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Aleppo pine (*Pinus halepensis*) natural regeneration, without fire, in the Kassandra Peninsula, northern Greece

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ABSTRACT: The aim of this work is the study of *Pinus halepensis* natural regeneration, without fire, in the forests of the Kassandra peninsula, northern Greece. *Pinus halepensis* is a Mediterranean serotinous wind-dispersed species that easily regenerates after wildfires. However, in the absence of fire a significant seed release takes place during the hot summer. Considering that the seed release is adequate without fires, the particular stand conditions, where natural regeneration appears, were studied. Seedling density and height were measured. Also, stand and plot characteristics recorded included tree age, height, dbh, canopy cover, density and height of shrubs, topography, slope, aspect and the thickness of litter. The results point out an important effect of the stand conditions on *Pinus halepensis* regeneration. Thus, keeping in mind the particular stand conditions we can plan appropriate silvicultural treatments in order to accomplish satisfactory regeneration.

1 INTRODUCTION

Pinus halepensis is the most widely distributed pine throughout the Mediterranean region. It spreads from sea level up to 600-800 m in Quercetalia ilicis floristic zone. From a silvicultural-biological point of view it is a photophilic, dry-warm, frugal species, preferring alkaline to neutral soils (Quezel 1986), as well as being a serotinous, wind-dispersed species that easily regenerates after wildfires (Trabaud et al. 1985; Neeman et al. 1992; Daskalakou and Thanos 1996; Tsitsoni 1997; Thanos 2000). The relatively large cone crops are produced annually. Pollination takes place in spring, the fertilization occurs a year later and seed dispersal begins in the third year after pollination, (Panetsos 1981).

Indeed, fire does generate a massive release of *Pinus halepensis* seeds but considerable release also occurs independently of fire (Acherar et al. 1984; Tsitsoni and Zagas 1995; Daskalakou and Thanos 1996; Nathan et al. 1999). As an evolutionary strategy, serotiny requires a mechanism of seed release that is guided by environmental cues associated with favorable establishment opportunities. Fire is often regarded as the most effective cue and serotiny is therefore generally used as a synonym for fire-induced seed release. Cone opening depends primarily on the scale-reflex mechanism, and hence drying conditions that are not necessarily associated with high temperatures and fire, are needed to induce seed release (Nathan et al. 1999). For example, Dawson et al. (1997) found that *Pinus radiata* cones opened in response to low relative humidity in a constant 'normal' temperature of 23 ^{o}C.

Considering that the seed release is adequate without fires, the purpose of this research was: to study the natural regeneration of *Pinus halepensis*, without fire and the particular stand conditions that favor the natural regeneration in the forest of the Kassandra Peninsula, northern Greece.

2 MATERIALS AND METHODS

The research was conducted in the forest of the Kassandra peninsula, northern Greece. The selection of this forest was based on the fact that, according to Tsitsoni (1991), *Pinus halepensis* reaches its optimal growth in this area while its existence and conservation is very important for the already high touristic development of the area. The climate of the area belongs to the Mediterranean type and according to the bioclimatic diagram of Emberger (1959) it belongs to the sub-humid mediterranean zone (Tsitsoni 1997). According to the data from the meteorological station of Kassandria (period 1978-1997) the mean annual rainfall reaches 581 mm, while the mean annual air temperature is 16.3 ^{o}C and the mean maximum air temperature of the warmest month (July) is 30.1 ^{o}C. The dry period begins in the middle of April and lasts until the middle of September (Tsakaldimi, 2001). The soils occupied by the *Pinus halepensis* in the Kassandra, are loamy-clayey and neutral to alkaline (pH 7.0 to 8.4) (Tsitsoni 1997; Tsakaldimi 2001). The vegetation of the studied area belongs to *Quercetalia ilicis* froristic zone. The forest, in fact, is not under systematic management but there are protection measures from wildfires.

For the estimation of the natural regeneration 32 sample plots were taken only in mature stands (over 80 years old) of *Pinus halepensis*, distributed along the forest area of the Kassandra peninsula. The plots were located in four areas in Sani-Kassandria, Hanioti, New Skioni and Siviri. The sample plots were 500 m^2; in each plot we recorded the height and dbh of mature trees, the canopy cover as the percentage of the total area of sky vertically above the plot hidden by the canopy, the shrub cover and the average height of shrubs (as the mean value of 10 random selected stems), the topography, the slope, the aspect and the thickness of litter (average value of three measurements). For the estimation of *Pinus halepensis* natural regeneration, a subplot of 10m x 10m was taken in the center of each plot, where the number and the height of the seedlings or saplings were recorded (Ganatsas 1993). Seedlings were classified into three height classes, less than 50 cm, 50-100 cm and more than 100 cm (Vickers and Palmer 2000). We defined as regeneration index the number of seedlings per square meter multiplied by mean seedling height (Corona et al. 1998).

Statistical analysis was performed by the SPSS program. Analysis of variance was used to determine the relationships between the regeneration characteristics and the stand factors. T-test was used wherever we had comparison of two means. (Snedecor and Cochran 1988).

3 RESULTS

3.1 *Characteristics of the stand plots*

Totally 18 plots were taken in Sani-Kassandria area, 4 plots in Hanioti, 2 plots in Nea Skioni and 8 plots in Siviri. The mother trees of all studied plots were in the mature phase; 80-120 years. In the Sani-Kassandria area, we found plots of all kind of aspects, situated mainly in the upper and medium position on the hillside and their slope ranged from 5% to 30 %. The mean height of mature trees was 17.8 m and the mean dbh was 40.9 cm. In the Hanioti area, the general aspect of the plots was northern. The plots were situated in the down position on the hillside and the slope was 45-60 %. The mean height of mature trees was 17.6 m and the mean dbh was 38.3 cm. In the Nea Skioni area, the general aspect of the plots was north-eastern. The plots were situated in the medium position on the hillside and the slope was 40-45 %. The mean height of mature trees was 17 m and the mean dbh was 38.4 cm. In the Siviri area, the general aspect of the plots was western. The plots were situated in the medium position on the hillside and the slope was around 15 %. The mean height of mature trees was 17.2 m and the mean dbh was 37.5 cm.

The shrub story of the above areas was dominated mainly by the species *Quercus coccifera, Pistacia lentiscus, Myrtus communis*, *Phillyrea latifolia, Arbutus andrachne*, *Arbutus unedo*, *Erica arborea, Cistus spp*., *Smilax aspera*.

3.2 *Characteristics of the natural regeneration*

In all studied stands there were trees in the mature phase, which have produced a large cone crop (open and closed). Thus the lack of regeneration in some plots cannot be attributed to the lack of seeds but to other factors related to the environment and stand conditions. The regeneration of *Pinus halepensis* presents a great variability. In some sites the regeneration is scarce or zero while in other sites it is over-satisfactory for the stands renewal (maximum number of seedlings recorded was 11,600 seedlings/ha), (Table 1). The greater seedling densities were observed in the height classes of 50-100 cm and > 100 cm (0.21 and 0.17 seedlings/m^2 respectively). The seedlings' height also presented a great variability and ranged from 9 cm to 127 cm. This variability can be attributed to the differences in seedlings' age, which varied, between 1 and 15 years. The regeneration index ranged from 0.45 to 103.03.

However, the average number of seedlings recorded was 3,400 seedlings/ha for Sani-Kassandria area, 3,200 for Siviri and 0,00 for the other two areas. It is worth pointing out that this regeneration establishment is due to a natural forest process and not a result of the appropriate silvicultural interventions that aimed at the stand regeneration.

3.3 *Factors affecting the natural regeneration*

Based on the above, we distinguished two stand categories, the first, where natural regeneration was established regardless of the size and the density of seedlings, and the second where the stands are characterized by the lack of natural regeneration. A data analysis was performed to identify the force factors that probably are the reasons for the regeneration failure. T-test process revealed that there were significant differences between the two categories in the total plant cover (tree and shrub cover) and shrub height. The litter thickness did not present significant differences (Table 2). In the first stand category, the average total cover was 98.5 %, the mean height of shrubs 98 cm and the thickness of litter 2.11 cm. In the second stand category the average total cover was very high 146.7 %, the mean height of shrubs 239.2 cm and the thickness of litter 2.50 cm.

The analysis of variance showed that three stand factors (tree canopy cover, shrub cover and height of shrubs) are the main factors that significantly affected the seedling density, the regeneration index and the height of seedlings (Table 3).

The influence of the stand factors on the seedling density is clearly shown in the Figures 1 and 2. The maximum regeneration density was observed in plots of 30% and 50% canopy cover, when the shrub cover was 40% and 60% and the height of shrubs was 70 cm and 60 cm respectively.

Table 1. Characteristics of *Pinus halepensis* natural regeneration without fire in the Kassandra Peninsula, northern Greece.

Site	Seedling density (seedlings / m^2)						Seedling height (cm)			Regeneration index		
	Mean	Min	Max	<50 cm	50-100 cm	>100 cm	Mean	Min	Max	Mean	Min	Max
Sani-Kassandria	0.34	0.00	1.16	0.05	0.21	0.08	91.43	65.80	126.78	29.49	0.00	103.03
Hanioti	0.00	0.00	0.00	0.00	0.00	0.00	-	-	-	0.00	0.00	0.00
Nea Skioni	0.00	0.00	0.00	0.00	0.00	0.00	-	-	-	0.00	0.00	0.00
Siviri	0.32	0.03	0.69	0.07	0.08	0.17	68.60	9.00	125.04	36.36	0.45	84.42

Table 2. Characteristics of *Pinus halepensis* stands in relation to the distinction between regeneration emergency and regeneration failure.

Stand category	Mean canopy cover (%)	Mean shrub cover (%)	Total cover (%)	Mean height of shrubs (cm)	Litter thickness (cm)
Regeneration emergency	55.2 *	43.5 **	98.5 *	98 **	2.11 ns
Regeneration failure	70.3 *	76.7 **	146.7 *	239.2 **	2.50 ns

T-test, *: P<0.05, **: P<0.01, ns: non significant differences.

Table 3. The analysis of variance for the relationship between the stand factors (canopy cover, cover of shrubs, height of shrubs) and the regeneration characteristics.

Independent variable: canopy cover (%)						
		Sum of squares	df	Mean square	F	Sig.
Seedling density (seedlings/m^2)	Between Groups	3.787	6	0.631	16.529	0.000
	Within Groups	0.955	25	0.038		
	Total	4.742	31			
Regeneration index	Between Groups	37371.468	6	6228.578	65.564	0.000
	Within Groups	2374.983	25	94.999		
	Total	39746.450	31			
Mean seedlings height (cm)	Between Groups	25696.045	4	6424.011	17.741	0.000
	Within Groups	5431.442	15	362.096		
	Total	31127.488	19			
Independent variable: cover of shrubs (%)						
Seedling density (seedlings/m^2)	Between Groups	3.958	8	0.495	14.513	0.000
	Within Groups	0.784	23	0.034		
	Total	4.742	31			
Regeneration index	Between Groups	27617.097	8	3452.137	6.546	0.000
	Within Groups	12129.353	23	527.363		
	Total	39746.450	31			
Mean seedlings height (cm)	Between Groups	28627.459	6	4771.243	24.810	0.000
	Within Groups	2500.028	13	192.310		
	Total	31127.488	19			
Independent variable: Height of shrubs (cm)						
Seedling density (seedlings/m^2)	Between Groups	3.531	13	0.272	4.039	0.004
	Within Groups	1.211	18	0.067		
	Total	4.742	31			
Regeneration Index	Between Groups	33894.840	13	2607.295	8.020	0.000
	Within Groups	5851.610	18	325.089		
	Total	39746.450	31			
Mean seedlings height (cm)	Between Groups	28835.412	8	3604.426	17.298	0.000
	Within Groups	2292.076	11	208.371		
	Total	31127.488	19			

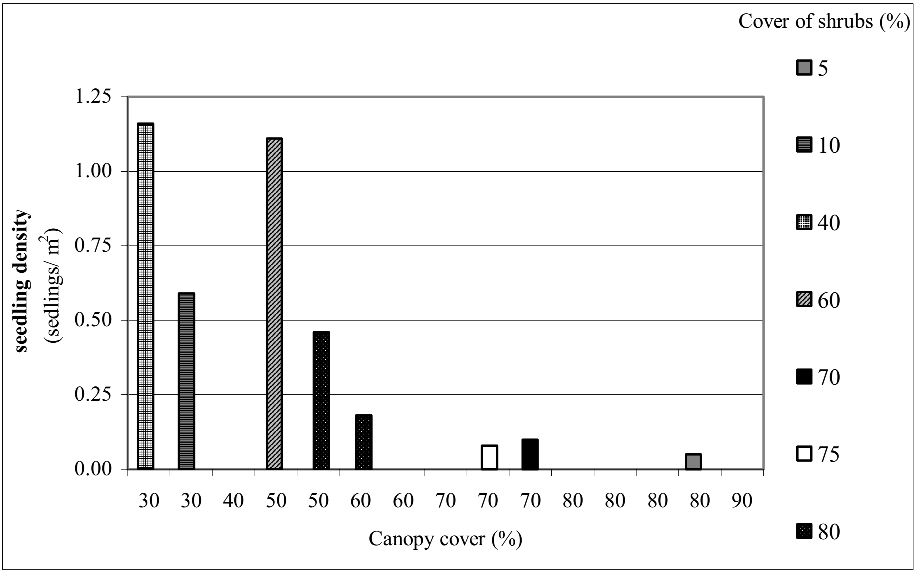

Figure 1. Seedling density of *Pinus halepensis* as affected by the tree canopy cover and the shrub cover.

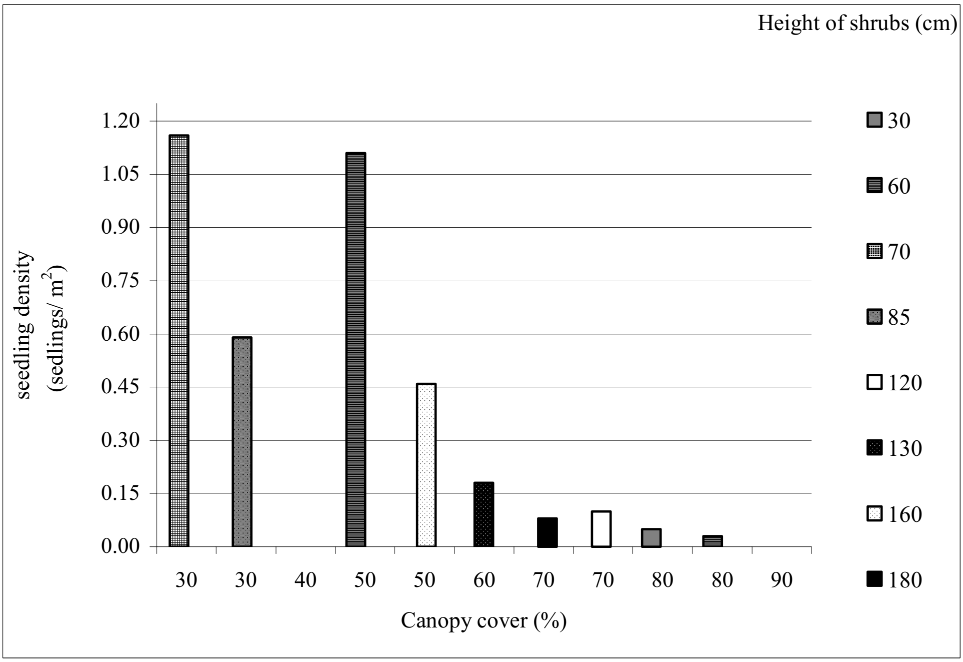

Figure 2. Seedling density of *Pinus halepensis* as affected by the tree canopy cover and the height of shrubs.

4 DISCUSSION

Natural regeneration of *Pinus halepensis* without fire in mature stands in Kassandra peninsula northern Greece was found satisfactory in some plots while in others there was no regeneration establishment. This can be attributed to the stand conditions prevailing in the studied areas. The seedlings or saplings density in the plots where the stands factors were favorable, ranged from 0.03 to 1.16 seedlings/ m^2 and their height ranged from 9 to 127 cm. Similar results reported by Tsitsoni and Zagas (1995) who found *Pinus halepensis* seedling densities between 0.12 and 1.44 seedlings/ m^2.

Comparatively, the seedling/sapling densities of the unburned stands are slightly lower than that reported for burned stands. Trabaud et al. (1985) found that the seedling density of *Pinus halepensis* was 0.1 seedlings/ m^2 five years after fire, while 5-15 years after fire it was 1.0 seedlings/ m^2. Also, Zagas et al. (2003), in Sithonia peninsula North Greece, found that the seedling density of *Pinus halepensis* was 0.15 seedlings / m^2 in the first year after fire, 0.16 in the second and 0.28 seven years later. However, Tsitsoni and Zagas (1995) reported that the seedlings densities of *Pinus halepensis* in Kassandra peninsula were between 0.7 and 11 seedlings / m^2 twelve years after fire, while Tsitsoni (1997), in the same area, found seedling densities between 0.6 and 14.26 seedlings/ m^2 eight years after fire.

The lower seedling/sapling densities in unburned stands are clearly related to the stand conditions (Table 3). The tree canopy cover, the shrub cover and the height of shrubs significantly affect the regeneration emergence or failure (Table 2). The close plant cover associated with the high shrub vegetation does not allow light or precipitation to reach the forest floor (Ganatsas 1993) and do not leave available space for *Pinus halepensis* seeds to germinate and grow. Under these conditions and without taking any tending measure it is very difficult for *Pinus* seedlings to emerge and establish themselves (Zhu et al. 2003). Vickers and Palmer (2000) also found that sapling density of *Pinus sylvestris* is clearly related to canopy cover by a quadratic relationship.

The maximum regeneration density was observed in the stands with canopy cover 30 and 50 %, shrub cover 40 and 60 % and height of shrubs 70 and 60 cm respectively (Figure 1 and 2). Thus it can be concluded that *Pinus halepensis* regeneration is easily established under relative low tree canopy cover where there is a medium shrub cover of relative low height (up to 80 cm).

However, in spite of the abundant literature produced in the last years for Mediterranean pines response to fire (Trabauld et al. 1985; Tsitsoni 1997; Arianoutsou and Ne'eman 2000; Spanos et al. 2000; Thanos 2000; Kazanis and Arianoutsou 2002) there are scarce reports concerning *Pinus halepensis* natural regeneration without fire. Thus, the authors believe that the natural regeneration of unburned stands of *Pinus halepensis* will therefore be better understood if it can be studied in long-term experiments designed to control certain environmental factors.

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