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Seasonal Response of Honey Mesquite to Herbicides

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SUMMARY

Honey mesquite (*Prosopis juliflora* (Swartz) DC. var. *glandulosa* (Torr.) Cockerell) was sprayed with 0.56 + 0.56 kilogram per hectare[1] (kg/ha) of picloram (4-amino-3,5,6-trichloropicolinic acid) + 2,4,5-T (2,4,5-trichlorophenoxy) acetic acid) or 1.12 kg/ha of 2,4,5-T at 22 dates during 1972 and 1973. Honey mesquite was most effectively controlled during late April, May, and June. With this and another 2-year study, at the 17 best dates, picloram + 2,4,5-T alone reduced the canopy 92 percent and killed 59 percent of the plants, while 2,4,5-T was less effective, reducing the canopy 66 percent and killing 5 percent of the plants. Over 36 dates from March 24 to October 9, during a 4-year period, percent honey mesquite canopy reduction was directly correlated with total phloem thickness, rate of new xylem ring radial growth, and rate of upward methylene dye movement in the xylem, and was inversely correlated with minimum leaf moisture stress. In simple regression equations, for all 36 dates from March 24 to October 9, rate of new xylem radial growth gave the best predictive equation. For 33 dates between April 29 and August 31, the best equation contained soil moisture level at a depth of 91 centimeters (cm), minimum leaf moisture stress, or rate of upward methylene blue dye movement. At 13 increasingly effective early season dates, control was best predicted by soil temperature at a depth of 91 cm. At 22 decreasingly effective summer dates, control was best predicted by minimum leaf moisture stress for percent canopy reduction by both herbicides and by rate of new xylem ring radial growth for percent plants killed by picloram + 2,4,5-T. Rate of new xylem ring radial growth and thickness of translocating phloem were the factors appearing most often in the equations.

[1]See Appendix for equivalent English units.

Seasonal Response of Honey Mesquite to Herbicides

R. E. Meyer*

Honey mesquite varies widely in its response to herbicides. In some cases almost all plants are killed by a given treatment; at other times very few plants are killed. In west Texas, when growing conditions are favorable, 0.56 kilogram per hectare (kg/ha) of 2,4,5-T generally destroys most top growth and kills about 25 percent of the plants (5). The most effective treatments have occurred 50 to 80 days after the first leaves appeared in the spring when the leaves were fully formed and dark green. Treatments have been ineffective when applied before this time or during summer and fall when the plant was not actively growing.

Dahl et al. (2) found that soil temperature of 27° C and above at the 46-centimeter (cm) depth was the most important factor affecting the response of honey mesquite to 2,4,5-T. No plants were killed when soil temperature was in the low 20's C or below. Plants most easily killed were those having mature, dark-green foliage and mature legumes. Trees on upland and sandy soils were apparently more susceptible to 2,4,5-T than were those on bottomland and clay sites because of the difference in soil temperature.

Robison, Fisher, and Cross[2] and Fisher et al. (6) have shown that honey mesquite is more susceptible to mixtures of picloram + 2,4,5-T than 2,4,5-T alone. In six ranch tests, picloram + 2,4,5-T at 0.28 + 0.28 kg/ha killed an average of 52 percent of the plants compared to 21 percent for 0.56 kg/ha of 2,4,5-T alone. Thus, factors were present that prevented the death of all plants. Meyer et al. (10) found that picloram alone and picloram + 2,4,5-T (1:1) at 0.56- and 1.12-kg/ha rates were equally effective and more effective than 2,4,5-T at the same rates.

Meyer et al. (11) showed that the toxic agents from 2,4,5-T, picloram, and picloram + 2,4,5-T sprays were translocated from the leaves to the stem of honey mesquite within 4 days after application. Brady (1) found herbicide applications in May to be more effective than those made later in the growing season on sweetgum (*Liquidambar styraciflua* L.), green ash (*Fraxinus pennsylvanica* Marsh.), and water oak (*Quercus nigra* L.). Effective killing of plant tops was attributed to the high rates of absorption and translocation of the herbicide. A 4-day absorption period was closely correlated with the control of top growth 1 year later. Davis et al. (3) sprayed honey mesquite with 0.56- and 1.12-kg/ha per acre rates of 2,4,5-T, picloram, and a mixture of picloram + 2,4,5-T. After 48 hours, highest concentrations of herbicides occurred in the phloem of those plants sprayed in June and lowest in those sprayed in August. Similar levels of 2,4,5-T occurred in the phloem from application of either 0.56 or 1.12 kg/ha, but more than three times as much picloram occurred in plants sprayed with 1.12 kg/ha as in those sprayed with 0.56 kg/ha.

At College Station, Texas, honey mesquite leaves begin emerging about the end of March (13). Emergence is probably controlled by environmental conditions of high temperatures (9). The new stems elongate for approximately 1 month beginning about the first of April and continuing until tip aboration occurs (13). Then the plant enlarges radially in May and June, producing new translocating phloem and a new xylem growth ring. Fisher, Fults, and Hopp (4) and Meyer, Haas, and Morton[3] showed that upward translocation of dye occurred in the new, outermost xylem ring of honey mesquite; the dye streak widened from about 0.4 cm at the point of

Robison, E. D., C. E. Fisher, and B. T. Cross. 1970. Control of mesquite and associated west Texas brush with 2,4,5-T/picloram combinations. Proc. South. Weed Sci. Soc. 23:219 (Abstr.).

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[3]Meyer, R. E., R. H. Haas, and H. L. Morton. 1965. Mesquite stem, its structure, seasonal growth characteristics, and area of active xylem dye movement. Proc. South. Weed Sci. Soc. Conf. 18:632 (Abstr.).

injection to about a 5-cm width at 1.2 meter (m) and moved about 52 cm per hour.

Meyer, Haas, and Wendt (12), using greenhouse plants under controlled conditions, showed that either low soil temperature (13° C) or cool aerial environment (11° to 25° C) retarded shoot growth; however, maximum shoot growth occurred as a result of an interaction of optimum soil temperature (29° C) and aerial environment of 20.9 millimeters (mm) vapor pressure deficit (23° to 40° C).

Several workers studied the total available carbohydrate level in honey mesquite stems and roots (5, 14, 15). Total available carbohydrate level was lowest in May. At this time the partial drain of food reserves was used for leaf and floral production and radial enlargement of stems and roots.

Haas and Dodd (8) studied water stress of the honey mesquite leaf petiole. They showed a diurnal pattern of low stress at pre-dawn and post-sunset periods and high stress during the day. A gradual increase in stress occurred at all three periods throughout the season when leaves were present. Meyer et al. (10) found similar results in untreated plants; herbicides slightly reduced stress levels during the maximum stress periods for 2 or 3 days before the leaf was killed.

Meyer et al. (10) found that most effective control of honey mesquite occurred from treatments with picloram, picloram + 2,4,5-T, and 2,4,5-T applied between April 30 and July 6. Generally, thickness of translocating phloem, rate of upward dye movement in the xylem, lower minimum relative humidity, high soil moisture, and higher rainfall before spraying were directly correlated with higher plant control, while measurements of new xylem thickness, air temperature, maximum relative humidity before spraying, maximum soil temperature, rainfall after spraying, and leaf moisture stress were inversely correlated with high percentage control by herbicide treatments.

The objectives of this study were to develop a reliable means of estimating the ultimate response of honey mesquite to herbicides and to determine the interrelationships of various plant and environmental variables. This study is similar to that of Meyer et al. (10); major differences are that this was conducted on a different site, the number of chemical treatments was reduced from six to two, the number of dates sprayed was increased from 14 to 22, and the percentage of spraying dates was increased during the May, June, and July period. Appropriate data from both experiments were combined.

MATERIALS and METHODS

Experimental Site and Plot Layout

A 13-ha site near Millican, Texas, with a dense stand of honey mesquite plants 1.2 to 2 m tall was selected. Most honey mesquite plants had three t five stems that had emerged near the base of th plant.

The area was an upland site with a 1- t 3-percent slope. The soil was a Wilson clay loam About 1,200 plants were tagged in groups of five with at least a 1-m space between plants from adjoin ing plots. Five replications of plants were used fo each of two treatments at each of 22 dates listed i Table 1 during the 1972 and 1973 period. A factori design was used.

Chemical Applications and Control Ratings

The herbicide treatments included a 0.56 + 0.56-kg/ha rate of picloram + 2,4,5-T and a 1.12 kg/ha rate of 2,4,5-T alone. The potassium salt o picloram and the propylene glycol butyl ether este of 2,4,5-T were applied in water containing 0.1 per cent volume per volume (v/v) of the surfactant, Mu tifilm X-77, containing alkylarylpolyoxyethylen glycols, free fatty acids, and isopropanol.

The herbicides were applied either in the eve ning or early morning with a hand-carried compres sed air, three-nozzle boom sprayer. The herbicide were applied at a spray volume of 187 liters per hec tare (L/ha).

Visual ratings of percent canopy reduction which measure the amount of stem tissue killed and percent dead plants were made July 31, 1973 and May 28, 1974, the season following spraying.

Plant Characteristics

New stem length was measured at weekly inte vals after the onset of elongation growth in March Plant characteristics measured at each spraying dat included transectional dimensions of stem tissue o the day of spraying, rate of upward movement o dye in the stem xylem within a day of spraying, pe cent total available carbohydrates in the stem th day of spraying, and minimum and maximum lea moisture stress within a day of spraying.

Unsprayed plants in the experimental area wer used for all measurements. For the most part, th same methods were used in this study as used b Meyer et al. (10). Five new stems were tagged o each of five trees and measured at weekly interval until May, when elongation growth had stopped Stem tissue transectional dimensions were mea sured from pieces of stem cut 15 to 30 cm above th ground from 10 trees. Thicknesses of the perider total and translocating phloem, and xylem growt rings were measured. Rate of new xylem ring radia growth during the 2-week period before sprayin was calculated from the total new ring thicknes measurements taken during the growing season.

Rate of upward methylene blue dye movemen was determined in 20 trees at each date. A 0.1-per cent aqueous methylene blue dye solution was in fused into the stem xylem from a transfusion bottl equipped with a No. 16 hypodermic needle. The needles were inserted under the bark between 9:00 and 9:30 a.m. CST and removed 30 minutes later. The rate is presented as cm/hr.

Percent total available carbohydrates was determined from stem samples cut 15 to 30 cm above the ground from 5 to 10 trees. The bark was peeled and xylem segments from the outermost 1 to 2 mm of xylem were ground to pass a 23.6-mesh/cm sieve. A spectrophotometric method was used (15). The stem tissue was digested in 0.2 N HC1 for 2 hours, the mixture was filtered through activated charcoal, a green color was developed by adding an anthrone reagent, the solution was heated to 97° C for 10 minutes, and the light absorption of the cooled solution was read at 612 millimicrons ($m\mu$). Samples collected in 1969 and 1970 by Meyer et al. (10) were also analyzed by this method, and the results were used for statistical computations.

Moisture stress in the leaves was determined with a Scholander pressure apparatus (8). Moisture stress was determined in 20 mature (when available) leaves collected from four or five plants. The minimum readings were made before dawn at 4 to 5 a.m. CST, and the maximum readings were taken 10:30 to 11:30 a.m.

Environmental Variables

Environmental variables measured included mean air temperature the day of spraying and the 1-week period before spraying; mean soil temperature at depths of 30 and 91 cm the week of spraying; percent soil moisture at depths of 0 to 30 (hereafter 30), 31 to 61 (hereafter 61), and 62 to 91 (hereafter 91) cm the week of spraying; and rainfall the 1-week and 1-month periods before spraying.

Mean air temperatures were recorded at the site with a hygrothermograph. Soil temperatures were taken with a recording soil thermograph. Soil moisture was determined weekly using gravimetric analysis; five cores were dug with a screw-type auger (7). Rainfall data collected at College Station, about 26 kilometers (km) away, were used for the determination of rainfall.

Statistical Analyses

An analysis of variance and Duncan's multiple range test were calculated to determine significance for percent canopy reduction and percent dead plants using a factorial design.

A complete set of simple correlations was calculated for all combinations of herbicide treatments (0.56 + 0.56 kg/ha of picloram + 2,4,5-T and 1.12 kg/ha of 2,4,5-T), plant characteristics, and environmental variables in this and in the 1969 and 1970 study by Meyer et al. (10).

Regressions were calculated to develop an indicator for predicting plant response to herbicides at any given date with plant characters and environmental factors. Also, the number of days from January 1 to the spraying date (T) and the time period (T) squared (T^2) factors were added to account for the curvilinear response of honey mesquite to herbicides with time. A maximum R^2 improvement regression analysis was used. Equations were calculated with the best one- and three-plant and environmental variables. Means for all treatment replicates were used for herbicide responses in all correlation and regression analyses.

RESULTS and DISCUSSION

Plant Response to Herbicides

Within 4 days after spraying, most leaves of plants sprayed with picloram + 2,4,5-T had remained intact, turned brown, and died. By 7 days, all leaves were dead. Leaves of plants sprayed with 2,4,5-T turned yellowish-green by the end of the third day. Some defoliation occurred, with the leaflets first detaching from the rachises. By the end of 7 days, the remaining portions of the leaves were dead. Death of the foliage generally occurred a day or two sooner when the plants were sprayed in late summer than in April or May.

In this study, picloram + 2,4,5-T at 0.56 + 0.56 kg/ha caused more canopy reduction and killed more plants than 2,4,5-T at 1.12 kg/ha (Table 1). In 1972, picloram + 2,4,5-T reduced the plant canopy most from April 29 to June 5, while in 1973 the mixture reduced plant canopy most from May 8 through June 22. The period for largest percentage of plants killed occurred during a slightly shorter interval than for most effective canopy reduction. The 2,4,5-T treatment caused the greatest amount of canopy reduction on May 21 in 1972 and during the period of May 16 through June 22 in 1973. Thus, both treatments were most effective in late April, May, and June. This period corresponds to the recommended 50 to 80 days after bud break for spraying honey mesquite. The 2,4,5-T treatment killed no significant numbers of honey mesquite plants at any date in either year. These results are similar to those in a 1969 and 1970 study by Meyer et al. (10). Plant control was slightly greater in this study because a greater proportion of the applications was made during the susceptible treatment period.

Figure 1 shows the seasonal response of honey mesquite during the 4-year period (1969, 1970, 1972, and 1973). The data are plotted as the means of all treatments applied during the first and last half of each month. Plant control attains maximum effectiveness in late April, remains more or less constant during May and June, and then decreases rather rapidly later in the season. This general seasonal response curve is well known; however, on lighter soils, the 2,4,5-T treatment usually kills a significant number of plants.

Table 1. Percent canopy reduction and dead honey mesquite sprayed with two herbicides at 22 dates during 1972 and 1973 at Millican, Texas[1]

Date of spraying	Picloram + 2,4,5-T Canopy reduction (%)	Picloram + 2,4,5-T Dead plants (%)	2,4,5-T Canopy reduction (%)	2,4,5-T Dead plants (%)
		1972		
April 29	92 abcd	70 abc	55 klm	10 hi
May 8	96 ab	80 ab	61 jk	8 hi
May 14	95 ab	72 abc	62 ijk	4 hi
May 21	97 a	72 abc	76 fgh	4 hi
June 5	93 abcd	56 bcd	55 klm	0 i
June 12	81 def	36 defg	56 klm	0 i
June 19	81 def	24 efghi	53 klm	0 i
July 6	79 efg	36 defg	55 klm	0 i
July 19	72 fghij	16 fghi	41 n	0 i
July 31	44 lmn	8 hi	37 n	0 i
		1973		
May 8	94 abc	56 bcd	62 ijk	0 i
May 16	97 a	84 a	75 fghi	8 hi
May 29	94 abc	72 abc	78 efgh	12 ghi
June 7	84 bcdef	48 cde	67 ghijk	4 hi
June 20	97 a	84 a	66 ghijk	4 hi
June 22	89 abcde	40 def	66 ghijk	0 i
June 26	81 def	20 fghi	62 jk	0 i
July 4	78 efgh	16 fghi	57 kl	0 i
July 12	82 cdef	28 efgh	44 lmn	0 i
July 23	56 klm	0 i	33 np	0 i
August 13	21 q	0 i	23 pq	0 i
August 31	18 q	0 i	17 q	0 i
Mean	78 x	42 s	55 y	2 t

[1]Values in columns for canopy reduction of both herbicides, dead plants for both herbicides, and in the horizontal line for mean of canopy reduction for both herbicides or dead plants for both herbicides not followed by the same letter are significantly different at the 5% level using the Duncan's multiple range test. Ratings were made July 31, 1973, and May 28, 1974, for the 1972 and 1973 treatments, respectively.

Plant Characteristics

New stems were initiated between March 15 and April 1, and they elongated rapidly until about April 30. In 1972, the 25 new stems averaged 30 cm in length by April 29 and showed no further growth. The 25 stems tagged in 1973 averaged 18 cm by May 3 and grew no further. The stem tips died and aborted after elongation ceased. No new stems were produced during either year. Thus, stem elongation almost ceased before maximum plant control was obtained.

Stem transections measured at each spraying date were 15 to 21 mm in diameter. Annual radial stem growth occurred largely in the xylem. The new xylem ring began developing about the middle of April and attained a maximum thickness of 1.64 mm on July 31, 1972, and 1.58 mm on July 12, 1973 (Table 2). The xylem ring essentially ceased enlarging radially in the middle of July.

The other stem tissue thicknesses varied somewhat; however, they fell in the following ranges: periderm — 0.16 to 0.29 mm; total phloem — 0.53 to 0.87 mm; translocating phloem — 0.12 to 0.37 mm; and mean for xylem rings other than that produced the current year — 1.12 cm in 1972 and 1.71 mm in 1973.

Upward movement of methylene blue dye occurred almost entirely in the outermost xylem ring. The most rapid dye movement occurred during May when the leaves had just fully matured (Table 2). The dye movement during this period was generally greater in 1973 than either in 1972 or in 1969 and 1970 (10). Warm mornings with full sunlight and adequate soil moisture seemed to promote the most rapid dye translocation.

Total available carbohydrates varied from 17.0 to 25.8 percent (Table 2). In 1972, the total available carbohydrate level was low only on April 29. In 1973, the carbohydrate level increased progressively from May 8 to a maximum on June 20 and 22. The data for percent total available carbohydrate levels in the stem samples collected in 1969 and 1970 (10) and assayed using the spectrophotometric method were the following: March, 27.7 percent; April, 13.8 percent; May, 18.4 percent; June, 28.4 percent; July 22.3 percent; August, 21.9 percent; and October, 21.6 percent. Normally the carbohydrate level is low only during the period of abundant leaf, flower, and fruit production and elongation and radial enlargement of the stem. In this study the low levels occurred either before or during the early part of the best spraying period.

Moisture stress levels in leaves have a daily cycle (8, 10), being at a minimum at night and reaching a maximum during late morning through the afternoon. Minimum (pre-dawn) moisture stress was lowest at the earliest spraying dates and increased gradually during late April, May and June, and then accelerated in July and August (Table 2). Minimum stress varied from 6.9 to 13.8 bars. Maximum leaf moisture stress was normally two to three times higher than minimum stress. Maximum stress levels increased rapidly from late April to the middle of May and then increased only slightly thereafter. The levels varied from 15.8 to 32.4 bars.

Environmental Variables

Over both years, the range of mean air temperature the 1-week period before spraying during April, May, and June varied from 19° to 28° C (Table 3). Temperature increased progressively at least during May and June.

Soil temperature at 91 cm increased from about 20° to 23° C in early May to 26° C by May 21 to 29. High temperatures of 28° or 29° C were first obtained June 5 to July 12. No soil temperature above 29° C occurred through August 31. In this study, soil temperature at the 30 cm depth (data not shown) re-

Table 2. Plant characteristics at 22 dates of spraying honey mesquite at Millican, Texas

Date sprayed	Phloem thickness: Total (mm)	Phloem thickness: Trans-locating (mm)	Xylem ring thickness: Total for year (mm)	Xylem ring thickness: Rate of growth (mm/2 wk)	Rate of upward dye movement (cm/hr)	Total available stem carbohydrates (%)	Leaf moisture stress: Predawn (bars)	Leaf moisture stress: Midday maximum (bars)
					1972			
April 29	0.53	0.12	0.19	0.19	143	18.2	8.4	15.8
May 8	.65	.14	.75	.21	192	23.5	9.0	24.7
May 14	.67	.13	.71	.25	180	23.1	9.1	24.0
May 21	.87	.25	.63	.25	169	25.1	8.5	25.7
June 5	.63	.18	.75	.24	92	24.2	9.7	28.9
June 12	.74	.22	1.18	.25	122	23.6	8.7	23.5
June 19	.65	.16	1.29	.25	148	23.2	9.4	25.9
July 6	.67	.29	1.32	.25	43	24.5	12.8	30.3
July 19	.71	.34	1.59	.25	105	25.6	11.1	28.1
July 31	.57	.29	1.64	.05	67	25.6	11.8	32.4
					1973			
May 8	.61	.37	.16	.16	328	17.0	7.7	19.2
May 16	.65	.25	.34	.34	332	17.2	7.2	17.7
May 29	.70	.21	.49	.29	307	18.4	10.4	24.2
June 7	.54	.19	.89	.30	157	21.0	8.5	24.2
June 20	.61	.24	1.06	.30	113	25.8	6.9	22.2
June 22	.61	.24	1.06	.30	113	25.8	6.9	22.2
June 26	.61	.23	1.20	.30	79	25.5	9.3	22.4
July 4	.79	.26	.97	.23	113	25.3	6.9	25.9
July 12	.55	.24	1.58	.08	88	23.0	9.3	22.3
July 23	.66	.26	1.22	.07	68	24.4	10.8	26.9
Aug 13	.69	.29	1.55	.07	55	24.4	12.6	26.8
Aug 31	.58	.24	1.21	.07	31	25.6	13.8	26.1

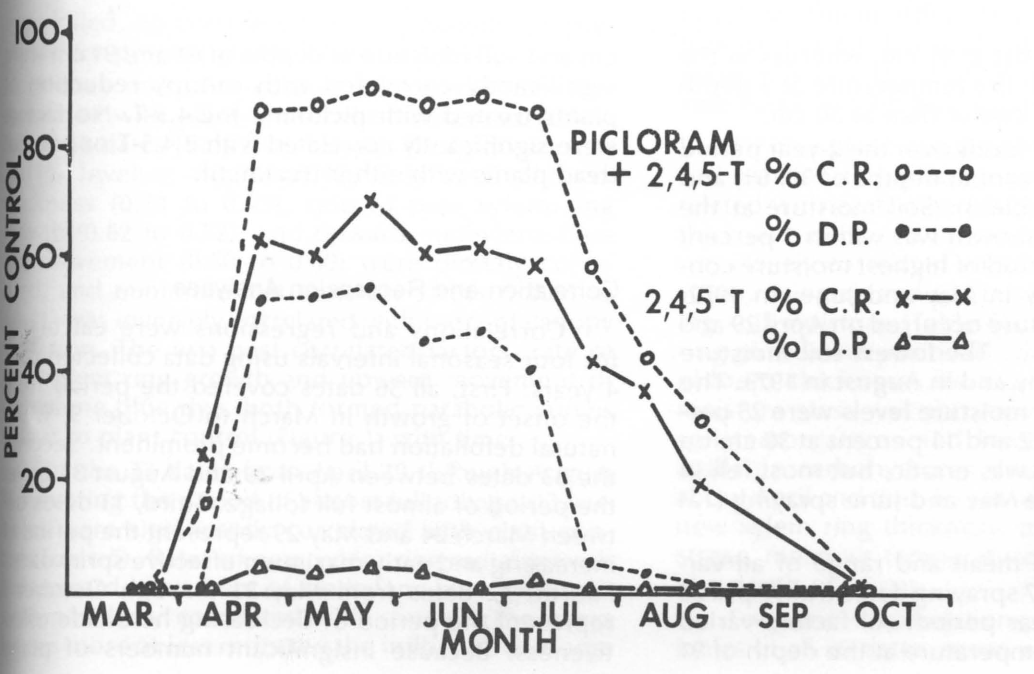

Figure 1. Influence of 0.56 + 0.56 kg/ha of picloram + 2,4,5-T and 1.12 kg/ha of 2,4,5-T on percent canopy reduction (% C.R.) and percent dead honey mesquite plants (% D.P.) treated on 36 dates during 1969, 1970, 1972, and 1973 at Bryan and Millican, Texas.

Table 3. Environmental conditions at 22 dates of spraying honey mesquite at Millican, Texas[1]

Date sprayed	Mean air temperature 1 wk before spraying[2] (°C)	Soil temperature at 91 cm[3] (°C)	Soil moisture 30 cm (%)	Soil moisture 91 cm (%)	Rainfall 1 wk before spraying (cm)	Rainfall 1 mo before spraying (cm)
1972						
April 29	21	22	15	18	2.2	3.8
May 8	22	23	20	21	2.6	6.2
May 14	21	24	22	22	11.6	17.8
May 21	23	26	18	21	2.5	19.6
June 5	24	28	11	17	.0	15.6
June 12	25	28	23	24	.7	11.1
June 19	27	28	19	19	8.5	9.2
July 6	27	29	17	18	.2	8.5
July 19	28	28	15	16	.5	1.8
July 31	29	28	14	14	.1	3.8
1973						
May 8	19	20	21	23	3.6	16.6
May 16	21	23	21	23	1.3	12.0
May 29	25	26	13	22	.2	5.2
June 7	26	27	19	22	6.9	11.2
June 20	28	26	22	22	.3	20.6
June 22	27	26	22	22	.6	20.9
June 26	25	26	18	22	.6	20.7
July 4	28	27	14	21	.0	18.4
July 12	28	28	16	20	1.5	13.6
July 23	29	28	12	18	.0	2.5
August 13	28	29	12	16	.5	6.1
August 31	28	28	12	14	.1	2.9

[1]Soil temperature and moisture were measured the week of spraying. Air temperature was measured the day and 1-week period before spraying. Rainfall was recorded the 1-week and 1-month period before spraying.

[2]Mean air temperature the day of spraying was no more than 3 degrees different from the mean of the 1-week period before spraying.

[3]Soil temperature at 30 cm did not vary from soil temperature at 91 cm by more than 2°C at any date.

mained within 2° C of that at 91 cm, whereas in the 1969 and 1970 study (10) the temperature at a depth of 91 cm was 3° to 6° C cooler than at 30 cm.

Mean soil moisture levels over the 2-year period were 17, 19, and 20 percent at depths of 30, 61, and 91 cm, respectively (Table 3). Soil moisture at the 61-cm depth (data not shown) was within 3 percent of that at 91 cm. The period of highest moisture content occurred generally in May and June. In 1972, however, low soil moisture occurred on April 29 and June 5, as well as in July. The lowest soil moisture occurred during late July and in August in 1973. The highest and lowest soil moisture levels were 25 percent at 61 cm on June 12 and 11 percent at 30 cm on June 5 in 1972. Rainfall was erratic, but most fell in the periods prior to the May and June spraying (Table 3).

Table 4 shows the mean and range of all variables during the best 17 spraying dates from April 29 to July 6 over the 4-year period. All factors varied widely, and only soil temperature at the depth of 91 cm and soil moisture at depths of 61 and 91 cm were significantly correlated with canopy reduction of plants treated with picloram + 2,4,5-T. No factors were significantly correlated with 2,4,5-T or percent dead plants with either treatment.

Correlation and Regression Analyses

Correlations and regressions were calculated for four seasonal intervals using data collected over 4 years. First, all 36 dates covered the period from the onset of growth in March to October 9, when natural defoliation had become prominent. Second, the 33 dates between April 29 and August 31 cover the period of almost full foliage. Third, 13 dates between March 24 and May 29 represent the period of increasing and early maximum effective spray dates. Fourth, 22 dates from May 21 through October 9 represent the period of decreasing herbicide effectiveness. Because insignificant numbers of plants

Table 4. Means and range of honey mesquite control, plant characteristics, and environmental variables at the 17 best spraying dates occurring from April 29 to July 6 during 1969, 1970, 1972, and 1973

Variable	Mean	Minimum	Maximum
2,4,5-T, % canopy reduction	66	50	78
2,4,5-T, % dead plants	5	0	15
Picloram + 2,4,5-T, % canopy reduction	92	77	97
Picloram + 2,4,5-T, % dead plants	59	15	84
Upward Methylene dye movement, cm/hr	155	28	332
Leaf moisture stress (bars)			
Minimum	8.5	6.5	11.1
Maximum	24.1	13.6	30.2
Phloem thickness, mm			
Total	.59	.37	.87
Translocating	.18	.08	.37
New xylem ring thickness, mm			
Total	.74	.16	1.59
Rate during 2-wk period before spraying	.25	.10	.36
Total available carbohydrates, %	21.8	12.0	30.4
Mean air temperature, °C			
Day of spraying	23.9	19.0	32.0
1 wk-period before spraying	23.7	19.0	30.0
Soil temperature, °C			
30 cm deep	25.7	21.0	32.0
91 cm deep	23.2	17.0	28.0
Rainfall, cm			
1-wk period before spraying	2.81	.00	11.60
1-month period before spraying	11.20	.60	22.30
Soil moisture, %			
0 to 30 cm deep	18.2	8.0	30.0
30 to 61 cm deep	21.1	16.0	27.0
61 to 91 cm deep	21.5	17.0	25.0

were killed, no correlations or regressions are presented for percent plants killed by 2,4,5-T.

Honey mesquite control with herbicides was correlated with plant and environmental variables. For all 36 dates (data not shown), R^2 significance at 5%/1% level = ±0.32/±0.42, only total phloem thickness (0.34 to 0.43), rate of new xylem ring growth (0.62 to 0.72), and upward methylene blue dye movement (0.50 to 0.60) were directly correlated, and minimum leaf moisture stress (−0.35 to −0.41) was inversely correlated with percent canopy reduction. The two best correlated factors, rate of new xylem ring growth and upward movement of methylene blue dye, both formed parabolic curves similar to plant control (Figure 1) with time.

For the 33 dates from April 29 through August 31, covering the period of almost full foliage, 13 variables were significantly correlated with plant control (Table 5). Rates of new xylem ring radial growth and upward movement of methylene blue dye again were positively correlated with control. The other factors more or less reflected the influence of a large number of treatments at the best to decreasingly effective dates. Rainfall and soil moisture levels at all three depths were positively correlated at this period, because high soil moisture in March and early April and after fall rains had begun was not accompanied by effective plant control.

For the 13 increasingly effective spraying dates at the early part of the growth cycle (Table 5), total phloem thickness, rate of new xylem ring growth, upward rate of methylene blue dye movement, minimum and maximum leaf moisture stress, mean air temperature, and soil temperatures were directly correlated with plant control. Percent soil moisture at 61 cm was inversely correlated with control. Soil temperature at a depth of 91 cm was most correlated with control, and this finding supports the work of Dahl et al. (2) who found that the percentage of plants killed in June by 2,4,5-T was best correlated with increasing soil temperature at depths of 46 and 91 cm in northwest Texas. Apparently after the soil temperature reaches a threshold of 18° to 20° C, honey mesquite actively initiates and undertakes stem elongation growth, foliage production, and some new phloem and xylem radial growth. Both minimum and maximum leaf moisture stress were increasing, and soil moisture at 61 cm was decreasing at this period but did not limit plant control.

For the 22 decreasingly effective dates from May 21 through October 9 (Table 5), plant control was directly correlated with rate of new xylem ring growth, rainfall 1 month before spraying, and percent soil moisture at 91 cm. Minimum leaf moisture stress and total new xylem ring thickness were inversely correlated with plant control. Rate of new xylem radial growth was decreasing, while the total new xylem ring thickness was increasing, especially during the period from late May through June. Minimum leaf moisture stress was increasing rapidly as rainfall the month before spraying and soil moisture decreased. Upward methylene blue dye movement was not significantly correlated because the rate had fallen off faster than plant control.

Of the plant variables, over all 36 dates, total and translocating phloem essentially were only correlated with each other (0.73). Total new xylem ring thickness increased to a maximum in late June and was closely correlated with increasing leaf moisture stress, rising air and soil temperatures, and decreasing soil moisture (Table 6). The rate of new xylem ring growth was positively correlated with increasing phloem thickness. As expected, increasing leaf moisture stess was accompanied by higher air and soil temperatures and lower soil moisture. Total available carbohydrates decreased to a minimum about April and then increased again along with total new xylem ring thickness, maximum leaf moisture stress, mean air temperature, and soil temperature at a depth of 91 cm.

For simple correlations of environmental variables at all 36 dates, mean air temperature the day

Table 5. Simple correlation coefficients between plant and environmental variables and percent canopy reduction (C.R.) by both herbicides and percent dead honey mesquite plants (D.P.) by picloram + 2,4,5-T [1]

	Time period[2]								
	33 Dates[3]			13 Increasingly effective dates[4]			22 Decreasingly effective dates[5]		
	2,4,5-T	Picloram + 2,4,5-T		2,4,5-T	Picloram + 2,4,5-T		2,4,5-T	Picloram + 2,4,5-T	
Variable	C.R. (%)	C.R. (%)	D.P. (%)	C.R. (%)	C.R. (%)	D.P. (%)	C.R. (%)	C.R. (%)	D.P. (%)
Phloem thickness, mm									
Total				.75	.79	.76			
Translocating									
New xylem ring thickness, mm									
Total	–.31	–.42	–.45		.61		–.49	–.45	–.48
Rate of radial growth	.54	.61	.55	.67	.74	.59	.66	.71	.68
Leaf moisture stress, bars									
Minimum	–.59	–.63	–.44	.60	.66	.77	–.71	–.78	–.62
Maximum			.73	.77					
Total available carbohydrates, %									.47
Upward methylene blue									
Dye movement, cm/hr	.49	.49	.58	.70	.71	.75			
Mean air temperature, °C									
Day of spraying	–.43	–.36	–.44	.74	.78				
1 wk before spraying	–.37	–.36	–.33	.80	.68				
Soil temperature, °C									
30 cm deep	–.38	–.43	–.47	.81	.67				
91 cm deep	–.43	–.36		.82	.85	.87			–.51
Rainfall, cm									
1 wk before spraying									
1 month before spraying	.41	.42	.33				.42	.45	.49
Soil moisture, %									
30 cm deep	.37	.40	.34						
61 cm deep	.60	.58	.40	–.60	–.72	–.75		.46	.54
91 cm deep	.66	.62	.43			–.68	.43	.50	.53

[1]C.R. = Canopy reduction; D.P. = Dead plants.

[2]33 Dates = April 29-August 31; 13 increasingly effective dates = March 24-May 29; 22 decreasingly effective dates = May 21-October 9.

[3]Correlation coefficients of ±0.33 or ±0.44 are significant at the 5% and 1% level, respectively.

[4]Correlation coefficients of ±0.54 or ±0.68 are significant at the 5% and 1% level, respectively.

[5]Correlation coefficients of ±0.42 or ±0.53 are significant at the 5% and 1% level, respectively.

of spraying was directly correlated with mean air temperature 1 week before spraying (0.87, significance at 5%/1% levels = ±0.32/±0.42, respectively). Soil temperatures at both depths were directly and highly correlated with each other and mean air temperature (0.79 to 0.87). Rainfall 1 week and 1 month before spraying were directly but weakly correlated with each other (0.46) and inversely correlated with mean air temperature (−0.34 to −0.44) and soil temperature (−0.38 to −0.51). Soil moisture levels at all three depths were directly and highly correlated with each other (0.79 to 0.94) and generally with rainfall (0.40 to 0.64) and were inversely correlated with mean air temperature (−0.62 to −0.72) and soil temperature (−0.72 to −0.78). This again reflects the warming and drying trend throughout the growing season.

Regression equations were developed from the data of all 4 years to compute the best estimate (Ŷ) for the observed percent canopy reduction and percent dead honey mesquite plants resulting from herbicide applications at any time during the growing season. Hopefully, these equations will closely fit data from similar treatments showing seasonal honey mesquite responses to 2,4,5-T and picloram + 2,4,5-T. If reliable equations can be developed, they can be used commercially to predict the amount of honey mesquite control that can be expected from the treatment under any given seasonal and plant growth conditions.

Simple regression equations were calculated for predicting (Ŷ) percent canopy reduction for 2,4,5-T and picloram + 2,4,5-T and percent plants killed by picloram + 2,4,5-T at four intervals during the 4-year study period (Table 7). An insufficient number of plants was killed by 2,4,5-T to calculate a significant equation for percent dead plants. At all 36 dates from March 24 to October 9, rate of new xylem radial growth gave the best equation for all three responses to herbicides. Apparently the plant was

Table 6. Simple correlations of selected honey mesquite plant variables with other plant and environmental variables at 36 dates between March 24 and October 9 over a 4-year period at Bryan and Millican, Texas[1]

Variable	New xylem ring thickness Total (mm)	New xylem ring thickness Rate (mm)	Leaf moisture stress Minimum (bars)	Leaf moisture stress Maximum (bars)	Methylene blue dye movement (cm/hr)	Total available carbohydrates (%)
Phloem thickness, mm						
Total		.56			.44	
Translocating		.43			.34	
New xylem ring thickness, mm						
Total			.63	.71	−.44	.51
Rate of radial growth			−.44		.45	
Leaf moisture stress, bars						
Minimum				.60	−.37	
Maximum						.39
Total available carbohydrates, %					−.42	
Mean air temperature, C						
Day of spraying	.82		.48	.77		.41
1 wk before spraying	.79		.54	.70	−.38	.41
Soil temperature, C						
30 cm deep	.78		.67	.81	−.42	
91 cm deep	.75		.62	.71		.34
Rainfall, cm						
1 wk before spraying			−.35	−.44		
1 month before spraying	−.41		−.59	−.60		
Soil moisture, %						
30 cm deep	−.41	.32	−.59	−.58		
61 cm deep	−.59		−.71	−.63		
91 cm deep	−.64		−.75	−.56	.41	

[1]Correlation of ±0.32 or ±0.42 are significant at the 5% and 1% level, respectively.

Table 7. Simple regression equations for predicting response of honey mesquite near Bryan and Millican, Texas, to herbicides with plant and environmental variables during four seasonal intervals over a 4-year period

Herbicide	Type control[1]	Equation	R^2*
		All 36 dates between March 24 and October 9	
2,4,5-T	% C.R.	$\hat{Y}$ = 28.6 + 123.8(rate of new xylem growth)	0.45
Picloram + 2,4,5-T	% C.R.	$\hat{Y}$ = 36.2 + 188.0(rate of new xylem growth)	.52
	% D.P.	$\hat{Y}$ = 3.18 + 164.9(rate of new xylem growth)	.39
		33 dates between April 29 and August 31	
2,4,5-T	% C.R.	$\hat{Y}$ = 5.54 + 3.08(% soil moisture, 91 cm)	.44
Picloram + 2,4,5-T	% C.R.	$\hat{Y}$ = 137.9 − 6.36(minimum leaf moisture stress)	.40
	% D.P.	$\hat{Y}$ = 13.7 + 0.20(upward methylene blue dye movement)	.33
		13 increasingly effective dates between March 24 and May 29	
2,4,5-T	% C.R.	$\hat{Y}$ = −25.7 + 4.09(soil temperature, 91 cm)	.67
Picloram + 2,4,5-T	% C.R.	$\hat{Y}$ = 48.3 + 6.14(soil temperature, 91 cm)	.73
	% D.P.	$\hat{Y}$ = −83.1 + 63.5(soil temperature, 91 cm)	.75
		22 decreasingly effective dates between May 21 and October 9	
2,4,5-T	% C.R.	$\hat{Y}$ = 108.2 − 5.64(minimum leaf moisture stress)	.50
Picloram + 2,4,5-T	% C.R.	$\hat{Y}$ = 162.2 − 8.85(minimum leaf moisture stress)	.60
	% D.P.	$\hat{Y}$ = −0.55 + 165.6(rate of new xylem growth)	.46

[1]% C.R. = % Canopy reduction; % D.P. = % Dead plants.
*All equations are significant at the 1% level.

using carbohydrates stored in the stem and roots for radial growth. Therefore, applied herbicides, which follow carbohydrate usage patterns, would be expected to be translocated rapidly to the stem and roots where they could kill the plants.

For 33 dates between April 29 and August 31, when the plants were generally fully foliated, the best equations pertained to moisture. Canopy reduction by 2,4,5-T was best predicted by percent soil moisture at a depth of 91 cm. For picloram + 2,4,5-T, canopy reduction and dead plants were best predicted by minimum leaf moisture stress and rate of upward methylene blue dye movement, respectively.

The early spring treatment dates were highly correlated with soil temperature at the depth of 91 cm. This occurred because of the steady increase in temperature along with plant control. However, in late summer, air and soil temperatures remained high, but plant control decreased markedly. Apparently a minimum temperature of about 20° C is required for honey mesquite to grow. Above this threshold temperature, growth processes increased up to a point. Later in the summer, as shown by the decreasing 22 dates, moisture stress appeared to be the major limiting factor for controlling honey mesquite. Even as late as October, air and soil temperatures were warm. Apparently at this time, rainfall and soil moisture usually decrease to a point where the plants enter a high period of stress.

In 1969, however, about 25 cm of rain fell during the month before the October 9 spraying. This rain increased the soil moisture at a depth of at least 91 cm, but failed to activate the plant growth even though temperatures were favorable. Apparently these honey mesquite plants were deep-rooted and extracted a large percentage of their water from deep in the soil.

Multiple regression equations with three variables were calculated to predict percent canopy reduction by 2,4,5-T and picloram + 2,4,5-T and percent plants killed by picloram + 2,4,5-T for all 36 dates, 33 dates between April 29 and August 31, 13 increasingly effective early dates between March 24 and May 29, and 22 decreasingly effective dates between May 21 and October 9 (Table 8).

For all 36 dates, rate of new xylem radial growth, percent total available carbohydrates, and percent soil moisture at the depth of 30 cm were the most important plant and environmental factors for the prediction of canopy reduction by both herbicides. However, the T-T^2 factors, to account for a parabolic curve, coupled with rate of upward movement of methylene blue dye was a better predictive combination for picloram + 2,4,5-T. For predicting the percentage of plants killed by picloram + 2,4,5-T, rate of new xylem radial growth, rate of upward movement of methylene blue dye, and translocating phloem thickness were most important.

For 33 dates between April 29 and August 31 (Table 8), rate of new xylem radial growth and translocating phloem thickness were important for predicting canopy reduction for both herbicides. The T-T^2 factors gave a better equation when coupled with translocating phloem thickness than the three plant variables for predicting percent canopy reduc-

Table 8. Three-factor multiple regression equations for predicting response of honey mesquite near Bryan and Millican, Texas, to herbicides with plant and environmental variables during four seasonal intervals over a 4-year period

Herbicide	Type control[1]	Equation	R^2*
		All 36 dates between March 24 and October 9	
2,4,5-T	% C.R.	$\hat{Y} = 90.8 + 161.5(X1) - 2.33(X2) - 1.00(X3)$	.67
Picloram + 2,4,5-T	% C.R.	$\hat{Y} = 93.3 + 226.4(X1) - 1.88(X2) - 1.29(X3)$	.61
	% C.R.	$\hat{Y} = -164.0 + 2.80(T) - 0.0083(T^2) + 0.116(X4)$	.76
	% D.P.	$\hat{Y} = 6.45 + 140.9(X1) + 0.16(X4) - 91.9(X5)$	.57
		33 dates between April 29 and August 31	
2,4,5-T	% C.R.	$\hat{Y} = 10.6 + 59.2(X1) - 64.4(X5) + 2.30(X6)$	.59
Picloram + 2,4,5-T	% C.R.	$\hat{Y} = 60.4 + 122.1(X1) + 0.10(X4) - 97.7(X5)$	.56
	% C.R.	$\hat{Y} = -111.4 + 2.79(T) - 0.0091(T^2) - 46.5(X5)$	.80
	% D.P.	$\hat{Y} = -51.5 + 3.55(X2) + 0.32(X4) - 147.3(X5)$	.54
		13 increasingly effective early dates between March 24 and May 29	
2,4,5-T	% C.R.	$\hat{Y} = -160.6 - 1.40(X2) + 5.43(X6) + 5.98(X7)$	.91
Picloram + 2,4,5-T	% C.R.	$\hat{Y} = -112.6 + 1.94(X3) + 5.66(X7) + 1.77(X8)$	.87
	% D.P.	$\hat{Y} = -51.3 + 1.14(X3) + 10.2(X7) - 5.84(X9)$	.94
		22 decreasingly effective dates between May 21 and October 9	
2,4,5-T	% C.R.	$\hat{Y} = -34.5 + 77.1(X1) + 4.31(X9) - 5.25(X10)$	.67
Picloram + 2,4,5-T	% C.R.	$\hat{Y} = -14.6 + 103.8(X1) + 5.15(X9) - 8.00(X10)$	.74
	% D.P.	$\hat{Y} = 53.3 + 188.9(X1) - 122.6(X5) - 25.6(X11)$	.65
	% D.P.	$\hat{Y} = 543.1 - 7.05(T) + 0.0152(T^2) + 9.78(X12)$	.80

[1]Type control are % C.R. = % Canopy reduction; % D.P. = Dead plants.

*Variable abbreviations are the following: T = time in days from January 1 to spraying date; T^2 = time period (T) squared; X1 = rate of new xylem ring radial growth; X2 = percent total available carbohydrates; X3 = percent soil moisture at the depth of 0 to 30.5 cm; X4 = rate of upward movement of methylene blue dye in the xylem; X5 = translocating phloem thickness; X6 = percent soil moisture at the depth of 61.0 to 91.4 cm; X7 = soil temperature at a depth of 91.4 cm; X8 = maximum daily leaf moisture stress; X9 = soil temperature at a depth of 30.5 cm; X10 = minimum daily leaf moisture stress; X11 = total new xylem ring radial growth; X12 = mean air temperature 1 week before spraying. The T, T^2 factors are presented only where they both occurred in the equation. All equations are significant at the 1% level.

tion by picloram + 2,4,5-T. Percent total available carbohydrates, rate of upward movement of methylene blue dye, and translocating phloem thickness best predicted the percentage of plants killed.

For the 13 increasingly effective early dates between March 24 and May 29 (Table 8), soil temperature at a depth of 91 cm occurred in all equations, as well as a soil moisture factor. The R^2 values at this time period were the highest of the four periods studied.

For the 22 decreasingly effective dates between May 21 and October 9 (Table 8), rate of new xylem ring radial growth occurred in three equations. Soil temperature at a depth of 30 cm and minimum leaf moisture stress occurred in canopy reduction equations for both 2,4,5-T and picloram + 2,4,5-T. The $T + T^2$ factors, indicating a hyperbolic curvilinear relationship, accompanied by mean air temperature 1 week before spraying gave the best predictive equation for the percentage of plants killed by picloram + 2,4,5-T. This equation was better than the one with the three plant variables including rate of new xylem ring radial growth, thickness of translocating phloem, and thickness of the new xylem ring.

In summary, the most effective period for spraying honey mesquite with these two herbicides was from late April through June which confirms other research and applied knowledge. The mixture of picloram + 2,4,5-T was more effective than 2,4,5-T alone. The plant and environmental variables most correlated with control varied depending on the seasonal period considered. For the period between April 29 and August 31, when plants were almost fully foliated, control was most correlated with soil moisture level at a depth of 91 cm, minimum leaf moisture stress, or rate of upward methylene blue dye movement. During the early spring growth period, control was most correlated (positively) with soil temperature at a depth of 91 cm when generally adequate moisture was present. Soil temperature is one of the easiest variables to measure and presumably could be used on a practical basis. Later in the season when temperature was adequate, moisture, as measured by daily minimum leaf moisture stress, became the most limiting factor (negatively) affecting at least percent canopy reduction. Therefore, a combination of warm temperature and adequate plant moisture content is necessary for effective control with the herbicides used. These results are applicable to clay soil sites at least in East Texas. However, the relative importance of these factors may change for plants growing on other soil types or in different climatic conditions.

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APPENDIX

English Units	Metric Units
Bar	0.99 Atmosphere
Centigrade (C)	5/9 (Fahrenheit − 32)
Meter (m)	3.28 Feet
Millimeter (mm)	0.039 Inch
Centimeter (cm)	0.39 Inch
Kilometer (km)	0.62 Mile
Hectare (ha)	2.47 Acres
Gram (g)	0.0022 Pound
Kilogram (kg)	2.2 Pounds
Kilogram per hectare (kg/ha)	0.89 Pound per acre
Liter (L)	1.06 Quarts

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does is imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

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