# Mulch Flammability

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## Introduction

Regardless of how horrible and devastating wildland fires are portrayed by the media, they are a natural disturbance that many native ecosystems depend on for regeneration. As the population of the United States increases, more individuals are building their homes in wildlands rather than urban landscapes. Homes built in undeveloped wildland vegetation create areas often referred to as the wildland-urban interface (Bradley 1984, Macie and Hermansen 2002). Approximately 44.8 million housing units (38.5% of all houses) are located in the interface (Radeloof et al. 2005). A high proportion of these homes occur in fire-dependent ecosystems.

To reduce fire risk, communities have implemented Firewise planning. The Firewise program (www.firewise.org) advises landowners to remove or reduce flammable materials within the first 30 feet around a home, a zone often referred to as "defensible space" or part of the "home ignition zone". In this zone, landscape plantings should be sparse and limited to trees and shrubs with low flammability. These austere conditions may not be acceptable to landowners who may prefer large, lush, landscape beds to beautify their property.

Landscape beds with mulches, if they are not maintained properly, may contribute to fire spread to structures during a wildfire or serve as an ignition source. To reduce risk, home and business owners need to remove dead plant material, maintain a distance between plants, space flammable mulches away from structures, and water on a regular basis. Both the type of shrubs and mulches used by the landowner may influence fire spread. Although there is limited research on shrubs and mulches with respect to individual flammability characteristics and their effect on fire behavior, less is known about mulches (Hickman and Perry 1996, Steward et al. 2003). In one study, Steward et al. (2003) examined ignitability of 13 landscape mulches under three different ignition scenarios—cigarettes, matches, and propane torch. They observed that fine material mulches (e.g., pine straw, shredded hardwood bark, and shredded cypress mulch) easily ignited. However, age of the mulch (amount of time on the ground) may play an important role. Similarly, the coarse material (e.g., small (1.3 to 2.5 cm) and large (2.5 to 5.0 cm) pine nuggets) took longer to ignite or did not ignite at all. Based on these findings, one might recommend large (coarse) mulches to reduce fire risk from landscape beds.

Flammability, however, has three other components in addition to ignitability: sustainability, combustibility, and consumability (Martin et al. 1994) (Table 1). Each component is influenced by the structure, chemical composition, and moisture content of the material, along with how the structural features influence the architecture of standing fuels and packing ratios of ground fuels (Etlinger and Beall 2004). Structurally, fuel size and shape also influence how rapidly a fuel might ignite and how long it will burn (Rundel 1981). Chemical composition may enhance flammability, whereas high moisture content may reduce flammability. Understanding how flammability components work synergistically will help to quantify fire risk to interface dwellings from mulches.

**Table 1.** Components of Flammability (Martin et al. 1994)

| | |
|---|---|
| Ignitability | How easily a fuel ignites by radiation, convection, embers (conduction) or direct flame contact (time to ignition). |
| Sustainability | How long fuel continues to burn (time of flaming, smoldering, or glowing combustion). |
| Combustibility | How much heat is released (kilowatts). |
| Consumability | How much of the fuel burns (percentage of weight or size). |

## Objective

Determined the flammability characteristics of four mulch types—pine straw, large and small pine bark, and shredded cypress mulch—both in the field and laboratory under two drought regimes.

## Methods

To quantify all four flammability components, the study was conducted at two locations. Field studies were conducted at the Ordway-Swisher Biological Station (OSBS), in Putman Hall, Florida and laboratory studies were conducted at the National Institute of Standards and Technology Building and Fire Research Laboratory (BFRL), in Gaithersburg, Maryland.

### *Field Study*

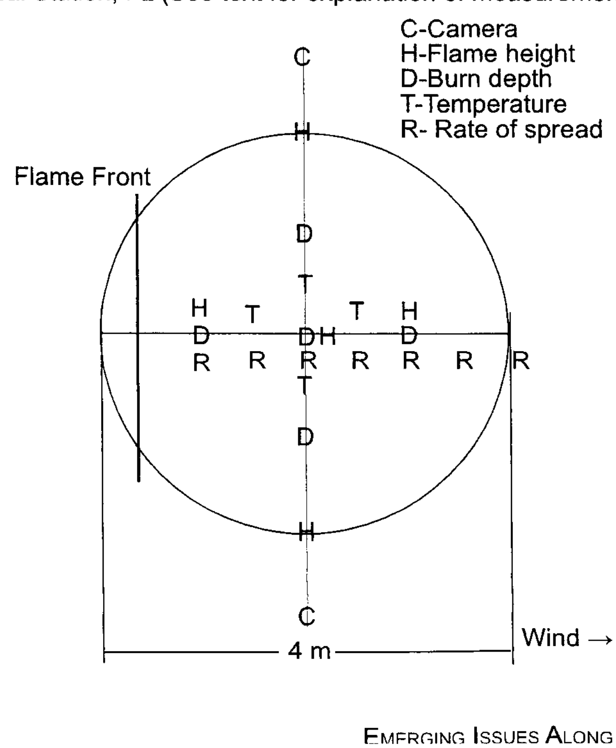
We used four common landscape mulches—pine straw (needles), shredded cypress wood and bark, small pine bark chunks and large pine bark chunks. The mulches represented an array of fuel types ranging from fine-1hr fuels (pine straw) to coarse-10 hr fuels (large pine bark). Experimental plots were 2 meters in radius (12.6 $m^2$ surface area) with 10-12 cm mulch depth. A 12 cm aluminum band bordered each plot. Plots were installed in January 2006 and burned in May of the same year, thus giving the mulch time to settle. Prior to the initiation of the experiment, each plot was irrigated weekly with 39 liters (10 gallons) of water (equivalent of approximately 1.25 inches of precipitation).

Starting in April, plots were subjected to three different drying treatments: 0 (control), 15, and 30 days. To maintain a regime, plots were covered and protected from precipitation. Three replicates of each mulch-drought combination were installed in a complete, randomized-block design. A total of 36 plots were required for the actual mulch flammability tests (3 blocks x 3 drying periods x 4 mulches). An additional four plots were established to test sampling protocols. Prior to plot installation, a 10 kg sample of each mulch type was dried and characterized by three fuel size classes (Pyne et al. 1996): (<0.6 cm (1/4 in.) diameter, 0.6-2.5 cm (¼-1 in.) diameter, 2.5-7.5 cm (1-3 in.) diameter.

Prior to ignition, mulch depth was measured at five points in each plot (center and 1.0 m from center), and three mulch samples were taken to measure moisture content. Samples were weighed and then dried at 65°C to a constant weight to determine percent moisture content on a dry weight basis. Weather data—wind speed and direction, relative humidity, temperature, and precipitation—were recorded at the Putnam Hall station of the Florida Automated Weather Network (FAWN, http://fawn.ifas.ufl.edu/), located 70 meters from the burn site. Plot ignition was initiated from a 2 m straight line of burning diesel/gasoline mixture applied 1.75 m from plot center on the upwind side of the plot in a 2-second period.

In addition to moisture content and weather data, the following measurements were taken at each plot: rate of fire spread, temperature in the flame zone, flame length, fuel consumption, and percentage of total area burned. Rate of spread (ROS) was determined by measuring the time it took for the flame front to reach a set of eight pins at given distances (0.5 or 1.75 m) and the opposite end of the plot (Figure 1). Flame temperatures were measured using aluminum tags painted with heat sensitive ceramic paint (Tempilaq®). Each tag was painted with seven paint strips representing a temperature range from 93°C to 427°C (200 to 800°F). Tags were attached to four pins and placed 25 cm above the ground at four points, 0.5 m from plot center. Flame length was captured using video from two cameras, placed 3.5 m from plot center and parallel to the flame front. Cameras were placed 40 and 60 cm above the ground. Measurements were taken using five 2-m rods alternately painted every 20 cm. Fuel consumption was measured using five wood stakes placed at plot center and 1.0 m from plot center at 90° angles. Stakes were driven into the ground, flush with the top of the mulch. The unburned portion of each stake was measured. Burned portion indicated depth of burned mulch (i.e., consumed material), and was determined by subtracting the unburned portion from the average mulch depth measurement. After 60 minutes, the plot was extinguished and the portion of plot burned was measured using an ocular estimate.

**Figure 1.** Aerial View of Plot Design Used to Study Mulch Flammability Under Field Conditions at the Ordway-Swisher Biological Station, FL (See text for explanation of measurements.)




### *Laboratory Study*

Although we were able to get a relative temperature of the flame using the heat sensitive ceramic paints, more precise measurements of temperature, total heat release, and mass loss were needed for modeling purposes. These measurements were obtained by burning samples in an oxygen consumption calorimeter at the BFRL. Samples were transported in 91x152x10 cm sample trays. Each replicate in the field study was duplicated in this laboratory portion of the study. Temperature was measured using a series of thermocouples placed at the surface and 25 cm above the sample. Heat release was measured using the calorimeter, and mass loss during the burn was measured using a load cell tared to zero prior to each burn. After the burn was completed, mulches were extinguished and discarded. The sample tray was weighed and its weight was subtracted from the total weight to give sample weight. In addition, samples were taken for moisture content, which were handled following the same procedure used for field samples. Flame length was measured using a procedure similar to the field. To facilitate burning, samples were ignited with a linear propane flame and exposed to a wind of 3.2 kmph.

### *Statistical Analyses*

An analysis of variance (ANOVA) was used to evaluate differences among mulch types and drought regimes for rate of spread (field and lab), flame length (field and lab), fuel consumption (field), flame temperature (field and lab), fuel moisture content (field and lab), peak heat and total heat release, and mass loss (lab). In this paper, only preliminary mean values are presented and data were pooled to provide an overall analysis of mulch type and drought regime effects.

## Results

### *Field Studies*

Flammability characteristics varied by mulch type. Pine straw had the fastest ROS. On average, flame traveled about 2.3 m/minute. Shredded cypress was the second fastest with a rate of 0.35 m/minute. However, cypress mulch burned only on the top surface, whereas pine straw burned through the complete layer. For flame lengths, pine straw again had the highest average (55 cm) followed by large pine bark (28.5 cm). The patterns for temperature at 25 cm above the surface and burn depth were the same. Both pine straw and large pine bark produced temperatures excessive of 350°C and burn depths of 10 cm or greater. In contrast shredded cypress had the lowest temperatures (175°C) and burn depths (5.1 cm). In most plots, less than 25% of the cypress was consumed, whereas consumption of pine straw was 100% in all plots.

### *Laboratory Studies*

Flammability characteristics also varied by mulch types. Pine straw had the highest peak heat release rate (over 300 kW) followed by large and small pine bark (80 kW and 50 kW, respectively). Shredded cypress mulch only sustained a heat release rate of 10 kW in the absence of the igniting flame. Heat release data also showed different burning patterns. Pine straw, as expected, burned very quickly releasing most of its heat (25-30 kW-hr) in less than 10 minutes. In contrast, both large and small pine bark showed a gradual increase in heat release rate over a 45-minute period, with large pine bark evolving 25 kW-hr of heat in that time. For shredded cypress heat release declined after the ignition source was removed and remained low for the next 45 minutes. Pine straw lost all its mass within 10 minutes of ignition; large pine bark showed a continual mass loss over the 45-minute burn period and shredded cypress and small pine bark had similar patterns of slow mass loss over the 45-minute burn time.

## Discussion

Pine straw, large pine bark, small pine bark, and shredded cypress mulches varied in their flammability characteristics—ignition, consumption, combustion, and sustainability (Table 2). Low, moderate and high were assigned based on the range of observed values for each characteristic. Based on the findings of Steward et al. (2003) and our ROS measurements, pine straw had the fastest ignition. Shredded cypress also had a relatively fast ignition. Data collected from this study showed that pine straw and large pine bark had highest consumption rates. In the field study, stakes, which measured burn depth, burned to the ground with these two mulches. These data were complemented by the mass loss data recorded in the lab. In contrast, only the surface area burned in the field and in the lab for the shredded cypress, which had the least mass loss. ROS was greatest for the pine straw followed by the shredded cypress mulch.

For the field study, both pine straw and large pine bark had flame temperatures over 350°C. These high temperatures were also reflected in peak heat release in the lab. Pine straw generated the highest peak heat release followed by large pine bark. Unlike the pine straw and shredded cypress, both large and small pine bark chunks showed a pattern of initial heat release and then a gradual build up of heat as more material ignited and burned. The continual burning of material is also reflected in high sustainability for both small and large pine chunks. Pine straw is rated low in sustainability because of how quickly all the fuel was consumed.

The differences in flammability characteristics by mulch types can be explained by the fire triangle. For a fire to continue to burn, it needs heat, oxygen, and fuel. Pine straw, a fine fuel with its high surface-area-to-volume ratio and high oxygen availability, burns very quick and hot. In both small and large pine bark mulches, oxygen is available throughout the depth of mulch because of the mulch structure. Once ignition occurs, these mulches are able to burn through the entire mulch depth and generate heat, which allows the fire to continue to burn. In contrast, shredded cypress mulch, because of its mixture of fine materials, forms a dense, thick layer of mulch, which may limit available oxygen and fuel (the mulch does not easily dry out) to sustain a fire through the complete layer. Subsequently, fires burn only across the surface and do not burn deep into the mulch except at openings in the mulch where oxygen is available. However, if left to burn, shredded cypress mulches could smolder for a long period of time; hence, our reason for giving a range from low to high for sustainability (Table 2).

So, which mulch should a homeowner use and where should they use it? First and foremost, each one of the tested mulches burned and none are 100 percent safe. Mulch should not be used next to flammable material or vinyl surfaces on buildings, as the heat released from each of the materials burned may ignite or melt adjacent wood or vinyl, respectively. Only decorative gravel or stones or some other non-flammable material should be used immediately adjacent to the home. Of the four mulches tested, we recommend that a densely packed mulch (similar to the shredded cypress) be used within 2 to 5 meters of the home. Other mulches may be used at a distance greater than 5 meters from a house or structure, depending on the type and density of landscape plants associated with them. For all mulch types, it is imperative that homeowners maintain their landscape beds by watering and removing dead material and ladder fuels (e.g. vines). Also, the flammability of shrubs planted within the defensible space must be considered. Homeowners need to select shrubs and other plants that also have low flammability characteristics. Guidelines for determining plants of low flammability can be found at http://www.interfacesouth.org/products/flammability_key.html. Similarly, homeowners should also consider the sustainability of materials used in their landscape. For example, though cypress mulch is a desirable mulch, it is a potentially non-sustainable resource.

**Table 2.** General Flammability Characteristics of Four Mulch Types [1]

| Mulch type | Flammability characteristics | | | |
|---|---|---|---|---|
| | Ignition | Consumption | Combustion | Sustainability |
| Shredded cypress | Moderate | Low | Low | Low-High |
| Large pine bark | Low | High | High | High |
| Small pine bark | Low | Moderate | Moderate | High |
| Pine straw | High | High | High | Low |

[1] Ignition information was adapted from Steward et al. (2003) and initial rates of spread in our studies.

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