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Forest and Range
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FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE
P.O. BOX 245, BERKELEY, CALIFORNIA 94701

RECOVERY OF YOUNG PONDEROSA PINES DAMAGED BY HERBICIDE SPRAYING

Jay R. Bentley David A. Blakeman Stanley B. Carpenter

USDA Forest Service
Research Note PSW-252
1971

Abstract: Foliage injury and over-all tree damage to ponderosa pine plantations from aerial sprays of 2,4,5-T in 1965 were evaluated. Damage in 1966 was compared to tree growth from 1966 to 1968. The herbicide treatment caused above-normal damage to young trees when applied in September in a year with above-average summer precipitation and freezing weather soon after treatment. In the second year after spraying, the damaged pines improved greatly in vigor and appearance. And by the third year, their height growth was about the same as the undamaged trees. Recovery was more complete and control of competing brush was more effective in young plantations than in older ones.

Oxford: 174.7 *Pinus ponderosa*–232.4:236.1:414.4–416.1.
Retrieval Terms: Pinus ponderosa; plantation stands; forest weed control; 2,4,5-T; herbicide damage; leaf damage; weather factors; recovery ratio.

In 1965, 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) was sprayed over young ponderosa pine *(Pinus ponderosa* Laws.*)* plantations near Mount Shasta, in northern California, to control competing broadleaf shrubs. Four pounds acid equivalent per acre of a low volatile ester, applied by helicopter from September 3 to 9, caused an unexpected amount of needle injury. The same dosage and time of treatment had produced little adverse effect on young pines in earlier tests.[1]

We attributed the extreme effects from the 1965 spraying to two unusual situations: a cloudy, cool summer preceding the spraying; and an unprecedented sharp freeze 2 weeks after spraying. Rainfall in August totaled 1.97 inches, in contrast to the normal sunny weather with no effective precipitation. Plants continued to grow late into the summer; tissues did not harden off in a typical manner. Pine buds still had many green bracts at the time of spraying. For 3 days—September 17 to 19—daily minimum temperatures were between 25° and 29°F. This period of freezing temperatures was followed by cold dry weather that caused moisture stress for weeks.

On sprayed areas, foliage on a high proportion of the trees changed color—first to white, yellow, pink, or red, and finally to brown. By late fall many buds appeared badly damaged or killed on more than half of the trees. Some trees on unsprayed areas also changed color during the dry period after the freeze, but the proportion of visibly affected trees was much lower than in sprayed plantations. Herbicide reaction

in the broadleafed shrubs during fall was much greater than observed from September spraying in most years of study. Leaves on the sprayed brush turned brown quickly—equal to the browning that usually occurs during the next May or June. A much better than average kill of brush resulted from the 1965 spraying.

PROCEDURES

The foliage injury that occurred in 1965 and the over-all tree damage present in 1966 were compared with tree growth in 1966, 1967, and 1968. Four transects of 100 trees each—a sample of 400 trees—were set up in a plantation. The starting point of a transect was arbitrarily selected near the end of a tree row, and 10 consecutive trees were numbered 1 to 10. The transect then was offset two rows, and trees 11 to 20 were numbered. The offsets continued until trees 91 to 100 had been identified. Thus, each staggered transect was spread over 10 rows to avoid concentration of samples in any one row that might have been differentially affected by the planting or spraying procedures.

Rating of foliage injury began in December 1965 and was completed the next spring. The amount of foliage remaining on each damaged tree was compared with the amount remaining on nearby trees that appeared to be unaffected. These unaffected trees retained green and brown needles in about the same proportion typical of similar aged trees on unsprayed areas. Each tree was placed into one of two groups: (1) more than 50 percent of normal foliage, or (2) less than 50 percent of normal foliage. These groups were subdivided according to color and vigor of the remaining needles. Condition and size of terminal buds also were recorded.

Over-all damage to each tree was rated in August 1966 and August 1967, using the system developed during earlier studies of ground-rig spraying.[1] Five damage classes were used:

None to light—Pines show no visible effects of spraying, or the needles may show some discoloration or twisting but are not markedly stunted. A few lateral branches may show moderate damage.

Moderate—Terminal whorl shows light to moderate effects. Lateral branches have many shortened, discolored or twisted needles; but less than half of the branches have dead buds or greatly shortened new needles.

Severe—Terminal whorl shows moderate to severe effects. More than half of the lateral branches have greatly stunted new needles or dead buds.

Terminal dead—Terminal bud is dead; lateral branches may show light, moderate, or severe damage.

Tree dead—No signs of live tissue observed.

Height of each tree was measured before start of growth in 1966 and during late summer in 1966, 1967, and 1968. All heights—up to tip of highest bud—were judged to the closest inch.

RESULTS

Effects of the herbicide on pines were similar in all plantations that had been planted in any one year. The damage differed, however, between ages of pines at the time of spraying. Consequently, in reporting the results, we grouped the data according to how old the pines were in September 1965:

	Age of pines (yrs.)	*Plantations (No.)*	*Pines in total sample (No.)*
Date of planting:			
Spring 1964	2	1	400
Spring 1962	4	5	2,000
Spring 1960	6	2	800

Two other plantation sampled in 1966 were dropped from the summaries because reactions from 2,4,5-T were not typical. In one plantation planted with ponderosa pine in 1959, the herbicide had little effect on either brush or pines. In another, where Jeffrey pine *(Pinus jeffreyi* Grev. & Balf.*)* had been planted in 1958, the herbicide was effective on the brush, but damaged pines only slightly. This result was attributed to the greater resistance of this species, as compared to that of ponderosa pine.[1]

Appearance of pines in 1966

The degree of damage to the pines was best shown by their over-all appearance in summer after spraying. Records of foliage damage during the winter of 1965-66 were of limited value. Most of the pines that showed "none to light" or "moderate" damage in summer, had retained more than half of a normal needle crop in winter *(table 1).* Conversely, most of the pines that were dead by summer had lost more than half of their needles in winter. Except for these broad conclusions, we found no consistant relationship between vigor of needles in winter and over-all tree damage apparent the next summer.

Damage in the plantations during the first summer after spraying is suggested by the percent of pines in each damage class *(table 1).* In the 2-year-old plantation only 43 percent of the pines showed "none to light" or "moderate" damage, as compared to 69

Table 1—*Pine damage in 1966 related to amount of needles remaining on the pines during winter after spraying, by age of pines at the time of spraying*

Normal needle crop remaining in winter, 1965-66 (pct.)	Tree damage class – August 1966					
	None to light	Moderate	Severe	Terminal dead	Tree dead	All classes
	Percent of pines in sample					
2-YEAR-OLD PINES						
> 50	20	21	11	20	([1])	71
< 50	([1])	2	([1])	10	16	29
Total	20	23	11	30	16	100
4-YEAR-OLD-PINES						
> 50	34	32	8	13	1	88
< 50	1	1	2	4	4	12
Total	35	33	10	17	5	100
6-YEAR-OLD PINES						
> 50	19	31	18	15	1	84
< 50	1	2	5	7	1	16
Total	20	33	23	22	2	100

[1] Less than 0.5 percent of sample.

percent of the 4-year-old pines and 53 percent of the 6-year-old pines. Percent of the 1965 pine stand that was dead in 1966 was greatest for the younger pines.

The most obvious effects from spraying were shown by the percent of trees severely damaged and of trees with dead terminals. The severely damaged pines had many dead branches, and on other branches the needles were stunted and discolored. These effects were most apparent in the 6-year-old pines because of their much greater size at the time of spraying.

Recovery of Pines in 1967

In each plantation in 1967, most of the pines produced new foliage and buds judged as normal in appearance. Thus, the over-all damage ratings improved greatly between 1966 and 1967 *(fig. 1)*. The pines with "moderate" damage in 1966 were rated "none to light" damage in 1967. On most pines with dead terminal in 1966, new leaders were developed by 1967. Many of these trees, especially the younger pines, were growing vigorously in 1967.

The improved damage ratings in 1967 represent improved vigor of most trees. However, these ratings do not indicate the number of pines showing some change in form caused by the herbicide damage. Most, if not all, of the trees rated "severe" or "terminal dead" in 1967 were at least slightly deformed. Lateral branches were missing on some of

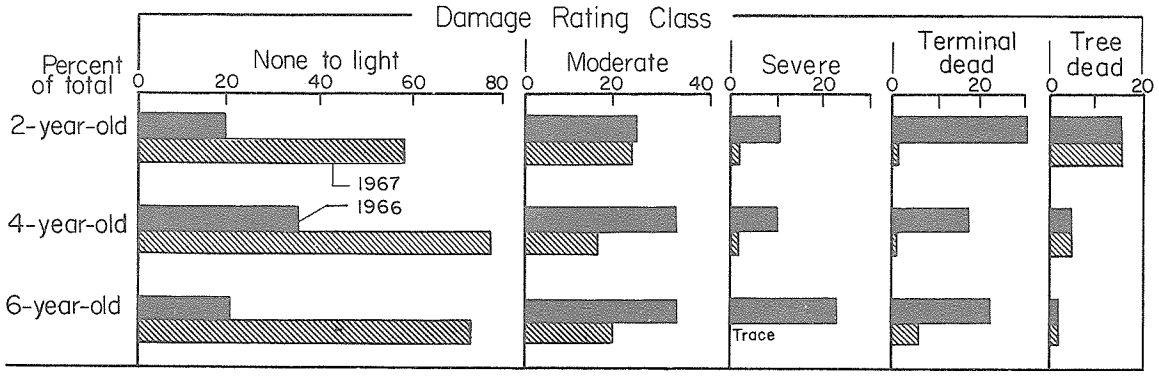

Figure 1—*Changes in appearance of pines, as shown by damage ratings, between 1966 and 1967.*

the trees with "moderate" rating. These longer lasting effects of spraying were much more apparent in the 6-year-old pines than in those that were younger and smaller at the time of spraying.

Damage Related to Pine Height

In each plantation the degrees of damage were summarized according to pine height at the time of spraying in 1965. Damage to the tallest 25 percent of the stand—the trees that had grown most vigorously and were most likely to be dominant in the future—was analyzed separately. The shortest 25 percent and the intermediate 50 percent of the pines were also analyzed separately for damage.

The dead pines were concentrated in the shortest groups *(table 2)*. In the older plantations, killing of the terminal bud was more common in the tallest group. However, except for the much greater mortality in the shortest group of 2-year-old pines, damage classes between height groups showed no marked differences.

Growth of Pines by Damage Classes

The major effects of spray damage on growth of pines occurred during the first year after spraying *(fig. 2)*. By the third year (1968), the average yearly growth was about the same for all damage classes within a plantation. Growth rate differed, of course, for pines of different ages.

Table 2—*Damage to ponderosa pines as related to height of trees at the time of herbicide spraying, by age of pines when sprayed*

Heights of pines in 1965	Extent of damage in August 1966				
	None to light	Moderate	Severe	Terminal dead	Tree dead
	Percent of pines in sample				
2-YEAR-OLD PINES					
Shortest	8	8	5	23	56
Intermediate	24	27	13	34	2
Tallest	22	31	14	29	4
All heights	20	23	11	30	16
4-YEAR-OLD PINES					
Shortest	30	34	12	14	10
Intermediate	37	34	10	16	3
Tallest	34	32	10	22	2
All heights	35	33	10	17	5
6-YEAR-OLD PINES					
Shortest	23	35	17	19	6
Intermediate	21	34	24	21	0
Tallest	16	29	26	27	2
All heights	20	33	23	22	2

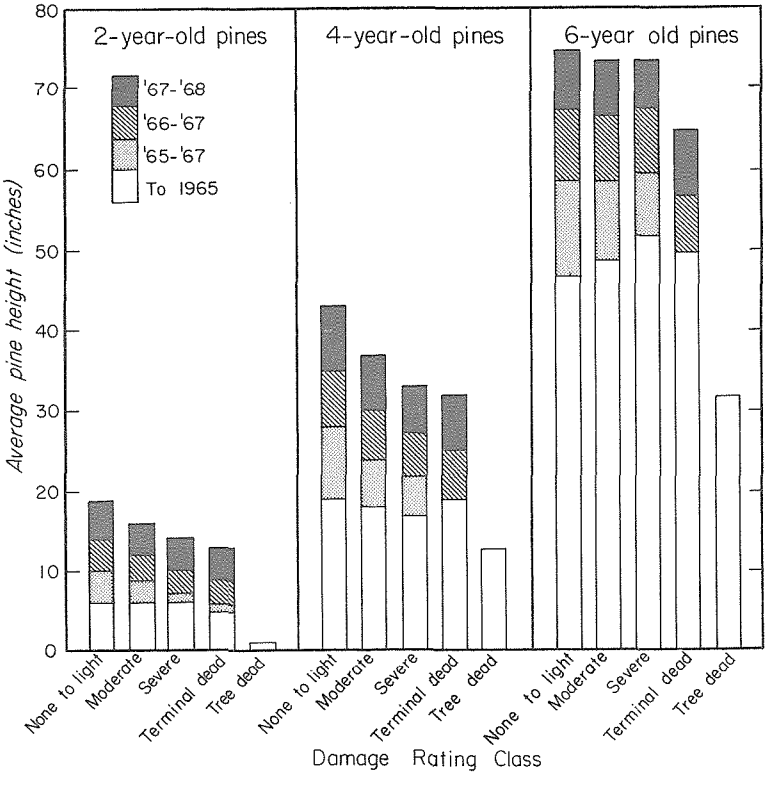

Figure 2—*Heights and growth of pines, 1965-1968 by 1966 damage classes.*

The heights and yearly growth of pines that were 2 years old at time of spraying were:

	1965 ht. (inches)	*Yearly growth (inches) 1966*	*1967*	*1968*
Damage class (1966):				
None to light	6	4	4	5
Moderate	6	3	3	4
Severe	6	1	3	4
Terminal dead	5	1	3	4
Tree dead	1	-	-	-

The terminal whorl was already dead at the time of spraying on more than one-fourth of the 2-year-old pines. On these plants the remaining live lateral buds were only about 1 inch above the soil surface. Most of these tiny plants were in the "tree dead" damage class in 1966, but some survived and grew well in 1968. The pines in the "terminal dead" class were taller plants with a living terminal bud at the time of spraying. Most of the damaged 2-year-old pines that were alive in 1966 recovered rapidly and appeared to be growing normally by 1968.

Heights and yearly growth of 4-year-old pines, by damage classes, were:

	1965 ht. (inches)	*Yearly growth (inches) 1966*	*1967*	*1968*
Damage class (1966):				
None to light	19	9	7	8
Moderate	18	6	6	7
Severe	17	5	5	6
Terminal dead	19	0	6	7
Tree dead	13	-	-	-

The 4-year-old pines with "moderate" or "severe" damage lost a few more inches of height growth in 1966 than pines with "none to light" rating. On most plants with "terminal dead" rating, none of the lateral branches had developed as new leaders in 1966. New leaders developed by 1967, and height growth was near normal in 1968. A few of these plants developed double leaders and required pruning in 1967. By 1968, the effects of spraying were not noticeable except on the few most severely damaged trees, which had made up about 2 percent of the stand in 1967 *(fig. 1)*.

In contrast to the similar results in all of the 4-year-old plantations, the degrees of damage and the yearly growth rates differed between the two 6-year-old plantations. At the time of spraying, the pines in plantation 6A averaged more than 10 inches taller than the pines in 6B. Plantation 6A is on a flat area below the other plantations. The pines there appeared to be less dormant on the date of spraying than pines elsewhere. And they appeared to be more damaged than trees in plantation 6B. In the 400-tree samples, 112 trees showed "severe" damage in 6A, but only 69 trees in 6B. However, terminal buds were killed on only 67 trees in 6A compared to 106 trees in 6B. Pruning of double leaders caused by spray damage was needed in both plantations.

Pine heights and yearly growth rates, by 1966 damage classes, for the 6-year-old plantations were:

	1965 ht. (inches)		*Yearly growth (inches) 1966*		*1967*		*1968*	
	6A	*6B*	*6A*	*6B*	*6A*	*6B*	*6A*	*6B*
Damage class (1966):								
None to light	53	43	12	12	8	9	5	8
Moderate	54	44	10	11	7	8	5	8
Severe	56	47	8	9	8	8	5	8
Terminal dead	58	46	-3	-3	10	10	6	9
Tree dead	23	43	-	-	-	-	-	-

The "severe" and "terminal dead" damage classes were concentrated among the taller pines in each plantation. Dead trees mainly were among the shorter pines in 6A, but were included in all pines in 6B.

By 1968, the yearly growth rate in both plantations was relatively low for the pines with "none to light" damage in 1966. This difference could have been caused in part by excessive competition from dense stands of brush plants that had been growing rapidly in 1965, the year of spraying. The brush was only partially controlled by the single herbicide application, particularly in 6A where the stand was dominated by tall plants of bittercherry *(Prunus emarginata* Dougl.*)*. Other factors could have contributed to the slow height growth of pines in 6A, which averaged only 5 inches in 1968. This low-lying plantation was more affected than the other plantations by cold weather during one winter and by insect damage to the foliage in 1968.

Stocking and Survival of Pines

Stocking of pines in 1965 *(table 3)* was related closely to density of planting. The 295 pines per acre in the 2-year-old plantation represented 81 percent survival from an original spacing of 10 by 12 feet. Average stocking of the 4-year-old pines equaled 85 percent survival; and for the 6-year-old pines, the average survival had been 82 percent.

By 1968, pine stocking in the 4-year-old and 6-year-old plantations still showed only slight effects of spraying; it averaged 81 percent of the number planted. In the 2-year-old plantation, however, the 1968 stocking was down to only 68 percent of the original planting density. Even so, the lower number of pines per acre, as compared to the older plantations, was caused more by low planting density than by spray damage.

Table 3—*Effects of spraying on survival and growth of pines, by age and height of pines at the time of spraying*

Pine height group in 1965	Pine stocking		Average pine height		Average pine growth
	1965	1968	1965	1968	1965–1968
	No. per acre		*Inches*		*Inches*
	2-YEAR-OLD PINES				
Shortest	74	34	1	12	11
Intermediate	147	144	5	15	10
Tallest	74	70	8	19	11
All heights	295	248	5	15	10
	4-YEAR-OLD PINES				
Shortest	116	104	10	23	13
Intermediate	233	225	18	38	20
Tallest	116	111	27	52	25
All heights	465	440	18	38	20
	6-YEAR-OLD PINES				
Shortest	140	132	32	49	17
Intermediate	280	279	49	72	23
Tallest	140	138	68	96	28
All heights	560	549	50	72	22

DISCUSSION AND CONCLUSIONS

Although the plantations showed extreme needle damage a few weeks after spraying in early September 1965, the general appearance of the pines had improved greatly by August 1967. Examinations of needle damage during fall and winter after spraying were of little value in judging the damage caused by the herbicide. But a more critical evaluation of spray damage could be made at the end of the first growing season after spraying. Much of the damage observed at that time was not long lasting however; growth of new needles and buds was normal on most of the pines by the second year.

These conclusions also were drawn from general observations of ponderosa pine plantations sprayed in other years when damage from 2,4,5-T applied in September was much less than occurred at Mt. Shasta in 1965. The limited damage typically was spotty and could be traced to uneven spray application. Mortality was negligible, and almost all of the damaged trees recovered by the second year.

The high mortality rate in the 2-year-old plantation that was sprayed in 1965 is not the typical result from spraying 2,4,5-T after buds are dormant. Pine seedlings still alive at the end of the second year ordinarily have more than one branch, and will survive even though much of the foliage is damaged. The exceedingly small seedlings that had only one or two basal branches in 1965 were easily killed if they received an overdose of herbicide. Yet, the small seedlings that were still alive in 1966 put on about as much height growth by 1968 as did the 2-year-old seedlings that were taller and had more foliage at the time of spraying.

Effects of the 1965 herbicide application on height growth of pines was determined by comparing growth of the more severely damaged trees with growth of trees showing "none to light" damage in 1966. This approach appeared sound; there was no indication that growth rate of the undamaged pines had been altered—either stimulated or retarded—by the herbicide treatment. Color and vigor of the undamaged trees appeared to be the same as that of unsprayed pines.

Growth of moderately damaged pines was not greatly affected during the 3-year period, 1966-68. Severely damaged trees lost about 1 year of growth. The total loss in height growth was of little importance in the younger plantations, where trees were putting on small height increment each year.

The effects of spraying on appearance of the plantation also were less long-lasting in the 2-year-old and 4-year-old plantations than in the 6-year-old plantations. The younger plantations in 1970 showed little effect on tree form that could be directly attributed to herbicide damage. In contrast, many of the taller pines in the 6-year-old plantations were still poorly formed, primarily because of missing branches that had been killed by the herbicide.

The pines in the younger plantations recovered well after suffering damage that was much greater than usually occurs from application of 2,4,5-T in September. The good control of brush obtained from the 1965 spraying should promote growth of the pines.[2]

In contrast, the pines in the older plantations did not recover so fully, particularly the taller pines that ordinarily would be kept as crop trees. Competing brush was poorly controlled. The abnormal damage from spraying in 1965 may well have offset any beneficial effects from the herbicide application.

These results support earlier conclusions that herbicides, if used, are best applied when brush plants are small and most easily killed.[3] The herbicide can be applied before the pines have been planted or while they are still small.

NOTES

[1]Bentley, Jay R., and Kenneth M. Estes. *Effects of herbicides applied by ground-rig sprayers on young pines.* 1969. (Unpublished MS. on file, Pacific SW. Forest & Range Exp. Sta., Berkeley, Calif.)

[2]Bentley, Jay R., Stanley B. Carpenter, and David A. Blakeman. *Early brush control promotes growth of ponderosa pine planted on a bulldozed site.* USDA Forest Serv. Res. Note PSW-238, Pacific SW. Forest & Range Exp. Sta., Berkeley, Calif. 6 p., illus. 1970.

[3]Bentley, Jay R., and Kenneth M. Estes. *Use of herbicides on timber plantations.* California Region, Forest Serv., San Francisco. 47 p. 1965.

The Author

JAY R. BENTLEY was formerly supervisory range scientist assigned to fuel-break studies, with headquarters in Berkeley, Calif. He joined the Station staff in 1933—after earning a B.S. degree at Kansas State University—and retired in 1971. DAVID A. BLAKEMAN is a forestry graduate of the University of California (B.S., 1966; M.S., 1970). Formerly with the fuel-break studies, he is now assigned to the Station's measurement techniques studies, at Berkeley. STANLEY B. CARPENTER was formerly assigned to fuel modification studies, at Berkeley. He earned forestry degrees from the University of Idaho (B.S., 1959) and the University of Washington (M.F., 1961).

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