Effects of Season and Rate of Application of 2,4-D and 2,4,5-T on Pine Seedlings and Mountain Whitethorn in California

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Abstract. Intermingled pines and mountain whitethorn were treated with foliar sprays of 2,4-D and 2,4,5-T to test their effects according to (1) season of year, (2) concentration of spray on individual tree-brush clumps, and (3) spray dosage applied on an area basis. Spraying with 2,4,5-T in September resulted in the best tree growth and most brush kill; 2,4-D caused the most tree damage and was less effective as a brush killer. The best brush kill resulted from application rates of 400 to 600 ppm of 2,4,5-T, but these concentrations reduced tree growth. After two full growing seasons, average height growth of the pines was greater on plots receiving from ¼ to 1 pound of 2,4,5-T per acre than on the control plots. Application rates of 2 and 4 pounds per acre (ppa) gave best brush kill but caused severe damage to the pines.

OVER MUCH of the Stanislaus-Tuolumne Experimental Forest, east of Sonora, Calif., the growth of natural conifer reproduction is markedly hampered by associated brush species. The Forest is typical of the mixed-conifer type of the westside central Sierra Nevada. We now have hope for releasing these handicapped trees from brush competition

A most convenient method of controlling unwanted brush is to destroy or suppress it by chemical weedkillers. But the use of weedkillers in wildland management calls for a combination of "the right herbicide, in the right concentration, at the right time" (*1*). The problem is compounded when herbicide-sensitive conifers also occupy the site along with "weeds." Climatic and edaphic variabilities further complicate the California brush problem (*7*, p. 86). Although blister rust control tests have yielded much basic data on the response of *Ribes* spp. to chemicals (*6*), relatively few tests have explored chemical control of the variety of other brush species prevalent in the Stanislaus-Tuolumne Experimental Forest (*9, 10*).

Much useful brush control information has come from herbicide tests elsewhere (*10*). One of the earliest reports on aerial release for conifers was that by Hawkes (*5*) on the Oregon coast. He found that an aerial application of 2 pounds of 2,4-D acid per acre killed alder, but did very little damage to the overtopped conifers. Now, aerial spraying to release conifers from brush competition will undoubtedly be one of the most profitable uses for herbicides on forest lands in southwestern Oregon (*7*, p. 74). Increased use also is being made of aircraft-applied herbicides to release conifers from competing hardwoods in the Lake States (*8*).

Preliminary screening of chemical treatments is most conveniently and economically performed on single plants because more combinations of treatments are possible on a limited area of uniform site characteristics, and most effective use is made of limited time and materials. Moreover, application rates can be converted approximately to an area basis by assuming application of fixed amounts of chemical per plant and estimates of bare ground and numbers of plants per acre.

This paper reports results of some recent California tests and shows how this information can be related to data from other areas in developing chemical control measures for local species of brush.

Materials and Methods

The major conifer species on the test area are: sugar pine (*Pinus lambertiana* Dougl.), ponderosa pine (*Pinus ponderosa* Laws.), Jeffrey pine (*Pinus jeffreyi* Grev. & Balf.), white fir (*Abies concolor* [Gord & Glend] Lindl), and incense-cedar (*Libocedrus decurrens* Torr.). The brush is predominantly mountain whitethorn (*Ceanothus cordulatus* Kell.), with some littleleaf ceanothus (*Ceanothus parvifolius* [Wats.] Trel.).

The responses of intermingled pines and brush plants to foliar applications of 2,4-D or 2,4,5-T were tested in the different studies involving effects of (a) season of year, (b) concentration of spray applied to individual pines growing in clumps of brush, and (c) spray dosage when applied to trees and brush on an area basis.

Throughout all these tests, butoxyethanol esters of 2,4-D or 2,4,5-T were mixed in water as a carrier and applied to the trees and brush by using a backpack pump. All treatments were applied before 8 a.m. to minimize evaporation losses

Initial heights of all test trees were measured before spray applications and compared to subsequent measurements in September of each year thereafter. Concurrently, we estimated damage to all the brush as a percent of stems killed (dried and brown) for each brush plant.

Seasonal study. — Treatments were assigned at random to individual tree-brush clumps, each consisting of a single, young sugar pine, 2 to 3 feet tall, surrounded by a mature mountain whitethorn plant. At monthly intervals during 1958-1959, five clumps were drenched with 2,4-D and five with

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2,4,5-T at a concentration of 200 ppm. Ten untreated controls and 10 mechanical brush removal replications were also established. The mechanical brush removal treatment consisted of removing the entire top of the brush plant, including the root crown. For comparison with mechanical and chemical tests, the controls furnished data on growth and development of trees not released from brush competition.

Concentration study.—In September 1958, five concentrations each of 2,4-D and 2,4,5-T were tested: 50, 100, 200, 400, and 600 ppm. For each chemical and concentration combination, five randomly selected tree-brush clumps were sprayed thoroughly to the runoff point. Ten unsprayed tree-brush clumps served as controls.

Broadcast study.—Six 1/10-acre plots were established in an area where brush cover, topography, age, and density of natural conifer reproduction were approximately uniform. The plots were mapped, marked with stakes, and randomly assigned different dosages of 2,4,5-T: 0, ¼, ½, 1, 2, and 4 pounds per acre (ppa). The appropriate amount of herbicide was applied in September 1959, using 50 gallons of carrier per acre to cover fully each plot, including bare ground.

Results

Seasonal study.—Good kill of the brush stems, with little respouting, occurred in the treatments with 2,4,5-T applied from May through September (Table 1). Little tree seedling injury occurred from 2,4,5-T, except when applied in June and July. The September 2,4,5-T application resulted in especially superior tree growth and brush kill. These trees exceeded the average control height growth by 43 percent and that from mechanical brush removal by 25 percent. In contrast, poor brush kill resulted from all 2,4-D tests except in May and June, when both brush and tree seedlings were damaged. The pines were injured severely by 2,4-D at all application dates except in September, although even then the average height growth lagged behind that of the controls.

Concentration study.—The best brush kill resulted from applications of 400 to 600 ppm of 2,4,5-T, but at this concentration tree seedling growth was inferior to control growth. The height growth of sugar pines receiving the 100 ppm application of 2,4,5-T was somewhat greater than that of the control trees, although the associated brush was not damaged severely (Table 2). None of the 2,4-D tests resulted in height growth of trees excelling that of the controls or in effective kill of mountain whitethorn. The highest concentration of 2,4-D (600 ppm) seriously damaged the pine seedlings, killing the leaders and resulting in negative height growth. The most height growth for sugar pine sprayed with 2,4-D was achieved with the 100 ppm rate.

Broadcast study. — Brush kill was low in the plot receiving the ¼ ppa treatment. Application rates of 2 and 4 ppa gave superior brush kill but caused more severe reduction in tree growth (Table 3). After two full growing seasons, average height growth for sugar pine was greater in the plots receiving from ¼ to 1 pound of herbicide per acre than that in the control plot. Initially, the sugar pines in the ¼ ppa test averaged a foot taller than the controls. These taller trees may have had superior root systems, providing greater access to soil water. Height increment of sugar pine was less than that of the control in plots receiving the 2 ppa rate, and the 4 ppa rate killed most of the trees. The survival of sugar pine also declined as chemical application was increased, particularly at rates of 2 and 4 ppa.

Ponderosa pine responded similarly to sugar pine, but the data are not as complete. Application rates of ¼ and ½ ppa resulted in height growth greater than that of the controls, but the 4 ppa rate killed several trees.

Supplementary observations indicated that white fir was highly susceptible to herbicides. Perhaps these trees can be chemically weeded out of pine stands.

Only one species of brush other than mountain whitethorn was observed: littleleaf ceanothus. It was killed by all treatments using more than 1 ppa of herbicide.

Discussion

These results conform to patterns set by earlier work in this locality as well as in Oregon. Both Schubert (*9*) and Gratkowski (*3*) found that 2,4,5-T was superior to 2,4-D in controlling mountain whitethorn. Schubert reported that applications in fall produced the most reduction in foliage, but very few roots were killed even at rates of 2,000 to 3,000 ppm. Brush kill may not have to be complete to release conifers (*9*). It appears that

TABLE 1.—GROWTH OF PINE AND DAMAGE TO BRUSH PLANTS RECEIVING AQUEOUS FOLIAGE SPRAYS OF BUTOXY-ETHANON ESTERS OF 2,4-D AND 2,4,5-T APPLIED IN VARIOUS MONTHS AT A CONCENTRATION OF 200 PPM[1]

Treatment	Sugar pine height growth[2]	Whitethorn foliage kill[3]
	Percent of control	
2,4-D		
April	50	2
May	60	72
June	4	74
July	34	4
August	15	36
September	94	15
2,4,5-T		
April	92	31
May	85	100
June	44	86
July	28	88
August	113	80
September	143	92
Mechanical	118	100

[1]Evaluated 3 years after application.
[2]A difference of 12 is significant at the 5-percent level.
[3]A difference of 7 is significant at the 5-percent level.

TABLE 2.—GROWTH OF PINE AND DAMAGE TO BRUSH PLANTS RECEIVING DIFFERENT CONCENTRATIONS OF AQUEOUS FOLIAGE SPRAYS OF BUTOXY-ETHANOL ESTERS OF 2,4-D AND 2,4,5-T IN SEPTEMBER[1]

Treatment[2]	Sugar pine height growth[3]	Whitethorn foliage kill[4]
	Percent of control	
2,4-D		
50	62	0
100	82	0
200	67	12
400	47	9
600	0[5]	46
2,4,5-T		
50	67	5
100	105	56
200	46	52
400	52	92
600	70	89

[1]Evaluated 3 years after application.
[2]Expressed as parts per million.
[3]A difference of 9 is significant at the 5-percent level.
[4]A difference of 13 is significant at the 5-percent level.
[5]Leaders killed.

TABLE 3.—EFFECT OF DIFFERENT APPLICATION RATES OF 2,4,5-T ON GROWTH AND SURVIVAL OF SUGAR PINE AND PONDEROSA PINE AND ON BRUSH CONTROL[1]

Application rate	Sugar pine		Ponderosa pine		Mountain whitethorn
	Height growth	Survival	Height growth	Survival	foliage kill
Pounds/acre	*Percent of original*				
0	29	100	28	100	0
¼	33	100	48	100	20
½	33	97	31	100	30
1	37	96	....	....	85
2	6	85	....	....	98
4	0[2]	26	0[2]	27	100

[1]Evaluated 2 years after application.
[2]Leaders killed.

low application rates repeated at intervals may suppress the brush sufficiently to allow the trees to become dominant (*3, 8*).

Not only was 2,4,5-T more damaging to whitethorn than was 2,4-D, but it was also less damaging to sugar pine, when applied in a water carrier. Another favorable point was the ability of sugar pine seedlings to recover even when damaged by herbicides. The pines, and especially sugar pine, have been considered particularly sensitive to herbicides (*4*). Our results do not bear out this belief. The trees and brush were heavily drenched. But in actual practice the trees probably would be at least partially screened by the brush (*5*). There even appeared to be an enhanced rate of growth after the lighter applications. In view of the relatively light damage to the surrounding brush, this height increase seems more likely to be the result of hormonal stimulation rather than greater availability of soil moisture or nutrients (*2*). Woods (*11*) has discussed the theory of such stimulation.

Information on chemical control of weeds is obtained slowly because of the many variables involved (*11*). Delayed action effects may not show up for 2 to 3 years or more after application. Repetition of treatments in different years is sometimes necessary because of weather variations. Seasonal changes in air and soil temperature, as well as moisture fluctuations, may effect herbicide work (*6*). As an example, we noted that the height growth of sugar pine on the area of the seasonal study was noticeably greater than that in the concentration study on a drier site a short distance away.

These results are based on only two herbicides, 2,4-D and 2,4,5-T, which are still the "work horses" of the weedkillers. Only water carriers were used with the esters of the two chemicals in this study. Addition of oil would have enhanced brush kill, but would also have resulted in more damage to the conifers (*2*).

Only one species of brush was tested here, but comparably favorable results have been obtained on similar species in earlier years (*9*) and in other areas (*3*). Prompt action seems advisable in preventing the brush from becoming too large. Seedlings and sprouts are easier to control than the large, mature plants (*9*). If a control program were begun immediately after burns or logging, very little old brush would be present.

Summary and Conclusions

1. Low volatile esters of 2,4-D or 2,4,5-T in a water carrier were applied to mature mountain whitethorn plants in intermingled, 10-year-old sugar pine reproduction at various times of the year and at different dosages.

2. The 2,4,5-T applications consistently caused more damage to the brush, and less to the pines than did 2,4-D. In addition to the type of chemical, other factors affecting results were concentration of chemical and month of application.

3. From 80 to 100 percent of the brush stems were killed by single applications of 200 ppm of 2,4,5-T in any month from May through September.

4. Sugar pine height growth exceeded that of the untreated controls after August or September applications of 2,4,5-T. The September 2,4,5-T spray resulted in greater pine height growth than when the brush was removed mechanically.

5. Increasing the 2,4-D concentrations of the September spray to 600 ppm killed only about half the brush and most of the pine leader growth. Application of 2,4,5-T at 100 ppm resulted in pines growing more than did the controls, although brush kill was low, suggesting hormonal stimulation.

6. For broadcast applications of 2,4,5-T, brush kill increased from 20 to 100 percent as dosage was increased from ¼ to 4 pounds per acre (ppa). Height growth of sugar pines receiving ¼ to 1 ppa exceeded that of the untreated controls, whereas the 2 ppa rates reduced growth, and the 4 ppa rate killed the new leaders. The poor brush kill at ¼ ppa again suggests a hormonal stimulation of pine growth or greater initial height.

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