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Thinning ponderosa pine in western Montana with prescribed fire

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THINNING PONDEROSA PINE IN WESTERN MONTANA WITH PRESCRIBED FIRE

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INTRODUCTION

As man's knowledge of his environment increases, he realizes more and more that if an element is removed from it "balance-of-nature" is upset. This has been demonstrated many times. Often, the removal of an adverse element results in another problem, at times worse than the original one. Because wildfire is a dangerous and detrimental factor, it has been almost entirely eliminated. In the same way that extinction of an organism has given rise to a new set of problems, so has the absence of fire.

In the past, fire has played a major role in perpetuation of the ponderosa pine type. Fires, started by lightning, Indians, or the early white men, occurred whenever sufficient fuel accumulated. Since these periodic fires kept the fuel level relatively low, damage to the residual stand of ponderosa pine was slight. Instead of damaging the ponderosa pine stands, the fires prepared mineral soil for seedbeds, eliminated or reduced competition and removed some species that were further along in the scheme of ecological succession. The result was a majestic, "park-like" forest void of accumulations of fuel or stagnated "dog-hair" thickets.

Fire, a powerful and destructive force without restraints, is used on a prescribed basis to accomplish some forest management tasks. Prescribed fire has proved to be an efficient and economical tool when used in range management, wildlife management, wildfire suppression and prevention and silviculture. Fire is being used more extensively as a silvicultural tool as we learn more about how to apply it properly and skillfully.

Since ecological studies (3, 33) have shown that the exclusion of wildfire is partly responsible for the problem of overstocked and stagnated stands of ponderosa pine (*Pinus ponderosa* Laws.), perhaps one of the best solutions would be prescribed fire. Harold Weaver,[1/] has advocated for the past twenty-five years the use of prescribed fire as a thinning agent.

The purpose of this study was to examine the possibility of using prescribed fire as a thinning agent in young overstocked ponderosa pine stands in western Montana. The research was conducted on the Lubrecht Experimental Forest owned and controlled by the School of Forestry, University of Montana, Missoula, Montana.

1/ Forester, recently retired from the Bureau of Indian Affairs, U. S. Department of the Interior, Portland, Oregon.

OBJECTIVES

The objectives of this study are:

1. To examine the possibility of using prescribed fire as a silvicultural thinning tool in 30- to 50-year-old, overstocked ponderosa pine stands on the Lubrecht Experimental Forest.
2. To define a fire-prescription suitable for conducting fire-thinning in overstocked stands of ponderosa pine. The fire-prescription includes weather considerations and firing technique.

LITERATURE REVIEW

Prescribed fire as a "silvicultural agent" was referred to as early as 1910 by F. E. Clements (13). It is utilized for hazard reduction, site preparation for seeding and planting, range improvement for wildlife and livestock, control of vegetation type and control of some insects and diseases (6). Harold Weaver, a pioneer in the field of prescribed burning has observed for over 25 years that fire can possibly be used as an effective and economical method of thinning ponderosa pine (28, 29, 30, 31, 32). Other researchers have observed that fire could feasibly be used as a silvicultural thinning tool (2, 3, 20).

Analysis of the role of fire in the forest, both wildfire and prescribed fire, shows that fire not only is a necessary ecological factor but also has excellent possibilities as a silvicultural tool. The role of wildfire has been accidental, yet the forests as we know them have largely resulted from fire. Man's use of fire cannot be accidental, he must become skilled in its application for the various specific uses.

Ecological Effects

Fire is an ecological factor that causes rapid and definite changes in the forest complex. The most obvious change is the mortality of various individuals or species of plants. It is evident that certain species have more tolerance to fire than others. Starker (23) ranked the first three species in order of fire resistance in Oregon and Washington as western larch, Douglas-fir and ponderosa pine. In the Rocky Mountain region Starker ranked ponderosa pine second and Douglas-fir third with western larch still the most fire resistant.

Seldom will the most intense fire completely kill an entire stand of ponderosa pine (10). Spots will be killed, and the younger understory may be completely destroyed, but the majority of larger trees will escape with varying degrees of damage. Lynch (16) concluded that fire is somewhat selective in that it kills smaller, weaker trees while the larger, more vigorous ones in the stand will withstand the same fire. Therefore, variable fire resistance is not just a characteristic between different species, but also exists among the individuals of a species.

The exclusion of fire from the forest through organized fire protection has halted the natural thinning process. As a result even-aged, dense, stagnated stands of ponderosa pine have developed. At the same time species further along in the scheme of ecological succession, namely, Douglas-fir and western larch, have invaded the areas.

When these more tolerant species invade the area they crowd out the reproduction and weaken the mature ponderosa pine, allowing insects and disease to attack them (24, 32).

Weaver found that in the past a fire burned through the stand approximately every ten years (33). These periodic fires in the ponderosa pine forests had the following effects on the ecology of this type:

1. Seedbed preparation.
2. Removal of fine materials from the seedling-sapling stand.
3. Removal of competing brush and invader species.
4. Thinning of the stand.
5. Removal of fuel that if allowed to accumulate would present a serious hazard to the stand.

Physiological Effects

Fire damages trees by killing portions of the cambium on the main stem, by killing leaves, buds, roots and branches (9). Often a combination of the above injuries occurs. Should this damage be great enough, such as girdling through cambium kill or by complete defoliation, the tree may die. Indeed, if the damage is great enough in any one of the above categories it will result in the death of the tree. Fire-caused defoliation and killing of the cambium seem to be the main causes of death in ponderosa pine (10, 11, 16). Wagener stated, regarding ponderosa and Jeffrey pines, that bud kill is much more important than foliage kill in ascertaining the possibility of a tree surviving fire damage (27).

Kramer and Kozlowski stated that the reduction of photosynthetic surface by defoliation is the most serious cause of fire injury (12). This definitely is true of the younger stands which are more likely to be defoliated than stands of larger trees. The required amount of damage to the foliage that will cause mortality is quite variable. Different researchers have found this value to be from approximately 60 percent of the crown being scorched to complete defoliation (10, 16, 20, 25). Again it should be noted that each individual will react differently to a given condition of fire damage. Wagener (27) stated that no one percentage of crown damage can be used as a guide for determining whether an injured tree will survive. He listed several variables that influence the chance of survival. They are:

1. Season in which the fire occurs.
2. Age of the tree.
3. Growth vigor of the tree before the fire.
4. Species.
5. Susceptibility to insect attack after the fire.

If cambium injury is present, the problem is additionally complicated.

Cambium injury is probably the most important single factor in the cause of tree mortality (27). Only a narrow band of cambium around the stem need be destroyed to effectively girdle the tree (12). Other sensitive critical parts of a tree that can be killed by heat and affect its chance of survival are phloem tissue, foliage, and buds. The generally accepted lethal temperature of vital tissues is 140°F. (4). This value, however, is dependent on other variables such as time of exposure, moisture content and initial temperature. By no means can it be stated as exactly one constant value.

The time of year in which the fire occurs is quite important. A fire in the spring will have a different effect in terms of tree damage, than a fire of the same intensity in the summer or fall. Wagener stated that a tree is most susceptible to fire damage when it is actively growing (27). During this time of growth the vital tissues are exposed and tender. Food materials are being consumed at a very rapid rate and consequently the stores of starch and sugars are quite low. Therefore, a given fire can inflict more initial damage while the tree is less able to recover. When rapid growth has ceased the vital tissues tend to "harden off" and the reserve of starch and sugars build up. Consequently, the later in the growing season that the fire occurs, the better the tree is able to resist and survive fire damage.

Insect Effect

Fire-weakened trees are quite susceptible to insect attacks, especially bark beetles. If the vigor of a tree is reduced, or if the tree is killed, the resin flow will be markedly reduced. The decreased flow enables bark beetles to invade the weakened tree. A healthy tree will "pitch out" invading beetles, except when overwhelmed by large numbers (13). The two major genera that invade after a fire in the ponderosa pine type are *Ips* spp. and *Dendroctonus* spp. (27). Wagener stated that bark beetles (*Ips* spp.) will first invade the small and medium sized trees that have been definitely killed by the fire. The red turpentine beetle (*Dendroctonus valens*) will invade the base of a tree where patches of cambium have been killed (27). These insects are considered secondary bark beetles and generally will invade only dead and dying trees.

Primary insects such as the western pine beetle (*Dendroctonus brevicomis*) and the mountain pine beetle (*D. monticolae*) do not immediately attack a burned area. When they do attack, they generally invade the smaller trees that are dying, yet have green cambium. These trees would most likely die regardless of bark beetle invasion (19). The magnitude of the bark beetle invasion depends on the size of the burn, the condition of the trees both before and after the fire, and the status of the insect population in the surrounding area (27). Trees that would normally recover if not exposed to adverse conditions are generally not attacked by bark beetles until the latter part of the year after the fire. Often they are not attacked until the second year (18). Very little is known about the relationship between fire and insects. Before the use of prescribed fire can be fully examined this insect relationship must be studied.

Determination of Mortality

Determination of dead and live trees shortly after a fire requires a high degree of skill. Mr. R. Popp, a forester on the Colville Indian Reservation, has had considerable experience in marking trees for cutting after wildfires.[2/] He has been able to determine the difference between dead and live trees within plus or minus five percent.

Wagener (27) and Herman (10, 11) have studied the factors that help in determining fire-caused mortality in ponderosa pine. Live buds are an important criterion. If the foliage

2/ Popp, R. 1966. Personal interview at Colville Indian Reservation, Washington.

on a twig has been burned it is quite probable that the buds are dead. Buds on twigs in the vicinity might also be dead. If the bases of the needles are green, the buds may be alive along with buds on nearby twigs. Another indication of dead buds is the presence of scorched needles on the twigs but set in an abnormal position.

The length of live crown that has been killed is also an important indicator of mortality. However, as discussed earlier, the amount of crown damage needed to kill a tree can be extremely variable. Extent of crown injury is important as an indicator, but definitely needs to be used in conjunction with other factors, such as fire intensity, stem damage and apparent tree vigor.

After several months, mortality differentiation becomes easier because dead foliage will be shed from live twigs. An abcission layer forms at the base of the dead needles on live limbs. Dead twigs, being unable to form the abcission layer, will retain the needles for several years.

Cambium condition is the prime importance in the determination of mortality. As discussed under a previous section, if the cambium at the base of the tree is injured the tree may be girdled. A cut can be made through the bark to check this possibility. If the bole has become completely or nearly girdled the tree will probably die. However, if the tree is only partially girdled it will likely survive (11). This writer has observed that the cambium region (including the phloem and cambium) when alive will be white to light pink in color and spongy in texture. When the cambium region is dead, the color is dark brown to tan, and quite thin. No difficulty is encountered in distinguishing between the two conditions. The problem is determining if the tree is girdled or just a patch of cambium is dead.

External indicators of dead cambium are extent of bark charring, and resin that has boiled out of ruptures in the bark. Signs of local fire intensity are also indicative of possible cambium damage. Stumps and downed logs that have burned close to the base of the tree almost always indicate killed cambium (27).

Good light is essential for determining mortality. It is difficult to assess the damage to the bole without adequate light and it is very difficult to determine color of foliage against an overcast sky. At least two people should undertake marking; one person observing the crown and the other examining the trunks and marking the trees (27). In all cases, the marker should supplement his decision with personal judgment, since no two trees will react to damage in the same manner (11).

Prescribed Burning Technique

Prescribed burning is not a simple technique. Each case, in which prescribed fire is used, requires a different type of fire. When the burning objective is decided upon, the proper conditions and techniques are used to produce the proper type of fire. A person's skill in prescribed burning is dependent on his ability to adapt the various methods into the final prescription. Often last minute changes are required in this prescription to accomplish the desired results (15).

Two factors that determine how the fire will react in a given fuel complex and a given terrain are weather conditions and the ignition method. Weather conditions are variable between geographic locations. DeSilvia (7) described the weather prescription that was in use in the Northern Rocky Mountain area in 1965 as follows:

Wind -- 5-mile maximum.

Humidity -- 40 percent minimum and on a rising trend.

Fuel Moisture -- Approximately 12 percent within the burn.

These guidelines are only general and are adjusted to fit the ground situations.

The second factor, the ignition method, is the most important single element in the total prescription. Fire can be manipulated by the method or pattern in which it is ignited (15). There are four basic types of patterns: (1) backing,

(2) heading, (3) flanking, and (4) spotting. Flanking fires are set in line with the wind. The fire then spreads perpendicular to the wind. Spotting refers to a series of small fires spaced through the area, which burn in all directions. They are close enough together so that no one spot can gain the needed intensity to start an uncontrolled run. A heading fire is one that is allowed to move with the wind or upslope. The backing fire moves against the wind or downslope (8). Many combinations or modifications of these methods can be used to develop the desired type of fire. The burning technique is the only fire condition that can be easily manipulated; therefore, it must be used to compensate for the various degrees of weather, fuel and terrain.

Thinning with Fire

Results of thinning ponderosa pine with fire have been studied, by Weaver, on one area that was actually burned for thinning. Davis and Lindenmuth have made surveys of intentional burns of ponderosa pine stands in Arizona. And several studies have been conducted on the thinning effect of wildfire.

Weaver's study, also examined by Morris and Mowat, was conducted on the Colville Indian Reservation in 1942 (20). The burn took place in the afternoon of October 6, 1942. Weaver stated:

"...burning conditions were considered satisfactory to produce moderate heat and allow safe control of the fire. Lower vegetation had cured and fallen pine needles provided abundant fuel to carry fire."3/

The sky was overcast. There was a steady, brisk southwest wind which brought moist air into the area. Both control and sufficient fire intensity were taken into account for the burn. Results indicated:

1. Competitors of crop trees were reduced by about 65 percent.
2. An average of 46 percent of the crown was scorched on each tree.
3. Twenty percent of the trees were fire scarred.
4. Crop trees grew 36 percent more in diameter and 7 percent more in height than those crop trees on unburned areas.
5. Both diameter growth and height growth showed a "beneficial effect" of burning along with the thinning effect.

Effects of a wildfire that occurred northwest of Nespelem, Washington, in a stand of ponderosa pine was studied by Weaver in 1943 and 1949 (28, 29). The stand originated in 1903, from

3/ Cited by W. G. Morris and E. L. Mowat from unpublished manuscript "The use of controlled fire in the thinning of dense sapling and pole stands of ponderosa pine" by Harold Weaver.

a combination of several factors. Overgrazing by Indian stock prepared an excellent mineral soil seedbed, and combined with a heavy seed crop and several successive "wet" summers, an extremely dense stand of ponderosa pine resulted. In 1914 a wildfire burned a portion of this stand leaving a natural study area. The results of this study are as follows (28):

Comparison of Stocking and Growth
30 Years After the Fire

	Diameter 1-foot Level (inches)	Average Height (feet)	Stocking (trees/acre)	Basal Area ($feet^2$/acre)
Fire Thinned	7.4	32.2	1,100	335
Unburned	1.7	12.3	14,800	234

Clearly the fire provided beneficial thinning measures. The stocking was reduced more than 90 percent and basal area was increased over 40 percent during the elapsed 30 years.

During the fall of 1956, 27,000 acres of ponderosa pine were intentionally burned on the Fort Apache Indian Reservation in Arizona. Lindenmuth reported the following results (14):

1. On the average fire intensity was low.
2. Crop trees that should have been released -- 16.2 percent.
3. Crop trees released -- 3.5 percent or 24.9 percent of crop trees that should have been released.

4. Crop trees killed -- 10.9 percent.

5. Crop trees damaged -- 8.1 percent.

6. Reduction of fuel was proportional to fire intensity.

7. Crop tree release was proportional to fire intensity.

The results of this study indicated that fire was not well adapted as a thinning agent. Analysis of the fire possibly explains the poor results. Lindenmuth described the fire accordingly:

> "Fire was used with a minimum of controls. It burned day and night through all variations of stand and topography over a period of 33 days...a period as long as 33 days includes a considerable variety of fire weather." (14).

Lindenmuth further stated that the objectives of the prescribed burn could certainly have been more closely met if the area had been subdivided into units having the same objectives. This would enable the units to be burned with a fire of a more uniform intensity, and an average higher fire intensity could be used.

Davis (5) reported on a 100-acre area of ponderosa pine in Arizona that was intentionally burned in 1959. This study was an extension of the study by Lindenmuth (14). Davis stated:

> "The area was burned in one afternoon during relatively stable burning conditions. Ignition was by strips 20 feet apart." (5).

Results show that only 9.7 percent of the crop trees needing release were released. It appears that this study was carried out without regard to the results of the earlier study after which it was patterned. Apparently little attempt was made to manipulate fire intensity.

From the literature it appears that thinning ponderosa pine with prescribed fire is feasible. In the past fire has been allowed to run loose on days conducive to low fire intensity, with a variety of results. Certainly those desired have been obtained in nature. In order to duplicate desired results that have occurred naturally it is essential that carefully controlled burns be conducted on small uniform areas. A variety of fire intensities need to be tested and the effects of the fire must be evaluated.

PROCEDURE

Introduction

The procedure used for testing prescribed fire as a thinning tool was divided into three main sections. The stand was evaluated, a fire of given intensity was applied, and the stand was re-evaluated to determine the results of the treatment. The study was carried out during the spring and summer of 1966 and the spring of 1967.

Stand Description

Three test areas, designated A, B, and C were selected at the Lubrecht Experimental Forest in western Montana. The areas for study were chosen because they represented stands that needed to be thinned in order to become a productive timber stand. The location of the areas was as follows:

Area A--Section 35, Township 14 N., Range 15 W., Montana Principle Meridian.

Areas B and C--Section 8, Township 13 N., Range 15 W., Montana Principle Meridian.

Area A was on the flat south of the Blackfoot River. Areas B and C were north of Highway 20 on a gentle south slope.

These areas contained fairly homogeneous stands of overstocked and stagnated second growth ponderosa pine. A few Douglas-fir trees were found on the areas, but the stands were considered to be pure ponderosa pine.

Figure 1.--Typical stand condition. Approximately 4500 stems per acre.

The average number of stems per acre, average basal area per acre and mean diameter are as follows:

Area	Average Stems (per acre)	Average Basal Area Per Acre (ft.^{2})	Mean Diameter (in.)
A	3079	185	2.93
B	5892	208	2.18
C	3942	212	2.71

The understory type at Area A was composed primarily of *Carex* spp., *Antennaria* spp. and *Festuca* spp. The understory type at areas B and C was primarily *Symphoricarpos albus*, *Arctostaphylos uva-ursi*, *Mahonia repens*, *Calamagrostis rubescens*, and *Rosa* spp.

Techniques

Plots

Six circular plots of 1/25 acre were established at each area. A metal rod was positioned in the ground at the center of each plot. From this center rod a radius of 23.55 feet marked the boundary of the plot which was designated by a wire laid on the ground. An effort was made to place these plots in a uniform part of the stand and to avoid openings or abnormal concentrations of fuel.

Circular plots were used because the stands were composed of thickets having small natural breaks or openings. The circular plot had the same shape as the clumps which on the average were approximately 50 feet in diameter. The plot, therefore, covered the largest amount of area possible. Also, it was much easier to establish the circular plots than some type of rectangular plot since only the center point and the radius were required.

The plots were permanently established for future reference and designated with the area capital letter and a Roman numeral. Hence the third plot in Area B is Plot B-III. There were a total of 18 plots in which the following data were collected: the number and size of crop trees, a stand table showing number of trees by diameter classes, amount and type of understory vegetation and fuel weight by various classes. Each plot was marked with a routed-wooden sign, giving the plot number, fire intensity, and date of burn.

Stand Tables

A stand table was constructed for each plot by making a 100-percent sample of diameters and species of all live stems. Diameters at breast height were measured to the nearest inch and the stand tables were made up in one-inch classes. Diameters were rounded off as follows:

0.0 inch to 1.5 inches -- 1-inch class

1.6 inches to 2.5 inches -- 2-inch class

2.6 inches to 3.5 inches -- 3-inch class

etc.

A similar stand table was constructed the following spring for determination of results of the treatment on the stand.

Crop Trees

Approximately 25 crop trees were selected on each plot. This equals about 650 stems per acre. The crop trees were selected on the basis of dominance, shape, vigor and spacing.

They were numbered clockwise around the plot, starting at the north side of the plot. Height and diameter measurements were recorded, so that at a later date the effects of fire on growth could be analyzed. Each crop tree was marked with spray-paint, plastic ribbon, and a numbered aluminum tag. Height and diameter measurements were recorded for each crop tree. Crop trees were picked on the basis of approximately 650 stems per acre. This was to provide an adequate number of trees for future study and, in a thinning program, for a commercial thinning ten years hence.

Understory Vegetation

Understory vegetation was noted and recorded for each plot. A species list was constructed for each plot and the relative amount of each species was determined by first estimating the amount of the plot that was covered with understory vegetation. The relative percentages of the major species were then estimated. The understory vegetation was found to have little effect on the fire intensity; however, these data were collected for future use in the continuation of this study since they may have value in further describing the effects of this type of a fire.

Fuel

A measure of the material that burns is necessary to describe a fire. Fuel, in this case, was measured before and after the fire. Fuels were categorized into two classifications, duff and twigs. Each type of fuel was sampled differently.

Duff is material on the ground that is composed of decaying foliage, woody materials and other organic materials. Three distinct layers of duff can be observed and each is quite different. Each layer was named by its major component and numbered with Roman numerals from the surface down, as follows:

I. New needles (freshly fallen, but brown in color).

II. Partly decomposed needles (black in color, matted).

III. Humus (incorporated organic matter).

Evaluation of duff consisted of two steps. First, the average depth of the three layers was determined for each plot by randomly picking a point, cutting through the duff layers into mineral soil, gently spreading the cut and measuring the thickness of each layer in centimeters. Ten points were sampled and averaged for each plot.

The second step was to determine the average bulk density of the three layers. This was accomplished by sampling three one-meter square sections (one at each area). The average depth of each layer in the square was measured and the individual layers were separated, collected, oven-dried and weighed. Having the thickness and the oven-dry weight, the bulk density in grams per centimeter per square meter was then computed by means of a ratio formula. Multiplying the bulk density value by the average depth, gave the amount of duff per plot in grams per square meter.

Differences in the bulk density values between areas were small; therefore, the average value was used for all plots. These values are:

Bulk Density Values for Duff Layers

I	New needles	339 $gm/cm/m^2$
II	Partly decomposed needles	813 $gm/cm/m^2$
III	Humus	2,322 $gm/cm/m^2$

Twigs, composed of all woody materials located on top of the duff layer, were sampled by means of a line intersect method. Five sample points were established on each plot, each point consisting of three line intersects, one meter in length. The location of each sample point was randomly selected along one of five rays originating from the center of the plot (Fig. 2). The first ray in each plot ran due north. The second line was located 72° clockwise from the first. The third 72° clockwise from the second, etc. (Fig. 3).

Each sample point was randomly located from one to 23 feet from the center of the plot, along its respective ray and was marked with a metal spike. The first of three line intersects extended from the spike one-half meter out along the ray and one-half meter back along the ray. Each end of the intersect was also marked with metal spikes. The second line intersect had the same center but was rotated 60° clockwise from the first line intersect, and the third 60° from the second (Fig. 2)

With the sample points established, one edge of a meter stick was laid along the intersect line. The diameter of each piece of wood crossed by the edge of the meter stick was tallied. By using the basic formula it was possible to determine the volume or weight per unit area (see Appendix for formula). In this case the weight in grams per square meter was used.

Fuels, both duff and twigs, were resampled as soon as possible after the fire. The duff was sampled in the same manner as before the fire, except for the use of new randomly located points. Ten points were again sampled on each plot. Twigs were sampled exactly the same as before the fire, using the same sample points. Knowing the amount of fuel before the fire and the amount that remained after the fire, it was possible to determine the amount and relative percent of fuel consumed.

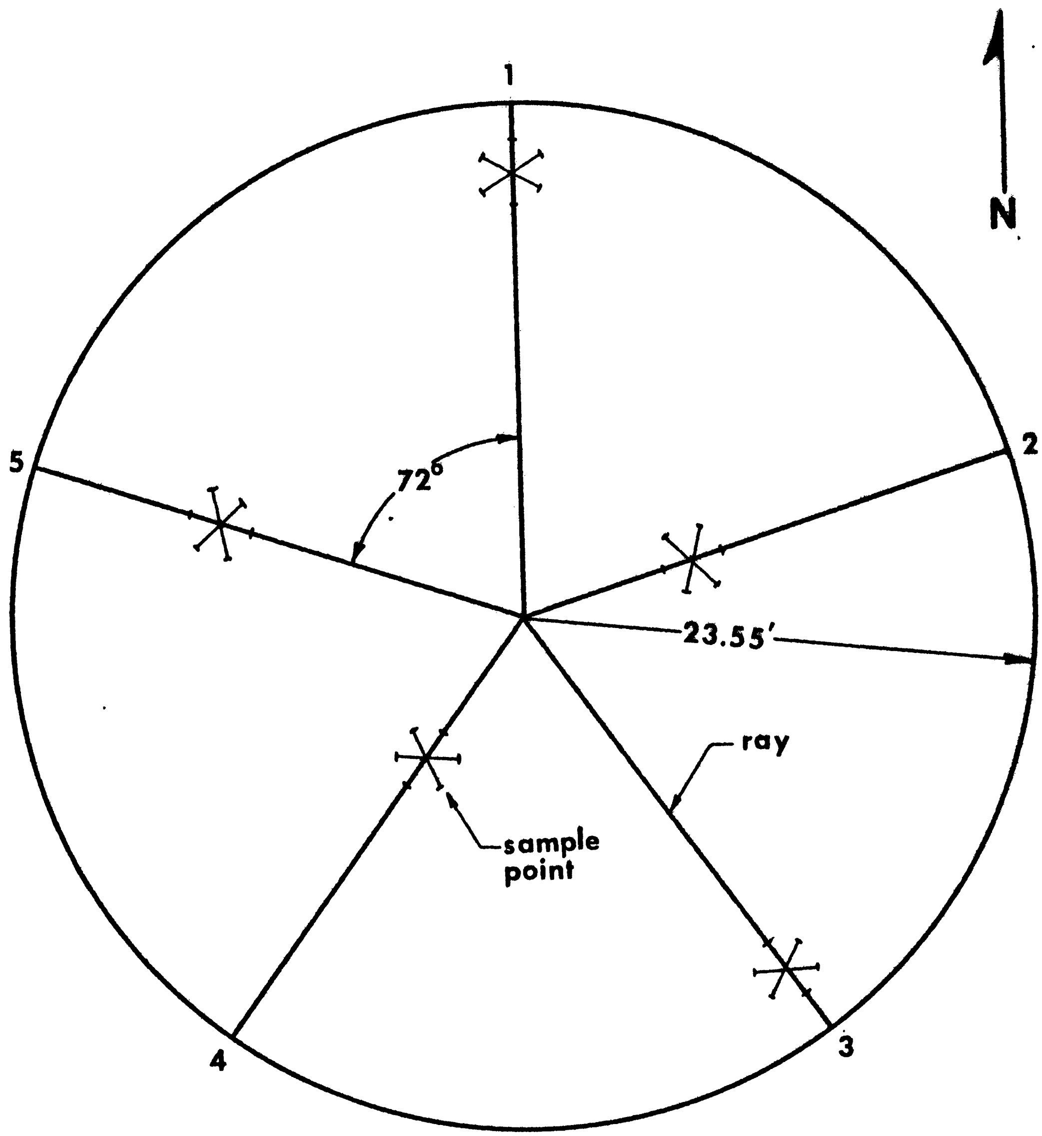


Figure 2.--Plot layout.

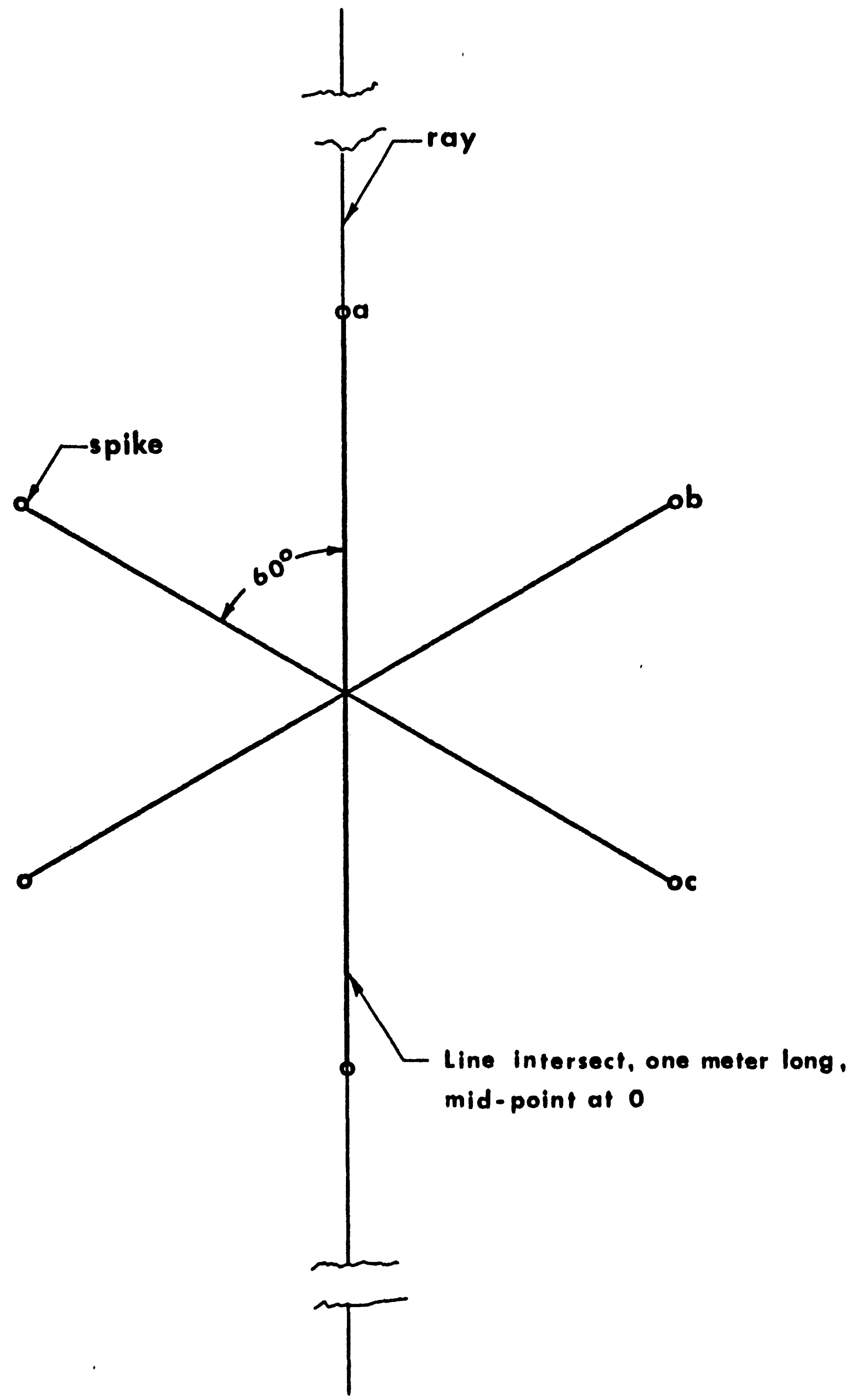


Figure 3.--Sample point layout.

Fire Intensity

A measure of the factors that influence fire intensity was necessary in order to know when to burn and to determine the relative intensity of the fires. Fire intensity indicators measured were weather conditions, fuel moisture content, and the amount of fuel consumed. A direct measure of fire intensity was made using water can analogs.[4/]

A complete fire weather station was set up in the vicinity of Area A. Weather data for Areas B and C were collected at a nearby weather station located at Greenough, Montana. Weather factors of principal interest were:

1. Relative humidity.
2. Temperature.
3. Wind.
4. Precipitation.

Weather data is summarized in the Appendix (page 65). Low relative humidity, from 9 to 16 percent, temperatures, 86°F. to 92°F., and about 7 days since last precipitation were characteristic of the high intensity fire level. Relative humidity of 20 to 46 percent, temperatures of 56°F. to 76°F., with about 3 days since last precipitation characterized the low fire intensity level.

Each area was burned at three levels of fire intensity. The criterion used to determine when to burn was that of fine fuel

4/ Beaufait, William R., An Integrating Device for Evaluating Prescribed Fires. For. Sci. 12: 27-29.

moisture. Fine fuel moisture contents that were strived for and used to designate the various fire intensities were:

6 percent fuel moisture content -- high intensity fire

10 percent fuel moisture content -- medium intensity fire

14 percent fuel moisture content -- low intensity fire

The method used to determine when the fuel moisture content approached the above values, and consequently when to burn, was a procedure described in a publication by Mactavish (17). The weather values required are relative humidity at noon, wind speed at noon, and the amount of precipitation. The theoretical fuel moisture content values represent a composite of weather conditions that influence the burnability of fuels. Subsequently, this value was used to predetermine the level of fire intensity.

Just prior to ignition, samples of fuel were collected from the respective plots for exact determination of fuel moisture content. Samples of all categories of fuel were weighed, oven-dried and re-weighed in order to calculate the percent moisture content (see Appendix for formula).

The following categories were sampled:

1. Twigs.
2. New needles (I).
3. Partly decomposed needles (II).
4. Humus (III).

The amount of fuel consumed was computed for each plot. The percentage of fuel consumed on each plot was used instead of the actual amount consumed because of the variability of fuels between plots.

Three water can analogs, 1-gallon paint cans painted flat black and filled with 2880 milliliters of water, were placed in each plot. The cans were placed so that one was located in a heavy concentration of fuel, one in average fuel conditions, and one in light fuel conditions. Just prior to the fire, the cans were vented and the water temperature was recorded. Immediately after the fire, the temperature was retaken, and the vent hole was sealed with tape. Water loss and/or temperature increase of the water gave an indication of fire intensity.

As more fuel is burned additional heat energy is expended. The water can analogs were used to characterize the fires. Temperature increase of the water was directly proportional to the fire intensity. Only a few cans lost much water in the fires. The weight-loss value was not representative of the fire intensities because the cans that lost a large amount of water were in heavy concentrations of fuel, and were indicative of only that location. The cans located in the light and medium concentrations of fuel rarely reached boiling temperature. Since light and medium fuel accumulation was typical of the amount of fuel on the plots, the temperature increase was a more suitable measure of fire intensity.

A summary of fire intensity indicators is given in Table 1. Included are:

1. Theoretical fuel moisture content.
2. Measured fuel moisture content.
3. Percent fuel consumed.
4. Water can analog temperature increase and weight loss.

Measured fuel moisture content was closely related to the theoretical value, as determined by the fire danger rating system, at least in the twigs and new needles classifications. The moisture content of partly decomposed needles and humus indicated the assumed trend; the higher the fire intensity the lower the moisture content. The amount of available fuel consumed was proportional to fire intensity; higher the intensity the more fuel consumed.

Ignition Technique

Two plots were burned under each fire intensity condition at each area. In other words, there were three treatments per area with two replications of each. The plots were randomly selected as to the type of treatment.

The plots that were burned under the high fire intensity period were burned with backing type fires (fires in which the flame front moves downslope or against the wind). All plots burned under low and medium intensity conditions were burned with strip heading fires (except for one plot which was burned with a backing fire). A strip heading fire is one in which the flame front is allowed to move upslope or with the wind for a given distance before it

TABLE I - INDICATORS OF FIRE INTENSITY

Fire Intensity	Theoretical Fuel Moisture Content (Percent)	Measured Fuel Moisture Content (Percent)				Fuel Consumed (Percent)	Water Can Analog	
		Twigs	New Needles	Partly Decomposed Needles	Humus		Temperature Increase °C 4/	Weight Loss Grams 5/
Low	11	10.8	12.1	35.0	28.7	38.0	16.2	103.0
Medium	8	9.6	10.0	22.6	28.6	40.0	29.5	31.1
High	6	7.2	6.8	13.8	16.9	44.2	39.2	230.7

4/ Only cans that did not reach boiling temperature (42 cans).

5/ Only cans that did reach boiling temperature (12 cans).

meets the previously ignited zone. The distance between strips partially determines the fire intensity.

Fire intensity was controlled on all plots except those where backing fires were used. An attempt was made to keep the fires out of the crowns and only in a few instances did the fire momentarily leave the ground.

Before the flame front approached the plot boundary and after it had passed the plot, the fire was manipulated so as to burn at different intensities. The only time the fire was completely under the influence of the fuel, topographic and weather conditions, was when a backing fire was used.

During the burning, rate of spread was mapped at 5-minute intervals. The mapping procedure consisted of a sketched line representing the fire front, labeled with the time. Unusual behavior, such as a flare-up of flames into the crown or a wind shift, was recorded.

Basically, on this study only strip heading and backing fires were used. It was impossible to dictate an exact ignition pattern, since each plot was different and required a different method of ignition. The main prerequisite was that the fire intensity could be decreased at any time. The type of fire sought was the highest intensity possible, without burning into the crowns. Backing fires were used for all high intensity condition fires because it was the only way the fire could be kept under control.

After the fire passed through the plot and all data had been collected, there was an opportunity to experiment with the fire and practice manipulating the intensity. It was found that during high intensity conditions a very narrow strip would cause the fire to go into the crowns. A 20-foot strip would cause a convection column to form and the flames would engulf all trees between the two fire fronts (the backing front of the original fire, and the heading front of the newly set strip fire). As soon as the fuel was expended, the flames would again settle to the ground. Any manipulation of the fire, in addition to the original backing fire, during high intensity conditions, caused the flames to go to the crowns.

Plots that were burned under low intensity conditions were burned with strip head fires, as this was the only way in which the fire would carry through the plot area. Often 30-foot wide strips were used. It was impossible to get the fire into the crowns, no matter how much fire front was built up.

The fires that burned under medium intensity conditions would back downhill or against the wind without trouble. With a wide strip head fire, the flames would burn into the crowns. The flame height could be regulated during medium fire intensity conditions by using a strip head fire and adjusting the width between strips. The distance between head fire strips appears quite critical. The wider the strip the higher the flames; therefore, when the conditions are so severe that a backing fire is needed to control the fire, burning should not take place. When the conditions are such that it is difficult to sustain a flame front, even with a heading fire, again burning should not take place. To determine how a fire will react a test fire should be set.

Figures 4, 5 and 6 show the three levels of fire intensity. Figure 7 shows method of ignition. Notice strip of flame that will become a backing fire. Figure 8 shows the strip head fire method. Figure 9 shows results of a strip head fire during a high intensity period.

Figure 4.--Low fire intensity level.

Figure 5.--Medium fire intensity level.

Figure 6.--High fire intensity level.

Figure 7.--Method of ignition. Note strip of flame that will become a backing fire.

Figure 8.--Strip heading fire method.

Figure 9.--Results of a strip head fire during a high intensity period.

Measure of Effect

During the spring of 1967 the initial results of the prescribed fires were observed and described. New stand tables were constructed for each plot and a measure of release was determined for the crop trees. The new stand tables were constructed in the same manner as the original, namely, a 100-percent sample of all stems.

The stems were classified as dead, alive, and marginal. The dead trees were those in which mortality was obvious; the live ones were those that were definitely not killed by the fire. In each case there was no doubt as to the classification of the trees. Trees classified as marginal are those that had indications of being alive but were badly damaged by the fire, and probably would not survive.

Classification of trees on each plot was accomplished by marking individual trees with plastic ribbon, as follows:

Alive -- blue

Dead -- orange

Marginal -- yellow

The marking of trees in each plot consisted of two phases: the first covered trees that were either alive or dead, the second covered unknown trees that were examined and ranked as dead, alive or marginal.

Figure 10.--Color coded plot, indicating mortality. Orange--dead; yellow--marginal; blue--alive.

All classification was done in direct sunlight, as it was practically impossible to distinguish scorched foliage when the sky was overcast. Two persons were used for the classification, one to observe at a distance, and the other to make necessary tests at the tree.

Foliage and cambium condition were the most important criteria used to classify an individual tree. Cambium condition was checked by two methods: the first consisted of cutting away the bark from the phloem and observing the tissues. With practice, it was easy to distinguish between dead and live tissues. Dead tissues were characteristically dark in color and the entire cambium and phloem region was quite thin. Live tissues in this area were white to light pink in color and rather soft in texture.

The second method of observing the phloem-cambium layer was by use of an increment hammer. If, upon extraction of the core from the increment hammer, the bark separated from the xylem, the cambium was dead at the sample point. A core in which the phloem and cambium were alive would be intact and the thick band of light-colored phloem would be visible. Several cores were taken around the base of the tree. If the cambium was dead completely around the stem, the tree was considered effectively girdled and classified as dead. In several cases where the tree was one of the dominants and the crown was dark green in color, it was classified as a marginal tree, even though it appeared to be completely girdled.

Foliage condition was almost as important as cambium condition in the classification scheme. Various degrees of foliage condition ranged from dark green color over the entire crown to complete defoliation of every single needle. If the crown was completely scorched, and the tree was not a dominant, it was ranked as marginal or dead. When the foliage was scorched and had a blackish cast to the color, the tree was generally dead. When a tree was completely defoliated it was always dead. In most instances foliage condition was used in conjunction with other tests even though it was important in itself.

Other tests included bud condition (on smaller trees in which the buds could be examined), severity of bark char, the presence of resin drops, blue stain, and apparent vigor.

It was observed that the smaller branches on dead trees tended to curl up, into the trunk. Another characteristic of dead trees was a "stiffness". When the trees were shaken back and forth, very little oscillation or bending resulted. Live trees had a "whiplike" action. The position that the tree occupied in the stand was an important consideration on borderline cases. All decisions were supplemented with personal judgment. The plots were visited nearly every week after the burning to observe differences between dead and live trees.

In an attempt to sample the effectiveness of the fire as a thinning agent, the following procedure was used to determine a relative release value for each crop tree. If all of the nearby competing trees were killed, the crop tree would be considered released. Only the four nearest competing non-crop trees were considered. If all four were dead, that crop tree was given a release value of 100 percent. If the four nearest competing non-crop trees were alive then the release value was zero percent. Marginal trees were given a value one-half that of a live tree. Therefore, four marginal trees competing with a crop tree would represent a release value of 50 percent, and one live tree plus two marginal trees would also equal a release value of 50 percent. This value was determined by giving each live tree a value of 25 and each marginal tree a value of 12.5. The four competing trees were assigned respective values and the total was subtracted from 100 percent, giving the release value for the crop tree.

The orderly fashion of numbering crop trees allowed a rapid analysis of fire behavior, such as a spot that crowned out. On plot C-VI a flare up of flames completely killed a small group of the trees. This is observed by the list of crop trees on plot C-VI. Crop trees 15 through 23 were affected (Appendix, p. 108). Trees 15 through 17 are listed in a marginal category, trees 18 through 20 are listed as dead and trees 21 through 23 are listed as marginal. This is a good example of how the marginal classification fits into the scheme of damage evaluation.

RESULTS

Thinning with fire was accomplished to varying degrees on the eighteen plots. A range of fire intensities was obtained. On one plot (B-II) burned during a high fire intensity period, the fire built up a tremendous amount of heat and went into the crowns, completely killing all trees on one-half of the plot (Appendix, p. 98). On a plot (C-I) that was burned during a low fire intensity period, the fire could not sustain itself. The plot was burned only because the fuel from the torch kept the fire going. The complete plot, rather than just strips, had to be ignited. Practically no trees were killed (Appendix, p. 85).

The author found that the thinning fire could be manipulated to develop relatively equal fire intensities under a variety of conditions. The fire was controlled by the weather and fuel conditions only when fire intensity conditions were at an extreme, either too high or too low. Intensity of fires, burned under medium intensity conditions, were influenced much more by the manipulation of the fire front than by fire intensity conditions. Generally, there was very little difference between the intensity of the fires that were burned at medium intensity conditions and those that burned at high intensity conditions.

Shortly after the burning was finished the presence of *Ips oregoni* and *Dendroctonus valens* was noted in all three areas. However, these bark beetles were present on only two plots. Other activity was adjacent to the plots. The trees that were invaded were classified as being killed by the fire. There was no presence of insects in any trees classed as marginal or alive.

All trees that were attacked were located in an area that had been burned by an extremely hot crown fire. The locations, where bark beetles had invaded, were burned before September 15, 1966. There was no insect activity noted on plots or areas burned later than this date.

The mean diameter of remaining trees became larger as fire intensity increased. Figure 11 shows the change in mean diameter for trees before the fire; for marginal and alive trees and for alive trees only, after the fire.

Fire Intensity	Before Fire (Inches)	Alive and Marginal Trees (Inches)	Alive Trees (Inches)
Low	2.55	3.36	3.58
Medium	2.51	3.45	3.88
High	2.52	3.47	3.91

Figure 11.--Mean tree diameter by fire intensity.

Figure 12 shows the distribution of trees in each size class after the fire according to fire intensity.

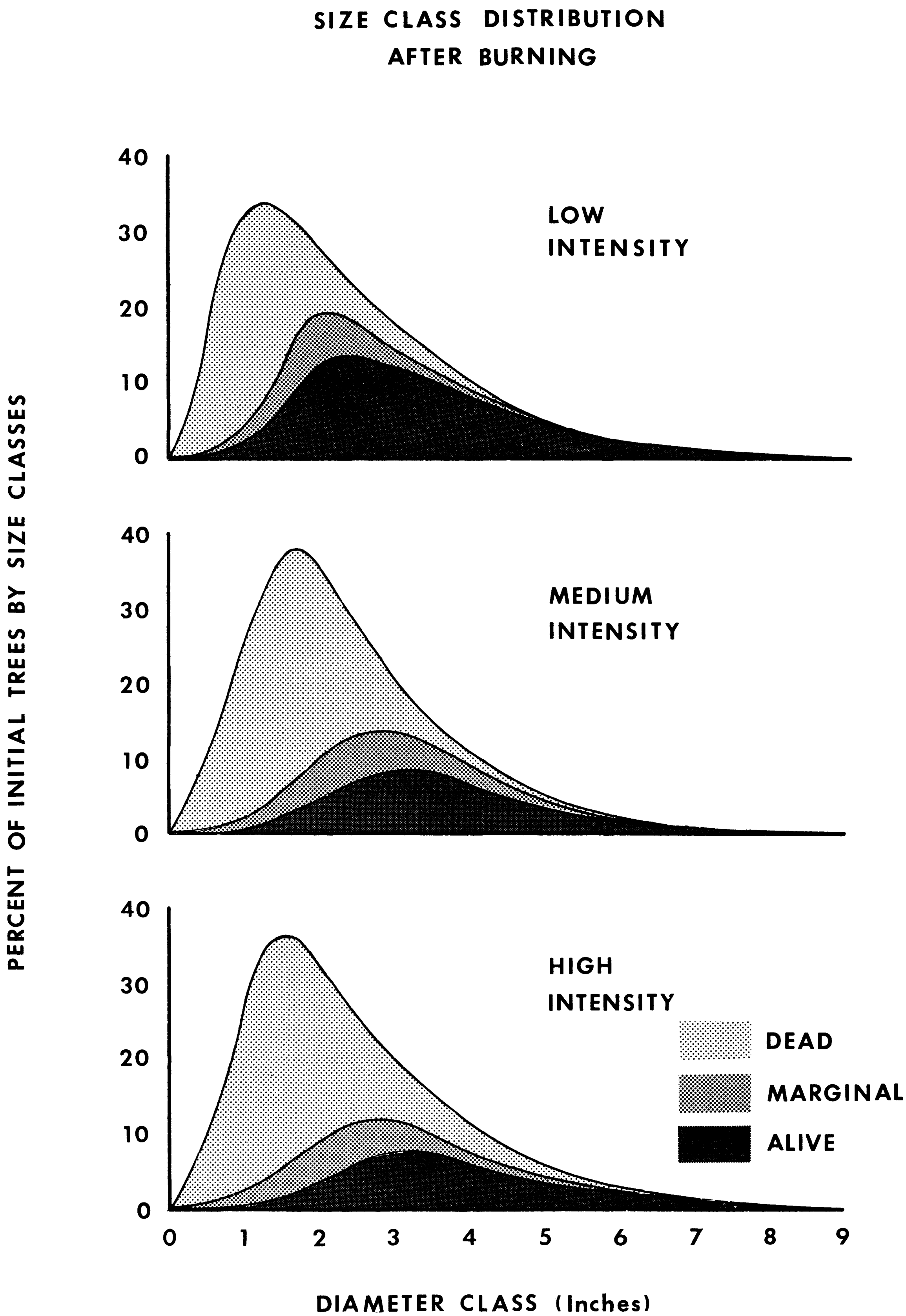

SIZE CLASS DISTRIBUTION
AFTER BURNING
PERCENT OF INITIAL TREES BY SIZE CLASSES
40
30
20
10
0
LOW
INTENSITY
MEDIUM
INTENSITY
HIGH
INTENSITY
DEAD
MARGINAL
ALIVE
0
1
2
3
4
5
6
7
8
9
DIAMETER CLASS (Inches)

Figure 12

Percent basal area reduction by fire intensity is as follows:

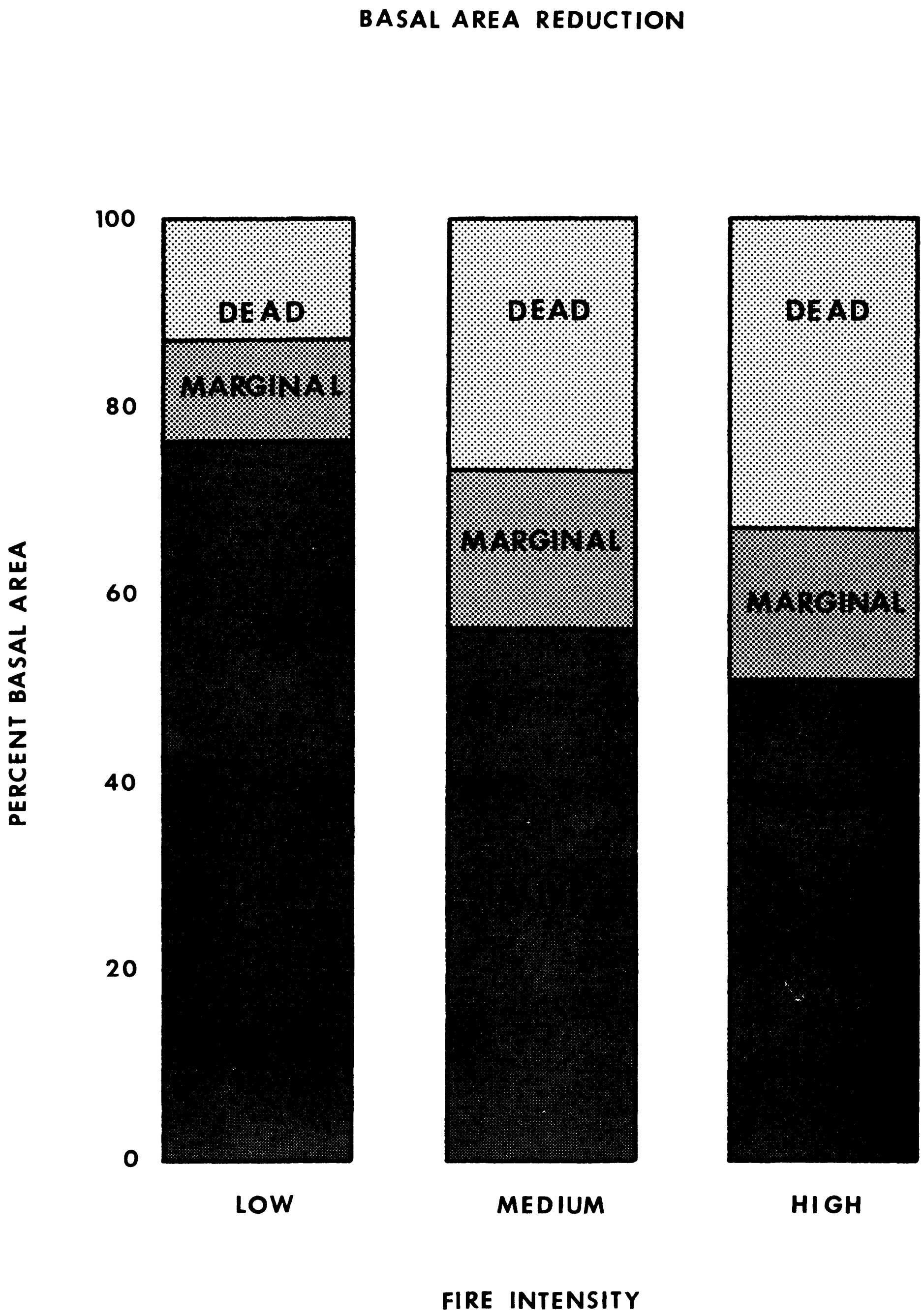
Fire Intensity	Percent Basal Area Reduced (Dead Only)	Percent Basal Area Reduced (Dead and Marginal)
Low	12.6	23.0
Medium	26.4	43.4
High	32.4	49.0

Figure 13 shows the distribution of basal area for each level of fire intensity. Alive, marginal and fire-killed categories are illustrated. The more intense the fire the greater the basal area reduction.

Percent release by fire intensity level is as follows:

Fire Intensity	Percent Release
Low	47.2
Medium	70.6
High	71.2

As fire intensity increases, a larger percentage of crop tree competition is killed or damaged.



BASAL AREA REDUCTION
100
80
60
40
20
0
PERCENT BASAL AREA
DEAD
MARGINAL
DEAD
MARGINAL
DEAD
MARGINAL
LOW
MEDIUM
HIGH
FIRE INTENSITY

Figure 13

Crop tree mortality for each fire intensity level is:

Fire Intensity	Crop Tree Mortality
Low	3.4 percent
Medium	14.6 percent
High	13.9 percent

DISCUSSION

Introduction

Three fire intensity levels were used, with the hope that the desired results would be bracketed. In other words, the high intensity fire would be too severe and would remove too much of the stand. The low intensity fires, in turn, would not remove enough of the stand. The medium fire intensity was assumed, beforehand, to be the correct fire intensity level to remove the proper amount of the stand.

If the fire was to reduce the basal area sufficiently and the mean diameter of the residual trees was greater than the mean diameter of the original stand, it would act as a selective thinning tool. Since these conditions did occur, the fires acted as a thinning agent. By using three fire intensity levels, a subjective analysis of the various factors (weather conditions, fuel conditions, and igniting method) was made so that the thinning prescription could be defined. It is important to determine the proper technique for using fire as a thinning tool in order to obtain the desired results consistently.

Procedure

The environmental factors that were measured to indicate what fire intensity level might be expected were verified by the behavior of the fires. Table I shows that the measured moisture content of twigs and new needles is approximated by the theoretical value. Moisture content of partly decomposed needles and humus is also directly related to the weather elements. The latter two categories of duff have a higher moisture content than the fine fuel because evaporation of moisture from these two layers is impeded by the layer of new needles and the layers are more compact, having less air space.

The percentage of available fuel consumed by the fires increased as the fuel moisture content decreased. The burnability of fuel decreases rapidly with a little increase in moisture since the fire has to raise the temperature of the water in the fuel to boiling temperature, vaporize the water and then raise the temperature of the water vapor to flame temperature before the fuel will burn. Therefore, consumption of fuels with lower moisture content will be greater than those with a higher moisture content.

When the plots were sampled for mortality during the spring of 1967, three classifications of fire damage were present. At first it was thought that only two classifications would exist: alive and dead. To fully assess the effects of the fire a third classification was added. Trees that were alive but had been extensively damaged, with slight hope of survival were classed as marginal. This classification allowed for a more comprehensive analysis of the results. Trees under the two classification scheme that were badly damaged but still showed signs of being alive would be tallied the same as a tree not damaged by fire. If the tree were to die from fire damage, the results would change. By using the three classification scheme the effect of the fire is more accurately shown.

Results

It appears feasible to thin young ponderosa pine stands in the location of Greenough, Montana, with prescribed fire. Basal area was reduced to approximately the desired level, the mean diameter of the residual stand is significantly larger than that of the stand before the fire, and a fair amount of crop tree competition was removed.

The more intense the fire the greater the basal area reduction. The high intensity fire level reduced the basal area between 32.4 and 49.0 percent. The medium intensity fire level reduced the basal area between 26.4 and 43.4 percent, while the low fire intensity level only reduced the basal area between 12.6 and 23.0 percent.

The differences between values of basal area reduction, crop tree release, diameter increase and crop tree mortality at the high and medium fire intensity levels are fairly small. This is because the actual fire intensity is a combination of two factors: natural conditions and firing technique. The fact that the strip heading fires at the medium fire intensity level approach the fire intensity of the backing fires at high intensity conditions is evident in all of the results. It is possible to produce a high intensity fire at medium intensity conditions by increasing the width of strip head fires. The intensity produced by a backing fire at high intensity conditions is fixed and can be increased only by changing to a strip head fire method. Therefore, it is possible to attain higher intensity fires using strip head fires under medium conditions, and still maintain control, than by using backing fires under high intensity conditions.

The most important factor in fire intensity at medium intensity level conditions is the method of manipulation, and not the weather or fuel conditions. To keep the fire at a desired intensity, close attention to control is necessary. In the past, fire has been used with too much caution, in terms of weather, accounting for poor results on the part of some researchers. Their usage of the word "control" in these cases meant to keep the fire intensity at a minimum level. The use of the same word in this study signifies that the proper fire intensity be maintain along with the ability to suppress the fire.

It is difficult to give a precise weather prescription resulting from this study. Only approximate ranges of weather conditions can be described. Certainly weather conditions must be more critical than those of previous guidelines. The conditions that were indicative of the weather during the medium intensity fires approximate the ranges. The range of these conditions are:

1. Wind -- less than 10 miles per hour; not variable or gusty.
2. Relative humidity -- 15 to 35 percent.
3. Temperature -- 60 to 85°F.

If the wind is too strong, changes direction or velocity, or comes in gusts, it is extremely difficult to control the thinning fire.

It is impossible to retract a portion of the flame front, if the wind changes direction or velocity. Therefore, wind is the most important weather element. Humidity and temperature are also important; but with fire manipulation it is possible to compensate for these two variables.

If weather conditions are at either extreme, such as those indicative of the high and low intensity fires, the fire cannot be controlled to attain the desired intensity. If the temperature is too low and the relative humidity too high, the resulting fire will be so "cool" that very few trees will be killed. A low intensity thinning fire not only reduces the stand insufficiently but removes enough of the fuel so that it is impossible to reburn the area when conditions are favorable. A thinning fire, too high in intensity, will reduce the stand more than desired as well as weaken the residual trees, leaving them prone to subsequent insect attack and disease.

Due to variable weather and fuel conditions encountered, it is difficult to define a strict technique or method of fire manipulation. It is possible, however, to relate fire intensity to flame height which can be used as a rough guide. Subjectively, the flame height for a desirable fire intensity should be equal to the distance from the ground to the bottom of the crown. In other words, the flames should just reach to the lower crown level of the stand. With the flames at this height the crowns of the smaller trees will be severely scorched while crowns of the taller trees will be only partially damaged.

Generally, the ignition technique required to achieve the desired flame height or intensity is a strip head fire method. The distance between the strips regulates the height of the flame. The greater the distance between strips the higher the flame since the heading fire front has a greater distance in which to build up intensity. If conditions are such that a backing fire produces flame heights that reach to or into the crowns, then it is impossible to reduce fire intensity. On the other hand, if conditions are such that a heading fire is needed to produce flame heights that reach to the crowns, it is then difficult to increase fire intensity as conditions change, such as a change in fuel quantity. It is extremely important that a thinning fire is not conducted under the extreme conditions mentioned, since control of the fire intensity is lost.

Fuel amount and type should also be considered in the thinning fire prescription. However, unless the fuel is very scarce or extremely heavy, it presents little difficulty since the manipulation of the fire intensity takes this into account. Fuel moisture is dictated solely by weather conditions and fuel size. Fuel conditions under a dense young ponderosa pine stand are generally such that abnormal sizes and concentrations of fuel do not occur.

SUMMARY AND CONCLUSIONS

Thinning with fire, in young ponderosa pine, was studied at three areas on the Lubrecht Experimental Forest. Eighteen plots were burned with prescribed fire during the summer of 1966. Three levels of fire intensity were used at each area with two replications of each level. The fire intensity level was determined by means of a fire danger rating system that gives a theoretical value for fine fuel moisture content. This value is a composite of the weather elements that affect the burnability of fuels.

Measured variables included fuel moisture content, amount of fuel consumed, a measure of fire intensity using water can analogs, the amount of damage to the stand and a relative amount of crop tree release. Stand tables were constructed before the fire, and again the following spring, to determine the effect of fire as a thinning agent. Basal area reduction, mean diameter increase and crop tree mortality were computed for each level of fire intensity.

Three classifications of fire damage resulted from the fires: dead, alive and marginal. Trees that had indications of being alive yet had been badly damaged by the fire, were classed as marginal. Measured moisture content, amount of fuel consumed and temperature increase of the water can analogs were proportional to fire intensity. Basal area reduction, percent crop tree release and mean diameter increase were also proportional to fire intensity.

At the high intensity fire level, basal area was reduced between 32.4 and 49.0 percent. The desired amount of basal area reduction was between 50 and 60 percent. Percent crop tree release at the high intensity level was 71.6 percent. By killing smaller trees the mean stand diameter was increased from 2.52 inches to between 3.47 and 3.91 inches at the high intensity level. The thinning fire was kept under control at all levels of fire intensity and manipulated at the medium level of fire intensity. Manipulation at the high level of fire intensity was not possible if control was to be maintained. At the low intensity level it was also impossible to manipulate the fire since it could not sustain itself. Success of the thinning fire depends on close supervision of the fire intensity through manipulation.

It is not possible to define a strict prescription of proper weather conditions under which to conduct the thinning fire. However, the conditions that describe the medium fire intensity level can be used as general limits for the western Montana area. At any rate, the thinning fire must be conducted under more severe conditions than in the past.

It is not possible to define a precise method of ignition to develop a given fire intensity. The greatest variety of fire intensities can be developed by manipulation of the fire front during conditions of medium fire intensity. The ignition technique that allows the most freedom in attaining the desired fire intensity is a strip head fire pattern. Changes in fuel concentration and fuel type will possibly necessitate variations of several techniques. A test fire is mandatory to determine if the weather and fuel moisture are correct for burning and to determine which burning technique should be used initially.

These conclusions were determined:

1. Thirty- to 50-year-old, overstocked ponderosa pine stands on the Lubrecht Experimental Forest can be thinned with prescribed fire.
2. Under the conditions studied prescribed thinning fires can be controlled and manipulated.
3. It is not possible from this study to define a precise prescription for weather and fuel conditions or a precise ignition pattern, only general recommendations can be made.
4. The most important factor in the success of the thinning fire is the manipulation of the fire front.
5. The thinning fire is best manipulated by using a strip head fire technique.

The following recommendations, as determined from the tested conditions, are given as a guide to the thinning fire prescription:

1. Weather conditions should generally be within these limits:
    a. Wind -- less than 10 miles per hour; not variable or gusty.
    b. Relative humidity -- 15 to 35 percent.
    c. Temperature -- 60 to 85°F.
2. Fine fuel moisture content should average between 6 and 10 percent.

3. Flame height should be used as a guide to fire intensity.
4. A test fire is mandatory.
5. The thinning fire should generally be a strip heading fire, with the flames reaching to the lower level of the crowns.
6. When a backing fire must be used to control the fire, conditions are too severe and burning should not be attempted. Also, if a heading fire is required to attain the desired, intensity, conditions are too mild for proper manipulation.

The following recommendations are made for the continuation of this study:

1. New stand tables should be constructed during the fall of 1967, 1968 and 1969. Release values should also be re-determined.
2. An evaluation of insect effect should be made.
3. Determine and compare future growth rates with past rates.
4. Determine the validity of the marginal classification of mortality.
5. Examine the impact of the thinning fire on the ecosystem.
6. Time of year in which the fire occurs should be evaluated for:
   a. Fire resistance in the tree.
   b. Effect of insects.

The author hopes to continue this study. Approximately one to two weeks of field work will be required each fall.

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APPENDIX

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MATHEMATICAL FORMULAE

1. **Bulk Density Determination**

$$\frac{\text{Sample layer thickness in cm.}}{\text{Oven-dry weight of sample}} = \frac{1.0 \text{ cm.}}{x \text{ gm.}}$$

2. **Basic Formulae for Line Intersect Method of Fuel Sampling**

$$\text{Volume} = \frac{\pi^2 \sum d^2}{8L}$$

$$\text{Weight} = \frac{\pi^2 S \sum d^2}{8L}$$

Where: L = length of sample line (cm.)

d = piece diameter (cm.)

S = specific gravity of the wood (pine = .40)

3. **Determination of Fuel Moisture Content**

$$\text{Percent moisture content} = \frac{\text{field weight - oven-dry weight}}{\text{oven-dry weight}} \times 100$$

WEATHER DATA SUMMARY

Fire Intensity	Plot	Date	Time	R.H.	Temp.	Days Since Last Ppt.
Low	A-I	9-2	3:05	20	76	2
	A-II	9-2	2:15	22	72	2
	B-III	9-15	2:10	37	58	3
	B-V	9-15	2:45	40	57	3
	C-I	9-15	3:45	44	56	3
	C-IV	9-15	4:10	46	56	3
Medium	A-IV	9-23	2:25	22	82	3
	A-VI	9-23	3:10	20	82	3
	B-I	9-24	1:55	29	71	4
	B-IV	9-24	2:50	30	70	4
	C-III	9-24	3:55	30	68	4
	C-V	9-24	4:35	30	68	4
High	A-III	9-9	2:40	12	86	9
	A-V	9-9	2:50	11	86	9
	B-II	9-6	2:25	9	92	6
	B-VI	9-6	2:50	9	92	6
	C-II	9-6	4:30	16	87	6
	C-VI	9-6	4:20	16	86	6

FINE FUEL MOISTURE CONTENT
FROM FIRE DANGER RATING TABLES6/

Fire Intensity	Plot	Moisture Content Percent	
Low	A-I	11	
	A-II	11	
	B-III	11	
	B-V	11	
	C-I	11	
	C-IV	11	
Medium	A-IV	8	
	A-VI	8	
	B-I	8	
	B-IV	8	
	C-III	8	
	C-V	8	
High	A-III	6	0.10 inch rain after fire
	A-V	6	0.10 inch rain after fire
	B-II	6	
	B-VI	6	
	C-II	6	
	C-VI	6	

6/ Forest fire danger tables, Canada (17).

FUEL MOISTURE CONTENT

Fire Intensity	Plot	Twigs	New Needles	Partly Decomposed Needles	Humus
Low	A-I	10.5	8.9	12.3	56.0
	A-II	8.4	10.0	71.4	43.3
	B-III	10.9	21.0	11.0	13.1
	B-V	9.8	9.2	24.0	8.1
	C-I	15.1	11.2	41.2	17.1
	C-IV	10.0	12.0	50.1	31.4
Average		10.8%	12.1%	35.0%	28.7%
Medium	A-IV	9.0	9.3	30.3	19.2
	A-VI	9.5	11.1	38.4	12.8
	B-IV	10.7	9.7	11.6	25.0
	C-III	9.9	9.6	15.5	42.7
	C-V	9.1	10.4	17.1	44.2
Average		9.6%	10.0%	22.6%	28.6%
High	A-III	6.9	7.9	21.3	17.2
	A-V	7.4	7.1	21.9	12.1
	B-II	7.4	6.6	12.4	17.9
	B-VI	6.3	5.2	6.3	22.3
	C-II	8.3	7.5	10.9	11.3
	C-VI	6.9	6.4	10.0	20.3
Average		7.2%	6.8%	13.8%	16.9%

FUEL REDUCTION

Fire Intensity	Plot	Total Fuel Before Fire gm/m^2	Total Fuel Consumed gm/m^2	Percent Consumed
Low	A-I	7685.7	2243.5	29.1
	A-II	7639.1	1895.7	24.8
	B-III	12921.0	9680.5	74.9
	B-V	5791.1	2865.4	49.4
	C-I	5449.2	1181.0	21.6
	C-IV	4971.6	1389.1	27.9
			Average	38.0
Medium	A-IV	3989.8	615.1	15.4
	A-VI	5861.7	2446.1	41.7
	B-I	5855.3	1749.4	29.8
	B-IV	8739.3	5385.3	61.6
	C-III	9573.2	4518.3	47.1
	C-V	6213.4	2672.7	43.0
			Average	40.0
High	A-III	4064.8	974.8	23.9
	A-V	5670.1	1919.9	33.8
	B-II	5971.1	3678.0	61.5
	B-VI	6146.8	3693.6	60.0
	C-II	4652.2	2475.8	53.2
	C-VI	5537.2	1816.7	32.8
			Average	44.2

SUMMARY OF ANALOG DATA TEMPERATURE AND WEIGHT

Fire Intensity	Plot	Average Temperature Gain °C	Average Weight Loss Grams
Low	A-I	14	--
	A-II	10	--
	B-III	23	-35.0
	B-V	17	-314.0
	C-I	--	-49.3
	C-IV	17	-13.7
Average		16.2	-103.0
Medium	A-IV	28	-26.0
	A-VI	31	-30.0
	B-I	18	-31.0
	B-IV	47	-29.0
	C-III	17	-43.3
	C-V	36	-27.3
Average		29.5	-31.1
High	A-III	38	-39.5
	A-V	23	-31.7
	B-II	39	-41.0
	B-VI	57	-216.0
	C-II	--	-1051.0
	C-VI	--	-5.0
Average		39.2	-230.7

FIRE CLASSIFICATION

Fire Intensity	Plot	Type
Low	A-I	Backing
	A-II	Strip head
	B-III	Strip head
	B-V	Strip head
	C-I	Strip head
	C-IV	Strip head
Medium	A-IV	Strip head
	A-VI	Strip head
	B-I	Strip head
	B-IV	Strip head
	C-III	Strip head
	C-V	Strip head
High	A-III	Backing
	A-V	Backing
	B-II	Backing
	B-VI	Backing
	C-II	Backing
	C-VI	Backing

BASAL AREA REDUCTION

Fire Intensity	Plot	Basal Area Before Fire ft^2/acre	Basal Area Alive and Marginal Trees ft^2/acre	Basal Area Alive Trees ft^2/acre
Low	A-I	196.81	192.59	183.46
	A-II	171.19	147.05	123.61
	B-III	168.99	122.39	95.00
	B-V	215.03	152.50	108.75
	C-I	208.36	205.91	204.55
	C-IV	231.21	220.50	202.65
	Total	1191.59	1040.94	918.02
Percent Reduced		--	12.6	23.0
Medium	A-IV	135.46	93.22	64.06
	A-VI	206.19	180.99	157.41
	B-I	230.31	145.84	111.49
	B-IV	199.43	89.54	30.12
	C-III	210.23	195.83	178.13
	C-V	221.25	179.63	139.83
	Total	1202.87	885.05	681.04
Percent Reduced		--	26.4	43.4
High	A-III	193.65	165.74	116.26
	A-V	206.75	171.73	149.37
	B-II	234.25	103.31	87.09
	B-VI	259.72	129.33	67.73
	C-II	207.90	153.36	123.46
	C-VI	192.25	151.67	116.52
	Total	1294.52	875.14	660.43
Percent Reduced		--	32.4	49.0

PERCENT RELEASE BY PLOTS AND
BY FIRE INTENSITY

Fire Intensity	Plot		Percent Release
Low	A-I		35.7
	A-II		44.2
	B-III		92.5
	B-V		57.4
	C-I		8.6
	C-IV		44.6
		Average	47.2
Medium	A-IV		54.2
	A-VI		67.7
	B-I		71.7
	B-IV		87.4
	C-III		62.3
	C-V		80.0
		Average	70.6
High	A-III		70.0
	A-V		53.4
	B-II		70.4
	B-VI		83.8
	C-II		83.4
	C-VI		65.9
		Average	71.2

A-I STAND TABLE

DBH	Before Fire PP	Before Fire D-f	After Fire PP Alive	After Fire PP Marginal	After Fire D-f Alive	After Fire D-f Marginal
1	11					
2	22		7	10		
3	31		28	3		
4	14		14			
5	10		10			
6	3		3			
7	3		3			
8	4		4			
9	1		1			

	Before Fire	After Fire Alive & Marginal	After Fire Alive Only
Total Trees	99	83	70
Stems/Acre	2475	2075	1750

A-II STAND TABLE

DBH	Before Fire PP	Before Fire D-f	After Fire PP Alive	After Fire PP Marginal	After Fire D-f Alive	After Fire D-f Marginal
1	17		2	4		
2	67		38	18		
3	31	4	14	4	3	1
4	13		11	2		
5	4	2	4		2	
6		2			2	
7	1	1		1	1	
8	1	1	1		1	

	Before Fire	After Fire Alive & Marginal	After Fire Alive Only
Total Trees	144	109	80
Stems/Acre	3600	2723	2000

A-III STAND TABLE

DBH	Before Fire PP	Before Fire D-f	After Fire PP Alive	After Fire PP Marginal	After Fire D-f Alive	After Fire D-f Marginal
1	25		2			
2	67		7	21		
3	36	1	24	10		
4	10	2	9	1		1
5	7	1	7		1	1
6	1		1			
7	1	1	1		1	
10		1			1	
13		1			1	

	Before Fire	After Fire Alive & Marginal	After Fire Alive Only
Total Trees	154	90	55
Stems/Acre	3850	2250	1375

A-IV STAND TABLE

	Before Fire		After Fire			
	PP	D-f	PP		D-f	
DBH			Alive	Marginal	Alive	Marginal
1	11	1		2		1
2	44	3	17	5	2	
3	27	1	15	4		1
4	17	3	7	5		1
5	5	1	3	2		
6	1	1	1		1	

	Before Fire	After Fire Alive & Marginal	After Fire Alive Only
Total Trees	115	67	46
Stems/Acre	2875	1676	1150

A-V STAND TABLE

DBH	Before Fire PP	Before Fire D-f	After Fire PP Alive	After Fire PP Marginal	After Fire D-f Alive	After Fire D-f Marginal
1	5			1		
2	40		12	5		
3	38	1	22	7	1	
4	23	2	14	5	1	
5	8	1	8		1	
6	3	2	3		1	
7	4		4			

	Before Fire	After Fire Alive & Marginal	After Fire Alive Only
Total Trees	127	86	68
Stems/Acre	3175	2150	1700

A-VI STAND TABLE

DBH	Before Fire PP	Before Fire D-f	After Fire PP Alive	After Fire PP Marginal	After Fire D-f Alive	After Fire D-f Marginal
1	8					
2	34	1	3	6		1
3	23		10	7		
4	14	2	11	3		1
5	7		6	1		
6	3		3			
7	2		2			
8	1	3	1		3	
11		1			1	
13		1			1	

	Before Fire	After Fire Alive & Marginal	After Fire Alive Only
Total Trees	100	60	41
Stems/Acre	2500	1500	1025

B-I STAND TABLE

	Before Fire		After Fire			
	PP	D-f	PP		D-f	
DBH			Alive	Marginal	Alive	Marginal
1	35					
2	84		7	12		
3	56		17	10		
4	23		15	4		
5	15		13	2		
6	1	1			1	

	Before Fire	After Fire Alive & Marginal	After Fire Alive Only
Total Trees	215	82	54
Stems/Acres	5375	2050	1350

B-II STAND TABLE

DBH	Before Fire: PP	Before Fire: D-f	After Fire: PP Alive	After Fire: PP Marginal	After Fire: D-f Alive	After Fire: D-f Marginal
1	136			2		
2	76		8	18		
3	42		17	5		
4	24	1	10			
5	10		6			
6	7		4			

	Before Fire	After Fire Alive & Marginal	After Fire Alive Only
Total Trees	296	70	45
Stems/Acre	7400	1750	1125

B-III STAND TABLE

DBH	Before Fire PP	Before Fire D-f	After Fire PP Alive	After Fire PP Marginal	After Fire D-f Alive	After Fire D-f Marginal
1	214	1				
2	37			11		
3	11		6	5		
4	6		3	3		
5	2		1			
6	1		1			
7		1			1	
8	1	1		1	1	
14	1		1			
15	1		1			

	Before Fire	After Fire Alive & Marginal	After Fire Alive Only
Total Trees	277	35	15
Stems/Acre	6925	875	375

B-IV STAND TABLE

DBH	Before Fire PP	Before Fire D-f	After Fire PP Alive	After Fire PP Marginal	After Fire D-f Alive	After Fire D-f Marginal
1	88	1	1			
2	82	1	2	4		
3	44		1	11		
4	19		2	14		
5	6		2	1		
6	1	1	1		1	
11	1		1			

	Before Fire	After Fire Alive & Marginal	After Fire Alive Only
Total Trees	244	41	11
Stems/Acre	6100	1025	275

B-V STAND TABLE

	Before Fire		After Fire			
	PP	D-f	PP		D-f	
DBH			Alive	Marginal	Alive	Marginal
1	27	1				
2	48	1	10	7		
3	35		12	4		
4	22		10	5		
5	10		5	5		
6	9		7	1		
7	1		1			
8	1		1			

	Before Fire	After Fire Alive & Marginal	After Fire Alive Only
Total Trees	155	69	46
Stems/Acre	3875	1725	1150

B-VI STAND TABLE

DBH	Before Fire PP	Before Fire D-f	After Fire PP Alive	After Fire PP Marginal	After Fire D-f Alive	After Fire D-f Marginal
1	46					
2	80	1		9		1
3	56		5	9		
4	25	1	7	6		
5	6		3	2		
6	8		6	2		
7	2		1	1		
8	1			1		

	Before Fire	After Fire Alive & Marginal	After Fire Alive Only
Total Trees	227	83	22
Stems/Acre	5675	1300	550

C-I STAND TABLE

	Before Fire		After Fire			
	PP	D-f	PP		D-f	
DBH			Alive	Marginal	Alive	Marginal
1	15	2	13	2		
2	43	10	39	2	8	
3	32	2	32		2	
4	21	5	21		5	
5	3	2	3		2	
6		4			4	
7	1	4	1		4	
8	1		1			

	Before Fire	After Fire Alive & Marginal	After Fire Alive Only
Total Trees	145	139	133
Stems/Acre	3625	3475	3375

C-II STAND TABLE

DBH	Before Fire PP	Before Fire D-f	After Fire PP Alive	After Fire PP Marginal	After Fire D-f Alive	After Fire D-f Marginal
1	54			6		
2	48		1	6		
3	25	1	6	10		1
4	24		17	5		
5	9		7	2		
6	9		8			
7	1		1			
8	1		1			

	Before Fire	After Fire Alive & Marginal	After Fire Alive Only
Total Trees	172	71	41
Stems/Acre	4300	1775	1025

C-III STAND TABLE

DBH	Before Fire PP	Before Fire D-f	After Fire PP Alive	After Fire PP Marginal	After Fire D-f Alive	After Fire D-f Marginal
1	52		1	13		
2	42		13	13		
3	24	3	20	4	1	1
4	11		11			
5	10	1	9	1	1	
6	7	1	7		1	
7	3		3			
8	2		2			
9	1		1			

	Before Fire	After Fire Alive & Marginal	After Fire Alive Only
Total Trees	157	102	70
Stems/Acre	3925	2525	1750

C-IV STAND TABLE

	Before Fire		After Fire			
	PP	D-f	PP		D-f	
DBH			Alive	Marginal	Alive	Marginal
1	10	1	1	5		1
2	32		13	9		
3	22	1	13	7		1
4	18	1	15	1		1
5	11		11			
6	7		7			
7	4		4			
8	3		3			
9	2		2			

	Before Fire	After Fire Alive & Marginal	After Fire Alive Only
Total Trees	112	94	89
Stems/Acre	2800	2350	1725

C-V STAND TABLE

	Before Fire		After Fire			
	PP	D-f	PP		D-f	
DBH			Alive	Marginal	Alive	Marginal
1	60	1		3		
2	78		3	13		
3	39		23	16		
4	25		23	2		
5	6		5	1		
6	7		6			
7	2		2			

	Before Fire	After Fire Alive & Marginal	After Fire Alive Only
Total Trees	218	98	62
Stems/Acre	5450	2450	1550

C-VI STAND TABLE

	Before Fire		After Fire			
	PP	D-f	PP		D-f	
DBH			Alive	Marginal	Alive	Marginal
1	36		2	10		
2	47		9	5		
3	22		13	4		
4	12	1	10	2		
5	12		8	3		
6	6		4	1		
7	6		4	1		

	Before Fire	After Fire Alive & Marginal	After Fire Alive Only
Total Trees	142	76	50
Stems/Acre	3550	1900	1250

CROP TREES

A-I May 1967

Number	Diameter	Height	Condition Class	Release Factor 7/	Percent Release
1-1	4.9	36	Alive	4	0
1-2	4.2	28	Alive	3	25
1-3	4.4	27	Alive	2+1m	37
1-4	4.4	37	Alive	3	25
1-5	5.1	36	Alive	3	25
1-6	6.0	40	Alive	2	50
1-7	5.2	36	Alive	1+1m	62
1-8	8.5	53	Alive	4	0
1-9	7.1	40	Alive	2+2m	25
1-10	9.5	46	Alive	2+2m	25
1-11	4.5	37	Alive	1+1m	62
1-12	5.4	36	Alive	1+3m	38
1-13	7.1	41	Alive	3+1m	12
1-14	8.0	43	Alive	3+1m	12
1-15	4.7	37	Alive	1+1m	62
1-16	5.6	35	Alive	1+2m	50
1-17	6.9	42	Alive	2	50
1-18	6.5	39	Alive	2m	75
1-19	5.5	37	Alive	1+2m	62
1-20	3.9	35	Alive	3	25
1-21	5.2	34	Alive	1+1m	62
1-22	4.5	32	Alive	2+2m	25
1-23	5.1	33	Alive	2+1m	37
1-24	3.5	27	Alive	3+1m	12

7/ Left digit represents number of four nearest competing trees that are alive; the second digit, marginal trees. Dead trees not represented.

CROP TREES

A-II

May 1967

Number	Diameter	Height	Condition Class	Release Factor[7]	Percent Release
2-1	4.1	28	Alive	4	0
2-2	7.7	38	Alive	4	0
2-3	4.1	23	Alive	4	0
2-4	3.8	26	Alive	2+1m	37
2-5	3.6	23	Alive	1+1m	62
2-6	3.6	25	Alive	1+1m	62
2-7	5.5	30	Alive	1m	87
2-8	4.1	23	Alive	4m	50
2-9	4.7	26	Alive	4m	50
2-10	2.8	23	Alive	4m	50
2-11	3.1	24	Alive	4m	50
2-12	5.3	32	Alive	0	100
2-13	3.6	26	Alive	2	50
2-14	4.0	25	Dead	--	--
2-15	4.0	30	Marginal	0	100
2-16	6.8	38	Marginal	0	100
2-17	3.5	26	Dead	--	--
2-18	3.0	24	Alive	1+2m	50
2-19	3.1	23	Alive	2+1m	37
2-20	3.0	22	Alive	4	0
2-21	3.1	25	Alive	4	0
2-22	4.6	24	Alive	4	0

CROP TREES

A-III

May 1967

Number	Diameter	Height	Condition Class	Release Factor[1]	Percent Release
3-1	4.3	25	Alive	1+1m	62
3-2	4.2	25	Alive	2+1m	37
3-3	3.4	25	Alive	1+2m	50
3-4	4.8	27	Alive	1	75
3-5	5.6	28	Alive	2	50
3-6	3.3	20	Alive	2+1m	37
3-7	5.4	29	Alive	1	75
3-8	4.7	29	Alive	3m	63
3-9	4.2	21	Alive	1m	87
3-10	5.0	27	Alive	1+1m	62
3-11	3.9	22	Alive	2m	75
3-12	3.9	24	Alive	1m	87
3-13	4.3	24	Alive	2m	75
3-14	4.6	29	Alive	2m	75
3-15	3.3	24	Dead	--	--
3-16	3.5	23	Alive	1m	87
3-17	4.1	25	Alive	1+1m	62
3-18	3.3	25	Alive	1m	87
3-19	3.4	23	Alive	2m	75
3-20	5.1	25	Alive	1m	87
3-21	5.2	31	Alive	0	100
3-22	4.1	26	Alive	1m	87
3-23	2.8	24	Marginal	0	100
3-24	3.3	25	Marginal	0	100
3-25	4.0	26	Marginal	2	50
3-26	6.9	36	Alive	2+2m	25
3-27	3.5	22	Alive	1+2m	50

CROP TREES

A-IV May 1967

Number	Diameter	Height	Condition Class	Release Factor[7]	Percent Release
4-1	4.3	30	Alive	3	25
4-2	4.5	29	Alive	3+1m	12
4-3	4.6	30	Marginal	1+2m	50
4-4	4.8	25	Dead	--	--
4-5	4.6	31	Alive	1+2m	50
4-6	3.4	17	Dead	--	--
4-7	3.7	26	Alive	0	100
4-8	3.5	26	Dead	--	--
4-9	3.8	26	Marginal	1	75
4-10	3.5	22	Alive	2+1m	37
4-11	5.5	32	Alive	2	50
4-12	3.6	23	Alive	3+1m	12
4-13	4.0	25	Alive	1+1m	62
4-14	3.6	27	Alive	1+1m	62
4-15	4.3	26	Marginal	0	100
4-16	4.4	26	Dead	--	--
4-17	3.6	26	Dead	--	--
4-18	3.9	27	Marginal	1	75
4-19	4.0	27	Marginal	0	100
4-20	5.9	36	Alive	1+1m	62
4-21	4.2	23	Alive	4	0
4-22	4.9	29	Alive	2	50

CROP TREES

A-V May 1967

Number	Diameter	Height	Condition Class	Release Factor[1]	Percent Release
5-1	4.1	28	Alive	2+1m	37
5-2	2.1	27	Alive	3	25
5-3	3.9	28	Alive	4	0
5-4	3.5	27	Alive	3	25
5-5	3.9	29	Dead	--	--
5-6	3.6	25	Alive	2+1m	12
5-7	4.3	30	Alive	2+1m	12
5-8	4.2	26	Alive	1m	87
5-9	5.7	36	Alive	1	75
5-10	6.6	34	Alive	2	50
5-11	6.6	33	Alive	2	50
5-12	7.4	49	Alive	1	75
5-13	4.5	33	Dead	--	--
5-14	5.0	30	Alive	2	50
5-15	6.4	41	Alive	1m	87
5-16	3.0	35	Marginal	2m	75
5-17	4.8	31	Alive	0	100
5-18	6.2	35	Alive	1m	87
5-19	3.8	35	Alive	2m	75
5-20	5.2	38	Alive	1	75
5-21	7.2	34	Alive	1	75
5-22	5.4	35	Alive	1+1m	62
5-23	4.9	35	Alive	1+1m	62
5-24	4.7	34	Alive	2+1m	37
5-25	4.7	33	Alive	3	25
5-26	4.1	24	Alive	3	25

CROP TREES

A-VI

May 1967

Number	Diameter	Height	Condition Class	Release Factor[7]	Percent Release
6-1	5.2	36	Alive	3m	63
6-2	3.9	29	Alive	1	75
6-3	7.6	44	Alive	2m	75
6-4	4.5	31	Alive	1	75
6-5	5.2	33	Marginal	0	100
6-6	4.7	32	Alive	2+1m	37
6-7	3.9	32	Alive	2	50
6-8	3.6	31	Marginal	1m	87
6-9	3.5	31	Marginal	1m	87
6-10	6.0	41	Alive	1	75
6-11	3.7	33	Alive	1	75
6-12	5.6	37	Alive	1+1m	62
6-13	6.0	44	Alive	1m	87
6-14	7.0	40	Alive	1	75
6-15	5.2	37	Alive	1m	87
6-16	4.7	33	Alive	1	75
6-17	4.2	34	Alive	2	50
6-18	5.3	37	Alive	3	25
6-19	4.4	33	Marginal	1	75
6-20	5.0	36	Alive	4	0
6-21	3.7	26	Alive	1m	87

CROP TREES

B-I May 1967

Number	Diameter	Height	Condition Class	Release Factor[7]	Percent Release
1-1	5.4	38	Alive	1m	87
1-2	4.7	37	Alive	2m	75
1-3	4.8	41	Alive	1+1m	62
1-4	4.2	36	Alive	2	50
1-5	4.4	34	Alive	0	100
1-6	4.9	36	Alive	2+2m	25
1-7	3.8	34	Alive	0	100
1-8	4.8	33	Alive	0	100
1-9	3.7	35	Alive	1	75
1-10	4.7	39	Alive	1+1m	62
1-11	5.0	38	Alive	2	50
1-12	4.8	38	Alive	1m	87
1-13	5.5	41	Marginal	0	100
1-14	5.2	41	Dead	--	--
1-15	4.7	37	Dead	--	--
1-16	5.4	39	Marginal	0	100
1-17	3.4	34	Dead	--	--
1-18	3.3	34	Dead	--	--
1-19	3.7	35	Dead	--	--
1-20	4.0	34	Dead	--	--
1-21	6.1	44	Alive	0	100
1-22	4.1	34	Alive	3m	63
1-23	4.9	37	Alive	3+1m	12
1-24	4.2	38	Alive	1+1m	62
1-25	4.9	34	Alive	2+1m	37
1-26	4.9	37	Alive	1m	87

CROP TREES

B-II

May 1967

Number	Diameter	Height	Condition Class	Release Factor[1/]	Percent Release
2-1	4.7	36	Alive	2	50
2-2	3.3	27	Alive	0	100
2-3	4.0	31	Alive	1	75
2-4	4.4	34	Alive	1	75
2-5	3.8	30	Alive	0	100
2-6	3.4	30	Dead	--	--
2-7	6.1	41	Dead	--	--
2-8	5.6	40	Dead	--	--
2-9	4.1	38	Dead	--	--
2-10	6.0	44	Dead	--	--
2-11	4.3	41	Dead	--	--
2-12	4.4	36	Dead	--	--
2-13	5.0	39	Dead	--	--
2-14	4.6	37	Dead	--	--
2-15	4.2	34	Dead	--	--
2-16	4.7	37	Alive	0	100
2-17	5.9	45	Alive	0	100
2-18	4.0	31	Alive	1	75
2-19	4.8	31	Alive	2+1m	37
2-20	4.5	38	Alive	1m	87
2-21	5.0	37	Alive	3+1m	12
2-22	6.5	43	Alive	1m	87
2-23	4.6	38	Alive	1+1m	62
2-24	5.6	40	Alive	2	50
2-25	2.8	27	Dead	--	--
2-26	5.9	40	Dead	--	--
2-27	3.9	30	Alive	1	75
2-28	5.1	40	Alive	1	75
2-29	5.1	33	Alive	2+1m	37

CROP TREES

B-III

May 1967

Number	Diameter	Height	Condition Class	Release Factor[1]	Percent Release
3-1	5.6	40	Alive	0	100
3-2	14.8	75	Alive	0	100
3-3	3.1	23	Alive	0	100
3-4	4.0	28	Alive	0	100
3-5	4.4	31	Alive	2	50
3-6	4.8	32	Alive	1m	87
3-7	3.5	25	Alive	1m	87
3-8	3.7	27	Dead	--	--
3-9	3.7	25	Marginal	0	100
3-10	4.0	25	Marginal	1m	87
3-11	4.1	26	Marginal	0	100
3-12	7.7	42	Marginal	0	100
3-13	14.5	69	Alive	0	100

CROP TREES

B-IV

May 1967

Number	Diameter	Height	Condition Class	Release Factor[7]	Percent Release
4-1	4.0	31	Marginal	0	100
4-2	5.0	33	Alive	2+1m	37
4-3	3.9	30	Marginal	1m	87
4-4	5.4	35	Alive	3m	63
4-5	4.6	35	Marginal	0	100
4-6	4.5	37	Marginal	0	100
4-7	4.5	34	Marginal	2m	75
4-8	3.8	32	Marginal	0	100
4-9	4.2	30	Marginal	0	100
4-10	3.2	30	Dead	--	--
4-11	5.5	42	Dead	--	--
4-12	2.8	29	Dead	--	--
4-13	3.3	30	Dead	--	--
4-14	3.3	18	Dead	--	--
4-15	2.9	33	Dead	--	--
4-16	3.6	30	Dead	--	--
4-17	4.1	34	Dead	--	--
4-18	4.0	29	Dead	--	--
4-19	5.0	38	Dead	--	--
4-20	5.6	40	Alive	1m	87
4-21	4.3	34	Marginal	2m	75
4-22	3.6	31	Marginal	0	100
4-23	11.0	44	Alive	0	100
4-24	4.5	29	Marginal	0	100

CROP TREES

B-V

May 1967

Number	Diameter	Height	Condition Class	Release[1]/ Factor	Percent Release
5-1	4.2	31	Alive	3m	63
5-2	5.0	44	Alive	2+2m	25
5-3	6.7	44	Alive	1+3m	38
5-4	4.5	39	Alive	2+2m	25
5-5	5.6	40	Alive	3	25
5-6	4.5	38	Alive	2	50
5-7	4.9	40	Marginal	1m	87
5-8	5.2	39	Alive	4	0
5-9	4.4	36	Alive	4	0
5-10	6.5	42	Alive	1m	87
5-11	4.3	36	Marginal	2	50
5-12	3.9	37	Alive	2	50
5-13	6.4	41	Alive	3	25
5-14	6.2	43	Alive	1m	87
5-15	5.3	39	Marginal	2m	75
5-16	6.2	46	Alive	1	75
5-17	5.9	46	Alive	2	50
5-18	4.4	41	Marginal	1m	87
5-19	5.9	47	Alive	0	100
5-20	4.7	40	Marginal	1m	87
5-21	8.3	45	Alive	0	100
5-22	6.5	39	Marginal	0	100
5-23	5.8	42	Dead	--	--
5-24	5.5	42	Marginal	1	75
5-25	4.9	37	Alive	2+1m	37
5-26	5.0	36	Alive	2+1m	37

CROP TREES

B-VI May 1967

Number	Diameter	Height	Condition Class	Release Factor[1]	Percent Release
6-1	5.3	40	Marginal	1m	87
6-2	8.0	55	Marginal	2m	75
6-3	5.8	42	Alive	2m	75
6-4	4.5	38	Alive	1m	87
6-5	4.3	33	Alive	1	75
6-6	4.4	35	Marginal	2m	75
6-7	3.1	33	Marginal	0	100
6-8	4.1	31	Alive	1m	87
6-9	4.0	27	Alive	1+1m	62
6-10	4.0	32	Marginal	0	100
6-11	5.7	42	Alive	1	75
6-12	6.8	49	Marginal	0	100
6-13	5.7	48	Alive	1	75
6-14	5.0	30	Dead	--	--
6-15	3.6	37	Dead	--	--
6-16	6.3	45	Marginal	0	100
6-17	3.8	35	Dead	--	--
6-18	4.1	37	Dead	--	--
6-19	6.2	42	Marginal	0	100
6-20	6.5	45	Alive	1m	87
6-21	4.7	41	Marginal	0	100
6-22	5.6	44	Alive	1	75
6-23	6.6	44	Alive	1	75
6-24	6.3	43	Alive	1	75
6-25	4.9	42	Alive	1	75

CROP TREES

C-I

May 1967

Number	Diameter	Height	Condition Class	Release Factor 7/	Percent Release
1-1	3.5	27	Alive	4	0
1-2	5.3	31	Alive	4	0
1-3	3.6	26	Alive	4	0
1-4	3.8	23	Alive	4	0
1-5	3.9	29	Alive	3+1m	12
1-6	4.2	28	Alive	4	0
1-7	3.7	27	Alive	4	0
1-8	5.0	29	Alive	4	0
1-9	7.8	39	Alive	4	0
1-10	4.0	29	Alive	4	0
1-11	4.3	30	Alive	4	0
1-12	3.8	29	Alive	3	25
1-13	4.4	30	Alive	4	0
1-14	4.5	30	Alive	4	0
1-15	4.4	30	Alive	3+1m	12
1-16	3.4	28	Alive	4	0
1-17	4.0	32	Alive	3	25
1-18	3.4	23	Alive	3	25
1-19	4.1	35	Alive	3	25
1-20	4.8	28	Alive	3	25
1-21	4.5	28	Alive	3	25
1-22	4.5	28	Alive	4	0
1-23	6.7	31	Alive	3	25

CROP TREES

C-II

May 1967

Number	Diameter	Height	Condition Class	Release Factor[1]	Percent Release
2-1	5.7	35	Alive	0	100
2-2	4.0	32	Marginal	0	100
2-3	4.3	31	Alive	0	100
2-4	4.2	33	Alive	0	100
2-5	4.6	32	Alive	0	100
2-6	3.7	30	Alive	0	100
2-7	4.1	31	Alive	1	75
2-8	4.1	33	Alive	0	100
2-9	6.3	33	Alive	1m	87
2-10	5.4	36	Alive	1m	87
2-11	6.2	37	Alive	1m	87
2-12	5.6	37	Alive	1m	87
2-13	5.6	41	Alive	2m	75
2-14	5.9	38	Alive	1	75
2-15	5.4	36	Alive	2+1m	37
2-16	8.2	44	Alive	1+1m	62
2-17	4.9	34	Alive	1+1m	62
2-18	5.8	39	Alive	2+2m	25
2-19	6.0	40	Alive	0	100
2-20	6.6	38	Alive	0	100
2-21	5.1	36	Alive	1+1m	62
2-22	4.6	32	Alive	1m	87
2-23	5.2	26	Dead	--	--
2-24	3.6	30	Marginal	0	100
2-25	4.3	30	Alive	2m	75
2-26	5.4	35	Marginal	1m	87
2-27	6.5	37	Alive	0	100

CROP TREES

C-III

May 1967

Number	Diameter	Height	Condition Class	Release Factor[7]	Percent Release
3-1	4.0	27	Alive	1	75
3-2	7.0	41	Alive	1+1m	62
3-3	6.1	45	Alive	2	50
3-4	5.8	45	Alive	1+1m	62
3-5	4.6	36	Alive	3m	63
3-6	9.4	51	Alive	4	0
3-7	7.6	42	Alive	0	100
3-8	6.0	42	Alive	2	50
3-9	5.0	32	Alive	2+1m	37
3-10	8.2	50	Alive	1m	87
3-11	7.0	47	Alive	1	75
3-12	5.0	39	Alive	2	50
3-13	7.1	41	Alive	1+2m	50
3-14	3.7	29	Alive	0	100
3-15	5.1	34	Alive	1m	87
3-16	5.8	31	Alive	1m	87
3-17	4.4	31	Alive	3	25
3-18	4.0	30	Alive	1m	87
3-19	5.5	36	Alive	2+1m	37
3-20	4.9	36	Alive	1	50
3-21	4.7	31	Alive	1	75
3-22	4.6	32	Alive	2	50
3-23	4.4	36	Alive	1	75
3-24	4.7	38	Alive	2	50
3-25	5.8	36	Alive	3	25
3-26	6.4	40	Alive	1m	87
3-27	5.8	36	Alive	1m	87

CROP TREES

C-IV

May 1967

Number	Diameter	Height	Condition Class	Release Factor[7/]	Percent Release
4-1	5.8	37	Alive	1+1m	62
4-2	6.6	39	Alive	1m	87
4-3	4.7	34	Alive	3	25
4-4	5.3	35	Alive	2	50
4-5	4.5	33	Alive	4	0
4-6	8.9	44	Alive	1+2m	50
4-7	6.6	45	Alive	2+2m	25
4-8	7.5	45	Alive	2+1m	37
4-9	5.5	46	Alive	4m	50
4-10	8.4	45	Alive	2+2m	25
4-11	5.4	42	Alive	1m	87
4-12	9.5	51	Alive	1m	87
4-13	5.0	38	Alive	2	50
4-14	5.5	35	Alive	1+1m	62
4-15	5.8	34	Alive	1+2m	50
4-16	7.6	43	Alive	1+3m	38
4-17	5.9	38	Alive	2	50
4-18	4.9	34	Alive	2+1m	37
4-19	6.1	35	Alive	3m	63
4-20	5.2	37	Alive	1+3m	38
4-21	4.1	34	Alive	4	0
4-22	7.7	39	Alive	2+2m	25
4-23	6.7	37	Alive	4	0
4-24	5.4	34	Alive	1+1m	62
4-25	6.1	38	Alive	2	50
4-26	6.5	39	Alive	2	50

CROP TREES

C-V May 1967

Number	Diameter	Height	Condition Class	Release Factor[1]	Percent Release
5-1	5.6	36	Alive	1+1m	62
5-2	4.4	31	Alive	1m	87
5-3	3.1	34	Alive	1+1m	62
5-4	4.1	31	Alive	0	100
5-5	4.5	27	Alive	1	75
5-6	6.5	36	Marginal	0	100
5-7	6.0	40	Alive	1m	87
5-8	4.3	36	Marginal	0	100
5-9	6.4	41	Alive	0	100
5-10	6.6	43	Alive	1m	87
5-11	4.3	33	Alive	1m	87
5-12	4.5	30	Alive	0	100
5-13	4.0	39	Alive	1m	87
5-14	6.0	40	Alive	1m	87
5-15	4.3	35	Alive	1m	87
5-16	4.9	33	Alive	0	100
5-17	5.0	37	Alive	0	100
5-18	5.7	38	Alive	2+2m	25
5-19	5.0	38	Alive	1	75
5-20	4.6	36	Alive	1m	87
5-21	4.4	29	Alive	2	50
5-22	7.0	36	Alive	1	75
5-23	3.0	24	Alive	0	100
5-24	4.1	29	Alive	1+1m	62
5-25	5.6	36	Alive	1+1m	62
5-26	3.9	29	Alive	1+3m	38

CROP TREES

C-VI May 1967

Number	Diameter	Height	Condition Class	Release Factor[1]	Percent Release
6-1	4.0	29	Alive	1m	87
6-2	7.6	46	Alive	1+1m	62
6-3	4.3	32	Alive	3m	63
6-4	5.5	32	Alive	1m	87
6-5	5.9	39	Alive	2+1m	37
6-6	4.6	37	Alive	1+1m	62
6-7	5.3	38	Alive	1m	87
6-8	4.6	33	Alive	2	50
6-9	3.9	29	Alive	1	75
6-10	4.7	35	Alive	2+1m	37
6-11	4.5	31	Alive	2	50
6-12	6.5	39	Alive	4	0
6-13	7.1	37	Alive	1+1m	62
6-14	6.5	36	Alive	2	50
6-15	5.4	37	Marginal	0	100
6-16	5.2	32	Marginal	0	100
6-17	5.3	30	Marginal	0	100
6-18	6.3	42	Dead	--	--
6-19	7.4	38	Dead	--	--
6-20	5.0	38	Dead	--	--
6-21	5.8	37	Marginal	0	100
6-22	7.4	43	Marginal	0	100
6-23	4.5	27	Marginal	2+2m	25
6-24	4.6	33	Alive	2+2m	25
6-25	5.5	34	Alive	1m	87
6-26	7.5	40	Alive	2	50
6-27	6.8	37	Alive	1m	87