Effect of *Pinus sylvestris* L. and *Pinus nigra* Arn. thinning on juvenile cork oak *(Quercus suber* L.*)* growth in Bozoo (Burgos, Spain)

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Abstract

Bozoo cork oak forest is located in the northeast of Burgos province (north of Spain), in the "Sierra de Besantes" Public Forest. "Sierra de Besantes" is at the eastern part of the Natural Park of "Montes Obarenes", also included in the Nature2000 network.

A number of particular characteristics can be found in the Bozoo cork oak forest, namely: (1) the little surface of this relict forest, around 400 ha, growing under unusual climate conditions for the species. (2) cork oak grows under a Pinus sylvestris and Pinus nigra 50 year-old reforestation and (3), the poor light conditions and the water and nutrients competition of the pines do not permit an appropriate development of cork oak.

A collaboration programme between the Burgos Forest Service (Junta de Castilla y León) and the University of Huelva began in 2003 to analyse the response of the cork oaks to the pine thinning or clearcut. Two plots of 1530 and 1800 m^2 were installed and pines were clearcutted in half of each plot. Cork oak response is monitored with 100 analogical dendrometers and 9 electronic point dendrometers. In addition, some dendrometers have been installed in *Quercus ilex, Arbutus unedo, Pinus sylvestris* and *Pinus nigra* . In order to obtain correlations between climate and growth parameters, a meteorological station was installed in the experimental plot. Air temperature, rainfall, radiation, wind, humidity, soil temperature and soil moisture are measured every 15 minutes. Simultaneously, the Burgos Forest Service has designed a pine thinning programme in the area with cork oak presence. The goal to be achieved is the recovery of cork oak forest through the improvement of light conditions and regulation of competition with pines. In spring of 2004, 9 ha were thinned.

Those cork oaks in the thinned area showed primary and secondary growth in autumn 2004, while no growth has been in cork oak under the pine cover. No damage has been registered in the cork oak of the thinned area due to heavy snowfalls of winter of 2005.

Main goals to be achieved with the study are: (1) to develop a growth model for the Bozoo cork oak forest, including the analysis of the environmental and silvicultural variables and (2) to ellaborate a silvicultural pattern with the aim of the recovery of the cork oak forest.

Keywords: cork oak growth, thinning, thinning program, climate, silviculture, pine competition

Introduction

Bozoo cork oak forest is located in the northeast of Burgos province (north of Spain), in the "Sierra de Besantes" Public Forest. "Sierra de Besantes" is at the eastern part of the Natural Park of "Montes Obarenes", also included in the Nature2000 network.

A number of peculiar characteristics can be found in the Bozoo cork oak forerst, namely: (1) The little surface of this relict forest, around 400 ha, growing under unusual climate conditions for the species. (2) Cork oaks grow under a *Pinus sylvestris* and *Pinus nigra* 50-year-old reforestation and (3), the poor light conditions and the water and nutrients competition of the pines do not permit an appropriate development of the cork oaks.

Concerned of the significant peculiarity of cork oaks, there are two ongoing activities: (i) Junta de Castilla y León (regional administration in charge of the forest management) is undertaking a thinning programme to improve cork oak physiological condition within its range. (ii) Universidad de Huelva and Junta de Castilla y León are monitoring the response of cork oaks to pine thinning.

Recent evolution of Bozoo cork oak forest

There are some historical references describing Bozoo forest, like Madoz (1849), that included evergreen oak (*Quercus ilex*), cork oak (*Quercus suber*), pines (*Pinus sylvestris* and *Pinus pinaster*) and mediterranean oaks (*Quercus faginea* and *Quercus pyrenaica*). The Forest Administration promoted a reforestation that began on 1950. By that time, there were very few pines remaining and cork oaks where just little shrubs due to the intense livestock use (sheep), creating a mixture of rangeland and grassland landscape.

The area reforested each year is shown in Table 1. The species used were *Pinus sylvestris*, *P. nigra* and *P. pinaster*. The density was 2.500 trees/ha.

Year	1950	1952	1953	1956	1974
Area (ha)	100	100	100	105	25

Table 1. Yearly area reforested at Bozoo.

In a very first moment after reforestation works, cork oaks recovered due to the ban on livestock use of the forest. But soon pines grew and completely shadowed cork oak, that had been growing since then in a very poor condition.

A number of thinnings has been made in the 80's and 90's, in those afforested sectors with better site index, to reduce pine intrespecific competition. As a consequence, cork oaks

could get some light for a time in these areas, and their condition improved slightly. The goal of these thinnings was the increase of pine wood production, and the survival of cork oak was seldom considered. Table 2 shows wood volume extracted in thinnings.

From Table 2 it can be easily inferred that most of the reforestation remained unthinned by 2.000.

Year	Volume (m^3)
1.981	369
1.984	60
1.991	358
1.994	900
1.995	1.594
1.999	2.408

Table 2. Years of thinning and volume extracted in each.

Description of ecological characteristics of the forest

Cork oak at Bozoo can be found in 400 ha, between 700 and 900 m.a.s.l., in moderate slopes of S or SW aspect. There is a high level of geological complexity and clayous marls, calcareous marls, limestone and sandstone can be found at the forest. Some species that can be found in cork oak range are *Arbutus unedo*, *Erica cinerea, Erica scoparia, Calluna vulgaris.* Climate is a nemoromediterranean $VI(IV)_2$ (Allué, 1990) with mean annual precipitation of 878 mm, mean annual temperature of 10ºC and a slight drought period of 0,36 months.

Pine forest density before thinning was 1.700 trees ha^{-1} with a basal area of 71 m^2 ha^{-1}, mean height of 12 m and mean diameter of 23 cm. In those areas morew densely covered by cork oak the density of this species is 590 trees ha^{-1} with a basal area of 10,02 m^2 ha^{-1}, mean height of 4,3 m and mean diameter of 15 cm

Due to the continuous pine canopy cover and, in a second term, to the nutrient and water competition from pines, cork oak were in a critic situation, many of them close to death. Only those cork oaks growing on forest roads borders could keep some green branches.

Heavy-thinning programme

The estate of conservation of this relict forest was not acceptable, taking also into account that the forest is included in a Natural Park and in Nature2000 network. A heavy-thinning programme began in 2003. The main goal to be achieved is to improve cork oak condition to get in the future a real cork oak forest.

A selective thinning on 9 ha covering the study area was done on 2004. Those pines high competitors with cork oaks were removed (Volume=68,29 m^3 ha^{-1} , G=10,65 m^2 ha^{-1}, 256 trees ha^{-1}).

Cork oak response to pine thinning

Materials and methods

The experimental design consists in two treatments (with and without pine release) and two replications (plot A=1.530 m^2 and B=1.802 m^2) were installed in April 2003. Previous to thinning dbh, tree heights, crown heights and crown radius were measured in all trees inside the plots (228 in plot A and 236 in plot B). All trees have been also mapped with a topographical total station to account for level of competition previous to thinning.

The thinning affected only to pine species (*P. sylvestris* and *P. nigra*) in half of the two plots in which the experiment is going on. Thinning was made in May 2004.

Cork oak response is monitored with 70 band dendrometers (35 for each replication and treatment) and 8 electronic point dendrometers (4 for each replication and treatment). In addition, 48 analogical dendrometers have been installed in six *Quercus ilex*, four *Arbutus unedo*, 30 *Pinus sylvestris* and 8 *Pinus nigra*. Also one electronic dendrometer have been installed on *Pinus sylvestris* and on *Pinus nigra*. The objective of installing electronic point dendrometers is to quantify the thinning effect with higher accuracy, to compare the growth period and growth rates of cork oak and pine species and to explain the daily variation (mainly due to sap flow) that can be found in the data.. Electronic point dendrometers records data each 15 min with an accuracy of 4 microns. Band dendrometers are measured monthly. Six monthly measurements are already available.

Two soil moisture sensors and two soil temperature sensors for continuous data gathering was installed in August 2004 in plot B (one in the thinning area and one in the no-thinning area) with the objective is to relate soil moisture and temperature changes with tree growth.

To establish some links between cork oak secondary growth and climatological characteristics a meteorological station (model Vantage Pro, from Davis Instruments) was installed in plot A. Each 30 min air and soil temperature, relative humidity, wind speed, air pressure, radiation and soil moisture content at two depths are logged.

Results

Thinning quantification

Main dendrometric variables per plot and species are presented in Table 3. Circumference distribution related to plot A and B previous to thinning is presented in Figure 1.

Plot	Especies	Tree basal area (dm^2)			Tree height (m)			Crown length (m)		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
A	*Q. suber*	1,43	0,23	4,36	4,0	1,2	8,9	0,1	2,2	7,1
	P. sylvestris	4,59	0,81	9,11	12,2	6,2	14,6	3,6	6,0	7,9
	P. nigra	2,44	1,40	4,24	12,4	11,3	13,6	4,8	6,1	7,1
	Q. ilex	0,29	0,13	0,54	2,3	0,8	5,6	1,4	0,5	5,6
	A. unedo	0,51	0,16	0,72	2,8	2,0	3,8	4,3	3,4	5,8
B	*Q. suber*	1,68	0,35	4,72	4,9	1,9	10,4	0,0	2,6	6,0
	P. sylvestris	6,05	2,24	11,08	12,8	10,4	15,7	6,8	4,2	10,1
	P. nigra	3,66	1,09	10,52	13,9	10,0	17,7	7,4	3,2	4,7
	Q. ilex	0,50	0,11	1,15	4,2	3,2	4,7	3,3	2,9	3,7
	A. unedo	0,16	0,13	0,20	3,7	3,2	4,0	2,9	2,6	3,5

Table 3. Dendrometric values in plots A and B (Bozoo, Burgos, Spain)

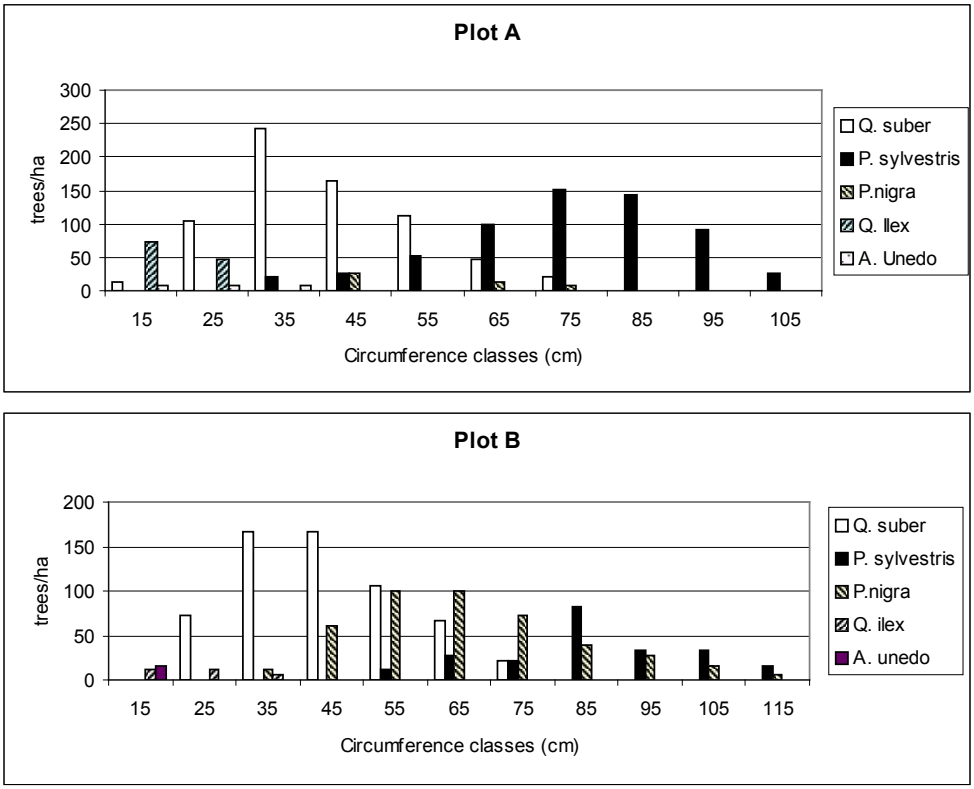

Figure 1. Circumference distribution previous to thinning in plots A and B

Total number of trees per ha previous to thinning was 1490,19 in plot A and 1309,65 in plot B. Thinning quantification is shown in Table 5

	Before thinning									
	Basal area (m^2 ha^{-1})					Trees ha^1				
Plot	*Q. suber*	*P. sylvestris*	*P. nigra*	*Q. ilex*	*A.unedo*	*Q. suber*	*P. sylvestris*	*P. nigra*	*Q. ilex*	*A.unedo*
A	9,98	28,18	1,12	0,34	0,10	699,35	614,38	45,75	117,65	19,61
B	10,06	13,77	15,84	0,14	0,03	599,27	227,50	432,81	27,74	16,65
	Thinning									
A		17,23	1,12				398,69	45,75		
B		2,91	6,61				49,94	216,40		
	After thinning									
A	9,98	10,95	0,00	0,34	0,10	699,35	215,69	0,00	117,65	19,61
B	10,06	10,86	9,24	0,14	0,03	599,27	177,56	216,40	27,74	16,65

Table 5. Thinning quantification in basal area and trees per ha in plots A and B

Band dendrometers

Data from band dendrometer analysis show significative differences among species (Table 6). Smaller circumference increments were recorded in the first year (2003) due to the fact that dendrometers probably need a little period to get adjusted. Highest circumference increments were recorded on *Pinus nigra* (11-15 mm per year) while lowest on *Quercus suber* (0,59-1 mm per year).

		Circumference increment (mm)					
Species	sampled trees	Mean 2003	Mean 2004	Mean 2005	Standard deviation 2003	Standard deviation 2004	Standard deviation 2005
Arbutus unedo	1	2,23	2,84	2,11			
Pinus nigra	6	4,87	15,46	11,02	3,10	5,61	4,25
Pinus sylvestris	6	2,95	8,13	7,53	1,80	1,66	3,40
Quercus ilex	4	0,26	4,25	4,34	0,67	3,43	1,62
Quercus suber	99	0,39	0,59	1,00	2,40	0,91	1,83
Total	116	0,78	1,89	1,98	2,62	3,99	3,34

Table 6. Circumference increments recorded from the 5 species at Bozoo experimental plot on 2003, 2004 and 2005.

Thinning treatment showed a significative effect on *Quercus suber* for years 2004 and 2005 (p=0,010 for 2005 and p=0,026 for 2004 with CAP as covariable -0,016 and 0,046 without covariable- Table 7). Trees in thinned area grew more that double compared to those where no trees were removed. No significative differences were recorded on 2003, because dendrometers were not fine-adjusted then and the thinning were not completed after august 2004. Differences among plots are not significant.

			Circumference increment (mm)					
Plot	Treatment	N	Mean 2003	Mean 2004	Mean 2005	Standard deviation 2003	Standard deviation 2004	Standard deviation 2005
A	No thin	20	0,04	0,41	0,41	0,40	0,81	1,37
	Thinning	29	0,58	0,82	1,52	2,45	1,09	2,01
	Total	49	0,30	0,61	0,93	1,92	0,99	1,81
B	No thin	27	0,77	0,44	0,77	3,83	0,71	1,53
	Thinning	23	0,11	0,76	1,43	0,25	0,97	2,17
	Total	50	0,48	0,58	1,06	2,82	0,84	1,85
Total	No thin	47	0,41	0,42	0,616	2,91	0,75	1,46
	Thinning	52	0,35	0,79	1,48	1,85	1,03	2,06
	Total	99	0,39	0,59	1,00	2,40	0,91	1,83

Table 7. Quercus suber circumference increment under both treatments.

Electronic point dendrometers

DBH cork oak increment is shown in Figure 6. Growth pattern on 2004 showed a high dbh increment until mid September-mid October, and finished by the end of October. On

2005, dbh growth began on the second April fortnight. Until the last data gathered (August), a roughly constant dbh increment has been recorded. A diminution of dbh increment rate at the beginning of June was recorded in one tree of the thinned area.

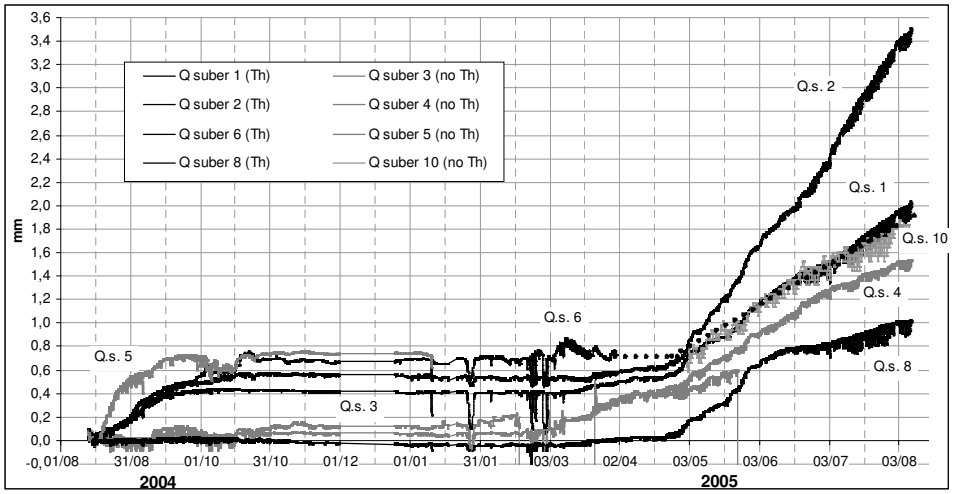

Figure 2. Radius increment (mm) of cork oak at Bozoo. Trees 1, 2, 6 and 8 grow in thinned areas and trees 3, 4, 5 and 10 in unthinned.

Pines growth pattern show some remarkable differences compared to cork oak's (Figure 3). Dbh increment began one month before and finished in mid june (Pinus sylvestris) and mid august (Pinus nigra). DBH rate is not constant along the period.

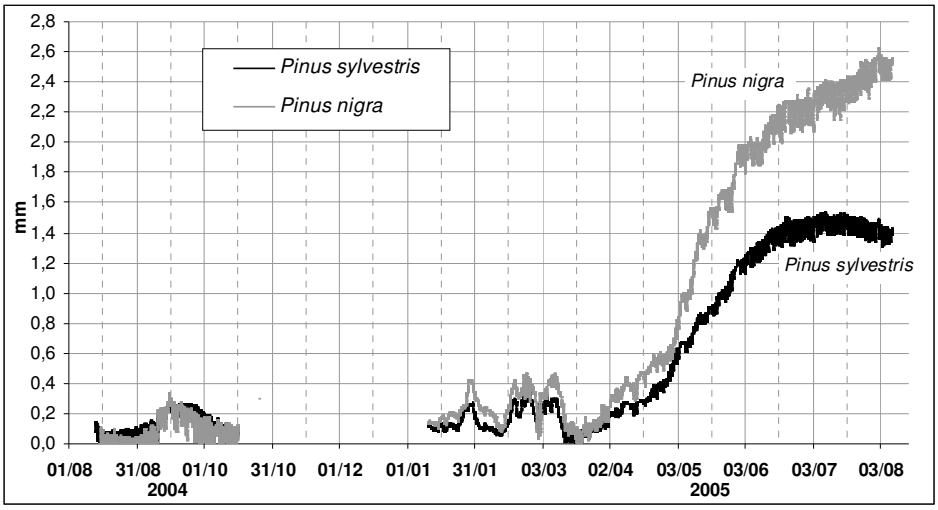

Figure 3. Radial increment of two pines at Bozoo.

Soil sensors

Soil temperature at 30 cm depth is influenced by thinning. Compared to unthinned areas, temperature is roughly 3º higher on hottest period and 0,5º lower in coldest period. Range varies from 2ºC (at the beginning of March) to 23ºC (by mid July).

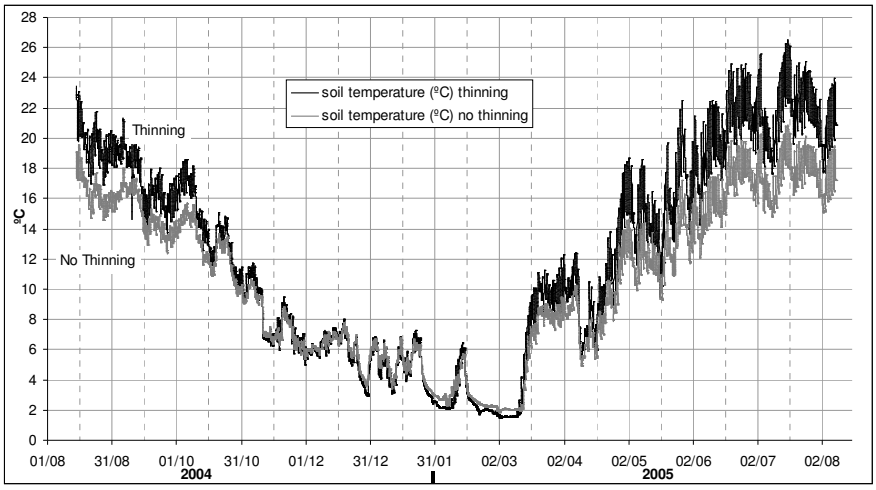

Figure 4. Soil temperature at 30 cm depth in thinned and unthinned areas.

Soil moisture is also influenced by the thinning treatment. It lasts longer and recovers more easily in thinned plots (Figure 5).

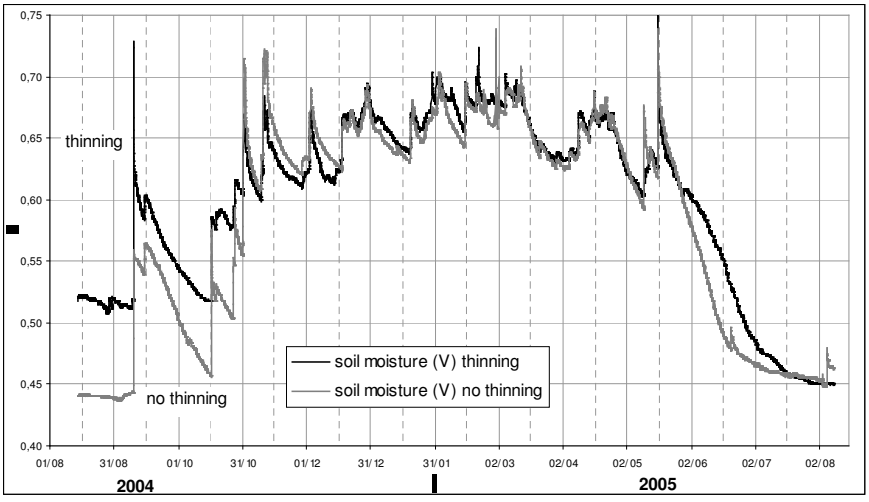

Figure 5. Soil moisture at 10-30 cm depth (values are expressed in volts. Field capacity is reached at 0,68 V and wilting point at 0,44 V).

Conclusions

Pine cover thinning had a significant effect on cork oak growth, with a mean circunference increment in thinned plots double than in unthinned areas. Thinning also affected soil temperature showing higher values in summer in thinned areas. Soil water content evolution was modified: water lasts longer and recovers more easily in thinned plots. Cork oak and pine species show a different growth patters with pine species starting cambial activity one month earlier than cork oak and finishing the growth period also earlier.

Acknowledgements

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