Potential Fire Effects on Seed Germination of Four Herbaceous Species

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ABSTRACT

Fire is a natural component of grasslands throughout the world, but information on the impact of fire on seed germination is lacking. Our objective was to determine the influence of different levels of heat on Johnsongrass (*Sorghum halepense*), Lamb's quarters (*Chenopodium album*), partridge pea (*Cassia chamaecrista*), and rough pigweed (*Amaranthus retroflexus*) seed germination under laboratory conditions. Seeds were heat-treated in 4 replicates for 120 seconds at 200, 400, 600, 800, and 1000°F, plus a control. Germination was determined on 100 randomly selected seeds of each species from each heat treatment and control replicates. None of the species had increased germination after being subjected to heat treatments when compared to controls. In all species, germination was reduced when treatment temperature reached 600°F, and germination was eliminated at 800 and 1000°F. Laboratory evaluations indicate the heat generated by prescribed fires is adequate to sterilize seed not buried below the soil surface. These responses support the general recommendation to burn during the winter dormant season to promote forbs for wildlife species by burning under cooler conditions to reduce heat damage to seeds of desirable plant species.

KEYWORDS: fire, Johnsongrass, Lamb's quarters, Northern bobwhite, partridge pea, prescribed burning, rough pigweed

Fire is a naturally occurring, historic component of grasslands throughout the world. However, due to fire suppression, the natural ecological impacts of fire can generally only be realized using prescribed fires. Much like prescribed fires today (Masters et al., 1993), historic fires likely increased seed production in grassland systems, providing additional germplasm for dispersal and winter food sources for granivorous birds such as the Northern bobwhite (*Colinus virginiana*). In Texas, prescribed fire has effectively reduced broadleaf herbaceous plants in some situations, and increased broadleaf herbaceous plants in other situations (Wright and Bailey, 1982). This has been generally attributed to timing of the fire in relation to seedling establishment. However, this reduction in broadleaf herbaceous plants may be a result of seed sterilization from the passing fire front. Although post-fire plant response has been thoroughly studied, information on direct heat impacts to seeds during burning is lacking, because field data are difficult to conduct and replicate.

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The temperature of grassland headfires at the mineral soil surface is a linear function of the amount of non-compacted fine fuel available for combustion (Wright and Bailey, 1982). Average soil surface temperatures of grass fires have been reported to vary from 215 to 730°F when fine fuel ranged from 1500 to 7000 lb/acre (Stinson and Wright, 1969). However, in monoculture grasslands, soil surface temperatures have been recorded as high as 1167 °F with weeping lovegrass (*Eragrostis curvula*) fine fuel loads of 4100 lb/acre (Rummel et al., 1999). Additionally, peak temperature in these fires occurred for 15 to 146 seconds with a maximum duration of 450 seconds.

Seeds are typically considered to be very tolerant to heat generated by burning because cellular material in the seeds is dormant and often dehydrated (Whelan, 1995). Seeds are often protected from direct heat during burning by burial in the soil, so seed banks accumulate in the soil, or in the canopy as serotinous cones or fruits (Keeley and Fotheringham, 1998). Some species, such as members of the families Cupressaceae and Fabaceae, exhibit increased seed germination following fire due to bradyspory or destruction of an impermeable seed coat (Whelan, 1995). Germination in some species may be fire-triggered by either heat shock or by combustion products such as smoke and charred wood (Keeley and Fotheringham, 1998). Grass species have been reported to tolerate temperatures of 180 to 240°F for up to 5 minutes (Sampson, 1944). However, little information is available on the impact of specific levels of heat on seed germination for plant species managed primarily for wildlife food sources. We hypothesized that lower levels of heat (i.e. 200°F), which simulate temperatures associated with fires occurring in low and medium (<2,000 lb/acre) fine fuel loads will promote seed germination, whereas higher levels of heat (i.e. 800 and 1000°F), simulating fires occurring in heavy (>4,000 lb/acre) fine fuel loads will inhibit seed germination of herbaceous species. Our objective was to determine the influence of different levels of heat on the germination of Johnsongrass (*Sorghum halepense*), Lamb's quarters (*Chenopodium album*), partridge pea (*Cassia chamaecrista*), and rough pigweed (*Amaranthus retroflexus*) seeds under laboratory conditions. These species were selected because they represent common sources of food for Northern bobwhite throughout much of the central U.S. (Dimmick, 1992).

MATERIALS AND METHODS

This laboratory study was conducted in 1998 at Texas Tech University. Single seed lots of each species were acquired from a commercial vendor. Four replicates of 0.18 oz of each species were placed in porcelain crucibles. The 0.18 oz sample of each species was heat-treated for 120 seconds at 200, 400, 600, 800, and 1000°F. These temperatures were chosen to represent the spectrum of temperatures likely to occur at the soil surface in grassland fires. Heat treatments were applied independently to the four replicates in an electric muffle furnace (Thermolyne Type 30400 Furnace). Temperatures were recorded at 15 second intervals to determine average temperatures for each treatment. Upon removal from the muffle furnace, seeds were emptied into individual trays to prevent potential seed damage from the residual heat of the crucibles. Four replicates of each species received no heat treatment and were maintained at room temperature (68 - 72°F) as controls.

Following heat treatment, seed germinability was determined by placing 100 seeds of each species from each heat treatment and control replicate into separate germination dishes lined with blotter paper. Approximately 1 oz of a solution of 2% KNO_3 and 1% captan ([N-[(trichloromethyl)-thio]-4-cyclohexene-1,2-dicarboximide}, a fungicide, were added to each dish. Dishes were stored at 40°F for 14 days to break seed dormancy

(Crosier, 1970), then placed in a germination chamber where temperature and light alternated from 68 and 86°F for 16 (dark) and 8 (light) h, respectively. A seed was considered to have germinated when the radicle emerged through the seed coat. The number of germinated seeds in each germination dish were counted, recorded, and discarded at 2 to 3-day intervals for 28 days.

The experiment was conducted as a completely random design with 4 replicates per treatment. A one-way analysis of variance was used to determine the influence of heat on seed germination. Treatment means were considered different at $\alpha=0.05$ (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Temperature was well controlled during all heat treatments. Average temperatures ($\bar{x}$ ± SE) for the 120 second treatment period were 199.85 ± 1.42, 398.08 ± 0.39, 596.75 ± 2.26, 792.28 ± 2.18, and 993.20 ± 5.71°F for the 200, 400, 600, 800, and 1000 °F temperature treatments, respectively. At the 800 °F treatment, the seeds on the surface of the crucible began to smolder, and at 1000 °F, the seeds on the surface of the crucible combusted. However, we had no problem randomly selecting 100 non-combusted seeds for germination.

None of the four species had increased germination after being subjected to heat treatments when compared to seeds stored at room temperature (Fig. 1). The lack of seed germination increase at 200°F failed to support our hypothesis that this low temperature treatment would increase germination, particularly in the hard-seeded partridgepea. In all species, seed germination was significantly reduced when treatment temperature reached 600°F, and germination was eliminated at 800 and 1000°F (Fig. 1). This elimination of germination at 800 and 1000°F supported our hypothesis that germination would be reduced at the highest temperatures.

In Johnsongrass, no differences in germination occurred among the control and treatment at 200 and 400°F. Average germination of seeds stored at room temperature and treated at 200°F was 52%, and seeds treated at 400°F was 52.75%, which is within the range of germination reported by Egley (1990). However, when the treatment temperature was elevated to 600°F, Johnsongrass seed germination was reduced to 16.75%, a value only 32% of the germination in the control seeds.

In Lamb's quarters, germination decreased with each increase in temperature from the control, to 200, 400, and 600°F (Fig. 1). However, germination at 600, 800, and 1000°F were similar, and were not different from 0% germination. Germination of seeds stored at room temperature was 19.25% and declined linearly ($r^2 = 0.98$) as temperature increased to 600°F. Lamb=s quarters seed germination was 13.25, 9.75, and 1.5% at 200, 400, and 600°F, respectively. Germination declined by an average of 57% for each 200 °F increase in temperature.

Partridgepea seed germination was lower than all other species in the seeds stored at room temperature, and averaged only 14% (Fig. 1), which is consistent with previous germination research on Cassia species (Martin et al., 1975). Partridgepea seed germination declined in a manner similar to Lamb's quarters, but germination was not different among the control, 200, and 400°F (Fig. 1). However, germination at 600°F was lower than the control. Only 6.5, 6.25, and 1.5% of partridgepea seeds germinated at 200, 400, and 600°F, respectively.

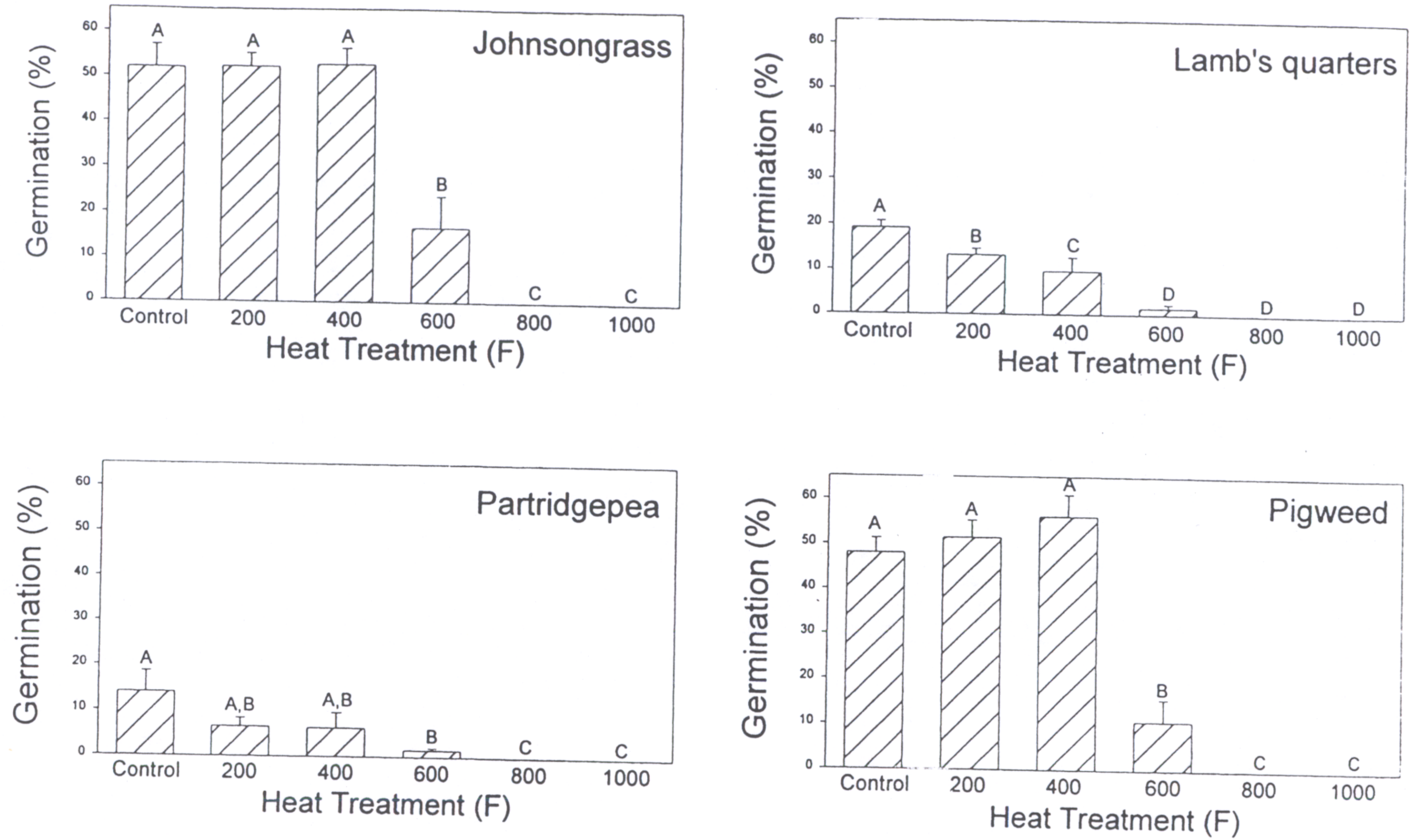

Figure 1. Mean germination ($\bar{x}$ ± SE) response of Johnsongrass, lamb's quarters, partridge pea, and pigweed treated for 120 seconds at 200, 400, 600, 800, and 1000°F, and controls. Different letters over bars indicate differences among treatments within a seed species ($P < 0.05$).

Pigweed seed germination responded to temperature increases similar to Johnsongrass (Fig. 1). In pigweed, no differences in germination occurred between the control and treatment at 200 and 400°F. Average germination of pigweed seeds stored at room temperature was 48%, which is higher than the 13% reported by Zahnley and Fitch (1941). Average germination of seeds treated at 200°F was 51.5%, and seeds treated at 400°F was 56.25%. However, as in Johnsongrass, when the treatment temperature was elevated to 600°F, pigweed seed germination was reduced to 10.75%, 22% of the germination in the control seeds.

Four species of herbaceous plants, 1 grass and 3 forbs, were subjected to heat treatments. Heat treatments did not increase seed germination in any of the species. Laboratory evaluations indicate the heat generated by prescribed fires is adequate to sterilize seed not buried below the soil surface. Although we did not directly simulate the conditions of fires in the field, the temperatures and duration we evaluated approximate those present in grassland fires at the soil surface. These responses support the general recommendation to burn during the winter dormant season to promote forbs for wildlife species such as Northern bobwhite by burning under cooler conditions to reduce heat damage to seeds of desirable plant species. Additionally, by burning in early winter, seeds have not yet germinated so seedlings will not be exposed to heat.

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