Thinning experiment in mixed Scot pine and Pyrenean oak stands

Objectives:

1) to decipher temporal complementarity by species differences in intra-annual cumulative radial increment patterns,
2) to evaluate the effects of thinning and climate intra-annual radial increment patterns for both species.

1. Materials and methods

2.1. Study site and experimental design

The experimental design was located in Palacio de Valdellorma (León, 42º 45' 42.4'' N, 005º 12' 39.6'' W) in north-wetern Spain. The experimental site was sited at 990 m.a.s.l. in a continental Mediterranean climate. The average annual rainfall is 515 mm with a marked summer drought episode between July and August, when 42 mm of precipitation are usually recorded (AEMET, 2016; Spanish State Meteorological Agency. 2661 Code of weather station. Based on 1981-2010 historical records). Annual mean temperature is 11.1 ºC and the hottest month is July, with an average temperature of 27.4 ºC. The probability of frost period is from December to February. Topography was moderate with a slope of 16% and soils consisted in acid conglomerates based on Miocene clay sediments (IGM). Weather of sampling years (2016-2017) was characterized by severe summer drought. Moreover, 2017 was a very dry year due to a low precipitation at the beginning of spring (March-April) and at the end of autumn (October). Besides, average of daily maximum temperatures for warmest month was higher than mean historical records (29.4-28.4 vs. 27.4ºC).

The forest is a mixed stand composed with *Q.pyrenaica* and *P.sylvestris* species. The stand was originated during 1970's by a re-introduction of pine after a harvest and bulldozer rippering of an original oak coppice stand. Afforestation was carried out after harvest through planting pines by strips. Oak coppice sprouts grew again via asexual reproduction between pines strips. Pine trees are even-aged (40 years old) and real cambial age of oak trees is unknown. Today, the stand is a mixed forest with a horizontal distribution of mixing species disposed by rows and with closed canopy cover.

Nine rectangular plots (50 x 40 m) were established in a Latin square design. The experimental design consisted of two thinning treatments with different intensity and unthinned control with three replicates each. Thinning treatment consisted in moderately and heavy thinning removing 25% and 50 % of initial basal area (Table 1). Both species were removed applying thinning from below, which involved logging the suppressed and intermediate trees. Thinning was carried out at the end of 2015 and the felled logs and branches were removed from plots. There were no statistical differences between treatments for each species before thinning (Table 1) according *mctp* function from 'nparcomp' R package (Konietschke et al., 2015), which computes the estimator of nonparametric relative effects based on global rankings, simultaneous confidence intervals and adjusted p-values based on contrasts Tukey contrasts. However, statistical differences were identified after thinning. Pine density differed between all three treatments, although there were no differences in tree diameter for moderate and heavy thinning either between moderate thinning and control basal area. There were not statistical differences between moderate and heavy thinning for density, diameter and basal area of oak trees after thinning (Table 1).

Table 1. Main stand characteristics before and after thinning for each species. Data shown are mean and standard deviation values by treatment. Different letters denote significant differences after thinning at the 0.05 significance level.

			Before thinning			After thinning		
Species	**Treatment**	**H_o (m)**	**Density ($n \cdot ha^{-1}$)**	**DBH (cm)**	**BA ($m^2 \cdot ha^{-1}$)**	**Density ($n \cdot ha^{-1}$)**	**DBH (cm)**	**BA ($m^2 \cdot ha^{-1}$)**
Pinus sylvestris	**Control**	12.5±1.	1,415±13	12.2±4.	19.6±2.	1,415±130	12.2±4.3**a**	19.6±2.3
	Moderate	10.7±1.	1,575±90	12.0±4.	19.5±3.	710±240**b**	16.0±3.3**b**	13.7±5.5
	Heavy (50%)	11.7±1.	1,580±13	11.8±4.	20.9±3.	390±197**a**	15.1±3.5**b**	9.0±4.6**a**
Quercus pyrenaica	**Control**	10.9±1.	2,960±71	5.9±3.2	12.6±1.	2,960±710	5.9±3.2**a**	12.6±1.6
	Moderate	10.7±0.	2,855±36	6.6±3.5	12.1±1.	1,195±286	9.2±4.6**b**	8.8±1.7**a**
	Heavy (50%)	11.3±1.	2,005±76	6.6±4.1	8.7±5.0	430±427**a**	9.3±6.3**b**	4.0±2.9**a**

H_0: dominant height; DBH: diameter at breast height; BA: basal area.

2.2. Stem radial variation measurements

We installed band dendrometers (DB 20, EMS Brno) after thinning treatment on five trees per species and plot. A total of 90 bands dendrometer were fitted at breast height (1.30 m) after smoothing and removal of the outermost dead bark to avoid the influence of hygroscopic bark swelling and shrinkage on dendrometer measurements. Trees were selected within the plots using stratified sampling approach that took diameter distribution into account. Overall, selected trees were carefully chosen attempting that local competition was representative to the plot thinning treatment. Band dendrometers

were read every two weeks from March to December along 2016 and 2017 years with a resolution of 0.1 mm. Besides, the measurements were corrected according thermal expansion ($11.2 \times 10^{-6} mm \circ C^{-1}$). Finally, girth increment data were transformed to radial increments based on a hypothetic cylindrical tree shape.