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MOISTURE CONTENTS OF BRUSHLAND FUELS DESICCATED FOR BURNING

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ABSTRACT: Plots in a manzanita brushfield at Mount Shasta, California, were prepared for burning by aerially spraying with 2,4-D and 2,4,5-T on November 3, 1966, and with paraquat on June 3, 1967. On plots burned June 23-24, only the leaves and twigs were dead and dry; most of the green stems were not consumed. On plots burned under similar conditions 1 year later, the stems had dried and were completely consumed. Spraying of herbicides appears to be a practical means of lowering the moisture content of brush fuels for burning.

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RETRIEVAL TERMS: brush clearance; herbicide applications; paraquat; 2,4-D; 2,4,5-T; desiccation; moisture content; prescribed burning; Shasta-Trinity National Forest.

Brushland fuels in California commonly are removed by prescribed burning to clear the site for planting trees or grass. The fuel mass is prepared ahead of burning to promote safe clean brush removal under weather unfavorable for buildup and spread of fire in surrounding natural fuels. Crushing the brush with a bulldozer usually has been the recommended treatment. It breaks off many stems, compacts the fuel mass, and causes severed plants to dry up. Aerial application of herbicides is an alternate fuel treatment where bulldozer crushing is not feasible. The objective is to lower moisture content of the leaves, twigs, and small stems of standing shrubs—for effective burning under prescribed weather conditions.

A few trials have demonstrated that brushfields desiccated by herbicides burn more readily than untreated natural vegetation. But little information has been available about the changes in moisture content of the fuel mass caused by herbicides.

To study the effects of herbicides on the moisture content of shrubby vegetation, we aerially sprayed plots in a brush field on the southwest slope of Mount Shasta, in northern California. We found that a combination of herbicides effectively killed and dried the leaves, twigs, and small stems. Spraying added only about 4 tons to the 12 tons per acre of small dry fuels already present in the natural, untreated brushfield. Even so, the treatment made it possible to remove the woody vegetation by prescribed fire under a low burning index—under weather conditions that will not allow effective burning of untreated brush.

STUDY SITE

The study site was set up at about 5,500 feet elevation on the Sacramento District, Shasta-Trinity National Forest. Estimated precipitation averages about 38 inches annually, mainly falling between October and May as half snow and half rain. Summers are usually dry.

Brush cover on the test plots is dominated by greenleaf manzanita *(Arctostaphylos patula* Green*)*. Major associated species are snowbrush *(Ceanothus velutinus* Dougl. ex. Hook*)* and chinkapin *(Castanopsis sempervirens* [Kell.] Dudl.*)*. These species form a dense, almost impenetrable stand of chaparral that is relatively low–averging about 4-feet tall.

On November 3, 1966, we sprayed all test plots with a 1:2 mix of 2,4,5-T and 2,4-D at 4 pounds acid equivalent per acre. And on June 3, 1967 we applied paraquat on these plots.[1] We collected moisture content samples of treated vegetation from June 10 to 15, 1967 on plots that had received paraquat at 4 pounds, a.e., per acre. Samples taken June 16, 1967 to June 13, 1968 were from plots that received only 1 pound, a.e., of paraquat per acre. We collected samples of natural untreated vegetation on the plots at the time they were first sprayed. Later, we collected the untreated samples from an area next to the sprayed plots. A few samples of crushed brush were taken from another nearby area.

SAMPLING PROCEDURES

Sampling in 1967 started June 10, about a month after snow had melted from most of the area. Samples were collected at intervals of a few days until moisture levels and trends had become established, and then at about 2-week intervals during the remainder of summer and fall. Sampling in 1968 started April 9, soon after the snow had melted, and continued until June 13.

Sampling was restricted to days suitable for fuel drying–no precipitation had fallen for 48 hours, relative humidity in the afternoon usually was between 22 and 38 percent, and maximum daily temperature was between 63 and 89°F. All samples were collected between the hours 1000 and 1600.

Two to four samples of each fuel component were taken at each sampling date, and the mean value for the date was computed. Each sample was a composite collected along a line across an entire plot. Three fuel components were sampled: (a) leaves, (b) 1/4-inch stems, and (c) 1/2-inch stems. Three condition classes of each component were recognized and sampled if present: (a) *"green"* material, (b) *"brown"* material, and (c) *"old dead"* material. The "green" samples represented normal live vegetation or treated vegetation that had not definitely changed in color. The "brown" samples–limited to sprayed plots–included vegetation that had definitely changed color after being killed or heavily affected by spraying. The "old dead" was upright vegetation that had been dead and leafless at the time of treatment.

The "green" and "brown" samples were not clearly differentiated before July 10, 1967; thus, the "green" samples included some material definitely affected by the spray treatments. After that date, we consistently distinguished between the two condition classes, and estimated the percentages of original live vegetation made up by each class for each fuel component on each sampling date. Manzanita fuel components were sampled on each date; other species were sampled when time permitted.

The sample material was clipped, bagged, sealed, and weighed during the same day. The sample was then removed, placed in a can, and dried in an oven at 103°C. for 24 hours or until a constant dry weight was achieved. Moisture content was calculated as a percentage of the dry weight.

WEATHER

The 1:2 chemical mixture was applied late in the season. Mean daily temperature was about 50°F. on the day of spraying–November 3–but dropped to about 30°F. 4 days later. Minimum daily temperature was below 32°F. on most days until the next spring. Plant respiratory activity was assumed to be at a low level for months after spraying.

Heavy snows fell in March and April 1967–cumulative precipitation from March 10 to June 5 was about 10 inches above normal. Mean daily temperature was below normal for most days. These conditions delayed plant growth for about 6 weeks. Paraquat was applied on June 3, as soon as possible after snow had melted, in an attempt to speed up drying of brush leaves. But air temperature (about 50°F.) was too low for the most effective action from paraquat. Air temperatures did not rise to above-normal level until after mid-June. This change probably promoted desiccation of leaves and fine twigs on the sprayed area.

In 1968, the cumulative seasonal precipitation was near normal on March 15, but April and May were dry months. By June 5 the total precipitation for the season was about 4 inches below normal. Temperatures remained near normal during the spring months.

RESULTS

Standing Live Manzanita Fuels

Mature Manzanita Leaves

Untreated.–The moisture content of mature manzanita leaf samples averaged 120 percent at the time of spraying in November, 1966–a relatively high level for late fall. By June 1, 1967 the moisture content had dropped to 110 percent *(fig. 1)*. In untreated manzanita the moisture in mature leaves continued to drop until mid-June, but climbed rapidly from 86

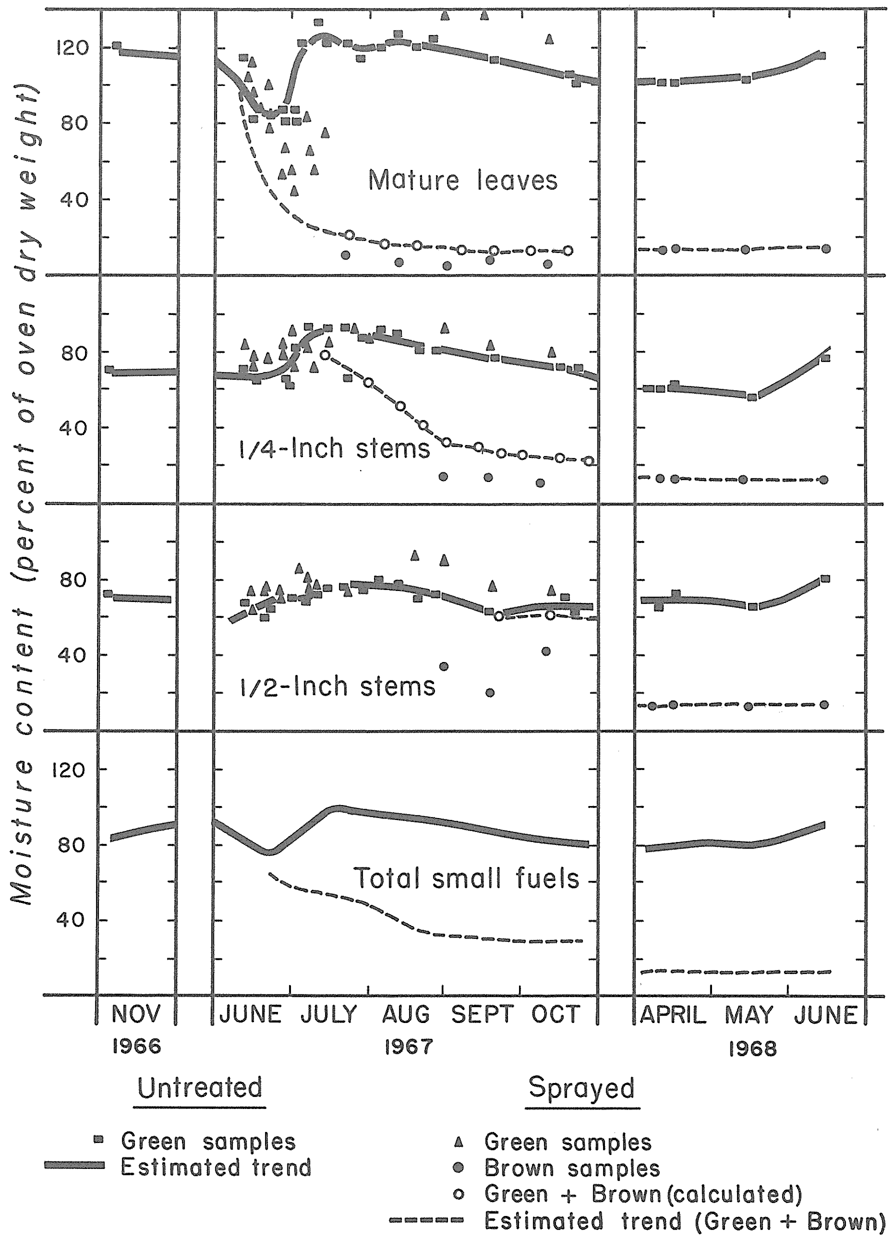

Figure 1–*Moisture trends of upright manzanita fuels alive at time of spraying. Open symbols show the average moisture contents obtained from field estimates of the proportion of "green" and "brown" vegetation that make up each fuel component in sprayed plots.*

percent on June 25 to 125 percent on July 10. During this 15-day period the above-normal air temperature favored rapid plant growth.

Moisture content of mature leaves fluctuated during the summer, but remained above 120 percent until August 25. It then declined slowly down to about 100 percent at the end of October–and stayed at this level until sampling was resumed in April 1968. It had risen by the last sampling date in June, and it probably would have been above 120 percent in early July.

The actual moisture content of total leaf fuel was even higher than that shown for mature leaves *(fig. 1)* because succulent new manzanita leaves added to the moisture content. For example, the moisture content of new leaves was 259 percent on July 13, when it was only 123 percent for the mature leaves that make up most of the leaf fuel.

Sprayed.–Condition of the brush leaves on plots sprayed with 4 pounds per acre of paraquat started changing rapidly about 1 week after spraying on June 3, 1967. Leaves began turning brown by June 15. By contrast, brush sprayed with 1 pound per acre of paraquat had changed only slightly.

The moisture content of samples collected as "green" leaves on the sprayed plots between June 15 and July 15, 1967 *(fig. 1)* did not show this definite decline. In fact, they showed highly variable moisture contents. The reason is that the samples included varying amounts of heavily affected leaves along with unaffected leaves, with a bias toward sampling of the greener leaves. This bias increased in July. After July 15, when "brown" and "green" leaves were kept separate and their proportions estimated, the low level of average moisture content of leaves on sprayed areas was clearly evident *(fig. 1)*. The average trend before July 15 was estimated to represent the condition on plots receiving 4 pounds of paraquat per acre. The moisture content levels after July 15 were obtained from samples on plots sprayed with 1 pound paraquat per acre.

Small Manzanita Stems

Untreated Area.–The moisture content of small stems followed about the same trend as for mature leaves but at a lower level. Moisture in 1/4-inch stems was 60 to 90 percent compared to 86 to 125 percent for the leaves *(fig. 1)*. The 1/2-inch stems had a lower average moisture content–ranging from 65 to 80 percent.

Sprayed.–Moisture content of 1/4-inch stems of sprayed manzanita held up through June 1967. But by July 20 part of these small stems had turned brown. And by the end of August most of them were brown, with a moisture content under 20 percent. For the combined "green plus brown" samples the average moisture content was calculated at 33 percent on September 1 and at 27 percent by the end of September. The samples in April 1968 showed an average moisture content of only 15 percent.

The drop in moisture content of small brush stems during August, 1967 was attributed to a delayed reaction from the fall application of the 1:2 mix. Similar reactions have been observed on immature brush regrowth in other years from late fall applications of 2,4,5-T and 2,4-D.

The spray treatment affected only slightly the average moisture content of 1/2-inch stems during summer and fall. A small proportion of these stems had turned brown by the end of August 1967, and showed a moisture level of 20 to 45 percent during fall *(fig. 1)*. But the "green" samples showed moisture contents above the untreated plots. The average moisture content of sprayed 1/2-inch stems was estimated as about the same as for untreated stems until near the end of October. By April, 1968, however, almost all of the stems were dead, with moisture contents of 15 percent for 1/2-inch stems and 16 percent for 1-inch stems.

All Manzanita Fuel Samples

All the samples of leaves, twigs, and stems under 1/2-inch diameter from sprayed manzanita that had been alive at the time of treatment were combined for analysis. The results show that these small fuels had become fairly well desiccated during summer and fall of 1967. The average moisture contents were 50 percent on August 1, 33 percent on September 1, and 30 percent at the end of October *(fig. 1)*. In untreated manzanita, the average moisture content of these fuels was stil above 80 percent in October. The desiccation of sprayed manzanita by late fall would have promoted better fuel consumption, even though moisture was still at a high level in 1/2-inch, and larger, stems.

At the time of spring burning in 1968 the leaves and small stems of standing manzanita plants had been thoroughly desiccated by the spray treatment first applied in November, 1966. Almost all of the brush fuel, including 2-inch stems, was consumed when the sprayed plots were burned on June 20, 1968.

Snowbrush and Chinkapin Fuels

Moisture in untreated snowbrush leaves was well above that in manzanita leaves in June and July, but by the end of August the snowbrush leaf moisture was a little below that of manzanita *(fig. 2)*. Chinkapin leaves had moisture contents lower than manzanita throughout the period of sampling. Stem moisture contents of snowbrush and chinkapin were similar; both were greater than for manzanita through the summer and fall.

Thus, a typical mixed stand of the three species would have somewhat different average moisture contents through the year than is shown in Figure 1 for the average trends of manzanita fuels. Moisture contents were calculated for a brushfield made up of 70 percent manzanita, 20 percent snowbrush, and 10 percent chinkapin–similar to the brush stand in the study plots. For this hypothetical mixed stand of untreated brush the estimated moisture content of live leaves, twigs, and stems under 1/2-inch was 88

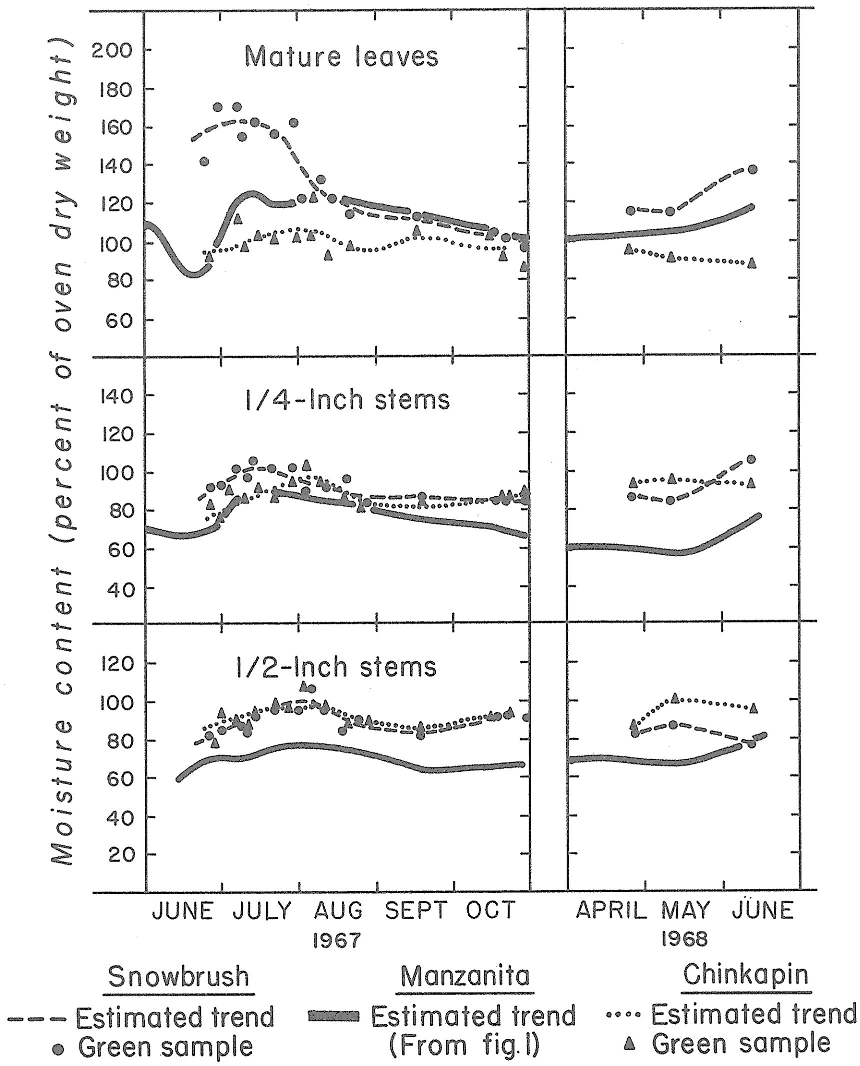

Figure 2–*Fuel moisture contents of three species –untreated upright vegetation.*

percent on June 20, compared to 79 percent for similar manzanita fuels. On July 1 it was 102 percent in the mixed stand, and 78 percent in manzanita. And by July 10 the mixed stand had 103 percent moisture content, and that of manzanita had increased to 99 percent. After August 1 the mixed stand and manzanita had about the same average moisture contents for the small standing live fuels.

Dead Fuels

The dense manzanita brushfield had a high proportion of naturally dead fuel, which had excellent horizontal and vertical continuity. Leaf and stem litter on the ground formed a fairly continuous layer of variable depth. Dry weight of litter was roughly estimated at 8 tons per acre on the sprayed plots sampled after June 16, 1968.[2] Upright dead stems under 1/2-inch diameter made up about 4 tons dry weight per acre. On branches alive at the time of spraying the dry weight of green leaves, twigs, and stems under 1/2-inch totaled about 4 tons. Thus, weight of the litter and the small fuels on upright vegetation totaled approximately 16 tons per acre, of which 12 tons was dead material before application of a herbicide desiccant. Larger upright stems added about 7 tons dry weight per acre, of which 2.5 tons was dead vegetation.

Moisture content of the litter and of the small, upright dead stems dropped to slightly under 15 percent by June 15, 1967, shortly after the end of the rainy season. Litter moisture fluctuated between 10 to 15 percent moisture on all subsequent days of sampling. Moisture content of the upright dead material–sampled as "old dead" stems under 1/2-inch diameter–averaged 14 percent on June 14, 1967, and 7 percent on June 20. It reached 5 percent by July 10, and increased to 9 percent in October. It was at 10 percent when sampling was resumed April 10, 1968 and stayed at about this level until June.

As the herbicide spray treatment added gradually to the amount of dead vegetation, the average moisture content of upright small fuels–live and dead combined–dropped from about 55 percent down to 12 percent *(fig. 3)*. The proportion of dry small fuels–litter plus upright material having a moisture content less than 15 percent–increased from about 75 percent up to essentially 100 percent of the total weight per acre, which was 16 tons. The first addition to the dry fuel was in dead leaves and fine twigs. Their weight was estimated at nearly 2 tons dry weight per acre. The small stems that died during summer added about 1 ton dry weight to the dead fuel. By April, 1968 the stems under 1/2-inch diameter were dead, making all of the litter, leaves, and small stems available as dry fuel.

Observations on an adjacent area where brush had been crushed with a bulldozer in October, 1967 indicated that most of the litter, leaves and small stems were dead and dry by June 15, 1967. Drying continued through July to an estimated 10 percent by August 1. Samples taken in April, 1968 showed an average moisture content of 13 percent for the small fuels. In addition to drying almost all of the small fuels by June 15, 1968, the crushing added much of the fine material to the ground litter, and it dried and compacted the larger stem fuel that had been upright before it was crushed.

DISCUSSION

Our results from moisture content studies of untreated brushland vegetation agree closely with the findings of other investigators. Buck[3] found that moisture content of old manzanita leaves rose sharply during the period of rapid growth–June 20 to July 20. He found that moisture content of new leaves ranged from a high of 226 percent on June 30 to a low of 106 percent on October 5. He also found that moisture content of both manzanita and snowbrush foliage tended to be lowest during afternoon hours. Philpot[4] found a seasonal trend in manzanita leaf

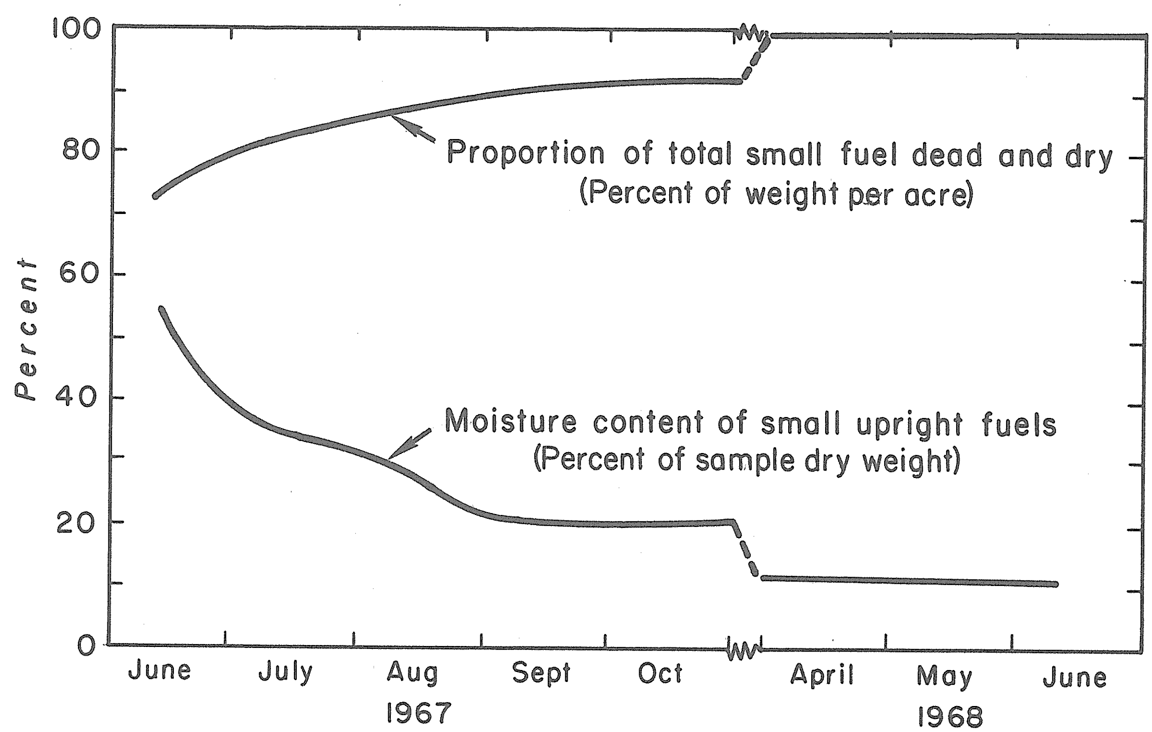

Figure 3–*Approximate average moisture content of small upright fuels (live and dead leaves, twigs and stems under 1/2-inch diameter), and proportion of total small fuels (upright vegetation plus litter) that was dead with moisture content less than 15 percent.*

moisture content similar to that described by Buck. And Philpot[5] also reported that moisture content of leaves was lowest from noon to 3 p.m. each day. Dell and Philpot[6] reported that leaves were the green vegetation components which showed major seasonal fluctuations in moisture content; stems showed minor changes. Moisture content of small dead fuel components largely reflected current weather conditions.

In our experience, burning of untreated manzanita brushfields under a low burning index does an inadequate clearing job, even when more than 10 tons per acre of dead, dry fuel is present. Usually, only the dead fuels and the green leaves and twigs are removed. We burned sprayed vegetation at a time when only the leaves and twigs had dried, but most of the green stems still remained unburned. In contrast, when we burned under the same low burning index 1 year later—after the stems had been killed by the spray treatment—almost all of the vegetation was burned to the ground surface.

The complete consumption of stems with diameters of 2 inches or greater may have been caused by killing and drying of these larger stems. This point was not checked by field moisture content samples. The effects of herbicide treatments on moisture content of large stems is now being studied.

The effective desiccation that promoted better consumption of brush stems appeared to come from slow dying and drying of the shrubs. This process extended over about 17 months—November 3, 1966, when spraying was done, until April 1968, after snow had melted and the litter had dried. We assume that this period can be shortened by spraying during the period of active plant growth in June or July and burning about 10 months later.

Notes

[1]The 1:2 mix included butoxy ethanol esters of 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) at 1.4 pounds and 2,4-D (2,4-dichlorophenoxyacetic acid) at 2.6 pounds—a total of 4 pounds, a.e.,—mixed with diesel oil to make 5 gallons total per acre. The paraquat (1,1′-Dimethyl-4, 4′-bipyridinium dimethylsulfate) was applied in mixtures with water to make 5 gallons per acre.

[2]Bentley, Jay R.; Conrad, Carol E.; and Schimke, Harry E. *Burning trials in brush desiccated with herbicides.* 1969. (Unpublished report on file at Pacific SW. Forest & Range Exp. Sta., U.S. Forest Serv., Berkeley, Calif.)

[3]Buck, Charles C. *Progress report on variations in the moisture content of green brush foliage on the Shasta Experimental Forest during three seasons.* 1939. (Unpublished report on file at Pacific SW. Forest & Range Exp. Sta., U.S. Forest Serv., Berkeley, Calif.)

[4]Philpot, C. W. *The moisture content of ponderosa pine and whiteleaf manzanita foliage in the central Sierra Nevada.* U.S. Forest Serv. Res. Note PSW-39, Pacific SW. Forest & Range Exp. Sta., Berkeley, Calif. 7 p. 1963.

[5]Philpot, C. W. *Diurnal fluctuation in moisture content of ponderosa pine and whiteleaf manzanita leaves.* U.S. Forest Serv. Res. Note PSW-67, Pacific SW. Forest & Range Exp. Sta., Berkeley, Calif. 7 p. 1965.

[6]Dell, John D., and Philpot, Charles W. *Variations in the moisture content of several fuel size components of live and dead chamise.* U.S. Forest Serv. Res. Note PSW-83, Pacific SW. Forest & Range Exp. Sta., Berkeley, Calif. 7 p., illus. 1965.

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