PROBABILITY OF SPOT FIRES DURING PRESCRIBED BURNS

John R. Weir

Spot fires have always been a problem on prescribed burns. Just the possibility of a spot fire can cause mental and physical stress on burn bosses and crews. Actual spot fires can cause personal injury or even loss of life, as well as costly damages and loss of public support for prescribed fire programs.

Many private and public land managers in Oklahoma have told me that they avoid prescribed burning for fear of spot fires and escaped fires. Many have the resources needed to conduct prescribed fires, but lack the experience or knowledge to deal with spot fires. A simple guideline or rule-of-thumb might help.

Variables Affecting Fire Behavior

Weather factors are the main variables that burn bosses can use to predict and monitor prescribed fire behavior. In general, there are three main weather factors:

- ***Relative humidity.*** Burning when relative humidity exceeds 40 percent significantly slows rates of spread (Lindenmuth and Davis 1973) and reduces danger from firebrands (Green 1977).
- ***Temperature.*** Bunting and Wright (1974) found that danger from firebrands was lower if the ambient air temperature is below 60 °F (15 °C) when burning.
- ***Windspeed.*** Windspeeds of at least 8 miles (13 km) per hour are needed to ignite and burn standing fuels (Britton and Wright 1971). However, windspeeds of more than 20 miles (32 km) per hour can create problems with firebrands and other blowing debris (Wright and Bailey 1982).

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Key Variable

At the Oklahoma State University Research Range (OSURR), we conduct prescribed burns during different seasons all over Oklahoma. Fuels include tallgrass prairie (NFES fuel models 1 and 3—see Anderson 1982), post oak–blackjack oak (fuel models 3, 8, and 9), eroded mixed prairie (fuel models 1 and 3), sandsage grassland (fuel model 4), and oak–pine (fuel models 3, 8, 9, and 11). Since 1996, we have

Firewhirl on a prescribed fire in Oklahoma. Fuels were tallgrasses, sand sagebrush, and scattered eastern redcedar. About 20 feet (6 m) tall, the firewhirl left the burn unit and started two small spot fires that were quickly contained. Photo: John Weir, Oklahoma State University Research Range, Stillwater, OK, 2001 been keeping track of spot fires on our prescribed burns. We consider a spot fire to be any fire outside the burn unit, no matter what the size or cause.

The size of a spot fire depends on fuel loads outside of the burn unit, crew size, crew experience, equipment present, equipment dependability, firebreak type and size, and weather conditions. Our spot fires have ranged in size from less than one square foot (0.09 m^2) to 120 acres (264 ha). Most of our spot fires were caused by firebrands from crowning eastern redcedar (*Juniperus virginiana*). The rest were usually caused by smoke, fire whirls, or flaming oak leaves or tallgrasses floating or blowing across the fireline.

When the OSURR crew conducts prescribed fires, we record weather data onsite before, during, and after the burn. We also note whether or not a spot fire occurred. When we reviewed the burn data, one weather variable stood out in association with spot fires: low relative humidity (fig. 1). From 1996 to 2002, we conducted 99 burns, 21 of which produced spot fires. All but two occurred when relative humidity was at or below 40 percent.

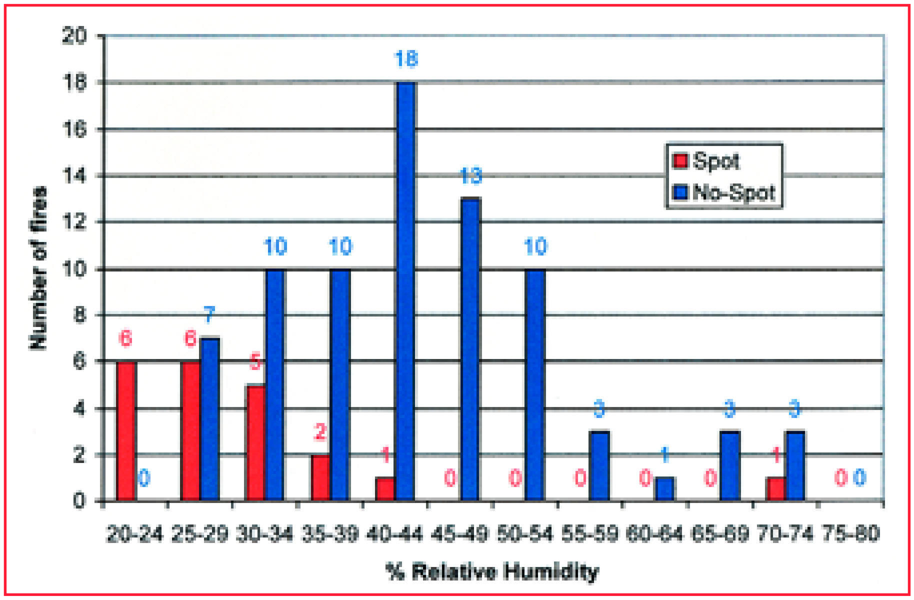

Figure 1—*Spot fires on prescribed burns in relation to relative humidity. Twenty-one of 99 prescribed fires conducted across Oklahoma from 1996 to 2002 were associated with spot fires, but only two spot fires occurred when relative humidity was greater than 40 percent.*

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40-Percent Threshold

Research has shown that fine fuels ignite and burn easily when relative humidity is below 40 percent, whereas ignition slows when relative humidity is above that threshold (Britton and Wright 1971; Green 1977; Lindenmuth and Davis 1973). Our experience validates the research. A threshold value of 40-percent relative humidity might suggest an excellent rule-of-thumb for conducting prescribed burns.

That does not mean that managers should never prescribe-burn when relative humidity falls below 40 percent. Some parts of the United States and some particular burn units might require low relative humidity to achieve the goals and objectives of a prescribed burn.

But it should be etched into every burn boss's mind that a spot fire might well occur on a prescribed burn when relative humidity is below 40 percent. Of course, burn bosses should always be ready for spot fires on every prescribed burn, no matter what the relative humidity. We recorded one spot fire when the relative humidity was as high as 73 percent. It was caused by firebrands thrown by a crowning eastern redcedar into heavy fuels across the firebreak.

Spot Fire Probability

What is the probability that a spot fire will occur when relative humidity is below 40 percent—or, for that matter, at any level? Knowing spot fire probability can be vital in preparing and safely conducting prescribed burns.

We used the information from our 99 prescribed burns to develop a set of spot fire probabilities at various levels of relative humidity. We used the following formula (based on Steele and Torrie 1980):

$$P = SF \div PF,$$

where P is the probability of a spot fire occurring, SF is the number of spot fires, and PF is the number of prescribed fires.

Our data showed a 21.2-percent probability of a spot fire occurring on a prescribed burn when relative humidity was between 20 and 80 percent, or about one out of five burns. For the 40-percent relative humidity threshold, the probability of a spot fire was 41.3 percent when relative humidity was below the threshold and only 3.8 percent when it was above the threshold—a substantial difference.

The data also showed that, below the 40-percent threshold, spot fire probability rose with each 5-percent drop in relative humidity (fig. 2). At 25-percent relative humidity, there appears to be another threshold: Below this point, there was a 100-percent probability of a spot fire occurring. But in the 25- to 29-percent relative humidity range, spot fire probability dropped from 100 percent to just 46.2 percent; and in the 30- to 35-percent range, only one out of three burns was likely to produce a spot fire.

Lessons for Burn Bosses

What does all this mean for burn bosses? It does not mean that managers should never prescribe-burn when relative humidity falls below 40 percent. But managers should still take the 40-percent threshold into account, particularly when inexperienced personnel are conducting prescribed burns, when heavy fuel loads are adjacent to the burn unit, or when a fire escape could result in terrible publicity or even litigation.

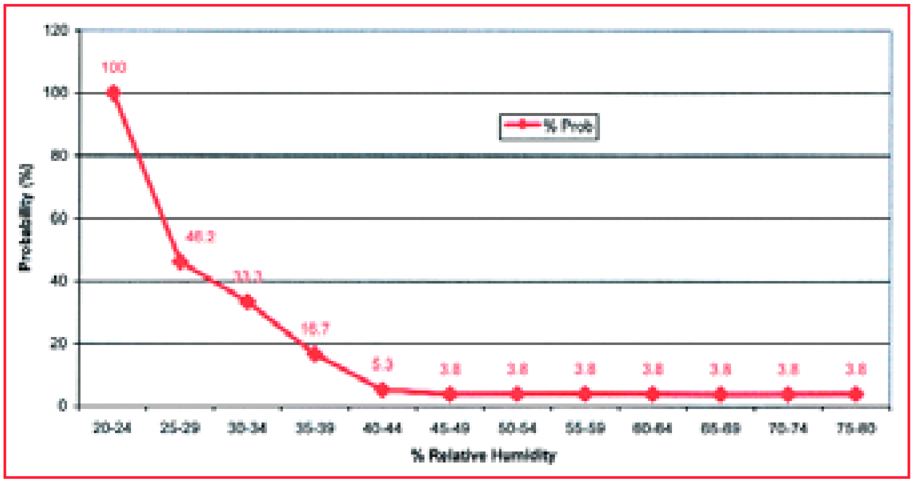

Figure 2—*The probability of spot fires as a function of relative humidity, based on 99 prescribed fires conducted across Oklahoma from 1996 to 2002.*

Within the range of 20- to 40-percent relative humidity, there is a large difference in the probability of a spot fire occurring. When relative humidity is below 25 percent, burn bosses should be prepared for a 100-percent probability of a spot fire. But they can cut the risk by about half with just a slight increase in relative humidity.

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This information can help burn bosses determine spot fire potential when considering burn units or burn days. It can also help them determine crew size and equipment needed. It might help relieve some of a crew's anxiety about spot fires on prescribed burns when relative humidity exceeds 40 percent. Best of all, it can help managers reduce risk and increase safety for their crews.

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