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FIRE ECOLOGY OF SEEDS FROM *RUBUS* SPP.: A COMPETITOR DURING NATURAL PINE REGENERATION'

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Abstract-Air-dried blackbeny (*Rubus* spp.) fruits were placed at three depths in a reconstructed forest floor and subjected to a simulated prescribed summer bum. Within the forest floor, fruits were placed on the L layer, at the upper-F/lower-F interface, and at the lower-F/mineral-soil interface. Wind for a headfire was generated by electric box-fans. Extracted seed viability was assessed during each of six 30- or 60day germination tests that alternated with 30 or 60 days of cold stratification over a period of 18 months. As depth within the forest floor increased, germinative capacity of blackberry seeds increased. For blackberries placed on the L layer and at the upper-F/lower-F interface during prescribed burning, cumulative seed germination averaged only 0.03 and 0.33 percent, respectively. At the lower-F/mineral-soil interface, mean seed germination did not differ ($P = 0.74$) from the 23 percent achieved by unburned control seeds.

INTRODUCTION

Forestry benefits from prescribed burning include: site or seedbed preparation, control of unwanted vegetation, disease control, thinning of dense young pine stands, increased growth and yield of pines, and improvement of wildlife habitat (Crow and Shilling 1980, Davis 1959). Therefore, prescribed burning continues to be widely used in southern pine management.

Prescribed burning can have positive and negative effects on wildlife habitat by increasing certain essential nutrients and palatability of forage, initially reducing leafy biomass followed by increases, and initially decreasing fruit yields followed by increases (Landers 1987). Consequently, it is important to determine the effects of prescribed fire on early successional plant species that both hinder natural pine regeneration and contribute wildlife habitat.

Blackberry (*Rubus* spp.) was chosen for this investigation because it occurs throughout the Southeastern U.S., is a predominant herbaceous vegetation component in naturally regenerated pine stands (Cain 1991, Shelton and Murphy 1994), and is an important food source for wildlife (Landers 1987, Matthews and Glasgow 1981). Because blackbeny seeds have hard, impermeable seedcoats, germination has been improved when seeds are scarified with concentrated sulfuric acid for 20 to 60 minutes (Brinkman 1974). Sumorization, or heat pretreatment of seeds before they germinate (Barbour and others 1987), may also enhance germination of blackberry seeds.

The purpose of the present investigation was to experimentally determine if germination of seeds from air-dried blackberry fruits might be enhanced when subjected to a simulated prescribed summer burn, depending upon vertical stratification of the fruits in a reconstructed forest floor.

METHODS

The study was located in southeastern Arkansas. The soil, a Sacul loam (clayey, mixed, thermic, Aquic Hapludult), is described as a moderately well drained upland soil with a site index of 80 ft for loblolly pine (*Pinus taeda* L.) at age 50 years (USDA 1976).

Within a pine seed-tree stand, an area was cleared of vegetation down to mineral soil and a 5- by 7-ft bum bed was framed with steel railings. Soil was leveled within the bed and allowed to settle 6 months at which time a forest floor was reconstructed on the bed using procedures developed by Shelton (1995).

In early July 1996, 7 days before burning. undisturbed forest floor material was obtained from beneath a closed forest canopy 300 ft from the bum site, where pine basal area averaged 90 ft^2 per acre. The forest floor was typical of similar stand conditions found elsewhere in the South (Switzer and others 1979). To facilitate reconstruction on the bum bed, forest floor material was collected in three layers - L, upper F, and lower F - using 1.3 ft^2 sampling frames. The L layer refers to the litter layer consisting of unaltered dead remains of plants (Pritchett 1979). The fermentation (F) layer was immediately below the L layer and consisted of fragmented, partly decomposed organic materials that were sufficiently preserved to permit identification as to origin (Ptitchett 1979). For this experiment, the F layer was subdivided into upper and lower zones based on visual evidence of decay. The undisturbed L layer averaged 0.24 in. in thickness: the upper F layer averaged 0.18 in.; and the lower F layer averaged 0.65 in. Each layer was removed separately: then layers were transferred from the undisturbed forest floor in paper bags and reconstructed on the bum bed during the day of removal. Within the bum bed, a 3- by 5.2-ft interior plot was subdivided into twelve 1.3 ft^2 cells (replications) for placement of the reconstructed forest floor and blackberry fruits. A reconstructed forest floor ensured uniform fuel conditions for burning (Hunger-ford and others 1994) and uniform litter layers for placement of blackbeny fruits.

Fresh blackberry fruits for the study were obtained in late June 1996 from forested pine stands in southeastern Arkansas, north-central Louisiana, and southwest Mississippi. Fruits were collected from a minimum of 25 blackberry canes per geographic location. These fruits were air-dried on wire screen at room temperature from the time of collection until the burn date. For each replicated cell in the burn bed, 12 blackberry fruits were used, with four fruits taken from each of the three geographic areas. To relocate

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all fruits per treatment cell after burning, the fruits were glued at l-in. intervals onto fiberglass cord with high-temperature silicone. This process was done 24 hours before the scheduled burn to permit the glue to cure. At the time of burning, fruit moisture content averaged 16 percent (oven-dry basis).

Just before fire ignition, three fiberglass cords containing four blackberry fruits each were transferred to **the center of** 12 bum cells at one of three randomly assigned **litter depths** in the reconstructed forest floor. Fruits were **placed on the L** layer, at the upper-F and lower-F interface, or **at the lower-F** and mineral-soil interface (fig. 1).

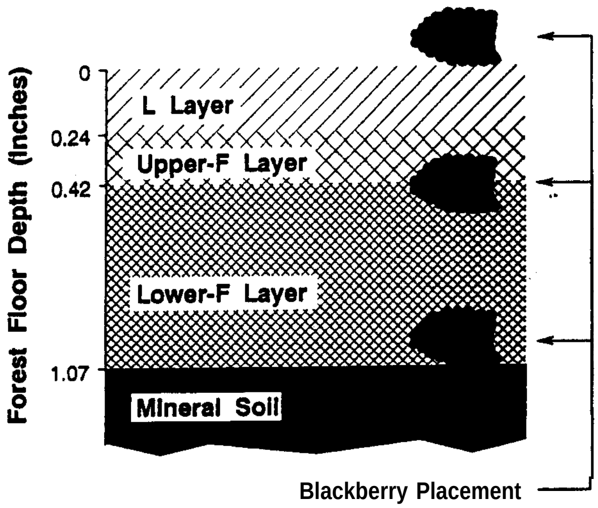

Figure l--Before prescribe burning, blackberry fruits were placed at three depths within the forest floor - on the L layer. within the **F layer,** and at the lower-f and mineral-soil interface.

Prescribed burning was conducted on July 8, 1996 **(table 1).** Wind for the simulated fire was provided from two **20-in.** electric box-fans positioned side-by-side **at ground level.** Fan-blade rotation was varied during burning **to maintain a** constant wind speed at the fire front. Fuel burned with the wind (headfire), and wind speed was determined **using an** electronic Turbo-Meter@ wind speed indicator. While burning was in progress, flame lengths were ocularly estimated to the nearest 0.5 ft. Fireline intensity was calculated from flame lengths (Byram 1959).

To accurately measure temperatures generated by the fire, Tempil® temperature indicator pellets with known melting points were placed atop the burning litter. The melting temperature for these pellets ranged from 119 to 1490 “F.

To determine fuel moisture, a separate 3-ft^2 subplot containing a reconstructed forest floor was set up **at the** bum site. Immediately after burning, three unburned **litter** samples were taken from this subplot within each **of the** three litter layers in proportion to the weight of **each layer.** Moisture determination was on an oven-dry basis. **After the** burn, four 1-ft^2 samples of residual litter were taken from within the burn bed to determine the weight of this unburned material on an oven-dry basis.

For each treatment (fruit location) and replication, blackberry fruits were removed from the fiberglass cords **after burning**

Table l-Fuel and weather conditions during a simulated prescribed summer bum in southeastern Arkansas

Fuel and weather variables	**Values**
Date of bum	**July 8, 1996**
Days since last precipitation	2
Amount of most recent precipitation (inches)	1.10
Time of burning (hours DST)	1,020
Dry bulb temperature (“F)	96
Relative humidity (percent)	49
Wind direction	**From the South**
Wind speed[a] (mph)	5.5
Forest floor moisture (percent)	
L layer[b]	**18**
Upper F	**16**
Lower F	**28**
Forest floor weight (tons/acre)	
L layer	**.9**
Upper F	**.7**
Lower F	**3.7**
Mean fire line intensity[c] (Btu/ft-sec)	**6.4**
Rate of spread (ft/min)	**3.2**

[a] Wind speed generated by two electric box fans positioned side-by-side at ground level.
[b] Fine-fuel moisture.
[c] $I = 5.67 L_f^{2.17}$, where L_f = **Ocular estimates of flame length.**

and placed in de-ionized water along with four replications of unburned control fruit to soak overnight. **After burning,** blackberry fruit recovery was **94 percent from the L layer, 98** percent from **the F layer, and 100 percent from the lower-**F/mineral-soil interface. Soaked fruits **were macerated by** hand in running tap water on **0.02-in.** sieves to **separate** seeds from the pulp. The pulp **mass was allowed to air dry** at room temperature overnight; then seeds **and pulp were** forced through **0.08-in.** sieves to remove the larger pulp. Percent germination was based on the number of sound blackberry seeds per replicate, which **was estimated from** air-dried weight of the fruit. The average air-dried fruit weighed 0.009 oz. There was an average of 7,560 seeds per oz of air-dried fruit with 89 percent of seeds being judged sound by float testing (Brinkman **1974). Residual** seeds and pulp were dispersed onto moist, sterile-sand flats for germination tests.

The germination phase of the study lasted **18** months during which six germination tests were conducted. From July through October **1996, 30-day** germination **tests alternated** with 30 days of stratification at 39 “F. Germination periods of 30 days each were retained through March 1997, but stratification time was increased to 60 days for the remainder of the study. From June through December **1997, 60-day** germination tests were used.

The first germination test was conducted without stratification using 10 hours of full-spectrum fluorescent light and 14 hours of darkness during each 24 hours. Light exposure during the remaining germination tests was increased to 16 hours per dav to simulate summer day length. Temperature in the germination room was maintained at 70 "F. Germination was considered complete when the radicle had emerged from the seedcoat and was at least 0.1 in. in length (Doucet and Cavers 1996).

The experiment was a randomized complete block design with four replications of three litter depths. Blocking was based on distance from the fans. Analysis of variance was used to compare germinative capacity of seeds relative to their location within the forest floor (SAS 1989). Germination percent was analyzed following arcsine square-root proportion transformation, but only nontransformed percentages are reported. Orthogonal contrasts were used to partition mean differences among seed locations within the forest floor as follows: $L+F_UF_L$ versus F_LS, and L versus F_UF_L (L is the L layer, F_U is the upper-F layer, F_L is the lower-F layer, and S is mineral soil). A second analysis of variance was used to compare the germinative capacity of seeds from the F_LS interface to that of unburned control seeds. Significance was accepted at the a = 0.05 probability level.

RESULTS AND DISCUSSION

The headfire completely traversed the bum bed, leaving no unburned gaps. Forest floor weight averaged 5.3 tons per acre before burning and 3.5 tons per acre after burning. Consequently, the fire consumed all of the L and upper-F layers and a portion of the lower-f layer. Subsequent germination of blackberry seeds varied directly with liir consumption. Blackberry fruits on the L layer and at the F_U/F_L interface were badly charred, yielding only 0.03 and 0.33 percent seed germination, respectively, during the next 18 months. Germinative capacity of blackberry seeds did not differ (P = 0.64) between these upper litter layers (table 2).

During the 18 months following the bum, cumulative germination of blackberry seeds from fruit placed at the lower-F/mineral-soil interface averaged 23.43 percent. This significant improvement (P <0.01) in seed germination over the mean from the L and upper-F/lower-F interface (table 2) was attributed to the heatshield provided by unburned litter at that lower depth. Moisture content of the lower F layer was 28 percent (table 1) at the time of burning, and residual forest floor litter weight after burning averaged 3.5 tons per acre. So, only 0.2 tons per acre of the lower F layer burned. Wade and Lunsford (1989) reported that when fine-fuel moisture approaches 30 percent, fires tend to bum slowly and irregularly, which may explain why litter at the lower depth did not bum in the present study. According to Alexander (1982). responses by minor vegetation following a fire are directly influenced by depth of the bum.

Table 2-Analysis of variance for germinative capacity of blackberry seeds by fruit location within the forest floor

Source of variation	Degrees of freedom	Mean square	P>F
Block	3	0.0074	0.38
Fruit location in the forest floor[a]	2	.2994	< .01
($L+F_uF_L$ vs F_LS	1)	.5973	< .01
(L vs F_uF_L	1)	.0015	.64
Error	6	.0061	

[a] L is the litter layer, F_uF_L is the upper-F/lower-F interface, and F_LS is the lower-F/mineral-soil interface,

During 18 months of germination cycles in this investigation, the mean germinative capacity of control seeds from unburned blackberry fruits averaged 23.49 percent. That proportion of germination was no different (P = 0.74, MSE = 0.0162, ANOVA not presented) than the 23.43 percent germination from seeds at the lower-F/mineral-soil interface. Cumulative germination for these two groups of seeds is illustrated in figure 2. Following each period of stratification, there was a pulse of germination from control seeds and seeds placed at the lower-F/mineral-soil interface. Within the first 300 days of germination testing, less than 5 percent of these seeds had germinated. Yet, within the next 200 days, seed germination increased by 20 percentage points (fig. 2). Similarly, Heit (1967) found that seeds from cultivated hybrid blackberries germinated over a period of several years without special treatment and maximum delayed germination was obtained in the third year.

At 184 days after the germination tests began, seeds at the lower-F/mineral-soil interface averaged somewhat better germination over unburned controls, and that trend continued for the next 300 days (fig. 2). However, t-tests comparing germination of those two groups for each germination date produced nonsignificant results (P >0.05). Still, the consistent trend toward more rapid germination suggests that heating blackberry fruit by fire might enhance seed germination.

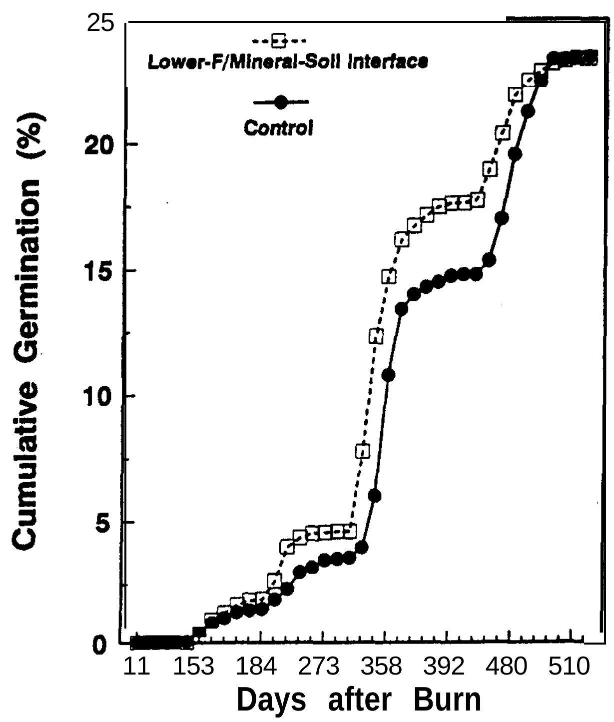

Figure 2—Cumulative germination of blackberry seeds taken from unburned control fruit and fruit placed at the lower-f and mineral-soil interface during a simulated prescribed summer bum.

In this experimental prescribed burn, blackberry fruit placed at the lower-F/mineral-soil interface (fig. 1) produced the highest germination of seeds, which did not differ from unburned control seeds. Viability of seeds at this depth was mainly attributed to the fact that the lower-f layer was not completely consumed by fire. Although killing of plant tissue has been reported to occur at about 120 °F (Davis 1959), both temperature and its duration are important. On these 7- by 5-ft beds, melting of Tempil® pellets indicated that temperatures ranged from 550 to 750 °F during this summer bum.

MANAGEMENT IMPLICATIONS

In operational prescribed winter bums (Cain 1993) conducted on sites similar to those described here, fireline intensities were greater (47 to 134 Btu per sec per ft), fine-fuel moisture was lower (6 to 15 percent) and wind speeds were higher (3 to 13 mph) than reported in the present simulated bum. Under those environmental conditions, it is unlikely that blackberry fruits with a moisture content of 16 percent will remain intact during prescribed bums if they are located on the litter layer or in the upper-F layer of the forest floor.

Whether heat pretreatment or cracking of the impermeable seedcoat by fire can enhance the establishment of blackberries from seed was not answered in this investigation because the air-dried blackberry fruits tended to be charred by the fire when placed in the upper litter layers of a forest floor, apparently destroying the seeds. In contrast, seeds from fresh blackberry fruits that are exposed to fire might exhibit an entirely different response, because the high moisture content of fresh fruit should protect seeds from complete consumption by fire. Operationally, such burning would be limited to a narrow window during late spring or early summer when blackberries ripen in the Southeastern U.S. Additionally, fruits eaten by animals may be embedded in an entirely different matrix, altering seed response to fire.

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