



**SOUTHERN
Fire Exchange**

Uniting Fire Science and Natural Resource Management



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BACKFIRE TECHNIQUE FOR PRESCRIBED BURNING

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This is one of a series of fact sheets authored by Dale Wade, a prescribed burn researcher and specialist in the South for over 45 years. They are designed to meld current technology with Dale's unequalled experience with fire and science. The fact sheet series is available within the "Prescribed Fire" section at www.southernfireexchange.org/SFE_Publications/Fact_Sheets.html. The Southern Fire Exchange thanks Dale for these contributions from his wit and wisdom, which, in Dale's words, "was sharpened by the many people he worked

DEFINITION

The term 'backfire' refers to a commonly used method for prescribed burning in which the igniter sets a line of fire that slowly backs into the wind. This technique should not be confused with the colloquial use of the term 'backfire' for 'suppression fire,' which refers to any fire set ahead of a wild-fire in an attempt to stop it.

CHARACTERISTICS

Some managers prefer a backfire because they think it is a 'cooler' fire. Actually flame temperatures are about the same regardless of the type of fire. Backfires do, however, spread slower than other types of fire because they move forward against the wind which means the flames are bent over into the already burned area behind the flame zone. In-stand winds thus cool, rather than preheat, the fuel in front of the advancing flame zone and tend to direct any falling vertical fuels to behind the leading edge of the flame front rather than ahead of it, thereby eliminating spotting which would otherwise increase fire spread. Backfire rates of spread range from less than 60 feet per hour to a maximum of about 200 feet per hour, irrespective of wind speed.

The goal of most prescription burns is to consume the fuel during flaming combustion rather than by smoldering combustion (see Smoke section in this fact sheet). Backfires invariably do just that; although the total amount of fuel consumed (available fuel) may be considerably less when a backfire is used because shorter flames will ignite less understory foliage. Backfires have shorter flames than other fire types which means the heat energy is released closer to the ground enhancing downward heat transfer, thereby allowing backfires to burn deeper into the forest floor. Thus, backfires typically consume more of the forest floor than other fire types. And as one might suspect, this has a direct effect on residence time. Fuel particle residence time refers to the amount of time an individual fuel particle, whether a pine needle or a log, will burn, while flame zone residence time is defined as the duration of flaming combustion at a given location. However, as Nelson (2003) and Nelson & Hiers (2008) point out, the time it takes a



Backfires move forward against the wind, with the flames bending over the already burned area behind the flame zone. Note the lack of intermittent flaming and smoldering combustion behind flame front. Photo by Dale Wade, USFS Southern Research Station.

fire to pass a given point is typically longer than the time it takes to consume the available fuel downward into the fuel-bed; Nelson solves this problem by using the term 'fuelbed residence time.'

INTENSITY

Shorter backfire flame lengths translate into less understory fuel consumption when this technique is used. Fire intensity¹ is lower in a backfire than in any other kind of fire, although the total heat released per unit area burned will be higher if the fire is confined to just the litter layer. This apparent contradiction is explained as follows: Where no overstory is present, in prairies and pastures for example, the layer of decomposing dead vegetation (excluding any underlying organic soil) is typically very shallow and is generally all consumed regardless of the type of fire. When a canopy is present, however, the forest floor is thicker, so there is more dead material available.

¹ In this fact sheet, the term 'fire intensity' refers to fireline intensity (also called Byram's or frontal intensity) and not reaction or Rothermel's intensity unless noted. The difference is considerable and is explained in the fact sheet, *Fire Intensity and Fire Severity: How Hot Is Your Fire and Why Is That Important?*

Whether it all burns or not depends upon a number of factors, but as mentioned above, a backfire will burn deeper into the duff than other fire types. Backfire depth of burn depends primarily on the steepness of the forest floor moisture gradient while in-stand winds have little effect on rate of spread. Headfires, on the other hand, consume less of the forest floor as wind speed increases (at least in litter-bed combustion room studies, likely because more of the heat released is blown away). But whenever an understory is present, head and flank fires will consume considerably more of these standing fuels than backfires (longer flame lengths), so rate of spread and thus overall fire intensity will be higher in head and flank fires.

In fuel types that contain tall herbaceous plants, such as plume grass or broomsedge, these stems tend to burn through near the base with the upper portions falling to the ground where they can then be consumed as horizontal rather than vertical fuels. This process also helps keep backfire heat release closer to the surface.

SMOKE

A backfire produces only about $\frac{1}{3}$ the emissions of a headfire under the same conditions because more fuel burns in the efficient flaming phase of combustion than in the smoldering phase (for more information on combustion in wildland fuels, see the Encyclopedia of Southern Fire Science: <http://www.forestencyclopedia.net/p/p447>). Temperatures are several hundred degrees lower in smoldering combustion, which results in less complete combustion and thus more intermediate compounds including many noxious combustion products, both solid (particulate) and gaseous. Therefore, a backfire is often used when smoke sensitive areas (SSA's) are identified downwind of the burn unit. But there are downsides—backfires don't build much of a convection column compared to other fire types. This means the smoke remains nearer the ground where it can negatively impact humans rather than being lofted into the atmosphere where it would be more rapidly diluted and dispersed. And because it takes longer to treat a unit using a backfire than with other types of fire, the heat and smoke will be released over a longer time period thereby increasing the time adjacent areas are exposed to risk, as well as increasing the time one has to monitor any SSA's.

Virtually all the water present in fuels that carry a prescribed fire (live and dead herbaceous material, foliage, surface litter, and twigs less than about $\frac{1}{2}$ inch in diameter) has to be driven off before ignition will occur. Converting this liquid water to a vapor requires considerable heat energy, which means the wetter the fuel, the more heat energy that has to be diverted for this purpose. When conducting a burn when ambient temperatures are below about 27°F, this water will be in a solid form (ice) and thus require additional heat to first convert it to a liquid. This is the primary reason fires conducted in below freezing weather are less 'perky' than fires under the same conditions except with ambient temperature above freezing. The vaporized water released during combustion is not a pollutant, but it certainly reduces visibility and in a worst case scenario results in zero visibility, a condition called super fog². Because there is little preheating of these fine fuels ahead of a

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backfire, backfires require drier fuel conditions than other fire types.

It follows that the drier the fuelbed, the less moisture there is that needs to be vaporized and thus the less impact on visibility. However, care must be taken not to burn when conditions are too dry to avoid killing overstory feeder roots, as explained in the When To Use section in this fact sheet. Water vapor produces the characteristic white color in a smoke plume, while high fireline intensities and incomplete combustion produce the characteristic black (sooty) color.

SAFETY

Many land managers believe a backfire is the safest technique because of its short flames and low fire intensity. This is true, but the prudent burner keeps in mind that any change in wind direction will result in an increase in rate of spread and thus fire intensity. Likewise any escape will result in a more intense fire running with the wind.



The white color in smoke is caused by vaporized water released during combustion. While this is not a pollutant, it reduces visibility and can potentially result in zero visibility, a condition called super fog. Photo by Wayne Adkins, USFS Southern Research Station.

Regardless of what firing technique(s) will be used to burn a unit, one should invariably first ignite the downwind side of the unit and let this line of fire back into the unit, thereby widening the control line; this is called blacklining and can be done a few days in advance of burning the rest of the unit. If you do decide to blackline a unit a few days before the actual burn, do so when nighttime relative humidity (RH) is expected to rise above about 80% because as this threshold is approached, the backfire will go out on its own without having to be extinguished (although you will have to stay with the fire into the evening to make sure it does go out). Unlike the west-

² A term coined by Gary Achtemeier, fire meteorologist and smoke modeler with the USFS Southern Research Station, who has developed a model to predict the likelihood of occurrence.

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ern U.S., practitioners east of the Mississippi can count on close to full RH recovery every night except immediately after passage of a cold front.

An advantage to blacklining a day or two before burning the rest of the unit is that you can do it in mid to late afternoon when burning conditions are conducive to fire spread, thus accomplishing the task in a more efficient manner. The downside is that the fire has to be extinguished, either naturally as the nighttime humidity and thus fuel moisture rises, or with human intervention. This problem is easily solved, however, because units to be burned with a backfire typically require interior lines, as explained in the Tips section of this fact sheet. Where this is the case, one can simply let the backfire spread up to the first interior line where it will go out. If you plan to burn this downwind segment days ahead of the main burn, when the interior lines are put in one can construct this bottom interior line 30 to 50 feet upwind of the downwind control line. It can then be ignited after lunch and be out and mopped up within 2 hours.

Trying to get a backfire to carry first thing in the morning is an exercise in futility, requiring a lot of effort and torch mix until solar radiation lowers the RH and ‘burns’ off any dew. I, for one, was always anxious to get the main burn underway so I could start mop-up sooner and get home at a decent hour. Head and flank fires will carry under these damper burning conditions so one is sometimes tempted, if the blackline was not completed ahead of time, to force things by stringing a headfire 15 to 20 feet in from the downwind line assuming it can be stopped at the control line. One of the unwritten laws of pyrodynamics is that dense hazardous fuel conditions will exist immediately across the downwind control line, and I can assure you that sooner or later you will have a slop-over. If you don’t catch it within a few minutes, your initial optimism of husbanding the land will quickly turn into frustration.

WHEN TO USE

I have been known to say that one uses a backfire only when he/she is too scared to use another technique and there is much truth to that statement as backfires have the shortest flames and slowest rate of spread of any firing technique. The process of combustion converts the potential energy stored in a piece of fuel into thermal energy. Heat energy is released about equally along the surface of the flame front so shorter flames concentrate this heat release closer to the forest floor where it can girdle larger stems than either head or flank fires.

Without treatment, most southern plant communities quickly develop a dense understory of shrubs and trees. Periodic fire will keep this rank growth in check; the objective is generally not to eradicate species but to simply reduce their stature. A chronic fire regime (once every year or two), especially in the growing season, will result in open park-like stands with an amazing diversity of groundcover species. When a new stand is established through either land-use conversion (e.g., abandoned farmlands) or clearcutting an existing stand, fire should

be introduced within the first 5 to 6 years to reduce hazardous fuels and prevent non-crop trees from getting too large to be controlled by fire. If the objective is forest management, then one has to know the relative fire tolerance of the desired crop trees so fire use can be tailored to enhance their growth.

Plants that develop a thick bark at an early age such as longleaf, slash, shortleaf, and loblolly pines become very resistant to stem damage (but not bud damage) once they attain a basal diameter of about 2 inches. The above species are listed in the order they develop thick bark so, for example, fire can be used in a longleaf plantation soon after the trees have bolted to eliminate unwanted loblolly regeneration that seeded in from adjacent stands. Thin-barked species, such as red maple and elm, up to 4 to 5 inches diameter at breast height (DBH) can sometimes be girdled by a single backfire; they will, however, send up copious basal sprouts. Many trees are only partially girdled, but over the course of several fires they will either succumb or develop into hollow den trees utilized by wildlife. Some species, such as dogwood, deciduous oaks, and hickories, once established can survive multiple low intensity fires for decades or longer.

Succession is fairly rapid in many southern plant communities, so fuel reduction resulting from a fire is temporary—lasting as little as 3 to 5 years. If the fire-free interval exceeds 3 or 4 years on good sites or roughly a decade on poor sites, a backfire will likely be the technique of choice because it will girdle larger woody stems. Shorter flames and slower backfire spread allow the wind and ambient temperature to more effectively cool the rising combustion products and dissipate the rising heat energy. A backfire thus minimizes scorching/igniting overhead foliage in all canopy layers.

Because backfires burn deeper into the duff layer, the downward heat pulse is both higher and lasts longer than with other fire types. This has several important ramifications for prescribed burners. First, it means that backing fires will provide more effective control of pests and pathogens in or on the forest floor, such as the white pine cone beetle and annosus root rot. But there is also a substantial downside to this increased forest floor consumption because the lower duff and humus layer is rife with overstory feeder roots, especially on nutrient-poor sandy soils that dominate the Atlantic Coastal Plain. These roots have little protective covering and are thus very susceptible to heat kill. Young fast-growing trees typically replace damaged roots with little effect on growth. However,



Open, park-like stands with high groundcover diversity can be achieved by a frequent fire regime of every 1 to 2 years. Photo by Taylor Oxarart.

in biologically old trees, transpiration is almost equal to respiration which means these trees have virtually no carbohydrate reserves and are therefore killed because even minor root damage often tips the balance toward mortality, especially if post-burn weather continues dry. These forest veterans are often the very trees a restoration burn is intended to favor and protect against high-intensity wildfire.

The bottom line is to be very pessimistic of the outcome when contemplating use of a backfire in a long-unburned stand! Humidity is higher in these dense stands, little sunlight reaches the forest floor, and the rank understory impedes wind flow; the combined effect is a forest floor that dries exceedingly slow. When the forest floor finally dries enough to carry a backfire, it is too dry. The overriding objective when reintroducing fire into plant communities that have been long-unburned is to topkill shrubs and midstory trees, and SLOWLY reduce forest floor depth over a series of burns. Burn prescriptions seldom call for total consumption of the forest floor when it is thick (old) enough to include humus.

TIPS

Backfires spread slowly and thus one often cannot simply ignite the downwind side of a unit and have the fire reach the upwind edge within the available prescription window. This presents three choices for the manager:

- 1) Use another firing technique,
- 2) Reduce the size of the unit into one-day burn units, or
- 3) Break the unit into multiple subunits by constructing one or more interior lines and ignite the subunits at roughly the same time.

When determining how many interior lines are needed, I assume a spread rate of 100 feet/hour for ease of calculation. The first decision is what wind direction you want to use and to make sure there is a good probability that wind direction will occur frequently and with other acceptable weather parameters during the season you select for the burn. You can find such calculations for several locations in Georgia on the Georgia Forestry Commission forestry weather website at <http://weather.gfc.state.ga.us>. It is important to get this right because once you construct an interior line, you are limited to two diametrically opposite wind directions.

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Next determine the length of the unit from the upwind to the downwind edge. If less than 200 feet, divide by two; if longer, divide by 100 and subtract 1 to determine the number of interior lines you will need to construct. One can make the downwind subunit less than 100 feet deep and burn it several days before the rest of the unit. I personally do not like plowlines because even very low berms can be a formidable barrier to small critters. Therefore, I use natural barriers, such as creeks or ecotones (a change between two vegetation types, one of which is less likely to carry low intensity fire than the other). Bush-hogs, mowers, or blowers (on dry sandy sites with just a few oak leaves) and disked lines or wetlines are all alternatives to plowlines. Where a plowline is needed, however, it should be used; construct it just deep enough to create a mineral soil barrier. Consider rehabbing it after the burn.

If blessed with multiple staff, all lines can be ignited at the same time on burn day. Otherwise ignite the downwind subunit first and progressively work upwind to the most windward unit without stopping; ignite the upwind side of each subunit or you will have defeated the purpose of the interior lines because you will have just lit headfires. One obviously needs interior access to the unit to construct and ignite interior lines. Large units can be subdivided in this manner and the burn completed in less than 2 hours which should allow ample time for mopup. The amount of mopup and distance in from outside control lines should be part of the written plan and not determined by how one feels when flaming combustion is over.

A consistent wind is necessary for a trouble-free backfire. In-stand winds only need to be strong enough to give the fire di-

BACKFIRE

WHERE USED	ADVANTAGES	DISADVANTAGES
<ul style="list-style-type: none">• Heavy fuel accumulations• When ladder fuels present• Young pine stands, except longleaf• Near control lines• Near SSA's• Control pests in forest floor• Top-kill unwanted species• When other techniques too risky	<ul style="list-style-type: none">• Lowest intensity• Shortest flames = less chance of crown scorch• Lowest spotting potential• Fewest particulates• Less smoldering = less mopup• Girdles larger trees• Increase in wind speed not a problem• Less skill needed	<ul style="list-style-type: none">• Slow, thus expensive• Max ROS ~200 feet/hour (average ~125 feet/hour)• If interior lines needed, added cost & limits useable wind directions• Requires steady wind• Lulls in wind = scorch• Need access to unit interior• Any change in wind direction increases fire intensity• Can be high severity• Need drier conditions

rection but they should be continuous. Higher winds will produce longer flames, but they will bend over into the burned area and are of no consequence as long as the wind blows. Higher winds tend to result in less directional variation although backfires can accommodate up to about 30° deviation either side of the general direction (this means that a north wind for example, can vary from about 150° to 210° azimuth) without problems.

If, however, lulls in the wind occur, the flames will stand straight up and subject tree canopies above to more heat which translates into the likelihood of overstory crown scorch. Crown scorch is unsightly and if more than about $\frac{1}{3}$ of the crown is browned, will likely slow tree growth for a year or two depending upon the amount of live crown killed. Southern pines (longleaf, slash, loblolly, and shortleaf) as well as pond pine and pitch pine are amazingly resilient to crown scorch and rarely die even when crown scorch approaches 100% as long as this thermal defoliation does not take place between late August and December, and providing there is no bud mortality. If any live foliage is actually consumed, assume that the buds on that branch have been thermally killed; as little as 25% bud kill can result in 75% mortality in southern pines, but not pond or pitch pine which both typically produce epicormic branches after severe thermal canopy damage.

When surface litter fuel moisture is greater than about 15% in hardwood litter, a backing fire will not carry. The same is true of moistures above ~20% in long needle pine litter. It is difficult to maintain a backing fire at a relative humidity greater than 65 to 70%. The prudent burner is aware that in the unlikely event the fire escapes, it will turn into a head fire running with the wind and thus the higher the wind speed, the harder the escape will be to catch and stop, and spotting will likely become a significant problem because of the drier fuels necessary to conduct a backfire.

The bottom line is that if you have determined that a backfire should be used to burn the unit, don't get impatient and think about speeding things up; in my experience, thinking that the current situation is 'different' often led to a less than stellar outcome.

REFERENCES

Nelson R.M. Jr. (2003). Reaction times and burning rates for wind tunnel headfires. *International Journal of Wildland Fire* 12, 195–201.

Nelson R.M. Jr., & Hiers, J.K. (2008). The influence of fuelbed properties on moisture drying rates and timelags of longleaf pine litter. *Canadian Journal of Forest Research* 38(9): 2394–2404.

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