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Effects of Burning and Canopy Density on Seedling Growth in an Iowa Oak/Hickory Forest

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Abstract

In areas like central Iowa that are dominated by prairie, forests have not received the study they deserve. We examined the effects of late fall burning and canopy density on a variety of representative tree species' seedlings in the upland White Oak forest of the Conard Environmental Research Area (CERA). The number, diameter, and height of seedlings was estimated in annually burned and unburned experimental plots. Significant findings included a lack of Quercus alba *(White Oak) seedlings in all plots and an extremely low seedling density of all species in burned plots. We also found a negative correlation between canopy density and height among* Carya cordiformis*, and a negative correlation between diameter and canopy density among Ulmus spp. and* Juglans nigra. *Due to the few seedlings in burned plots, it was impossible to compare plant diameter or height between burned and unburned plots. A better understanding of how factors such as frequency of burn and interactions between seedling species affect the role of fire in the forest is needed, especially in light of the present use of fire in conservation and forest maintenance.*

Introduction

Although a considerable amount of forested land has been set aside in North America for conservation and experimental purposes, there is still a need for development of effective forest management strategies. One proposed method of forest maintenance is prescribed burning, which affects the growth of tree seedlings and saplings. Burning clears the soil surface of litter and leads to increased soil temperature, creating optimal conditions for tree seedling growth (Ehrenreich & Aikman 1963). Depending on the type of forest and the frequency of burning, fire can also act as a stabilizing factor by maintaining species composition and abundance (Anderson & Brown 1986). Finally, if burning does not occur for a protracted amount of time, litter accumulates to such an extent that when a fire starts, it burns with enough intensity to damage the canopy structure (Anderson & Brown 1986.)

This study examines the effects of annual prescribed burning and varying canopy density on seedling height, density and diameter in the upland White Oak forest at the Conard Environmental Research Center (CERA) near Kellogg, Iowa. The species examined are *Carya cordiformis* (Bitternut Hickory), *Ulmus americana* and *Ulmus nigra* (American and Slippery Elm), *Celtis occidentalis* (Northern Hackberry), *Juglans nigra* (Black Walnut) and *Quercus alba* (White Oak) many of which are indicator species for the common White Oak forests of North America (Kricher, 1988).

Not all of these species are equally tolerant of fire. For example, species in the *Quercus* family will resprout following burn damage (Peterson & Reich 2001), while species with thin bark such as *Carya cordiformis* do not resprout as easily (Smith 2003). Another important factor that affects the growth of seedlings is canopy density, which determines the amount of sunlight that reaches seedlings and affects stand height (Chazdon 1999).

Methods

The data were collected between October 4th and November 10th, 2004 in the experimental plots in the upland White Oak forest at CERA. The plots extend between the open prairie and a river. There are ten annually burned plots and nine unburned plots measuring 25 by 25 meters square. The plots, which have been burned since 1997, are generally burned in November, but during some years the plots were burned in April, December, January or February. They are arranged in rows of two or three plots, in an alternating burn pattern (see Figure 1).

To examine the seedlings in each plot, we marked off a circle with a 5m radius in the center of each plot and surveyed the seedlings in the circle. Seedlings were defined as trees measuring between 10 and 150 cm high. By taking our samples from the center of each plot, we controlled for the edge effects that occur because burn lines are raked on the edges of the plots before burning each year. We recorded the species,

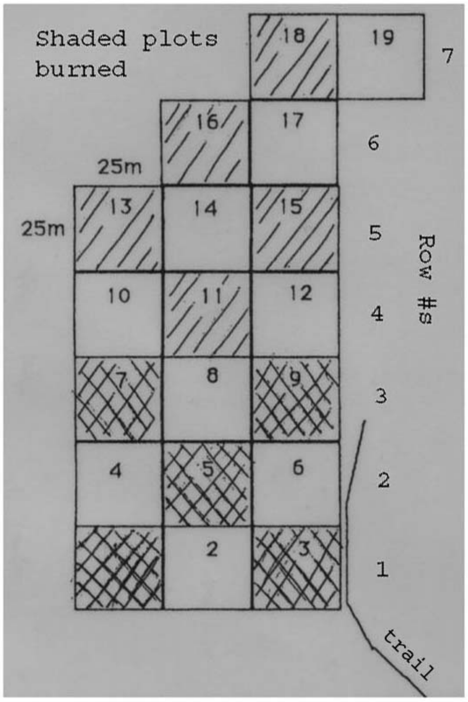

Fig. 1: CERA oak forest plot layout.

height, and diameter of every seedling in the circle, but we did not measure seedlings that were attached to mature trees. We measured the diameter of the main stem of each seedling at a height of 10cm from the soil using calipers. On October 13th we measured the canopy density, or percent of the canopy covered by foliage and branches, at the center of each plot using a hand-held densitometer. We used t-tests to compare burned vs. unburned plots for mean height, diameter, density, burn treatment, and canopy density for each species. We also examined the correlation between these measure and canopy density in unburned plots (due to limited data in burned plots).

Results

The plots contained *Carya cordiformis* (Bitternut Hickory), *Ulmus americana* and *Ulmus nigra* (American and Slippery Elm), *Celtis occidentalis* (Northern Hackberry), *Juglans nigra* (Black Walnut) and *Quercus alba* (White Oak) seedlings. Because of the similarity between *U. americana* and *U. nigra*, we were unable to tell them apart once the leaves had fallen off, so the two species are grouped together in our data and will hereafter be referred to as *Ulmus*. We also eliminated *Q. alba* from the data analysis because we only found two individual seedlings in all of the plots surveyed.

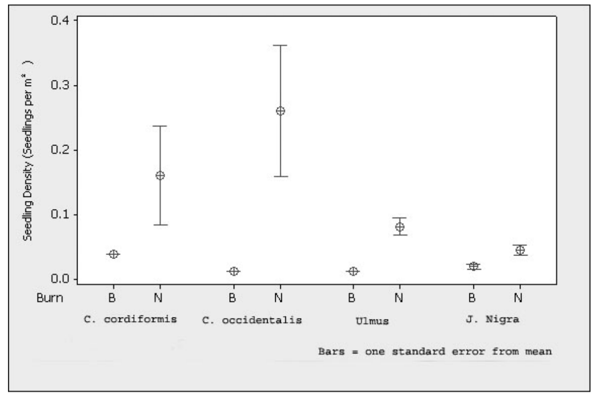

Fig. 2: Density of C. cordiformis, C. occidentalis, Ulmus, J. Nigra for burned versus unburned plots.

We then compared the heights, diameters, and densities of each species in the burned and unburned plots using t-tests. For all species, the unburned plots had significantly higher seedling density (see Fig. 2). The seedling densities in burned plots were similarly low for all species, but the density of *C. occidentalis* in unburned plots was significantly higher than that of both the *Ulmus* species and *J. nigra*. The density of *C. cordiformis* in unburned plots was significantly greater than that of *J. nigra*, as well.

We did not have sufficient data regarding seedling height and diameter in burned for a comparison with seedling height and diameter in unburned. However, we did find a strong positive correlation between canopy cover and row number ($r = 0.795$; $p = 0.000$). This indicates that the plot rows that were further from the prairie (with higher row numbers) generally had a greater percentage of canopy cover. Using ANCOVA, we removed the influence of row number on canopy density and found that canopy density for unburned plots was on average lower than for burned plots ($p = 0.016$).

C. cordiformis height had significant negative correlation with canopy cover ($r = -0.794$; $p = 0.019$). The average heights of *J. nigra, Ulmus* and *C. occidentalis* had no significant correlation with canopy cover. *Ulmus* diameter displayed a significant negative correlation with canopy cover ($r = -0.669$; $p = 0.035$), and *J. nigra* diameter was also negatively correlated, but only marginally so ($r = -0.539$; $p = 0.087$). Results for average diameter of the other species were not significant.

We also found general trends between the relative number of each species and the percentage of canopy cover. There were many more individual *C. occidentalis* seedlings in areas of greater percent cover (see figure 3). There was

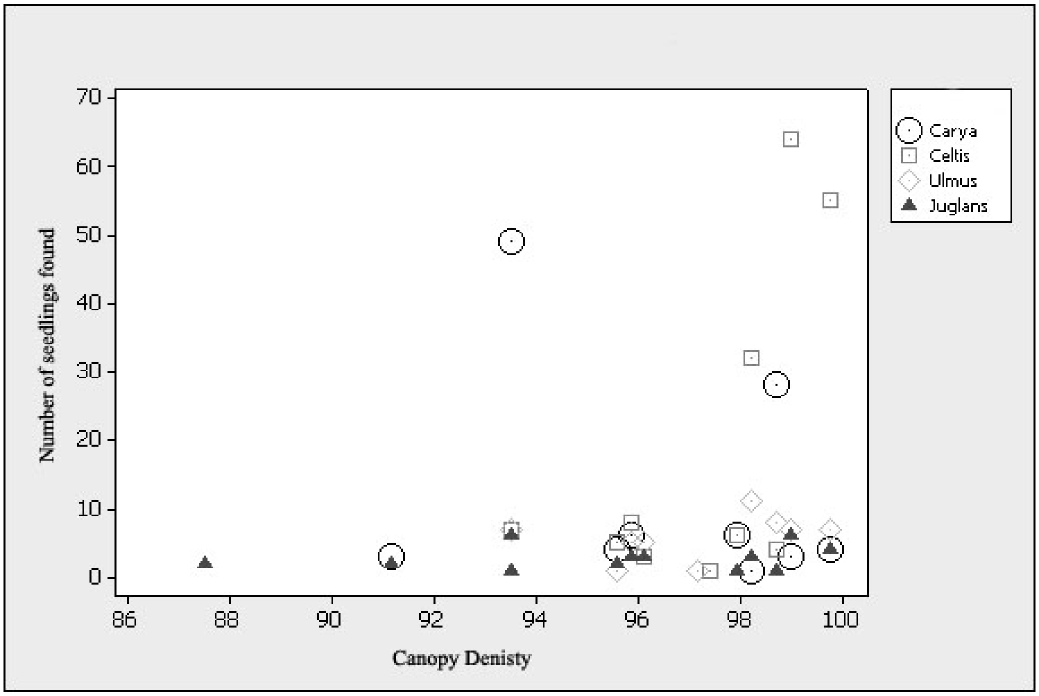

Fig. 3: Density of: C. cordiformis, C. occidentalis, Ulmus, J. nigra vs. canopy density.

no clear trend relating numbers of *J. nigra*, *C. cordiformis,* or *Ulmus* seedlings with changes in percent cover. We did not perform this type of analysis on the data from the burned plots or the data for *Q. alba*, as there was not sufficient data.

Discussion

Our most striking finding was the extreme paucity of *Q. alba* seedlings, despite the number of mature trees of this species in the plots. In our survey of all nineteen plots, were found only two *Q. alba* seedlings (these two were in unburned plots) and no other types of *Quercus*. Typically, research shows *Q. alba* is more fire-resistant than the other species we sampled, and even tends to dominate in areas with frequent fire (Crow et al., 1994), so it is improbable that burning caused the dearth of this species. The region near CERA has a high population of white-tailed deer, which are known to prefer *Q. alba* seedling and acorns (Strole & Anderson, 1992). Furthermore, deer are known to eat twigs and leaves from the lower branches of mature trees, which has been proven to decrease acorn production throughout the whole tree (Hochwender et al., 2003). We surmise that these two effects combine to significantly reduce the amount of *Q. alba* seedlings in both burned and unburned plots. Also, in the unburned plots, the suppression of fire could have played a role in reducing the amount of *Q. alba* seedlings. Studies have shown that fire creates an optimal seedbed for *Q. alba*s' acorns by increasing sunlight to the forest floor and suppressing other species, so the *Q. alba* acorns may have been at an even greater disadvantage in the unburned plots than in the burned plots (Abrams, 2003).

Our finding that the annually burned plots had virtually no seedlings when compared with the unburned plots is consistent with many studies. For example, in Briggs' study of woody plants in a tallgrass prairie, tree species remained all but absent in the annually burned areas (Briggs et al., 2002). The same suppression of seedlings held true for an oak savanna burned at least thrice per decade (Peterson & Reich 2001). The species we studies are known to be susceptible to fire damage. *C. occidentalis* has thin bark and is thus susceptible to burning. It can resprout after fires, but it can only survive if fires are absent for a long time (Briggs et al., 2002). Ulmus species are also known to resprout vigorously after burning, which explains how they can survive when burned annually (Briggs et al., 2002).

Our discovery of a gradient in canopy density across plots allowed us to evaluate effects of light levels in growth of species in unburned plots. When significant, all correlations were negative. For example, *J. nigra,* whose diameter was negatively correlated with percent cover, is reported in other studies to be intolerant of heavy shade (Fewless, 2001). The *Ulmus* diameters had a negative correlation with canopy density, which is consistent with relationships found shading and and size of this species by Parker & Leopold (1983). *C. cordiformis* likewise has been found to be intolerant of shade (Smith 2004), although our data did not support this.

The finding that canopy cover was affected by annual burning was our most surprising finding. Other studies of frequency of burning and forest composition have found that biennial burning decreased canopy cover (Peterson & Reich 2001). If burning does decrease canopy density, increased light levels should increase growth for these shade intolerant species, perhaps compensating somewhat for the negative effects of fire on density. However, *annual* burning may be too frequent to allow seedling survival and should therefore not be used as a forest management technique.

Although our data did reveal significant trends, our sampling method may not have been ideal for surveying this forest. One study suggests that long, narrow rectangular quadrats are more effective than circular areas for collecting data because they control for natural clustering and variance of tree seedlings (Lindsey 1955). Our study could be replicated using this sampling method in order to obtain more representative data and thus draw stronger conclusions about the effects of burning and canopy density on seedlings.

There is some existing research on the effects of burning and canopy density on tree species in forests like the one in CERA, which occur near a prairie. However, there are still numerous opportunities for future research. One general direction for further study would be to investigate how *C. cordiformis*, *U. americana* and *U. nigra*, *C. occidentalis, J. nigra* and *Quercus alba* grow and affect each other when they occur together in a forest. Another possibility would be to investigate how the combined effects of annual burning and canopy density affect the seedlings of these species, knowledge of which should lead to better methods of forest conservation.

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