Control of Dalmatian Toadflax[1]

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Highlight

Trials of several chemicals over a 6-year period showed that phenoxypropionic herbicides were superior to phenoxyacetic herbicides in controlling Dalmatian toadflax. Satisfactory control was obtained with silvex at a minimum rate of 3 lb/acre. Rates of silvex required to significantly reduce or control the plant did no significant injury to perennial grasses. Picloram applied in granular form to the soil in the fall was more effective than a foliar application at the same rate in the spring. A combination of silvex plus picloram, 2 plus 0.5 or 2 plus 0.25 lb/acre, respectively, also controlled Dalmatian toadflax. Cultural and managerial, as well as chemical control methods may be necessary for economic and effective control of the plant.

The potential of Dalmatian toadflax (*Linaria dalmatica* (L.) Mill) as a range weed has become widely recognized, and information concerning this plant has appeared from time to time since the early 1950's. Alex (1962) presented detailed description of the taxonomy, history, and distribution of the plant.

Response of Dalmation toadflax to herbicides has been variable, and a treatment for its control which is both effective and economical is still needed. Lange and Wolfe (1954) recommended a borate-chlorate mixture applied at a rate of 2 to 3 lb/300 ft^2 in late summer and fall for treatment of spot infestations. In 1958, Lange reported that borate-chlorate was still the most satisfactory herbicide, and he pointed out the inconsistent results obtained with 2,4-dichlorophenoxyacetic acid (2,4-D). Muzik et al. (1960) cited data which indicated effectiveness of 2,3,6-trichlorobenzoic acid (2,3,6-TBA) at 2 lb/acre. Talbert (1965) stated that in California, 2-(2,4,5-trichlorophenoxy)propionic acid (silvex) at 5 lb in water at 80 gal/acre was effective and that 2,4-D was unsatisfactory at all rates used. He reported soil sterilants also were ineffective, although atrazine at 20 to 40 lb/acre and a commercial mixture of sodium chlorate, sodium metaborate and a maximum of 2.4% 3-(*p*-chlorophenyl)-1,1-dimethylurea (monuron) at 9 lb/rod^2 (1,440 lb/acre) were satisfactory.

A study of the feasibility of revegetating areas recently infested with St. Johnswort (*Hypericum perforatum* L.) with adapted grasses in competition with Dalmatian toadflax was conducted from 1957 to 1960 by Gates and Robocker (1960). Dalmatian toadflax and grasses both became established on cultivated sites, but not on uncultivated sites. A second experiment by Robocker et al. (1961) combined 2,3,6-TBA and disking treatments to reduce survival of Dalmatian toadflax and improve conditions for establishment of Siberian wheatgrass. Established toadflax was reduced by 2,3,6-TBA, but reduction of competition from other susceptible plants, together with an improved seedbed, significantly increased survival and establishment of toadflax seedlings. A supplementary test of 3-amino-1,2,4-triazole (amitrole) at the time indicated that it was not satisfactory for control of Dalmatian toadflax.[2]

An additional herbicide trial was initiated in 1960, accompanied by study of herbicides on the total vegetation complex. In that trial it became apparent that effects of herbicides on Dalmatian toadflax were being confounded with decline of the stand from another cause. Trials were then continued to find the most reliable herbicide for selective control of Dalmatian toadflax, taking into consideration a limited life span of original crowns and the production of adventitious stems from lateral roots.

Methods and Materials

Herbicide trials were carried on from 1960 to 1966 north of Spokane, Washington, on a pasture planted in 1957 to crested wheatgrass (*Agropyron desertorum* (Fisch. ex Link) Schult.), Chewings fescue (*Festuca rubra* L. cultivar Chewings), and alfalfa (*Medicago sativa* L.), variety unknown, but probably Ladak. A heavy stand of Dalmatian toadflax had also become established the year of reseeding. The area has a mean annual precipitation of approximately 18 inches, most of which falls in the fall, winter, and spring. The soil contains much coarse sand and very fine gravel and is classified as a gravelly loam.

1960 Trial.—This experiment was performed to test effectiveness of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), silvex, and 2,3,6-TBA for Dalmatian toadflax control, alone or each in combination with disking before herbicide treatment or mowing after treatment. Follow-up control of seedlings with 2,4-D or silvex was superimposed over each cultural treatment. The design consisted of three replicates with 10 $\times$ 30-ft plots. Replicates were split in the east-west direction into cultural treatment sub-blocks. Sub-blocks were split in the north-south direction with primary herbicides at rates of 0, 2, or 4 lb/acre of the propylene glycol butylether esters of 2,4,5-T or silvex and at 0, 4, or 8 lb/acre of the sodium salt of 2,3,6-TBA. Splits of each sub-block (cultural treatments) in the east-west direction consisted of no herbicide, or 2 lb/acre of the PGBE ester of 2,4-D or silvex applied in the second and third years across

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[2] Unpublished data.

the first herbicide treatments, and will be referred to as "cross" treatments.

Plots were disked in early April; herbicide treatments were applied on May 31, and appropriate plots mowed on July 8, 1960. In early April 1960, 1961, 1962, and 1963, Dalmatian toadflax crowns and perennial grass plants were counted on transects measuring 1 × 20 ft. Percentage cover of annual broadleaf and annual grass plants on the entire plot was estimated. Plots were protected from grazing until fall each year for 4 years.

1962 Trial.—Treatments consisting of mowing on June 7 or July 18 or on both dates and 15 variations of herbicides, carriers and surfactant (Table 3) were applied June 7, 1962, to 10 × 30-ft plots in 3 replications of randomized complete blocks. A volume of 15 gpa of water-herbicide mixture was used unless otherwise indicated. In addition to herbicides previously used, others included were an oil-soluble amine of silvex, the oleyl 1,3-propylene diamine salts of 2,4,5-T and 2,4-D, and butoxyethanol ester of 2-(2,4-dichlorophenoxy)propionic acid (dichlorprop) the dimethylamine salt of 2-methoxy-3,6-dichlorobenzoic acid (dicamba), and 5-bromo-3-isopropyl-6-methyluracil (isocil). The surfactant (alkylarylpolyoxypropylene glycols) was added at 0.75% by volume. Crowns of Dalmatian toadflax in each plot were counted prior to treatment in 1962 and again on May 21, 1963.

1964 Trial.—On June 3, 1964, an additional trial of promising herbicides and two new materials, 4-amino-3,5,6-trichloropicolinic acid (picloram) at 1/2, 1 or 1.5 lb/acre and 2,3,6-trichlorobenzyloxypropanol at 2 or 4 lb/acre, were applied in a volume of 20 gpa to 10 × 20-ft plots in three blocks of low, medium or high numbers of toadflax plants per plot. A mixture of silvex at 1 lb/acre and picloram at 0.5 lb/acre was also applied. Plants were counted on May 25, 1965.

1965 Trial.—Silvex and picloram alone and in four combinations, plus a second trial of 2,3,6-trichlorobenzyloxypropanol, were applied to three replicates of 10 × 20-ft plots in a volume of 20 gpa. Materials were applied at the early bloom stage on June 7, 1965. Surviving plants, including any which may have developed from seedlings, were counted on June 7, 1966.

1965–66 Trial.—A 2% granular formulation of picloram at 0.5, 1, or 1.5 lb/acre was applied on three replicates of 10 × 30-ft plots on November 5, 1965. On May 23, 1966, additional plots were treated with silvex or picloram or a combination of both in water at a total volume of 20 gpa. The uniform stand of toadflax was 1 year old and in vigorous condition. Stand counts before treatment were made on all plots; final number was determined November 7, 1966, approximately 2 months after the fall growth of normal plants appeared.

Results and Discussion

1960 Trial.—Untreated plots in this experiment showed a rapid decline in stand of Dalmatian toadflax from 1961 to 1963. Toadflax surrounding the experimental plots and in adjacent areas showed a similar decline, and only an occasional plant occurred a year or two later in the experimental area. In a part of the pasture with a southwest slope, the stand persists with fluctuating density. Soil samples in a loamy sand in this area revealed unusually high soil moisture at a depth of 24 inches in 1964, indicating an excellent site for stand establishment. Quicker warming of the soil in the spring with earlier germination and seedling growth may also be a contributing factor to stand persistence.

Although the stand of toadflax declined from 1960 to 1961, enough plants remained to make a broad comparison of the herbicide treatments applied in 1960. The 1961 data contained a number of zero and extreme readings; hence all data were transformed to the scale of $\sqrt{X + 0.5}$ before analysis. Actual means, compared by least significant difference, are reported in the tables. The variable nature of the data (coefficient of variability of 49% on transformed numbers) reduced the value of statistical analysis. Nevertheless, it appeared that silvex was superior to 2,4,5-T and economically preferable to 2,3,6-TBA. The follow-up (cross) treatments were not begun until 1961, and showed no measurable effects on Dalmatian toadflax because of the natural mortality.

Cultural treatments caused no significant difference in numbers of toadflax plants, although some temporary benefit in the form of latent shoot bud stimulation to the toadflax may have followed from the disking.

Newly emerged toadflax seedlings were present every year. Frequency of occurrence in 1963 is shown in Table 1. Very few seedlings survived the summer in the 4 years of the study. Lack of establishment is attributed to the combination of competition and unfavorable weather conditions.

Table 1. Average number of live, primary crowns of Dalmatian toadflax in three 1 × 20-ft transects per main herbicide plot and frequency of toadflax seedlings in 1963.

Treatment[1]	Rate (lb/acre)	Crowns in 1960[2]	1961[3]	1962	1963	Sdlg. freq. 1963, %[4]
Herbicide						
2,4,5-T	0	57.9	26.7**	0.7	0.1	35
	2	64.8	6.2**	0.1	0	20
	4	59.4	1.9	0.1	0	27
Silvex	0	57.7	14.8**	0.1	0	33
	2	53.2	1.1	0	0	35
	4	58.1	0.7	0	0	17
2,3,6-TBA	0	65.0	17.4**	0.1	0	15
	4	57.0	0.8	0	0	12
	8	62.0	0.3	0.8	0.4	17

[1] Specified treatment over all other treatments.
[2] Readings before initial treatments.
[3] Readings before supplemental 2,4-D and silvex cross treatments.
[4] Frequency of toadflax seedlings is average percentage occurrence in ten 20 × 50-cm samples per plot on plots receiving no cultural treatment in 1960.
** Significantly greater than stands with 1 plant per transect or less at 1% level.

Plots were not protected from grazing in 1964 and 1965. The plot area remained free of toadflax until 1965, when seedlings became established to produce a moderate stand in 1966.

Analysis of variance showed a significant reduction in the stand of grass, primarily Chewings fescue and a small amount of wheatgrass, by primary (1960) herbicide treatments in 1963 (Table 2). Although the largest reduction was from 8 lb/acre of 2,3,6-TBA, the stand on check plots in the 2,3,6-TBA block was also low, and the change in stand on the basis of herbicide effect is questionable. The trend in difference in stand among the three herbicide blocks in 1963 paralleled those of 1960; i.e., the respective stand means per transect under herbicide treatments for 1960 and 1963 were: 2,4,5-T, 50 vs. 42; silvex, 50 vs. 40; and 2,3,6-TBA, 43 vs. 33. An analysis of variance showed no significant interaction of effects of herbicides on grass stands between 1960 and 1963. There was no significant difference in stands of perennial grass between the untreated check plots and those cross-treated with silvex or 2,4-D, Table 2.

In 1963, no significant effect on stands of grass resulted from disking in 1960. The difference between the pretreatment stands in 1960 and 1963, as affected by cultural treatments, approached significance, however. The respective stand means per transect under cultural treatments for 1960 and 1963 were: check (no treatment) 31 and 34; mowed, 45 and 46; and disked, 67 and 34. Without supporting data, it could be expected that disking would be injurious. The data, in this case, show the stand on the disked plots to be the same as on the check, but still approximately 50% below the 1960 stand. Lack of statistical significance again may be attributed to the high variability in the stand with a coefficient of variability for 1963 data at 46%.

Percentages of annual broadleaf weeds and annual grasses (Table 2) were based on visual estimates of percentage of plot area covered, regardless of other vegetation class coverage, and were not subjected to statistical analysis. Herbicides had little effect in changing the population of annual weeds in the year after treatment. Since most of the annual broadleaf weeds had matured before treatment, and the annual grasses (*Bromus* spp.) flowered after treatment, extensive damage from herbicides did not occur.

1962 Trial.—Crown counts and the reduction or decline of stand are presented in Table 3 to show the herbicide effect. Natural mortality in this trial was 96% on the untreated plots; therefore precise evaluation of herbicide effects from plant counts alone was impossible. Little benefit was gained by use of diesel oil as a carrier. Use of a surfactant in this trial was not warranted. Amiben and 2,4-D appeared to be ineffective, and the 2,3,6-TBA and dicamba were promising. However, the cost on a per-acre basis did not put 2,3,6-TBA or dicamba in a competitive position with the two phenoxypropionic compounds. Isocil was not only ineffective, but the stand appeared to have been increased by the reduced stand of grasses, since reduction in stand of Dalmatian toadflax was only 74%. Other broadleaf vegetation was eliminated by isocil; and in 1963, the average number of Dalmatian toadflax seedlings in fifteen 20 × 50-cm samples in plots treated with isocil was 44. Many of these seedlings survived the summer and produced a good stand of toadflax.

Mowing, as in the 1960 trial, may have deferred

Table 2. Summary of average number of perennial grass plants per 1 × 20-ft transect and estimated percentage cover of annual grass and broadleaf weeds in 1963 after treatment with herbicides in 1960 and cross treatments at 2 lb/acre in 1961 and 1962.[1]

Herbicide in 1960	Rate (lb/acre)	Perennial grass (plants/transect)				Annual broadleaf cover (%)			Annual grass cover (%)		
		None[2]	2,4-D	Silvex	Av.[3]	None	2,4-D	Silvex	None	2,4-D	Silvex
2,4,5-T	0	*40*	48	50	45	*14*	15	13	*43*	33	40
	2	30	41	40	37	16	16	12	45	40	42
	4	35	42	45	41	17	15	12	40	36	37
Silvex	0	*40*	35	38	38	*18*	16	15	*47*	41	40
	2	36	37	40	38	18	13	15	35	29	38
	4	41	43	52	46	17	15	13	34	28	32
2,3,6-TBA	0	*34*	36	32	34	*14*	18	17	*38*	37	42
	4	34	34	37	34	18	17	15	42	42	40
	8	27	33	34	32	22	21	18	45	41	37
Average	–	35	39	41	38	17	16	14	41	36	39

[1] Stands of perennial grass, as affected by cross treatments, were not significantly different at 5% level.
[2] Numbers in italics are from plots not treated with herbicides at any time during the experiment.
[3] LSD for herbicides at 5% level, 8.1.

Table 3. Average crowns per plot and percentage reduction or decline of Dalmatian toadflax to clipping or herbicides, treated in 1962.

Treatment[1]	Rate (lb/acre)	Av. crowns, 1963	Reduc. or decline from 1962 (%)
None	0	11	96
Mowed early (6-7-62)	–	13	66
Mowed late (7-18-62)	–	11	82
Mowed early + late	–	21	38
Amiben	4	7	92
2,4-D[2]	2	9	91
2,4-D PGBE + surfactant	2	4	96
Silvex[2]	2	3	95
Silvex PGBE	2	1**	99
Silvex PGBE + surfactant	2	tr**	99+
2,3,6-TBA	4	tr**	99+
2,3,6-TBA + surfactant	4	3	98
Dicamba	4	3	98
Dicamba + surfactant	4	1*	99
Dichlorprop	2	0**	100
Dichlorprop + surfactant	2	tr**	99
2,4,5-T[2]	2	1*	99
2,4,5-T PGBE[3]	4	1**	99
Isocil + surfactant	3	38**	74

[1] Surfactant, where indicated, .75% by volume.
[2] Amine in diesel oil.
[3] Applied in diesel oil.
* Significantly different from no treatment at 5% level.
** Significantly different from no treatment at 1% level.

Table 4. Average crowns per plot of Dalmatian toadflax, 1 year after treatment in 1964 and 1965, and 6 months after treatment in 1966.

Herbicide	Rate (lb/acre)	Treated in 1964	Treated in 1965	Treated in 1966
None[1]	0	44	—	—
2,4-D	2	47**	—	—
2,4,5-T	2	24**	—	—
Dichlorprop	1	48**	—	—
	2	11*	—	—
	3	4	—	—
2,3,6-trichlorobenzyl-oxypropanol	2	17**	14**	—
	4	2	17**	—
Silvex	1	37**	—	20**
	1½	—	—	12**
	2	9*	4*	—
	3	4	2	2
Picloram (granular)	½	—	—	4**
	1	—	—	1
	1½	—	—	0
Picloram (in water)	½	2	5**	8**
	1	tr	1	11**
	1½	0	tr	7**
Silvex + picloram	1 + ¼	—	2	57**
	1 + ½	tr	tr	—
	2 + ¼	—	2	3**
	2 + ½	—	tr	—

[1] Excluded from statistical analysis.
* Significantly different from "0" or "tr" in same column at 5% level.
** Significantly different from "0" or "tr" in same column at 1% level.

the decline of the stand. All plots were practically free of Dalmatian toadflax by 1964. Data were transformed to the scale of $\sqrt{X + 0.5}$ for analysis of variance and actual values are reported in Tables 3 and 4.

1964 Trial.—Results of the applications of 2 lb/acre of 2,4-D and 2,4,5-T in 1964 (Table 4) confirmed their ineffectiveness for controlling toadflax. The 1-lb/acre rates of dichlorprop and silvex were not sufficiently toxic. The 2,3,6-trichlorobenzyloxypropanol showed enough activity to warrant another year's testing. Treatment with 2 lb/acre of dichlorprop was as effective as silvex. Picloram was promising and more research was warranted. A low rate of silvex plus a low rate of picloram (1 plus 0.5 lb/acre appeared to be additive in activity and also merited further testing.

1965 and 1965–66 Trials.—The higher rates of silvex, picloram, and silvex plus picloram were effective in the 1965 spring trial (Column 2 of Table 4). An apparent enhancement of effects of silvex and picloram was again noted.

Normal growth and development of toadflax was inhibited by an extremely dry year in 1966. This is shown by the reduced effectiveness of treatments in the spring of 1966 (Table 4). Data indicated a highly significant improvement in performance of picloram applied in the fall. Winter moisture promoted movement of picloram into the soil. No significance was found between the control of toadflax attained with 1 or 1.5 lb/acre of granular picloram applied in the fall and 3 lb/acre of silvex applied the next spring. Results from the 3 years 1964–1966 indicated that under varying conditions of weather, 3 lb/acre is a minimum rate for use of silvex. Silvex plus picloram, 2 plus 0.5 or 2 plus 0.25 lb/acre, respectively, controlled Dalmatian toadflax as well as silvex when averaged over 1965 and 1966 and could provide a broader spectrum of weed control.

A current study on the life history of Dalmatian toadflax shows that the species is a short-lived perennial (as first indicated in the 1960 study). The life of a vigorous primary crown is from 2 to 4 years. Examination of crowns of varying age indicate that death could be from a physiological, pathological, or an anatomical cause, but the principal factor is still undetermined. Depending on environmental conditions, longevity of a stand may be increased by adventitious buds arising from lateral roots. When such vegetative propagation occurs, a stand may persist indefinitely, even though the parent crown and older adventitious stem-crowns arising from lateral roots have died.

Chemical control alone is presently impractical for all but small infestations. Since seedlings of Dalmatian toadflax do not easily become established in vigorous competing vegetation, a control program must also give attention to improvement of stands of grasses either through seeding or improved grazing management.

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