Relationships between Water Use and Environmental Parameters in a Young Post-Fire Maritime Pine Stand after Precommercial Thinning

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Abstract

This study investigated the effect of heavy thinning in the relationships between water use and environmental variables in an 8-year-old post-fire-regenerated maritime pine (*Pinus pinaster* Ait.) stand in north-western Spain over two growing seasons. Three different treatment levels were selected: control (unthinned, 40,200 saplings ha^{-1}), intense thinning (leaving 3,850 saplings ha^{-1}), and very intense thinning (leaving 1,925 saplings ha^{-1}), and sap flow measurements on ten saplings in each treatment were carried out along two growing seasons following thinning. Soil water availability, vapour pressure deficit and net radiation were continuously monitored. Sap flow density in control saplings was more related to soil moisture content, probably as a consequence of more limited soil water conditions, whereas in thinned plots, sap flow density was more related to vapour pressure deficit and net radiation. Thinned saplings showed higher stomatal conductance than control saplings as a consequence of the improvement of the growing conditions after the treatment.

INTRODUCTION

Regeneration of maritime pine after wildfire can be extremely high if recruitment conditions are optimal (Vega et al., 2002; Madrigal et al., 2004). In this case, heavy thinning is recommended to regulate sapling competition, improve sapling growth and form, accelerate seed production, and to reduce fuel accumulation (Vega et al., 2002; Madrigal, 2004). Transpiration may be drastically altered following thinning treatments (Schiller et al., 2003; Lagergren and Lindroth, 2004). However, at present, there is little information about the specific effect of early heavy thinning on residual young saplings' transpiration and soil water availability (Reid et al., 2006; Jiménez et al., 2008).

We hypothesised that following the treatment, sap flow density of thinned saplings would increase as a consequence of the improvement of the growing conditions, with an increase in resources (soil water, incoming radiation) availability. Consequently, the objective of this study was to analyze the influence of environmental conditions on sap flow density in a post-fire 8-year-old *Pinus pinaster* saplings stand during the first two growing seasons following precommercial thinning.

MATERIALS AND METHODS

Area of Study

The study was conducted in a typical post-fire over-stocked 8-year-old *Pinus pinaster* stand in Laza – Orense (NW Spain). The fire took place in September 1996, and affected 575 ha. The site is a west-facing 20% slope, at 700 m.a.s.l. The climate is Mediterranean, with a slight continental influence. Soils are alumi-umbric regosols and leptosols of about 30 cm depth. For more details see Jiménez et al. (2008).

Site Selection and Sap Flow Density and Environmental Measurements

Fifteen plots (20 x 20 m) were installed in an area with abundant pine regeneration

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(mean density of 54,700 saplings ha^{-1} and mean sapling height of 1.6 m) in February 2003. In February 2004 heavy thinning treatments were carried out in 10 of the 15 randomly selected plots, by clear strip felling. In five plots a very intense thinning treatment was carried out (VIT), leaving a residual density of 1,925 saplings ha^{-1}. In the other five treated plots, thinning was intense (IT), leaving 3,850 saplings ha^{-1}. The other five plots (NT) were left unthinned as controls, with a mean density of 40,200 saplings ha^{-1}.

Before treatment, two saplings were selected for sap flow measurements in each plot (a total of 30 pines were monitored – Table 1). Sap flow sensors were installed in March 2004. Sap flow density was measured by the dissipation heat method (Granier, 1987). Sap flow density was measured discontinuously between April and September 2004 (47 whole days) and 2005 (37 days). For more details see Jiménez et al. (2008). We transformed sap flow density on a sapwood basis into sap flow density on a leaf area basis from regression analysis by relating these parameters with dendrometric variables estimated by destructive sampling carried out in the study site. Daily stomatal conductance (mmol m^{-2} s^{-1}) was calculated with the simplified Penman-Monteith equation (Reid et al., 2006; Jiménez et al., 2008).

Precipitation, net radiation, air temperature and relative humidity were measured continuously with a meteorological station installed at the study site. Values were averaged every 30 minutes. Vapour pressure deficit (D) was obtained from air temperature and relative humidity values. During the study, mineral soil samples were collected periodically from 0-20 cm depth within each plot (ten samples per plot) to determine the percentage of soil moisture by gravimetry.

Possible relationships between sap flow density on leaf area basis and stomatal conductance and environmental variables were explored with simple regressions. We could not use multiple regression method to analyse relationships between sap flow on leaf area basis and environmental parameters because meteorological variables (D and net radiation) showed moderate colinearity. In this analysis we used diurnal (daylight period) instead of daily sap flow density. Soil moisture was as well used, being the averaged value for each treatment. In days without soil moisture value, this was calculated by interpolation between closest dates. An ANOVA of regression coefficients was developed to test if the slopes of the regression relationships obtained differed between treatments. Previously these regressions were transformed to linear relations.

RESULTS AND DISCUSSION

Higher values of daily sap flow density on leaf area basis were generally observed comparing thinned plots (VIT and IT) with NT plots (Fig. 1) for both study periods, probably due to the improvement of the growing conditions, with an enhanced access to available water among other factors. Only in some dates during 2004 VIT plots showed lower values (points inside the dashed line), corresponding with the first measurement dates after the thinning treatment due to an abrupt stand opening (Donner and Running, 1986; Medhurst et al., 2002). Although this type of treatments can result in an increase of resistance to water flow through the stem by wind loading (Reid et al., 2006), the higher diameter growth observed in thinned saplings (Jiménez et al., 2008) may result in a higher proportion of earlywood (Reid et al., 2006), which is more efficient at conducting water because of greater tracheid diameter.

Significant relationships between environmental variables and diurnal sap flow density on leaf area basis were observed in 2004 (Table 2). These relationships were different between all treatments. However, these relationships were not found in 2005 (Table 1), which could reflect and increase of stomatal control on transpiration (Jones and Sutherland, 1991; Pataki et al., 2000; Teobaldelli et al., 2004) and the reduced range of the variation of the values. Whereas diurnal sap flow density in thinned plots showed positive significant relationships with D and radiation (power functions), unthinned plots were negatively related with soil moisture content (power function), likely as a consequence of lesser soil water availability, resulting in stomatal closure to avoid xylem cavitation process (Pataki et al., 2000; Teobaldelli et al., 2004).

Significant relationships were also observed between stomatal conductance and D (power functions) for all treatments in 2004 and 2005 (Fig. 2). No significant differences were found between VIT and IT plots, but both treatments showed higher values than NT plots for similar D values, reflecting the improvement of the growing conditions (Jiménez et al., 2008), the increase in incoming radiation to the lower crown section, the development of more photosynthetic tissues, the increased wind exposure, and greater soil water availability (Reid et al., 2006).

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Literature Cited

Donner, B.L. and Running, S.W. 1986. Water stress response after thinning *Pinus contorta* stands in Montana. For. Sci. 32: 614–625.

Granier, A. 1987. Evaluation of transpiration in a Douglas–fir stand by means of sap flow measurements. Tree Physiol. 3: 309–320.

Jiménez, E., Vega, J.A., Pérez-Gorostiaga, P., Cuiñas, P., Fonturbel, T., Fernández, C., Madrigal, J., Hernando, C. and Guijarro, M. 2008. Effects of pre-commercial thinning on transpiration in young post-fire maritime pine stands. Forestry 81: 543-557.

Jones, H.G. and Sutherland, R.A. 1991. Stomatal control of xylem embolism. Plant Cell Environ. 6: 607-612.

Lagergren, F. and Lindroth, A. 2004. Variation in sapflow and stem growth in relation to tree size, competition and thinning in a mixed forest of pine and spruce in Sweden. For. Ecol. Manage. 188: 51–63.

Madrigal, J., Martínez–Herranz, E., Hernando, C., Guijarro, M., Díez, C., Vega, J.A., Pérez–Gorostiaga, P., Fonturbel, T., Cuiñas, P., Alonso, M. and Beloso, M.C. 2004. Respuesta a corto plazo del regenerado post–incendio de *Pinus pinaster* Ait. a clareos mecanizados intensos. Silva Lusitana 12*:* 1–14.

Medhurst, J.L., Battaglia, M. and Beadle, C.L. 2002. Measured and predicted changes in tree and stand water use following high–intensity thinning of an 8–year–old *Eucalyptus nitens* plantation. Tree Physiol. 22: 775–784.

Pataki, D.E., Oren, R. and Smith, W.K. 2000. Sap flux of co–occurring species in a western subalpine forest during seasonal soil drought. Ecology 81: 2557–2566.

Reid, D.E.B., Silins, U. and Lieffers, V.J. 2006. Sapwood hydraulic recovery following thinning in lodgepole pine. Ann. For. Sci. 63: 329-338.

Schiller, G., Unger, E.D., Moshe, Y., Cohen, S. and Cohen, Y. 2003. Estimating water use by sclerophyllous species under east Mediterranean climate. II. The transpiration of *Quercus calliprinos* Webb. in response to silvicultural treatments. For. Ecol. Manage. 179: 483–495.

Teobaldelli, M., Mencuccini, M. and Piussi, P. 2004. Water table salinity, rainfall and water use by umbrella trees (*Pinus pinea* L.). Plant Ecol. 171: 23–33.

Vega, J.A., Hernando, C., Pérez–Gorostiaga, P., Guijarro, M., Fonturbel, T., Martínez, E., Cuiñas, P., Alonso, M., Madrigal, J. and Beloso, M.C. 2002. Post–fire regeneration in a *Pinus pinaster* Ait. forest: effects of a very early heavy thinning of seedlings and brush clearing. Forest Fire Research and Wildland Fire Safety. Millpress, 9 p.

Tables

Table 1. Mean values of characteristics of the ten saplings for each treatment monitored for sap flow. Standard error in brackets. (VIT=very intense thinning; IT=intense thinning; NT=no thinning).

Parameters	VIT	IT	NT
Total height (cm)	266.50 (15.65)	265.40 (15.75)	280.80 (28.20)
Basal diameter (mm)	65.03 (4.23)	66.00 (3.79)	72.68 (3.29)
Crown width (cm)	100.65 (8.86)	99.95 (5.52)	96.50 (8.35)
Sapwood (dm^2)	0.09 (0.01)	0.10 (0.01)	0.12 (0.01)
Leaf area (dm^2)	149.06 (25.87)	144.30 (15.47)	136.79 (22.27)

Table 2. Relationship between diurnal sap flow density on leaf area basis per treatment with environmental parameters in 2004 and 2005. D: vapour pressure deficit; RAD: net radiation; SM: soil moisture. (VIT=very intense thinning; IT=intense thinning; NT=no thinning). s.e.: standard error.

	2004			2005		
Parameter	VIT	IT	NT	VIT	IT	NT
D (kPa)	R^2=0.56; s.e.=0.94	R^2=0.80; s.e.=0.87	n.s.	n.s.	n.s.	n.s.
RAD (W m^{-2})	n.s.	R^2=0.47; s.e.=1.17	n.s.	n.s.	n.s.	n.s.
SM (%)	n.s.	n.s.	R^2=0.66; s.e.=1.27	n.s.	n.s.	R^2=0.28; s.e.=1.25

Figures

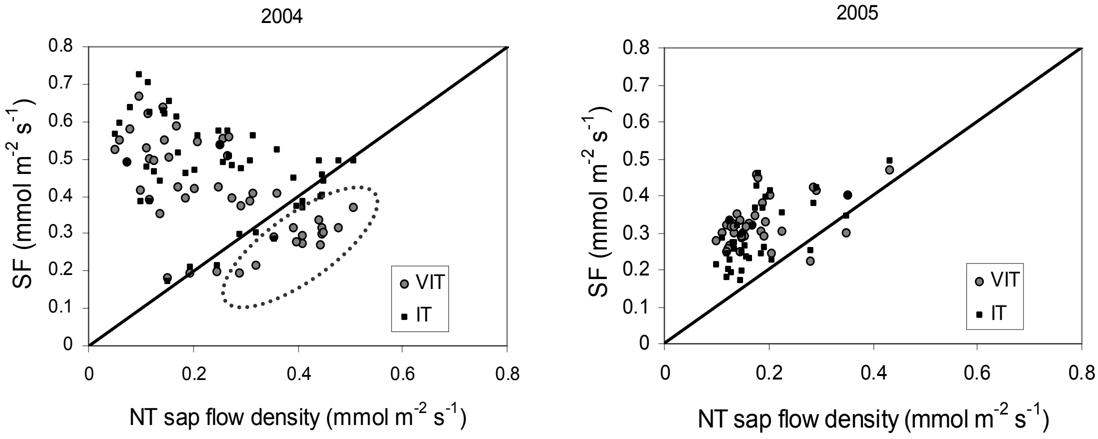

Fig. 1. Relationship between thinned and unthinned plots daily sap flow density (SF) on leaf area basis (mmol m^{-2} s^{-1}) in 2004 (left) and 2005 (right). (VIT=very intense thinning; IT=intense thinning; NT=no thinning). The area plotted in dashed line in 2004 represents dates with VIT plots showing lower values than NT plots.

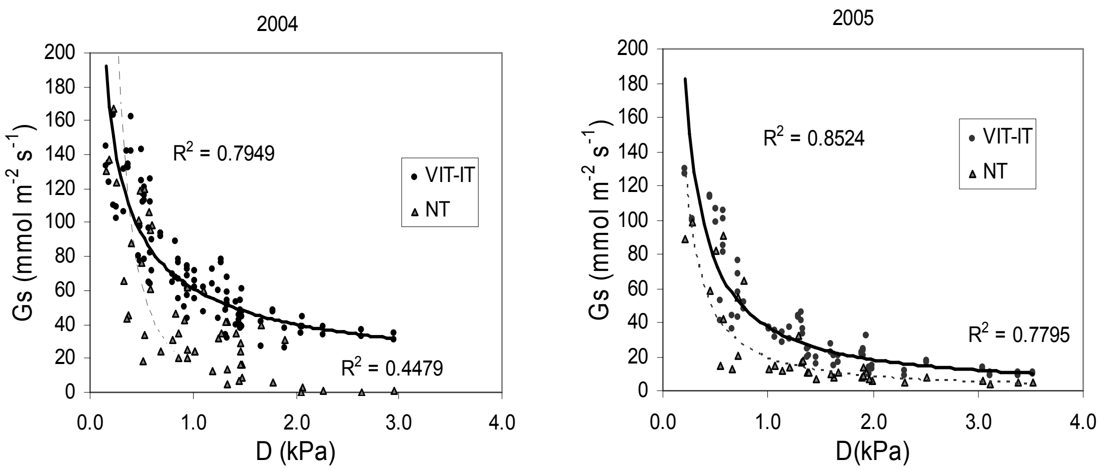

Fig. 2. Relationship between daily stomatal conductance (Gs) and daily vapour pressure deficit (D) in 2004 (left) and 2005 (right). (VIT=very intense thinning; IT=intense thinning; NT=no thinning).