# Reducing Invasion by Targeting Vulnerable Life Stages: Effects of Fire on Survivorship of *Lespedeza cuneata*

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**Abstract.** There is growing interest in whether invasive species may be controlled by targeting key life stages. In this study, I test whether fire applied at potentially vulnerable life stages can increase mortality and limit the spread of the invasive legume, sericea. Although laboratory experiments indicated that fire inflicted extremely high mortality on sericea seeds, fire enhanced germination rates in the field suggesting that seeds may be protected from fire by mixing with soil. Furthermore, fire had little effect on seedling survival even for very young plants. This suggests that sericea seedlings may quickly reach a size from which they are capable of resprouting. These results illustrate that, although certain life stages are presumed to be vulnerable to disturbance, such untested assumptions can result in unanticipated outcomes due to interactions between biotic and abiotic factors.

**Introduction.** All invaders possess unique characteristics that allow successful invasion into native ecosystems. Despite such differences, all species share key demographic features such as survivorship, growth rate, and fecundity [1] that, coupled with transitions between key life stages, may offer an opportunity to utilize management practices targeting vulnerable life stages of invasive species in order to reduce invasion success [2, 3]. Fire is a common management tool in grasslands as it typically favors native species which are adapted to burning. Although some problematic invaders are able to resprout following fire, presumably during colonization, these species could potentially be vulnerable to fire at the seed or seedling stage. In this study, I examine the possibility that the timing of prescribed burns may be utilized to induce mortality by targeting potentially vulnerable life stages of the model invasive legume sericea (*Lespedeza cuneata* ([Dum.-Cours.] G. Don)).

In this study, I addressed the following questions: 1) Does fire have suppressive or facilitative effects on sericea recruitment? 2) Is this suppressive or facilitative effect on sericea recruitment due to changes in seed germination or seedling survivorship? 3) At what size or life stage does sericea become insensitive to burning? To test these ideas, I manipulated the timing of prescribed burns to quantify the probability of mortality on sericea plants of different ages under field conditions. In addition, I quantified the germination rates of sericea seeds under different burning conditions in the lab.

**Methods.** In March 2010, ninety 1 x 1 m plots were arrayed in a grid with 0.5 m between plots in a restored prairie located in NE Kansas. Nine burn and seed addition treatment combinations were replicated ten times and arranged in a randomized, complete block design to account for underlying spatial variability. Sericea seed were sown into the six burn treatments in each block as well as an unburned control at a rate of 4000 seeds per $m^2$. The timing of burns was manipulated so that each block contained plots burned on 21 April, 25 May, 21 June, 21 July, and 4 September of the first growing season (2010) and 21 April of the second growing season (2011). Within each burned plot, a prairie burn was simulated using a propane torch to ignite the vegetation. The target temperature of the burns was 350 to 400°C. Temperature was monitored using temperature-sensitive paint applied to aluminum strips that were placed within the plot prior to the burn. Each block also contained an unseeded control that was burned on 21 April, 2010, and an unseeded, unburned control.

Plots were monitored until sericea germinants were positively identified on 14 April, 2010. Cohorts throughout the first growing season were established to quantify the effect of burning on plants of different ages. Every twenty days throughout the growing season, up to four sericea seedlings were randomly selected and marked with metal rings in each plot. To maintain cohort discreteness, all unmarked seedlings within plots were pulled every ten days to ensure that each marked seedling was no more than ten days old.

A laboratory burn experiment was conducted to test how fire, light, or litter influenced sericea germination rates. Four burn treatments were utilized to determine whether burning the seed, soil or litter influenced germination responses to fire: seed burned with litter on soil, soil and litter burned followed by seed addition, seed burned and then added to unburned soil in the absence of litter, and unburned soil and seed in the absence of litter. All treatments were replicated 12 times in a fully crossed design. The burns were conducted in an aluminum tray with a propane torch that mimicked the field burn with target temperatures of 350 to 400°C, which were monitored with temperature-sensitive paint applied to aluminum strips. In addition to burning, light availability was also manipulated corresponding to burned (100%) or unburned (38% of full light) field plots by covering the trays with 60% shade cloth. Sieved soil collected from the field site was added to 25 x 25 x 4 cm trays with transparent covers and 100 sericea seeds were added to each treatment. Prior to sowing, seeds were cold-stratified by placing the trays in a freezer for two weeks after the seed additions and burns to simulate overwintering. During the germination trials, trays were watered daily and germination was recorded after 17 days.

**Results/Discussion.** For the field experiment, multiple regression analysis revealed that sericea survivorship was dependent on plant age combined with the timing of burn. However, this relationship explained only a small amount of the variation in sericea survivorship ($R^2$ = 0.093, $P$ = 0.032, $F_{2, 150}$ = 7.69). The timing of burns had strong effects on cumulative germination through April of the second growing season ($F_{6, 54}$ = 6.27, $P$ < 0.0001). Cumulative germination (mean number of seedlings per plot) of plots burned in April of the first growing season ( $\bar{x}$ = 155.2 $\pm$ 18.3), May ( $\bar{x}$ = 193.6 $\pm$ 26.8), June ( $\bar{x}$ = 177.9 $\pm$ 30.8), July ( $\bar{x}$ = 196.1 $\pm$ 35.2), and September ( $\bar{x}$ = 186.7 $\pm$ 25.9) of the first growing season were similar to each other and higher than the unburned control. In contrast, cumulative germination in the unburned control ( $\bar{x}$ = 77.5 $\pm$ 9.3) was similar to the cumulative germination of those plots burned in April of the second growing season ( $\bar{x}$ = 89.9 $\pm$ 12.4).

Under laboratory conditions, a reduction from 100% to 40% light availability had very little effect on sericea germination rate ($F_{1, 77}$ = 0.80, $P$ = 0.37). The various burn treatments, however, had an extremely large effect on germination rate ($F_{3, 77}$ = 423, $P$ < 0.0001). Germination rates of unburned seeds added to burned soil and litter ( $\bar{x}$ = 80.3% $\pm$ 2.3) did not significantly differ from the unburned control ( $\bar{x}$ = 78.3% $\pm$ 3.5). In contrast, when soil, litter, and seed were burned, germination rates were substantially lower ( $\bar{x}$ = 9.5% $\pm$ 1.4) than unburned controls and seed only burned treatments were significantly lower ( $\bar{x}$ = 0.46% $\pm$ 0.21) than all other treatments.

Although fire reduced sericea survivorship in the field burn, this reduction in invasion success was mitigated by enhanced cumulative germination in burned plots. Enhanced germination following burns was surprising given that, in the lab burn, fire greatly reduced germination suggesting that seed-soil mixing in the field likely protects sericea seed from fire. Additionally, laboratory assays indicated that seed viability was unexpectedly high compared to those found in the field [4], which may explain reports of persistent seed banks in sericea [5, 6] that repopulate stands eradicated by herbicides. These results illustrate how complex interactions among biotic and abiotic factors complicate potentially detrimental effects of managed disturbance that target specific life stages of invaders.

**Conclusion.** Fire inflicted high mortality rates on sericea seed in the laboratory but had minimal effect on the survivorship of sericea seedlings in the field. This discrepancy, coupled with the flush in sericea germination following the burns under field conditions, illustrates that careful experiments are necessary before employing management strategies that target presumably vulnerable life stages of invasive species.

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