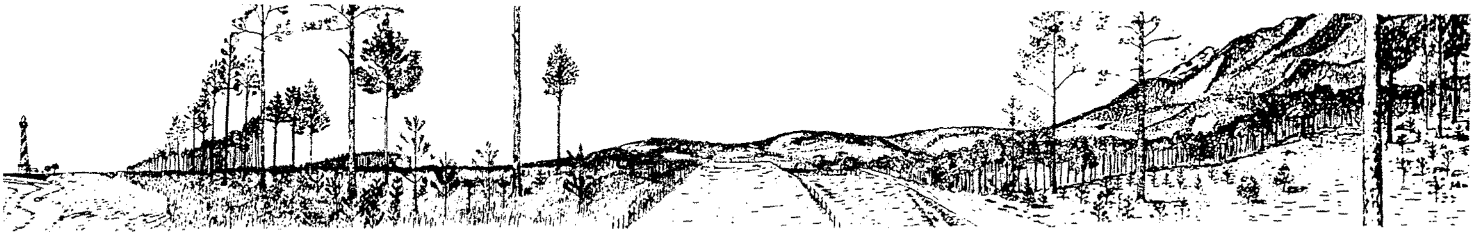

USDA Forest Service Research Note SE- 173 May 1972

MOISTURE CONTENT INFLUENCES IGNITABILITY OF SLASH PINE LITTER

Abstract.--The influence of moisture content on the ignitability of slash pine litter was measured by dropping lighted matches onto fuel beds conditioned to different levels of moisture content. The percentage of matches igniting the fuel bed was used to indicate ignition probability at each moisture content. The "critical range" of fuel moisture contents within which the ignition percent changed from near 100 to near 0 was relatively narrow and was different for each of three different sizes of matches: 16 to 25 percent for a wooden miniature match, 18 to 30 percent for a wooden kitchen match, and 24 to 40 percent for three kitchen matches bound together.

The ignitability of litter fuels is an important consideration in estimating forest fire danger. It is particularly important because wildfires can spread much more rapidly when small firebrands develop along moving fire fronts and are cast into unburned fuel, thereby causing numerous spot fires. At present, we know little about how the ignitability of natural fuels is influenced by such conditions as moisture content, particle size and arrangement, chemical content of particles, and other key fuel properties. Also, we have no well-established technique for measuring the effect that these properties have on the ignitability of forest fuels. This report presents one approach to studying ignition probability and shows how moisture content can affect the ignitability of slash pine (*Pinus elliottii* var. *elliottii*) needle litter, a common forest fuel in the Southeast.

Of the many properties which affect the ignitability of forest fuels, moisture content is one of the more important. Wright[1] developed a test for measuring the influence of fuel moisture on flammability. He placed lighted matches on the litter surface while shielding them by a windscreen. Rate of spread of the spot fire, flame size, and ash residue were used to estimate flammability. He also observed the range of fuel moisture contents below which ignition was near certain and above which ignition rarely occurred. He found that this range of moisture

[1]Wright, J. G. Forest fire hazard research as developed and conducted at the Petawawa Forest Experiment Station. Forest Fire Res. Inst. Ottawa, Ontario, Inf. Rep. FF-X-5, Forest Fire Hazard Pap. 2, 63 pp. 1932.

Southeastern Forest Experiment Station • Asheville -North Carolina
U.S. Department of Agriculture- Forest Service

contents was about 19 to 29 percent for red pine litter and 16 to 18 percent for mixed. litter of red, white, and jack pines. His experiments raise the question of what this range of moisture contents would be for other kinds of fine fuel. The large difference in the size of these two ranges in moisture content (10 percent for red pine and 2 percent for the mixed pine litter) suggests that the effect of moisture on ignitability may vary widely among different kinds of fuel.

METHODS

Tests of the ignitability of slash pine litter were conducted with an apparatus which ignites 25 wooden matches and drops them simultaneously on a fuel bed (fig. 1). The fuel beds were 36- by 36-inch sections of undisturbed pine needle litter which had been removed intact from the field (fig. 2).

Before the ignition tests were made, the fuel beds were conditioned in an environmental chamber until the surface needles reached a specified moisture content. The dry-bulb temperature in the conditioning chamber was maintained at 80” ± 5” F. The wet-bulb temperature was varied to produce the desired equilibrium moisture content of the surface needles. Moisture contents above 30 percent were obtained by soaking the fuel in water for 24 hours and then drying it slowly until the surface needles reached the desired moisture content. This procedure usually produced a moisture gradient in the fuel bed, whereas allowing the fuel to reach an equilibrium moisture content in an atmosphere of constant relative humidity and temperature produced a uniform moisture content throughout the fuel bed. All tests were made in the combustion laboratory in still air at approximately the same wet- and dry-bulb temperatures that were used to condition the fuel.

Three different sizes of firebrands were used in making the ignition tests: (1) a miniature match, (2) a standard kitchen match, and (3) three standard kitchen matches bound together.

The procedure for making a single ignition test consisted of (1) igniting 25 firebrands simultaneously, (2) dropping the firebrands approximately 3 to 5 seconds after ignition, (3) determining whether or not ignition had occurred at each ignition point, and (4) extinguishing the fires produced. Ignition of the fuel was assumed to have occurred if the spot fire continued to burn after the firebrands went out. The firebrands igniting the fuel were counted after each drop (fig. 3). The “ignition percent,” an indicator of ignition probability for’ the fuel at a specific moisture content, was expressed by the following ratio:

$$\frac{\text{No. firebrands igniting fuel x 100}}{\text{No. firebrands dropped}}$$

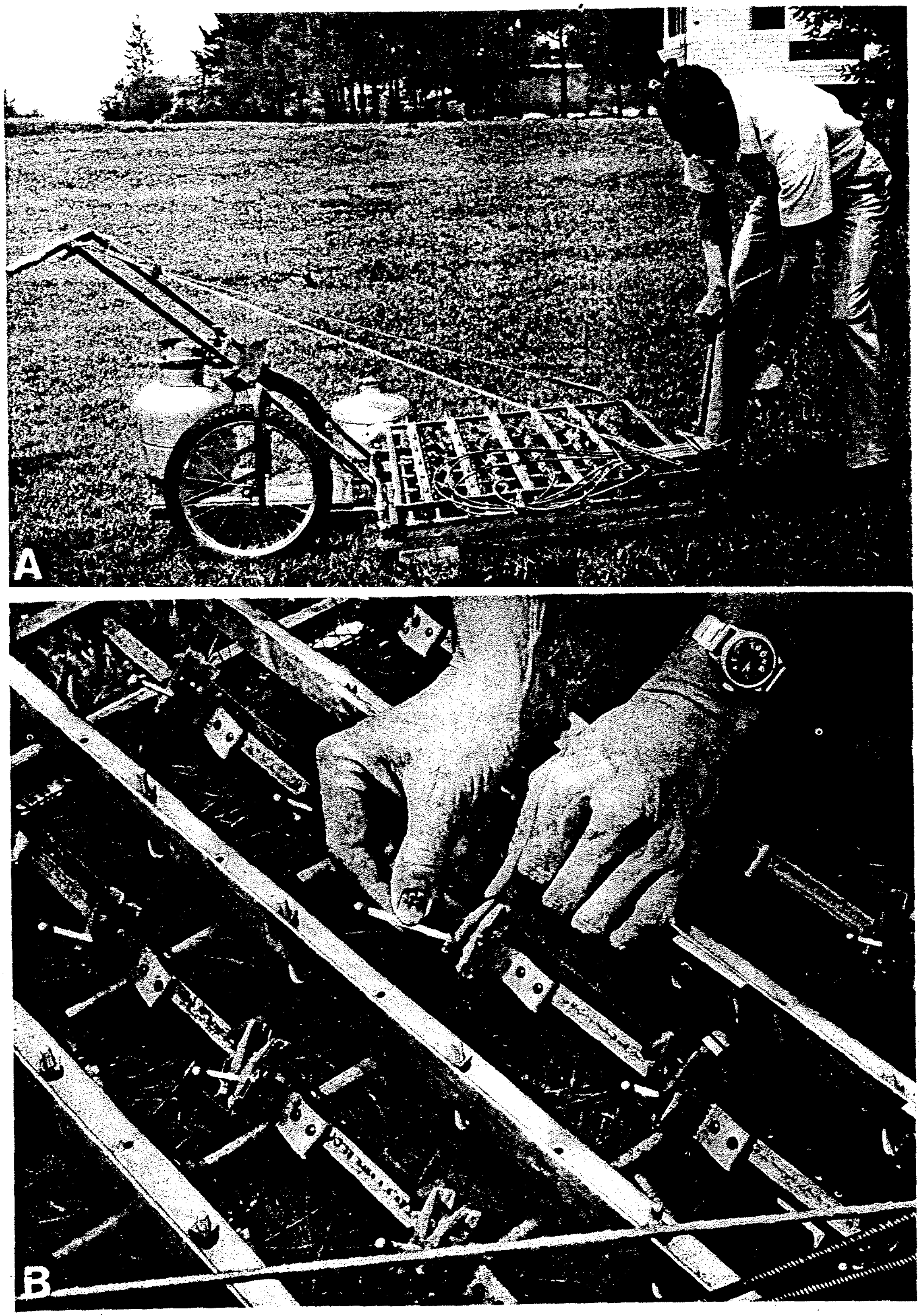

Figure 1.--Apparatus used to ignite and drop up to 25 flaming firebrands on fuel beds (A). Matches, which are held by spring clips, are ignited by the gas flame at each ignition point and are released simultaneously by opening the clips with a cable release (B).

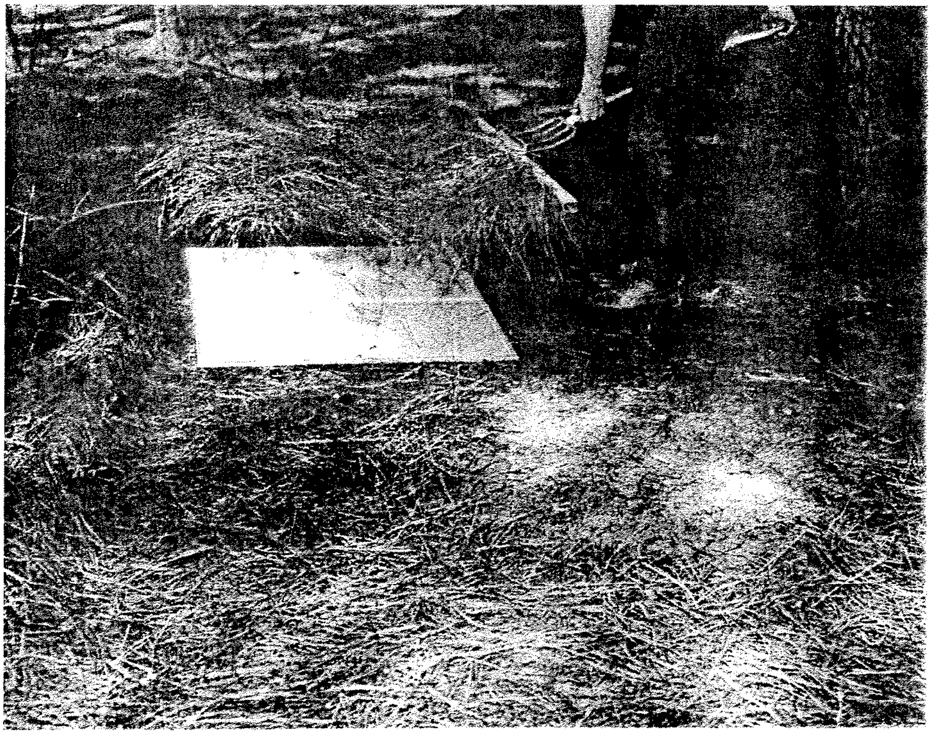

Figure 2. --Natural fuel beds were collected from a slash pine plantation by removing the entire litter layer from a 36- by 36-inch area and placing it on an aluminum screen.

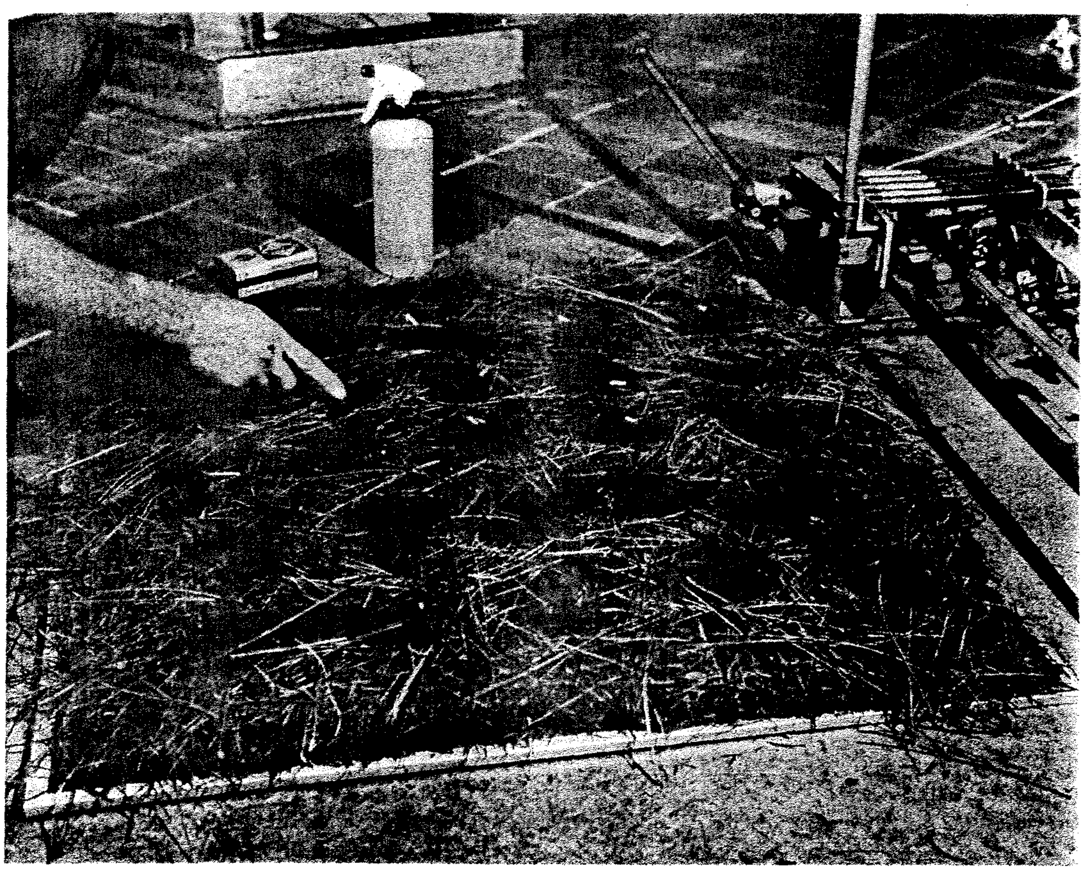

Figure 3. --The ignition percent was determined by the number of firebrands that ignited the fuel after each drop of 25 firebrands.

RESULTS AND DISCUSSION

Fuel moisture content definitely influenced the ignitability of slash pine needles. Ignitability at a specific moisture content was also affected by firebrand size. Figure 4 shows that the ignition percent changed from near 100 to near 0 within a relatively narrow range of fuel moisture contents (hereafter called the "critical range"). This range was different for each type of firebrand. The critical range for the miniature matches was only 16 to 25 percent. The critical range for the single kitchen matches was somewhat larger, about 18 to 30 percent. This range agrees closely with Wright's data (see footnote 1) for red pine, i.e., 19 to 29 percent. The critical range for the three-match firebrahds was the widest, about' 24 to 40 percent. The wider critical range for the three-match firebrands may have resulted, in part, from the nonuniformity of moisture distribution in the fuel beds which were over 30 percent in moisture content. This nonuniformity resulted from uneven drying while these fuel beds were being conditioned. However, such uneven drying also occurs in the field because of variable shading, compactness, and surface irregularities of litter on the forest floor.

Because the firebrands were spaced approximately 6 inches apart, it is possible that the 25 ignition points on each test bed influenced one another. The burning needles at one point could have influenced the ignition at an adjacent point by producing drafts or adding heat as the perimeter of the spot fire expanded. 'As a result, the higher ignition percentages may be biased slightly in a positive direction. That is, they may be higher than they would have been had each of the 25 firebrands been dropped at different times. As the ignition percentages approach zero, this interaction among ignition points should decrease because of the increased distance between the points on the fuel bed where ignition occurred.

After slash pine litter in the field has been well soaked from rain, it will usually burn as soon as the surface needles have dried to less than 45 percent moisture content. If the moisture content of the needles is over 50 percent, they will not carry a fire which has been started from a point ignition source, regardless of its heat output.

The scatter diagrams in figure 4 suggest a reverse-S curve with the maximum rate of change in ignitability near the midpoint of the critical range. The width of the critical range is probably influenced by the normal variation in the characteristics of the fuel bed, plus variation in the experimental technique. If it were possible to obtain perfectly uniform fuel beds with respect to all properties that affect ignition and to duplicate exactly the experimental conditions under which the tests were made, then the length of the critical range for a given firebrand would be minimized. The end points of the range would be drawn closer together around the median moisture content. This is the moisture content at which ignition percent equals 50 (M. C. 50) and could be considered the "critical moisture content" for a particular fuel and

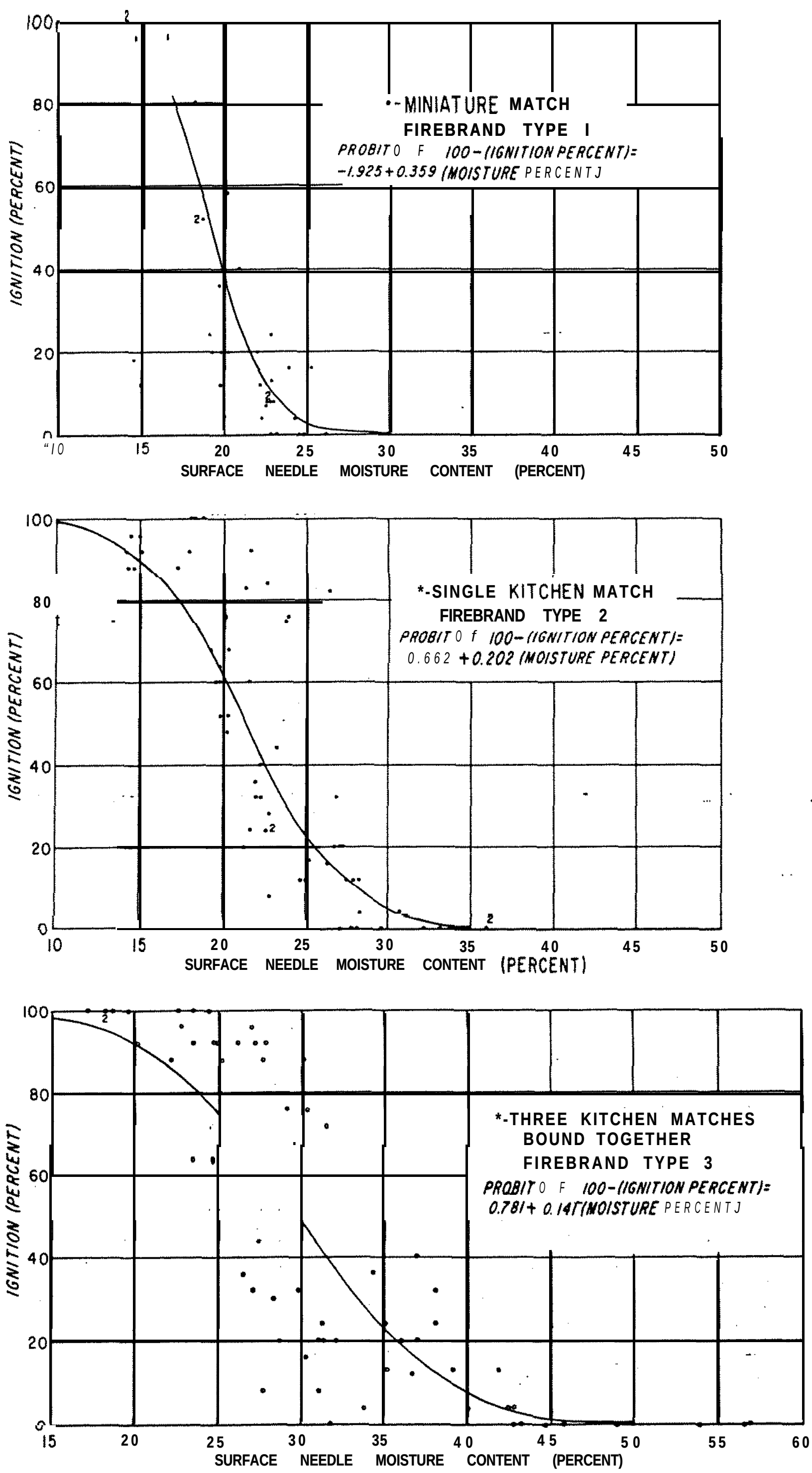

Figure 4. --ignitability of slash pine litter at different levels' of moisture content with three types of flaming firebrands. (Probit values were converted to ignition percentages by consulting appropriate table s in Kinney, D. J. Probit analysis. 256 pp. Cambridge Univ. Press. 1947.)

firebrand. The critical moisture content corresponds to what Finney[2] calls the "median effective dose" in his discussion of the probit method of statistical analysis used in biological assay. Probit analysis was used to fit regression lines to the data in figure 4. According to Finney, the moisture content corresponding to 50 percent ignition can be estimated more reliably than can the moisture contents near the extremes of 100 or 0 percent ignition. Therefore, the M. C. 50 should provide a better index for comparing other fuels and other kinds of firebrands.

The values of M. C. 50 for the three firebrands were:

Firebrand	M. C. 50	Standard error	d. f.
Miniature match	19.3	0.44	40
Kitchen match	21.5	.64	60
3 Kitchen matches	29.9	.84	72

There are obvious differences between the three firebrands which do not need substantiating by statistical tests for significant differences. Statistical comparisons among values of the M. C. 50 would be valid only if certain assumptions about the data are true. One of these is that the mathematical model used in fitting the probit regression line to the data must represent the actual relationship between the X and Y variable (X = moisture content; Y = ignition percent). Another assumption is that the regression lines for the different firebrands being compared must be parallel. There is evidence that these assumptions may not be true for our data. Therefore, no tests for significant differences have been made.

Figure 4 clearly demonstrates the effectiveness of moisture content in controlling the ignitability of slash pine needles. The interaction between fuel moisture content and firebrand size (heat output) is also clearly shown. Apparently, the prediction of ignition probability in this fuel, and probably others as well, will require that one know the distribution of sizes of firebrands as well as fuel moisture content.

[2] Finney, D. J. Probit analysis. 256 pp. Cambridge Univ. Press. 1947.

Winfred H. Blackmarr, Associate Forest Fuels Scientist
Southern Forest Fire Laboratory
Macon, Georgia