Effects of Fire on Different Size Individuals of *Schinus terebinthifolius*

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ABSTRACT: *Schinus terebinthifolius* (Brazilian pepper) has become an aggressive, woody weed in southern Florida, displacing native vegetation and rapidly invading disturbed sites. Fire is one of several management options for control of this exotic pest plant. This study began in 1979 to evaluate the effect of fire on different size individuals of *S. terebinthifolius*. Fifty study plots were established to monitor changes in numbers and size of *S. terebinthifolius* stems, height and width of *S. terebinthifolius* canopy, and percent cover of fine fuels (grasses) under each plant. Sites (containing several plots each) were burned as often as fuel conditions permitted (usually once every two years) through 1985. The original size of the plant was related to the amount of fuel available around the plant, larger plants having less fuel. Smaller, recently established plants were severely retarded in growth or killed from the burning, while larger plants either rapidly recovered from less severe burning or did not burn at all, thus continuing to increase in size. The results suggest that fire is effective in controlling smaller, younger trees with heavy fuel accumulations around them, but that even repeated burning will not prevent the invasion of *S. terebinthifolius* into large areas.

INTRODUCTION

The remarkable vegetation and flora of southern Florida have fascinated scientists and naturalists since the discovery of the region and were a primary reason for the establishment of Everglades National Park (ENP). One cause of this fascination is the presence of a high percentage of West Indian species in the south Florida flora. Of approximately 1600 species of vascular plants in Dade, Monroe, and Collier counties, Florida, 60 to 70 percent are in taxonomic groups that have centers of distribution in the tropics (Small 1904, Long 1974, Little 1978, Tomlinson 1980). Another noteworthy feature of the south Florida flora is the rather high degree of local endemism: approximately 65 taxa are endemic to southern Florida (Davis 1943, Alexander and Crook 1975, Loope and Avery 1979). Everglades National Park at present contains an example of south Florida's original flora and vegetation. About 830 vascular plant species have been recorded, including about one-half of the species endemic to south Florida and numerous other rare plant species.

Plant communities and individual taxa of south Florida have proved extremely vulnerable to disturbance from human activities. Although the area was settled late compared to most eastern states, and was in a near pristine condition prior to 1900, changes occurred rapidly in the early decades of the twentieth century (Small 1929). This deterioration has continued with the expansion of agricultural and urban use of the land, artificial drainage, wildfires, and the introduction of exotic species. One exotic species of major concern is *Schinus terebinthifolius* (Brazilian pepper), a woody shrub (to small tree) from South America. It is already heavily invading (or on the verge of doing so) several native plant communities (particularly coastal and mesic prairies and pineland) as well as 2000 hectares of former agricultural rockplowed land known as the "Hole-in-the-Donut" (Figure 1) within ENP. *S. terebinthifolius* was introduced into southern Florida around 1900 as an ornamental, and was spread throughout the region by frugivorous birds.

This study used prescribed spring season fires to evaluate the potential of regular burning to control the invasion of *S. terebinthifolius* into large areas where mechanical or chemical treatment of individual stems is not practical. These areas include the "Hole-in-the-Donut," a 2000-ha area of disturbed substrates created by intensive farming where *S. terebinthifolius* stem densities of up to 11,355 stems/ha have been recorded (Doren and Whiteaker 1990). Fire was considered because of its effect in maintaining early successional seres in many native plant communities within Everglades National Park (Chaikin 1952, Lotti 1956, Ferguson 1957, Hughes and Knox 1964, Bender and Cooper 1968, Grano 1970, Landgon 1971, Grenlen 1975, Lewis and Harshbarger 1976, and Wade et al. 1980) and because it is relatively easy and inexpensive to use. Previous work by

Loope and Dunevitz (1981) showed that *S. terebinthifolius* within the pinelands of ENP is largely excluded by fire. The purpose of this study was to examine the effects of repeated burning on individual *S. terebinthifolius* plants to determine if prescribed fire promotes the replacement of *S. terebinthifolius* by herbaceous, graminoid vegetation on the disturbed substrates created by farming.

STUDY AREA

The study area is located in the extreme southern everglades in Everglades National Park, Ranges 36 and 37 East, Township 58 South in Dade County, Florida (Figure 1). The natural features and vegetation of the area have been described by Davis (1943), Egler (1952), Robertson (1955), Craighead (1971), Alexander and Crook (1973), Hilsenbeck (1976), Wade et al. (1980), and Krauss (1987). Soils were mapped and described by the U.S Department of Agriculture (1958). The study area is within the "Hole-in-the-Donut" (Figure 2). Postfarming successional associations have been described by Ewel et al. (1982) and Krauss (1987).

METHODS

The burn study was conducted using 50 1-m² permanent plots. Each plot was located in areas where *S. terebinthifolius* and grass

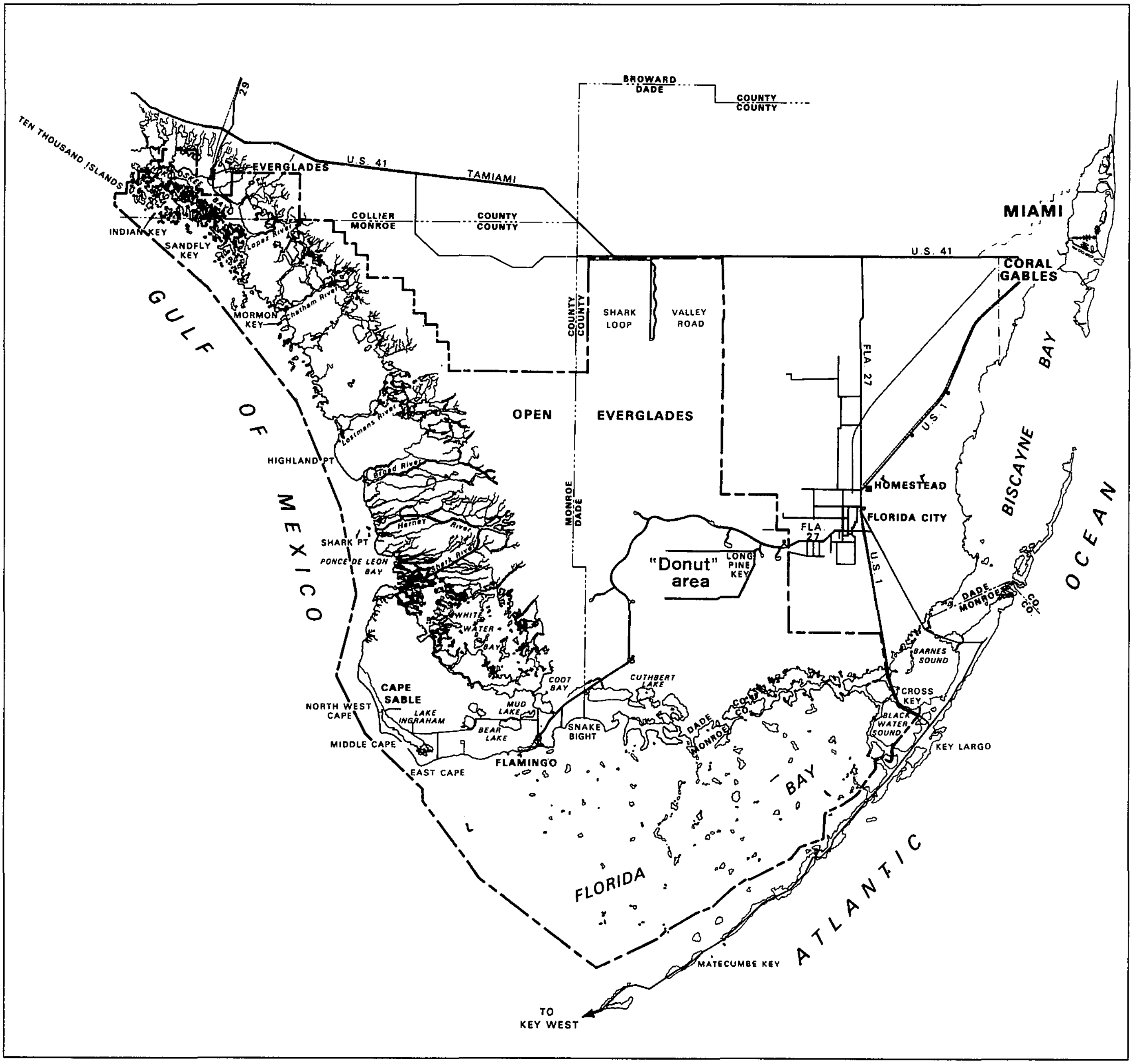

FIGURE 1. Map of southern Florida indicating Everglades National Park and the "Hole-in-the-Donut" area.

fuels, primarily paragrass (*Brachiaria mutica*) interfaced. These areas were chosen because they were the only locations with sufficient accumulations of fine fuels to carry fire. In the "Hole-in-the-Donut," stands of *S. terebinthifolius* mixed with occasional individuals of other hardwood species do not burn under normal conditions because of high live fuel moisture and a lack of fine fuels. Plots were selected to have only one individual per plot (presence or absence of seedlings was not a selection criterion) and were centered around each tree. Specific size criteria were not used for initial tree selection. However, trees in a range of sizes and locations were selected, so that the variation in tree sizes within each site could be sampled. The following information was collected: plot number; percent cover paragrass; percent cover other grasses; number stems each of *Ludwigia* spp., *Baccharis halimifolia*, *S. terebinthifolius*, and other hardwoods. Stems were tabulated in five different size classes: <1 cm bd (basal diameter), ≥1<2.5 cm bd, ≥2.5<5.0 cm bd, ≥5.0<10 cm bd, ≥10 cm bd. The number of *S. terebinthifolius* seedlings was recorded and the height and canopy width of the individual *S. terebinthifolius* in each plot were measured. Burn results were recorded for each 1-m² plot using the following burn classes: 2 = completely burned, 1 = partially burned, 0 = essentially no burn. Over the full term of the study, sites were combined into three groups: plots that burned completely every year (All Burn), individual plots that either burned partially or burned less than every year (Differential Burn), and plots that never burned (Never Burn). Burn treatments on the areas surrounding the *S. terebinthifolius* plots were attempted each year, but these generally burned only every two years when fine fuels had accumulated enough to carry a fire. Burning was conducted during the late spring lightning season using backing (moving into the wind) fires.

Backing fires were employed because they consumed essentially 100 percent of the fine fuels present. Head fires were tried on several preliminary burns but were discontinued in favor of backing fires. Conclusions in the fire reports indicate that head fires consistently left 25 to 30 percent of the fine fuels unburned (Everglades National Park fire records). This appears to be due to the high percentage of live fine fuels (approximately 50 to 60 percent) and an average live fine fuel moisture of 68 percent. The dead fine fuel moisture averaged 16 percent. The proportion of live to dead fine fuels in paragrass is higher than that found in south Florida's native prairie grasses (Herndon and Taylor 1986); and nonvolatile live fuels (such as *Muhlenbergia capillaris* (Lam.) Trin. and *Brachiaria mutica*) are considered heat sinks (Burgan 1979).

Differences between the All Burn, Differential Burn, and Never Burn groups were tested using the t-test for unpaired plots (Freese 1962).

RESULTS

Graphs of average height, average width, and total number of stems of *S. terebinthifolius* for all plots over time show that each of these variables increased over the course of this study (Figure 3). When average height and average width of *S. terebinthifolius* are plotted by burn category (Figure 4), plots that were in the All Burn category show no change in these two variables over the five years, while those in the Never Burn and Differential Burn categories show increases in these two variables, which are reflected in the graph for all plots (Figure 3). Additionally, individual trees in the All Burn category were significantly smaller (P<0.5) at the beginning of the study than trees in the other two categories (Figure 4 and Table 1). Trees in the All Burn category also had significantly more fuel

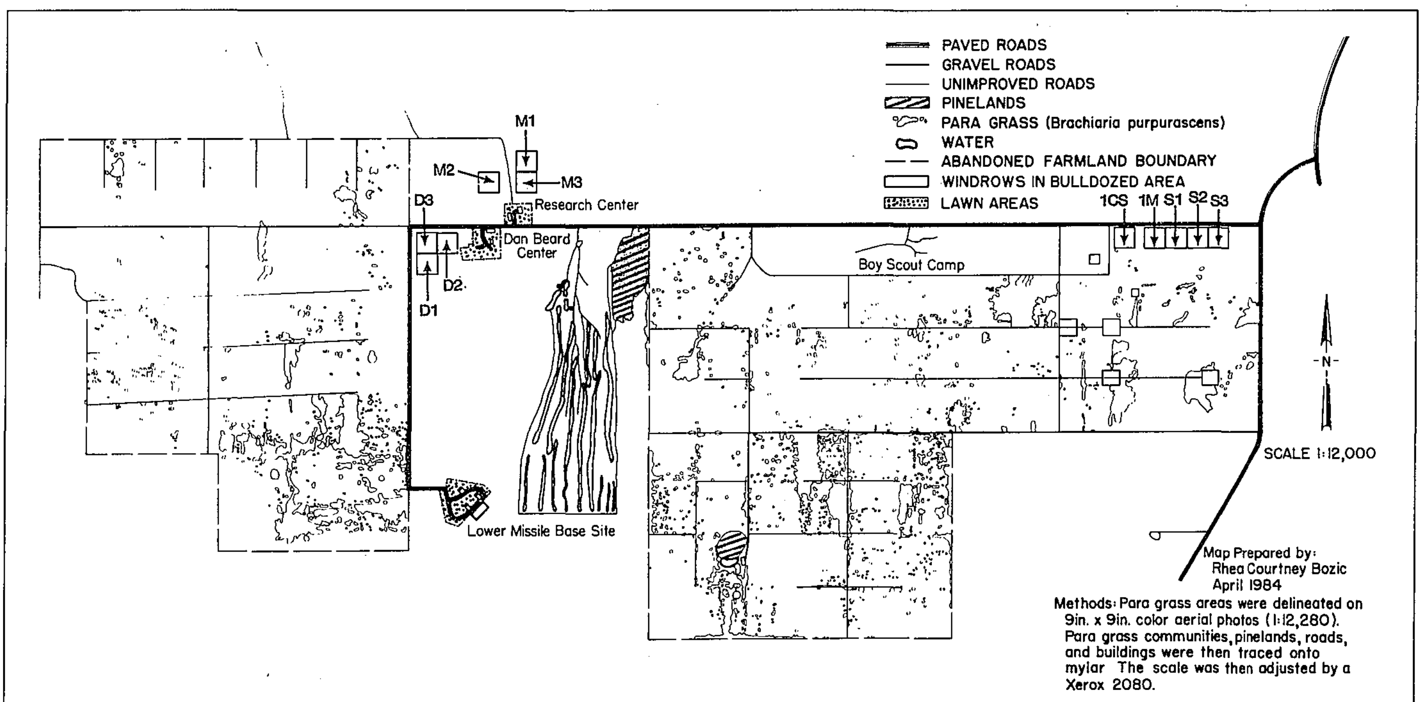

FIGURE 2. "Hole-in-the-Donut" map indicating study transects (A, B, C, D, E, and control (L); transects shown larger than scale).

TABLE 1. Comparison of probabilities (t-test for unpaired plots) of no difference between the All Burn, Never Burn, and Differential Burn groups, comparing tree height, canopy width, and grass cover before burning was initiated.

Variable	All/Never	Never/Differential	All/Differential
Height	0.001	0.2	0.001
Width	0.001	0.5	0.001
Grass Cover	0.05	0.5	0.02

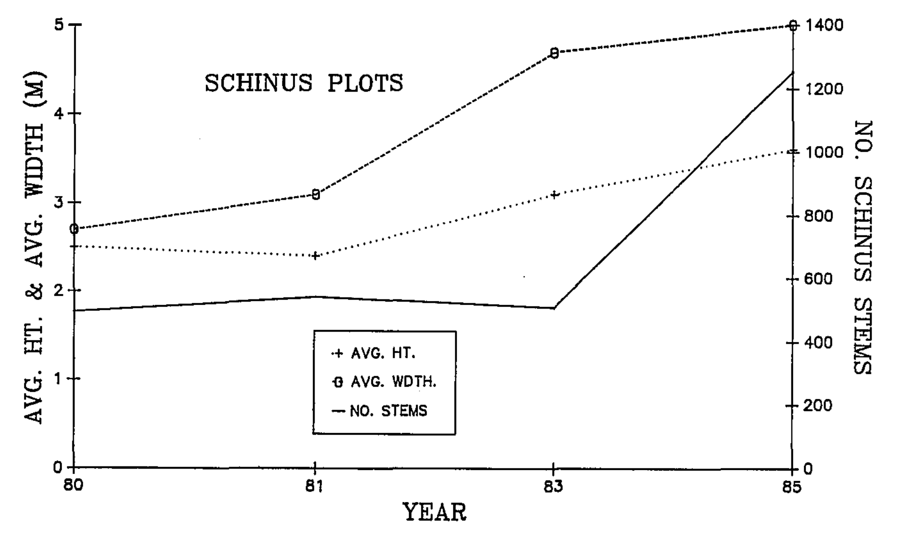

FIGURE 3. Plot of the average height and width, and number of stems of *S. terebinthifolius*, by year, combining all fifty plots.

around them initially (Figure 5 and Table 1) when compared with fuel amounts in the other two categories (Figures 6 and 7 and Table 1). Fuels initially present showed a decreasing trend in total amount from the All Burn plots through the Differential Burn plots to the Never Burn plots (Figures 5, 6, and 7 respectively).

Plots of numbers of *S. terebinthifolius* stems by size class for all burn categories combined show that four out of five size classes increased in number of stems over the five years of this study (Figure 8). Only the ≥1 <2.5 cm size class showed a decrease in number of stems. The number of stems of *S. terebinthifolius* for all size classes decreased in the All Burn category (Figure 5) during the course of this study. One size class (≥1 <2.5 cm) went from zero stems at the beginning of the study to one stem at the end of the study, but that was down from a high of six stems in 1981. Paragrass in these plots showed no overall change in cover during this same period (Figure 5). Two size classes (≥5 <10 cm and ≥10 cm) never occurred in All Burn plots.

The number of *S. terebinthifolius* stems by size class for Differential Burn and Never Burn plots both show overall increases in the number of stems for four out of five size classes (Figures 6 and 7). Only the ≥1 <2.5 cm size class had a decrease in number of stems. Overall, the canopy height and width and percent of grass cover for the Differential Burn and Never Burn categories, in 1980, was significantly different (P<0.5) from the All Burn plots (Table 1). Paragrass decreased slightly in cover during the study in both categories, and was significantly less abundant initially when compared with the All Burn plots (Figures 5, 6, and 7 and Table 1). The Differential Burn and Never Burn plots were not significantly different when comparing tree height, canopy width, and grass (fuel) cover using the t-test for unpaired plots (Freese 1962).

DISCUSSION AND CONCLUSIONS

Data from all 50 *S. terebinthifolius* plots show increases in total number of stems, average height, and average width of the plants sampled. The increases in these variables indicate that most *S. terebinthifolius* individuals continued to grow in spite of the burning treatment. In general, therefore, we conclude that repeated burning does not retard or reduce the growth of individual *S. terebinthifolius* trees on abandoned farmland.

However, when the stem data for all plots is plotted by size class (Figure 8), one size class (≥1 <2.5 cm) decreased in number over the period of study. If this decrease is considered to be a result of only repeated burning, then a long-term treatment effect on individual *S. terebinthifolius* trees might be expected. However, the increase in number of stems in the larger size classes had to result from recruitment from smaller size classes, including the ≥1 <2.5 cm size class; this size class is likely to grow in the future as a result of recruitment from the <1 cm stems, which increased in number in 1985. Therefore, these data do not conflict with our general conclusion.

We considered whether effectiveness of fire type (head or backing) and resulting intensity might have been a significant factor in our results. However, the type of fire used (i.e., the intensity) has not been considered as important as season when the goal is hardwood kill (Ferguson 1957, Bender and Cooper 1968, Platt et al. 1988a, 1988b).

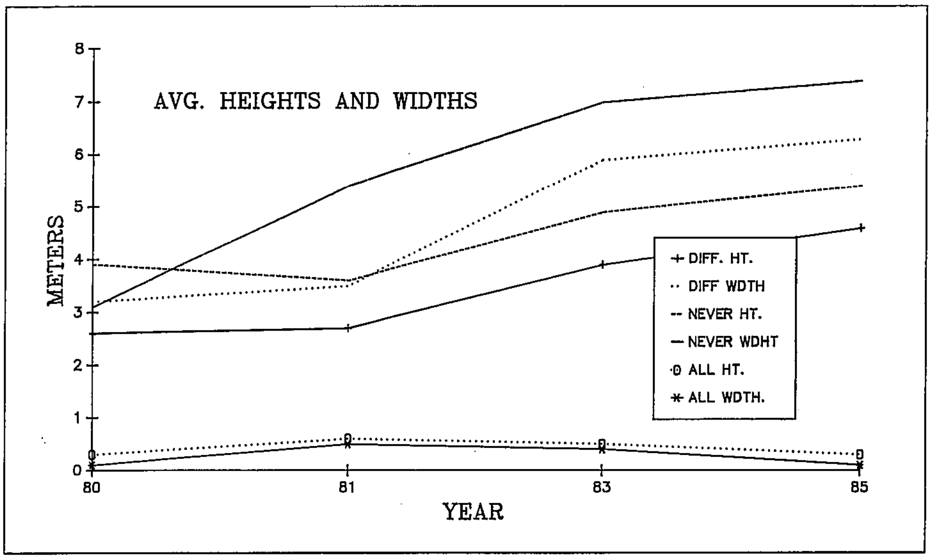

FIGURE 4. Plot of the average heights and widths of *S. terebinthifolius* trees by burn group (All = burned completely every year, Diff. = either did not burn completely or did not burn every year, Never = never burned).

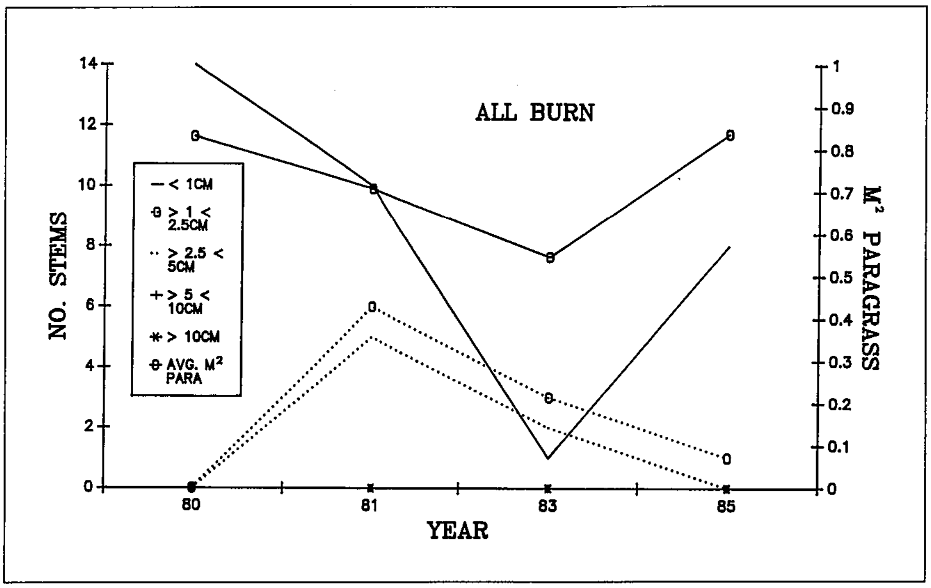

FIGURE 5. Plot comparing the number of *S. terebinthifolius* stems by size class with the average square meters of paragrass cover by year for only the All Burn plots.

Since intensity is measured as kw/m² (absolute heat released per unit area) and kw/m/sec (heat released per unit of flaming front over time) (Deeming et al. 1977, Nelson 1980), the backing fires used in this study (when compared with trial head fires) burned more fuel and moved more slowly, releasing more heat per unit area through time than the head fires would have done.

Lightning season fires, especially spring fires (Platt 1988a, 1988b), have been considered most effective in suppression of hardwoods (Chaikin 1952, Lotti 1956, Ferguson 1957, Hughes and Knox 1964, Bender and Cooper 1968, Grano 1970, Landgon 1971, Grenlen 1975, and Lewis and Harshbarger 1976). We therefore conclude that fire intensity and season of burn were optimum for the objectives of this study.

When plots are further classified by category of burn frequency during the period of study, a relationship between initial size of the individual *S. terebinthifolius* plants, frequency of burning, and total amount of fuel can be seen (Figures 4, 5, 6, and 7 and Table 1). The All Burn plots initially contained significantly smaller plants and more fuel than the other two groups (Figures 4 and 5 and Table 1). Also, these smaller stems decreased in total number, while the average height and average width showed no significant change (Figure 4 and 5 and Table 1).

These data support the results of Loope and Dunevitz (1981), which showed that many smaller (<1 m tall) *S. terebinthifolius* individuals are killed by fire. However, it has been shown that fire cannot prevent *S. terebinthifolius* from spreading over larger areas (Loope and Dunevitz 1981), particularly on the disturbed substrate in the "Hole-in-the-Donut" (Doren et al. in press). Even in these small plots, <1 cm stems increased in overall number between 1983 and 1985, which indicates that *S. terebinthifolius* will not be removed or excluded to any significant extent from these sites by even frequent burning.

Further, initial cover of paragrass averaged more than 75 percent in plots that always burned, which was greater than ($P<0.5$) the other plots (Table 1, Figure 5). Paragrass provided the large amount and rapid accumulation of fine fuels needed to support frequent burning. However, Doren et al. (in press) found that over larger areas—which presumably take in more of the community dynamics—fire does not promote the expansion of paragrass or other grasses in the "Hole-in-the-Donut." On sites that lack the coverage of paragrass, less frequent fires can be expected and the individual *S. terebinthifolius* will be less affected because they will have time to grow to a size at which they are relatively resistant to fire. The inability of repeated burning to exclude the invasion of this exotic plant is largely due to the differential behavior of fire over the relatively large areas that need to be managed: all areas do not burn in every burn event (Doren et al. in press). Therefore, it cannot be expected that individual *S. terebinthifolius* in areas that are repeatedly burned will show the negative effects exhibited by trees in the All Burn plots of this study. Once *S. tere-*

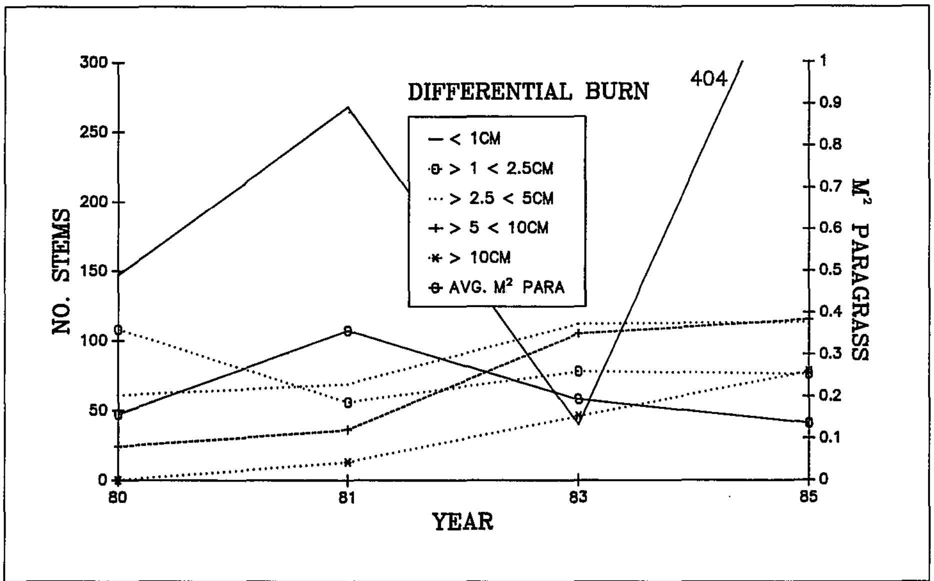

FIGURE 6. Plot comparing the number of *S. terebinthifolius* stems by size class with the average square meters of paragrass cover by year for only the Differential Burn plots.

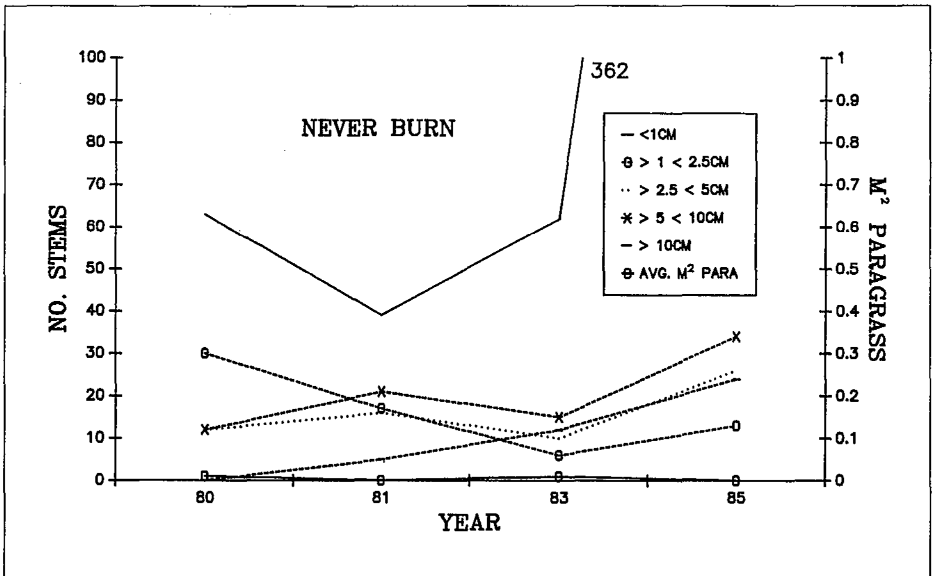

FIGURE 7. Plot comparing the number of *S. terebinthifolius* stems by size class with the average square meters of paragrass cover by year for only the Never Burn plots.

binthifolius reaches a certain size, even in areas with heavy fuel accumulations, the amount of fuel adjacent to an individual seems to be significantly reduced (Table 1), thus reducing the ability of fire to affect it (Loope and Dunevitz 1981, Doren et al. in press).

In summary, we generally found that repeated burning does not retard or reduce the growth of individual *S. terebinthifolius* trees. However, some smaller individuals showed negative treatment effects if very frequent burning was supported by large amounts of rapidly accumulating fine fuels. Even these trees showed some indications of growth (increase in the number of <1 cm stems) by the end of the study. This implies that the growth of even some of these smaller trees was merely retarded and they will not be eliminated on these sites. Further, significant reduction would occur only under these special fuel conditions, not over the larger areas or the total extent of the various plant communities invaded by *S. terebinthifolius*.

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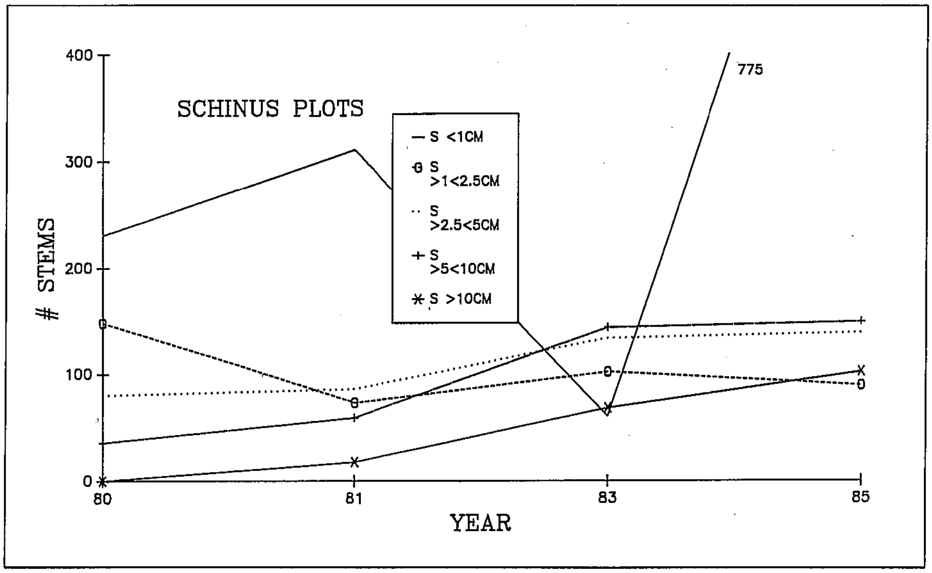

FIGURE 8. Plot of *S. terebinthifolius* stems by size class by year for all fifty plots.

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