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Influence of Environment and Stage of Growth on Honey Mesquite (*Prosopis glandulosa*) Response to Herbicides[1]

ROBERT E. MEYER and RODNEY W. BOVEY[2]

Abstract. **Honey mesquite (*Prosopis glandulosa* Torr. #[3] PRCJG) was treated with four herbicides at 1.1 kg ae/ha at 14 dates from April 30 through September 23 over a 2-yr period. Overall, clopyralid (3,6-dichloro-2-pyridinecarboxylic acid) was the most effective herbicide, killing 80% or more of the honey mesquite at most dates. Picloram (4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid), triclopyr {[(3,5,6-trichloro-2-pyridinyl)oxy] acetic acid}, and 2,4,5-T [(2,4,5-trichlorophenoxy)acetic acid] were less effective than clopyralid. Honey mesquite control was correlated with Julian day of year sprayed, 15 plant, 11 environmental, and 8 herbicide concentration variables. Most effective control was negatively correlated with Julian day of year sprayed and new xylem ring thickness. Control was positively correlated with total daily apparent photosynthesis, upward methylene blue dye movement in the xylem, and herbicide concentration in the xylem 3 days after spraying. The only environmental variable of 11 measured that was significantly correlated with honey mesquite control was soil water and that was only with picloram. The concentration of herbicide in the stem was highest for clopyralid, followed by picloram, and then by 2,4,5-T and triclopyr, which were about equal. Variables most useful in regression equations for predicting control with herbicides were total daily apparent photosynthesis and rate of upward movement of methylene blue dye. Variables most incorporated into regression equations relating honey mesquite control with herbicide content were herbicide concentrations in the xylem 3 or 30 days after treatment.**

Additional index words. **Brush control, herbicide content, clopyralid, picloram, 2,4,5-T, triclopyr, PRCJG.**

INTRODUCTION

Honey mesquite, a woody legume that occurs on about 25 million ha of Texas rangeland[4] makes maximum stem growth in warm temperatures (14). It competes for light, soil moisture, and soil nutrients with desirable forage species and hinders efficient handling of livestock.

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, 0.6 kg/ha of 2,4,5-T generally kills most of the aboveground stems and about 25% of the plants (7). The combination of 2,4,5-T plus picloram has also been used commercially and is slightly more effective than 2,4,5-T alone (2, 13)[5,6]. The most effective treatments have occurred about 50 to 90 days after the first leaves appear in the spring when they are fully formed and dark green. More recently, triclopyr has been found to be effective for control of honey mesquite (11). Also, clopyralid has been found to be highly effective for controlling honey mesquite (1, 12).

Bovey and Meyer (2) have summarized the factors influencing the response of honey mesquite to herbicides. Dahl et al. (4) found that soil temperature of 27 C and above at the 46-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 those on bottomland and clay sites because of the difference in soil temperature.

Meyer et al. (13, 16) found that over 36 spraying dates during a 4-yr period, percentage of honey mesquite canopy reduction was directly correlated with total phloem thickness, rate of new xylem ring radial growth, and rate of upward methylene blue dye movement in the xylem, and was inversely correlated with minimum leaf moisture stress. In simple regression equations for 36 dates of application, rate of new xylem radial growth gave the best predictive equation. At 13 increasingly effective early season dates, control was best predicted by soil temperature at a depth of 61 to 91 cm. At 22 decreasingly effective summer dates, percentage of canopy reduction was best predicted by minimum leaf moisture stress.

More recently, Hanson (9) and Hanson and Dye (10) studied photosynthesis patterns of honey mesquite. Using their method, Meyer et al. (15) found that honey mesquite control with herbicides was more closely correlated with maximum daily photosynthesis rate than with percentage of soil water, rate of upward movement of methylene blue dye, or xylem pressure potential.

Davis et al. (5) studied the uptake of picloram and 2,4,5-T in leaves of 10 woody species including honey mesquite and found that picloram entered faster and accumulated in higher concentrations than 2,4,5-T. In a field study, Davis

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[2] Plant Physiol. and Res. Agron., Agric. Res. Serv., U.S. Dep. Agric., Dep. Range Sci., Texas A&M Univ., College Station, TX 77843. Headquartered at Grassland, Soil and Water Laboratory, Temple, TX.

[3] Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds, Weed Sci. 32, Suppl. 2. Available from WSSA, 309 West Clark St., Champaign, IL 61820.

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et al. (6) found that highest tissue concentrations of 2,4,5-T and picloram were associated with dates of most effective honey mesquite control. Mitchell and Stephenson (17) postulated that the high susceptibility of red maple (*Acer rubrum* L.) to picloram was a result of xylem blockage. Bovey and Mayeux (1) found that greenhouse-grown honey mesquite accumulated higher concentrations of clopyralid in stems and roots 3, 10, and 30 days after application to soil or foliage than 2,4,5-T, triclopyr, or picloram.

The purposes of this study were to: a) develop an indicator for predicting the effectiveness of honey mesquite control, b) correlate control with amounts of herbicide in the stems, and c) determine interrelationships of seasonal herbicide translocation patterns of herbicide sprayed on the foliage. The data are complementary to a study reported by Bovey et al. (3).

MATERIALS AND METHODS

Experimental site and plot layout. Sites were selected in 1980 and 1981 near Bryan, TX, in a dense stand of honey mesquite plants 1 to 2 m tall. Most honey mesquite plants had two to four stems that had emerged near the base of the plant.

The areas were upland sites with a 1 to 3% slope. The soils of the study sites were a Wilson clay loam (a member of the fine, montmorillonitic, thermic Vertic Ochraqualfs) in 1980 and a Lufkin fine sandy loam (a member of the fine, montmorillonitic, thermic Vertic Albaqualfs) in 1981. About 1450 plants were tagged in groups of five, with at least a 1-m space between plants from adjoining groups. The plant groups were divided into 10 areas, one for each replicate. Each replicate contained 29 plant groups with four herbicide treatments for each of seven dates plus an untreated group. Six replicates of herbicide treatments, selected at random, and the untreated group were used for evaluating plant control. The other four replicates of plants were used for herbicide residue analysis. Stem samples were taken from nine of the ten trees in the two replicates of plants 3 and 30 days after spraying.

Chemical applications and control ratings. The herbicide treatments included the monoethanolamine salt of clopyralid, the potassium salt of picloram, the propylene glycol butyl ether ester of 2,4,5-T, and the butoxyethanol ester of triclopyr. All herbicides were applied at 1.1 kg ae/ha.

The herbicides were applied either in the evening or early morning with a hand-carried, compressed-air, three-nozzle boom sprayer. The herbicides were applied at a spray volume of 187 L/ha at a pressure of 207 kPa.

Visual ratings of percentage of canopy reduction, which measures the amount of stem tissue killed, and percentage of dead plants were made approximately 1 yr following spraying.

Plant characteristics. Unsprayed plants in the experimental areas were used for all plant measurements and samples except for herbicide concentration. Measurements or samples were collected within 24 h after herbicide application. For the most part, the same methods were used in this study as in earlier studies (13, 16).

For new stem length, five new stems were tagged on each of five trees, and their lengths were measured at each of the seven spraying dates during the year. Stem tissue transectional dimensions were measured from stem increments 1 to 2 cm in diameter taken about 10 to 16 cm above the soil surface. The stem sections were cut into 1-cm lengths, fixed in a Craf solution (18), dehydrated in ethanol and tert-butyl alcohol, and embedded in a mixture of paraffin and plastic. Transections were cut about 15 μ thick and stained with a safranin-fast green staining series according to the recommendations of Sass (18). Measurements were made using a microscope equipped with an ocular micrometer. Stem and pith diameters were measured. Also, thickness of the periderm, total phloem, and xylem rings were measured. Rate of new xylem ring radial growth during the 2-week period before spraying was calculated from the total new xylem ring thickness measurements taken during the growing season.

Rate of upward methylene blue dye movement was determined in 20 trees at each date. A 0.1% (w/v) aqueous methylene blue dye solution was infused into the stem xylem from a transfusion bottle equipped with a No. 16 hypodermic needle. The needle was inserted under the bark between 9:00 and 9:30 a.m. Central Standard Time (CST) and removed 30 min later. The bark was stripped from the stem, and the length of the blue dye streak was measured. The rate is presented as cm/h.

Moisture stress in the leaves was determined with a Scholander pressure apparatus (20). Moisture stress was determined immediately following collection of 20 mature leaves from four trees at each sampling period. The readings were made before dawn from 4 to 5 a.m., at 10 a.m., 1 p.m., 3 p.m., and 6 p.m. CST. Stress levels at predawn (minimum) and 3 p.m. (maximum) are presented in –MPa. Also, total leaf moisture stress during daylight is presented as $-\mathrm{MPa \cdot h^{-1}}$ with and without the daily minimum subtracted.

Photosynthesis was estimated using an equation developed by Hanson from the work of Hanson (9) and Hanson and Dye (10) and used by Meyer et al. (15) where net photosynthesis (Pn in mg CO_2 dm^{-2} leaf area h^{-1}) is estimated after air temperature, solar radiation, and leaf diffusion resistance to water vapor have been measured. Solar radiation was measured five times per day for 10-min periods with a LI-COR model LI-190S quantum sensor attached to a model LI-555 printing integrator[7,8]. Leaf diffusion resistance to water vapor was measured at the same periods with a LI-COR model LI-60 diffusive resistance meter with a LI-20S diffusive resistance sensor[7] having a 3.5- by 20-mm aperture. Solar radiation for 1980 data was estimated because it was not measured in the field at time of spraying.

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[7] Manufactured by Lambda Instrument Corp., Lincoln, NB.

[8] Mention of a trademark name or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Dep. Agric. and does not imply their approval to the exclusion of other products that may also be suitable.

Environmental variables. Environmental variables used include maximum, mean, and minimum temperature, daylight degree hours above 18 C the day of spraying; the mean temperature in the 1-week period before spraying; soil temperature at the 30-cm depth; the percentage of soil water at depths of 0 to 30 cm (hereafter 30), 31 to 61 cm (hereafter 61), and 62 to 91 cm (hereafter 91) the day of spraying; and rainfall during the 1-week and 1-month periods before spraying.

Maximum, mean, and minimum air temperature and rainfall data were recorded at College Station, TX, about 15 km away. Daylight degree hours were calculated from air temperatures recorded five times during the day at the experimental site within 24 h of spraying. Soil temperature was measured about sunrise with a remote recording thermometer. Soil water was determined in an untreated area at the experimental site the day of herbicide application using gravimetric analysis; five cores were dug with a screw-type auger (8).

Herbicide content. Methods for sampling and determining the concentration of clopyralid, picloram, 2,4,5-T, and triclopyr have been described by Bovey et al. (3). Two or three stem increments 15 cm long were collected just below the leaves in the upper part of the plant and from the multistems just above the soil surface. The sample increments were wrapped with masking tape before spraying to prevent surface contact with the spray applications. Then stem samples from three trees were pooled per replicate. Three replicates with three samples per replicate were harvested at each date 3 and 30 days after spraying. The phloem-periderm and outer xylem tissues were removed and then frozen until the herbicide concentration was determined by gas chromatography. Concentrations of herbicides at various dates are presented by Bovey et al. (3).

Statistical analyses. The experiments were designed as a randomized, complete block (19, 21). Percentage of canopy reduction and percentage of dead plants were analyzed as percentages and as arcsine-transformed values. There was no meaningful difference between the two analyses. For ease in presenting the results, the untransformed values of these variables are presented here. Fisher's Least Significant Difference Test was used for separating canopy reduction and dead plant means, and Duncan's multiple range test was used to separate means of environmental and plant characteristics.

A complete set of simple correlations was calculated for all combinations of herbicide treatments, dates of treatment, plant characteristics, environmental variables, and herbicide concentrations.

Regressions were calculated both to develop an indicator for predicting plant response to herbicides at any given date with plant characteristics and environmental factors and to relate herbicide content in various parts of the plant. Also, the Julian calendar date (T), the number of days from January 1 to the spraying date, and date squared (T^2) factors were added to account for the curvilinear response of honey mesquite to herbicides with time. A step-up maximum R^2 improvement regression analysis was used. Equations for predicting control were calculated with the best one-, two-, and three-plant and/or environmental variables. Equations for relating herbicide concentrations were calculated with the best one- and two-herbicide concentration variables. Means for all six treatment replicates were used for herbicide variables in all correlation and regression analyses.

RESULTS

Response to herbicides. Honey mesquite responded to herbicides differently by year, herbicide, and date of application. Generally, the herbicides controlled the honey mesquite more effectively in 1980 than in 1981. Over all 14 dates (percent canopy reduction/percent dead plants), clopyralid (92/72) was the most effective herbicide followed by picloram (73/44), triclopyr (66/27), and 2,4,5-T (57/14), respectively (Table 1).

Clopyralid reduced the canopy at least 90% at all but the last three dates in 1981. Clopyralid killed 80% or more of the honey mesquite at all dates in 1980, except May 5, and in 1981 during the period of April 29 through June 12 (Table 1). Subsequently, control was progressively less effective in 1981. Picloram reduced the canopy 82% and killed 60% or more of the honey mesquite population during May 21 through June 27, 1980, and April 29 through June 12, 1981. Subsequently, control decreased, particularly in 1981.

Overall, triclopyr tended to be slightly more effective than 2,4,5-T, but both were less effective than either clopyralid or picloram for controlling honey mesquite. Triclopyr reduced the canopy 84 to 87% and killed 53% of the honey mesquite in June 1980 and reduced the canopy 90% and killed 63% in May 1981 (Table 1). It was particularly ineffective in September 1980 and from July through September in 1981. The 2,4,5-T reduced the canopy 75 to 81% and killed 20 to 47% of the honey mesquite in May and June 1980, but it killed no more than 20% of the plant population in 1981.

Plant characteristics. New stems were initiated between March 15 and April 1 in both years. By the time spraying was begun in late April or early May, the new stem elongation growth had been completed. Mean new stem length was 31 and 39 cm in 1980 and 1981, respectively. The length by year may have been a characteristic of the plants sampled and not necessarily a seasonal effect because the plants were growing on different sites.

Stems sampled for anatomical dimensions over the 2-yr period varied from 12.4 to 19.6 mm in diameter with the average being 14.6 mm (Table 2). The stems sampled May 5, 1980, were slightly larger than subsequent ones. Periderm thickness varied from 0.47 to 0.78 mm with the average being 0.55 mm (data not shown).

Total phloem reached a maximum thickness in May, decreased slightly in June and July, and progressively decreased in August and September (Table 2). Maximum thickness is associated with young, but full-size cells. Subsequently, part of the phloem, particularly the outer, nontranslocating phloem is crushed by underlying secondary xylem growth.

Table 1. Percent canopy reduction and dead honey mesquite with four herbicides applied at 1.1 kg/ha at 14 dates during 1980 and 1981 near Bryan, TX[a].

Date of application	Canopy reduction				Dead plants			
	Herbicide				Herbicide			
	Clopyralid	Picloram	2,4,5-T	Triclopyr	Clopyralid	Picloram	2,4,5-T	Triclopyr
	(%)							
	1980							
May 5	90	81	74	80	63	37	23	33
May 21	98	98	75	73	90	87	20	17
June 10	98	86	76	87	87	63	30	53
June 27	97	82	81	84	87	60	47	53
July 18	96	60	62	77	83	17	7	33
August 26	96	69	62	77	80	43	20	30
September 23	98	77	43	54	83	23	7	7
	1981							
April 29	96	93	64	76	83	77	17	33
May 12	100	83	69	90	100	73	20	63
June 17	99	96	53	77	90	87	0	37
July 9	90	74	43	36	77	33	3	0
July 30	89	57	36	54	37	3	0	20
August 25	74	30	29	30	37	4	3	0
September 22	62	33	28	28	10	3	0	0
$LSD_{5\%}$ = 13%	Untreated = 3%				$LSD_{5\%}$ = 25%		Untreated = 0%	

[a] Ratings were made July 1, 1981, and July 29, 1982, for the 1980 and 1981 treatments, respectively. LSD's were calculated from data subjected to the arcsin transformation.

New xylem ring thickness increased until the new ring was slightly more than 2 mm thick in July of each year (Table 2). After radial growth had ceased, the ring thickness remained about the same the remainder of the year. The older xylem rings averaged 1.7 and 1.4 mm thick in 1980 and 1981, respectively, (data not shown). In both years the mature new growth rings were thicker than the average of the older rings. Rate of new xylem ring growth varied seasonally with most rapid growth in May and June in 1980 and June to early July in 1981 (Table 2). Pith diameter varied widely from 0.45 to 1.44 mm and averaged 0.83 mm, but there was no seasonal trend (data not shown).

Rate of upward movement of methylene blue dye varied widely seasonally when infused into the xylem (Table 2). Rate of upward dye movement in April 1981 and May and June of both years was appreciably higher than in the remainder of the year sampled. The rate in April through June averaged 152 cm/h and varied from 92 to 218 cm/h, whereas in July through September the average was 59 cm/h and varied from 21 to 93 cm/h.

Several leaf moisture stress measurements were made, including the predawn minimum and the midday maximum as measured in –MPa and totals in daylight and in daylight at 18 C and above temperature as measured in $-\text{MPa}\cdot\text{h}^{-1}$ (Table 3). Predawn stress was always less than the midday maximum. The highest predawn stress, over 1.0 –MPa occurred from mid-July through August. Lower readings occurred in May and June when soil moisture was more readily available and also in late September. The other three leaf moisture stress variables were similar to those at predawn except that their maximum tended to occur earlier in the season and extended over a longer period. The midday maximum leaf moisture stress proportionally varied less throughout the season than the other stress variables.

Table 2. Plant anatomical characteristics and upward dye movement in xylem in honey mesquite at Bryan, TX, at 14 dates[a].

Date	Stem diameter	Total phloem	Xylem		Rate of upward dye movement
			New ring thickness	Growth of new ring	
	(mm)			(mm/2 wk)	(cm/h)
	1980				
May 5	19.6 a	0.14 a	0.37 e	0.37 ab	142 bc
May 21	13.8 b	0.11 b	0.76 de	0.39 ab	179 ab
June 10	14.8 b	0.07 cd	1.35 bcd	0.34 ab	170 b
June 27	12.6 b	0.06 d	1.76 abc	0.35 ab	122 cd
July 18	12.4 b	0.07 cd	2.08 a	0.22 cd	93 de
August 26	13.8 b	0.05 d	2.24 a	0.06 ef	80 ef
September 23	14.1 b	0.04 d	2.02 ab	0.00 f	57 ef
	1981				
April 29	15.4 b	0.05 d	0.42 e	0.20 cd	145 bc
May 12	15.0 b	0.10 bc	0.57 e	0.16 de	218 a
June 17	15.2 b	0.05 d	1.28 cd	0.28 bc	92 de
July 9	14.6 b	0.06 d	2.24 a	0.42 a	60 ef
July 30	12.8 b	0.06 d	1.96 ab	0.16 de	51 fg
August 25	14.8 b	0.05 d	2.37 a	0.10 def	51 fg
September 22	14.8 b	0.05 d	2.37 a	0.00 f	21 g

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

Table 3. Leaf moisture stress and photosynthesis in honey mesquite at Bryan, TX, at 14 dates[a].

Date	Leaf moisture stress				Photosynthesis[b]			
					Daily maximum		Daily total	
	Predawn	Midday maximum	Total in daylight	Total in daylight above 18 C	Apparent	Theoretical	Apparent	Theoretical
	(−MPa)		(−MPa·h)		(Pn)[c]		(Pn·h)[c]	
1980								
May 5	−0.33 f	−1.93 f	−17.0 c	−12.6 de		25.7		244
May 21	−0.48 e	−1.94 cd	−20.9 de	−13.9 cd		24.4		253
June 10	−0.66 d	−3.01 a	−33.5 ab	−23.3 a		23.3		231
June 27	−0.87 c	−2.89 a	−38.1 a	−24.9 a		23.3		123
July 18	−1.33 a	−2.98 a	−38.2 a	−17.9 bc		23.2		137
August 26	−1.05 b	−3.03 a	−36.3 a	−21.1 bc		21.3		167
September 23	−0.69 d	−2.82 a	−27.2 bcd	−18.2 bc		23.5		233
1981								
April 29	−0.70 d	−2.21 e	−22.5 cde	−12.1 de	24.7 a	25.3	237 a	216
May 12	−0.70 d	−2.34 de	−22.8 cde	−12.5 de	22.5 bc	21.4	227 ab	209
June 17	−0.73 d	−2.57 bc	−29.0 bc	−18.1 bc	23.9 b	24.2	244 a	253
July 9	−0.67 d	−2.49 bcd	−27.4 bcd	−17.2 bc	24.0 ab	24.2	210 abc	227
July 30	−1.03 b	−2.63 b	−32.2 ab	−16.6 bcd	20.8 c	21.0	203 bc	170
August 25	−1.34 a	−2.96 a	−33.9 ab	−14.3 cd	21.0 c	19.1	148 d	167
September 22	−0.99 b	−2.32 de	−21.4 de	−0.81 e	24.0 ab	23.0	181 cd	234

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

[b] The 1980 apparent photosynthesis values were not available because actual solar radiation measurements were not taken.

[c] Pn in CO_2 $dm^{-2} \cdot h^{-1}$.

The daily maximum apparent and theoretical photosynthesis estimates varied only slightly throughout the season (Table 3). The highest photosynthetic rates generally occurred in April, May, June, and September, and the lowest rate generally occurred in August, during the hottest and driest period of the growing season. Daily total apparent and theoretical photosynthesis followed a trend similar to that for the daily maximum but varied more proportionally among dates.

Environmental variables. Five air temperature variables were recorded (Table 4). They included the maximum, mean, minimum, and daylight degree days at and above 18 C on the day of treatment, and also the mean air temperature during the 1-week period prior to treatment. Soil temperature was recorded at a 30-cm depth the day of treatment. The highest values for all air temperature variables and soil temperature occurred from mid-June through August (Table 4).

In 1980, percentage of soil moisture at 30 cm was highest in May and September subsequent to major rainfall periods (Table 4). Percent soil moisture in 1981 was highest at 20 to 23% at the 61-cm depth on June 17, July 9, and in September (Table 4) when major rainfall occurred later in the spring and summer period and in the fall than in 1980. Percentage of soil moisture in 1981 was lowest in late July and August. Generally, the shallower depths contained a higher percentage of moisture than the lower depths during periods of significant rainfall. The reverse tended to occur as the soil moisture was depleted.

Herbicide concentration in stems. The data on herbicide concentration in honey mesquite stems 3 and 30 days after treatment have been presented by Bovey et al. (3). Averaged over all dates, clopyralid concentrations at 3 days after application were 13.6, 7.1, 7.1, and 3.3 μg/g fresh stem tissue in the upper stem phloem, upper stem xylem, lower stem phloem, and lower stem xylem, respectively. Picloram concentrations at 3 days were intermediate at 4.6, 1.6, 2.0 and 1.0 μg/g in the same tissues, respectively. Least were 2,4,5-T concentrations at 1.1, 0.4, 0.4, and 0.2 and triclopyr concentrations at 0.8, 0.4, 0.2, and 0.1 μg/g in the same tissues, respectively. At 30 days after treatment, clopyralid, 2,4,5-T, and triclopyr concentrations were less, whereas picloram concentrations were similar to those at 3 days. Herbicide concentrations varied during the year but generally were lowest in August of both years and September of 1980. Herbicide concentrations were higher than normal in September 1981 because of the presence of new foliage resulting from summer rains.

Correlation and regression analyses. Correlations among time, plant, environmental, and herbicide variables are presented in Tables 5 through 9 where some were significant. Table 5 shows the correlation between honey mesquite control and the various variables where coefficients of ±0.53 and ±0.66 are significant at the 5 and 1% levels, respectively. Honey mesquite control was generally negatively correlated with Julian day number of year and new xylem ring thickness. It was highly positively correlated with total daily apparent photosynthesis (measured only in 1981) and upward

Table 4. Environmental conditions at 14 dates of herbicide application to honey mesquite at Bryan, TX.

Date of application	Air temperature: Day of application: Maximum	Mean	Minimum	Daylight degree days above 18 C	Mean 1 week before application	Soil temperature day of application (1980)	Soil moisture[a]: 0–30 cm	31–61 cm	62–91 cm	Rainfall: 1 week before	1 month before
	(C)			(C•h⁻¹)	(C)		(%)			(cm)	
						1980					
May 5	24	20	16	29	22	20	18.0 c	17.9 bc	17.7 abc	3.30	7.85
May 21	33	29	18	139	23	22	20.6 ab	19.6 b	18.8 ab	3.05	13.87
June 10	34	29	18	165	27	25	13.7 d	18.1 bc	19.7 a	0.03	9.25
June 27	41	34	26	252	31	31	9.4 e	14.0 de	15.4 b-e	0.20	0.23
July 18	39	35	26	243	32	34	7.2 e	12.5 de	13.5 de	0.00	0.20
August 26	36	32	24	194	31	31	7.8 e	10.7 e	12.5 e	0.08	3.35
September 23	36	31	24	175	25	29	19.3 bc	18.6 bc	16.3 a-d	0.41	6.78
						1981					
April 29	31	27	22	130	22	21	8.2 e	11.3 e	12.3 ef	1.80	2.82
May 12	28	23	18	75	21	18	13.9 d	15.7 cd	15.1 b-e	2.08	6.83
June 17	35	30	23	170	26	26	22.0 a	23.0 a	18.8 ab	10.36	25.93
July 9	37	32	26	195	28	28	20.2 abc	20.4 ab	16.8 a-d	6.15	20.85
July 30	37	32	24	208	31	26	7.6 e	13.1 de	12.1 ef	0.15	7.42
August 25	38	31	23	195	29	29	2.2 f	7.1 f	8.6 f	0.00	0.15
September 22	33	27	21	119	21	24	11.8 d	20.4 ab	14.8 cde	0.00	18.59

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

methylene blue dye movement in the xylem. Thus, herbicides seem to be most effective when the plants are actively producing photosynthates and translocating moisture in the xylem. Soil moisture at two depths was the only environmental variable significantly correlated with honey mesquite control, and it was positively correlated only with honey mesquite control by picloram.

As expected, percentage of canopy reduction was highly correlated with percentage of dead plants (Table 5). Honey mesquite control with the various herbicides was positively correlated with herbicide concentration, primarily the herbicide concentration found in the xylem, particularly in the lower stem area 3 days after spraying.

Clopyralid concentration in the lower stem phloem at 3 and 30 days and picloram at 30 days were also positively correlated with honey mesquite control.

The concentration of clopyralid in the plant, particularly the lower stem at 3 days, was negatively correlated with Julian day of the year and new xylem ring thickness (Table 6). Clopyralid concentration in most plant parts was positively correlated with total daily apparent photosynthesis and upward methylene blue dye movement in the xylem. All environmental variables were poorly correlated with clopyralid concentrations in the plant.

Concentrations of clopyralid in various plant parts of honey mesquite 3 and 30 days after treatment were positively correlated with the amounts in other parts of the plant (Table 6). Some of the higher correlations were upper stem xylem at 3 days with lower stem xylem at 3 days, upper stem xylem at 30 days with lower stem xylem at 30 days, and lower stem phloem at 3 days with lower stem xylem at 3 days and upper and lower stem xylem at 30 days.

The concentration of picloram in the upper stem xylem at 3 and 30 days and lower stem phloem at 30 days was negatively correlated with Julian day number (Table 7). Picloram concentration in the upper stems 3 days after spraying was directly correlated with stem diameter.

Picloram concentration, except for the upper stem phloem at 3 days, was directly correlated with total daily apparent photosynthesis and generally with high moisture stress and rainfall 1 week before spraying. Picloram concentration was negatively correlated with air and soil temperatures. Concentrations in the various plant parts 3 and 30 days after spraying were most positively correlated with concentrations in other plant parts sampled the same date.

The 2,4,5-T concentration, particularly in the xylem, was negatively correlated with Julian date and new xylem ring thickness (Table 8). Higher 2,4,5-T concentrations were generally present in larger than in smaller stems. The 2,4,5-T concentration was more positively correlated with total daily apparent photosynthesis 3 days than at 30 days after spraying. Upward methylene blue dye movement in the xylem was more positively correlated with 2,4,5-T concentration in the xylem than in the phloem. The 2,4,5-T concentration was generally directly correlated with leaf moisture stress and negatively correlated with soil and air temperatures. The 2,4,5-T concentration in various plant parts was directly correlated with the concentration in most

Table 5. Simple correlation coefficients between various date, plant, and environmental variables and percent canopy reduction (C.R.) and dead honey mesquite plants (D.P.) that had been treated with herbicides near Bryan, TX, in 1980 and 1981 and rated 1 yr later.

	Herbicide[b]							
	Clopyralid		Picloram		2,4,5-T		Triclopyr	
Variable[a]	C.R.	D.P.	C.R.	D.P.	C.R.	D.P.	C.R.	D.P.
Time of year sprayed								
Julian day of year	−0.53	−0.55	−0.73	−0.74	−0.73	−0.46	−0.68	−0.62
Plant variables								
New stem length (cm)	−0.46	−0.43	−0.42	−0.25	−0.68	−0.56	−0.53	−0.24
New xylem ring thickness (mm)	−0.48	−0.48	−0.72	−0.72	−0.66	−0.40	−0.66	−0.56
New xylem ring growth rate (mm/2 wk)	0.41	0.45	0.59	0.51	0.60	0.44	0.38	0.31
Mean thickness of older xylem rings (mm)	0.16	0.23	0.36	0.21	0.57	0.52	0.35	0.29
Total daily apparent photosynthesis (Pn•h)	0.84	0.79	0.96	0.87	0.83	0.41	0.83	0.72
Maximum apparent daily photosynthesis rate (Pn)	0.14	0.36	0.51	0.55	0.38	0.20	0.19	0.07
Maximum theoretical daily photosynthesis rate (Pn)	0.33	0.38	0.65	0.47	0.46	0.22	0.33	0.12
Upward methylene blue dye movement rate (cm/h)	0.63	0.68	0.71	0.77	0.84	0.64	0.80	0.76
Predawn leaf moisture stress (−MPa)	−0.01	0.00	0.74	0.60	0.50	0.34	0.37	0.23
Total leaf moisture stress in daylight above 18 C (−MPa•h)	−0.55	−0.49	−0.30	−0.18	−0.40	−0.50	−0.40	−0.40
Environmental variables								
Soil moisture 0–30 cm deep (%)	0.34	0.40	0.61	0.46	0.20	−0.05	0.14	−0.03
Soil moisture 61–91 cm deep (%)	0.41	0.46	0.67	0.55	0.49	0.28	0.40	0.28
Other herbicide variables								
Canopy reduction (%)	1.00	0.93	1.00	0.89	1.00	0.85	1.00	0.91
Herbicide in upper xylem, 3 days (μg/g)	0.51	0.50	0.45	0.29	0.72	0.47	0.50	0.42
Herbicide in lower phloem, 3 days (μg/g)	0.62	0.60	0.48	0.36	0.27	0.20	0.37	0.37
Herbicide in lower xylem, 3 days (μg/g)	0.63	0.63	0.56	0.36	0.54	0.31	0.78	0.76
Herbicide in upper xylem, 30 days (μg/g)	0.55	0.65	0.65	0.75	0.42	0.33	0.41	0.52
Herbicide in lower phloem, 30 days (μg/g)	0.48	0.53	0.56	0.63	0.19	0.15	0.25	0.33
Herbicide in lower xylem, 30 days (μg/g)	0.39	0.48	0.53	0.64	0.54	0.38	0.40	0.57

[a] Variables were measured or samples collected within 24 h of spraying, except where otherwise indicated.

[b] Correlation coefficients of ± 0.53 or ± 0.66 are significant at the 5 and 1% level, respectively.

Table 6. Simple correlation coefficients between various date, plant, and environmental variables and clopyralid concentration in the upper and lower stems of honey mesquite near Bryan, TX, treated in 1980 and 1981.

	Day sampled after treatment[b]							
	3				30			
	Upper		Lower		Upper		Lower	
Variable[a]	Phloem	Xylem	Phloem	Xylem	Phloem	Xylem	Phloem	Xylem
Time of year sprayed								
Julian day of year	−0.30	−0.59	−0.64	−0.72	−0.33	−0.53	−0.36	−0.42
Plant variables								
New xylem ring thickness (mm)	−0.09	−0.45	−0.60	−0.65	−0.13	−0.38	−0.28	−0.42
Total daily apparent photosynthesis (Pn•h)	0.10	0.50	0.76	0.89	0.49	0.54	0.74	0.47
Maximum apparent daily photosynthesis rate (Pn)	−0.28	0.21	0.20	0.55	−0.26	0.13	0.25	0.05
Upward methylene blue dye movement rate (cm/h)	0.16	0.57	0.76	0.65	0.36	0.72	0.39	0.64
Other herbicide variables								
Upper phloem, 3 day (μg/g)	1.00	0.45	0.43	0.36	0.59	0.27	0.00	0.23
Upper xylem, 3 day (μg/g)	0.45	1.00	0.57	0.71	0.46	0.51	0.18	0.25
Lower phloem, 3 day (μg/g)	0.43	0.57	1.00	0.85	0.64	0.77	0.51	0.78
Lower xylem, 3 day (μg/g)	0.36	0.71	0.85	1.00	0.44	0.54	0.55	0.54
Upper phloem, 30 day (μg/g)	0.59	0.46	0.64	0.44	1.00	0.78	0.43	0.62
Upper xylem, 30 day (μg/g)	0.27	0.51	0.77	0.54	0.78	1.00	0.43	0.76
Lower phloem, 30 day (μg/g)	0.00	0.18	0.51	0.55	0.43	0.43	1.00	0.62
Lower xylem, 30 day (μg/g)	0.23	0.25	0.78	0.54	0.62	0.76	0.62	1.00

[a] Variables were measured or samples collected within 24 h of spraying, except where otherwise indicated.

[b] Correlation coefficients of ± 0.53 or ± 0.66 are significant at the 5 and 1% level, respectively.

other parts 3 and 30 days after spraying, but many of the correlations were not statistically significant.

Triclopyr concentration, particularly in the xylem 3 days after application, was positively correlated with stem size but negatively correlated with Julian day of year and new xylem ring thickness (Table 9). Upward methylene blue dye movement was positively correlated with triclopyr concentration in the xylem of both parts of the plant after both intervals of application. Triclopyr concentration in most parts of honey mesquite was inversely correlated with soil and air temperature. Triclopyr in various plant parts was generally positively correlated with triclopyr concentration in other plant parts, but only correlations of upper stem xylem at 3 days with lower stem xylem at 3 days, lower stem phloem at 3 days with lower stem phloem at 30 days, upper stem phloem at 30 days with upper stem xylem at 30 days, and upper stem xylem at 30 days with lower stem xylem at 30 days were statistically significant.

Regressions were calculated for both plant and environmental variables that could be used to predict honey mesquite control with herbicides and herbicide concentrations that show the relationships between herbicide concentration following spraying and honey mesquite control. Table 10 shows simple regressions for predicting honey mesquite control using the total daily apparent photosynthesis data for seven dates in 1981 (data were not collected for 1980). Highest R^2 values were attained with this variable for canopy reduction and dead plants for clopyralid and picloram and canopy reduction for 2,4,5-T and triclopyr. Total daily apparent photosynthesis was not well correlated with percentage of plants killed by 2,4,5-T. Subsequent data show results for all 14 days over the 2-yr period. Only the rate

Table 7. Simple correlation coefficients between various date, plant, and environmental variables and picloram concentration in the upper and lower stems of honey mesquite near Bryan, TX, treated in 1980 and 1981.

Variable[a]	Day sampled after treatment[b]							
	3				30			
	Upper		Lower		Upper		Lower	
	Phloem	Xylem	Phloem	Xylem	Phloem	Xylem	Phloem	Xylem
Time of year sprayed								
Julian day of year	–0.05	–0.54	–0.45	–0.51	–0.36	–0.69	–0.57	–0.49
Plant variables								
Stem diameter (mm)	0.63	0.86	0.61	0.70	0.06	0.17	0.15	0.13
Periderm thickness (mm)	0.34	0.76	0.48	0.60	–0.15	–0.02	–0.11	–0.13
Total phloem thickness (mm)	0.02	0.58	0.43	0.58	0.12	0.52	0.11	0.21
New xylem ring thickness (mm)	–0.10	–0.67	–0.46	–0.52	–0.31	–0.67	–0.53	–0.47
New xylem ring growth rate (mm/2 wk)	–0.15	0.38	0.41	0.56	0.25	0.44	0.24	0.25
Mean thickness of older xylem rings (mm)	0.21	0.74	0.46	0.67	–0.17	0.09	–0.09	–0.09
Pith diameter (mm)	0.08	0.53	0.40	0.53	–0.13	–0.01	–0.08	–0.08
Total daily apparent photosynthesis (Pn•h)	–0.05	0.82	0.84	0.68	0.63	0.80	0.91	0.74
Maximum apparent daily photosynthesis (Pn)	0.61	0.81	0.47	0.57	0.53	0.38	0.47	0.28
Maximum theoretical daily photosynthesis rate (Pn)	0.28	0.72	0.50	0.66	0.26	0.34	0.29	0.17
Upward methylene blue dye movement (cm/h)	–0.32	0.27	0.18	0.27	0.08	0.66	0.41	0.44
Predawn leaf moisture stress (–MPa)	0.25	0.74	0.60	0.76	0.32	0.53	0.32	0.35
Midday leaf moisture stress (–MPa)	0.58	0.69	0.47	0.57	0.71	0.63	0.40	0.36
Total leaf moisture stress in daylight (–MPa•h)	0.67	0.69	0.38	0.52	0.56	0.50	0.34	0.31
Environmental variables								
Soil moisture 0–30 cm (%)	0.25	0.52	0.46	0.66	0.29	0.55	0.41	0.54
Soil temperature at 30 cm (C)	–0.46	–0.53	–0.30	–0.35	–0.54	–0.58	–0.45	–0.44
Maximum air temperature (C)	–0.50	–0.73	–0.47	–0.55	–0.24	–0.42	–0.32	–0.30
Mean air temperature (C)	–0.57	–0.69	–0.43	–0.48	–0.22	–0.37	–0.26	–0.28
Mean air temperature 1 week before spraying (C)	–0.60	–0.55	–0.18	–0.32	–0.42	–0.49	–0.36	–0.36
Degree days above 18 C (C•h)	–0.59	–0.69	–0.42	–0.50	–0.26	–0.40	–0.27	–0.30
Rainfall 1 week before spraying (cm)	0.36	0.47	0.59	0.61	0.44	0.61	0.73	0.76
Rainfall 1 month before spraying (cm)	0.55	0.22	0.28	0.33	0.53	0.39	0.43	0.53
Other herbicide variables								
Upper xylem, 3 day (μg/g)	0.52	1.00	0.78	0.88	0.17	0.30	0.26	0.20
Lower phloem, 3 day (μg/g)	0.39	0.78	1.00	0.90	0.18	0.34	0.33	0.33
Lower xylem, 3 day (μg/g)	0.33	0.88	0.90	1.00	0.18	0.40	0.31	0.30
Upper phloem, 30 day (μg/g)	0.40	0.17	0.18	0.18	1.00	0.61	0.57	0.45
Upper xylem, 30 day (μg/g)	0.03	0.30	0.34	0.34	0.61	1.00	0.80	0.85
Lower phloem, 30 day (μg/g)	0.14	0.26	0.33	0.31	0.57	0.80	1.00	0.91
Lower xylem, 30 day (μg/g)	0.14	0.20	0.33	0.30	0.45	0.85	0.91	1.00

[a] Variables were measured or samples collected within 24 h of spraying, except where otherwise indicated.

[b] Correlation coefficients of ± 0.53 or ± 0.66 are significant at the 5 and 1% level, respectively.

Table 8. Simple correlation coefficients between various date, plant, and environmental variable and 2,4,5-T concentration in the upper and lower stems of honey mesquite near Bryan, TX, treated in 1980 and 1981.

	Day sampled after treatment[b]							
	3				30			
	Upper		Lower		Upper		Lower	
Variable[a]	Phloem	Xylem	Phloem	Xylem	Phloem	Xylem	Phloem	Xylem
Time of year sprayed								
Julian day of year	0.05	−0.87	−0.51	−0.81	−0.27	−0.51	−0.37	−0.68
Plant variables								
Stem diameter (mm)	0.37	0.45	0.80	0.59	0.58	0.20	0.79	0.49
Periderm thickness (mm)	0.15	0.41	0.67	0.48	0.41	0.01	0.69	0.41
Total phloem thickness (mm)	−0.06	0.55	0.57	0.41	0.42	0.45	0.63	0.74
New xylem ring thickness (mm)	−0.04	−0.77	−0.57	−0.84	−0.42	−0.56	−0.48	−0.81
New xylem ring growth rate (mm/2 wk)	−0.17	0.62	0.25	0.41	−0.04	0.06	0.20	0.18
Mean thickness of older xylem rings (mm)	0.17	0.64	0.69	0.46	0.47	0.26	0.75	0.45
Pith diameter (mm)	0.10	0.45	0.62	0.19	0.42	0.16	0.72	0.36
Total daily apparent photosynthesis (Pn•h)	0.06	0.89	0.72	0.80	0.13	0.35	0.19	0.36
Maximum apparent daily photosynthesis (Pn)	0.56	0.55	0.32	0.43	0.26	−0.07	0.41	0.14
Upward methylene blue dye movement (cm/h)	−0.23	0.65	0.29	0.64	0.18	0.70	0.22	0.83
Predawn leaf moisture stress (−MPa)	0.12	0.49	0.48	0.56	0.36	0.26	0.54	0.53
Midday leaf moisture stress in daylight (−MPa•h)	0.43	0.40	0.55	0.44	0.63	0.28	0.64	0.57
Total leaf moisture stress in daylight above predawn baseline (−MPa•h)	0.59	−0.02	0.34	0.10	0.61	0.21	0.46	0.36
Environmental variables								
Soil temperature at 30 cm (C)	−0.40	−0.37	−0.56	−0.58	−0.68	−0.55	−0.61	−0.79
Maximum air temperature (C)	−0.39	−0.47	−0.75	−0.60	−0.74	−0.52	−0.80	−0.81
Mean air temperature (C)	−0.45	−0.42	−0.77	−0.59	−0.78	−0.55	−0.81	−0.79
Mean air temperature 1 week before spraying (C)	−0.55	−0.24	−0.42	−0.46	−0.64	−0.42	−0.54	−0.62
Minimum air temperature (C)	−0.24	−0.28	−0.47	−0.44	−0.57	−0.43	−0.60	−0.78
Degree days above 18 C (C•h)	−0.46	−0.35	−0.70	−0.53	−0.75	−0.50	−0.78	−0.77
Rainfall 1 week before spraying (cm)	0.18	0.39	0.22	0.54	−0.03	0.00	0.07	−0.01
Other herbicide variables								
Upper phloem, 3 day (μg/g)	1.00	0.05	0.36	0.11	0.76	0.00	0.51	0.00
Upper xylem, 3 day (μg/g)	0.05	1.00	0.65	0.85	0.31	0.45	0.45	0.49
Lower phloem, 3 day (μg/g)	0.36	0.65	1.00	0.62	0.75	0.44	0.91	0.55
Lower xylem, 3 day (μg/g)	0.11	0.85	0.62	1.00	0.31	0.48	0.37	0.55
Upper phloem, 30 day (μg/g)	0.76	0.31	0.75	0.31	1.00	0.43	0.87	0.52
Upper xylem, 30 day (μg/g)	0.00	0.45	0.44	0.48	0.43	1.00	0.35	0.84
Lower phloem, 30 day (μg/g)	0.51	0.45	0.91	0.37	0.87	0.35	1.00	0.54
Lower xylem, 30 day (μg/g)	0.00	0.49	0.55	0.55	0.52	0.84	0.54	1.00

[a] Variables were measured or samples collected within 24 h of spraying, except where otherwise indicated.

[b] Correlation coefficients of ± 0.53 or ± 0.66 are significant at the 5 and 1% level, respectively.

of upward methylene blue dye movement was slightly better correlated for predicting percentage of dead plants with triclopyr.

Table 10 also shows simple regressions for percentage of canopy reduction and dead plants using environmental and other plant variables measured or sampled at or before treatment. Rate of upward methylene blue dye movement (X1) was the most effective variable for predicting honey mesquite control in all regressions except percentage of canopy reduction by picloram. Here, predawn or lowest leaf moisture stress (X2) accounted for the most variability.

Table 11 shows two- and three-variable regressions for predicting honey mesquite control. Rate of upward methylene blue dye movement (X1) occurred in most equations. Other plant variables included leaf moisture stress measured in three ways: new stem length, thickness of periderm, and new xylem ring, or mean of older xylem rings in the stem. Environmental variables included mean or maximum air temperature, rainfall 1 week before spraying, and percentage of soil water at 0 to 30 or 61 to 91 cm.

Table 12 shows the relationship between honey mesquite control and herbicide concentration in the stem 3 or 30 days after treatment. All equations were significant at the 5% level except for percentage of dead plants with 2,4,5-T. In all simple regressions, best precision was obtained by herbicide concentration in the xylem, particularly 3 days after spraying.

Adding the second variable to the equation increased the R^2 value about 10% (Table 12). Upper phloem concentration at 3 days was added to the equation for clopyralid and 2,4,5-T. All but two equations, which had two xylem

Table 9. Simple correlation coefficients between various date, plant, and environmental variable and triclopyr concentration in the upper and lower stems of honey mesquite near Bryan, TX, treated in 1980 and 1981.

	Day sampled after treatment[b]							
	3				30			
	Upper		Lower		Upper		Lower	
Variable[a]	Phloem	Xylem	Phloem	Xylem	Phloem	Xylem	Phloem	Xylem
Time of year sprayed								
Julian day of year	0.11	−0.77	−0.34	−0.82	−0.39	−0.47	−0.44	−0.42
Plant variables								
Stem diameter (mm)	0.43	0.58	0.50	0.53	0.10	0.12	0.45	0.14
Periderm thickness (mm)	0.13	0.57	0.54	0.57	−0.06	−0.07	0.33	−0.08
New xylem ring thickness (mm)	−0.05	−0.82	−0.39	−0.83	−0.50	−0.53	−0.54	−0.46
Mean thickness of older xylem rings (mm)	0.16	0.57	0.39	0.61	−0.02	0.10	0.19	0.12
Pith diameter (mm)	0.18	0.35	0.63	0.34	−0.14	0.07	0.40	0.08
Total daily apparent photosynthesis (Pn•h)	−0.16	0.63	0.29	0.76	0.18	0.32	0.50	0.33
Maximum apparent daily photosynthesis (Pn)	0.26	0.54	−0.37	0.38	0.17	−0.11	−0.08	−0.07
Maximum theoretical photosynthesis (Pn)	0.17	0.62	0.06	0.45	0.08	−0.13	0.13	−0.18
Upward methylene blue dye movement (cm/h)	−0.25	0.55	0.21	0.79	0.48	0.68	0.24	0.63
Predawn leaf moisture stress (−MPa)	0.09	0.48	0.18	0.60	0.31	0.26	0.23	0.20
Midday leaf moisture stress in daylight (−MPa)	0.45	0.53	0.30	0.29	0.71	0.35	0.56	0.22
Total leaf moisture stress in daylight (−MPa•h)	0.50	0.48	0.22	0.27	0.65	0.36	0.48	0.27
Total leaf moisture stress in daylight above predawn baseline (−MPa•h)	0.60	0.30	0.16	−0.12	0.66	0.30	0.50	0.22
Environmental variables								
Soil temperature at 30 cm (C)	−0.41	−0.59	−0.34	−0.56	−0.73	−0.60	−0.63	−0.54
Maximum air temperature (C)	−0.44	−0.66	−0.56	−0.60	−0.48	−0.50	−0.64	−0.47
Mean air temperature (C)	−0.50	−0.59	−0.54	−0.58	−0.49	−0.52	−0.64	−0.50
Mean air temperature 1 week before spraying (C)	−0.50	−0.50	−0.08	−0.36	−0.69	−0.46	−0.40	−0.40
Minimum air temperature (C)	−0.37	−0.46	−0.37	−0.56	−0.56	−0.47	−0.40	−0.40
Degree days above 18 C (C•h)	−0.51	−0.55	−0.47	−0.50	−0.53	−0.49	−0.59	−0.46
Other herbicide variables								
Upper phloem, 3 day (μg/g)	1.00	0.16	0.36	−0.04	0.29	−0.08	0.54	−0.08
Upper xylem, 3 day (μg/g)	0.16	1.00	0.43	0.80	0.22	0.17	0.54	0.18
Lower phloem, 3 day (μg/g)	0.36	0.43	1.00	0.46	−0.03	0.20	0.79	0.24
Lower xylem, 3 day (μg/g)	−0.04	0.80	0.46	1.00	0.10	0.34	0.41	0.39
Upper phloem, 30 day (μg/g)	0.29	0.22	−0.03	0.10	1.00	0.65	0.35	0.50
Upper xylem, 30 day (μg/g)	−0.08	0.17	0.20	0.34	0.65	1.00	0.42	0.97
Lower phloem, 30 day (μg/g)	0.54	0.54	0.79	0.41	0.35	0.42	1.00	0.42
Lower xylem, 30 day (μg/g)	−0.08	0.18	0.24	0.39	0.50	0.97	0.42	1.00

[a] Variables were measured or samples collected within 24 h of spraying, except where otherwise indicated.

[b] Correlation coefficients of ± 0.53 or ± 0.66 are significant at the 5 and 1% level, respectively.

concentration variables, had one phloem and one xylem variable.

DISCUSSION

This research confirms that clopyralid is superior to picloram for the control of honey mesquite (3, 12), which is more effective than either 2,4,5-T or triclopyr (3, 11). Clopyralid is the most effective herbicide for controlling honey mesquite but does not have the broad spectrum of activity on most other woody species as do the other three herbicides evaluated (12). The herbicide 2,4,5-T at the present time is the least expensive herbicide of the four and probably will continue to be used for controlling honey mesquite if retained commercially. Triclopyr has activity similar to 2,4,5-T.

Generally, the level of honey mesquite control with 2,4,5-T or picloram plus 2,4,5-T begins from bud-break about April 1, increases through April, reaches a maximum in May and June, and then decreases in July, August, and September (13). In this study, herbicide treatments were made beginning at the most effective period, and the last was made in September. Research of Dahl et al. (4) and Meyer et al. (13) showed that early in the growing season increasing levels of honey mesquite control were positively related with warming soil temperature, adequate soil moisture, and a complete complement of enlarging leaves. Subsequently, soil temperature continues to increase without a progressive increase in herbicide effectiveness. Thus, May and June are generally periods with adequate soil and air temperature and soil moisture for plant growth. During this time, radial enlargement is proceeding most rapidly causing the stem

Table 10. Simple regression equations for predicting response of honey mesquite near Bryan, TX, to herbicides over a 1- or 2-yr period.

Herbicide	Type control[a]	Equation[b]	R^2 [c]
		Total daily apparent photosyntheses (PHS) over 7 dates in 1981	
Clopyralid	C.R.	$\hat{y} = 15.96 + 0.34\,(PHS)$	0.70
	D.P.	$\hat{y} = -100.69 + 0.78\,(PHS)$	0.63
Picloram	C.R.	$\hat{y} = -93.47 + 0.77\,(PHS)$	0.92
	D.P.	$\hat{y} = -163.69 + 0.98\,(PHS)$	0.76
2,4,5-T	C.R.	$\hat{y} = -37.83 + 0.40\,(PHS)$	0.69
	D.P.	$\hat{y} = -15.19 + 0.10\,(PHS)$	0.17[d]
Triclopyr	C.R.	$\hat{y} = -73.33 + 0.62(PHS)$	0.69
	D.P.	$\hat{y} = -84.57 + 0.51\,(PHS)$	0.52[e]
		Environmental and other plant variables over 14 dates in 1980 and 1981	
Clopyralid	C.R.	$\hat{y} = 79.45 + 0.12(X1)$	0.39
	D.P.	$\hat{y} = 39.94 + 0.30\,(X1)$	0.46
Picloram	C.R.	$\hat{y} = 117.05 + 53.65(X2)$	0.55
	D.P.	$\hat{y} = -0.10 + 0.41(X1)$	0.60
2,4,5-T	C.R.	$\hat{y} = 29.05 + 0.26(X1)$	0.70
	D.P.	$\hat{y} = -1.94 + 0.15(X1)$	0.41
Triclopyr	C.R.	$\hat{y} = 34.85 + 0.29(X1)$	0.64
	D.P.	$\hat{y} = -1.80 + 0.27(X1)$	0.58

[a] C.R. = Percent canopy reduction; D.P. = percent dead plants.

[b] Variable abbreviations are the following: PHS = Total daily apparent photosynthesis (Pn•h); X1 = rate of upward methylene blue dye movement (cm/h); X2 = lowest leaf moisture stress (–MPa).

[c] All equations are significant at least at the 2% level, except where noted.

[d] Significant at the 36% level.

[e] Significant at the 7% level.

and root to form a sink for new photosynthates and foliar-translocated herbicides.

Information from this study and others (13, 15) suggests that increasing water stress and reduction in photosynthesis seem to be the regulating factors in effective control from July through August. In September, when temperatures are lower, photosynthesis increases compared with that in August, but soil water generally does not.

Thus, variables that can be measured relatively easily at time of treatment, such as soil and air temperature and soil moisture, are important in predicting control during the increasingly effective period of April. During the post-optimum period for control in July and August, as was included in this study, in a period of increasing moisture stress the most useful variable to measure was rate of methylene blue dye upward movement in the xylem. This variable is relatively inexpensive to measure, requiring little time and technical training. Photosynthesis rate is probably a more accurate measure of plant activity, but it is difficult to estimate accurately without specialized equipment. Also, the photosynthetic rate was not closely correlated with the September treatment.

The relationship between plant control and herbicide concentration in the stem 3 and 30 days after treatment is variable. The overall concentration in the stem among herbicides is directly related to the amount of honey mesquite control. For instance, clopyralid gave more effec-

Table 11. Two- and three-variable multiple regression equations for predicting response of honey mesquite near Bryan, TX, to herbicides with plant and environmental variables over a 2-yr period.

Herbicide	Type control[a]	Equation[b]	R^2 [c]
		Two-variable equations	
Clopyralid	C.R.	$\hat{y} = 60.13 + 0.11(X1) - 1.20(X2)$	0.66
	D.P.	$\hat{y} = -94.20 + 0.49(X1) + 5.16(X3)$	0.73
Picloram	C.R.	$\hat{y} = 91.26 + 82.96(X1) - 1.75(X4)$	0.72
	D.P.	$\hat{y} = -6.72 + 0.39(X1) + 4.43(X5)$	0.78
2,4,5-T	C.R.	$\hat{y} = 88.94 + 0.21(X1) - 1.59(X6)$	0.84
	D.P.	$\hat{y} = -24.13 + 0.15(X1) - 1.38(X2)$	0.63
Triclopyr	C.R.	$\hat{y} = 7.75 + 0.29(X1) - 1.68(X2)$	0.77
	D.P.	$\hat{y} = -41.84 + 0.32(X1) - 1.24(X4)$	0.73
		Three-variable equations	
Clopyralid	C.R.	$\hat{y} = 107.4 - 1.6(X2) - 43.9(X7) - 11.9(X8)$	0.80
	D.P.	$\hat{y} = -133.2 + 0.48(X1) + 6.0(X3) + 1.6(X9)$	0.87
Picloram	C.R.	$\hat{y} = 26.6 - 23.2(X8) + 4.1(X10) + 46.6(X11)$	0.91
	D.P.	$\hat{y} = 22.1 + 0.4(X1) + 4.5(X5) - 41.4(X12)$	0.88
2,4,5-T	C.R.	$\hat{y} = 57.8 + 0.2(X1) - 1.1(X2) - 1.2(X6)$	0.91
	D.P.	$\hat{y} = -43.2 + 0.1(X1) - 1.5(X2) + 13.7(X13)$	0.72
Triclopyr	C.R.	$\hat{y} = 15.2 - 2.5(X4) - 30.4(X8) + 1.7(X14)$	0.87
	D.P.	$\hat{y} = 12.9 + 0.3(X1) - 2.6(X4) - 2.9(X10)$	0.81

[a] C.R. = Percent canopy reduction; D.P. = percent dead plants.

[b] Variable abbreviations are the following: X1 = rate of upward methylene blue dye movement (cm/h); X2 = leaf moisture stress in daylight above the night baseline pressure (–MPa•h); X3 = maximum daily air temperature (C); X4 = total leaf moisture stress in daylight (–MPa•h); X5 = rainfall 1 week before spraying (cm); X6 = new stem length (cm); X7 = stem periderm thickness (mm); X8 = new stem xylem ring thickness (mm); X9 = soil moisture at 0 to 30 cm (%); X10 = mean daily air temperature (C); X11 = lowest leaf moisture stress (–MPa); X12 = stem pith diam (mm); X13 = older stem xylem ring thickness (mm); X14 = soil moisture at 61 to 91 cm (%).

[c] All equations are significant at the 1% level.

Table 12. One- and two-variable multiple regression equations for relating response of honey mesquite near Bryan, TX, with herbicide content in the stems.

Herbicide	Type control[a]	Equation[b]	R^2[c]
		Simple regression equations	
Clopyralid	C.R.	$\hat{y} = 73.41 + 5.49(X1)$	0.39
	D.P.	$\hat{y} = 48.41 + 6.30(X2)$	0.43
Picloram	C.R.	$\hat{y} = 57.48 + 7.5(X2)$	0.42
	D.P.	$\hat{y} = 17.70 + 12.73(X2)$	0.56
2,4,5-T	C.R.	$\hat{y} = 36.88 + 55.49(X3)$	0.52
	D.P.	$\hat{y} = 4.30 + 27.13(X3)$	0.22[d]
Triclopyr	C.R.	$\hat{y} = 37.63 + 295.95(X1)$	0.60
	D.P.	$\hat{y} = -0.12 + 284.83(X1)$	0.58
		Two-variable equations	
Clopyralid	C.R.	$\hat{y} = 80.81 + 6.49(X1) - 0.78(X4)$	0.48
	D.P.	$\hat{y} = 76.49 + 7.31(X2) - 2.33(X4)$	0.57
Picloram	C.R.	$\hat{y} = 50.43 + 10.04(X1) + 5.84(X2)$	0.53
	D.P.	$\hat{y} = 26.51 + 16.02(X2) - 4.31(X5)$	0.63
2,4,5-T	C.R.	$\hat{y} = 43.57 + 56.76(X3) - 6.54(X4)$	0.63
	D.P.	$\hat{y} = 8.98 + 28.02(X3) - 4.58(X4)$	0.32[e]
Triclopyr	C.R.	$\hat{y} = 43.99 + 292.21(X1) - 7.53(X4)$	0.67
	D.P.	$\hat{y} = -2.69 + 446.42(X1) - 55.90(X3)$	0.69

[a] C.R. = Percent canopy reduction; D.P. = percent dead plants.

[b] Variable abbreviations are the following: X1 = lower stem xylem concentration after 3 days; X2 = upper stem xylem concentration after 30 days; X3 = upper stem xylem concentration after 3 days; X4 = upper stem phloem concentration after 3 days; X5 = upper stem phloem concentration after 30 days. All variables are expressed as µg/g tissue.

[c] All equations are significant at the 5% level, except where otherwise indicated.

[d] Significant at the 9% level.

[e] Significant at the 12% level.

tive control and occurred in higher concentrations in the stem than 2,4,5-T. However, the seasonal variation in control by a given herbicide is positively, but not necessarily highly related to the concentration in the stem. Certainly, large variation occurred because of analyzing a relatively small number of samples, only a small portion of the total stem, and none of the root tissue. The concentration of herbicide in the xylem was generally more correlated with control than that in the phloem. This occurred probably because there is more living tissue in the spring wood of the xylem that could absorb herbicide than in the phloem. Probably, the capacity of the phloem to hold a given herbicide was soon saturated, thus accounting for its lower correlation with control.

More detailed research is needed to monitor herbicide movement in field-grown woody plants. Probably, the foliar-translocated herbicides move rapidly downward in the phloem and quantities are moved into the cambial and xylem regions where they are complexed with other organic compounds. Subsequently, if the tissue has not been killed either directly by the herbicide or indirectly by isolation because of other tissue being killed, the herbicide probably can be cycled back into the translocation system under the right conditions. Therefore, it could be translocated to actively growing areas and concentrated in toxic quantities.

This study has compared the relative effectiveness of herbicides for the control of honey mesquite when applied throughout most of the growing season. It also has identified several variables for predicting the final level of control of honey mesquite by herbicide and has indicated the relationships between herbicide concentration in honey mesquite stems and control.

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Influence of Surfactants on the Toxicity of Asulam to Johnsongrass (*Sorghum halepense*) and Sugarcane (*Saccharum* sp.)[1]

EDWARD P. RICHARD, JR.[2]

Abstract. **The influence of surfactant type and concentration on the efficacy of asulam {methyl [(4-aminophenyl) sulfonyl] carbamate} for controlling rhizomatous johnsongrass [*Sorghum halepense* (L.) Pers. #[3] SORHA] was evaluated in field and greenhouse studies. Under field conditions, nonoxynol (9 to 10 POE) [α-lp-nonylphenyl)-*w*-hydroxypoly(oxyethylene)] applied at concentrations of 6% (v/v) with asulam at 2.8 kg ai/ha reduced rhizomatous johnsongrass biomass by 35%, with no consistently significant difference in asulam's performance between surfactant concentrations of 0 and 3% (v/v) being observed. Asulam applied with nonoxynol at concentrations of 3 and 6% (v/v) reduced sugarcane (*Saccharum* interspecific hybrids) yields and significantly offset any advantages from increased johnsongrass control. In greenhouse studies, where johnsongrass foliage was washed either 0, 1, 6, 24, or 48 h after treatment (HAT), the degree of johnsongrass control with asulam was generally not affected by the type of surfactant (paraffin-base petroleum oil-surfactant blend or alcohol-surfactant-water mixture) used. At least 48 h was needed to insure adequate basipetal translocation, hence maximum inhibition of rhizome regrowth with asulam applied alone. Increasing the surfactant concentration shortened this interval to 48 h (0.25%) to 24 h (0.5 to 1%) to 6 h (3%) to 1 h (6%).**

Additional index words. **Absorption, SORHA.**

INTRODUCTION

Johnsongrass is the most widespread and economically most important weed of sugarcane in Louisiana (2). This weed is currently being controlled in sugarcane with postemergence applications of asulam (15). Asulam possesses good postemergence herbicidal activity on many monocotyledonous weeds (10, 15, 18), is translocated in a source to sink pattern affecting all meristematic regions (20), and is relatively nonphytotoxic to sugarcane when used at recommended rates (10, 15). Control of johnsongrass with asulam has been inconsistent in Louisiana because asulam is applied to johnsongrass ranging in growth from two to three leaves to flowering and under a wide range of soil moisture and temperature conditions. In addition, rainstorms occur frequently during the peak usage period and the chances for washoff are great. Thus, any factor that might increase the degree or rate of absorption should be beneficial in insuring consistent performance with asulam.

Surfactants have been used to enhance herbicide absorption. The degree of enhancement depends on the type, rate, and formulation of herbicide (8, 11); surfactant (4, 6, 9, 17); and weed species (1, 6). By enhancing herbicidal absorption, surfactants insure consistency in the performance of postemergence herbicides, particularly when they are applied under conditions of low relative humidity (11, 13), to mature plants (16), to those stressed by temperature (12), or where the time interval between herbicide application and rainfall is likely to be short (5, 7).

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[1] Received for publication April 8, 1985, and in revised form August 15, 1985. Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Dep. Agric. and does not imply its approval to the exclusion of other products that may also be suitable.

[2] Res. Agron., U.S. Sugarcane Field Lab., Agric. Res. Serv., U.S. Dep. Agric., Houma, LA 70361.

[3] Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds, Weed Sci. 32, Suppl. 2. Available from WSSA, 309 West Clark St., Champaign, IL 61820.