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followed by *Acacia* and *Albizia*, while the lowest yield was obtained from *A.indica*. Using legumes as intercrops also improved the trees' biomass production as compared to using cereals as intercrops or sole cultivation of trees.•

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Effects of fertilization on the production of female flowers in Stone pine (*Pinus pinea* L.)

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Pinus pinea L., commonly known as Stone pine, is famous for its edible seeds, called pine nuts. It is native to the Mediterranean area, and requires between 400-800 mm annual rainfall and 4-6 dry months for fruiting (Mutke *et al*. 2007).

Worldwide, the seeds of Stone pine are known as Mediterranean pine nuts. Nuts in specific amounts are scientifically proven to reduce the risk of vascular accidents (López 2007). They contain high amounts of vegetable protein, unsaturated fatty acids, fiber (Salas-Salvadó *et al*. 2005), vitamins (folic acid, niacin, tocopherols, Vitamins B6 and B2) and minerals. The nuts are low in sodium and contain various healthy bioactive compounds such as phytosterols and polyphenols (Blomhoff *et al*. 2006). Nuts are thus considered high in nutritional value (Segura *et al*. 2006).

Fertilizers, meanwhile, have demonstrated the capability to increase crop yields and improve product quality. Moreover, fertilization promotes root development and aerial plant growth, thereby contributing to the efficient use of soil and water (Sotomayor *et al*. 2001). Research on the effects of fertilization is readily available on walnut, chestnut and other species that produce edible seeds or nuts (Calama *et al*. 2007).

*Pinus pine*a nuts are one of the most important edible fruits produced in the Mediterranean forests. Research results over the years have recognized that fertilization and irrigation increase cone production and biomass of roots, leaves and trunks. However, there is limited scientific knowledge about the effects of fertilizer application on Stone pine plantations and orchards. Two studies have been conducted to monitor the effects of fertilization on Stone pine.

The first one monitored cone production and quality in a 40-50-year-old forest located on poorly drained, slightly acidic soils. Different doses of lime superphosphate, dolomite and potassium chloride were compared. Results showed a positive response to fertilization in the quantity and quality of cones produced, especially in the treatments that incorporated a greater quantity of dolomite (Calama *et al*. 2007). Nevertheless, the effect of mineral fertilization on the quantity and quality of cones was less than expected. The authors suggested that future studies should explore the incorporation of nitrogen fertilizers and organic matter to improve the structure of sandy soils.

The second research was conducted in Turkey to evaluate the effects of nutrients in the loss of cones. Results showed a negative correlation between nitrogen, phosphorus, calcium and manganese present in the needles and the loss of cones—i.e., when nutrients declined, cone loss increased (Kilci 2011). The authors recommended that phosphorus and calcium should not be applied in drought-stricken areas as it could contribute to cone loss.

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A further study was conducted in Chile that evaluated the effects of fertilization in a young plantation by counting the number of female flowers of Stone pine trees after 1-2 years of application.

Methodology

A plantation of 1.8 ha was established in 1993 in Toconey (latitude 35° 24 '42.99'' S, longitude 72° 3' 32.76'' W), Pencahue in the Maule River Valley, Maule Region. The area has a slope of 20-25 percent. Stone pine trees were planted using 5 m x 5 m spacing. In the winter of 2009, 16-year-old Stone pine trees, were thinned by cutting diagonals (geometric thinning), thereby achieving a final average spacing of 7 m x 7 m. Formation and lift pruning were also applied.

Soil analysis recorded very low values for available phosphorus, boron, nitrogen, potassium, and exchangeable calcium. Medium values were obtained for organic matter, manganese, copper and iron. High values were obtained for magnesium.

The study considered the application of base fertilization according to soil analysis values. Base fertilization was applied in two plots at different exposures plus the control—P1: fertilization northwest exposure (n=27), P2: fertilization north exposure (n=27), PT: unfertilized north exposure (n=9) or control plot.

Fertilization was applied in September 2009. It used a mixture of phosphoric acid and calcium phosphate (60 g per plant), zinc sulfate (10 g per plant); sodium borate (20 g per plant), potassium sulfate (60 g per plant) and carbamide (50 g per plant).

Two evaluations were made in 2010 and 2011, counting female flowers by visual observation from the ground, with the help of a ladder located against the slope and by using prismatic lenses. Cone production was also evaluated, differentiating them by size: large (> 350g), medium (350 - 200 g) and small (<200 g).

Statistical analyses were done using InfoStat 2011. When there were significant differences, a multiple comparison of Fisher's LSD tests was made.

Results

Female flowers. The average number of flowers showed statistically significant differences between the two plots one and two years after fertilizer application. The results highlighted that fertilized plots have significant differences in the presence of cones (Table 1).

In 2010, fertilized trees increased cone production by 41 percent as compared to unfertilized trees. The northwest exposure plot (P1) achieved the highest increase, (46%). In 2011, female flower production decreased in both fertilized and control plots, although statistical significance was maintained between trees with and without fertilization. P1 maintained a greater increase in relation to the control (59.4%), while P2 reached a 47.8 percent increase in relation to control.

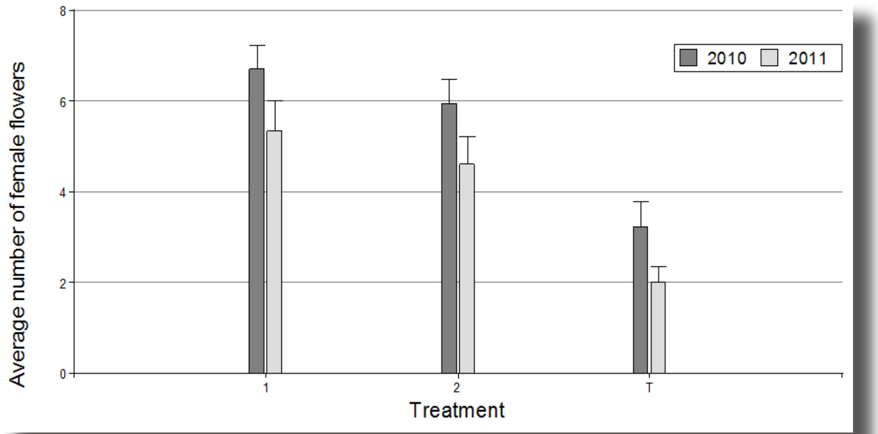
Figure 1 illustrates the number of female flowers per year. Figure 2 shows the appearance of Stone pine's female flowers.

Table 1. Number of *P. pinea* female flowers (± standard error) by treatment. production.

Year	Plot	N° female flowers	Percentage increase vs. control
2010	1 (NW Exposure)	6.70 ± 0.50 a	46
	2 (N Exposure)	5.96 ± 0.51 a	36.8
	T (N Exposure)	3.22 ± 0.86 b	---
2011	1 (NW Exposure)	5.33 ± 1.02 a	59.4
	2 (N Exposure)	4.62 ± 0.60 a	47.8
	T (N Exposure)	2.00 ± 0.14 b	---

*Small letters indicate significant differences between treatments using the LSD Fisher test ($p \leq 0.05$).

Fig. 1. Average of female flowers (± standard error) by treatment.



Considering both years, an average of 5.6 flowers per tree (average range of 1.75-13 flowers/tree) was obtained in fertilized plots, while 2.6 flowers per tree (average of 1-5 flowers/tree) were obtained in the control plot (Table 2) A previous study by Venegas (2010) recorded female flowers on the same plantation, establishing a range of 4-8 female flowers per

The production of female flowers in 2010 would allow 2.5 cones per tree without fertilization and 5.4 cones per tree with fertilization (Table 3) three years later, since the fruits take 3.5 years to mature. Considering the current density of 204 trees/ha, cone production would reach between 170 kg/ha (510 cones/ha) and 367 kg/ha (1.102 cones/ha). These values are significantly lower than the 500 kg/ha of cones harvested in 2009.

According to Crawford (1995), the normal minimum yields are 500 kg of cones/ha/year, with a planting density of 100 trees/ha. This corresponds to 15 cones per tree (3 cones = 1 kg). This level of productivity is usually achieved in dense plantations in Chile without management interventions. The level of flower and cone production depends on alternate bearing, characteristic of the species and diminished spring water availability(rainfall), as stated by Mutke *et al*. (2007).

Fruiting. Stone pine is characterized by a rounded crown to maximize the interception of light and increase fruiting (Mutke 2005). Loewe *et al*. (2011) conducted a study in 2009 to observe the effect of thinning on the development of tree crowns. Two years later, there was a significant increase in crown area which would increase flowering. These results did not match with the results of this study as P2 had a higher increase in crown surface than P1, at 76.3 percent and 56.4 percent, respectively (Figure 3). Table 3 shows P1 with more flowers than P2. It should be noted that at these densities increased light availability quickly allows crown expansion.

Cones. There were no statistical differences in the first and second year after fertilization. These results did not agree with Salazar y Lazcano-Ferrat (2003) when they studied fruit trees and found that the application of fertilizers caused an increase in fruit size. There were differences in the total cone number between treatments two years after fertilization (Table 4).

The analysis of production in relation to tree diameter done by Ximénez de Embún (1958) and cited by Calama and Montero (2007), indicated that normal cone production in a tree of 27 cm DBH is 5.75 kg/year, while in 28 cm DBH trees, cone production is 6.8 kg/year. These values were

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Fig. 2. Pinus pinea female flowers.

Table 2. Minimum and maximum quantity of female flowers.

Year	Plot	Nº female flowers		
		Minimum	Maximum	Average
	1 (NW Exposure)	3	14	6.7
	2 (N Exposure)	2	11	5.9
2010	T (N Exposure)	1	6	3.2
	1 (NW Exposure)	1	14	5.3
	2 (N Exposure)	1	13	4.6
2011	T (N Exposure)	1	4	2

Table 3. Projection on the average number of cones in the third year of treatment.

Plot	No. of female flowers (2010)	Projected no. of cones (2013)	Projected yield of cones (kg/ha) -2013	No. of female flowers (2011)	Projected no. of cones (2014)	Projected yield of cones (kg/ha) (2014)
1	6.7	5.4	1.102 / (367)	5.3	4.2	857 / (285)
2	5.9	4.7	959 / (319)	4.6	3.7	755 / (251)
T	3.2	2.5	510 / (170)	2	1.6	326 / (109)

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significantly higher than those obtained in Toconey, where trees with 28 cm DBH produced a maximum of 3.1 kg of cones in P1, and trees with 27 cm DBH produced 3.2 kg of cones. These results confirmed the alternate bearing characteristic of Stone pine and highlighted the remarkable growth of the species in Chile as compared to Spain, where the same diameters were obtained 23-27 years earlier (Table 5).

Dasometric parameters. Dasometric parameters one and two years after fertilization are shown in Table 6. Results showed that there were no significant differences from fertilization and plot exposure.

There was no significant difference found among fertilized and non-fertilized plots for dasometric (DBH and height) parameters (Table 7). The observed growth rates were higher than those reported by Montoya (1990) who indicated that a maximum of 0.39 m/year height growth was observed in 23-year-old trees, and 0.3 m/year was observed in 17-year-old trees. Martinez *et al.* (1993) indicated that the average diameter growth is 0.29 cm/year with a maximum of 1.47 cm. These values were also largely exceeded in this study.

Conclusions

Results showed that fertilization had a significant effect on female flower production. This study demonstrated an increase in Stone pine flowers by 41 percent and 54 percent after one and two years of fertilizer application, respectively. There were no significant differences found regarding the effect of fertilization on the size of trees.

The application of base fertilization, meanwhile, addressed the nutritional deficiencies of the soil. Results showed that base fertilization increased cone

Table 4. Average of *P. pinea* cones (± standard error) by treatment.

Year	Treatment	Number of Cones by size			
		Big	Medium	Small	Total
2009	Fertilized	0.19 ± 0.05a	3.29 ± 0.38a	0..81 ± 0..17a	4.29 ± 0.48a
	Control	0.84 ± 0.13b	2.38 ± 0.9a	0..87 ± 0..39a	2.21 ± 1.14a
2010	Fertilized	0.80 ± 0.24a	3.03 ± 0.57a	1.38 ± 0.27a	3.62 ± 0.63a
	Control	2.25 ± 0.57b	4.13 ± 1.75a	1.75 ± 1.08a	2.58 ± 1.48a
2011	Fertilized	2.03 ± 0.46a	0.89 ± 0.18a	0.24 ± 0.06a	3.15 ± 0.53b
	Control	1.21 ± 1.08a	0.63 ± 0.43a	0 ± 0.13a	1.84 ± 1.26a

Table 5. Cone production (kg) by age, diameter and country.

Age	Diameter (cm)	Cone production (kg/tree)	Country
17*	28.5	2.2 ± 0.48	Chile
17**	28.7	3.1 ± 0.35	Chile
17***	27	3.2 ± 0.41	Chile
36	25	5	Spain
38	26	5.6	Spain
40	27	5.8	Spain
42	28	6.8	Spain
44	29	7.4	Spain

*Non Fertilized Northern exposure

*** Fertilized Northern exposure

Fig. 3. Increase in crown area (m2) by exposure.

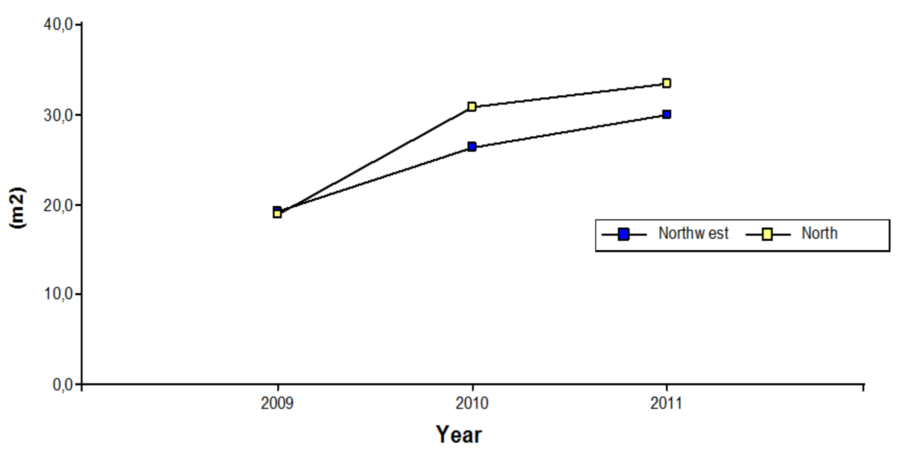

Fig. 4. Fertilizer application on Pinus pinea.

productivity by 2.3 times based on projections of the number of female flowers produced. This effect would be even greater if fertilization is used to specifically address cone production and applied every year or regularly after Stone pine trees reach sexual maturity. This study showed that fertilization did not affect cone size, an aspect that should be explored in further studies.•

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References: (1) Blomhoff, R., M. Carlsen, L. Frost Andersen, D. Jacobs.2006. Health benefits of nuts, potential role of antioxidants. Br J Nutr 96: S52-S60; (2) Calama, R. and G. Montero. 2007. Cone and seed production from stone pine (Pinus pinea L.) stands in Central Range (Spain). European Journal of Forest Research 126(1). Pp. 23-35; (3) Calama, R., G. Madrigal, J. Candela, G. Montero. 2007. Effects of fertilization on the production oj an edible forest fruit: stone pine (Pinus pinea L.) nuts in south-west Andalucía. Investigación agraria: sistemas y recursos forestales. 16(3): 241-252, 2007; (4) Crawford, M. M. 1995. Nut pines. Yearbook. West Australian Nut and Tree Crops Association. 19: 56-66; (5) Kilci, M. 2011. Effects of nutrients on conelet losses of stone pine (Pinus pinea L.) in Kozakk province. Agropine 2011 International meeting on Mediterranean stone pine for Agroforestry. Valladolid-Spain, 17-19 November 2011; (6) Loewe, V., A. Venegas, C. Delard, M. Gonzalez. 2011. Thinning effect in two young stone pine plantations (Pinus pinea L.) in central southern Chile. AGROPINE2011, International Meeting on Mediterranean Stone pine for agroforestry. Valladolid (Spain), November 2011; (7) E. Lopez. 2007. ¿Seguro que los frutos secos engordan y son malos para la salud? [En línea]. [Fecha de consulta: 09 septiembre 2011]. Disponible en: www.puntovital.cl/alimentacion/sana/nutricion/frutos_secos.htm; (8) Martinez, J., P. Ara, I. Gonzalez. 1993. Ecuaciones alométricas de tres variables: Estimación del volumen, crecimiento y porcentaje de corteza de las principales especies maderables españolas. Madrid, España. Investigación Agraria, Sistemas y Recursos Forestales 2(2): 211-228; (9) Montoya, J.M. 1990. El pino piñonero. Ediciones Mundi-Prensa, Madrid, España. 98 p; (10) Mutke, S., J. Gordo, L. Gil. 2000. Fenología de Pinus pinea L. en un banco clonal (Valladolid). ETSIIAA de Palencia. Universidad de Valladolid; (11) Mutke, S. 2000. Fenología de Pinus pinea L. en un banco clonal (Valladolid). Memoria para optar al título de Ingeniero de Montes, Universidad de Valladolid, Escuela Técnica Superior de Ingenierías Agrarias de Palencia, Valladolid (España). 91 p.; (12) Mutke, S. 2005. Modelización de la arquitectura de copa y de la producción de piñón en plantaciones clonales de Pinus pinea L. Tesis Doctoral. Ingeniero de Montes. Madrid, España. Universidad Politécnica de Madrid. Escuela Técnica Superior de Ingenieros de Montes. Departamento de Silvopascicultura. 95 p. ;(13) Mutke, S., S. Iglesia, L. Gil. 2007. Selección de clones de pino piñonero sobresalientes en la producción de piña. Invest. Agr.: Sist. y Recur. For. Vol 16(1). Pp. 39-51; (14) Salas-Salvado, J., E. Ros Arola, J. Sábato Casillos. 2005. Frutos secos, salud y culturas mediterráneas-. Ed. Glosa. S.L. 337p; (15) Salazar, G., I. Lazcano-Ferrat. 2003. La fertilización en "sitio especifico" incrementa los rendimientos y el tamaño de la fruta del aguacate en México. Actas V Congreso Mundial del Aguacate. Pp. 373-379.; (16) Segura, R., C. javierre, M. Lizarraga, E. Rs. 2006. Other relevant components of nuts, phytosterols, folate and minerals. Br J Nutr 96: S36-S44; (17) Sotomayor, A., E. Garcia, G. Valdebenito. 2001. Manual de plantaciones forestales para pequeñas propiedades. Manual 30. INFOR. 41 p.; (18) Venegas, A. 2010. Uso de reguladores de crecimiento y su influencia en los brotes reproductivos y vegetativos en Pinus pinea L. Memoria para optar al título de Ingeniero Forestal. Santiago, Universidad de Chile, Facultad de Ciencias Forestales, Departamento de Manejo de Recursos Forestales. 53 p.

Fig. 5. A general view of the research plot in winter.

Table 6. DBH and height (± standard error) one and two years after fertilization.

Plot (Exposure)	2009		2010		2011	
	DBH (cm)	Height (m)	DBH (cm)	Height (m)	DBH (cm)	Height (m)
1 (NW)	26.54 ± 3.70 a	9.57 ± 1.15 a	28.75 ± 4.18 a	10.13 ± 1.08 a	29.70 ± 3.97 a	10.63 ± 1.34 a
2 (N)	26.37 ± 3.90 a	9.79 ± 1.03 a	27.01 ± 4.50 a	10.53 ± 1.19 a	28.62 ± 5.06 a	11.06 ± 1.47 a
T (N)	26.45 ± 3.79 a	9.68 ± 1.09 a	28.54 ± 4.84 a	10.15 ± 0.86 a	30.49 ± 5.59 a	10.94 ± 1.10 a

Means with the same the letter have no significant differences ($p <= 0.05$)

Table 7. Annual increment in DBH and height after fertilization.

Plot	DBH Increment (2009-2010) (cm)	Height Increment (2009-2010) (m)	DBH Increment (2010-2011) (cm)	Height Increment (2010-2011) (m)
1	2.20 ± 0.28 a	0.56 ± 0.06 a	0.95 ± 0.27 a	0.50 ± 0.10 a
2	0.64 ± 0.28 b	0.75 ± 0.06 a	1.61 ± 0.27 a	0.52 ± 0.10 a
T	1.41 ± 0.46 ab	0.65 ± 0.10 a	1.95 ± 0.44 a	0.79 ± 0.17 a

*Means with the same small letter have no significant differences ($p <= 0.05$).