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Thinning effect in two young stone pine plantations (*Pinus pinea* L.) in central southern Chile

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Abstract. In Chile stone pine was introduced more than a century ago, mainly by Italian and Spanish immigrants who brought it as part of their culture; interest for this nut in Chile is recent and has been gradually increasing. Crown development is one of the most important factors on pine nut production because it is influenced mainly by light. In winter 2009 two young *P. pinea* plantations, 15 and 16 years old, located in central Chile (Casablanca –Valparaíso Region– and Pencahue –Maule region), where thinned in order to evaluate the effect of this intervention. Variables evaluated were DBH, height and crown diameter. With the software ArcGIS 9.2, an analysis of crown area growth was made before and after thinning. Results showed a positive increase in dasometric variables one and two years after the intervention in both situations. A significant increase in tree crown area was found; crowns tend strategically to take advantage of light and space, taking a rounded form, change that would have a significant effect on pine nut production.

Keywords. Crown area – *Pinus pinea* – Pine nut production – Stone pine – Thinning.

Effet de l'éclaircie dans deux jeunes plantations de pin pignon (*Pinus pinea *L.) dans le centre sud du Chili

Résumé. *Au Chili le pin pignon a été introduit il y a plus d'un siècle, principalement par des immigrants italiens et espagnols qui l'ont amené dans le cadre de leur culture, mais au Chili l'intérêt pour cette noix est récent et progressif. Le développement du houppier est l'un des facteurs ayant le plus d'impact sur la production de pignons, car celle-ci est principalement influencée par la lumière. Pendant l'hiver 2009, deux jeunes plantations de* P. pinea*, de 15 et 16 ans, situées dans le centre du Chili (Casablanca, région de Valparaíso, et Pencahue, région de Maule), ont été éclaircies afin d'évaluer l'effet de cette intervention. Les variables évaluées sont la hauteur, le diamètre et la projection de la surface du houppier. Plus tard, avec le software ArcGIS 9.2, une analyse de la croissance de la surface du houppier projetée avant et après éclaircie a été réalisée. Le résultat fut une augmentation positive des variables dasométriques un et deux ans après l'intervention dans les deux situations. On a trouvé une augmentation significative de la surface du houppier des arbres, qui tendent de manière stratégique à profiter de la lumière et de l'espace, formant un houppier arrondi, changement qui aurait un effet significatif sur la production de pignons.*

Mots-clés. *Eclaircie* – Pinus pinea – *Production de pignons – Surface du houppier.*

I – Introduction

The forestry sector in Chile has been focused primarily on production of mainly two species, *Pinus radiata* and *Eucalyptus* spp. However, currently there is a great interest of public and private stakeholders in the diversification of productive species, not only for producing timber and cellulose, but also to identify sustainable alternatives, especially for medium and small landowners.

An alternative to traditional forest activity is promoting the production of non-timber forest products (NTFPs), among which pine nuts from stone pine (*Pinus pinea* L.) are an interesting option. This species is a conifer with edible seeds called "pine nuts", highly demanded, native to

the Mediterranean area; it requires between 400-800 mm of annual rainfall with winter rainfall regime and four to six dry months (Mutke *et al,.* 2007).

Stone pine is characterized by an abundant and rounded crown; fruit bearing begins at 15-18 years in its origin area. Female flowers are placed on vigorous shoots of the year in the upper crown area, so many authors describe that larger trees have greater vigor and flowering (Gordo *et al.* 1999; Loewe *et al.,* 2011).

In Chile, stone pine was introduced more than a century ago, mainly by Italian and Spanish immigrants who brought it as part of their culture, being used primarily to fix dunes, control erosion and provide shade for livestock, but the interest for its fruit is recent. The Chilean Forestry Institute (INFOR) has studied the species since 1994 and more recently, since 2008, is conducting the project "The edible pine nut of stone pine (*Pinus pinea* L.), an attractive business for Chile", in order to design, implement and evaluate productive models to cultivate stone pine oriented to pine nut production, or combined to produce wood and fruit, and to analyze productivity, nut quality, among other topics.

As part of these activities, management trials have been carried out on pre-existing plantations, considering pruning and thinning, with interesting results (Loewe *et al*., 2011). The objectives of thinning *P. pinea*, as Montero and Candela (1998) state, correspond to control mass density in different stages of development in order to maximize production and profits, improving plant vigor and quality of the remaining trees, and to obtain secondary products that have a market value.

In traditional timber producing species the main objective of thinning is to increase tree diameter and height growth, in order to obtain higher yields and better quality timber (Sotomayor *et al*., 2002). Nevertheless, in species whose goal is fruit production, such as *P. pinea*, thinning can be done to increase crown growth and tree biomass which will also increase fruit production. According to Muñoz *et al*. (2008), crown increase allows higher amount of light to be intercepted by the canopy, improving productivity and stand dynamics.

In this context, the goal of this study was to evaluate the thinning effect in growth parameters of the species at two locations in central Chile, in order to stimulate the production of pine nuts due to its remarkable value in the international market.

II – Material and methods

The study area corresponds to two sites located in the central region of Chile, Casablanca and Pencahue.

1. Casablanca

The plantation located in Casablanca (latitude 33º22'37"S, longitude 71°19'18"W), Valparaíso Region, corresponds to a European provenance trial established by INFOR in 1994. The plantation, 0.6 ha, was established on a site with minimal slope (0-2%), with an initial spacing of 2 x 3 m; it has three blocks of six plots each (49 trees per plot). Provenances are Lombardy and Tuscany (Italy); Slovenia; and Meseta Castellana, Western Andalucía and Sierra Morena (Spain).

In July 2009 the plantation was thinned extracting 47.8% of all alive trees (mortality was 30% at that moment). Prior to thinning, for each tree it was measured height, DBH and crown diameter on NE and SW orientations.

2. Pencahue

Plantation located in Toconey (latitude 35º24 '42"S, longitude 72°3'32"W), county of Pencahue,

located in the Maule River Valley, Maule Region, established on 1993. The plantation, 1.8 ha, was established in a northern exposure hillside with a slope of 20-25% at a spacing of 5 x 5 m.

In winter 2009, a thinning was done, extracting rows diagonally (geometric thinning), achieving a final average spacing of 7 x 7 meters.

The evaluation was performed considering three different exposure plots: P1). Northwest, 52 trees; P2). North, 53 trees; and P3). Northeast, 51 trees. Before and after thinning, for each tree there were measured four crown radius, facing north, east, south and west.

At one side of each plantation there was taken as reference one GPS point in UTM projected coordinates, WGS 84 datum zone 19 south, and with an image of Google Earth there was made a tree distribution map. In both situations, with the software ArcGIS 9.2, an analysis of tree crown area before (2009) and after thinning was done (2010 and 2011) in order to evaluate the effect of thinning on crown area. Data were analyzed with the Software Infostat 2009 version, and if there were significant differences, Duncan's multiple comparison test was used.

III – Results and discussion

1. Casablanca

Western Andalucia, Slovenia and Meseta Castellana, are the provenances that most increased crown area one year after thinning, with an average of 31.6% over the other three provenances, while Tuscany had the lowest increase (23% lower than the other five provenances). However, Lombardy had a greater increase two years after thinning, with a 131.7% crown area increase. Between 2010/11 the increase was lower in all provenances compared with the first period, being again Western Andalucia and Slovenia the ones that showed a better answer to thinning, with an average increase of 29.3% over the other four provenances. Two years after thinning the tendency of the period 2009/10 was the same, being Western Andalucia, Slovenia and Meseta Castellana, the ones who showed the highest crown area increase (Table 1).

Table 1. Crown area average increase in Casablanca

Provenance	Growth (m^2)					
	2009-2010	%	2010-2011	%	2009-2011	%
Meseta Castellana	2.57 ± 0.26 c	103.2	1.55 ± 0.19 bc	29.9	4.12 ± 0.34 c	159.5
Slovenia	2.32 ± 0.25 c	95.2	1.6 ± 0.23 c	32.3	3.92 ± 0.41 c	154.6
Western Andalucia	2.34 ± 0.25 c	90.2	1.49 ± 0.26 c	30.4	3.84 ± 0.35 c	144.7
Sierra Morena	2.24 ± 0.2 bc	105.1	1.09 ± 0.17 b	26.3	3.34 ± 0.23 b	159.0
Tuscany	1.70 ± 0.17 a	84.2	1.11 ± 0.16 bc	35.9	2.81 ± 0.2 ab	145.4
Lombardy	1.55 ± 0.21 ab	131.7	0.62 ± 0.13 a	25.5	2.17 ± 0.22 a	175.3

Different letters indicate significant differences between treatments according to Duncan's test ($p \leq 0.05$)

Figure 1 illustrates the thinning effect in the three blocks of Casablanca trial, highlighting the significant increase one year after thinning (2009/10). Block 3 is the one with largest increases because trees are larger due to better soil quality.

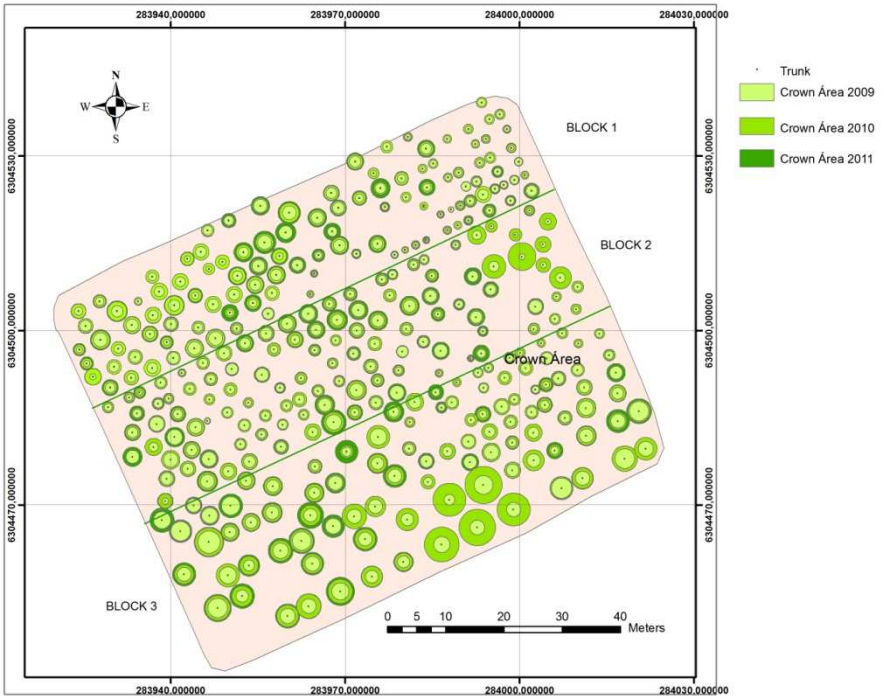

Fig. 1. Thinning effect in Casablanca stone pine trial.

DBH mean values two years after thinning show significant differences among provenances. Western Andalucia showed the highest growth two years after thinning, achieving a DBH increase of more than 3.5 cm. However, even though there are significant differences, DBH increases were similar throughout the plantation, as Meseta Castellana (provenance that showed the lower answer), increased an average of 3 cm in DBH in the same period (Fig. 2).

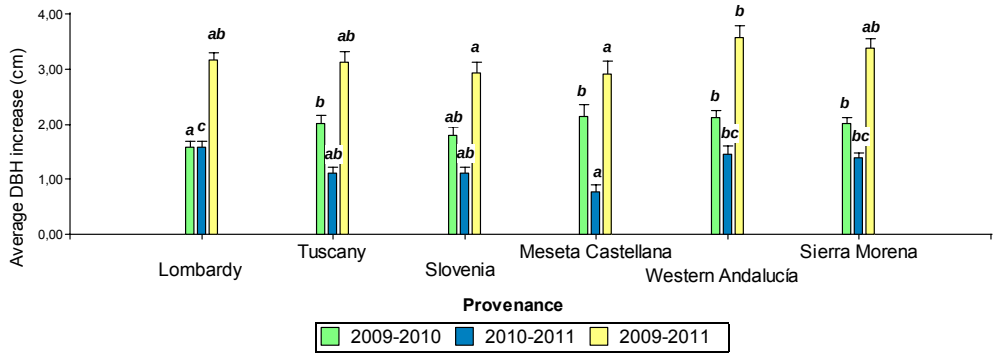

Fig. 2. DBH average increase in Casablanca trial by provenance. Different letters indicate significant differences between treatments according to Duncan's test ($p \leq 0.05$).

The results obtained two years after thinning showed statistically significant differences for

height; three provenances (Sierra Morena, Western Andalucía Meseta Castellana) were superior showing significant differences, with a 35% increase (Fig. 3).

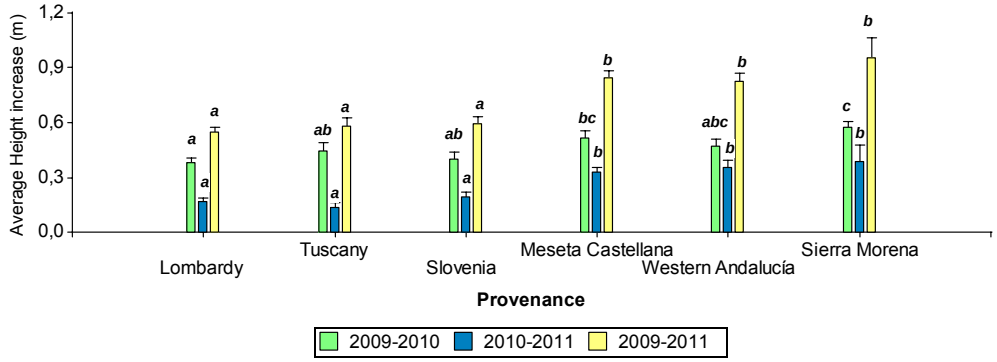

Fig. 3. Height average growth in Casablanca by provenance. Different letters indicate significant differences between treatments according to Duncan's test ($p \leq 0.05$).

2. Pencahue

Mean crown increase values showed significant differences between orientations (Table 2). The Northeast plot displayed a greater effect of thinning the second year with significant differences compared to the other plots, reaching a 93% increase. In the period 2010/11 it was observed a slight increase in crown area in all plots, ranging among 2.6 and 4 m^2. Again the Northeast plot had the highest significant increase (3.97 m^2), and the Northwest plot achieved the highest crown area increase (15.6%).

Table 2. Crown area average increase in Pencahue

Plot	Growth (m^2)					
	2009-2010	%	2010-2011	%	2009-2011	%
Northwest	7.08 ± 0.88 a	39.1	3.73 ± 0.43 ab	15.6	10.81 ± 1.01 a	60.6
North	11.33 ± 0.87 b	65.4	2.62 ± 0.43 a	9.7	14.44 ± 1.00 b	81.2
Northeast	13.96 ± 0.90 b	72.2	3.97 ± 0.44 b	12.4	17.93 ± 1.04 c	93.0

Different letters indicate significant differences between treatments according to Duncan's test ($p \leq 0.05$).

Figure 4 illustrates the effect of thinning in the three orientations in Pencahue plantation, highlighting the significant increase the first year after thinning (period 2009/10). Plot 3 (Northeast) had the largest increases.

Results obtained two years after thinning indicate significant differences for DBH between plots; the Northwest plot presented a significant increase, 23.1% above other plots, while the Northern plot had the lowest increase for this variable (10% lower than other plots) (Fig. 5).

Mean height values two years after the intervention showed significant differences between plots/exposure. Unlike the result for DBH, the northeast plot showed the highest difference, statistically significant over the other plots in all periods, with an increase of 40% over the others in the period 2009/11 (Fig. 6).

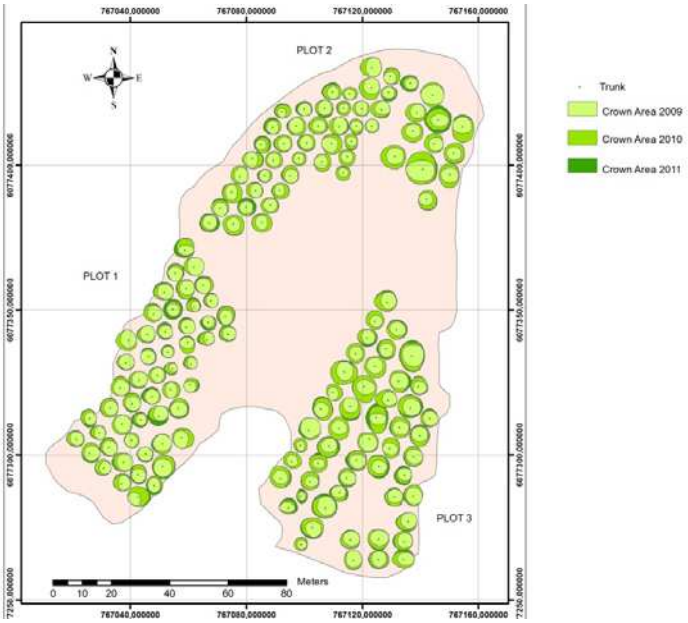

Fig. 4. Thinning Effect on Pencahue stone pine plantation.

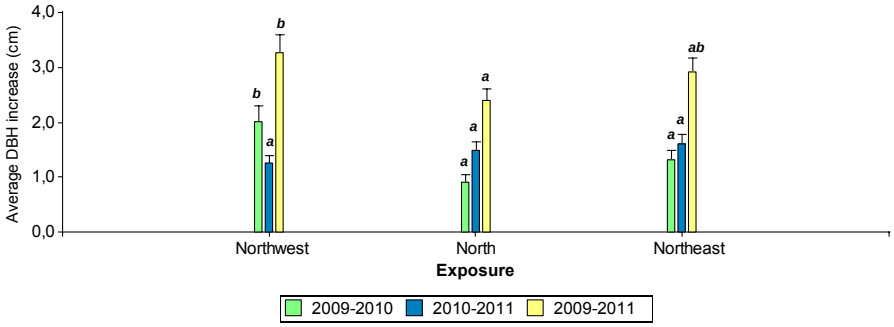

Fig. 5. DBH average increase in Pencahue by exposure. Different letters indicate significant differences between treatments according to Duncan's test ($p \leq 0.05$).

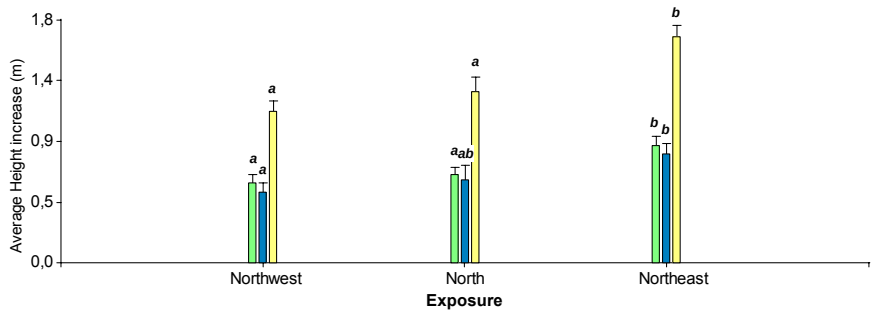

Fig. 6. Height average increase in Pencahue by exposure. Different letters indicate significant differences between treatments according to Duncan's test ($p \leq 0.05$).

IV – Discussion

This study found that thinning produces an increase in crown tree area one and two years after the intervention. Muñoz *et al.* (2008) point out that when removing individuals, the remaining trees have greater access to light, accelerating the growth dynamics in natural forest, generating more biomass. This is coincident with what expressed by Mutke *et al.* (2003), who state that stone pine requires high amounts of light to increase fruit productivity, so when increasing the distance between trees they tend to grow in crown area to intercept more light.

Montero and Candela (1998), conducted a literature review of thinning experiences in Spain, Italy and Portugal, finding great coincidence of several authors in recommending early thinning, between 12 and 15 years old. Following this criterion, interventions performed in both plantations were held at the optimal time limit (15 years in Casablanca and 16 years in Pencahue), so the trees had a rapid response. However, Gordo *et al*. (2009) suggest thinning even earlier, before 10 years. Considering the high vegetative vigor and growth that the species shows in many situations in Chile, we suggest that this option should be tested.

Stone pine has a particular ecological strategy: it shares its biomass in reproductive structures in similar or higher amounts that the one allocated to vegetative growth (Cabanettes *et al*. (1981) cited by Mutke *et al*., 2007). This strategy was confirmed in this study, since in both plantation plots that showed the highest crown area increase did not exhibit the same tendency for DBH and height parameters, i.e. situations of less vigorous and tree development had a higher DBH increase rather than crown area increase; trees seem to devote their energies to consolidate first, and later to a greater fruit production. That is why the maximum expression of tree growth is found in dominant or isolated trees, whose crowns are not limited and where the strategy of the species is not growing in height but in crown area.

V – Conclusions

We observed a positive effect of thinning in both *P. pinea* plantations one and two years after the intervention; trees tend strategically to maximize space and light, forming rounded and more productive crowns. Although we couldn't assess the thinning influence on fruit production given the duration of the fruit life cycle, we expected it to be positive given the background information on this topic.

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