCC-C4243 + Roundup	0.56 + 2.8	97	77	73	40	96	77	80	48
6. UCC-C4243 + Roundup	0.56 + 5.6	98	93	88	77	97	93	93	80
7. Roundup	2.8	53	87	63	43	63	87	73	53
8. Roundup	5.6	77	95	93	70	82	95	94	77
9. UCC-C4243 + Roundup	0.28 + 2.8	90	53	57	47	90	53	72	60
10. Arsenal + Oust	1.12 + 0.11	10	72	99	99	18	72	99	99
11. Check	-----	0	0	0	0	0	0	0	0
$LSD_{0.05}$		8	16	19	20	9	16	20	20

[1]All treatments were applied on 27 May 1993.
[2]All herbicide treatments except treatments 9 and 10 had a crop oil added at 0.25% v/v.
[3]Percent weed control was rated on a 0 to 100 scale where 0 = no control and 100 = complete control for each species of concern.
[4]DAT = Days After Treatment.
[5]MAT = Months After Treatment.

Table 62. Effect of UCC-C4243 and Roundup herbicides on silver bluestem and Italian ryegrass in ODOT Division 4 (Experiment 4-H-72-93).

Treatments[1,2]		Rate (kg ai ha^{-1})	Percent Silver Bluestem Control[3]				Percent Italian Ryegrass Control	
			14 DAT[4]	1 MAT[5]	2 MAT	3 MAT	14 DAT	1 MAT
1.	UCC-C4243	0.28	8	2	1	1	8	4
2.	UCC-C4243	0.56	12	6	3	2	18	8
3.	UCC-C4243 + Roundup	0.28 + 2.8	91	82	73	43	100	80
4.	UCC-C4243 + Roundup	0.28 + 5.6	99	98	83	82	100	98
5.	UCC-C4243 + Roundup	0.56 + 2.8	100	100	100	70	100	100
6.	UCC-C4243 + Roundup	0.56 + 5.6	100	100	100	92	100	100
7.	Roundup	2.8	78	98	100	80	87	97
8.	Roundup	5.6	92	100	100	80	100	100
9.	UCC-C4243 + Roundup	0.28 + 2.8	98	98	100	83	100	98
10.	Arsenal + Oust	1.12 + 0.11	23	88	100	100	32	93
11.	Check	-----	0	0	0	0	0	0
$LSD_{0.05}$			7	13	27	20	11	16

[1]All treatments were applied on 27 May 1993.
[2]All herbicide treatments except treatments 9 and 10 had a crop oil added at 0.25% v/v.
[3]Percent weed control was rated on a 0 to 100 scale where 0 = no control and 100 = complete control for each species of concern.
[4]DAT = Days After Treatment.
[5]MAT = Months After Treatment.

Table 63. Effect of UCC-C4243 and Roundup herbicides on switchgrass in ODOT Division 4 (Experiment 4-H-72-93).

		Percent Switchgrass Control[3]											
	Rate	14 DAT[4]			1 MAT[5]			2 MAT			3 MAT		
Treatments[1,2]	(kg ai ha^{-1})	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
1. UCC-C4243	0.28	0	NA	NA	0	NA	NA	0	NA	NA	0	NA	NA
2. UCC-C4243	0.56	10	NA	NA	10	NA	NA	5	NA	NA	5	NA	NA
3. UCC-C4243 + Roundup	0.28 + 2.8	10	40	95	10	60	85	5	25	80	5	20	40
4. UCC-C4243 + Roundup	0.28 + 5.6	50	80	90	80	90	100	50	95	90	50	50	50
5. UCC-C4243 + Roundup	0.56 + 2.8	80	75	NA	90	75	NA	80	60	NA	50	20	NA
6. UCC-C4243 + Roundup	0.56 + 5.6	NA	90	NA	NA	95	NA	NA	99	NA	NA	90	NA
7. Roundup	2.8	5	NA	40	80	NA	75	80	NA	20	40	NA	15
8. Roundup	5.6	40	NA	90	90	NA	95	90	NA	30	90	NA	30
9. UCC-C4243 + Roundup	0.28 + 2.8	60	NA	NA	80	NA	NA	85	NA	NA	60	NA	NA
10. Arsenal + Oust	1.12 0.11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
11. Check	-----	NA	0	0	NA	0	0	NA	0	0	NA	0	0

[1]All treatments were applied on 27 May 1993 and a statistical analysis was not performed on this data set.
[2]All herbicide treatments except 9 and 10 had a crop oil added at 0.25% v/v.
[3]Percent switchgrass control was rated on a 0 to 100 scale where 0 = no control and 100 = complete control.
[4]DAT = Days After Treatment.
[5]MAT = Months After Treatment.

Table 64. Effect of UCC-C4243 and Roundup herbicides on common pepperweed in ODOT Division 4 (Experiment 4-H-72-93).

			Percent Common Pepperweed Control[3]											
			14 DAT[4]			1 MAT[5]			2 MAT			3 MAT		
	Treatments[1,2]	Rate (kg ai ha^{-1})	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
1.	UCC-C4243	0.28	10	5	10	5	2	5	2	5	5	2	5	2
2.	UCC-C4243	0.56	20	10	10	10	10	5	2	5	2	2	5	2
3.	UCC-C4243 +	0.28 +												
	Roundup	2.8	90	85	100	90	50	100	15	50	100	15	50	50
4.	UCC-C4243 +	0.28 +												
	Roundup	5.6	100	100	NA	95	100	NA	90	100	NA	80	80	NA
5.	UCC-C4243 +	0.56 +												
	Roundup	2.8	100	100	100	100	100	100	100	100	100	90	90	80
6.	UCC-C4243 +	0.56 +												
	Roundup	5.6	100	100	NA	100	100	NA	100	98	NA	90	90	NA
7.	Roundup	2.8	100	90	50	100	100	100	100	100	100	90	80	80
8.	Roundup	5.6	100	100	100	100	100	100	100	100	100	90	80	100
9.	UCC-C4243 +	0.28 +												
	Roundup	2.8	100	100	98	100	100	95	100	100	100	90	80	100
10.	Arsenal +	1.12 +												
	Oust	0.11	20	50	30	100	100	80	100	100	100	100	100	100
11.	Check	-----	0	0	0	0	0	0	0	0	0	0	0	0

[1]All treatments were applied on 27 May 1993 and a statistical analysis was not performed on this data set.
[2]All herbicide treatments except 9 and 10 had a crop oil added at 0.25% v/v.
[3]Percent common pepperweed control was rated on a 0 to 100 scale where 0 = no control and 100 = complete control.
[4]DAT = Days After Treatment.
[5]MAT = Months After Treatment.

APPENDIX J

Evaluation of an Experimental Herbicide for Complete Control of Vegetation on Roadside Shoulders in ODOT Division 8 (Experiment 8-H-35-93)

Experiment: Evaluation of an experimental herbicide for complete control of vegetation on roadside shoulders in ODOT Division 8 (Experiment 8-H-35-93).

Objective: To determine if the quick action of UCC-C4243 (experimental herbicide) reduces translocation and therefore control of grasses with Roundup and evaluate UCC-C4243 for maintaining bareground in Roundup combinations under field conditions in ODOT Division 8.

Cosponsor: Uniroyal

Date of Treatment: 2 June 1993

Plot Size: 0.54 x 15 m

Dates Scored: 17 June or 14 days after treatment (DAT), 2 July (30 DAT), 2 August (50 DAT) and 2 September 1993 (90 DAT).

Methods of Scoring: Percent control by specific species where 0 = no control and 100 = complete control; percent total vegetation control (percent bareground) where 0 = no control and 100 = complete control (complete bareground).

Discussion: Although there appears to be an initial advantage by the addition of UCC-C4243 to Roundup for the burndown of bermudagrass (14 DAT), the effect seems to diminish (1 to 3 MAT) with time (Table 65). No treatment of Roundup alone or in combination with UCC-C4243 provided acceptable season-long control (3 MAT) of bermudagrass. The treatment which exhibits the best season-long bermudagrass control was the standard treatment of Arsenal plus Oust (treatment 10).

The best treatment in this experiment for total vegetation control (3 MAT) was the combination treatment (standard) of Arsenal plus Oust (treatment 10) (Table 65).

Additional information (raw data) for little barley, common ragweed and switchgrass control is provided in Tables 66, 67, and 68 respectively, although no statistical analysis are available due to missing plot data. From these data it appears that most if not all of the herbicide treatment effectively controlled little barley. All herbicide treatments except UCC-C4243 alone or the low rate of UCC-C4243 combined with Roundup effectively controlled common ragweed. The only treatment which may have potential for switchgrass control appears to be the combination of the higher rates of UCC-C4243 plus Roundup (treatment 6).

Table 65. Effect of UCC-C4243 and Roundup herbicides on bermudagrass control in ODOT Division 8 (Experiment 8-H-35-93).

Treatments[1,2]		Rate (kg ai ha^{-1})	Percent Bermudagrass Control[3]				Percent Total Vegetation Control			
			2 WAT[4]	1 MAT[5]	2 MAT	3 MAT	2 WAT	1 MAT	2 MAT	3 MAT
1.	UCC-C4243	0.28	33	25	2	2	35	19	2	2
2.	UCC-C4243	0.56	72	58	28	15	73	63	23	17
3.	UCC-C4243 + Roundup	0.28 + 2.8	83	45	11	6	83	45	16	12
4.	UCC-C4243 + Roundup	0.28 + 5.6	100	88	60	42	98	92	60	47
5.	UCC-C4243 + Roundup	0.56 + 2.8	95	80	53	37	94	78	60	45
6.	UCC-C4243 + Roundup	0.56 + 5.6	98	94	72	58	98	94	82	70
7.	Roundup	2.8	8	22	28	18	17	23	33	27
8.	Roundup	5.6	77	93	77	68	77	93	83	67
9.	UCC-C4243 + Roundup	0.28 + 2.8	97	82	60	47	96	87	73	52
10.	Arsenal + Oust	1.12 + 0.11	10	50	92	92	8	53	85	88
11.	Check	-----	0	0	0	0	0	0	0	0
$LSD_{0.05}$			9	23	31	26	9	22	32	27

[1]All herbicide treatments were applied on 2 June 1993.
[2]All herbicide treatments except treatments 9 and 10 had a crop oil added at 0.25% v/v.
[3]Percent weed control was rated on a 0 to 100 scale where 0 = no control and 100 = complete control for each species of concern.
[4]WAT = Weeks After Treatment.
[5]MAT = Months After Treatment.

Table 66. Effect of UCC-C4243 and Roundup herbicides on little barley in ODOT Division 8 (Experiment 8-H-35-93).

Treatments[1,2]	Rate (kg ai ha^{-1})	Percent Little Barley Control[3]					
		14 DAT[4]			1 MAT[5]		
		Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
1. UCC-C4243	0.28	50	70	NA	5	50	NA
2. UCC-C4243	0.56	80	90	80	80	100	100
3. UCC-C4243 + Roundup	0.28 + 2.8	NA	NA	100	NA	NA	95
4. UCC-C4243 + Roundup	0.28 + 5.6	100	100	NA	100	100	NA
5. UCC- C4243 + Roundup	0.56 + 2.8	NA	NA	NA	NA	NA	NA
6. UCC-C4243 + Roundup	0.56 + 5.6	NA	100	100	NA	100	100
7. Roundup	2.8	50	30	NA	90	90	NA
8. Roundup	5.6	80	95	100	100	100	100
9. UCC-C4243 + Roundup	0.28 + 2.8	100	100	NA	100	100	NA
10. Arsenal + Oust	1.12 + 0.11	NA	NA	NA	NA	NA	NA
11. Check	-----	0	0	0	0	0	0

[1]All herbicide treatments were applied on 2 June 1993 and a statistical analysis was not performed on this data set.
[2]All herbicide treatments except treatments 9 and 10 had a crop oil added at 0.25% v/v.
[3]Percent little barley control was rated on a 0 to 100 scale where 0 = no control and 100 = complete control.
[4]DAT = Days After Treatment.
[5]MAT = Months After Treatment.

Table 67. Effect of UCC-C4243 and Roundup herbicides on common ragweed in ODOT Division 8 (Experiment 8-H-35-93).

		Percent Common Ragweed Control[3]											
	Rate	14 DAT[4]			1 MAT[5]			2 MAT			3 MAT		
Treatments[1,2]	(kg ai ha^{-1})	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
1. UCC-C4243	0.28	5	30	20	5	20	10	5	2	5	0	2	5
2. UCC-C4243	0.56	75	NA	NA	10	NA	NA	5	NA	NA	0	NA	NA
3. UCC-C4243 + Roundup	0.28 + 2.8	80	NA	80	100	NA	60	5	NA	100	0	NA	100
4. UCC-C4243 + Roundup	0.28 + 5.6	100	NA	NA	80	NA	NA	2	NA	NA	2	NA	NA
5. UCC-C4243 + Roundup	0.56 + 2.8	NA	98	NA	NA	100	NA	100	NA	NA	NA	90	NA
6. UCC-C4243 + Roundup	0.56 + 5.6	100	98	98	90	100	100	100	100	100	100	90	100
7. Roundup	2.8	0	5	70	10	50	50	75	100	50	50	50	50
8. Roundup	5.6	75	95	60	100	100	90	90	100	90	80	90	90
9. UCC-C4243 + Roundup	0.28 + 2.8	100	98	NA	90	90	NA	50	100	NA	50	90	NA
10. Arsenal + Oust	1.12 + 0.11	NA	5	20	NA	100	80	NA	90	100	NA	100	100
11. Check	-----	NA	0	NA	NA	0	NA	NA	0	NA	NA	0	NA

[1]All herbicide treatments were applied on 2 June 1993 and a statistical analysis was not performed on this data set.
[2]All herbicide treatments except treatments 9 and 10 had a crop oil added at 0.25% v/v.
[3]Percent common ragweed control was rated on a 0 to 100 scale where 0 = no control and 100 = complete control.
[4]DAT = Days After Treatment.
[5]MAT = Months After Treatment.

Table 68. Effect of UCC-C4243 and Roundup herbicides on switchgrass in ODOT Division 8 (Experiment 8-H-35-93).

		Percent Switchgrass Control[3]											
	Rate	14 DAT[4]			1 MAT[5]			2 MAT			3 MAT		
Treatments[1,2]	(kg ai ha^{-1})	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
1. UCC-C4243	0.28	30	20	20	10	10	10	5	2	2	0	2	2
2. UCC-C4243	0.56	50	NA	NA	5	NA	NA	5	NA	NA	5	NA	NA
3. UCC-C4243 + Roundup	0.28 + 2.8	NA	80	NA	NA	90	NA	NA	20	NA	NA	20	NA
4. UCC-C4243 + Roundup	0.28 + 5.6	NA	95	95	NA	98	98	NA	90	50	NA	40	40
5. UCC-C4243 + Roundup	0.56 + 2.8	NA	75	95	NA	60	95	NA	60	85	NA	30	50
6. UCC-C4243 + Roundup	0.56 + 5.6	NA	NA	95	NA	NA	98	NA	NA	90	NA	NA	75
7. Roundup	2.8	30	5	15	70	10	20	50	50	50	20	25	50
8. Roundup	5.6	80	NA	50	90	NA	80	80	NA	75	40	NA	50
9. UCC-C4243 + Roundup	0.28 + 2.8	90	80	NA	85	80	NA	90	80	NA	60	60	NA
10. Arsenal + Oust	1.12 + 0.11	10	5	10	30	20	30	50	50	20	40	40	50
11. Check	-----	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

[1]All herbicide treatments were applied on 2 June 1993 and a statistical analysis was not performed on this data set.
[2]All herbicide treatments except treatments 9 and 10 had a crop oil added at 0.25% v/v.
[3]Percent switchgrass control was rated on a 0 to 100 scale where 0 = no control and 100 = complete control.
[4]DAT = Days After Treatment.
[5]MAT = Months After Treatment.

APPENDIX K

Bareground Experiment 4-H-83-95

Experiment: Bareground Experiment 4-H-83-95

Objective: To evaluate the efficacy of Endurance herbicide combined with either Roundup or Arsenal for total vegetation control (encroachment) along roadside shoulders.

Cosponsor: Sandoz Company

Date of Treatment: 14 June 1995

Plot Size: 0.6 x 15 m

Dates Scored: 14 July or 1 month after treatment (MAT), 14 Aug (2 MAT), 18 September (3 MAT) and 26 October (4 MAT).

Methods of Scoring: Visual observations of percent control of individual plant species where 0 = no control and 100 = complete control. The following plant species were evaluated using the Bayer code for identification and in Table 69:
% CYNDA control = % Bermudagrass control
% PANVI control = % Switchgrass control
% DEMIL control = % Illinois bundleflower control
% SORHA control = % Johnsongrass control
% LOLMU control = % Italian Ryegrass control
% ANOSA control = % Silver Bluestem control
% DIGSA control = % Hairy Crabgrass control
% ERACU control = % Weeping Lovegrass control
EPHHT number = number of prostrate spurge plants per plot

Discussion: Due to the amount of data generated from this experiment, the following discussion will be primarily focused on the 4 MAT evaluation.

Overall, the combination treatments of Roundup plus Endurance provided better control of bermudagrass (90 to 93%) as compared to the combination treatments of Arsenal plus Endurance (72 to 87%). Roundup alone exhibited 78% control while one of the standard treatments used in this experiment, the combination treatment of Arsenal plus Oust resulted in 87% control. The other standard used in this experiment, the combination of Arsenal plus Karmex was disappointing, as it exhibited only 5% control of bermudagrass (Table 69). Unless there could have been an antagonism exhibited from this combination treatment, a reason for this behavior cannot be explained at the present time.

A similar trend was observed for switchgrass (PANVI) control (Table 69). The combination treatments of Roundup plus Endurance provided better overall control (89 to 92%) as compared to the combination treatments of Arsenal plus Endurance (68 to 80%). Roundup alone provided good control of switchgrass (92%). Both standards used in this experiment, Arsenal plus Oust and Arsenal plus Karmex did not provide an acceptable level of switchgrass control (43 to 60%).

Although little information was made available for Illinois bundleflower (DEMIL) control, due to the lack of plants present in plots (missing data), none of the treatments evaluated were effective in controlling this plant species (10 to 50%).

Only the standard treatment of Arsenal plus Karmex had johnsongrass (SORHA) present to evaluate in this experiment. Initial control looked promising (95%), however, had declined to an unacceptable level (50%) by 4 MAT.

All herbicide treatments provided 100% control of the annual grass specie, Italian ryegrass (LOLMU) throughout the duration of this experiment.

In a trend similar to the ones seen for both bermudagrass and switchgrass control, the combination treatments of Roundup plus Endurance provided better overall control (98 to 100%) of silver bluestem (ANOSA) as compared to the combination treatments of Arsenal plus Endurance (90 to 92%). Roundup alone and both standards of Arsenal plus Oust and Arsenal plus Karmex provided acceptable silver bluestem control (95 to 98%).

Information was available for only one-half of the treatments in this experiment for the control of hairy crabgrass (DIGSA) due to missing data (plants) in the treated plots. For those in which data was collected, 100% control of hairy crabgrass was visually observed.

Weeping lovegrass (ERACU) control was evaluated only in 6 of 10 treatments due to the lack of plants present (missing data) in the experimental area. The combination treatment of Roundup plus Endurance (5.6 plus 1.12 kg ai ha^{-1}) provided 100% control of weeping lovegrass followed closely by the treatment of Roundup alone (95%). Arsenal plus Endurance combination treatments resulted in only 60 to 90% control. The standard treatment of Arsenal plus Oust provided only marginal (70%) control.

The actual number of prostrate spurge (EPHHT) plants were counted at 3 and 4 MAT. Overall, fewer plants were present in plots treated with Arsenal plus Endurance as compared to treatments of Roundup plus Endurance. It is interesting to note that fewer plants were present in both of the standard treatments of Arsenal plus Oust with none being present in plots treated with Arsenal plus Karmex.

Table 69. Effect of Endurance tank mixes on control of common bermudagrass (CYNDA), switchgrass (PANVI) and Illinois bundleflower (DEMIL) (Experiment 4-H-83-95).

Treatments[1]	Rate (kg ai ha^{-1})	Percent CYNDA Control				Percent PANVI Control				Percent DEMIL Control			
		1 MAT	2 MAT	3 MAT	4 MAT	1 MAT	2 MAT	3 MAT	4 MAT	1 MAT	2 MAT	3 MAT	4 MAT
1. Check	-----	0	0	0	0	0	0	0	0	0	0	0	0
2. Roundup	5.6	92	97	88	78	90	93	92	92	95	50	60	50
3. Arsenal + Endurance	1.12 1.68	37	87	87	83	38	47	70	78	20	5	40	30
4. Arsenal + Endurance	1.12 1.4	33	87	83	72	33	37	75	80	NA	NA	NA	NA
5. Arsenal + Endurance	1.12 1.12	40	87	87	87	43	47	48	68	50	10	10	10
6. Roundup + Endurance	5.6 1.68	92	97	94	93	88	94	93	89	NA	NA	NA	NA
7. Roundup + Endurance	5.6 1.4	95	97	93	92	96	93	93	90	NA	NA	NA	NA
8. Roundup + Endurance	5.6 1.12	93	97	93	90	96	93	93	92	NA	NA	NA	NA
9. Arsenal + Oust	1.12 0.11	47	92	88	87	47	52	60	60	5	40	10	10
10. Arsenal + Karmex	1.12 2.69	85	20	10	5	57	58	40	43	15	15	25	30
$LSD_{0.05}$		10	5	6	20	NA	21	16	20	NA	NA	NA	NA

[1]All herbicide treatments had X-77 surfactant added at 0.25% v/v.

Table 70. Effect of Endurance tank mixes on control of johnsongrass (SORHA), Italian ryegrass (LOLMU) and silver bluestem (ANOSA) (Experiment 4-H-83-95).

Treatments[1]	Rate (kg ai ha^{-1})	Percent SORHA Control				Percent LOLMU Control				Percent ANOSA Control			
		1 MAT	2 MAT	3 MAT	4 MAT	1 MAT	2 MAT	3 MAT	4 MAT	1 MAT	2 MAT	3 MAT	4 MAT
1. Check	-----	NA	NA	NA	NA	0	0	0	0	0	0	0	0
2. Roundup	5.6	NA	NA	NA	NA	100	100	100	100	93	100	100	97
3. Arsenal + Endurance	1.12 1.68	NA	NA	NA	NA	100	100	100	100	40	85	100	92
4. Arsenal + Endurance	1.12 1.4	NA	NA	NA	NA	100	100	100	100	47	75	100	92
5. Arsenal + Endurance	1.12 1.12	NA	NA	NA	NA	100	100	100	100	50	82	97	90
6. Roundup + Endurance	5.6 1.68	NA	NA	NA	NA	100	100	100	100	98	100	100	98
7. Roundup + Endurance	5.6 1.4	NA	NA	NA	NA	100	100	100	100	97	100	100	100
8. Roundup + Endurance	5.6 1.12	NA	NA	NA	NA	100	100	100	100	98	100	100	100
9. Arsenal + Oust	1.12 0.11	NA	NA	NA	NA	100	100	100	100	62	88	100	98
10. Arsenal + Karmex	1.12 2.69	95	90	75	50	100	100	100	100	80	72	100	95
$LSD_{0.05}$		NA	NA	11	NA	NA	NA	NA	NA	14	15	3	8

[1]All herbicide treatments had X-77 surfactant added at 0.25% v/v.

Table 71. Effect of Endurance tank mixes on control of hairy crabgrass (DIGSA), weeping lovegrass (ERACU) and prostrate spruge (EPHHT) (Experiment 4-H-83-95).

Treatments[1]	Rate (kg ai ha^{-1})	Percent DIGSA Control				Percent ERACU Control				EPHHT Number	
		1 MAT	2 MAT	3 MAT	4 MAT	1 MAT	2 MAT	3 MAT	4 MAT	3 MAT	4 MAT
1. Check	-----	NA	NA	NA	NA	0	0	0	0	13	13
2. Roundup	5.6	100	100	100	100	100	100	100	95	46	48
3. Arsenal + Endurance	1.12 1.68	NA	NA	NA	NA	30	50	70	60	13	15
4. Arsenal + Endurance	1.12 1.4	100	100	100	100	50	20	90	90	11	11
5. Arsenal + Endurance	1.12 1.12	100	100	100	100	NA	NA	NA	NA	18	18
6. Roundup + Endurance	5.6 1.68	NA	NA	NA	NA	NA	NA	NA	NA	121	121
7. Roundup + Endurance	5.6 1.4	100	100	100	100	NA	NA	NA	NA	58	64
8. Roundup + Endurance	5.6 1.12	100	100	100	100	100	100	100	100	47	50
9. Arsenal + Oust	1.12 0.11	NA	NA	NA	NA	75	40	70	70	5	5
10. Arsenal + Karmex	1.12 2.69	NA	NA	NA	NA	NA	NA	NA	NA	0	0
$LSD_{0.05}$		NA	NA	NA	NA	NA	NA	NA	NA	93	94

[1]All herbicide treatments had X-77 surfactant added at 0.25% v/v.

APPENDIX L

Appendix of Trade, Common and Chemical Names of Herbicides

APPENDIX L: Appendix of Trade, Common and Chemical Names of Herbicides.

TRADE NAME	COMMON NAME OF ACTIVE INGREDIENT	CHEMICAL NAME OF ACTIVE INGREDIENT
Aatrex 4L	atrazine	6-Chloro-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine-2,4-diamine
Arsenal	imazapyr	(±)-2-{4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-3-pyridinecarboxylic acid
Asulox	asulam	methyl[(4-aminophenyl)sulfonyl]carbamate
Assure	quizalofop-p	(R)-2-[4-[(6-chloro-2-quinoxalinyl)oxy]phenoxy]propanoic acid
Banvel	dicamba	3,6-dichloro-2-methoxy-benzoic acid
Bladex	cyanazine	2-[[4-chloro-6-(ethylamino)-1,3,5-trizin-2-yl]amino]-2-methylpropanenitrile
Campaign	glyphosate + 2,4-D	glyphosate + 2,4-D
Corn Gluten Meal		
2,4-D	2,4-D	(2,4-dichlorophenoxy)acetic acid
Endurance	prodiamine	2,4-dinitro-N^3,N^3-dipropyl-6-(trifluoromethyl)-1,3-benzenediamine
Escort	metsulfuron methyl	{Methyl 2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]-carbonyl]-amino]sulfonyl]benzoate}
Fusilade	fluazifop	(±)-2-[4-[[5-(trifluro-methyl)-2-pyridinyl]oxy]penoxy]propanoic acid
Garlon 3A, Garlon 4	triclopyr	[(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid
Hoelon	diclofop	(±)-2-[4-(2,4-dichlorophenoxy)phenoxy]propanoic acid

TRADE NAME	COMMON NAME OF ACTIVE INGREDIENT	CHEMICAL OF ACTIVE INGREDIENT
Hyvar	bromacil	5-bromo-6-methyl-3-(1-methylpropyl)-2,4(1H,3H)pyrimidinedione
Karmex	diuron	N-(3,4-dichlorophenyl)-N,N-dimethylurea
Krovar	bromacil + diuron	bromacil + diuron
Lexone	metribuzin	[4-Amino-6-(1,1dimethylethyl)-3-(methylthio)-1,2,4 triazin-5(4H)-one]
MSMA	MSMA	monosodium methanearsonate
Oust	sulfometuron methyl	{Methyl 2-[[[[4,6-dimethyl-2-pyrimidinyl)-amino]carbonyl] amino]sulfonyl]benzoate}
Plateau	imazameth	(±)-2-{4,5-dihydro-4-methyl-4-(1-methyl-ethyl)-5-oxo-1H-imidazol-2-yl]-5-methyl-3-pyridinecarboxylic acid (CA)
Poast	sethoxydim	2-[1-ethoxyamino)-butyl]-5-[2-(ethylthio)-propyl]-3-hydroxy-2-cyclohexene-1-one
Primo	trinexapac ethyl	ethyl 4-cyclopropyl(hydroxy)methylene-3,5-dioxocyclohexanecarboxylate
Princep	simizine	6-chloro-N,N'-diethyl-1,3,5-triazine-2,4-diamine
Prograss	ethofumesate	(±)-2-ethoxy-2,3dihydro-3,3-dimethyl-5-benzofuranyl methanesulfonate
Pursuit	imazethapyr	2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-ox0-1H-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid
Rifle	primisulfuron	3-[4,6-bis(difluromethyl)-pyrimidine-2-yl]-1-methoxy-carbonyl-phenyl)sulfonyl)-urea
Roundup, Rodeo	glyphosate	N-(phosphonomethyl)glycine

TRADE NAME	COMMON NAME OF ACTIVE INGREDIENT	CHEMICAL OF ACTIVE INGREDIENT
Scepter	imazaquin	2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-ox0-1H-imidazol-2-yl]-3-quinolinecarboxylic acid
Select	clethodim	(E,E)-(±)-2-[1-[[(3-chloro-2-propenyl)oxy]imino]propyl]-5-[2-ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one
Solicam	norflurazon	4-chloro-5-(methylamino)-2-(3-(trifluoromethyl)phenyl)-3(2H)-pyridazinone
Stomp	pendimethalin	N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzene-amine
Surflan	oryzalin	4-(dipropylamino)-3,5-dinitrobenzenesulfonamide
Telar	chlorsulfuron	2-chloro-N-[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)-aminocarbonyl] benzenesulfonamide
Tordon K	picloram	4-amino-3,5,6-trichloro-2-pyridine carboxylic acid
Transline	clopyralid	3,6-dichloro-2-pyridine-carboxylic acid
Velpar	hexazinone	3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione
Verdict	haloxyfop	(±)-2-[[3-chloro-5-(trifluoromethyl)-2-pytidinyl]oxy]oxy]phenoxy]propanoic acid
Whip, Horizon	fenoxaprop	(±)-2-[4-[(6-chloro-2-benzoxazolyl)oxy]phenoxy]propanoic acid