Reprinted from *WEED SCIENCE*
Vol. 17, No. 3, July, 1969

Control of Live Oak by Herbicides Applied at Various Rates and Dates[1]

R. W. Bovey, H. L. Morton, and J. R. Baur[2]

Abstract. Herbicides 4-amino-3,5,6-trichloropicolinic acid (picloram) and 5-bromo-3-*sec*-butyl-6-methyluracil (bromacil) effectively controlled live oak *(Quercus virginiana* Mill.) when applied in the spring and fall in south Texas. A mixture of picloram plus (2,4,5-trichlorophenoxy)acetic acid (2,4,5-T) also was effective. Higher rates of bromacil were required than for picloram or picloram plus 2,4,5-T for effective control. Bromacil was more injurious to herbaceous vegetation. The phenoxy herbicides (2,4-dichlorophenoxy)acetic acid (2,4-D) and 2,4,5-T were ineffective.

Introduction

Live oak *(Quercus virginiana* Mill.), an evergreen woody plant, infests large acreages of rangeland on the Gulf Coast Prairie in Texas. Previous studies have shown that 4-amino-3,5,6-trichloropicolinic acid (picloram), 5-bromo-3-*sec*-butyl-6-methyluracil (bromacil), and mixtures of picloram plus (2,4,5-trichlorophenoxy)acetic acid (2,4,5-T), or of bromacil plus 1,1′-dimethyl-4,4′-bipyridinium salts (paraquat) control live oak (1, 4, 5). However, bromacil and paraquat have limited usefulness because they are toxic to desirable forage species. Likewise, growth of susceptible crops adjacent to pasture lands limits the use of picloram and 2,4,5-T to seasons other than spring and summer, because injury to crops may result from spray drift and volatilization of the herbicides. Most woody plants are susceptible to foliar applications of herbicides at some specific time during the growing season. For example, foliar herbicides applied during active periods of growth in the spring months control honey mesquite *(Prosopis juliflora* (Swartz) DC. var. *glandulosa* (Torr.) Cockerell), post and blackjack oak *(Quercus stellata* Wangenh. and *Quercus marilandica* Muenchh.), and sand shinnery oak *(Quercus havardii* Rydb.). Some juniper species *(Juniperus* spp.) can be killed in spring or fall[3].

This study was conducted to determine the most effective herbicides, rates, and time of foliar application for live oak control.

Materials and Methods

Manual applications. We made initial herbicidal treatments October 14, 1963, on native stands of live oak near Victoria, Texas. Bovey *et al.* (3) described the climate, soil, and vegetation of the treated areas. Live oak shrub-type growth was 3 to 4 ft in height. Occurrence of 150 stems or more per sq rod was not uncommon. We applied herbicides with a hand-carried boom that delivered a spray volume of 30 gpa in a swath width of 5 ft. Each plot was 10 by 50 ft. The experimental design was a randomized block with three replications. Herbicides applied in water included the 2-ethylhexyl ester of (2,4-dichlorophenoxy)acetic acid (2,4-D), the potassium salt of picloram and the triisopropanolamine salts of 2,4-D plus picloram.

We established additional hand treatments May 9, June 14, and September 9, 1966, and February 23, April 19, May 16, and June 19, 1967, to compare rates and dates

[1]Received for publication January 16, 1969. Cooperative investigations of the Crops Research Division, Agr. Res. Serv. U.S. Dep. of Agr. and Texas A&M University, College Station, Texas.

[2]Agronomist and Plant Physiologists, Crops Research Division, Agr. Res. Serv., U.S. Dep. of Agr.

[3]Johnsen, T. N., Jr. 1967. Herbicide measures for controlling noncommercial conifers on rangelands. Proceedings of Symposium: Herbicides and Vegetation Mgmt., Corvallis, Oregon.

of application. The live oak had been mowed 2 years before treatment. In this experiment, we applied herbicides in water at 20 gpa to 10 by 30-ft plots in triplicate. Herbicides included paraquat, 2-ethylhexyl ester of 2,4, 5-T, potassium salt of picloram plus 2,4,5-T, and bromacil and picloram sprays and granules. Herbicides were applied at 3 and 6 lb/A. Surfactant X-77[4] (alkylaryl polyethylene glycol, free fatty acids, and isopropanol) was added at 0.5% of the finished water-spray solution.

Herbicide evaluations were made 1 and 2 years after treatment by estimating percent canopy reduction of plants in each plot.

Mechanical applications. We applied herbicides with a boom sprayer mounted on a truck (6) October 12, and August 25, 1963; April 14, May 12, July 13, and October 29, 1964; and June 17 and 14, 1965 and 1966, respectively, to shrub live oak 6 to 12 ft tall. We made retreatments 1 year later on selected plots in the August and October 1963, and May 1964 treatments. Herbicides included: 3,6-dichloro-*o*-anisic acid (dicamba), 6,7-dihydrodipyrido-(1,2-*a*:2′,1′-*c*)pyrazinediium salts (diquat), 2,3,6-trichlorobenzoic acid (2,3,6-TBA), S,S,S-tributyl phosphorotrithioate (hereinafter referred to as DEF), 5-bromo-3-isopropyl-6-methyluracil (isocil), bromacil, 1,1-dimethyl-3-phenylurea (fenuron), paraquat, picloram, 2,4-D, and 2,4,5-T. Surfactant X-77 was added 0.5% of the finished spray solution. We applied herbicides at 10 gpa except bromacil which was applied at 20 gpa. We fenced the treatment area (50 A) from livestock, divided it into blocks, and bulldozed roadways for passage of the truck sprayer. Plots were usually 22 by 100 ft in a randomized block design with two replications per treatment. Control of live oak was determined by visually estimating percent canopy reduction of plants in each plot at 1, 2, and 3 years after treatment.

Results and Discussion

Bromacil and isocil at 10 lb/A controlled live oak and were the most effective treatments in the study (Table 1). Most other treatments were not effective.

Of the treatments repeated, only paraquat + dicamba and paraquat + bromacil were moderately effective. Picloram at 4 lb/A was the most effective herbicide applied by hand equipment in October 1963 (Table 2). Combinations of picloram + 2,4-D and 2,4-D alone were ineffective at rates used. Picloram applied by truck at 8 lb/A, bromacil at 10 lb/A, and paraquat + bromacil at 4 + 5 lb/A controlled more live oak than other herbicides (Table 3). Retreatment in October 1964 was ineffective except for the paraquat + bromacil combination (Table 3).

Picloram and bromacil treatments, made in April 1964, on dense live oak before the leaves were fully expanded, were not as effective as the October treatments (Table 3). Picloram at 8 lb/A produced 93% control 1 year after treatment, but control declined thereafter. Picloram is effective when absorbed through roots as well as through foliage (2). Apparently, residues of picloram in the soil were not adequate to prevent regrowth. Low residue may have been caused by abundant rainfall following treatment, the light soils on which live oak was growing, and the interception of spray by the dense live oak stands.

Picloram applied at 4 lb/A in May 1964, was more effective after 3 years than the same treatment applied in October 1963 or April 1964 (Table 3), and was more effective than repeated treatments of dicamba, 2,4,5-T, and paraquat. Picloram treated at 1 lb/A in 1964, and retreated in 1965, was not as effective as the 4 lb/A of picloram applied once.

July treatment of picloram at 8 lb/A was ineffective on live oak 3 years after treatment; however, bromacil at 10 lb/A provided excellent control (Table 3). Combina-

Table 1. Percentage reduction of live oak treated with 33 herbicides from a truck mounted sprayer August 25, 1963.

Herbicide	lb/A	Years after treatment 1	2	3	Mean[b]
Dicamba	4[a]	58	55	35	49 de
Dicamba	8	40	13	5	19 klm
Dicamba	12	60	40	20	40 efgh
Diquat	2	5	8	10	8 no
Diquat	4	15	13	10	13 lmno
Diquat	8	15	3	10	9 mno
Paraquat	2	35	18	10	21 jkl
Paraquat	4[a]	40	80	25	48 de
Paraquat	8	35	13	5	18 lmn
Paraquat + dicamba	4+4[a]	78	85	70	78 c
2,3,6-TBA	4	25	3	0	9 mno
2,3,6-TBA	8	10	3	5	6 o
2,3,6-TBA	12	58	18	20	32 ghi
2,4,5-T	4[a]	55	70	40	55 d
2,4,5-T	8	68	30	25	41 efgh
2,4,5-T	12	78	28	20	42 efg
2,4-D + 2,4,5-T	2+2[a]	40	70	30	47 de
2,4-D + 2,4,5-T	4+4	48	20	15	31 hij
2,4-D + 2,4,5-T	6+6	73	35	38	48 de
2,4-D + dicamba	4+4	73	33	20	42 efg
2,4,5-T + NH_4SCN	4+0.5	55	18	20	31 hij
2,4,5-T + DEF	4+4	70	33	25	43 ef
DEF	2	5	0	0	2 o
DEF	4	15	13	0	9 mno
DEF	8	10	5	10	8 no
Isocil	2.5	34	37	15	28 ijk
Isocil	5	90	95	80	88 b
Isocil	10	100	100	98	99 a
Bromacil	2.5	35	20	8	21 jkl
Bromacil	5	95	88	70	84 bc
Bromacil	10	100	100	100	100 a
Paraquat + bromacil	4+5[a]	85	95	75	85 bc
Fenuron	5	5	3	5	4 o
Check		0	3	5	3 o
Mean[b]		47 a	36 b	27 c	

[a]Retreated 1 year after original treatment with the same herbicide except rates of paraquat + dicamba and paraquat + bromacil were reduced by one-half in the second year.

[b]Numbers followed by the same letter do not differ significantly at the 5% level using Duncan's multiple range test.

Table 2. Percentage reduction of live oak treated with 2,4-D, picloram, and 2,4-D + picloram with a hand boom sprayer October 14, 1963.

Herbicide	lb/A	Years after treatment 1	2	Mean[a]
2,4-D	1	40	3	22 de
2,4-D	2	47	23	40 bcd
2,4-D	4	60	35	48 bc
Picloram	1	40	13	27 de
Picloram	2	67	50	58 b
Picloram	4	78	82	80 a
2,4-D + picloram	0.7+0.3	28	3	16 ef
2,4-D + picloram	1.4+0.5	50	18	34 cde
2,4-D + picloram	2.9+1.1	73	27	50 bc
Check		0	0	0 f
Mean[a]		49 a	26 b	

[a]Numbers followed by the same letter do not differ significantly at the 5% level using Duncan's multiple range test.

[4]Mention of trademark name or a proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture or Texas A&M University and does not imply its approval to the exclusion of other products that may also be suitable.

Table 3. Percentage reduction of live oak 3 years after treatment with several herbicides at six dates of application from a truck mounted sprayer at Victoria, Texas.

Herbicide	lb/A	Date of treatment					
		Oct 1963	Apr 1964	May 1964	July 1964	Oct 1964	June 1965
Paraquat	1	10	—	25[a]	—	—	—
	4	15[a]	0	50[a]	—	—	13
	8	13	20	—	10	—	13
Dicamba	1	5	—	25[a]	—	—	—
	2	—	—	—	—	3	—
	4	18[a]	—	25[a]	—	—	13
	8	60	—	—	20	13	48
2,4,5-T	1	5[a]	—	15[a]	—	—	—
	2	—	—	—	—	0	—
	4	13[a]	5	58[a]	—	—	30
	8	13	10	—	20	5	20
	12	—	15	—	—	—	—
2,4-D	8	—	—	—	35	—	—
Picloram	1	13	—	55[a]	—	—	—
	2	—	10	—	—	13	13
	4	28	50	73	—	—	48
	8	97	30	—	50	100	98
Bromacil	2.5	5	—	—	—	—	—
	4	—	—	—	—	—	28
Bromacil	5	80	—	—	—	75	—
	8	—	—	—	—	—	98
	10	99	—	—	100	97	—
Picloram + 2,4-D	0.2+0.8	0	—	—	—	—	—
	0.8+3.2	20	—	—	—	—	—
	1.6+6.4	50	—	—	—	—	—
Picloram + 2,4,5-T	4+4	—	—	—	—	—	63
Paraquat + dicamba	1+1	15	—	—	—	—	—
	2+4	5	—	—	—	—	—
	4+4	13	5	—	30	—	65
Paraquat + 2,4,5-T	4+4	15	38	—	15	—	68
Paraquat + picloram	4+4	—	20	—	15	—	73
Paraquat + bromacil	4+4	—	—	—	—	—	43
Paraquat + bromacil	4+5	100[a]	23	—	62	—	—
Picloram + bromacil	2+4	—	—	—	—	—	50
2,4-D+2,4,5-T	4+4	—	10	—	100	—	—

[a]Plots retreated 1 year after original treatment with same herbicide except rate of paraquat + bromacil was reduced by one-half in the second year.

Table 4. Percentage reduction of live oak treated with six herbicide applications from a truck-mounted sprayer June 14, 1966.

Herbicide	lb/A	Years after treatment		Mean[a]
		1	2	
Picloram	2	88	43	66 d
Picloram	4	99	94	97 a
Picloram + 2,4,5-T ester	2+2	95	87	91 ab
Picloram + 2,4,5-T amine	2+2	96	85	91 ab
Picloram + 2,4,5-T ester + paraquat	2+2+2	93	73	83 bc
Check		0	0	0 e
Mean[a]		81 a	64 b	

[a]Numbers followed by the same letter do not differ significantly at the 5% level using Duncan's multiple range test.

Table 5. Percentage reduction of live oak treated at seven dates of application with 15 herbicides during 1966 and 1967[a].

Herbicide	lb/A	Date of treatment							Mean[b]
		May 1966	June 1966	Sept 1966	Feb 1967	Apr 1967	May 1967	June 1967	
Paraquat	3	77	83	93	30	83	58	55	69 c
Paraquat	6	82	78	70	22	60	83	73	67 c
2,4,5-T	3	70	83	75	15	75	83	75	68 c
2,4,5-T	6	82	82	67	37	73	83	83	72 c
Picloram	3	97	94	98	73	95	92	83	90 ab
Picloram	6	99	98	100	93	95	97	93	97 a
Picloram + 2,4,5-T	1.5+1.5	96	93	80	50	93	95	80	84 b
Picloram + 2,4,5-T	3+3	99	93	77	85	95	92	90	90 ab
Bromacil	3	37	62	40	48	67	47	23	49 d
Bromacil	6	91	96	88	67	90	75	78	84 b
Bromacil granules	3	80	88	98	3	87	78	78	73 c
Bramacil granules	6	97	94	95	42	95	97	87	87 b
Picloram granules	3	98	97	86	43	95	95	87	86 b
Picloram granules	6	99	99	83	57	97	95	93	89 ab
Check		0	15	17	18	33	7	3	13 e
Mean[a]		82 a	84 a	79 a	45 d	82 a	78 ab	72 c	

[a]Plots were treated with a hand boom sprayer and evaluated 1 year after treatment.

[b]Numbers followed by the same letter do not differ significantly at the 5% level using Duncan's multiple range test.

tions of paraquat with other herbicides usually were ineffective. Paraquat + bromacil, however, was as effective as picloram. None of the plots were retreated.

Bromacil applied at 5 and 10 lb/A and picloram at 8 lb/A in October 1964, killed a high percentage of live oak (Table 3). Dicamba at 2 and 8 lb/A, 2,3,4-T at 2 and 8 lb/A, and picloram at 2 lb/A were ineffective. None of the plots were retreated.

Three years after treatment, picloram and bromacil at 8 lb/A each were equally effective in controlling live oak when applied in June 1965 (Table 3). Almost as effective were mixtures of picloram + 2,4,5-T, paraquat + picloram, and paraquat + dicamba, all at 4 + 4 lb/A. Paraquat, dicamba, 2,4,5-T, and picloram at 2 lb/A were not effective.

Treatment with picloram at 4 lb/A in June 1966, was especially effective in controlling live oak, but not significantly different in effect from mixtures of picloram with the ester or amine of 2,4,5-T at 2 + 2 lb/A (Table 4). The addition of paraquat to picloram + 2,4,5-T reduced the effectiveness of the picloram: 2,4,5-T mixture. Picloram at 2 lb/A was only moderately effective and additions of 2,4,5-T at 2 lb/A markedly enhanced its activity.

In an experiment comparing seven dates of treatment, picloram applied as a spray or as pellets was consistently effective (Table 5). Mixtures of picloram + 2,4,5-T at 1.5 + 1.5 lb/A and 3 + 3 lb/A were not significantly different from picloram at 3 and 6 lb/A, respectively. Treatments applied in May, June, and September 1966, and April and May 1967, were not significantly different. Treatments applied in February were poorest. However, picloram at 6 lb/A as a spray in this month was effective. Reduced effectiveness for some herbicidal treatments made in June 1967, may have been because of droughty conditions following treatment.

General observations. Picloram and bromacil were effective on live oak when applied in spring and fall treatments. Canopy reduction of 90% or more was arbitrarily selected 1, 2, or 3 years after treatment as the acceptable level of control. Picloram was less injurious than bromacil to native grasses at similar dosages and controlled live oak at lower dosages per acre. However, bromacil at 8 and 10 lb/A controlled live oak more consistently than picloram. Mixtures of picloram plus 2,4,5-T and paraquat plus bromacil were effective, but the latter required high dosages and markedly damaged forage production.

These and concurrent studies (5) show that summer applications may not be as effective as spring and fall treatments and that effectiveness appears to be related to adequate soil moisture and favorable growing conditions for live oak before and after treatment.

Dicamba, diquat, paraquat, 2,4-D, 2,4,5-T, and mixtures of these materials usually did not satisfactorily control live oak, even at high dosages or if retreatments were applied.

Residue levels of picloram or bromacil must persist in soil and plant tissue for several months after treatment to account for killing oak regrowth. If these residues are not present in sufficient amounts to kill regenerative tissue, the plants recover. Apparently, sufficient residues of 2,4,5-T were not present even at high rates (12 lb/A) to kill regrowth.

Effectiveness of most treatments declines with time and control does not improve beyond 1 year after treatment (bromacil is sometimes the exception). Consequently, if the herbicide does not show good results after 1 year, it is not likely to improve. Repeated treatments were usually more effective than if the total amount of herbicide was applied at one time.

These studies indicate that available herbicides will effectively control live oak in the fall when other susceptible crop species are not growing in these areas of Texas.

LITERATURE CITED

1. BOVEY, R. W., F. S. DAVIS, and H. L. MORTON. 1968. Herbicide combinations for woody plant control. Weed Sci. 16:332–335.
2. BOVEY, R. W., F. S. DAVIS, and M. G. MERKLE. 1967. Distribution of picloram in huisache after foliar and soil applications. Weeds 15:245–249.
3. BOVEY, R. W., R. E. MEYER, F. S. DAVIS, M. G. MERKLE, and H. L. MORTON. 1967. Control of woody and herbaceous vegetation with soil sterilants. Weeds 15:327–329.
4. BOVEY, R. W. and S. K. LEHMAN. 1967. Aerial and ground application of herbicides for control of running live oak. Proc. WWCC 21:47 (Abstr.)
5. BOVEY, R. W., S. K. LEHMAN, H. L. MORTON, and J. R. BAUR. 1968. Control of running live oak in South Texas. J. Range Mgt. (In Press).
6. MEYER, R. E., H. L. MORTON, and T. O. FLYNT. 1967. A truck sprayer for applying chemicals to brush. Weeds 15:286–287.