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Burning Modifies Composition of Emergent Seedlings in Fescue Prairie☆

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ABSTRACT

Fire plays a crucial role in mediating species composition in Fescue Prairie. However, previous studies focused on responses of plant community to burning without disentangling the effects of burning on seedling emergence in Fescue Prairie. In this study, seedlings emerging in the field and from soil seed banks incubated in a greenhouse were examined after burning in the spring of 2012 and 2013 near Saskatoon, Canada. Soil seed bank samples were taken from the top 5 cm of the soil profile, separated into litter, 0- to 1-cm soil, and 1- to 5-cm soil layers. In the 2-yr field study, 11 plant families with 1 graminoid and 22 nongraminoids were identified among emerged seedlings. Burning significantly increased the number of 3 native and 1 non-native seedlings emerging, as well as total seedlings emerging from the field in both years ($P < 0.05$). Species richness and diversity of seedlings emerging from the field were increased by burning. Species composition of emerged seedlings from the field was significantly altered by burning in 2012 ($P = 0.03$) and 2013 ($P < 0.01$). In the 2-yr soil seed bank study, 19 plant families with 10 graminoids and 56 nongraminoids emerged. Burning had more prominent effects on seedling density of native species and forbs, rather than non-native species and graminoids. Species composition was altered by burning in all studied soil layers ($P < 0.05$). Fire appears to stimulate recruitment of some species, especially early seral species, contributing to potential changes in species composition of the Fescue Prairie.

Introduction

Fescue Prairie, found largely in central and southwestern Alberta and west central Saskatchewan (Coupland and Brayshaw, 1953), has been shown to be a fire-tolerant ecosystem. As a natural disturbance, fire plays a crucial role in mediating community composition in Fescue Prairie (Romo, 2003; Gross and Romo, 2010). Effects of burning vary among functional groups and generally favor the establishment of perennial forbs in Fescue Prairie (Anderson and Bailey, 1980). Regeneration after burning in grasslands occurs with vegetative reproduction (resprouters) and seedling emergence from seeds (seeders) (Paula and Pausas, 2008). Fire is a selective force in grasslands, leading to high germination and seedling establishment immediately after burning (Keeley et al., 2012). Although it has been well known that different fire regimes, including fire severity (Wright, 1971), frequency (Anderson and Bailey, 1980), and seasonality (Bailey and Anderson, 1978) mediate species composition in Fescue Prairie, it is not clear how seedling establishment alters species composition after burning.

Broadly, burning effects on seed germination and seedling emergence can be divided into direct and indirect effects (Santana et al., 2013). Direct effects include heat shock, ash, and smoke produced by burning. While burning kills many viable seeds in the litter layer due to high temperature and flame on the soil surface (Anderson and Bailey, 1980; Archibold et al., 1998), heat shock may break seed dormancy, especially physical dormancy, and stimulate germination of seeds buried in the soil (Shea et al., 1979; Warcup, 1980). It has been well established that plant-derived smoke can break seed dormancy and stimulate germination (Dixon et al., 1995; Nelson et al., 2012). Germination of different species can be increased, decreased, or unaffected by ash (Sweeney, 1956; Enright et al., 1997; Zuloaga-Aguilar et al., 2011). Among indirect effects, burning increases temperature fluctuation, light, and nutrient availability but reduces soil water content that, in turn, influences germination and seedling emergence (Walck et al., 2011). Archibold et al. (2003) tested effects of spring, summer, and autumn burns on modifying microenvironmental conditions in Fescue Prairie. Temperature at the 1-cm soil depth exceeded 40°C during a summer burn but was not affected during spring and autumn burns. Surface albedos dropped to 0.03 from 0.27 immediately after burning. Spring, summer, and autumn burns reduced winter snowpack by 36%, 53%, and 67%, respectively, as compared with the control.

As an immediate source of recruitment after disturbance, soil seed banks play a significant role in determining the composition of plant communities (Leck et al., 1989). Various fire-related factors have been shown to exert effects on seed germination and seedling emergence of soil-stored seeds from a range of vegetation types worldwide (Roche et al., 1997). Some researchers have focused on the effects of specific fire-related factors, such as heat and smoke, on seedling emergence

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from the soil seed banks (Izhaki et al., 2000; Ghebrehiwot et al., 2012), others studied the overall impact of burning (Cespedes et al., 2012). Responses of seedling emergence to different fire cues are species dependent (Van De Venter and Esterhuizen, 1988). Burning history and seasons of burning modified species richness, diversity, and composition of seedlings emerging from the soil seed bank in Fescue Prairie (Romo and Gross, 2011).

Most studies have focused on plant community responses to burning without disentangling the vegetative regeneration and seedling emergence responses in Fescue Prairie. While seeds buried in the soil seed bank exhibit the potential capability of new seedling recruitment in the habitat, seedling emergence in the field is mediated by multiple factors, such as temperature, light, moisture, nutrition, and species interactions. The objective of our study was to determine the effects of burning on seedling emergence in Fescue Prairie. The following hypotheses were tested: 1) In comparison with indirect effect, direct effect of burning plays a more important role in modifying the density, composition, and emergence rate of seedlings from the field in Fescue Prairie; 2) burning favors species density and richness of forbs and native species emerging from soil seed banks; and 3) effects of burning on density and composition of seedlings emerging from the soil seed bank vary among different soil profile depths.

Material and Methods

Study Site

Field studies were conducted at the University of Saskatchewan's Kernen Prairie in 2012 and 2013. Kernen Prairie is near Saskatoon, SK, Canada (lat 52°10′N, long 106°33′W, elevation 510 m) and approximately 130 ha in size. The long-term annual temperature averages 2.2°C (Environment Canada, 2013), while the long-term average growing season (May, June, July, and August) temperatures are 11.5°C, 16.0°C, 18.2°C, and 17.3°C, respectively (Environment Canada, 2013). The long-term annual precipitation averages 350 mm, with more than half of it received during May to August (Environment Canada, 2013). Kernen Prairie is a C3 plant — dominated grassland with *Fescuta hallii* Vasey as its principal graminoid (Coupland and Brayshaw, 1953). Soils in Kernen Prairie are Bradwell and Sutherland Orthic Dark Brown Chernozems (Acton and Ellis, 1978). The growing season has approximately 110 frost-free days (Gross and Romo, 2010).

Experimental Design

An area approximately 45 × 30 m in size, where the vegetation community was representative of the Fescue Prairie, was chosen for field studies in 2012 and 2013. This study site was burned in 1986 and 1997 and lightly grazed by cows during growing seasons between 2006 and 2011. In total, 150 experimental plots measuring 3 × 3 m were established on 17 April 2012. Among the 75 plots established for study in 2012 and 2013, respectively, 25 were untreated controls; 25 were mowed to a 2-cm stubble height with plant material removed by raking; and 25 were burned with headfires. Mowing was used to test whether defoliation created similar microenvironmental conditions as burning, representing the indirect effects caused by burning. The experimental design was a randomized-complete-block design (RCBD) with 25 replicates within each year. Each block contained control, mowed, and burned treatments. Plots were mowed or burned individually on 17 April 2012 or 4 May 2013. Seedling emergence was determined in a 1 × 1 m subplot in the center of each plot that was set up immediately after burning and mowing. After species identification, new seedlings were pulled gently from the soil to confirm they were coming from the seeds.

Data Collection

Fire temperatures during burning were recorded using pyrometers, as described by Wally et al. (2006). Twenty-four lacquers manufactured to melt at specific temperatures (Tempil Division, Big Three Industries Inc., South Plainfield, NJ), ranging from 66°C to 704°C, were painted on oval copper tags. After drying, another copper tag was used to sandwich the painted surface and these two tags were linked by gauge wire. The longer edge of each pyrometer was placed in contact with the soil surface when recording fire temperatures. Fire temperatures were estimated by recording the highest temperature-threshold lacquer that was melted. Three subsamples were used for recording fire temperatures in each burned plot.

Immediately after burning and mowing, soil temperatures at the 2-cm depth were recorded hourly using a Campbell Scientific 21X data logger (21X micrologger, Campbell Scientific, Logan, UT). Temperature probes were installed in 10 plots for each of the three treatments during each study year. Volumetric soil water content at 0- to 12-cm soil depth was determined with a CD620 hydrosense system (Campbell Scientific) at weekly intervals with three subsamples in each plot. In 2013, light intensity was determined with an AccuPAR LP-80 system (Decagon Devices, Pullman, WA) measured weekly with three subsamples in each plot. Emerged seedlings were marked with colored paper clips at weekly intervals from the first week after treatment until 14 and 12 wk in 2012 and 2013, respectively. Marked seedlings were allowed to grow to the stage when they could be identified to species. Numbers of seedlings that could not be identified before they died were recorded. At the end of the growing season, seedlings that could not be identified in the field were transplanted to a greenhouse and grown until identification was possible.

Soil Seed Bank Study

Twenty-five 25-cm^2 soil core samples were collected at a 5-cm depth in each of the 25 burned plots in 2012 and 2013 before and immediately after burning, which were regarded as control and burning treatments, respectively, for the soil seed bank study. These soil core samples were taken from outside of the 1 × 1 subplot used to determine seedling emergence. Each soil core sample was cut into litter, 0- to 1-cm soil, and 1- to 5-cm soil layers in the laboratory and air-dried for 1 wk. The reason why we separated soil core samples into three layers was due to the different effects of fire on the seeds within each layer. For example, fire kills most of the viable seeds in the litter layer (Anderson and Bailey, 1980). The heat produced by fire causes no significant temperature change at soil depth >1 cm (Archibold et al., 2003). Common layers of the 25 soil core samples from the same plot that belonged to the same treatment were combined, mixed, and spread in plastic trays. Root fragments, rhizomes, and plant materials were removed. The depth of soil in each tray was kept <1 cm. The litter layer was put on a 1-cm thickness of sterile sand spread on the bottom of a plastic tray to hold water. Trays holding soil core samples of control and burning treatments from the same plot, including litter, 0- to 1-cm, and 1- to 5-cm layers, were put together as one block. Because there were 25 plots in the field for each year, in total, there were 25 blocks for the soil seed bank study in 2012 and 2013, respectively. Trays within blocks were randomly placed on benches in a greenhouse. Air temperature during the growing season in the greenhouse averaged 27 ± 3°C during the day and 21 ± 4°C at night. Natural light was supplemented with two 400-W, high-pressure sodium lights (18-h photoperiod, average of 600 μmol/m^2/s) for each bench. All trays were watered daily. Seedling emergence was recorded weekly for 14 wk, and new seedlings were transplanted to pots until they could be identified. In total, seedling emergence data from five layers (litter layer, 0- to 1-cm depth, 1- to 5-cm depth, 0- to 5-cm depth, and all layers combined [litter layer plus 0- to 5-cm depth soil layer]) were analyzed.

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