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# GROWTH RESPONSE OF MARITIME PINE (*PINUS PINASTER*) TREES TO HIGH-INTENSITY PRESCRIBED FIRE

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## ABSTRACT

A study was undertaken to examine the consequences of relatively intense prescribed burns on tree growth. Two experimental fires were conducted up-slope and with the wind in maritime pine stands of Northern Portugal. Crown damage descriptors were measured at the individual-tree level, and radial and height increments of the surviving trees and nearby control trees were taken for three years after the fire.

Only minor and often statistically non-significant differences were detected when comparing tree growth in the burned and unburned plots. The effect of crown scorch severity was not clearly related with postburn growth, which seemed to depend more of prefire growth rate. The results are consistent with the high fire-resistance of maritime pine reported by previous studies and allow the expansion of the current burning prescription range.

**Keywords**: Prescribed burning, Fire effects; Tree growth, Crown scorch, *Pinus pinaster*, Maritime pine, Portugal.

# INTRODUCTION

Research over the last years has shown that prescribed burning is an efficient, harmless and cost-effective way to reduce hazardous fuel accumulations in southern Europe forests.

Because trees can be physically damaged by fire, minimization of the negative effects on tree health and growth is one of the major concerns when designing fire prescriptions. Crown scorch and bole damage are commonly used as fire injury criteria (e.g. Martin 1963, Van Wagner 1973, Peterson & Ryan 1986, Ryan & Amman 1993). Crown scorch occurs as a result of flame and convective heat concentration underneath the live crown, with the level of damage depending on the amount of heat received from the combustion zone.

The physiological effects of fire have been related to crown scorch (e.g. Wade & Johansen 1986, Peterson & Ryan 1986, Rigolot el al. 1994). As might be expected, tree growth can be adversely affected by partial defoliation. The removal of leaf area reduces the source of assimilates, changes transpiration patterns and water use efficiency, and unbalances the photosynthesis-to-respiration ratio (Chambers et al. 1986, Ryan 1993). However, tree efficiency can be improved by the elimination of unproductive lower branches by fire (Villarubia & Chambers 1978). Indirect benefits of precribed burning upon pine growth can result from decreased competition with the understory vegetation (Grisson 1985) and stand stocking reduction (Mitchell et al. 1983, Grisson 1985, Wade and Johansen 1986). Soil nutrient availability (Landsberg et al. 1984, Reinhardt & Ryan 1988, Rego 1986) and water regime changes (Rego et al. 1990) following fire are also likely to play a role in tree development.

Both increases (Johansen 1974, Wyant et al. 1983, Lilieholm & Hu 1987) and decreases (Landsberg et al. 1984, Johansen & Wade 1987, Ryan 1993) in pine growth rate after prescribed fire are reported in the literature. Landsberg (1993) summarizes the highly variable and often contradictory results of a large number of studys on this subject, and concludes that such divergent findings can be attributed to differences in site and tree species, type and season of fire, burning conditions and postburn stresses.

The growth of maritime pine (*Pinus pinaster*) trees in mature (Rego 1986) and young (Botelho 1996) stands is not affected by low-intensity prescribed fire. Opportunities for prescribed underburning in Mediterranean Europe could be expanded by including headfire as an alternative ignition technique, similarly to what is currently performed elsewhere (e.g. Woodman & Rawson 1982). However, those fires would necessarily be more intense, and could result in unaceptable tree damage and thus jeopardize the successful application of prescribed fire. Maritime pine mortality caused by intense prescribed fire was previously examined and modelled (Botelho et al. 1996) and is now followed by the analysis of postburn growth, in order to appraise the extent of losses in both tree diameter and heigth increment.

## METHODS

The experimental fires were conducted in two plantations of *Pinus pinaster*, respectively aged 20 and 18 years and located at Sevivas and Tinhela in Serra da Padrela, northern Portugal. One plot was burned at each local and control plots were established in similar conditions near the burned plots. Dimension descriptors of 30 trees per plot were measured before fire; since tree mortality attained 20% on each site (13% within the first and second postburn years), the annual growth of 24 trees per burned plot (plus an equal number of control trees) was monitored for three years after the fires.

Fuel, wind speed, fire behaviour and overstory fire effects descriptors were measured or estimated at the individual tree level. A full description of data, methodologies and results concerning preburn conditions, fire behaviour and fuel reduction is given in Botelho et al. (1996). The burns were carried up-slope with the wind. Estimated fireline intensities at the tree level varied in the ranges 94-1499 and 44-2369 kW $m^{-1}$, for Tinhela and Sevivas, respectively.

Diameter over bark at breast height (1.30 m) and tree height of each tree were measured before (1994) and after fire (1997) in the burned plots (Sevivas and Tinhela) and in their controls (TSevivas and TTinhela). Radial and height growth annual increments were measured in trees from burned and unburned plots. After the 1997 growing season, cores were extracted from 24 trees in each plot. The width of the last preburn (1994) growth ring and those of the years after fire (1995, 1996, 1997) were measured to determine radial growth. The annual apical elongation was measured to determine height growth. Those measurements were made using respectively a micrometer (to the nearest 0.01 mm) and an hipsometer (to the nearest 0.1 m).

Two weeks after the fires scorch height was measured to evaluate crown damage using ratio of crown scorched (RCs) (Wyant et al. 1986) and fraction of scorched crown volume

(Ck) (Peterson & Ryan 1986) as descriptors. Scorched crown volume was also visual estimated (Csv) (Ryan & Reinhardt 1988).

Relative increments in radial and height growth were calculated to account for differences in annual growth:

$$RGrij = \frac{idmij\ (burnt)}{idmij\ (control)} \qquad HGrij = \frac{ihmij\ (burnt)}{ihmij\ (control)}$$

where RGr is radial growth rate (mm), HGr is height growth rate (m), idm is mean radial growth increment (mm), ihm is mean height growth increment (m), i is the year and j is the site. Data was analyzed as a function of the relative growth increments, calculated for the year before fire and for the following three years. Analysis of variance and mean comparison with controls were used to explain postfire tree growth.

## RESULTS AND DISCUSSION

The temperature at a given height of a fire's convection column depends on the intensity of the heat source, the ambient temperature and the wind speed (Van Wagner 1973). However, fireline intensity at the individual tree level and degree of crown scorch were poorly correlated.

Table 1. Mean and standard deviation in diameter at breast height and total height for the trees before (1994) and after (1997) fire as a function of crown scorch fraction (Ck) class.

| Ck | N° trees | dbh, cm | | ht, m | |
|---|---|---|---|---|---|
| | | 94 | 97 | 94 | 97 |
| 0.25 | 6 | 10.98 | 11.85 | 6.30 | 7.53 |
| | | (3.73) | (3.89) | (1.25) | (1.16) |
| 0.50 | 32 | 10.23 | 11.02 | 6.05 | 7.25 |
| | | (2.72) | (2.82) | (1.41) | (1.54) |
| 0.75 | 10 | 9.68 | 10.33 | 5.35 | 6.42 |
| | | (4.18) | (4.62) | (1.41) | (1.59) |

Crown damage ranged from mild to moderate scorching and affected essentially the lower branches, but a few trees were completely scorched. Ratio of crown scorch and scorch height were reported to be good crown damage indicators by Reinhardt & Ryan (1988), Rigolot (1990) and Botelho (1996), among others. However, fraction of crown killed (Ck), when combined with dbh in a logistic model, was the variable that best explained mortality in this study plots (Botelho et al. 1996). Ck scorch classes (Table 1) were discarded from further analysis since the effect of different degrees of defoliation on growth was non-significant ($p>0.05$); nevertheless, diameter and height growth diminish slightly with scorch intensity. Non-significance may arise from the large amount of variance in the data, or from a large variation within Ck classes. Preburn diameter growth nearly equaled preburn growth at low and medium scorch levels, and the lowest postburn diameter growth occured when crown scorch was higher.

Bole damage was not taken into account since no apparent trunk injury was observed. In similar trees, the phloem and xylem became oriented to favor sap flow around the fire wounds, and no significant effect on growth was detected when cambium damage was artificially inflicted (Botelho 1996). Van Wagner (1970) stated that crown scorch, rather than cambium damage is the main cause for mortality in pine trees.

There are significant differences in tree diameter and height between sites, but not between the burned and control plot trees in each site (Table 2). Trees are smaller in Sevivas than in Tinhela, and the rate of prefire tree growth was higher in Sevivas than in Tinhela. Within three years after the burns, growth in Sevivas was reduced in height but not in diameter. Both variables decreased in Tinhela. Burned trees in Sevivas grew 12.7% in diameter and 23.8% in height during the three years that followed fire, while in Tinhela the pines only increased 3.6% in dbh and 16.2% in total height. The trees in Sevivas control plot grew less in diameter (7.5%) but more in height (29%), while in Tinhela diameter and height increased 7.8% and 20.0%.

The mean growth increments of the unburned trees were used to adjust for inherent differences in growth rate among trees in the burned plots. The analysis of radial growth from increment cores (Fig. 1) did not reveal statistically significant differences in growth rate between Sevivas and Tinhela.

Table 2. Mean and standard deviation in diameter at breast height and total height for the trees before (1994) and after (1997) fire, categorized by study plot.

| Plots | dbh, cm | | ht, m | |
|---|---|---|---|---|
| | 94 | 97 | 94 | 97 |
| Sevivas | 9.00<br>(2.42) | 10.14<br>(2.93) | 4.91<br>(0.68) | 6.08<br>(0.88) |
| Tsevivas | 9.05<br>(2.67) | 9.73<br>(2.92) | 5.28<br>(1.01) | 6.81<br>(1.13) |
| Tinhela | 11.42<br>(3.34) | 11.83<br>(3.55) | 7.05<br>(1.08) | 8.19<br>(1.31) |
| Ttinhela | 10.71<br>(3.18) | 11.55<br>(3.49) | 6.96<br>(1.10) | 8.35<br>(1.30) |

n=24 in all plots.

A growth decrease in the burned trees in the first year after fire and a subsequent increase in relation to control trees is evident from Fig. 1. Slightly scorched trees had significantly greater diameter growth than unscorched trees, which can be attributed to the death of noncontributing lower limbs. Thus, fire has a similar effect to a pruning operation. [illegible]sing the same positive postfire growth response when scorch is confined to the lower branches foliage (Villarubia & Chambers 1978, Botelho 1996). The thinning effect of the fire released the small trees more than the larger ones; smaller trees can be expected to grow better since they are generally in the suppressed and intermediate crown classes.

Growth in height was more affected by burning than radial growth (Fig. 2), which was also reported by Botelho (1996). There were significant differences in height between the trees in burned and unburned plots even before burning (1994), but not in the last year (1997). Fire seemed to temporarily retard growth, which returned to normal except in severely scorched small trees. Ryan (1982) pointed out that young rapidly growing trees on good sites can withstand a much greater reduction in the ratio of live crown to total height than can older, slower growing trees.

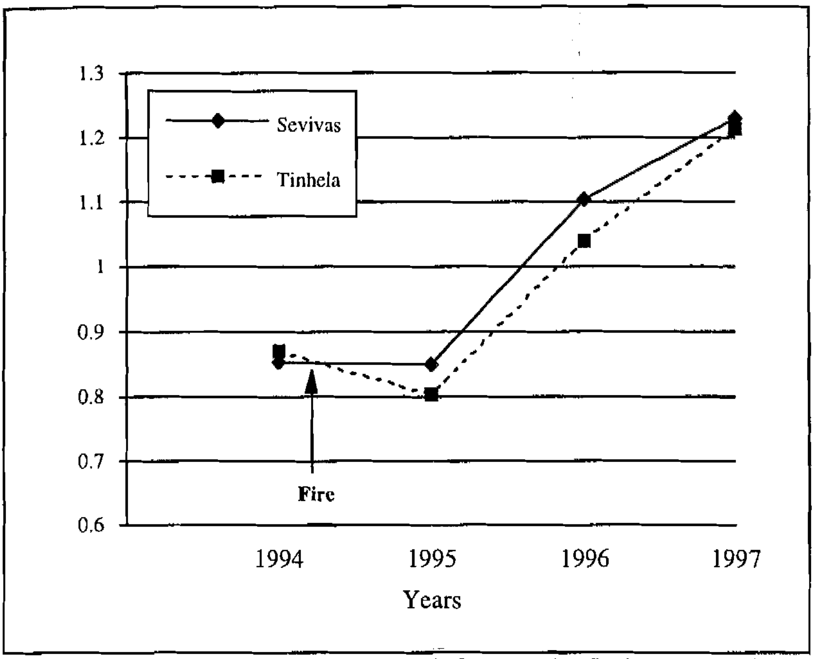

Fig 1. Relative radial growth rate increment before and after fire in the study plots.

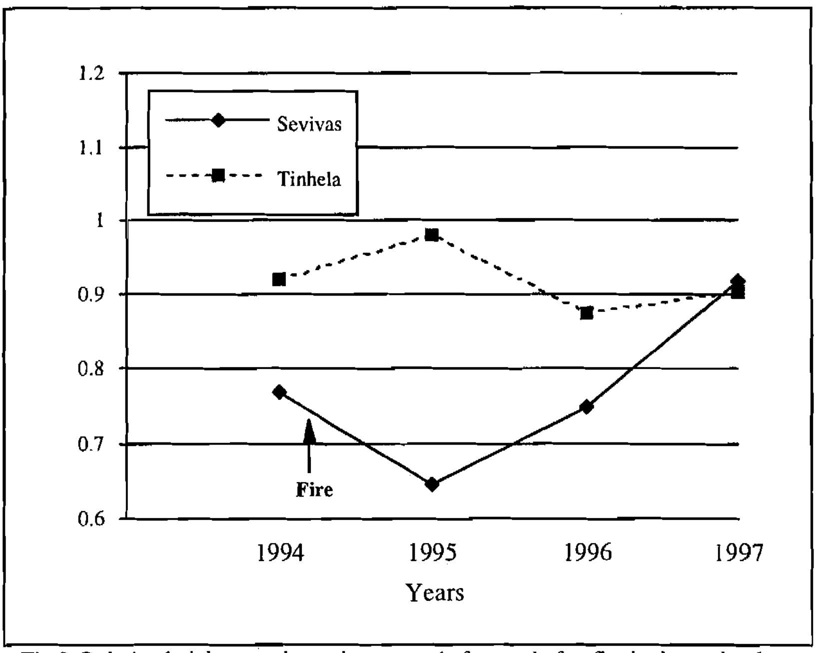

Fig 2. Relative height growth rate increment before and after fire in the study plots.

The response of growth in height was more apparent in the second and third years after fire. According to Ryan (1993), stem growth depends mainly on the current year production of carbohidrates, but leader growth is influenced by the previous years growing co is. Botelho (1996) found that the effect of fire on tree height growth was significant o two years after burning. Since height is not influenced by tree density, the thinning effe not expected to be related with these results.

Diameter and height increments in growth were analysed using prefire grow a covariate over the three years period after fire. The test showed actual tree growth to b ire explained by prefire growth than by scorching severity, which agrees with the results o ed by Botelho (1996).

## CONCLUSION

The experiments were carried under environmental conditions that conformed he necessities of enlarging the prescription window and defining prescribed burning appl on thresholds. The results are consistent with what was found for mortality (Botelho et al 6) and have important practical implications. The results suggest that prescribed burn re intense than those that are currently performed may cause severe crown scorch – espec in young or unpruned stands - but their impact upon growth rate will be negligib nd temporary.

This study further confirms and strengthens that maritime pine has an excep al ability to sustain fire damage when compared with other fire-resistent coniferous tre as stated by Ryan et al. (1994a,b). The observation of tree development during a more ext ed period will provide adittional information on the subject of high-intensity prescribed bu ng effects upon maritime pine trees growth. The use of prescribed headfire looks prom g, especially when fuel moisture content is too high for backfiring, and in the managem of naturally regenerated stands, but further research is needed to define sound prescriptions.

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