HERBICIDE EVALUATION FOR WEED CONTROL
ON OKLAHOMA HIGHWAYS

By

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CHAPTER I

INTRODUCTION

The highway system in Oklahoma requires modern, efficient methods of establishment and maintenance of desirable vegetation on the rights-of-way if it is to provide adequate services with a minimum of expenditure. Herbicides have been used successfully in some areas to minimize hand labor in the maintenance programs around guardrails and signposts, and also to reduce costs of weed control on grass-covered areas. Current maintenance programs in some states utilize herbicides for the control of weedy grasses and broadleaf plants, sometimes in combination with growth inhibitors. Such programs commonly reduce maintenance costs while improving the stand of grass.

Likewise, soil sterilants have been used in several states to reduce the maintenance costs by the elimination of vegetation under guardrails and around signposts. In addition, soil sterilants are employed occassionally for the purpose of preventing the destruction of the asphaltic shoulders by living vegetation.

A problem common to the southern states particularly is the infestation of roadsides with johnsongrass (Sorghum halepense). This plant spreads by seeds and rhizomes, and is detrimental to both the appearance of roadsides and the drivers' safety. To combat this problem highway maintenance departments frequently employ mechanical mowing of johnsongrass as a means of control. However, the possibility exists perhaps that more effective methods can be found to eliminate existing stands of johnsongrass through the use of herbicides.

Herbicides would seem to afford some help in maintenance of the desired grass on medians and roadsides by decreasing undesirable plant competition and by increasing the benefit of applied fertilizer. A dense, protective cover of grass would reduce soil erosion and maintenance costs for repairs and mowing.

Public safety on highways depends upon adequate sight distance ahead and to the side of the road. This oftentimes becomes limited, however, during the warm season of the year by the growth of weeds unless there is frequent mowing. Safety also depends upon solid, smooth highway shoulders for emergencies. Shoulders which have been weakened structurally by the physical forces of weather or vegetation, or shoulders upon which old vegetation and debris have collected may be extremely hazardous to the motoring public.

In an attempt to minimize destruction of the hard surfaced highway shoulder by vegetation, and reduce the maintenance cost from mowing along Oklahoma highways, research was initiated in 1963 to study the use of herbicides for soil sterilization, the elimination of johnsongrass, and the control of weeds on the highway system. In the study of soil sterilants, efforts were made to prevent the growth of all plants under guardrails, around signposts, and on highway shoulders. If such conditions could be achieved, presumably a substantial savings could be realized in the maintenance budget through a reduction in the amount of hand labor required for mowing and by minimizing costly shoulder repairs.

The research on the control of broadleaf plants and weedy grasses was designed to evaluate various herbicides for the selective eradication of undesirable plants as a means of providing good sight distance for public safety and minimizing maintenance costs for these areas.

Because of the widespread occurrence of johnsongrass in Oklahoma and because of the usual rapidity of regrowth following mowing which not only is unsightly but creates a driving hazard as a result of reduced sight distance, an investigation was initiated to study the possible selective eradication of johnsongrass with chemicals. With the elimination of johnsongrass and other undesirable plants alongside the highways, a substantial savings should be effected in maintenance costs.

The research results reported herein, even though involved with a common investigation, will be presented as three separate studies for the purpose of clarity and convenience. The overall presentation will encompass the combined results of the three related investigations.

CHAPTER II

LITERATURE REVIEW

Literature related to the use of chemicals for the control of undesirable plants is voluminous. Many investigations deal with weed control in cultivated crops, the results of which frequently are applicable where an edible crop is involved. Because the literature on chemical weed control is so broad in coverage, the review presented in this paper has been purposely selected as particularly pertinent to the possible use of herbicides for weed control along Oklahoma's highways.

General Review

Chamberlin (9) reported the total maintenance cost on highway medians in Pennsylvania was reduced by $4.70 per acre through the use of three contract spray applications per season during 1958 and 1959. On highway medians in Connecticut Deakin (11) reported mowing was required only twice following the application of maleic hydrazide combined with 2,4-D, whereas mowing was required nineteen times in the untreated areas.

Beasley (21) reported that guardrail maintenance in Massachusetts might require eight man hours per mile repeated five times per season, whereas one hour of spraying at two m.p.h. (2-3 man hours) would accomplish results which were similar to those accomplished with eighty man hours of the conventional maintenance. Button and Wright (24) reported that maintenance by hand cost $50 per mile of guardrail. Button and

Potharst (23) indicated that chemical materials for guardrail maintenance may cost as little as $10 permile. The cost of trichloracetic acid for the recommended highway shoulder treatment in Texas, when repeated twice during the season, was $6.25 per foot mile in 1961 McCully (29) reported.

Species other than bermudagrass invaded the highway shoulders when trichloroacetic acid was used to suppress plant growth, as reported by Bowmer and McCully (22). These species included certain bunchgrasses, Convolvulus arvensis, and weeds like Euphorbia prostrata. Button and Wright (24) reported the invasion of Chenopodium album, Cenchrus pauciflorus, Digitaria spp., and other weeds one year following the application of diuron or simazine. Fortunately, many of the species that encroach on the highway shoulders can be effectively controlled with herbicides. Where soil sterilization is aimed at the control of perennial grasses, systemics might be used the year following application of a sterilant. The systemics would control annual grasses and broadleaf weeds as reported by Schofield (32).

Fertig and Furrer (13) reported that the use of herbicides caused late germinating annual grasses and perennial broadleaf weeds to appear in corn. They went on to report that atrazine, linuron, and prometryne, and amiben in combination with other herbicides were successful for the control of some of these emerging species.

Button and Wright (24) in 1960 used mulches in an attempt to reduce the erosion hazard of soil sterilants while increasing their persistance in the soil. This practice must have proven successful for Button and Potharst (23) referred to this procedure in 1962 as though it were a regular feature of highway maintenance in Connecticut. Ahrens (20) in 1959 already had concluded that bitumen increased the persistance of sterilization treatments in Connecticut.

Anderson and Moffett (6) reported a reduction in weed competition due to the use of herbicides on Maryland highways. Chamberlin (9) reported that the desirable grasses increased in density in conjunction with the reduction of weeds due to the use of phenoxy herbicides.

For the eradication of *Sorghum halepense*, Hicks and Fletchall (39) recommended 3-4 applications of dalapon per year when the plants were between six and twelve inches in height. They reported *Sorghum halepense* had been eradicated in two years time or less. Rea (41) reported high degrees of johnsongrass control in Texas with repeated applications of disodium methanearsonate (DSMA).

CHAPTER III

METHODS AND MATERIALS

All chemicals included in the three studies presented in this report were provided without charge by the manufacturers. The rates of application for all chemicals are given here in terms of active ingredient (a.i.). In the investigation of herbicides for the control of broadleaf weeds and weedy grasses the materials listed in Table I were used at two or more of five locations in 1963 and 1964. These chemicals were applied in 1963 with a spray-boom mounted on a small tractor with an air compressor which was driven by the power-take-off. In 1964 a power driven spray rig, with boom, was mounted on a 1 1/2 ton, four speed transmission, pickup truck and was used for these herbicide applications. A speedometer, calibrated in one-half mile-per-hour increments up to a maximum of ten m.p.h., was used to facilitate accurate spraying. In 1963 the speedometer was driven by the front wheel of the tractor. In 1964 the speedometer was driven when engaged by the right rear wheel on the pickup truck. In both years a dry-type pressure regulator was used for the selective herbicidal treatments; thus, agitation was provided only while spraying.

The chemicals used for soil sterilization along the highway shoulders and under guardrails are listed in Table II. Those materials which were applied in water in 1963 on the shoulders were applied with the spray

TABLE I

HERBICIDES USED FOR THE CONTROL OF BROADLEAF PLANTS AND WEEDY GRASSES AND THEIR SOURCE

HERBICIDE	CONCENTRATION	FORM	TIME APPLIED	SUPPLIER
Betasan	4 lbs/gal	Emulsifiable liq.	Pre	Stauffer
Dacthal	75% WP	Wettable powder	Pre	Diamond Alkali
Dicamba	4 lbs/gal	Soluble liq.	Post	Velsicol
Diuron	80% WP	Wettable powder	Pre	Du Pont
MH-30	3 lbs/gal	Soluble liq.	Post	United States Rubber
MH-30T	3 lbs/gal	Soluble liq.	Post	United States Rubber
Simazine	80% WP	Wettable powder	Pre	Hooker
Tritac	2 lbs/gal	Emulsifiable liq.	Pre	Hooker
Tritac-D	2.2 lbs/gal	" "	Pre	Hooker
2,4-D	4 lbs/gal	Emulsifiable liq.	Post	Dow

TABLE II

CHEMICALS USED FOR SOIL STERILIZATION ALONG HIGHWAY SHOULDERS AND UNDER GUARDRAILS

HERBICIDE	CONCENTRATION	FORM	SUPPLIER
Baron	4 lbs/gal	Emulsifiable liq.	Dow
Borea T-10	58%	Granular	Chipman
Borocil	98%	Granular	U. S. Borax
Bromacil	80%	Wettable powder	Du Pont
Bromacil	50%	Water soluble powder	Du Pont
Chlorea	93.4%	Granular	Chipman
Dalapon	85%	Water soluble powder	Dow
Fenac	1.5 lbs/gal	Water soluble liq	Amchem
Fenatrol	1.9 lbs/gal	Emulsifiable liq.	Amchem
Paraquat	2 lbs/gal	Soluble liq.	California Chemical
Monobor-chlorate	98%	Granular	U. S. Borax
Monobor-chlorate-D	98%	Granular	U. S. Borax
Monuron	80%	Wettable powder	Du Pont
Prometone	2 lbs/gal	Emulsifiable liq.	Geigy
TCA	94 or 95%	Water soluble pellets or powder	Dow & American Paint
Ureabor	98%	Granular	U. S. Borax
Urox	3 lbs/gal	Oil soluble liq.	Allied Chemical

equipment used in the study of broadleaf weed and weedy grass control. For guardrail spraying in 1963, the same equipment was used with the exception of the boom. The boom was adapted for mechanical positioning so that the two drops were always centered over the guardrail. Off-center nozzles completed this adaptation so that two overlapping bands of spray were directed beneath the guardrail. In 1963 a dry-type pressure regulator was used for spraying the soil sterilants; thus, air agitation was provided when spraying. In 1964 a John Bean pump with a capacity of five g.p.m. with a by-pass pressure regulator was used; this provided continuous agitation. The granulars were applied by hand. A one-gallon tin can with holes punched in the bottom was used for the guardrail study in 1963. In the study of chemicals for sterilization of highway shoulders in 1963 a hand-operated rotary seeder was used. In 1964 a simple horn seeder was used for all granular applications.

Herbicides used for the control of johnsongrass are listed in Table III. These materials were applied with a two-gallon, hand operated pressure sprayer. A power-driven, sickle type Jari mower, with a three-foot cutter bar was used to clip the johnsongrass in those plots that were to be treated at a specified time after mowing.

In the analyses of research data from these studies there were two experimental situations for which order or rank statistics were used. These situations prevailed where numerical entries in the data could not be expressed as multiples of a basic unit and 2)where homogeneous variance could not be assumed.

TABLE III

HERBICIDES USED FOR THE CONTROL OF

JOHNSONGRASS ALONG THE HIGHWAYS

HERBICIDE	CONCENTRATION	FORM	SUPPLIER
Calcium acid methanearsonate (CMA)	1 lb/gal	Soluble liq.	Vineland
Monobor-chlorate (CBM)	98%	Granular (soluble)	U. S. Borax
Monobor-chlorate-D	98%	Granular (wettable)	U. S. Borax
Dalapon	85%	Wettable powder	Dow
Disodium methanearsonate (DSMA)	63%	Soluble powder	Ansul

With ranked data, the occurrence of a relatively low or high rank for a particular treatment, consistently, is clear evidence for a treatment effect. Furthermore, a consistent association of a treatment with an extreme in rank within each replication would affect the total sum of squares. Thus, with order statistics, the calculated statistic is compared with the tabulated statistic for the purpose of determining whether the distribution of ranks within the data is characteristic of a random distribution. Significant differences among treatments imply that at least one treatment gave readings which were significantly different than the others. However, statistical comparisons cannot be made among selected herbicidal treatments in this study with the use of order statistics.

The Friedman method for a two-way classification was used in this paper as described by Hays (15) and Siegel (33). With this method the ranking is done within each replication. An example of this method is given in Appendix Table III.

CHAPTER IV

RESULTS AND DISCUSSION

For clarity and convenience in presentation the results of this study will be discussed in three separate parts corresponding to the three distinct areas of investigation.

PART I

HERBICIDE EVALUATION FOR THE CONTROL OF BROADLEAF PLANTS AND WEEDY GRASSES

INTRODUCTION

Mechanical mowing costs comprise about one-sixth of the annual budget of the Maintenance Division of the Oklahoma Highway Department. This expense could be substantially reduced perhaps by a combined program of chemical weed control and soil fertilization. The objective following chemical weed control would be to establish a dense stand of grass such as bermuda, which could effectively compete with subsequent weed growth.

The availability of pre- and post-emergence herbicides that are effective in the control of many plants, offers possibilities for their successful and economical use in the maintenance of Oklahoma's highways. The use of chemicals for weed control in combination with an effective fertilization program would enhance soil stabilization for erosion control and beautification while substantially reducing costs of highway maintenance.

LITERATURE REVIEW

In an experiment in Ohio (1) where the weeds were annual grasses and *Amaranthus retroflexus*, atrazine, simazine, or atrazine combined with simazine gave 97 to 100 percent control one month after treatment in corn, while dicamba at 2 lbs/acre gave 88 percent control. In a similar experiment with soybeans weed control of 86 to 99 percent was achieved with the triazines ipatone, atratone, prometryne, and atrametryne. At the same time weed control of 94 percent or greater was achieved with amiben or amiben combined with CIPC.

Fertig and Furrer (13) reported simazine, atrazine and linuron were quite effective in the control of *Agropyron repens* and annual grasses as well as such perennial broadleaf plants as *Solanum carolinense*, *Physalis spp.*, *Convolvulus arvensis*, *Convolvulus sepium*, *Rumex crispus*, and *Asclepias spp.* In some earlier studies the triazines had often been unsuitable for the control of some grasses which germinated later in the season. Soon it was recognized that the failures occurred in conjunction with lower amounts of precipitation. They noted in another experiment that atrazine controlled only the broadleaf plants successfully when applied alone as a pre-emergence treatment. However, post-emergence treatments with atrazine combined with amiben pre-emergence and atrazine combined with linuron pre-emergence were found to be quite effective, as were pre-emergence treatments of amiben, linuron, and amiben combined with either atrazine or linuron.

For *Setaria* species, which often come in when weed competition is reduced, it was reported in the summary section of the *Proceedings of the North Central Weed Control Conference* of 1961 (3) that pre-emergence treatments with simazine, atrazine, amiben, and CDAA were successful.

Picloram was reported by Mose (19) in Texas to have successfully controlled such perennial weeds as *Convolvulus arvensis*, *Solanum elaeagnifolium*, and *Helianthus ciliaris*. He noted even after two seasons, picloram gave 98 percent control of *Convolvulus arvensis*. One year after the treatment of *Solanum elaeagnifolium* with 3 lbs/acre, picloram gave 95 percent control.

The research report prepared for the North Central Weed Control Conference, 1964 (4) included a report of 100 percent control of *Convolvulus arvensis* with picloram at 2 lbs/acre. The readings were made in the fall of 1964 in two separate experiments which were begun in 1963 and 1964, respectively. In addition, rates of picloram averaging about 2 lbs/acre gave 98 percent control of *Euphorbia esula* and 84 to 100 percent control of *Cirsium arvense*. Similarly picloram was successful at rates up to 2 lbs. per acre in the Northeast (5) for the control of *Convolvulus arvensis* and *Cirsium arvense*. In addition it was reported that dicamba at 2 lbs. per acre was successful for the control of *Aster spp.*, *Solidago spp.*, and *Solanum carolinense* specifically.

From a study of herbicide activity in Texas Lea (16) reported that dicamba at 3 lbs/acre or less on non-crop sites caused distortions in leaves and stems of most broadleaf plants in addition to killing the roots if the plants had been treated at less than three weeks of age.

Rea also reported downwind damage to cotton for twenty feet as a result of drift and/or volatility of the dicamba. The volatility problem was pointed out by Rea when he reported damage to *Ambrosia trifida* fifty feet downwind due only to the vapors of dicamba.

In field trials in Massachusetts, Beasley (7) found that maleic hydrazide was inadequately applied to grasses in many of those cases where failures have been reported with this material. In two large areas in Connecticut in 1959, Button (8) reported that maleic hydrazide reduced the mowing requirement from two times during the season to one in one area and completely eliminated mowing in the other. The clipping weight of fescues and perennial bluegrass was significantly reduced by maleic hydrazide until August 15 when crabgrass became the dominant species. Results from other tests on median and roadside grass in Connecticut showed that the mowing requirement was reduced from one time to none on the roadside, and from two or three times to once on the median.

Hargan and Sweet (14) reported results from five experiments in which pre-emergence or early post-emergence treatments were tested for weed control in carrots in New York. In each of two experiments the common weeds included *Digitaria spp.*, *Chenopodium album*, *Ambrosia spp.*, and *Amaranthus retroflexus*. Prometryne or linuron at 3.6 lbs/acre were rated at 8.2 to 9.0 on a zero to ten scale for control. Linuron appeared slightly the better of the two herbicides for the particular purpose. Linuron was equally effective when applied post-emergence at 1 lb/acre as when applied pre-emergence at other rates. In an experiment where *Digitaria spp.*, *Chenopodium album*, *Portulaca oleracea*, and *Ambrosia spp.* were common, linuron at 1 lb/acre and prometryne at 2 lbs/acre rated 9.0 and 8.4, respectively. Either linuron or prometryne rated 8.0 or better at 1 lb. per acre and 8.5 or better at 2 lbs/acre when applied pre-emergence to _Digitaria spp._, _Eragrostis spp._, _Portulaca oleracea_, and _Amaranthus retroflexus_. The same treatments were rated 9 when applied to quite young plants. In another experiment where there was a heavy stand of crabgrass and _Amaranthus retroflexus_ the herbicides prometryne at 1 lb/acre, amiben at 4 lbs. per acre, or linuron at 3 lbs/acre rated 8.0 or higher in the control of these plants.

A recommended practice for weed control in Midland bermudagrass in New York (12) involves the pre-emergence application of simazine at 1.5 or 3 lbs/acre or trifluralin at 4 or 6 lbs/acre.

METHODS AND MATERIALS

In the years 1963 and 1964 two experiments were initiated on Interstate 40 and three on Interstate 35 for the control of broadleaf weeds and annual grasses. On Interstate 40 one experiment was near Hydro in west central Oklahoma, and the other was near Shawnee in the central part of the state. Two of the experiments on Interstate 35 were located in central Oklahoma, with one located at the Seward Road interchange, and the other near Mulhall Road. The other experiment on Interstate 35 was located in north central Oklahoma, 5.7 miles north of U.S. 64 near Perry. Bermudagrass (*Cynodon dactylon*) was the dominant perennial grass in the two experiments on Interstate 40 and at Seward Road. Near Mulhall Road the grass composition was varied, ranging from nearly pure stands of native grasses or bermuda to a mixture of species.

Eight weeds were common to the three experiments in which bermudagrass was the dominant species. These included *Setaria spp.*, *Chenopodium album*, *Haplopappus ciliatus*, *Conyza canadensis*, *Chrysopsis pilosa*, *Bromus spp.*, and *Ambrosia psilostachya*. These weeds were also in the experiment near Shawnee as well as the one at Seward Road in addition to *Diodia teres*, *Plantago purshii*, *Aristida oligantha*, *Lamium amplexicaule*, and *Digitaria sanguinalis* which were common in the area. There were seventeen perennial or biennial species in the experiment near Mulhall Road as shown in Table IV. In contrast, in the experiment north of Perry essentially only one species occurred in early summer, whereas three others appeared as the season progressed. In early summer *Haplopappus ciliatus*

TABLE IV

WEEDS MOST COMMONLY FOUND ON INTERSTATE 35 NEAR [illegible] ROAD IN JULY 1963

ANNUAL BROADLEAF & GRASSY WEEDS	PERENNIAL AND BIENNIAL BROADLEAF WEEDS		PERENNIAL GRASSES
Plantago purshii	Solanum carolinense	Prunus spp.	Cynodon dactylon
wooly plantain	Carolina horsenettle	wild plum	bermudagrass
Cassia fasciculata	Apocynum cannabinum	Rudbeckia hirta	Andropogon scoparius
showy partridgepea	hemp dogbane	blackeyedsusan	little bluestem
Conyza canadensis	Cirsium undulatum	Asclepiodora spp.	Andropogon saccharoides
horseweed	wavy-leaved thistle	antelopehorn	silver bluestem
Aristida oligantha	Erigeron strigosus	Aster ericoides	Sporobolus cryptandrus
annual tripleawn	daisy fleabane	heath aster	sand dropseed
Bromus japonicus	Strophostyles leiosperma	Euphorbia corollata	Sorghum halepense
Japanese brome	smoothseed wildbean	snow-on-the-mountain	johnsongrass
Eragrostis spp.	Achillea millefolium	Solidago missouriensis	Sorghastrum nutans
lovegrass	western yarrow	Missouri goldenrod	indian grass
	Ambrosia psilostachya	Desmanthus illinoensis	Panicum virgatum
	western ragweed	Illinois bundleflower	switchgrass
	Oxalis stricta	Medicago spp.	
	yellow woodsorrel	burclover	

occurred throughout the experiment. During mid-summer *Aristida oligantha* came in. Then in the fall two winter annual grasses, *Bromus spp.* and *Hordeum pusillum* emerged.

In the experiment located on I-35 near Seward Road the pre-emergence herbicides were applied on March 28 in 1963 with the exception of Betasan which was applied on April 9. The post-emergence treatments were applied two months later on May 28 and 29 and were reapplied on July 29. Near Mulhall Road the pre-emergence treatments were applied on March 30, 1963 with the exception of Betasan which was applied ten days later on April 9. The post-emergence treatments were applied on May 28 and reapplied on August 1.

In 1964 the pre-emergence herbicides were applied near Shawnee on March 31, with the post-emergence treatments made on June 28. In the experiment near Hydro, the pre-emergence applications were made on April 3, and the post-emergence materials were applied on June 17. Near Perry the pre-emergence herbicides were applied on April 8. In this experiment no post-emergence herbicide treatments were included.

The post-emergence herbicides were applied in both years (1963 and 1964) when the air temperature was between 84 and 95 degrees Fahrenheit. Flood or T-jet nozzles were used throughout the study. The flood nozzles were used only when the wind speed was greater than 15 m.p.h.

In June 1963 the plant composition was determined in the Seward Road experiment using a foot-square quadrat. The quadrat was dropped every three paces down the middle of each plot for a total of seven times. The plant species were identified, counted, and recorded within the quadrat each time it was dropped. In September the percentage composition of each individual weed species was determined. This was done through the use of a step-point quadrat which is a heavy wire pointer that was placed 100 times in each plot as it was crossed in a zig-zag manner. The nearest weed to the pointer was identified and recorded for each position in which the pointer was placed. Bermudagrass was excluded from this count. The estimated percent composition for a particular species within a given plot was the exact number of times that the species was recorded within the plot.

The ground cover of bermudagrass in the experiment near Seward Road was estimated on a zero to ten scale during both years. This was done by taking seven readings per plot with a square foot quadrat in June 1963, and increasing the readings to ten quadrats per plot in September.

All other estimates of weed control or bermudagrass cover were whole plot estimates on a zero to ten scale. In all weed control estimates ten represents complete control and zero represents no apparent effect. In the evaluation of bermudagrass cover ten represents a solid stand of bermudagrass while zero indicates its complete absence.

The weed control plots were 10 feet wide and 100 feet long in 1963 but were shortened to 50 feet in length in 1964 but still 10 feet wide. Each herbicide was generally applied at two rates. The concentration, form, time and rates of application for each herbicide are shown in Table V.

TABLE V

PRE- AND POST-EMERGENCE HERBICIDES AND RATES USED FOR THE CONTROL OF BROADLEAF PLANTS AND WEEDY GRASSES

HERBICIDE	CONCENTRATION	FORM	TIME APPLIED	POUNDS A.I. PER ACRE			
				1963	1964		
				TWO LOCATIONS	SHAWNEE	HYDRO	PERRY
Betasan	4 lbs/gal	Emulsifiable liquid	Pre	9.0	—	—	—
Dacthal	75%	Wettable powder	Pre	9.0	6.3	6.3	6.3
				13.5	9.5	9.5	9.5
Dicamba	4 lbs/gal	Soluble liquid	Post	—	0.6	—	—
				—	1.1	1.4	—
Diuron	80%	Wettable powder	Pre	1.0	0.7	0.7	0.7
				2.0	1.4	1.4	1.4
MH-30	3 lbs/gal	Soluble liquid	Post	4.0	—	—	—
				6.0	—	—	—
MH-30T	3 lbs/gal	Soluble liquid	Post	—	2.3	2.8	—
				—	3.4	—	—
Simazine	80%	Wettable powder	Pre	1.0	0.7	0.7	0.7
				2.0	1.4	1.4	1.4
Tritac	2 lbs/gal	Emulsifiable liquid	Pre	2.0	1.1	1.4	1.4
				3.5	—	2.4	2.4
Tritac-D	2.2 lbs/gal	Emulsifiable liquid	Pre	—	1.3	1.5	1.5
				—	2.2	2.7	2.7
2,4-D	4 lbs/gal	Emulsifiable liquid	Post	1.0	0.6	0.7	—
				2.0	1.1	1.4	—
2,4-D & dacthal[1]			Pre	1 & 9	—	—	—
				1 & 13.5	—	—	—
2,4-D & MH-30[2]			Post	1 & 4	—	—	—
				1 & 6	—	—	—

1. Dacthal was applied as the 75% WP, and 2,4-D as the emulsifiable liquid as shown above.
2. MH-30 was applied as the soluble liquid, and 2,4-D as the emulsifiable liquid as shown above.

RESULTS AND DISCUSSION

The average weed density per square foot in the median experiment at Seward Road as recorded in June 1963 is shown in Table VI. The greatest reduction in weed population was obtained from simazine applied pre-emergence at the rate of 2 lbs/acre. Diuron and tritac, and 2,4-D alone or in combination with the 4 lb. rate of maleic hydrazide were also effective in reducing the weed population in this experiment. Although the low rate of tritac does not appear effective according to Table VI, the appearance in the field seemed to indicate it was rather good. The contradiction here perhaps is due to the fact that there were two rather inconspicuous species that survived in high numbers in plots treated with tritac at the low rate which were duly recorded as shown in Table VI but from a distance were not evident. These species were *Aristida oligantha* and *Plantago purshii*. The herbicidal effects in this experiment were evaluated again in September of 1963 as recorded in Table VII. The most common species at this time were *Paspalum straminium*, *Aristida oligantha*, *Digitaria sanguinalis*, *Diodia teres*, *Chrysopsis pilosa*, and *Heterotheca subaxillaris*. The best broadleaf weed control in this first year of testing was attained with 2,4-D and with 2,4-D combined with the low rate of maleic hydrazide. Simazine and diuron also were noticeable in effectiveness for the control of these broadleaf plants. Tritac was noticeably effective for the control of *Diodia teres* and *Chrysopsis pilosa*.

TABLE VI

AVERAGE NUMBER OF WEEDS PER SQUARE FOOT OF MEDIAN IN JUNE 1963 FOR EACH HERBICIDAL TREATMENT ON INTERSTATE 35 NORTH OF SEWARD ROAD.

HERBICIDE[1]	RATE/ACRE LBS. A.I.	TIME APPLIED	AVERAGE NUMBER WEEDS/SQUARE FOOT
Simazine	2	Pre	3.82
Simazine	1	Pre	10.96
Diuron	1	Pre	27.82
Tritac	3.5	Pre	30.25
2,4-D and MH-30	1 & 4	Post	35.29
Diuron	2	Pre	36.03
2,4-D	2	Post	37.25
2,4-D and MH-30	1 & 6	Post	43.60
Tritac	2	Pre	54.82
2,4-D and Dacthal	1 & 13.5	Pre	55.42
Betasan	9	Pre	55.75
Dacthal	13.5	Pre	57.92
Check	—	—	59.75
2,4-D and Dacthal	1 & 9	Pre	69.65
2,4-D	1	Post	73.38
MH-30	4	Post	73.85
Dacthal	9	Pre	83.32
MH-30	6	Post	117.96

1. All post-emergence treatments were applied twice during the season at the rates shown, once on May 28 and again on July 29, whereas the pre-emergence treatments were applied only once.

TABLE VII

ANNUAL OR PERENNIAL WEED POPULATION FOR SIX COMMON SPECIES ON I-35 NORTH OF SEWARD ROAD IN SEPTEMBER 1963.

HERBICIDE[1]	RATE/ACRE LBS. A.I.	AVERAGE POPULATION IN PERCENT						
		Diodia teres (annual)	Aristida oligantha (annual)	Paspalum stramineum (perennial)	Chrysopsis pilosa (annual)	Heterotheca subaxillaris (annual or biennial)	Digitaria sanguinalis (annual)	other species
2,4-D	1	1.75	40.25	35.75	0.00	2.25	3.50	13.50
2,4-D	2	0.25	36.00	25.50	0.00	0.00	3.50	34.75
Dacthal	9	13.50	19.75	19.50	10.00	9.75	1.27	26.23
Dacthal	13.5	23.00	11.75	18.00	11.75	16.50	0.00	19.00
Diuron	1	1.50	36.75	29.00	1.25	5.0	1.50	25.00
Diuron	2	0.00	35.75	35.25	5.75	2.75	2.25	27.25
Simazine	1	2.25	26.25	35.75	00.25	1.75	2.50	30.25
Simazine	2	1.00	15.00	40.00	00.75	1.75	5.75	35.75
Tritac	2	2.67	33.30	26.00	0.67	12.67	2.33	22.36
Tritac	3.5	1.00	25.50	24.75	1.50	14.75	15.00	17.50
Betasan	9	16.00	12.33	14.33	20.00	16.33	1.33	19.68
2,4-D & MH-30	1 & 6	2.00	30.50	37.00	3.25	2.50	3.50	21.25
2,4-D & MH-30	1 & 4	0.25	30.25	41.75	3.25	0.00	4.75	22.75
MH-30	4	17.75	24.50	19.50	4.25	10.75	2.25	21.00
MH-30	6	15.50	24.50	8.75	11.50	4.75	5.00	13.00
Dacthal & 2,4-D	9 & 1	14.00	7.50	25.25	15.75	15.25	3.00	21.25
Dacthal & 2,4-D	13.5 & 1	10.75	24.75	26.75	9.00	15.00	1.00	11.75
Check	—	8.50	15.75	29.00	14.75	8.25	4.25	19.50

1. All post-emergence treatments (2,4-D and MH-30 alone and in combinations) were applied twice during the season at the rates shown, once on May 28 and again on July 29, whereas the pre-emergence treatments were applied only once.

Dacthal alone or in combination with 2,4-D, Betasan, and diuron were about equal in the control of _Digitaria sanguinalis_ and _Aristida oligantha_ with the exception of diuron which was generally very ineffective in the control of _Aristida oligantha_.

A visual estimate of the herbicide effectiveness was made also in September at this location, as shown in Table VIII. A highly significant difference in treatment effects was noted at this time. The most effective herbicides were found to be tritac, simazine, the high rate of diuron, and 2,4-D alone or in combination with maleic hydrazide. The herbicide effect on bermudagrass either directly or indirectly through control of the competitive vegetation is indicated in Table VIII. No statistical difference in treatment effects could be found even at the 10 percent level of confidence.

On August 7, 1964 estimates were again made on I-35 at Seward Road of the control of broadleaf weeds and bermudagrass cover as shown in Table IX. These results reflect the chemical effect after one year, since no herbicides had been applied since 1963. The treatment differences were not significant at the ten percent confidence level. However, 2,4-D where applied twice in 1963 at 2 lbs. a.i./acre which had been effective for weed control eleven months before, appeared to be responsible for the best control of weeds in 1964 and the highest cover of bermudagrass as well.

At the experiment near Mulhall Road it was impossible to obtain more than one reading because the plots were mowed immediately before the intended reading in the fall. The population of perennial and biennial broadleaf weeds was found to be significantly different among treatments at the one percent level of confidence as shown in Table X. Tritac, 2,4-D combined with 4 lbs. of maleic hydrazide peracre, and the high rates of

TABLE VIII

WEED CONTROL AND BERMUDAGRASS COVER ON A ZERO TO TEN SCALE WHERE 10 EQUALS COMPLETE CONTROL OR COVER IN THE EXPERIMENT ON I-35 NORTH OF SEWARD ROAD IN SEPTEMBER 1963.

HERBICIDE[1]	RATE/ACRE LBS. a.I.	WEED CONTROL**	BERMUDAGRASS COVER
2,4-D	1	7.6	4.6
Tritac	3.5	7.6	5.3
2,4-D	2	7.3	5.45
Simazine	1	7.3	4.8
Simazine	2	7.2	4.6
2,4-D & MH-30	1 & 4	6.9	4.3
Tritac	2	6.8	5.2
Diuron	2	6.8	4.2
2,4-D & MH-30	1 & 6	6.3	4.4
Diuron	1	5.6	3.7
Check	—	4.8	4.0
Dacthal	10	3.9	4.0
Dacthal & 2,4-D	10 & 1	3.8	4.0
Dacthal & 2,4-D	15 & 1	3.6	4.2
Betasan	10	3.6	3.4
MH-30	4	3.4	4.5
Dacthal	15	2.9	3.6
MH-30	6	2.6	2.7

Bermudagrass	Weed Control
Chi-square (.10) tabulated 26.0	Chi-square (.01) tabulated 33.4
Chi-square calculated 19.3 n.s.	Chi-square calculated 45.1**

1. All post-emergence treatments (2,4-D and MH-30 alone and in combinations) were applied twice during the season at the rates shown, once on May 28 and again on July 29, whereas the pre-emergence treatments were applied only once.

** The treatment differences are significant at the one percent level of probability.

TABLE IX

WEED CONTROL AND BERMUDAGRASS COVER ON A ZERO TO TEN SCALE WHERE 10 EQUALS COMPLETE CONTROL OR COVER IN THE EXPERIMENT ON I-35 NORTH OF SEWARD ROAD ON AUGUST 7, 1964.

HERBICIDE[1]	RATE/ACRE LBS. a.I.	WEED CONTROL**	BERMUDAGRASS COVER
2,4-D	2	6.5	7.4
2,4-D & MH-30	1 & 6	5.2	5.5
Diuron	1	5.1	4.0
2,4-D	1	4.9	5.0
2,4-D & MH-30	1 & 4	4.8	5.5
Tritac	4	4.5	5.5
Check	—	4.2	5.8
Simazine	1	3.9	4.5
Simazine	2	3.9	5.8
Tritac	2	3.8	3.7
Diuron	2	3.1	3.5
Betasan	9	3.0	4.7
Dacthal	9	3.0	5.5
Dacthal & 2,4-D	13.5 & 1	2.6	3.9
MH-30	6	2.1	2.6
Dacthal & 2,4-D	9 & 1	1.9	5.9
Dacthal	13.5	1.2	4.6
MH-30	4	1.1	3.8

Bermudagrass		Broadleaf weeds	
Chi-square tabulated (.10)	24.8	Chi-square tabulated (.01)	33.4
Chi-square calculated	22.2 n.s.	Chi-square calculated	51.3**

1. All post-emergence treatments (2,4-D and MH-30 alone and in combinations were applied twice during 1963 at the rates shown, whereas the pre-emergence treatments were applied only once.

** The treatments were significantly different at the one percent level of probability.

TABLE X

PLANT POPULATION ON A ZERO TO TEN SCALE WHERE 10 EQUALS COMPLETE STAND IN THE EXPERIMENT ON I-35 NEAR MULHALL ROAD IN JULY 1963

HERBICIDE[1]	RATE/ACRE LBS. A.I.	TIME APPLIED	RELATIVE PLANT POPULATION BROADLEAF WEEDS ANNUAL	PERENNIAL**	GRASSY PLANTS ANNUAL	PERENNIAL
Tritac	4	Pre	0	0	1.3	7.0
Tritac	2	Pre	0	1.3	2.3	7.7
2,4-D & MH-30	1 & 4	Post	0	1.5	2.5	5.8
Diuron	2	Pre	0	2.0	2.3	5.0
Dacthal	13.5	Pre	0	2.0	2.7	7.3
Simazine	1	Pre	0	2.3	2.7	5.7
Simazine	2	Pre	0	2.5	2.0	7.5
2,4-D	2	Post	0.8	2.5	4.5	6.0
2,4-D & MH-30	1 & 6	Post	2.0	2.5	5.2	4.2
2,4-D	1	Post	0.2	3.0	5.5	5.5
Dacthal & 2,4-D	13.5& 1	Pre	0	3.2	3.5	6.0
MH-30	4	Post	1.0	3.2	3.5	7.2
Check	—	—	1.5	3.5	4.8	5.8
Dacthal & 2,4-D	9 & 1	Pre	1.8	3.5	5.0	5.0
Dacthal	9	Pre	1.7	3.7	2.7	7.3
Betasan	13	Pre	3.0	5.2	4.5	5.8
MH-30	6	Post	0.5	5.5	2.2	7.8
Betasan	8.5	Pre	3.2	6.8	3.2	4.2

Annual broadleaf
Chi-square tabulated (.10) 26.0
Chi-square calculated 24.1 n.s.

Perennial broadleaf
Chi-square tabulated (.01) 33.4
Chi-square calculated 37.6**

Annual grass
Chi-square tabulated (.10) 26.0
Chi-square calculated 23.4 n.s.

Perennial grass
Chi-square tabulated (.10) 26.0
Chi-square calculated 19.9 n.s.

1. All post-emergence treatments (2,4-D and MH-30 alone and in combinations) were applied twice during 1963 at the rates shown, once on May 28 and again on August 1, whereas the pre-emergence treatments were applied only once.

** The treatment differences are significant at the one percent level of probability.

diuron and dacthal appeared to be the most effective treatments.

The weeds found to be most common in late April of 1964 in the experiment on I-40 near Shawnee were Lamium amplexicaule, Plantago purshii, and Vicia spp. in three of four check plots and in most of the treated plots. However it was noted that where tritac-D was used, neither of these broadleaf species was present.

On July 8 the herbicides were evaluated on the basis of their effectiveness for weed control and the extent of bermudagrass cover in the treated plots. The weed species which were present in most of the plots at this time were Ambrosia psilostachya, Haplopappus ciliatus, Lespedeza japonica, Diodia teres, Conyza canadensis, Solanum rostratum, Bromus spp., Digitaria sanguinalis, and Aristida oligantha. The post-emergence herbicides had been applied only ten days before this reading, thus the estimates shown in Table XI cannot be considered more than estimates of the speed of activity of these materials. However, their ability to control weeds in the test at Shawnee is shown in Table XII. When these materials were evaluated on July 8 tritac, tritac-D, simazine, and the high rate of diuron appeared to be the most effective herbicides as shown in Table XI for the control of broadleaf plants and weedy grasses. A significant difference among treatments existed at the one percent level of probability as shown in Table XI. Although the post-emergence effects were not fully developed on July 8, the broadleaf weeds were damaged where dicamba or 2,4-D had been applied. As indicated in Table XI, there were significant differences in bermudagrass stand at the ten percent confidence level. There appeared to be a marked release of bermuda due to weed control with tritac-D and simazine.

TABLE XI

WEED CONTROL AND BERMUDAGRASS COVER ON A ZERO TO TEN SCALE WHERE 10 EQUALS COMPLETE CONTROL OR COVER IN THE EXPERIMENT ON I-40 NEAR SHAWNEE ON JULY 8, 1964.

HERBICIDE	RATE/ACRE LBS. A.I.	TIME APPLIED	WEED CONTROL**	BERMUDAGRASS COVER
Tritac-D	2.2	Pre	8.8	4.8
Tritac-D	1.3	Pre	8.0	5.1
Tritac	1.1	Pre	7.6	3.8
Simazine	0.7	Pre	7.4	5.1
Diuron	1.4	Pre	7.1	4.5
Simazine	1.4	Pre	6.6	5.3
Diuron	0.7	Pre	5.8	4.0
Dicamba	0.6	Post	5.1	4.1
2,4-D	1.1	Post	5.0	3.4
Dicamba	1.1	Post	4.9	3.8
2,4-D	0.6	Post	4.4	4.5
MH-30T	2.3	Post	4.0	4.6
Betasan	6.3	Pre	3.9	3.6
Check	—	—	3.8	5.0
Dacthal	9.5	Pre	3.8	3.0
MH-30T	3.4	Post	3.5	4.0
Betasan	10.0	Pre	3.4	2.6
Dacthal	6.3	Pre	3.4	2.6

Bermudagrass
Chi-square tabulated (.10) 24.8
Chi-square calculated 25.4

Weed Control
Chi-square tabulated (.01) 33.4
Chi-square calculated 50.0**

** The treatment differences are significant at the one percent level of probability.

The final evaluations of herbicides for the control of broadleaf weeds and for bermudagrass cover on I-40 near Shawnee were made on October 13 and are presented in Table XII. It is interesting to note that 2,4-D ranked no better than ninth place on either July 8 or October 13, whereas dicamba, also applied post-emergence, gave weed control rated at 9.4 while the check was given a 5.8 score. There were highly significant differences among treatments in the control of broadleaf weeds at this location on October 13, 1964 as indicated in Table XII. Dicamba and the higher rate of tritac-D appeared to be the most effective materials tested. No statistical differences among treatments could be detected in bermudagrass cover when tested at the 10 percent confidence level. Perhaps dicamba was applied too late to permit maximum growth of bermuda during the early part of the summer. The mid-summer season was extremely dry after which the rains allowed only a brief opportunity, perhaps, for bermuda to recover from the drouth. On the other hand, tritac-D applied at the high rate pre-emergence, provided weed control for the entire season, and it appeared to release the bermudagrass. It should be mentioned, too, that herbicidal effectiveness of one single herbicide is not necessarily sufficient to affect the statistical results to any great extent when order statistics are used. The rather dense cover of bermuda in the check plots perhaps was the result of a light stand of weeds on these plots initially.

At the experiment near Hydro about the only rainfall within one month following the pre-emergence treatments was 2.2 inches according to the record for Weatherford; that rainfall came on April 17. By the time of the reading of July 6, the plants were in a rather drouthy condition.

TABLE XII

BROADLEAF WEED CONTROL AND BERMUDAGRASS COVER ON A ZERO TO TEN SCALE WHERE 10 EQUALS COMPLETE CONTROL OR COVER IN THE EXPERIMENT ON I-40 NEAR SHAWNEE ON OCTOBER 13, 1964.

HERBICIDE	RATE/ACRE LBS. A.I.	TIME APPLIED	BROADLEAF WEED CONTROL**	BERMUDAGRASS COVER
Dicamba	0.6	Post	9.4	5.6
Tritac-D	2.2	Pre	9.2	7.4
Dicamba	1.1	Post	9.2	5.2
Simazine	0.7	Pre	8.8	7.5
Simazine	1.4	Pre	8.8	7.0
Diuron	1.4	Pre	8.4	6.1
Tritac	1.1	Pre	8.0	4.6
Tritac-D	1.3	Pre	7.4	4.5
2,4-D	1.1	Post	6.0	5.4
2,4-D	0.6	Post	6.0	5.1
Diuron	0.7	Pre	5.2	5.1
Check	—	—	5.2	6.8
MH-30T	2.3	Post	3.8	6.0
Betasan	6.3	Pre	2.8	4.5
Betasan	10.0	Pre	2.5	3.5
Dacthal	9.5	Pre	2.0	5.2
MH-30T	3.4	Post	1.8	5.2
Dacthal	6.3	Pre	1.0	4.2

Bermudagrass
Chi-square tabulated (.10) 24.8
Chi-square calculated 15.5 n.s.

Weed Control
Chi-square tabulated (.01) 33.4
Chi-square calculated 49.7**

** The treatment differences are significant at the one percent level of probability.

At that time the weeds found to occur most frequently in the plots, and in various combinations of few to several were Melilotus alba, M. officinalis, Chenopodium album, Haplopappus ciliatus, Chrysopsis pilosa, Oenothera laciniata, Ambrosia psilostachya, and Setaria spp. Tritac and tritac-D appeared to be the most effective herbicides for the control of these broadleaf plants shown in Table XIII. Simazine exhibited some weed control but was noticeably less effective than either tritac-D of tritac. There were highly significant differences in treatment effects as indicated in Table XIII. The bermudagrass cover did not vary significantly among treatments when tested at the 10 percent confidence level. This seemingly poor response of bermuda especially in those treatments that gave good weed control was probably a reflection of the drouth effects on the grass.

TABLE XIII

BROADLEAF WEED CONTROL AND BERMUDAGRASS COVER ON A ZERO TO TEN SCALE WHERE 10 EQUALS COMPLETE CONTROL OR COVER IN THE EXPERIMENT ON I-40 NEAR HYDRO ON JULY 6, 1964.

HERBICIDE	RATE/ACRE LBS. A.I.	TIME APPLIED	BROADLEAF WEED CONTROL**	BERMUDAGRASS COVER
Tritac-D	2.6	Pre	9.4	6.9
Tritac-D	1.5	Pre	9.3	5.8
Tritac	2.4	Pre	9.0	6.4
Tritac	1.4	Pre	8.8	7.1
Simazine	0.7	Pre	6.8	4.8
Simazine	1.4	Pre	6.4	5.2
Dicamba	1.4	Post	3.8	4.4
Betasan	9.5	Pre	3.7	5.0
2,4-D 1	1.4	Post	3.4	4.8
Diuron	0.7	Pre	3.0	6.4
Check	—	—	2.5	5.1
2,4-D	0.7	Post	2.4	6.4
Diuron	1.4	Pre	2.4	5.1
Dacthal	6.3	Pre	1.8	4.7
Dacthal	9.5	Pre	1.5	4.9
MH30-T	0.9	Post	1.5	5.2
Betasan	6.3	Pre	1.0	3.8

Bermudagrass	Weed Control
Chi-square tabulated (.10) 23.5	Chi-square tabulated (.01) 32.0
Chi-square calculated 19.2 n.s.	Chi-square calculated 48.2**

** The treatment differences are significant at the one percent level of probability.

SUMMARY

In 1963 research was conducted along Oklahoma highways to determine the effectiveness of several pre- and post-emergence herbicides for the control of broadleaf plants and weedy grasses which occurred in the highway areas. In addition to the evaluation of these materials for the control of undesirable plants their effect on the desirable grass species was determined where possible.

Four experiments were located in north central Oklahoma and one in the west central portion of the state near Hydro. In 1963 two experiments were begun in the north central section on I-35. In the one located near the Seward Road interchange simazine was the most effective herbicide tested for the control of broadleaf weeds and weedy grasses in early summer. Diuron, tritac, and 2,4-D either applied alone or in combination with four pounds of maleic hydrazide per acre were about equal in effectiveness for weed control, but they were noticeably less effective than simazine. By September the most effective treatment for broadleaf weed control was 2,4-D. At that time, the stand of bermudagrass was greatest where 2,4-D and tritac were used; however, not significantly so when measured at the ten percent confidence level. In August 1964 this experiment was evaluated again. There had been no herbicidal applications since 1963. Although the treatment differences were found to non-significant for both weed control and bermuda stand, the better control of weeds was associated with the two-pound rate of 2,4-D which had also been quite effective in September of 1963.

At the experiment on I-35 near Mulhall Road the treatment differences were declared significant for the control of biennial and perennial broadleaf weeds. It appeared that tritac, 2,4-D in combination with the four-pound rate of maleic hydrazide, and the high rates of diuron and dacthal were effective for the control of these broadleaf weeds. There was no apparent effect of the herbicidal treatments on the perennial grasses.

In 1964 tritac-D and dicamba were included in the tests. In the experiment at Shawnee, it appeared that tritac-D and simazine were the most effective herbicides for weed control and at the same time these plots showed the greatest amount of bermudagrass early in the season. Tritac applied at 1.1 pounds per acre appeared to give weed control without releasing the bermudagrass. Dicamba gave good weed control by October 15, but the bermuda did not increase in area appreciably perhaps due to drouthy conditions that prevailed. At Shawnee, 2,4-D was only applied one time and was ineffective. Perhaps a retreatment, or the use of a higher rate would have given results more like those attained in 1963 at Seward Road.

The drouth of 1964 seemingly restricted the growth of bermudagrass substantially even when the weeds were effectively controlled in west central Oklahoma. Early in the season tritac-D, tritac, and simazine, in that order, were found to be effective in the control of broadleaf weeds.

In conclusion, it is apparent that tritac-D, tritac, and simazine each reduced the stand of weeds in at least four of five experiments. Based upon the evaluation of dicamba in one experiment it appears that dicamba may be quite effective for the control of broadleaf plants. It is felt that the desired grasses in the test at Shawnee in October of 1964 and at Seward Road in both years responded to the effective weed control even though significant statistical differences could not be shown due to limitations inherent in the methods of analyses. Associations of weed control with higher stands of bermudagrass were indicated at both experiments. The drouth in west central Oklahoma and the inherent variability in the experiment near Mulhall Road are reasons why weed density or perennial grass stand responses may not have been shown in the data for those experiments.

PART II

EVALUATION OF CHEMICALS FOR SOIL STERILIZATION ON HIGHWAY SHOULDERS AND AROUND GUARDRAILS

INTRODUCTION

Soil sterilization is currently employed in several state highway maintenance programs for more economical maintenance of guardrails and shoulders. Soil sterilization is used for the protection of highways which could be severly damaged if plant growth in the asphaltic shoulders were not controlled. Through the action of various natural and physical forces, minute indentations or hairline fissures form in the highway shoulder which enlarge with time as plants invade and grow until the continuous phase of asphalt is cracked rather extensively. When this occurs the highway base soon gives way as water moves in, and the road is ultimately destroyed. The potential benefits of these chemicals are offset in some cases by the lateral movement down the slope from the place of application, killing all vegetation, thereby leaving the soil exposed to erosion and perhaps ultimate loss of the highway at that point.

The plant species which are commonly found and oftentimes quite difficult to control on Oklahoma highways are bermudagrass (*Cynodon dactylon*) and johnsongrass (*Sorghum halepense*). These become troublesome when the rhizomes or shoots break through an asphalt surface such as would be found commonly on highway shoulders in Oklahoma.

Maintenance around quardrails and other similar structures involves primarily all hand labor, which becomes more expensive each year. The orderly removal or prevention of plant growth immediately adjacent to these areas through the use of chemicals, extensive enough that mechanical equipment such as mowers could be operated safely and effectively, might reduce the time and labor involved in maintenance.

LITERATURE REVIEW

Some of the problems in the maintenance of highway shoulders were defined by McCully (31) when he pointed to the fact that gravel base materials often contain roots and weed seeds so that plants like bermudagrass may grow under the shoulder and then enter by root penetration. Weed seeds lodge in cracks and initiate destructive growth. The latter situation is especially difficult to deal with. However, pre-surface treatments with herbicides make it readily possible to prevent the emergence of plants for several years following construction.

Curtis et. al. (25) reported that dalapon at the rates of 9 or 18 pounds per acre combined with periodic treatments with 2,4-D throughout the season gave satisfactory control of *Festuca rubra*, *Dactylis glomerata*, *Poa pratensis*, and *Agropyron repens* under guardrails. All of these grass species recovered by the end of the growing season following treatment with the nine-pound rate in one experiment, but in another test they were effectively controlled. For a highway shoulder, it should be mentioned that the emergence alone of any plant damages the physical structure of the shoulder, whereas a satisfactory treatment for a guardrail could be one which allowed some vegetation to grow near the end of the growing season.

Extensive tests were conducted by Johnson et. al. (27) in three states in which various herbicides were evaluated for guardrail maintenance. The tests in the two states of New York and Connecticut involved Agropyron repens, Dactylis glomerata, Poa pratensis, and various biennial and perennial broadleaf plants; in an Ohio experiment there was a dense stand of Festuca rubra, F. arundinacea, and Poa pratensis as well as light stands of Daucus carota, Chicorium intybus, and Trifolium repens. The herbicide treatments were made in New York in early May whereas the treatments were applied in late July in Ohio and Connecticut. Dalapon combined with 2,4-D and monuron comprised a single treatment which gave an average of approximately 78 percent control. When simazine was used instead of monuron, the combination averaged approximately 74 percent control. In a comparison of simazine and monuron applied singly, simazine was tested at 4, 10, and 20 lbs./acre and monuron at 8, 16, and 32 lbs./acre. Monuron at 16 and 32 lbs./acre gave greater than 70 percent control of either broadleaf weeds or grass throughout the season, whereas 20 lbs./acre was the only rate of simazine that gave greater than 70 percent control by July 23, but simazine became more effective in controlling the grasses as the season progressed, and all rates of simazine were excellent for the control of broadleaf weeds following the month of June. In the same study a combination treatment of 20 pounds of Baron and 21 pounds of dalapon per acre gave approximately 84 percent control of broadleaf weeds and grasses on June 23, but the control was substandard later in the season.

Le Baron (28) reported two experiments in Virginia where the common species to be controlled were Sorghum halepense, Cynodon dactylon, Cyperus spp., Lonicera spp., trumpet vine, Virginia creeper, Rhus radicans, Echium vulgare, fennel, and several species of the Solanum, Rumex, and Euphorbia genera. In the pre-emergence test which was begun on March 20 the successful herbicides at the end of the season in order of decreasing effectiveness were hyvar or hyvar-X, chlorea, monuron, atrazine, urox, Dybar, and diuron. Baron had been effective for three months earlier in the season. Simazine was not satisfactory in this test just as had been reported for simazine in previous years at that station. Urox 100 was unsatisfactory also. In the second test, applications were made on June 6 after the plants were growing. Immediate and continued control was attained with the herbicides bromacil, bromacil plus atrazine, prometone plus TCA, urox, Baron, and picloram plus TCA. Atrazine, prometone plus TCA, and Urox J were not satisfactory for the entire season. Trumpet vine, Sorghum halepense, and bermudagrass in this descending order were the most difficult to control.

Bowmer and McCully (22) reported that TCA at 200 pounds, applied to asphaltic highway shoulders, was effective in suppressing plant growth as were combinations of TCA with bromacil, erbon, tritac, or fenac. In addition, three problems were described that occurred where TCA was used this way in Texas. 1. There were many grasses and broadleaf plants that were not susceptible to TCA. Aristida spp., Digitaria spp., Andropogon saccharoides, Paspalum dilatatum, Concolvulus arvensis, Euphorbia prostrata, and others, including bunchgrasses, were among these plants. In an earlier report McCully (30) also mentioned Tribulus terrestris and Amaranthus spp. 2. At least two applications of any material were necessary where post-surface treatments were used. 3. Cracks and seams were not easily treated.

Button and Wright (24) reported the occurrence of shallow rooted species such as *Linaria spp.*, *Stellaria spp.*, *Lipidium spp.*, *Chenopodium spp.*, *Cenchrus pauciflorus* and *Digitaria spp.* the year after treatment of guardrails with either simazine or diuron. They also reported that the application of 0.4 gallons of bitumen per square yard was a standard operation in conjunction with the application of soil sterilants. This additive reduced sidekill and erosion. The benefit of using bitumen or tar with soil sterilants was reported by Ahrens (20) and Button and Potharst (23). The purpose of this addition was to lenghthen the persistance of the herbicidal treatment.

METHODS AND MATERIALS

Five experiments were conducted for the prevention of all vegetation and especially for the elimination of existing bermudagrass on highway shoulders and around guardrails. The shoulder sterilization experiments were located on State Highway 51 (one-half mile west of Stillwater), on State Highway 51 near Interstate 35, and three miles south of State Highway 33 on State Highway 99. These experiments were all in central Oklahoma. The guardrail experiments were located one mile west of State Highway 56 on U.S. 270 at Wewoka, in east central Oklahoma, and near the Cimarron River on Interstate 35 in central Oklahoma. The shoulder experiment near Stillwater on State Highway 51 and the guardrail experiment at Cimarron River were treated during the dormant season of 1963, whereas the remaining three experiments were treated in 1964 following the emergence of bermudagrass. The three shoulder sites were characterized by relatively thin infestations of bermudagrass along with other species. The shoulder experiments on State Highway 51 near Interstate 35 and on State Highway 99 had broken pieces of asphalt still present. At the guardrail site near the Cimarron River most of the plots had solid asphalt on the highway side of the guardrail. The guardrail site on U.S. 270 near Wewoka had a consistently good stand of bermudagrass.

The herbicides used, the form, the concentration of the commercial product, and the rate of application are shown in Table XV. The inclusion of diesel fuel with some herbicides in the test on SH-51 near I-35 was for the purpose of comparing water and diesel fuel as carriers. The

TABLE XV

CHEMICALS INCLUDED IN STUDIES OF SOIL STERILIZATION

ALONG THE HIGHWAY SHOULDERS AND UNDER GUARDRAILS

CHEMICAL	FORM	CONCENTRATION	CIMARRON RIVER	SH-51 (Stillwater)	SH-51 (near I-35)	SH-99	WEWOKA
			POUNDS A.I. PER ACRE				
Baron	Emulsifiable liquid	4 lbs/gal	120	100	120	120	100
			160	136	160	160	130
Baron & dalapon[1]	Emulsifiable liquid & soluble powder	4 lbs/gal & 85%	—	68, 17	68, 17	68, 17	56, 14
			—	—	80, 10	80, 10	65, 8
Borocil	Granular	98%	218	218	218	436	218
			327	—	327	654	327
Borea T-10	Granular	58%	—	250	250	250	250
			—	500	500	500	500
Bromacil & TCA[1]	Wettable powder or soluble powder, and soluble powder or pellets	80% or 50% and 95%, resp.	5, 80	4, 63	10, 80	6, 99	4,65
			10, 80	8, 63	— —	12, 99	8,65
Bromacil	Wettable powder or soluble powder	80% or 50%, resp.	10	12	12	12	10
			20	22.5	24	24	20
Chlorea	Granular	93.4%	—	—	1430	1430	650
			—	870	1920	1920	870
Fenac	Water sol. liquid	1.5 lbs/gal	—	—	20	20	16
			—	—	30	30	25

TABLE XV CONTINUED

CHEMICAL	FORM	CONCENTRATION	POUNDS A.I. PER ACRE				
			CIMARRON RIVER	SH51 (Stillwater)	SH-51 (near I-35)	SH-99	WEWOKA
Fenac & TCA[1]	Water soluble (liq. & pellet, resp.)	1.5 lbs/gal & 95%	—	11.2, 80 11.2,115	8, 100 8, 150	8, 100 8, 150	6.5, 80 6.5,120
Fenatrol	Emulsifiable liquid	1.9 lbs/gal	8.5 17.0	7.7 14.2	— —	— —	— —
Monobor-chlorate	Granular (soluble)	98%	— —	870 1740	870 1740	870 1740	870 1740
Monobor-chlorate-D	Granular	98%	436 —	— —	— —	— —	— —
Monuron	Wettable powder	80%	20 40	— —	32 64	32 64	26 52
Prometone	Emulsifiable liquid	2 lbs/gal	18 24	15 20	20 40	20 40	16 33
TCA[1]	Soluble powder (1963) or pellet (1964)	94% & 95%, respectively	150 200	44 88	— 300	150 300	120 250
Ureabor	Granular	98%	871 —	— —	400 —	400 1200	400 1200
Urox	Oil soluble liquid	3 lbs/gal	22.5 30	22.5 30	150 300	399 798	150 300

1. The sodium salt of each of these herbicides.

inclusion of paraquat in the same experiment was for the purpose of simulating dormant season application by applying a knockdown to the live vegetation prior to the application of the other herbicide. Urox was accidentally applied in water instead of diesel fuel in the experiment near the Cimarron River. Otherwise this chemical was applied in 100 gallons of diesel fuel per acre, with the exception of the guardrail on U.S. 270 where the rate of diesel fuel was 605 gallons per acre. The plots in the experiment on SH-51 one-half mile west of Stillwater were scraped on June 11, 1963. It was impossible to estimate the damage.

At the Cimarron River location the guardrail plot size was two feet by 40 or 50 feet (two replications of each length). The herbicides were applied on April 20-28, 1963. In 1964 the guardrail plot length was reduced to 18 feet. The plot size of the shoulder plots in 1963 was 40 inches by 100 feet. The herbicides were applied on April 8, 1963 with the exception of borocil and urox which were applied on May 11 and 13. The plot size in the two shoulder sites of 1964 was 5 feet by 50 feet. The guardrail treatments in 1964 were made on June 29 and 30, and the shoulder applications on SH-99 and on SH-51 on June 2-5 and June 10-15, respectively. At the guardrail site in 1964 prometone at the high rate and both dalapon-Baron combinations were applied on July 30. Borocil was not applied until July 15 on SH-51 in 1964.

At the Cimarron River experimental area the spray volume was 82 gallons per acre, applied at a speed of 2.65 m.p.h. and a pressure of 60 psi. The shoulder experiment which was begun in 1963 was sprayed at a rate of 50 gallons per acre with a pressure of 40 psi, using 8006 T-jets. On U.S. 270 the water-applied treatments were applied at 82 gallons per acre at 2.46 m.p.h. and 60 psi. It was intended in 1964 to deliver 100 gallons per acre to the shoulder plots.

The soil temperature was above 90 degrees Fahrenheit at the time of the guardrail treatments in 1964. The air temperature in 1964 was about 75 degrees during the treatment on SH-99, and about 80 during treatment on SH-51. There were only three replications in the guardrail experiment on U.S. 270, whereas all other soil sterilization experiments had four replications. A randomized block design was used in all the sterilization studies.

The percent kill of bermudagrass was recorded in the experiments near the Cimarron River and on U.S. 270. In the experiment on SH-51 in 1963 an estimate was made of the percent control, based upon a standard concept of an average check plot. In 1964, the herbicide effects were evaluated on the basis of the estimated percent ground cover with bermuda. The shoulder experiments which were begun in 1964 were evaluated on the basis of percent ground cover with bermuda and the extent of sidekill. In 1963 sidekill was expressed as the average distance which bermuda or other species were killed. In 1964 the maximum distance of sidekill which characterized 25 feet or more of a plot was recorded as the estimated sidekill where perennial grasses were concerned.

Except for the herbicides TCA, Baron, and Baron combined with dalapon, the treatments were intended for seasonal control as a minimum. Therefore the end-of-the-season readings are the best estimates of effectiveness in the soil sterilization experiments.

RESULTS AND DISCUSSION

In the guardrail experiment near the Cimarron River on I-35 in 1963 an evaluation of the chemical effectiveness for soil sterilization was made in mid-June. The treatments which gave greater than 90 percent top-kill of bermudagrass at that time were TCA at either 150 or 300 lbs./acre urox at 22.5 lbs./acre, Baron at 160 lbs./acre, and prometone at 24 lbs./acre as shown in Table XVI. The treatment differences for plant kill were highly significant. The rate of application of each herbicide except urox appeared to correspond well with both the percent of topkill of bermudagrass and the severity of sidekill. Baron applications resulted in neatly sterilized bands which did not appear to constitute an erosion hazard. Ureabor, TCA, and bromacil moved downslope to a greater extent than all other chemicals tested. A highly significant difference existed among treatments in sidekill. However, bromacil resulted in essentially no sterilization in the treated band. Prometone and the combination of bromacil and TCA resulted in sidekill in excess of the width of the treated area. The only herbicide which seemed to be satisfactory in all replications was Baron. It was noted on August 5, 1963, that neither rate of Baron had permitted regrowth of vegetation to an extent that required retreatment.

On August 5, 1963 it was noted that plots which had been treated with TCA on April 24 were being reinfested with bermudagrass. Three days later TCA was reapplied at the initial rates. At that time, of the eight plots, two hardly had any bermudagrass, and one plot had none. The other plots only had regrowth in isolated spots. Even in the isolated spots, the stand was very sparse. One month later, however, it was evi-

TABLE XVI

PERCENT KILL OF BERMUDAGRASS UNDER THE GUARDRAIL AND TO THE SIDE IN FEET AT CIMARRON RIVER IN JUNE 1963.

HERBICIDE	RATE/ACRE LBS. A.I.	UNDER GUARDRAIL**	SIDEKILL**
Baron	160	100.0	1.8
Prometone	24	100.0	3.6
TCA	200	97.0	7.8
Ureabor	870	95.0	5.8
TCA	150	93.0	4.2
Urox	22.5	92.0	1.2
Baron	120	75.0	0.5
Prometone	18	68.0	2.5
Urox	30	66.0	0.6
Bromacil plus TCA	10 & 80	58.0	4.0
Monuron	40	40.0	0.0
Monuron	20	33.3	0.0
Bromacil plus TCA	5 & 80	26.2	3.2
Bromacil	20	2.5	16.8
Monobor-chlorate-D	436	0.0	0.0
Borocil	218	0.0	0.0
Fenatrol	8.5	0.0	0.0
Fenatrol	17	0.0	0.0
Check	---	0.0	0.0
Borocil	327	0.0	1.0
Bromacil	10	0.0	5.3
Ureabor (2 plots)	1045	---	8.0
Ureabor (2 plots)	1630	---	12.5
Monobor-chlorate-D	1310	---	3.2

** The treatment differences are significant at the one percent level of probability.

Chi-square tabulated (.01) 20.0
Chi-square calculated for the treated band 50.96**
Chi-square calculated for sidekill 53.6**

dent that the retreatment had not suppressed regrowth. Complete kill was noted in one replication of each rate of TCA. Otherwise, recovery of bermudagrass had occurred. Digitaria sanguinalis was evident, having been burned back only temporarily by the retreatment. The maintenance department sprayed the guardrails of this experiment on September 12 with diesel fuel, monuron, and gasoline.

On June 11, 1963 estimates were made of the distance the vegetation was killed downslope from the treated plots in the experiment on SH-51, one-half mile west of Stillwater as shown in Table XVII. Sidekill exceeded six feet in all replications of Borea T-10, three replications of chlorea at 870 lbs./acre, and with two replications each of the treatments with bromacil at 22.5 lbs./acre and bromacil plus TCA at 8 and 63 lbs./acre. The lower rates of both bromacil and the combination of bromacil with TCA had no sidekill.

On October 26, 1963 there was sidekill in at least three replications with Borea T-10 and Monobor-chlorate at the high rates as indicated in Table XVIII. In the other plots sidekill, if any, was of small magnitude. The occurrences of small amounts of sidekill as shown in Table XVIII perhaps was due to movement of the herbicide with the soil that was scraped off the shoulder on June 11. On October 26 Monobor-chlorate, bromacil, bromacil plus TCA, borocil, chlorea, and prometone applied at the respective high rates appeared especially effective in controlling bermudagrass within the treated band.

On June 17, 1964, more than one year after the herbicides were applied, considerable residual and/or cumulative suppression of vegetation was associated with several treatments. The percent ground cover was found to be as little as two percent (Table XIX). The treatment

TABLE XVII

ESTIMATED SIDEKILL OF BERMUDAGRASS IN FEET ON JUNE 11, 1963 IN THE SHOULDER STERILIZATION TEST ONE-HALF MILE WEST OF STILLWATER ON STATE HIGHWAY 51

HERBICIDE	RATE/ACRE LBS. A.I.	REPLICATION I	II	III	IV
Bromacil	12	0	0	0	0*
Bromacil	22.5	0	0	7	10
TCA	44	0	0	0	0
TCA	88	0	0	0	0
Bromacil plus TCA	4, 63	0	0	0	0
Bromacil plus TCA	8, 63	0	0	4*	12
Fenac plus TCA	11.2, 80	0	0	0	0
Fenac plus TCA	11.2,115	0	0	0	0
Dalapon plus Baron	17, 68	0	0	0	0
Baron	100	0	0	0	0
Baron	136	0	0	0	0
Urox	22.5	0	0	0	0
Urox	30.0	0	0	0	0
Borocil	218	2.5	0	1*	0*
Borea T-10	250	6	6	10	10
Borea T-10	500	6	9	10	10
Chlorea	870	6	10	0	10*
Monobor-chlorate	870	0	0	0	0
Monobor-chlorate	1742	0	0	0	0
Prometone	15	0	0	0	0
Prometone	20	1	0	0	0
Fenatrol	7.7	0	0	0	0
Fenatrol	14.2	0	0	0	0
Check	—	9	0	0	0

* These plots and the downslope area adjacent to them were scraped very thoroughly, and the surface remained nearly bare throughout 1963.

TABLE XVIII

PERCENT CONTROL OF BERMUDAGRASS AND SIDEKILL AS ESTIMATED ON OCTOBER 26, 1963 IN THE SHOULDER STERILIZATION TEST ONE-HALF MILE WEST OF STILLWATER ON STATE HIGHWAY 51

HERBICIDE	RATE/ACRE LBS. A.I.	PERCENT CONTROL OF BERMUDAGRASS	SIDEKILL IN FEET
Chlorea	870	100	0.8
Monobor-chlorate	1740	100	1.1
Bromacil plus TCA	8, 63	93	0.8
Bromacil	22.5	90	0.2
Borocil	218	86	0.0
Prometone	20	84	0.5
Bromacil	12	79	0.3
TCA	88	76	0.0
Borea T-10	500	75	2.6
Monobor-chlorate	870	71	0.6
Borea T-10	250	69	2.2
Fenac plus TCA	11.2,115	66	0.0
Bromacil plus TCA	4, 63	66	0.0
Fenac plus TCA	11.2, 80	62	0.0
Urox	30	62	0.0
Prometone	15	59	0.0
TCA	44	55	0.0
Check	---	46	0.0
Baron	100	32	0.0
Dalapon plus Baron	17, 68	37	0.0
Urox	22.5	36	0.5
Fenatrol	7.7	32	0.0
Fenatrol	14.2	34	0.0

TABLE XIX

BERMUDAGRASS COVER IN PERCENT AS ESTIMATED ON JUNE 17, 1964, ABOUT ONE YEAR AFTER TREATMENT IN THE SHOULDER STERILIZATION EXPERIMENT ON STATE HIGHWAY 51 ONE-HALF MILE WEST OF STILLWATER.

HERBICIDE	RATE/ACRE LBS. A.I.	PERCENT COVER** OF BERMUDAGRASS
Chlorea	870	2.0
Bromacil plus TCA	8 & 63	4.6
Bromacil	22.5	4.8
Borocil	218	6.2
Prometone	20	7.5
Bromacil plus TCA	4 & 63	17.0
Monobor-chlorate	1740	24.3
Prometone	12	26.8
TCA	88	29.0
Urox	22.5	30.2
Fenac plus TCA	11 & 115	30.5
Borea T-10	500	32.8
Prometone	15	33.2
Borea T-10	250	33.8
Monobor-chlorate	870	33.8
TCA	44	41.2
Fenac plus TCA	11 & 80	42.8
Urox	30	46.6
Check	—	54.5
Fenatrol	14.2	54.8
Baron	136	57.0
Dalapon plus Baron	17 & 68	59.5
Baron	100	69.5
Fenatrol	7.7	72.2

Chi-square tabulated (.01) 41.6

Chi-square calculated 49.3**

** The treatment differences are significant at the one percent probability level.

differences for the control of bermudagrass in the treated band were highly significant. It was interesting to note that applications of chlorea, bromacil at 22.5 lbs./acre, and the combination of bromacil with TCA at eight and 63 lbs./acre were still effective in 1964 in spite of the apparent loss of chemical from the treated band in 1963 as indicated by the sidekill shown in Table XVII.

Monuron and urox were applied at rates far below the recommended rates in 1963. Accordingly, it was only in 1964 that those herbicides which contain monuron showed a degree of toxicity which resembled the herbicides related to the substituted uracils. The latter group were bromacil, bromacil plus TCA, and borocil. The group including monuron were ureabor, Borea T-10, chlorea, and monuron itself.

At the experiment located on SH-99 there was very little precipitation until August. However, the total precipitation following treatment reached ten inches by the time of the final evaluation in October. The herbicides chlorea, borocil, and urox at all rates and the high rate of Monobor-chlorate, monuron, Borea T-10, bromacil, ureabor, prometone, and the combination of bromacil and TCA would be arbitrarily considered unsatisfactory as tested for shoulder sterilization because of possible erosion hazards created by sidekill of such magnitude as shown in Table XX. A highly significant difference was found among treatments in bermudagrass control, as well as extent of sidekill.

In comparing the sidekill caused by treatments that contain a substituted uracil with other herbicides in Table XX, it appears that the herbicides which contain the substituted uracil tend to result in greater sidekill than the other materials tested. This seems to imply

TABLE XX

BERMUDAGRASS COVER IN PERCENT AND SIDEKILL IN FEET

ON SH-99 NEAR DRUMRIGHT ON OCTOBER 7, 1964.

HERBICIDE	RATE/ACRE LBS. A.I.	PERCENT BERMUDA COVER**	SIDEKILL OF BERMUDA IN FEET**
Chlorea	1430	0	5.6
Chlorea	1920	0	5.1
Monuron	64	0	6.6
Borocil	654	0	8.1
Borea T-10	500	0	5.8
Bromacil	24	0	6.0
Urox	399	0	15.8
Monuron	32	0	2.7
Urox	798	0.12	15.6
Borea T-10	250	0.17	2.8
Ureabor	1200	0.17	5.3
Borocil	436	0.25	9.3
Bromacil & TCA	12& 99	0.38	4.5
Monobor-chlorate	1740	0.50	4.0
Prometone	40	0.52	3.9
TCA	300	0.68	1.1
Ureabor	400	0.86	1.4
TCA	150	1.12	1.6
Baron	160	2.5	1.1
Bromacil	12	2.6	3.1
Bromacil & TCA	6 & 99	2.7	3.5
Monobor-chlorate	870	3.1	1.2
Fenac & TCA	8 & 150	3.9	1.8
Fenac	20	5.0	1.8
Prometone	20	6.4	0.5
Fenac & TCA	8& 100	6.4	0.4
Baron	120	9.0	0.5
Dalapon & Baron	17& 68	14.0	0.7
Fenac	30	15.8	2.2
Dalapon & Baron	10& 30	32.0	0.2
No check			

Cover

Chi-square tabulated (.01) 50.9
Chi-square calculated 85.3**

Sidekill

Chi-square tabulated (.01) 50.9
Chi-square calculated 83.7**

** The treatment differences are significant at the one percent level of probability.

that herbicides which contain the substituted uracils reach toxic levels to the side out of proportion to the area within the treated band. This appears also to be true for bromacil and for the combination of bromacil with TCA in the experiment at the Cimarron River on I-35 as shown in Table XVI. This does not appear to be true in the two other experiments that were begun in 1964, however. In those experiments herbicides were included which contained monuron; these treatments in particular showed a level of toxicity resembling the uracils.

The evaluation of herbicides at the end of the growing season that were included in the experiment on SH-51 one-half mile west of Stillwater is presented in Table XXI. The number of treatments with nearly complete control of bermudagrass in the treated band and the distance of sidekill were both lower than in the experiment on SH-99. Monuron and urox seemed to be quite toxic with respect to sidekill. This is in agreement with the results obtained from the test on SH-99 where both materials were found to be quite toxic in the treated band. Both urox and the high rate of monuron caused extensive sidekill. Thus, when the two experiments were compared, it appeared that urox and monuron, closely related chemically, were quite toxic to bermudagrass in both experiments. Furthermore, those treatments which contained the substituted uracil compounds borocil, bromacil, and bromacil combined with TCA seemed to be quite toxic to bermudagrass in both experiments. Except when bromacil at 12 lbs./acre and bromacil at 6 lbs. combined with 99 lbs. of TCA per acre were used on SH-99, the toxicity of the uracil-related herbicides was apparent in the treated band consistently, and oftentimes as sidekill in addition. The toxicity of Borea T-10 to bermuda

TABLE XXI

BERMUDAGRASS COVER IN PERCENT AND SIDEKILL IN FEET

ON SH-51 NEAR I-35 ON OCTOBER 1, 1964.

HERBICIDE	RATE/ACRE LBS. A.I.	PERCENT BERMUDA COVER**	SIDEKILL OF BERMUDA IN FEET**
TCA	300	0	3.9
Bromacil	24	0	7.6
Urox	300	0	8.4
Monuron	64	0.025	5.2
Borocil	327	0.25	3.5
Bromacil	12	0.3	5.8
TCA & bromacil	80 & 10	0.4	3.5
Monuron	32	0.5	4.0
Borocil	218	1.3	2.4
Prometone	40	1.5	0.7
Chlorea	1920	1.8	2.4
TCA & fenac	100 & 8	2.5	1.4
Urox	150	2.9	4.6
Borea T-10	250	3.0	4.8
Baron & dalapon	80 & 10	3.2	2.1
Chlorea	1430	3.8	0.9
TCA & fenac	150 & 8	3.9	2.8
Baron & dalapon	68 & 17	5.0	3.5
Monuron in diesel	32	5.2	3.2
Monobor-chlorate	1740	5.4	0.2
Baron & knockdown	120	5.5	1.2
Prometone	20	6.0	0.4
Ureabor	400	6.2	1.9
Monobor-chlorate & knockdown	870	8.1	0.5
Borea T-10	500	9.2	6.1
Baron	160	9.2	1.0
Monobor-chlorate	870	10.2	0.0
Ureabor & knockdown	400	14.5	3.0
Baron	120	18.8	1.0
Monuron & knockdown	32	18.9	4.1
Check	—	23.0	0.0
Fenac	20	23.6	0.0
Fenac	30	27.9	0.0

Bermudagrass cover	Sidekill
Chi-square tabulated (.01) 53.5	Chi-square tabulated (.01) 59.9
Chi-square calculated 64.1**	Chi-square calculated 97.5**

** The treatment differences are significant at the one percent level of probability.

in the study on SH-51 was apparent in the area outside the plot where sidekill occurred, however, the kill in the treated band was not impressive. Chlorea, which contains monuron, showed less toxicity to bermuda inside and outside the treated area on SH-51 than on SH-99. In both experiments the herbicides which moved to the side most extensively were bromacil, urox, Borea T-10, and monuron. The rate of application influenced the sidekill consistently in the test on SH-51. Both borocil and chlorea resulted in relatively little sidekill in this experiment compared to other treatments which contained bromacil or monuron, respectively. Borocil was applied at a rate far above what is recommended in the study on SH-99, which should account for the excessive sidekill obtained in this experiment.

Highly significant differences were found among treatments in the experiment on SH-51 in the control of bermudagrass as well as the extent of sidekill as shown in Table XXI. The addition of paraquat or diesel fuel to monuron, Baron, Monobor-chlorate, or ureabor did not seem to improve the herbicidal properties in this experiment.

Little precipitation occurred at the experimental site on U.S. 270 until August, after which a total of 15 inches was recorded by November 14. The herbicides used in this study for soil sterilization around guardrails were evaluated on November 14 and the results are reported in Table XXII. These data show those treatments which gave 80 percent kill of bermudagrass also gave sidekill that exceeded the original width of intended kill with the exception of TCA at 250 lbs./acre which was the sole exception, with sidekill of only 1.2 feet. The treatment differences for both sidekill and bermudagrass control were highly significant. With

TABLE XXII

ESTIMATES OF THE PERCENT KILL OF BERMUDAGRASS UNDER THE GUARDRAIL AND TO THE SIDE IN FEET ON U.S. 270 NEAR WEWOKA ON NOVEMBER 14, 1964.

HERBICIDE	RATE/ACRE LBS. A.I.	PERCENT KILL BERMUDA**	SIDEKILL OF BERMUDA IN FEET**
Borea T-10	250	100	2.8
Borea T-10	500	99.7	4.0
Urox	300	99.7	4.2
Ureabor	1200	99.0	3.7
Urox	150	96.7	3.2
Monuron	52	96.7	3.5
Bromacil	20	95.0	3.2
TCA	250	89.7	1.2
Borocil	218	87.7	3.2
Ureabor	400	85.0	2.2
Bromacil & TCA	8 & 65	81.7	2.5
Chlorea	870	81.0	2.2
Monobor-chlorate	1740	80.0	1.5
Baron	130	78.3	0.0
Baron	100	78.3	0.5
Borocil	327	78.3	4.2
Dalapon & Baron	8 & 56	77.0	0.0
Bromacil & TCA	4 & 65	75.0	1.3
Chlorea	650	75.0	1.5
Dalapon & Baron	14 & 56	75.0	2.0
Monuron	26	72.7	2.0
Bromacil	10	71.7	1.7
Fenac & TCA	6.5&120	48.3	0.3
TCA	120	43.3	0.0
Monobor-chlorate	870	41.7	1.7
Fenac	25	33.3	0.5
Prometone	16	30.0	0.2
Prometone	33	30.0	0.3
Fenac	16	23.3	0.0
Fenac & TCA	6.5& 80	21.7	0.0
Check	---	11.7	0.0

Bermuda Cover	Sidekill
Chi-square tabulated (.01) 50.9	Chi-square tabulated (.01) 50.9
Chi-square calculated 266.2**	Chi-square calculated 65.6**

** The treatment differences are significant at the one percent level of probability.

the exception of borocil applied at 327 lbs./acre, the compounds which contained a substituted uracil or monuron were toxic in the treated band when applied at the higher rates.

In conclusion, considering both control and sidekill, it appeared that the combinations of bromacil and TCA applied at the higher rate compared favorably in three experiments. Other indications were too variable for much to be concluded at this time. However, certain treatments compared favorably in two experiments. These were chlorea at 870 lbs., Monobor-chlorate at 1740 lbs., Ureabor at 400 lbs., Borea T-10 at 250 lbs., borocil at 218 lbs. (in a third experiment the toxicity was excessive, probably due to an accidental double application), and either Prometone or TCA at the higher rates.

From the results of these two years of research it would seem that fenac up to 30 lbs./acre, fenac at 8 lbs. combined with TCA at 100 or 150 lbs./acre, dalapon in combination with Baron at the rates of 10 lbs. and 80 lbs./acre or at 17 lbs. and 68 lbs./acre, and Monobor-chlorate at 870 lbs./acre were not effective for the control of bermudagrass in the area where they were tested in Oklahoma.

In order to develop satisfactory chemical methods for the control of vegetation, either different herbicides must be tested or sidekill must be prevented with those materials which are reported here.

SUMMARY

A study was initiated in 1963 for the purpose of determining whether herbicides could be used to effectively control vegetation around guardrails and signposts, and on asphaltic highway shoulders in Oklahoma. Particularly, an effort was made to find chemicals which would control bermudagrass and _Sorghum halepense_ in these areas.

In 1963 and 1964 five experiments were initiated to evaluate a number of chemicals for weed control through soil sterilization. Four of the experiments were located in central Oklahoma of which three were concerned with soil sterilization on highway shoulders and the others around guardrails. A fifth experiment, which was concerned also with guardrail sterilization, was located in east central Oklahoma at Wewoka. In the experiment located near the Cimarron River on I-35, an evaluation there in mid-June of 1963 showed that TCA, ureabor, and urox caused the most extensive amounts of sidekill, yet, these herbicides gave better than 90 percent control of bermudagrass in the treated band, as did Baron and prometone also. Baron was the only treatment which appeared effective in four replications for most of the summer.

On June 11, 1963 it appeared that extensive sidekill occurred where Borea T-10, chlorea, bromacil, or bromacil plus TCA were applied to the highway shoulder on SH-51 one-half mile west of Stillwater. At the end of the season in the same experiment, sidekill did not appear to be a problem except, perhaps, where Borea T-10 was used. Control of bermu-

dagrass was relatively high at that time particularly where the following treatments were used: Monobor-chlorate at 1740 lbs./acre, bromacil at 22.5 lbs./acre, bromacil plus TCA at 8 lbs. and 63 lbs./acre, borocil at 218 lbs./acre, chlorea at 870 lbs./acre, and prometone at 20 lbs./acre. On June 17, 1964 these herbicides were still quite effective with the exception of Monobor-chlorate which was no longer effective.

In the experiment at SH-99, 3.0 miles south of SH-33, eight of the most effective treatments for kill of bermudagrass in the treated band were related to monuron. The herbicides that were related to either the uracils or monuron were found to be rather undesirable with respect to sidekill. However, the treatments related to the uracils were among the top ten in the eradication of bermudagrass in the treated band on SH-51 one-half mile west of Stillwater, whereas, some of the treatments related to monuron ranked near the bottom. Of the treatments related to monuron which did poorly at SH-51 in the treated band, monuron and ureabor combined with the knockdown treatment of paraquat, or monuron applied in diesel, as well as Borea T-10 resulted in sidekill of three feet or more. Chlorea applied on SH-51, although it did not move over 2.4 feet to the side, was not impressive with respect to kill of bermudagrass in the treated band at this location on SH-51.

Those herbicides which contained either the uracils or monuron were ranked high in the eradication of bermudagrass near Wewoka on U.S. 270, at least when applied at the higher rates, with the exception of chlorea and the combination of bromacil plus TCA. These herbicidal treatments, however, were applied at lower rates than in the other two experiments of 1964.

In the experiments located near the Cimarron River, on SH-99, on SH-51 one-half mile west of Stillwater, and near Wewoka on U.S. 270 the high rate of TCA caused less sidekill than herbicides with similar effectiveness in the treated band. TCA effectiveness in the treated band was relatively high at Cimarron River, SH-51, and Wewoka.

PART III

JOHNSONGRASS (*SORGHUM HALEPENSE*) ERADICATION STUDIES ON THE OKLAHOMA HIGHWAY SYSTEM

INTRODUCTION

Johnsongrass (*Sorghum halepense*) infestations are frequent along Oklahoma highways. When allowed to grow, the plants reach heights that may interfere with the drivers' view at curves, intersections, or railway crossings. In addition to the possibility that driving hazards may be created by johnsongrass, the plants detract from the general aesthetic value of the landscape. A substantial portion of the mowing cost on Oklahoma highways is expended for the intended control of johnsongrass. Even though this could be accomplished eventually by frequent mowing at low heights, the expense would be prohibitive.

The nature of the rhizomes of johnsongrass is such as to make the plant a persistant perennial. Its food reserves are generated quickly following seedling emergence according to Hicks (38) and McWhorter (40), and the rhizomes ordinarily become extensive and capable of sending up new growth repeatedly for a long period even when mowed. Therefore, the control of johnsongrass with a herbicide would normally require either that the herbicide be translocated throughout the rhizomes, or that the soil be completely sterilized.

Although there are several soil sterilants which will kill the rhizomes of johnsongrass, the use of soil sterilants will often prevent the establishment of a vegetative cover for at least one year following treatment. Dalapon or arsenicals used as systemics can be used to reduce infestations to less than 10 percent of the original stand after one season of treatment, with three to five applications per year.

Whereas there are serious limitations with the current herbicidal treatments for rhizomatous plants, any of several pre-emergence herbicidal treatments may be used for the control of seedling johnsongrass. These pre-emergence herbicides include amiben, EPTC, atrazine, simazine, fenac, and trifluralin.

LITERATURE REVIEW

Rea (41) reported the results from 28 non-crop sites which were treated from September 12 to November 5, 1962 for the control of johnsongrass. The herbicide DSMA applied at rates ranging from 0.78 to 2.75 pounds per 100 gallons of water was tested alone and in combination with a surfactant. This solution was applied at the rate of 50 to 200 gallons per acre, depending on the amount of foliage present. Through the use of a mowing operation on one-half of the plots, two stages of growth were compared. All of the mowing was done previous to the first application of herbicide. At the time of the first treatment the plants at the two stages of growth were less than 12 inches and 3 to 6 feet in height, respectively. In addition to the first treatments, there were generally one or two retreatments in 1962.

It was difficult to wet the younger johnsongrass plants adequately according to Rea (41), and the symptoms were less dramatic than with applications of DSMA to the later stage of growth. The younger plants became chlorotic, and subsequent growth and resprouting were suppressed. When DSMA was applied at the later stage of growth, the foliage was killed within ten days, provided the coverage had been thorough. Many plots which had been treated at the later stage of growth did not resume growth nor resprout during the fall that followed the initial treatment. The results during the season in which treatments were made depended more on the percent of wetting agent than on the rate of DSMA. The following spring there was at least 95 percent control where applications had been made to plants less than 12 inches in height. The later dates for initial treatment of plants at the younger stage of growth resulted in less control than the earlier treatments at the younger stage of growth. Where applications of DSMA had been made during seed formation there were five sites in which rhizomes were not affected by the spring following treatment. Whereas control on the regrown plots was no less than 50 percent, applications to the older plants resulted in less control generally and in more variability such that the range of control was zero to 99 percent.

McWhorter (40) reported a study in which rhizomes and seeds of johnsongrass were planted in a fertile soil. The food reserves in the rhizomes which produced the rhizomatous plants were dissipated in 2 to 3 weeks after initiation of the experiment. At that time production of secondary rhizomes began with either rhizomatous or seedling plants, and production of secondary rhizomes continued through mid-summer. In mid-summer the plants began producing a smaller, less vigorous type of rhizome. Rhizome development was slow relative to topgrowth up to the bloom stage of growth. In the 47 days up to the bloom stage of growth, less than eight feet of rhizomes had been developed. During the following 47 days, 85 feet of rhizomes were produced. It is interesting to note that although the average rhizome length was 100 feet in August, the rhizome length averaged 43 feet in September. Perhaps this has something to do with the frequent reports that herbicides perform better on johnsongrass which is in the seedhead stage of growth.

METHODS AND MATERIALS

Two sites were chosen in 1963 for the evaluation of herbicides as a means of johnsongrass control. Both sites were near Stillwater, in north central Oklahoma. One site was a relatively flat area along I-35 near SH-51. Initially, the johnsongrass was considered to be in a rather poor condition at that location, whereas at the other site which was located on SH-33 the johnsongrass was vigorous and stood about six feet tall or taller. Three replications of the experiment on SH-33 were located on a south-facing fill slope which was quite steep. A fourth replication was located below the fill slope in a flat area.

In 1964 two sites were chosen for the initiation of new experiments. One was located on SH-18 in north central Oklahoma. At this location there were two replications on an east-facing slope, and two on a west-facing slope. The johnsongrass in these plots was semi-dormant as the result of drouth conditions and about 2 1/2 feet in height when the research was initiated. The other experiment was located on U.S. 64 near Tulsa, in northeast Oklahoma on a rather flat site. Johnsongrass plants there were thick, and six feet or more in height.

Disodium methanearsonate (DSMA); 2,2-dichloro-propionic acid (dalapon), and Monobor-chlorate-D were included in the tests during 1963. Calcium acid methane arsonate (CMA) was added to the new experiments in 1964, and Monobor-chlorate was used rather than Monobor-chlorate-D. The rates and names of the surfactants for the experiments begun in 1963 are shown in Table XXIII. Dynawet surfactant, manufactured by Dow Chemical, was used initially in the experiment near Tulsa. It was used at one percent with dalapon and at 0.2 percent with DSMA. For the retreatment in that experiment, Depester Herbicide Surfactant was used at one percent for both dalapon and DSMA. The retreatment included DSMA and CMA at initial rates and dalapon at 0.9 and 1.6 lbs./10 gallons of spray.

Dalapon, DSMA, and CMA were completely soluble. Monobor-chlorate-D was not 100% soluble, because the diuron additive could only be suspended in water. But, Monobor-chlorate was soluble at 3 lbs./gallon with agitation. Monobor-chlorate-D was applied as a spray in 1963 with the use of constant agitation. A surfactant was applied with DSMA in all cases, although various rates of surfactant were used.

The dates for retreatment in the experiments which were begun in 1963 are shown in Table XXIII. There was one retreatment during the fall following the initial application in the experiment near Tulsa; the date of that retreatment was October 7, 1964. The experiments on I-35 and SH-33 were retreated four times during 1964. At one time during 1964 each of these two experiments was mowed as was done originally to allow for repetition of the stage of growth comparison. This was done on June 1 in the experiment on I-35 and on July 18 in the experiment on SH-33.

Estimates were made of the stand of live johnsongrass at various times during 1964. The plots were scored on the basis of 0 to 10 with ten representing maximum density and zero denoting a complete absence of johnsongrass.

TABLE XXIII

DATES OF HERBICIDE APPLICATION AND SURFACTANTS USED IN 1963 FOR THE CONTROL OF

JOHNSONGRASS ALONG STATE HIGHWAY 33 AND INTERSTATE 35

DATE	HERBICIDE	RATE/ACRE LBS. a.I.	SURFACTANT	RATE	EXPERIMENT
Aug. 22-25,1963	Monobor-chlorate-D	643 & 1039/acre	None	—	SH-33
	Dalapon	10 & 15/acre	Dow's Dynawet	0.5%	SH-33
	DSMA	1.9 & 3.2/100 gal.	Dow's Dynawet	0.37%	SH-33
Aug. 26-28,1963	Same herbicides	Same rates	Same	Same	I-35
October 6, 1963	Dalapon	1/10 gal.	Dow's Dynawet	1%	I-35
	DSMA	1.9/100 gal.	Dow's Dynawet	0.32%	I-35
October 11,1963	Same	Same	Same	Same	SH-33
May 16, 1964	Dalapon	1/10 gal.	Dow's Dynawet	1%	SH-33
	DSMA	1.9/100 gal.	Dow's Dynawet	0.37%	SH-33
June 23, 1964	DSMA	1.9 & 3.2/100 gal.	Dow's Dynawet	0.37%	I-35
	Dalapon	10 & 15/acre or	Dow's Dynawet	1%	I-35
Aug. 6, 1964	DSMA	1.9 & 3.2/100 gal.	Depester Herbicide Surf.	0.2%	SH-33
	Dalapon	10 & 15/acre or spot treatment	Depester Herbicide Surf.	1%	SH-33
	Monobor-chlorate	Spot treatment	None	—	SH-33
August 8,1964	Same as SH-33	Same as SH-33	Same as SH-33	—	I-35
Sept. 16, 1964	DSMA	1.9 & 3.2/100 gal.	Dow's Dynawet	0.2%	I-35
Sept. 17, 1964	Dalapon	10 & 15/acre	Dow's Dynawet, except plots 1, 13, & 24 with Depester Herbicide Surf	1%	I-35 & SH-33
	Monobor-chlorate	234 & 428/acre	None	—	I-35 & SH-33
Sept 22, 1964	DSMA	1.9 & 3.2/100 gal.	Depester Herbicide Surf.	0.2%	SH-33
October 17,1964	DSMA	1.9 & 3.2/100 gal.	Emulsifying Agent A	1%	I-35 & SH-33
	Dalapon	1 & 2/10 gal.	Emulsifying Agent A	1%	I-35 & SH-33

RESULTS AND DISCUSSION

The stand of johnsongrass in early spring in the experiment on SH-33 the year after treatment was less in the mowed plots than in the unmowed ones wherever either dalapon or DSMA was used, as shown in Table XXIV. The treatment differences were significant at the five percent level of probability. Where applied to mowed plots, dalapon appeared to reduce the stand of johnsongrass from 45 percent down to four or less, whereas the stand was 26 percent in the unmowed check plots. DSMA seemed to be more effective at the low rate than at the high rate. However, either rate of DSMA applied to mowed plots was less effective than dalapon applied to mowed plots. Monobor-chlorate-D appeared to have given almost perfect control at either rate when applied to either mowed or unmowed plots. In the experiment on I-35 the results appear to be similar to those obtained on SH-33 as shown in Table XXV. The treatment differences were highly significant. Dalapon at either rate appeared to be more effective than DSMA for the control of johnsongrass when scored on May 25, 1963, but not as effective as Monobor-chlorate-D. Dalapon applied to unmowed plots performed better on I-35 than on SH-33. Again the occurrence of living plants in the Monobor-chlorate-D treated plots was due to a single replication.

The plots were mowed in the experiment on I-35 in the spring as they had been in August of 1963. This mowing operation in itself appeared to induce changes in the plant population as indicated by a reading taken preceeding the retreatment of dalapon and DSMA three weeks later. At

TABLE XXIV

THE EFFECT OF THREE HERBICIDES APPLIED IN AUGUST 1963 ON THE STAND OF JOHNSONGRASS (*SORGHUM HALEPENSE*) IN MOWED AND UNMOWED PLOTS ON MAY 16, 1964 ON STATE HIGHWAY 33 NEAR COYLE.

HERBICIDE	INITIAL RATE LBS. A.I./ACRE	RELATIVE DENSITY IN PERCENT[1]	
		MOWED	UNMOWED
Check	—	44*	26
DSMA	1.9 lbs./100 gal.	6	19
DSMA	3.2 lbs./100 gal.	12	26
Dalapon	10 lbs./acre	4	21
Dalapon	15 lbs./acre	0	22
Monobor-chlorate-D	643 lbs./acre	0	12
Monobor-chlorate-D	1039 lbs./acre	0	0

* There were only two plots, one of which was damaged in 1963.

Chi-square tabulated (.05) 21.0

Chi-square calculated 22.7[1]

1. The treatment differences are significant at the five percent level of probability.

TABLE XXV

THE EFFECT OF THREE HERBICIDES APPLIED IN AUGUST 1963 ON THE STAND OF JOHNSONGRASS (SORGHUM HALEPENSE) IN MOWED AND UNMOWED PLOTS ON MAY 25, 1964 ON I-35 NEAR MULHALL ROAD

HERBICIDE	INITIAL RATE LBS. A.I./ACRE	RELATIVE DENSITY IN PERCENT**	
		MOWED	UNMOWED
Check	—	60	47
DSMA	1.9 lbs./100 gal.	13	32
DSMA	3.2 lbs./100 gal.	18	39
Dalapon	10 lbs./acre	10	29
Dalapon	15 lbs./acre	11	24
Monobor-chlorate-D	643 lbs./acre	0	5
Monobor-chlorate-D	1089 lbs./acre	0	0

Chi-square tabulated (.01) 27.7

Chi-square calculated 40.1**

** The treatment differences are significant at the one percent level of probability.

the time of that reading DSMA appeared to be equally as effective where applied to johnsongrass in the seedhead stage of growth as where applied to plants in the vegetative stage following mowing as shown in Table XXVI. Furthermore, the stand of johnsongrass in plots treated with dalapon was nearly the same in either mowed or unmowed plots. Where Monobor-chlorate-D had been applied in 1963, reinfestation was more serious in the mowed plots. These changes in plant population may have resulted from an increase in seed germination due to the mowing operation of June 1, 1964 as indicated by the check plots. The ratio of the plant population in mowed and unmowed check plots was less than 1 1/2 on May 25, whereas the ratio was greater than two on June 23.

In the period from August 6 to 8 another retreatment was made at the experiment on 1-35, including spot treatments with Monobor-chlorate (CBM) on those plots which had originally received Monobor-chlorate-D. The CBM was applied in those spot treatments at a uniform rate regardless of initial treatment. By September 18, DSMA and dalapon had given better control of johnsongrass where applied to the unmowed plots than when applied to the mowed ones as shown in Table XXVII. The treatment differences were highly significant. As in May, dalapon gave more control than DSMA, having attained 50 percent control or more. Compared with the stand of johnsongrass in June (Table XXVI), the Monobor-chlorate retreatment had given the most control where Monobor-chlorate -D had originally been applied at the high rate on mowed plots.

In the experiment on SH-33, retreatments of dalapon and DSMA were made on May 16. That experiment was also retreated on August 6, and spot treatments of Monobor-chlorate made in the appropriate plots. The relative stand of johnsongrass on September 22, 1964 is shown in

TABLE XXVI

THE RELATIVE STAND OF JOHNSONGRASS IN PERCENT TREATED INITIALLY IN AUGUST 1963 AS DETERMINED ON JUNE 23, 1964 ABOUT THREE WEEKS AFTER CLIPPING THE MOWED PLOTS ON I-35 NEAR MULHALL ROAD

HERBICIDE	INITIAL RATE LBS. A.I./ACRE	RELATIVE DENSITY IN PERCENT**	
		MOWED	UNMOWED
Check	—	100	46
DSMA	1.9 lbs./100 gal.	30	21
DSMA	3.2 lbs./100 gal.	20	19
Dalapon	10 lbs./acre	25	32
Dalapon	15 lbs./acre	23	21
Monobor-chlorate-D	643 lbs./acre	28	2
Monobor-chlorate-D	1089 lbs./acre	13	3

Chi-square tabulated (.01) 27.7

Chi-square calculated 37.2**

** The treatment differences are significant at the one percent level of probability.

TABLE XXVII

THE EFFECT OF THREE HERBICIDES ON THE RELATIVE STAND OF JOHNSONGRASS REPORTED IN PERCENT IN MOWED AND UNMOWED PLOTS FOLLOWING RETREATMENTS IN 1964 (TWO RETREATMENTS WITH DALAPON AND DSMA, AND ONE WITH CBM) AS SCORED ON SEPTEMBER 18, 1964 IN THE TEST ON I-35 NEAR MULHALL ROAD.

HERBICIDE	RETREATMENT RATE LBS. A.I./ACRE AUGUST 6 & 8, 1964	RELATIVE DENSITY IN PERCENT**	
		MOWED	UNMOWED
Check	—	100	81
DSMA	1.9 lbs./acre	75	58
DSMA	3.2 lbs./acre	92	67
Dalapon	10 lbs./acre	67	50
Dalapon	15 lbs./acre	67	33
CBM	SPOT TREATMENTS	62	69
CBM	SPOT TREATMENTS	25	50

Chi-square tabulated (.01) 27.7

Chi-square calculated 30.0**

** Treatment differences are significant at the one percent level of probability.

Table XXVIII. As shown in the table, treatment differences were highly significant. The cumulative control attained by September 22 with DSMA appeared better on mowed plots than on unmowed plots. Where the high rate of dalapon had been applied, the greater control was attained in mowed plots. Plots treated with Monobor-chlorate had been nearly bare throughout the summer, and the unmowed plots still exhibited excellent control of johnsongrass on September 22.

TABLE XXVIII

THE EFFECT OF THREE HERBICIDES ON THE RELATIVE STAND OF JOHNSONGRASS REPORTED IN PERCENT IN MOWED AND UNMOWED PLOTS FOLLOWING RETREATMENTS IN 1964 (TWO RETREATMENTS WITH DALAPON AND DSMA, AND ONE WITH CBM) AS SCORED ON SEPTEMBER 22, 1964 IN THE TEST ON SH-33 NEAR COYLE.

HERBICIDE	RETREATMENT RATE AUGUST 6, 1964 LBS. A.I./ACRE	RELATIVE DENSITY IN PERCENT**	
		MOWED	UNMOWED
Check	---	20*	43
DSMA	1.9 lbs./100 gal.	22	30
DSMA	3.2 lbs./100 gal.	13	33
Dalapon	10 lbs./acre or spot	20	9
Dalapon	15 lbs./acre or spot	12	22
CBM	Spot treatment	10	1
CBM	Spot treatment	8	4

* Only two plots, one of which was damaged in 1963.

Chi-square tabulated (.01) 26.2

Chi-square calculated 28.0**

** The treatment differences are significant at the one percent level of probability.

Essentially throughout the first two years of the study, initial treatments with Monobor-chlorate-D followed later with Monobor-chlorate retreatment gave the best control of the three herbicides tested in the two experiments begun in 1963.

Dalapon and DSMA appeared to be more effective in the early spring where applied to mowed plots. In the experiment on SH-33 even in September it appeared that where DSMA had been applied, the control of johnsongrass was still better in the mowed plots just as had been true in May. However, in the experiment on I-35 in September, the control of johnsongrass with either dalapon or DSMA appeared to be better on the unmowed plots. The stage of growth did not appear to be important in the other readings.

Considerable burn and suppression of plant growth was attained later in 1964. Prior to the late season retreatments in 1964 at the experiments which had been initiated the year before, it appeared that dalapon applied to unmowed vegetation was more effective than DSMA. In the experiment on SH-33, the averages for johnsongrass stand in unmowed plots for DSMA and dalapon were 31 and 15 percent, respectively, as shown in Table XXVIII, and for the experiment on I-35 the corresponding averages were 62 and 41 percent. Throughout most of 1964 early spring results were not improved nor were they maintained. The drouthy condition of the plants may be the reason for this failure.

In 1964 two new johnsongrass test sites were chosen. An estimate was made of the stand at the end of the season in the experiment located near Tulsa. Dalapon and Monobor-chlorate (CBM) treatments had reduced the stand considerably as shown in Table XXIX. When applied to the seedhead stage of growth these two herbicides at the high rates resulted in

TABLE XXIX

THE EFFECT OF FOUR HERBICIDES ON THE RELATIVE STAND OF JOHNSONGRASS REPORTED IN PERCENT IN MOWED AND UNMOWED PLOTS ON OCTOBER 15, 1964 FOLLOWING ONE RETREATMENT WITH DALAPON, DSMA, AND CMA ON OCTOBER 7, 1964 IN THE TEST ON US-64 NEAR SAND SPRING.

HERBICIDE	INITIAL RATE LBS. A.I./ACRE	RELATIVE DENSITY IN PERCENT	
		MOWED	UNMOWED
Check	—	100	93
DSMA	1.9 lbs./100 gal.	108	6
DSMA	3.2 lbs./100 gal.	88	7
Dalapon	10 lbs./acre	4	2
Dalapon	15 lbs./acre	1	0
CBM	643 lbs./acre	5	1
CBM	1089 lbs./acre	3	0
CMA	1.5 lbs./acre	100	10
CMA	2.5 lbs./acre*	100	4

* There are only two replications.

complete control of the johnsongrass. On mowed plots also, both herbicides appeared to perform better when applied at the high rates. The two arsenicals appeared quite effective at either rate when applied to the seedhead stage of growth, giving 90 percent or greater control.

SUMMARY

Johnsongrass infestation along Oklahoma highways causes higher maintenance costs because of mowing, and it is a detriment to driving safety and highway appearance. The rhizomes will send up new growth over a long period even though there is frequent mowing at very low heights. Mowing accounts for about one-sixth of the annual budget of the Maintenance Division of the Oklahoma Highway Department. Johnsongrass infestation can be credited with a substantial portion of this cost. Although soil sterilants may be used for johnsongrass eradication, these materials prevent the establishment of a vegetative cover for a considerable time in many cases. Meantime, the opportunity exists for soil erosion to take place.

Two experiments were initiated in 1963 to evaluate various herbicides for the control of johnsongrass along Oklahoma highways. The experiments which were begun in 1963 were located in north central Oklahoma. A third experiment was initiated in 1964 near Tulsa. The herbicides used in 1963 were disodium methanearsonate (DSMA), 2,2-dichloryl-propionic acid (dalapon), and Monobor-chlorate-D. Monobor-chlorate-D was replaced with Monobor-chlorate in the experiments that were initiated in 1964, and calcium methanearsonate (CMA) was added. One-half of the plots were mowed in each experiment to allow for initial treatment of the johnsongrass at two stages of growth in late August.

The control of johnsongrass which was attained with Monobor-chlorate-D in the spring of 1964 following treatments in 1963 and the control attained two and one-half months following treatment near Tulsa in 1964 were near 100 percent. In the experiments begun in 1963 there was perfect control in the spring of 1964 where Monobor-chlorate-D was applied initially to regrown plants. However, in the experiment near Tulsa in 1964 the better control with Monobor-chlorate was attained on plants which were treated at the seedhead stage of growth. Dalapon, where applied to mowed plots, seemed to be superior to DSMA when evaluated in the spring of 1964 following treatment in 1963. Dalapon applied at 15 lbs./acre in 1963 on SH-33 appeared to give 100 percent control. Compared to the unmowed check plots in that experiment, the 10-pound rate of dalapon appeared to reduce the relative stand from 26 percent or more to 4 percent. DSMA was less effective, but rates of 1.9 and 3.2 lbs./100 gallons of water resulted in spring densities of johnsongrass of six and twelve percent, respectively. At I-35 the average stand of johnsongrass when treated with DSMA on mowed plots was 16 percent, whereas dalapon applied to mowed plots reduced the stand to 10 percent when applied at either rate. Dalapon was also superior to DSMA in the experiment begun in 1964. The stand of johnsongrass ranged from zero to four percent where dalapon was applied. DSMA and CMA applied to mowed plots in the same experiment failed to effect a major reduction in stand. In the experiment near Tulsa, the higher rate of DSMA or CMA was equal to or more effective than the lower rate. This did not appear to be true in the experiments which were begun in 1963; in fact, the low rate of DSMA appeared more effective in the experiment at SH-33 as recorded in May, 1964.

Whereas the control attained in the spring of 1964 from treatments made in 1963 was higher in the mowed plots, the control attained in the experiment near Tulsa was higher in the unmowed plots as recorded in October.

CHAPTER VI

RESULTS AND DISCUSSION

The results of the three phases of this research are presented separately for convenience and ease of discussion.

CONTROL OF BROADLEAF PLANTS AND WEEDY GRASSES

In the experiment on I-35 near Seward Road the greatest reduction in weed population as recorded in June 1963 was obtained from simazine as shown in Table VI. Diuron and tritac, and 2,4-D alone or in combination with maleic hydrazide were also effective, but to a lesser extent. In September there was noticeable weed control with 2,4-D alone or in combination with maleic hydrazide, tritac, simazine, and the high rate of diuron as shown in Table VIII. When analyzed statistically, the treatment differences were highly significant. The treatment differences for bermudagrass stand were not significant at the ten percent level of probability. When the treatments were evaluated again more than one year following the first application of the treatments no significant treatment differences were found in the control of broadleaf weed nor bermudagrass at the ten percent level of probability as shown in Table IX.

In the experiment near Mulhall the treatment differences for perennial and biennial broadleaf weed control in July, 1963 were highly significant as shown in Table X. Tritac, 2,4-D in combination with four pounds of maleic hydrazide, and the high rates of diuron and dacthal appeared to be the most effective.

In an experiment near Shawnee an evaluation of the pre-emergence treatments was made on July 8, 1964 as shown in Table XI. Tritac, tritac-D, simazine, and the high rate of diuron gave substantial reductions in weed stand. Highly significant differences were found in the control of broadleaf plants and weedy grasses by these herbicides. Differences in bermudagrass stand were found to be significant at the ten percent level of probability. In October there were highly significant differences among treatments in the control of broadleaf weeds as shown in Table XII. Dicamba and the higher rate of tritac-D appeared to be more effective than the other treatments tested. The statistical analysis of the data on bermudagrass control did not indicate a release of bermuda due to weed control.

In west central Oklahoma near Hydro tritac-D and tritac appeared to be the most effective treatments tested for broadleaf weed control as shown in Table XIII. When analyzed statistically, the treatment differences were found to be highly significant.

SOIL STERILIZATION ON HIGHWAY SHOULDERS AND AROUND GUARDRAILS

An evaluation of chemicals for soil sterilization along guardrails in an experiment near the Cimarron River showed that at least one rate of the following herbicides gave greater than ninety percent kill of bermudagrass in the treated band as recorded in June 1963: TCA, urox, Baron, and prometone (Table XVI). Ureabor, TCA, and prometone caused the most severe and unwanted kill downslope from the treated area.

In a similar experiment on the shoulder of SH-51 located near Stillwater there was severe sidekill of bermudagrass on June 11, 1963 in two replications or more with Borea T-10, chlorea, bromacil, and bromacil in combination with TCA. The sidekill problem was largely absent by October 26 at which time a high degree of control of bermudagrass on the shoulder was attained with the higher rates of Monobor-chlorate, bromacil, bromacil in combination with TCA, borocil, chlorea, and prometone as shown in Table XVIII. Of these treatments, only Monobor-chlorate failed to retain a high degree of bermudagrass control seven months later

Of the top twelve treatments with respect to bermudagrass control on SH-99 all moved downslope more than 5.3 feet with the exception of the lower rates of monuron and Borea T-10 as shown in Table XX. The results obtained in 1964 from the experiment on SH-51 near I-35 were similar in that those treatments which controlled the bermuda to a high degree also caused a high degree of sidekill.

In the experiment located on U.S. 270 near Mewoka the twelve treatments which gave 80 percent or greater control of bermudagrass caused sidekill of more than two feet with the exception of TCA and Monobor-chlorate.

Highly significant differences in weed control from soil sterilization were found in every experiment tested. It was of interest to note that the most toxic herbicides generally contained either a uracil or urea derivative in each of the experiments begun in 1964.

JOHNSONGRASS ERADICATION STUDY

The control of johnsongrass in May 1964 appeared to be complete where Monobor-chlorate-D had been applied at SH-33 or I-35, with the exception of one plot in each experiment as shown in Tables XXIV and XXV. When these data were analyzed statistically, the treatments were found to be significantly different at the five percent level of probability on SH-33 and at the one percent level in the study on I-35. Substantial control was attained with dalapon and DSMA although dalapon appeared to be more effective than DSMA in both experiments where the herbicides were applied to mowed plots. It was noted that both DSMA and dalapon were more effective where applied to mowed plots. However, treatments on unmowed plots seemed to be more effective than treatments on mowed plots throughout the rest of 1964 in the experiment on I-35 near the SH-51 junction. Up through September 22, 1964, the retreatments of that year did not increase the control which had been attained earlier. In the experiment initiated in 1964 near Tulsa dalapon and Monobor-chlorate both reduced the stand by 95 to 100 percent as recorded on October 15 (Table XXIX). The arsenicals reduced the stand by 90 to 96 percent where applied to unmowed plots.

CHAPTER VII

SUMMARY

The purpose of this research was to find effective and economical herbicides for weed control along Oklahoma highways. In the study of soil sterilization, efforts were made to prevent the growth of all plants around guardrails, signpost, and on highway shoulders.

Beginning in 1963 five experiments were conducted to evaluate selected herbicides for the control of weeds in grass-covered areas. Tritac and 2,4-D in combination with maleic hydrazide appeared to give a significant degree of weed control in 1963. However, simazine was the most effective herbicide in one of these experiments as recorded in June of that year. In 1964 two new chemicals, dicamba and tritac-D, were included in the weed control tests. Both of these herbicides ranked high, while tritac and simazine were respectively less effective, although all of these herbicides effected substantial reductions in weed stand. The results from one experiment in each year indicated that bermudagrass was released due to weed control. In other tests, either the absence of bermuda or drouth conditions interfered with the proper evaluation of this factor.

An evaluation of chemicals for soil sterilization around guardrails near the Cimarron River in June 1963 indicated that at least one rate of the following herbicides gave greater than 90 percent kill of bermudagrass in the treated band: TCA, urox, Baron, and prometone. However, with the rather fine performance of these materials within the treated band, it was noted also that ureabor, TCA, and prometone caused the most severe sidekill.

In the shoulder sterilization experiment on SH-51 near Stillwater, severe sidekill of bermudagrass was noted in at least two replications with Borea T-10, chlorea, bromacil, and bromacil in combination with TCA when evaluated in June, 1963. Later when this experiment was evaluated on October 26 it was noted that a high degree of control of bermudagrass was attained with the higher rates of Monobor-chlorate, bromacil, bromacil in combination with TCA, borocil, chlorea, and prometone. Of these treatments, only Monobor-chlorate did not retain a high degree of control up to June 17 of 1964.

In the soil sterilization experiments begun in 1964 those herbicides which were effective in the treated band resulted in severe sidekill generally. The herbicides which performed consistently in this way were chlorea, Borea T-10, monuron, bromacil, urox, and prometone. Either in the treated band or alongside the treated band, those herbicides which contained either monuron or a substituted uracil were toxic in each of these experiments. The treatment differences in the experiments involving soil sterilization were highly significant in all cases tested.

In the johnsongrass eradication experiments on I-35 and SH-33 the results from treatments made in 1963 as evaluated in May 1964 indicated a very high degree of control with Monobor-chlorate-D. Dalapon and DSMA effected a substantial reduction in stand, especially where applied to mowed plots. Retreatments during 1964 did not increase the control. In a similar experiment initiated in 1964 near Tulsa dalapon and Monobor-chlorate both reduced the stand by 95 to 100 percent as recorded on October 15. The arsenicals DSMA and CMA gave 90 to 96 percent control where applied to unmowed plots.

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APPENDIX A

PRECIPITATION RECORD FOR STILLWATER AND GUTHRIE, OKLAHOMA FROM MARCH 1 TO NOVEMBER 1, 1963.

DATE	GUTHRIE	STILLWATER	DATE	GUTHRIE	STILLWATER	DATE	GUTHRIE	STILLWATER
March 1	0.06	...	May 23	0.11	...	July 29	0.47	...
March 2	0.08	...	May 24	...	0.05	July 30	0.78	0.10
March 4	0.15	0.84	May 25	0.01	...	August 7	...	0.46
March 5	0.31	...	May 26	0.02	2.59	August 8	0.16	...
March 9	0.33	0.29	May 27	1.01	...	August 10	...	1.29
March 11	0.35	0.33	May 30	0.09	0.23	August 13	0.71	0.23
March 15	0.03	...	May 31	0.94	0.39	August 14	0.02	...
March 18	0.11	...	June 1	0.32	0.22	August 18	...	0.12
March 30	...	1.19	June 2	0.05	...	August 19	0.08	0.51
March 31	1.16	0.26	June 3	0.23	0.35	August 29	0.09	0.55
April 5	...	0.05	June 16	1.17	0.35	September 1	0.03	0.29
April 6	0.54	0.30	June 17	...	0.04	Sept. 2	0.03	...
April 18	0.12	0.34	June 18	0.04	0.01	Sept. 4	1.98	0.76
April 24	...	0.24	June 22	5.08	...	Sept. 5	0.19	...
April 25	0.58	2.01	June 23	0.48	0.81	Sept. 6	0.09	...
April 26	0.03	...	July 7	0.07	0.08	Sept. 7	...	0.47
April 27	0.88	0.25	July 8	0.01	...	Sept. 8	0.23	...
April 28	0.54	...	July 11	1.22	2.46	Sept. 10	0.09	...
May 5	0.52	0.05	July 12	0.07	...	Sept. 12	...	0.07
May 14	1.78	0.14	July 13	0.31	0.37	Sept. 16	0.02	1.31
May 17	...	0.19	July 14	0.04	...	Sept. 25	0.21	0.13
May 19	...	0.04	July 26	0.01	...	Sept. 17	3.66	...
May 20	0.14	...	July 27	...	1.51	October 16	0.60	0.93
May 22	0.01	0.10	July 28	2.66	0.33	October 20	0.56	1.13
0						October 21	0.45	...
						October 23	...	0.01

APPENDIX B

DAILY PRECIPITATION IN 1964

DATE	PERRY	SAND SPRINGS	WEST BRANCH	WEATHER-FORD	DRUM-RIGHT	GUTHRIE	PERKINS	SHAWNEE	STILLWATER	WEWOKA
March 18	0	0.13	0	0	0	0	0	0	0	0
March 19	0.52	0.72	0.35	0.25	0.50	0.40	0.38	0.60	0.69	0.00
March 20	0.19	0.02	0.16	0	0.26	0.18	0.33	0.25	0	0
March 21	0.05	0	0	0	0	0.01	0.02	0	0	0
March 25	0.04	0.02	0	0	0	0	0	0	0	0
March 28	0	0	0	0	0	0.03	0	0	0	0
March 30	0	0.07	0	0	0	0	0	0	0	0.12
March 31	0	0	0	0.01	0.08	0.08	0.04	0.13	0	0
April 2	0	0.01	0	0	0.04	0	0.04	0	0	0
April 3	0	0.30	0	0	0	0	0	0.13	0	0.03
April 4	0.63	4.40	0.95	0	0.45	0.49	1.18	0.49	0.78	0.42
April 5	0.06	0.20	0.53	0.0	0.91	0.20	0.23	4.08	0.36	2.00
April 11	0	0.04	0	0	0	0	0	0	0	0
April 12	0	0.05	0	0	0	0	0	0	0	0
April 13	0	0	0	0	0	0	0	0	0.06	0
April 17	0.09	0	0.10	2.20	0.15	0.57	0.32	0	0.16	0
April 18	0	0.28	0	0	0	0	0	0.05	0	0.21
April 20	0	0.10	0	0	0	0	0	0	0.06	0.15
April 21	0.20	0.11	0.21	0	0.35	0.21	0.22	0.45	0.08	0.23
April 24	0	0.10	0.81	0	0	0.25	0	0	0.14	0
April 25	0	0	0	0.02	0	0	0	0	0	0
April 26	0.16	0.23	0	0.10	0	0.09	0	0.09	0.07	0.07
April 27	0	0	0.22	0	0.22	0	0.04	0	0	0.14
April 29	0	0.02	0	0	0	0	0	0	0	0
April 30	0.01	0.03	0.03	0	0	0	0.02	0	0	0

APPENDIX B CONTINUED

DATE	PERRY	SAND SPRINGS	WEST BRANCH	WEATHER-FORD	DRUM-RIGHT	GUTHRIE	PERKINS	SHAWNEE	STILLWATER	WEWOKA
May 1	0	0.50	0	0	0	0	0	0	0.31	0
May 2	1.76	0.07	0.97	0.15	0.10	0.16	0.20	0.91	0.08	1.09
May 6	0.65	0.54	0.08	1.77	0.43	0.20	0.19	1.37	0.06	0.70
May 7	0.00	0.02	0	0	0	0	0	0	0	0.04
May 8	0	0.31	0.07	0.30	0.10	0.23	0.02	1.10	0.28	0.64
May 10	0	2.29	0	0.28	0	0.02	0	1.67	0	1.17
May 11	1.67	0	1.89	3.34	2.90	3.90	3.73	2.07	2.24	3.31
May 12	0.02	0	0	0	0	0	0	0	0.01	0
May 14	0	0.01	0	0	0	0	0	0	0	0
May 15	0.02	0	0	0	0	0.01	0	0	0	1.00
May 16	0	0	0	0	0.05	0.05	0	0	0	0
May 27	0	0.55	0	0.25	0	0	0	0	0.28	0
May 28	0.79	0	0.32	0	0.48	0.37	0	0.74	0	0
May 29	0	0.03	0	0	0	0.11	0	0.12	0.38	0.39
May 30	0.73	0.45	0.70	2.70	0.76	1.00	0.89	1.49	0.36	1.29
May 31	0.23	0	0.20	0.07	0.15	0.18	0.25	0.09	0.04	0.10
June 2	0.22	0.45	0.20	0	0.10	0	0.04	0	0.11	0
June 3	4.04	0.09	0.06	0	0.04	0.16	0.07	0.07	0	0
June 4	0	0.09	0	0.07	0	0	0109	0	0.13	0
June 5	0.17	0.06	0.15	0.07	0	0.07	0.08	0.77	0.06	0
June 7	0	0.56	0.43	0	0	0	0.01	0	0.09	0
June 11	0.25	0	0	0.51	0	0.40	0	0	0.12	0
June 12	0	0.20	0	0.15	0*	0	0	0	0.02	0.19
June 13	0.15	0.05	0.22	1.34	0.05*	0	0	0	0.27	0
June 14	0.16	0.65	1.32	0	0	0.08	0.22	0	0	0
June 15	0.04	0.79	0.39	0.06	0	0	0	0	0	0
June 16	0	0	0.69	0	0	0	0	0	0	0
June 17	0.04	1.21	0.16	0	0	0	0.01	0.17	0.01	0.65
June 18	0	0	0	0	0.10*	0	0	0	0	0

* This data was collected at the experimental site; other entries were taken from the nearest weather station.

APPENDIX B CONTINUED

DATE	PERRY	SAND SPRINGS	WEST BRANCH	WEATHER-FORD	DRUM-RIGHT	GUTHRIE	PERKINS	SHAWNEE	STILLWATER	WEWOKA
June 21	0	0	0	0.05	0	0	0	0	0	0
June 22	0	0.09	0	0	0	0	0	0	0	0
June 23	0.40*	0.43	0.13	0.20	0.30*	0.28	0.20	0.62	0.50*	1.25
June 24	0	0	0	0	0	0	0	0.32	0	0.53
June 28	0	1.00	0	0	0	0	0	0	0	0
June 29	0	0	0.33	0	0*	0	0.90	0	0	0
June 30	0	0.12	0	0	0*	0	0	0	0	0
July 1	0	0.15	0.06	0.02	0	0.03	0.03	0	0*	0
July 2	0	0	0.18	0	0	0	0.10	0	0.07	0
July 8	0	0.15	0	0	0	0	0	0*	0	0
July 9	0	0.23	0	0.90	0	0	0	0.20*	0*	0
July 10	0	0	1.07	0.11	0	0	0.45	0.22	0*	0
July 12	0	0.05	0	0	0	0	0	0	0	0
July 13	0	0	0	0.02	0	0.16	0	0	0.03	0
July 25	0	0.20	0	0	0	0	0	0	0	0
July 26	0	1.02	0	0	0	0	0	0	0.01	0.06
July 27	0.80*	0	0	0	0*	0	0.68	0*	0*	0*
July 28	0	0	0*	0	0.40*	0	0.07	1.30*	0*	0*
July 29	0	0	0	0	0	0.08	0.41	0	0.04	0
August 6	1.25*	0	0.43*	0	0	0	0	0	1.42*	0.06
August 7	0	0	1.58	0.13	1.08	0.47	0.50	0	0.27	0
August 8	0	0	0.01	0	0	0	0	0.51*	0	0
August 10	0	0.32	0.19	0	0	0.02	0.02	0	0.10	0
August 11	0	0.03	0	0	0.05	0	0	0	0	0
August 13	1.10*	0.01	0*	0	0	0.06	0	0.03	0	0.04
August 14	2.20*	1.21	0	0	2.10*	0.02	0	2.50*	2.40*	2.20*
August 15	3.65	0.63	0	1.35	0	1.13	1.85	0	0	0
August 16	0	0	0	0	0	0	0.02	0	0	0
August 17	1.60*	0	2.50*	0	0.80*	0	0	0.90*	0.50*	0.60*
August 18	1.15	0.14	1.25	1.85	0	1.01	0.75	0	0	0

* These data were collected at the experimental site; other entries represent the nearest weather stations.

APPENDIX B CONTINUED

DATE	PERRY	SAND SPRINGS	WEST BRANCH	WEATHER-FORD	DRUM-RIGHT	GUTHRIE	PERKINS	SHAWNEE	STILLWATER	WEWOKA
August 20	0*	0*	0*	0	0*	0	0	0.30*	0*	0.60*
August 21	0	0*	0.06	0.10	0.07	0.02	0.03	0.34	0	0
August 24	0.20*	0*	0.40*	0	0.40*	0	0	0*	0*	1.20
August 25	0*	0.26*	0.15*	0	0.40*	0	0.26	1.35*	0*	0.11*
August 26	0.72*	0.40*	1.40*	0	0*	0.53	0	0*	0.72*	0*
August 27	1.20	1.00*	0.90*	0.42	1.20*	0.01	1.91	0	0	0
August 28	0.61	2.12	1.10	0.59	1.75	1.64	1.53	1.00*	0.34	0.65*
August 29	0	0.93	0	0	0	0	0	0	0	0
August 30	0.00	0.02	0.60	0	0	0	0	0	0.15	0
August 31	0.05	0	0.05	0	0.13	0	0	0.13	0	0
September 5	0	0.78	0	0.06	0	0	0	0	0	0
September 6	0.02	0	0	0	0	0	0	0	0	0.06
September 11	0.65*	0.35*	1.70*	0.17	0.60*	0.29	1.25	0.00	0.80*	0*
September 12	0	0	0.25	0	0	0.08	0.42	2.50*	0	0
September 15	0	0.04	0	0.16	0	0	0	0	0.02	0
September 16	0.05	0.34	0.08	1.01	0.25	0.42	0.32	0.53	0.14	0
September 17	0.85	0	0.27	0	0.35	0.67	0.17	0.51	0.19	0.57
September 20	0	0.05	0	2.00	0.06	0.18	0.36	1.21	0.07	0.77
September 21	0.01	0.07	0.06	0.15	0.06	0.05	0.11	0.37	0.05	0.51
September 22	0.16	1.17	0.34	0.02	0.17	0.62	0.11	0.47	0.25	0.95
September 23	0.22	0	0.10	0	0.07	0.32	0.11	0.09	0	2.00
September 26	0	0.38	0	0	0	0	0	0.05	0	0
September 27	0.53	0	0.33	0.33	0.25	0.06	0.18	1.21	0	1.09
September 28	0	0	0	0	0	0	0	0	0	0.06
October 12	0.01	0.74	0	0.02	0.13	0.09	0.10	0.59	0	0.70
October 13	0.03	0	0	0.02	0	0.02	0	0.10	0.05	0.15
October 14	0	0	0.12	0	0	0	0.22	0.11	0	0
October 25									0.36	0.04
October 26									0.13	0

* These data were collected at the experimental site; other entries represent the nearest weather stations.

APPENDIX B CONTINUED

DATE	STILLWATER[1]	WEWOKA[1]
November 3	0.01	0
November 4	1.75	1.73
November 5	0.12	0.02
November 6	0.22	0.56
November 7	0.61	0
November 12	0.09	0
November 15	0.28	0

APPENDIX C

ILLUSTRATION OF THE FRIEDMAN METHOD OF ANALYSIS FOR DATA ARRANGED IN A TWO-WAY CLASSIFICATION

In this example, Table A contains an example of raw data. Assume that the data represents control of weeds on a scale for which ten indicates complete control and zero indicates no control. Table B contains the rank for each treatment within each replication as well as the summation of ranks for each treatment. Each of these sums is squared and a total sum of squares is calculated as shown. The calculated chi-square is derived as shown.

Table A

Treatment No.	Replication I	II	III	IV
1	2	8	1	8
2	1	3	5	9
3	7	4	2	10
4	7	3	9	8
5	3	1	9	5

Table B

Treatment No.	Replication I	II	III	IV	Rank Sum	(Rank Sum)^2
1	4	1	5	3.5	13.5	182
2	5	3.5	3	2	13.5	182
3	1.5	2	4	1	8.5	72
4	1.5	3.5	1.5	3.5	10.0	100
5	3	5	1.5	5	14.5	210
						746

$$\text{Chi-square} = \frac{12}{KJ\ (J+1)} \left[\sum_j T_j^2 \right] - 3K\ (J+1)$$

Where K= no. of replications
J= no. of treatments
T_j= rank sum of the jth treatment

$$= \frac{12}{4 \cdot 5 \cdot 6}\ (746) - 3 \cdot 4 \cdot 6 = 2.6$$

This calculated value is compared with the tabulated value for J-1 degrees of freedom. The tabulated value (Probability 0.10) for four degrees of freedom is 7.779. The hypothesis of no difference among the J treatments is not rejected. Had the calculated value been larger than the tabulated value for P = 0.10, the hypothesis would have been rejected.

VITA

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