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BURNING TRIALS IN SHRUBBY VEGETATION DESICCATED WITH HERBICIDES

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USDA Forest Service
Research Note PSW-241
1971

Abstract: Woody vegetation was desiccated by crushing or by spraying herbicides for burning trials in northern California. All ignition methods produced intense fires under a low burning index in this shrubby vegetation that had rather continuous natural fuel—litter and dead twigs. Crushed brush was fully consumed. In sprayed upright brush, green stems were not burned, even though the dead leaves and twigs had burned fiercely. Sprayed brush was consumed if left an additional year until stems had died and dried. In area ignition trials, fires spaced about 48 feet apart interacted strongly and began coalescing within 7 minutes. Maximum fire build-up occurred about 14 minutes after firing by either a combination of center and line ignition, or by area ignition, in vegetation partially desiccated by spraying.

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To remove hardwood vegetation by burning under weather unfavorable for build-up and spread of fire requires a prefire treatment to desiccate the green plants. The fire is started and carried in small dry woody material.[1] The amount and continuity of the natural fuel determines how much of the green vegetation must be killed. If naturally dead fuels at ground level are sparse, the desiccation treatment must supply most of the small fuels by killing and drying leaves, twigs, and small stems. On the other hand, mature stands of California chaparral often develop appreciable natural fuel as litter on the soil surface and dead branches in the upright vegetation. This relatively continuous dead material will burn readily when dry. Yet, even with favorable natural fuel, the live portions of the shrubs are not consumed by burning under borderline weather conditions. Some type of desiccation treatment is necessary to assure consumption of the unwanted woody material.

Many methods of fuel preparation and burning have been used. A classic technique is the "slash and burn" operation practiced in the shifting agriculture of tropical regions. This treatment improves fuel structure by compacting the vegetation into a bed of fine particles, small branches, and larger stems. It also removes the green canopy and exposes the dead material to solar radiation. More recent versions of this technique involve crushing shrubs and small trees with a bulldozer blade, a roller, or a heavy chain. Other methods involve felling of trees or killing them by stem injection of herbicides, combined in various ways with crushing of shrubs or aerial application of herbicides, or both. All of these methods are very effective, but their use often is limited by cost, by steep terrain, by rocks, or by other factors that preclude safe and efficient ground operations.

Aerial application of herbicides can be widely used to desiccate vegetation ahead of burning. The aim is to kill and dry the ground story vegetation rather than to change fuel structure. Dead leaves may drop from both the understory and overstory vegetation and add litter at the soil surface.

An herbicide treatment first kills the leaves and small twigs, and finally it affects the stems. The mass of vegetation gradually dries until moisture content of the affected plant parts is in atmospheric equilibrium.

In developing techniques for aerial application of herbicides questions arise concerning how much of the potential fuel must be killed to assure consumption of the unwanted plants under conditions unfavorable for burning. We obtained some of the answers for a low shrubby vegetation type that naturally has many dead small fuel particles.

We conducted exploratory burning trials to find out to what extent special ignition techniques could promote burning and consumption of ground story vegetation that had been partially desiccated by herbicide application. Tests were made of area ignition—a procedure involving the setting of many small fires over an area simultaneously or in quick succession.[2] Different arrangements and spacings of ignition points were tried.

In shrubby vegetation that had rather continuous naturally dry fuel—about 12 tons per acre of litter and dead twigs and small stems—drying of the green leaves and twigs had a marked effect on fire behavior. Intense fires were generated in all herbicide-sprayed plots of crushed or upright shrubs. Few stems larger than 1/2-inch diameter were consumed, however, on sprayed upright shrubs burned in 1967. But, on plots where the sprayed vegetation was left for complete dying and drying of shrub topgrowth, burning in 1968 consumed the shrubs. Crushed brush was fully consumed on all plots. In vegetation partially desiccated by spraying, and burned in 1967, the time from ignition start to maximum flame build-up was about 14 minutes for 4-acre plots ignited by center line firing and for 18.5-acre plots that were area ignited. The small fires from individual ignition points interacted strongly when average spacing was 48 feet between points.

FUEL VOLUMES

The burning trials were conducted at 5,600 feet elevation on the west slope of Mount Shasta, Shasta-Trinity National Forests, California. The dense, relatively uniform chaparral cover was dominated by greenleaf manzanita *(Arctostaphylos patula* Greene*)*, about 4-feet tall. Two other evergreen shrub species were subdominant over all of the brushfield: snowbrush *(Ceanothus velutinus* Dougl.*)* and bush chinkapin *(Castanopsis sempervirens* [Kell.] Dudl.*)*.

The study site included two adjacent areas *(fig. 1)*. On one flat area we laid out eight small 4-acre plots.

Figure 1—*Plot layout showing 4-acre plots (1-8) on the right and portion of 18.5-acre plots (9 and 10) on the left.*

These eight plots, each 360 by 480 feet, were separated by 70-foot control lines. On the other area, with slightly rolling terrain, we set up four large plots, each 720 by 1,130 feet, or 18.5 acres.

Composition and weight of the cover before desiccation treatment were estimated by measuring 10 1-milacre quadrats. The samples were selected to represent the range in volume found on the study site. Total weight of the upright vegetation—both the dead and living components—on the quadrats ranged from 10 to 20 tons ovendry weight per acre. Most samples weighed about 16 tons per acre—selected as average for the eight small plots. Volume of shrubs was less on the four larger plots—estimated at 15 tons per acre.

Vegetation that was dead before the desiccation treatment—mainly dead branches on living plants—averaged about 40 percent of the total dry weight of the upright plants. Both the dead and living components of the upright vegetation were separated by small fuels (leaves, twigs, and small stems) and large fuels (stems over 1/2-inch diameter) *(table 1)*. Stems classed as dead had few leaves. The amounts of small fuels, both dead and living, were more consistent between milacre quadrats than were the amounts of large stems.

Weights of the litter layer on the ground, sampled on two 1-square-foot quadrats in each milacre, varied widely. A rough estimate of 8 tons ovendry weight per acre was considered typical of the entire brushfield. Thus, ground litter contributed about twice as much fine, dry fuel as in small, dead upright branches. Total amount of small dry fuel in the brushfield before burning was estimated at about 12 tons per acre.

The amount of small woody material remaining on each plot after burning was sampled in 3- by 3-foot quadrats on transects through the plot. The amount of large fuel that had been consumed was estimated from smallest diameters of the remaining stems.

Table 1—*Estimated tons, ovendry weight, per acre of live and dead fuels on small and large plots, Shasta-Trinity National Forests, California*

Potential fuel (fraction)	Small plots	Large plots
Upright living fraction:		
Small fuels[1]	5.0	4.0
Large fuels	5.0	4.5
Total	10.0	8.5
Upright dead fraction:		
Small fuels[1]	3.5	4.0
Large fuels	2.5	2.5
Total	6.0	6.5
All upright fraction:		
Small fuels[1]	8.5	8.0
Large fuels	7.5	7.0
Total	16.0	15.0
Ground litter	8.0	8.0
Total potential fuel	24.0	23.0

[1]Leaves, twigs, and stems less than 1/2-inch diameter.

FUEL DESICCATION

We prepared the eight small plots for burning by crushing the shrubs on one tier of four plots and then applying different herbicide treatments across the tiers of crushed and upright vegetation. The four large plots (Plots 9-12) received an herbicide treatment on upright vegetation *(table 2)*.

The paraquat (1,1'-Dimethyl-4, 4'-dipridium dimethylsulfate) was applied in mixture with water. The 1:2 mix included butoxy ethanol esters of 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) at 1.4 pounds, acid equivalent (a.e.), and 2,4-D (2,4-dichlorophenoxyacetic acid) at 2.6 pounds, a.e.—a total of 4 pounds a.e.—mixed with diesel oil. All applications were by helicopter at 5 gallons per acre.

Effects of the desiccation treatments on fuel moisture contents were estimated from samples taken on selected plots and from color transparencies that showed changes in color of leaves on the various plots.[3]

Moisture content sampling of the small plots started June 10, 1967, a few days before the eight plots were burned. Until then the November spray with the 1:2 mix and the June spray with paraquat had not affected the moisture content of small stems. Leaf moisture was dropping rapidly on the small plots sprayed with paraquat, but was less affected by the 1:2 mix. Sampling of the larger plots started June 16, 1967 when most of the leaves were still drying but stems were only slightly affected. Moisture contents of both leaves and stems had become stabilized at a low level when fuels were again sampled in June 1968.

BURNING INDEX

We tried to have weather conditions at the time of burning as uniform as possible for all trials. The brush burning index[4]—derived from a combination of fac-

Table 2—*Fuel preparation treatments and dates of herbicide application on eight 4-acre plots (plots 1-8) and four 18.5-acre plots (plots 9-12)*

Plot No.	Fuels crushed[1]	Herbicides applied		
		Type	Lbs. per acre	Date
1	No	–	–	–
2	Yes	–	–	–
3	No	Paraquat	4	June 3, 1967
4	Yes	Paraquat	4	June 3, 1967
5	No	1:2 mix[2]	4	Nov. 2, 1966
		Paraquat	4	June 3, 1967
6	Yes	1:2 mix[2]	4	Nov. 2, 1966
		Paraquat	4	June 3, 1967
7	No	1:2 mix[2]	4	Nov. 2, 1967
8	Yes	1:2 mix[2]	4	Nov. 2, 1967
9-12	No	1:2 mix[2]	4	Nov. 2, 1966
		Paraquat	1	June 3, 1967

[1]In October 1966.
[2]Ratio of 2, 4, 5–T and 2, 4–D.

tors that determine characteristics of ignition, fire spread, and fire intensity—was prescribed at 4 or 5 with a maxiumu of 7. The conditions were judged as marginal for effective use of fire in removing woody vegetation.

At least 2 days without rainfall immediately preceding burning was required for drying of small dead fuels. A minimum reading of 7 on the fuel sticks[4] was desired at the time of burning.

A relative humidity of 40 to 45 percent was prescribed, but slightly lower humidity was accepted in burning the first three small plots. Wind speed of 0 to 5 miles per hour was preferred, with a maximum of 10 m.p.h. Air temperature was not limiting, but temperatures greater than 60° F. were expected.

Other requirements were laid down to assure burning with minimum hazard. Burning was to be done in the late afternoon or evening when the brush burning index for the day was declining. A north or northwest wind direction was required, to avoid all possibility of a fire escaping into hazardous fuels next to the study site on the north and west sides. And stable weather with no fronts predicted within 12 hours was required.

Daily weather records were obtained from an official U.S. Weather Bureau station at 3,500 feet elevation, located 5 miles from the study site. A hygrothermograph was operated at the study site during periods when burning trials were underway. Spot records of air temperatures, relative humidity, and wind direction and speed were made as needed during burning and during collection of moisture samples. Fuel moisture sticks were placed on racks above the ground litter under vegetation that was to be burned and were reweighed as needed to evaluate conditions for burning or collecting samples.

SMALL-PLOT BURNING TRIALS

All of the 4-acre plots were ignited similarly. We lit a group of fires in the center of a plot, waited until the flames reached 6 feet, and then ignited the exterior lines quickly with drip torches. The center ignition involved 10 squibs wired in a series circuit and fired with a blasting machine.[5] Each squib was fused directly to a small diesel-gel fuel booster and was connected by a 20-foot fuse to another fuel booster that was lit about 3 minutes later.

The small plots were burned in sequence as numbered 1 to 8 *(table 3)*. In each pair, the southerly plot of upright brush was burned before the northerly plot that had crushed brush.

Trials in Unsprayed Plots

The unsprayed plots—plots 1 and 2—were burned June 14, 1967—8 days after cessation of rains that totaled 2 inches during a 1-week period. The brush burning index was 7 at 1832 hours P.s.t. when Plot 1 was ignited. Dry bulb temperature was 65°F., relative humidity was 36 percent, and wind speed was 4 m.p.h. These conditions held fairly constant, but the burning index dropped slowly and may have dipped to 5 by the time Plot 2 was ignited at 1852 hours.

Standing Untreated Shrubs

On June 14, the 1/2-inch dead stems showed a moisture content of 14 percent of the dry weight.

Table 3—*Summary of fire behavior and fuel consumption on plots, by treatment, burning date, and ignition method*

Plot size and fuel preparation treatment	Plot No.	Date of burn	Ignition method	Time to maximum build-up	Consumption of vegetation		Consumption of total woody material, dead and alive
					Small fuels	Large fuels	
				Min.	*Pct.*	*Pct.*	*Tons/acre*
4-acre plots:							
Untreated	1	June 14, 1967	Center, line	28	40	0	12
Crushed (Oct. '66)	2	June 14, 1967	Center, line	23	95	80	22
Crushed (Oct. '66) Sprayed (June '67)	4	June 15, 1967	Center, line	14	100	95	23
Sprayed (Nov. '66, June '67)	6	June 16, 1967	Center, line	13	100	95	23
Sprayed (Nov. '66)	8	June 16, 1967	Center line	16	100	95	23
Uncrushed Sprayed (June '67)	3	June 15, 1967	Center, line	15	60	5	14
Sprayed (Nov. '66, June '67)	5	June 15, 1967	Center, line	14	70	10	15
Sprayed (Nov. '66)	7	June 16, 1967	Center, line	13	70	10	15
18.5-acre plots:							
Uncrushed Sprayed (Nov. '66, June '67)	9	June 23, 1967	Area ignition	14	95	25	18
Sprayed (Nov. '66, June '67)	10	June 24, 1967	Area ignition	14	95	25	18
Sprayed (Nov. '66, June '67)	11	June 13, 1967	Mainly line	–	100	95	22
Sprayed (Nov. '66, June '67)	12	June 13, 1967	Line	–	100	95	22

For live manzanita the leaves had a moisture content of 85- to 95-percent, and small stems 65- to 70-percent. Litter had a moisture content of approximately 40 percent. In this untreated fuel the individual fire sets spread slowly; flames were never continuous across the entire plot. Flame activity reached maximum about 30 minutes after the first ignition. The fire burned down after an hour, and left islands of unburned brush that occupied about one-fourth of the plot.

Rate of fire spread and fire intensity undoubtedly were lower than would have occurred 10 days later when moisture content of litter and small dead stems had dropped. But fire behavior was typical of that observed in other attempts to burn untreated brush under a low burning index. Fuel consumption also was typical. On the part of the plot that was burned, the fire removed the litter and the upright dead stems; green leaves were partially consumed. All living stems were left.

Crushed Unsprayed Shrubs

Moisture content of small dead fuels on the ground was estimated at about 14 percent. The limited amount of small fuels that remained upright had an estimated 30- to 35-percent moisture content for living and dead material combined. Litter moisture was down to 15- to 20-percent, about half that under the dense green canopy in the plot of uncrushed vegetation. In the dry fuel, the small fires spread rapidly downwind, but never developed strongly over the entire plot. The reason probably was the need to ignite the plot as two separate units because of a truck trail through the plot. It took about 50 minutes to burn out the plot.

Fire intensity was lower than typically observed on larger areas of crushed brush burned under similar conditions. Most of the woody material was removed, although the remaining fragments were more numerous than on areas of crushed brush burned with more intense fires.

Trials in Sprayed Plots

The sprayed plots--plots 3-8--were burned on June 15 and 16, with ignition starting between the hours of 1840 and 2012 P.s.t. The ranges in burning conditions were:

Air temperature (°F.)	63-70
Relative humidity (pct.)	35-42
Wind movement (m.p.h.)	2- 3
Fuel sticks	6.5- 7
Brush burning index	4- 7

The six fires had certain similarities even though the plots differed greatly in desiccation treatment and in consumption of the woody material. Each plot contained enough continuous dry fuel to support an intensely hot fire. Each fire burned in rapidly from the upwind line, reached a maximum within 13 to 16 minutes after ignition, and soon hit the downwind line at maximum intensity. Heavy black smoke was produced through the period of greatest flame production. White smoke was produced first at the north end of each plot and over all of the plot a few minutes after maximum flame activity. The fires burned down in 30 to 35 minutes on June 15, and in 23 to 24 minutes on June 16.

Fire behavior differed to some extent between the plots of crushed shrubs and the plots of upright shrubs. In the crushed brush, where more fuel was being consumed during the same period of intense fire activity, flame whirls were formed and moved rapidly towards the downwind line. A strong main whirl was quite distinct in Plot 4 burned on June 15, but the whirls were of short duration in Plots 6 and 8 burned on June 16. In the plots of standing shrubs the fires developed less distinct whirls at the height of burning.

Sprayed, Crushed Shrubs

The herbicide applications browned the leaves and twigs of the few brush plants that remained alive after the crushing treatment. Consequently, almost all of the brush fuel was dead and dry on the sprayed plots of crushed brush. Moisture content of dead small stems was estimated at 10- to 14-percent and litter at 15 percent when the three plots were burned.

Consumption of woody material was almost complete on the plots, with no observable difference between the crushed brush sprayed with paraquat, with paraquat plus the mixture of 2,4,5-T and 2,4-D, or with the mixture alone. All of the small fuel was burned, except for a thin layer of moist litter that was intermingled with the surface soil particles. Of the estimated 5 tons per acre of large fuel alive at the time of crushing less than 0.5 ton remained as stumps of the largest plants. About 23 tons dry weight of litter and other fuel per acre--or 92 tons on 4 acres--had been consumed, most of it during a short period starting about 10 minutes after the first ignition and ending about 10 minutes later.

Sprayed, Standing Shrubs

On the three plots of uncrushed shrubs the approximate moisture contents were 12 percent for dead 1/2-inch stems and 15 percent for litter. Paraquat sprayed on plots 3 and 5 had partially browned the foliage; the green and brown leaves combined had an average moisture content of about 50 percent. The foliage appeared greener on plot 7 that had been sprayed with the mixture of 2,4,5-T and 2,4-D, but the moisture content was well below that of unsprayed green foliage. Stem moisture on all three plots was about the same as for unsprayed vegetation--about 70 percent.

Hot fires consumed about the same amount of fuel in each of the three plots regardless of the spray treatments. All upright dead material and much of the litter were burned. The layer of remaining litter was deeper than on burned plots of crushed brush, and it continued to smolder for several days. Leaves, twigs, and most of the small stems alive at the time of spraying were consumed by the fire. About 1 ton per acre of small upright fuel remained, along with almost all of the larger stems alive at the time of spraying. Approximately 10 tons of upright fuel and 5 tons of litter per acre--60 tons on 4 acres--were removed during the fires in Plots 5 and 7, with less in Plot 3 because of a small patch of unburned brush.

Access was greatly improved after burning of the partially desiccated upright vegetation, but the stiff branches on the remaining brush skeletons impeded movement through the burned areas. These stems were crushed with a bulldozer to prepare the areas for tree planting.

LARGE PLOT TRIALS IN SPRAYED, STANDING SHRUBS

Four large plots were established to test the effects of different ignition spacings in an area-ignition system. We intended to conduct the trial in woody vegetation with leaves desiccated by herbicide, but with stems still alive and green. Reaction was slow from the mixture of 2,4-5T and 2,4-D applied November 1966 at the start of winter weather. Snow fall was extremely heavy in spring; after snowmelt, little time remained to conduct the trials before onset of dry summer weather. A light application of paraquat in June 1967 was aimed at speeding up drying in the leaves.

Ignition spacing was tested on Plots 9 and 10 in 1967, but the prescribed weather conditions for burning other two plots did not occur until the vegetation had dried so far that tests would not be comparable.

Ignition Spacing Trials

Weather conditions at the start of each ignition spacing test were:

	Plot 9 burned June 23	Plot 10 burned June 24
Hour (P.s.t.)	1701	1853
Dry bulb (°F.)	76	76
Relative humidity (pct.)	41	43
Wind speed (m.p.h.)	3	3
Fuel stick	7	7
Brush burning index	7	5

Drying of fuels had progressed rapidly during the week between burning of the small plots and the large plots. By the dates of burning--June 23 and 24-- the old dead 1/2-inch stems had a moisture content of 10 percent and litter 10- to 15-percent. The leaves on manzanita plants were partially dead; brown leaves had a moisture content of about 20 percent, and greenish leaves, about 50 percent, for an estimated 35 percent for all leaves combined. The living 1/2-inch stems--not affected by the herbicide treatment--had moisture contents of 75- to 80-percent.

The ignition points, tied to 10 electrical circuits across each plot, had average spacings of 24 feet in Plot 9 and 48 feet in Plot 10. In Plot 9 one half of the 144 points per circuit were set to ignite when the squibs were fired. The remaining 72 points were fused to ignite 3 minutes later. In Plot 10 the 39 points per circuit were all to be ignited as the squibs were fired. The circuits in each plot were fired separately, but in rapid sequence. In Plot 9 many of the squibs in the west half did not fire, apparently because of excessive power drop along the circuits caused by grounding of the bare wires on green vegetation. We judged the effects of area ignition in the east half of the plot, and ignited the west half by line firing. In Plot 10 all points were ignited as the circuits were fired.

Both fires took about the same time to build up. Flame activity reached its peak 14 minutes after the first ignition on each plot. Production of heavy black smoke peaked at about 9 to 11 minutes; and of white smoke at 15 to 16 minutes. The fires burned down in 40 to 44 minutes.

Both plots burned fiercely. Many fire whirls were formed, and maximum flames reached more than 100 feet. The convection column over Plot 10 towered to about 16,000 feet elevation, and the column over Plot 9 was estimated at 12,000 to 14,000 feet. The brush fuels burned out quickly; thus, neither fire produced a violent firestorm covering an entire plot.

Fire build-up and spread from multiple ignition points were best judged from the Plot 10 trial, where the points were well distributed over the plot and all points along a circuit had been ignited simultaneously. The small fires at individual ignition points reached flame heights of 7 to 14 feet in about 3-1/2 minutes. At this stage they typically spread at about 5 feet per minute, and coalesced in about 7 or 8 minutes. In contrast, the larger fires formed by coalescence of several fires from ignition points were irregularly spaced. These strong fires influenced one another and overrode small fires from intermediate ignition points, causing whirls to form and other violent fire reactions which reached a peak at about 12 to 14 minutes after ignition.

These ignition trials showed that a 48-foot average spacing of ignition points caused quick interaction of small fires in the continuous, dry fuel under the prescribed low burning index.

Consumption of fuel appeared to be the same in both plots. All old dead fuels were consumed except for a thin layer of moist litter. The leaves, twigs, and most stems under 1/2-inch diameter also were consumed. Some larger stems of living plants, particularly snowbrush and chinkapin, were removed. The remaining woody material appeared to be less than remained after burning of the small plots of sprayed standing brush. We attribute this condition of better fuel consumption to lower fuel moisture contents by June 23-24, rather than to size of plot or method of ignition. We estimated that about 18 tons dry weight per acre of litter and of upright fuel--a total of some 270 tons per plot--had been consumed.

The remaining stand of partially burned manzanita plants having rigid, sharp-pointed stems was too thick for easy walking. These plants were crushed with a bulldozer before planting of pines on the burned areas.

Burning of Fully Desiccated Standing Brush

The two large plots not used for ignition spacing trials in 1967 were burned in June 1968. Dying and drying of the sprayed plants progressed slowly during summer and fall and rapidly during the cold winter weather.[3] Almost all brush plants appeared dead and dry by April 1968. Moisture content of 1/2-inch and 1-inch stems at the time of burning was about 12 percent.

The plots were ignited at 1830 and 1930 P.s.t. June 13. Weather conditions were:

	1830 hours	2130 hours
Dry bulb (^{o}F.)	61	51
Relative humidity (pct.)	38	47
Wind direction	NW	NW
Wind speed (m.p.h.)	8	10

Ignition procedures were rather simple and not fully planned because burning of both plots was done as a rush job when weather was favorable and fire control forces were on hand. Each plot was ignited with the men and equipment available at the time.

Plot 11 was ignited along the south half of the east side by starting small fires from squibs placed at 10-foot intervals on electrical circuits spaced 100 feet apart and extending about half way into the plot. These circuits were fired rapidly, starting near the southeast corner, as the east line was fired slowly with fusees. The south line was fired slowly from the southeast corner, using fusees. After the fires burned to the downwind (S) line, firing of the west line with fusees was started at the southwest corner to carry a wall of fire northward through the plot. This uniform line of flames was oriented diagonally from southwest to northeast across the plot. These ignition procedures were good for developing a uniformly hot fire with little pressure on the downwind line.

Plot 12 was ignited by setting a few fires in the southeast corner with two electrical circuits and by rapid firing of the south and west lines with a butane torch mounted on a pickup. The fires along the south line burned slowly. The fires that were started in the plot and along the west line developed at varying rates. The fastest spreading fires coalesced into a few fires that burned somewhat independently as violent firestorms. Two of these fires hit the downwind line at near full force and threw small embers into the dry brush windrows and across the wide control line, but did not start any spot fires. This fire behavior caused no problems under the weather conditions at the time of burning. Yet, it illustrates a hazard that can be avoided by better ignition procedures. An effective, safe procedure would be: first, burn out the downwind line in depth; and second, fire the side lines into the wind at the speed required to maintain a wall of fire across the area.

The fires consumed almost all of the brush stems on the two plots regardless of the ignition procedures and the manner in which the fires burned over the plots. Total consumption of woody material was essentially the same as on plots where the brush had been crushed and sprayed *(table 3)*. We assumed that complete burning of manzanita stems up to 2 inches, or larger, in diameter was the result of drying these stems with the herbicide, although moisture content of these larger fuels was not sampled before the plots were burned. Samples taken on other areas in May 1969 showed that similar herbicide treatments applied in 1968 had indeed dried the larger manzanita stems to less than 15 percent moisture.

CONCLUSIONS

Intense fires can be produced under borderline weather conditions in partially desiccated woody vegetation if it has enough dead, dry small fuels. Ten tons per acre of litter and dead branches, uniformly distributed with less than 20 percent moisture content, appears to be more than adequate. We define borderline conditions as clear weather with relative humidity of 40 to 45 percent and wind speed less than 5 miles per hour. Such conditions are about the best that can be expected for many kinds of woody vegetation, such as in tropical hardwood types, that grow under humid climates. These conditions, which fit into a low burning index, can be prescribed for other areas where the objective is to burn with minimum possibilities of fire spotting and building up outside of control lines.

Partial desiccation of leaves and twigs by herbicides influences fire behavior markedly—more than can be attributed to the small increase in dry fuel weight. Fires in sprayed brush build up quicker and spread over an area more rapidly and uniformly than do fires in untreated brush under similar poor burning conditions. Untreated green leaves with a high moisture content apparently exert a dampening effect on fire build-up—an effect that can be lessened by reducing leaf moisture content.

Area ignition can be achieved by spacing ignition points at least 50 feet apart in partially desiccated dense vegetation with adequate amount of naturally dead small fuel. For example, the small fires from individual ignitions interacted strongly on a 18.5-acre plot with average spacing of 48 feet between points. A wider spacing also would have been effective. A variety of procedures can be used to ignite this kind of fuel, including line firing against the wind.

Although fires in partially desiccated shrubby vegetation remove much hazardous fuel, more thorough desiccation is required before the main stems will be removed by burning. The necessary desiccation can be obtained by killing the top growth with herbicides. A period of several months will be required for killing and drying of the large stems.

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[3]Carpenter, Stanley B., Jay R. Bentley, and Charles A. Graham. *Moisture contents of brushland fuels desiccated for burning.* USDA Forest Serv. Res. Note PSW-202. Pacific SW. Forest & Range Exp. Sta., Berkeley, Calif. 7 p., illus. 1970.

[4]From the Wildland Fire Danger Rating System, 1958, developed jointly by the California Division of Forestry, the U.S. Weather Bureau, California Region of the Forest Service, and the Pacific Southwest Forest and Range Experiment Station.

[5]Schimke, Harry E., John D. Dell, and Franklin R. Ward. *Electrical ignition for prescribed burning.* U.S. Forest Serv. Pacific SW. Forest & Range Exp. Sta., Berkeley, Calif. 14 p., illus. 1969.

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This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife—if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

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