Control of honey mesquite with clopyralid, triclopyr, or clopyralid:triclopyr mixtures

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Abstract

Greenhouse and field experiments were conducted to evaluate clopyralid formulations and triclopyr ester alone and in mixtures with clopyralid for control of honey mesquite. In the greenhouse, mixtures of the butoxyethyl ester of triclopyr enhanced the activity of the 2-ethylhexyl ester, the monoethanolamine salt and the free acid of clopyralid when applied in 1:1, 1:2 or 1:4 clopyralid:triclopyr mixtures at total rates of 0.07, 0.14, and 0.28 kg ae/ha. The activity of triclopyr was not enhanced by addition of clopyralid. In the field, mixtures of the 1-decyl ester of clopyralid + the butoxyethyl ester of triclopyr were usually more effective than either herbicide applied alone. Addition of 0.14 kg/ha of triclopyr to clopyralid applied at 0.28 kg/ha markedly increased canopy reduction and mortality by at least 47% compared to either herbicide applied alone. Basal pours of diesel oil alone at 0.9 L/tree were usually as effective as diesel oil fortified with esters of clopyralid, 2,4,5-T or triclopyr at 4.8 or 9.6 g/L. Basal sprays of diesel oil + esters of clopyralid, 2,4,5-T or triclopyr in concentrations of 4.8 or 9.6 g/L applied at 0.5 L/tree caused high mortality of honey mesquite trees similar to basal pours. Triclopyr or clopyralid at 4.8 g/L were less effective in diesel oil:water carrier (1:4 or 1:3), respectively, than in diesel oil carrier.

Key Words: herbicides, canopy reduction, mortality, foliar sprays, basal treatments

Honey mesquite (*Prosopis glandulosa* Torr.) is a woody legume that occurs as a weed problem on several million hectares of rangeland in the southwestern U.S. (Meyer et al. 1971). Jacoby et al. (1982) and Bovey and Meyer (1985) found that the monoethanolamine salt of clopyralid (3,6-dichloro-2-pyridinecarboxylic acid) was superior at equivalent rates to 2,4,5-T [(2,4,5-trichlorophenoxy)acetic], dicamba (3,6-dichloro-*o*-anisic acid), picloram (4-amino-3,5,6-trichloropicolinic acid), and triclopyr {[(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid} for the control of honey mesquite in the field. Mixtures of clopyralid + picloram or clopyralid + triclopyr (1:1) were as effective as clopyralid applied alone when similar rates were used. The addition of picloram or triclopyr to clopyralid enhanced the absorption and transport of clopyralid into the leaves and upper-stem phloem by 1 day after treatment versus clopyralid applied alone (Bovey et al. 1988).

The potassium salt, free acid, 1-decyl ester, 2-ethylhexyl ester and the monoethanolamine salt were evaluated to determine the most effective chemical formulation of clopyralid for control of honey mesquite (Bovey et al. 1989). With the exception of the 2-ethylhexyl ester, all formulations were about equally effective in killing greenhouse-grown plants at rates of 0.21 or 0.28 kg/ha applied foliar. An oil-soluble formulation of clopyralid such as the esters is desired for aircraft spraying and individual plant treatment because of enhanced penetration of plant surfaces and miscibility with oil carriers and other oil-soluble herbicides. Triclopyr ester has been suggested to replace 2,4,5-T for basal treatments of honey mesquite (Welch 1988), but little data are available on its effectiveness. Therefore, our objectives were to compare the effectiveness of various clopyralid formulations alone and in combination with triclopyr ester for honey mesquite control as broadcast foliar sprays and as basal treatments.

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Materials and Methods

Greenhouse-Foliar Sprays

Honey mesquite plants were grown from seed in the greenhouse in pots (12.7 cm diam by 12.7 cm deep) containing a mixture of Bleiblerville clay (fine montmorillonitic Udic Pellusterts), sand and peat moss 1:1:1 (v/v/v), from February to August 1987. Daytime temperature was 35° C, and night temperature was 25° C. Day length was 14 h with PAR≈800 μm/m^2/sec at midday during sunlight. Two plants were grown/pot, and each had a single woody stem with an average height of 33 cm and 12 leaves/plant. Pots were watered daily. A commercial fertilizer (13-13-13) was applied at 0.85 g/pot every 6 weeks.

Foliar sprays of the 2-ethylhexyl ester, the monoethanolamine salt and the free acid of clopyralid, and the butoxyethyl ester of triclopyr were applied alone and in 1:1, 1:2, and 1:4 clopyralid:triclopyr mixtures at 0.035, 0.07, 0.14, and 0.28 kg ae/ha total herbicide. Applications were made in May and June 1987 in 93 L/ha water carrier in a laboratory spray chamber (Bouse and Bovey 1967) to pots containing 3-month-old honey mesquite. Rates of herbicide selected were based on previous studies at which these rates killed a percentage of stem tissue on each plant below, at, and above 50% (Bovey and Meyer 1985, Bovey et al. 1989). The soil was protected from spray by placing vermiculite in the pot before treatment and discarding it immediately following treatment. Plants were returned to the greenhouse and watered after 24 hours and daily thereafter. Care was taken not to wash any herbicide from the plant onto the soil.

Two months after spraying, the response of treated plants to herbicides was evaluated by visually estimating the percentage of dead stem tissue on each plant. Plants with 100% dead stem tissue and no resprouts were considered dead. Six replications (pots) with 2 plants/replicate were used in a randomized complete block design. Data were subjected to analysis of variance, and means were compared by the Fisher Protected least significant difference (LSD) at the 5% level (Steel and Torrie 1980). The experiment was repeated, and data for the May and June 1987 treatments were presented separately due to the date by treatment interaction.

Field-Foliar Sprays

Honey mesquite plants 1.5 to 2.0 m tall growing in a Wilson clay loam (fine, montmorillonitic thermic Vertic Ochraqualfs) near Bryan, Texas showed vigorous regrowth, usually multistemmed, on an area bulldozed several years before. Plants were numbered with metal tags in groups of 5 for each replication. Plants were >1 m apart within the groups (replication). Treatments were applied on 13 July 1987 with 3 replications per treatment (total 15 plants)

Table 1. Percent dead stem tissue of greenhouse-grown honey mesquite 2 months after foliar application of 13 herbicide treatments to 3-month-old plants using 3 clopyralid formulations in mixtures with triclopyr[1].

	Herbicide rate (kg/ha)							
	0.035		0.07		0.14		0.28	
Herbicide	May	June	May	June	May	June	May	June
Clopyralid	%							
2-ethylhexyl ester (2-EHE)	2	3	2	8	13	7	13	37
Monoethanolamine salt (MEA)	11	3	3	5	15	29	51	68
Free acid (FA)	4	3	18	32	36	61	69	88
Triclopyr								
Butoxyethyl ester (BEE)	20	29	20	29	57	74	100	93
Clopyralid + triclopyr								
2-EHE + BEE (1:1)			11	10	68	56	71	79
2-EHE + BEE (1:2)			5	30	73	84	72	89
2-EHE + BEE (1:4)			13	17	76	81	83	96
MEA + BEE (1:1)			13	28	41	53	76	95
MEA + BEE (1:2)			24	28	81	48	70	85
MEA + BEE (1:4)			19	37	68	76	91	93
FA + BEE (1:1)			22	53	62	86	94	95
FA + BEE (1:2)			36	54	85	92	91	93
FA + BEE (1:4)			33	51	77	64	100	100

[1]$LSD_{(0.05)}$ = 22% for May 1987 application and 24% for June 1987 application; untreated = 2% for May or June treatments.

arranged in a randomized complete block design. The entire experiment was repeated on 13 July 1988. The 2-ethylhexyl ester and the monoethanolamine salt of clopyralid were applied alone at 0.28 or 0.56 kg ae/ha, whereas the 1-decyl ester of clopyralid and the butoxyethyl ester of triclopyr were applied alone at 0.14, 0.28, or 0.56 kg/ha and in all paired mixtures at these rates except 0.56 + 0.56 kg/ha. The potassium salt of picloram + butoxyethyl ester of triclopyr were included at 0.28 + 0.28 kg/ha for comparison. The herbicides were broadcast sprayed on each honey mesquite tree in 190 L/ha of water at 210 kPa. A hand-carried 3 nozzle boom sprayer was used. Herbicide treatments were evaluated after 1 yr by estimating percent canopy reduction and/or mortality of each tree. Trees were considered dead if they were completely defoliated and had no living tissue or resprouts. Canopy reduction and mortality data were subjected to analysis of variance, and means were separated by the protected LSD procedure ($p \leq 0.05$) (Steel and Torrie 1980). Data from the foliar sprays applied in 1987 and 1988 (Table 2) were pooled for presentation since there was no date by treatment interaction.

Table 2. Percent canopy reduction and mortality of 1.5- to 2-m tall honey mesquite trees 1 yr after foliar application of ester formulations of clopyralid, triclopyr, and clopyralid:triclopyr mixtures on 13 July 1987 and 1988.

		Honey mesquite control	
Herbicide	Rate	Canopy reduction	Mortality
	(kg/ha)	(%)	
Clopyralid + triclopyr[1]	0.14 + 0.14	57	13
Clopyralid + triclopyr	0.14 + 0.28	82	33
Clopyralid + triclopyr	0.14 + 0.56	83	33
Clopyralid + triclopyr	0.28 + 0.14	87	57
Clopyralid + triclopyr	0.28 + 0.28	92	49
Clopyralid + triclopyr	0.28 + 0.56	94	57
Clopyralid + triclopyr	0.56 + 0.14	97	84
Clopyralid + triclopyr	0.56 + 0.28	94	57
Triclopyr (butoxyethyl ester)	0.14	40	3
Triclopyr (butoxyethyl ester)	0.28	57	3
Triclopyr (butoxyethyl ester)	0.56	69	10
Clopyralid (1-decyl ester)	0.14	20	0
Clopyralid (1-decyl ester)	0.28	39	10
Clopyralid (1-decyl ester)	0.56	87	50
Clopyralid (2-ethylhexyl ester)	0.28	49	3
Clopyralid (2-ethylhexyl ester)	0.56	83	47
Clopyralid (monoethanolamine salt)	0.28	69	33
Clopyralid (monoethanolamine salt)	0.56	94	80
Picloram + triclopyr[2]	0.28 + 0.28	86	33
Untreated	—	3	0
$LSD_{(0.05)}$		12	29

[1] 1-decyl ester of clopyralid plus the butoxyethyl ester of triclopyr
[2] potassium salt of picloram plus the butoxyethyl ester of triclopyr

Field-Basal Treatments

For individual plant treatment, trees 3 to 5 m tall were selected in the same general area as the foliar spray treatments. Trees had 1 to 5 stems from a single crown with stems 7 to 25 cm in diam. Trees were treated during the dry season (August 1984, 1985, 1986, and 1987) when the soil was pulled away from the base of the plant to allow penetration of the diesel oil and/or herbicide to the buds on the crown (Welch 1988). Treatments in 1984 and 1985 consisted of diesel oil alone or diesel oil:water carriers with the butoxyethyl esters of 2,4,5-T or triclopyr as basal pours or sprays. When applied as pours, 0.9 L of liquid was applied/tree, and triclopyr was applied at 4.8, 9.6 or 19.2 g/L of carrier while 2,4,5-T was applied at 9.6 g/L. Basal sprays were applied by thoroughly wetting the lower 5 cm of stem to runoff. Amount of spray applied depended upon stem diam and averaged about 0.5 L/tree. In basal sprays, concentration of triclopyr was 4.8 or 9.6 g/L, and 2,4,5-T was applied at 9.6 g/L of carrier. Basal treatments in 1986 and 1987 consisted of diesel oil alone compared to diesel oil or diesel oil:water (1:3) carriers + 2-ethylhexyl ester of clopyralid at 4.8 or 9.6 g/L.

Basal treatments consisted of 3 replications per treatment with groups of 5 plants per replicate identified with numbered tags. The studies were arranged in a randomized complete block design for each of 4 treatment dates (August 1984, 1985, 1986, and 1987). The 1984 and 1985 treatments were evaluated after 2 yr, and the 1987 and 1988 treatments were evaluated 1 yr following treatment by visually estimating percent canopy reduction and/or mortality of each tree. Trees were considered dead if they were completely defoliated and had no living tissue or resprouts. Canopy reduction and mortality data were subjected to analysis of variance, and means were separated by the protected LSD procedure ($p \geq 0.05$) (Steel and Torrie 1980). Data from the basal treatments applied in 1986 and 1987 (Table 5) were pooled for presentation since there was no date by treatment interaction. Data for individual plant treatments applied in 1984 and 1985 were shown separately (Tables 3–4) because some treatments applied were different.

Table 3. Percent expected and actual mortality of 1.5- to 2-m tall honey mesquite trees 1 yr after foliar applications of ester formulations of clopyralid + triclopyr on 13 July 1987 and 1988.

Clopyralid 1+ triclopyr	Expected mortality	Actual mortality
(kg/ha)	(%)	
0.14 + 0.14	0 + 3 = 3	13
0.14 + 0.28	0 + 3 = 3	33[1]
0.14 + 0.56	0 + 10 = 10	33
0.28 + 0.14	10 + 3 = 13	57[1]
0.28 + 0.28	10 + 3 = 13	49[1]
0.28 + 0.56	10 + 10 = 20	57
0.56 + 0.14	50 + 3 = 53	84[1]
0.56 + 0.28	50 + 3 = 53	57
	$LSD_{(0.05)}$ = 29	

[1]Synergistic mixtures (Data from Table 2).

Results and Discussion

Greenhouse-Foliar Sprays

There were usually no differences in the 3 clopyralid formulations or the butoxyethyl ester of triclopyr at 0.035 or 0.07 kg/ha in killing greenhouse-grown honey mesquite stems except that triclopyr was more effective than clopyralid formulations applied in June at 0.035 (Table 1). When applied in June, the free acid (FA) or clopyralid at 0.07 kg/ha was more effective than the 2-ethylhexyl ester (2-EHE) or the monoethanolamine salt (MEA) but not more effective than triclopyr. When applied in mixtures for a total of 0.07 kg/ha of herbicide, clopyralid formulations were frequently more effective than each clopyralid formulation applied alone at 0.035 kg/ha due to addition of triclopyr. The 1:1 and 1:2 mixtures of FA + triclopyr applied in June at a total of 0.07 kg/ha were the only combinations more effective than triclopyr applied alone at 0.035 or 0.07 kg/ha.

Addition of triclopyr to clopyralid for a total of 0.14 kg/ha of herbicide enhanced the activity of most clopyralid formulations applied alone at 0.07 or 0.14 kg/ha in killing honey mesquite stem tissue (Table 1). The activity of triclopyr was usually not enhanced by clopyralid since triclopyr was highly effective when applied alone.

Addition of triclopyr to clopyralid at a total of 0.28 kg/ha of herbicide increased the activity of all clopyralid formulations applied alone at 0.14 kg/ha and most applied alone at 0.28 kg/ha (Table 1). Combinations of the FA + triclopyr applied in June were not synergistic since the FA applied alone at 0.28 kg/ha killed 88% of the stem tissue. Since triclopyr alone killed a high percentage of stem tissue, addition of 1:1 and 1:2 mixtures of the 2-EHE and MEA clopyralid formulations with triclopyr in May reduced its effectiveness.

Data from the greenhouse are not consistent with data from the field relative to triclopyr effectiveness on honey mesquite. In the field, clopyralid was consistently more effective than triclopyr (Bovey and Meyer 1985, Bovey et al. 1988, Jacoby et al. 1982). Greenhouse data suggested possible synergistic or additive effects resulted from use of clopyralid:triclopyr mixtures to control honey mesquite.

Field-Foliar Sprays

Addition of triclopyr at 0.14, 0.28, or 0.56 kg/ha to the 1-decyl ester (1-DE) of clopyralid at 0.14 or 0.28 kg/ha significantly increased canopy reduction of honey mesquite when compared to clopyralid applied alone at 0.14 to 0.28 kg/ha (Table 2). The 1-DE of clopyralid applied at 0.14 kg/ha reduced the canopy by 20%, but the canopy was reduced 57 and 82% when 0.14 or 0.28 kg/ha of triclopyr was included, respectively. Mortality of honey mesquite

Table 4. Percent canopy reduction and mortality of 3- to 5-m tall honey mesquite trees 2 yr after application of herbicides as basal pours or basal sprays to individual plants August 1984[1].

Treatment	Rate/tree	Honey mesquite control: Canopy reduction	Mortality
	(g/L)	(%)	
Basal pour[2]			
Diesel oil	—	88	53
Diesel oil + 2,4,5-T	9.6	100	100
Diesel oil + triclopyr	4.8	96	87
Diesel oil + triclopyr	9.6	100	100
Diesel oil + triclopyr	19.2	100	100
Basal spray			
Diesel oil + 2,4,5-T	9.6	89	67
Diesel oil + triclopyr	4.8	82	53
Diesel oil:water (1:4) + triclopyr	4.8	6	0
Diesel oil + triclopyr	9.6	95	73
Diesel oil:water (1:4) + triclopyr	9.6	95	80
Diesel oil:water (1:3) + triclopyr	9.6	92	73
Diesel oil:water (1:1) + triclopyr	9.6	95	87
Untreated	—	6	0
$LSD_{(0.05)}$		23	33

[1]Butoxyethyl ester of 2,4,5-T or triclopyr
[2]0.9 L diesel oil, diesel oil:herbicide, or diesel oil:water herbicide mix applied/tree

Table 5. Percent canopy reduction and mortality of 3- to 5-m tall honey mesquite trees 2 yr after application of herbicides as basal pours or basal sprays to individual plants August 1985[1].

Treatment	Rate/tree	Honey mesquite control: Canopy reduction	Mortality
	(g/L)	(%)	
Basal pour[2]			
Diesel oil	—	93	67
Diesel oil + 2,4,5-T	9.6	95	73
Diesel oil + triclopyr	4.8	86	60
Diesel oil + triclopyr	9.6	92	67
Diesel oil + triclopyr	19.2	99	87
Basal spray			
Diesel oil + 2,4,5-T	9.6	84	60
Diesel oil + triclopyr	4.8	89	53
Diesel oil:water (1:4) + triclopyr	4.8	22	7
Diesel oil + triclopyr	9.6	83	33
Diesel oil:water (1:4) + triclopyr	9.6	43	20
Untreated	—	13	0
$LSD_{(0.05)}$		21	38

[1]Butoxyethyl ester of 2,4,5-T or triclopyr
[2]0.9 L diesel oil, diesel oil:herbicide, or diesel oil:water herbicide mix applied/tree

was significantly improved by most mixtures over clopyralid applied alone except for applications of clopyralid + triclopyr at 0.14 + 0.14 and 0.56 + 0.28 kg/ha, respectively. Mortality caused by triclopyr was also improved by addition of clopyralid at all combinations except for clopyralid + triclopyr at 0.14 + 0.14 and 0.14 + 0.56 kg/ha, respectively. Clopyralid + triclopyr mixtures were not synergistic in increasing canopy reduction, but clopyralid + triclopyr mixtures of 0.14 + 0.28, 0.28 + 0.14, 0.28 + 0.28 and 0.56 + 0.14 kg/ha were synergistic in increasing mortality in honey mesquite (Table 3). Synergism is defined as the phenomenon whereby the effect of 2 substances acting together is greater than the sum of their individual effects. For example, clopyralid alone at 0.28 kg/ha killed 10% of the plants; whereas, triclopyr alone at 0.28 kg/ha killed 3% of the honey mesquite for expected mortality of 13%. When combined at 0.28 + 0.28 kg/ha, mortality was significantly increased to 49% (Table 3).

Bovey and Meyer (1985) indicated that triclopyr could be substituted for equal portions of clopyralid in a 1:1 mixture without reducing the effectiveness of clopyralid on honey mesquite. The mixture improves the spectrum of weeds controlled and reduces clopyralid residues and treatment cost. Data in this report suggest that certain clopyralid:triclopyr mixtures are synergistic. The MEA salt of clopyralid was highly effective on honey mesquite and was significantly more effective than triclopyr at 0.56 kg/ha (Table 2). The 2-EHE of clopyralid was about equally effective as the 1-DE. Picloram + triclopyr at 0.28 + 0.28 kg/ha was about equally effective to clopyralid + triclopyr at the same rate (Table 2).

Field-Basal Treatments

Canopy reduction was not significantly different, but mortality was, between application of diesel oil pours alone then when fortified with 2,4,5-T or triclopyr in August 1984 (Table 4). Treatment with 9.6 g/L 2,4,5-T or triclopyr killed all plants. Basal sprays were as effective as basal pours, but when 1:4 diesel oil:water carrier was used with 4.8 g/L of triclopyr, canopy reduction was only 6% and killed no trees. Use of 9.6 g/L triclopyr in diesel oil or diesel oil:water carrier resulted in killing 73% or more of the trees. Apparently, higher herbicide concentration overcame any limitations resulting from using water in the basal spray.

Canopy reduction or mortality from applications of diesel oil pours alone were no different than diesel oil fortified with 2,4,5-T or triclopyr in the 1985 treatments (Table 5). Basal sprays of triclopyr at 4.8 or 9.6 g/L in diesel oil:water carrier killed few plants.

There was no advantage of fortifying diesel oil with the 2-EHE of clopyralid for basal pours since canopy reduction and mortality were no different among diesel oil or diesel oil + clopyralid (Table 5). Basal pours using diesel oil or diesel oil:water carriers (1:3) with 4.8 or 9.6 g/L clopyralid were equally effective. Basal sprays using diesel oil + clopyralid were markedly more effective than diesel oil applied alone (Table 6). Diesel oil:water carrier (1:3) with 4.8 g/L clopyralid was less effective than the same carrier with 9.6 g/L clopyralid or diesel oil + 4.8 g/L clopyralid.

These studies suggested that low rates of the 1-DE of clopyralid + triclopyr (0.28 + 0.14 kg/ha) caused high canopy reduction (87%) and mortality (57%) of honey mesquite when applied as foliar sprays. Basal pours of diesel oil alone were as effective as diesel oil fortified with esters of clopyralid, 2,4,5-T, or triclopyr, but in 1984 the addition of 2,4,5-T or triclopyr improved mortality. Basal sprays of diesel oil + esters of clopyralid, 2,4,5-T, or triclopyr produced high mortality in honey mesquite trees. Herbicide activity was sometimes reduced when diesel oil:water carrier was used with 4.8 g/L triclopyr or clopyralid esters compared to diesel oil carrier.

Table 6. Percent canopy reduction and mortality of 3- to 5-m tall honey mesquite trees 1 yr after application of herbicides as basal pours or basal sprays to individual plants August 1986 and 1987[1].

Treatment	Rate/ tree	Honey mesquite control: Canopy reduction	Mortality
	(g/L)	------(%)-----	
Basal pour[2]			
Diesel oil	—	99	90
Diesel oil + clopyralid	4.8	96	86
Diesel oil + clopyralid	9.6	98	90
Diesel oil:water (1:3) + clopyralid	4.8	97	87
Diesel oil:water (1:3) + clopyralid	9.6	99	97
Basal spray			
Diesel oil	—	93	53
Diesel oil + clopyralid	4.8	99	93
Diesel oil + clopyralid	9.6	98	90
Diesel oil:water (1:3) + clopyralid	4.8	97	83
Diesel oil:water (1:3) + clopyralid	9.6	99	97
Untreated	—	3	0
$LSD_{(0.05)}$		6	4

[1]2-ethylhexyl ester of clopyralid
[2]0.9 L diesel oil, diesel oil:herbicide, or diesel oil:water herbicide mix applied/tree

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