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Effects of wildfire season on the resprouting of kermes oak (*Quercus coccifera* L.)

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Abstract

The resprouting growth of kermes oak (*Quercus coccifera* L.) after wildfire, in relation to certain ecological parameters, has been studied. The effect of time of fire incident (beginning versus end of growth season) on growth (height and diameter) of new sprouts was examined. For each time of fire incidents, the influence of aspect (slope exposure), and pre-fire size of parental shrub, on resprouting ability and growth of kermes oak was also investigated. A total of 100 burned kermes oak shrubs were randomly selected on each burnt site: 25 per the main four aspects (north, east, south, west). The number of resprout influences their height and thickness. Three resprouts were kept per shrub, and their height and basal diameter were measured every 3 months for three vegetative periods. Statistical analysis of the data included standard procedures of comparison of means. Both sites comprised shrubs with similar pre-burn dimensions. Height growth showed no particular divergence between the two sites, following a typical sigmoidal tree growth curve, and reaching a maximum at the end of the second vegetative period. Height measurements showed highly significant differences between the two sites during the first two trimesters only, while differences in diameter were significant during the whole measurement period. Same-ages resprouts of Site 2 showed a faster initial height growth than those at Site 1. After the age of 12 months, however, height growth was more or less the same at both sites. Differences in aspects (orientation) were found only in plants of Site 2. Height and diameter of new resprouts were positively correlated to height of maternal sprout. Analysis of climatic data identified precipitation as the decisive factor in resprout development. The results of the present study conclude that the date of occurrence of wildfire does not affect the final dimensions of kermes oak shrubs, but it does affects initial growth rate. There are some differences in rate of growth after wildfires occurring at the end of the vegetative period especially relative to aspects. Moreover, after three vegetative periods, shrubs had regained a considerable part of their pre-burn height.

Keywords: Kermes oak; *Quercus coccifera* L.; Post-fire resprout; Regeneration; Wildfire; Greece

1. Introduction

Wildfire is a common and major disturbance factor in Mediterranean-type areas around the world, and

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constitutes one of the most decisive ecological factors for plant community regeneration. Many Mediterranean species have adapted strategies that allow them to survive periodical fires (Naveh, 1975; Trabaud, 1987; Pausas et al., 1999).

The way plant species survive fires, post-fire vegetation dynamics and growth rates have been subjects of many studies in the Mediterranean-type ecosystems around the world (e.g. Canadell et al., 1991; Farano et al., 1993; Moreno and Oechel, 1994), and also in Greece (Konstantinidis and Chatziphilippidis, 1993; Zagas, 1994; Arianoutsou and Thanos, 1996; Hatzistathis et al., 1999; Theodoropoulos et al., 2002).

Plant species regenerate after a fire either by seedling growth or by resprouting. While seed ecology is widely studied, because of its presumed importance in population growth of plants, there has been little such interest to resprout ecology (Westoby, 1998; Bond and Midgley, 2001). However, resprouting is the main regeneration mechanism after fire that allows the persistence of many perennial shrubs (Matlack et al., 1993; Olsen and Platt, 1995; Pausas et al., 1999; Lloret and Vilà, 1997). The response of sprouters is immediate. Sprouting ability can have a major impact on plant populations. Population turnover is reduced, and the effects of fire disturbance are minimized (Bond and Midgley, 2001).

The present work deals with the post-fire resprouting ability of kermes oak (*Quercus coccifera* L.). It is a slow growing, evergreen oak, thriving in a wide variety of contrasting environments (Balaguer et al., 2001), playing an important ecological role around the Mediterranean basin, and distributed over a large area: from 45°30′N in Peninsula of Istria to 31°00′N in Negev (Israel) and from 9°30′E in Cascais (Portugal) to 37°00′E on Mountains of Alaouites in Syria (Cañelas, 1993). It dominates low and high shrub formations, such as the garrigue in southern of France (Lossaint and Rapp, 1971; Poissonet et al., 1978), "coscojares" in Spain (Terradas, 1999; Loidi et al., 1994) and "prinones" in continental Greece (Mavrommatis, 1982; Papachristou, 1998), or even forests, such as in Crete (Kypriotakis et al., 1996). Usually it is presented in shrub-form, but in the absence of grazing it becomes, everywhere in Greece, a tree with a height of about 15 m (Athanasiadis, 1986). Despite its ecological role and wide distribution, and the general interest on the species (e.g. Malanson and Trabaud, 1988; Trabaud, 1974, 1984, 1987; Tsiouvaras, 1988; Tsiourlis, 1998), only few specific studies (Trabaud, 1991; Pausas, 1997) on the resprouting ability and post-fire growth of kermes oak or other oak species exist.

The resprouting growth of kermes oak after fire, in relation to certain ecological parameters, has been studied in the present work. Initially, the seasonal effect of fire incident (either beginning versus end of growth season) on growth of new sprouts was examined. Second, in both periods of fire incident, the influence of aspect (slope exposure) and pre-fire size of parental shrub on resprouting ability and growth of kermes oak was investigated.

2. Materials and methods

2.1. Study area

The study area is located in a typical *Pinus halepensis* L. forest with understory of dense Mediterranean maquis in the northern part of the Sithonia Peninsula (Chalkidiki, N. Greece). The forest was even-aged, 49 years old, regenerated after a large fire in 1945. It had a mean canopy closure of 50% and a shrubby layer cover of about 80%. The mean height was 14 and 2 m for the layers of trees and shrubs, respectively. Konstantinidis (1990) classified this forest in the association of Oleo-lentiscetum aegaeicum (Krause et al., 1963), which is a typical association for the Northern Mediterranean part of N. Greece, in the vegetation zone Oleo-lentiscetum.

The topography of the area is smooth with low slopes (inclination 10–15%). The area of N. Chalkidiki belongs to the geological department of Vertiskos in the Servomakedonia massif (Mountrakis, 1985). Substrates are, in general, acidic granites, and the soils emanated from igneous rocks, shallow, stony and with low fertility (Pavlidis, 1976).

The climate is typical thermo-Mediterranean (characterized by 100–150 days biologically "dry"; according to Bagnouls and Gaussen, 1957) with a dry period from May to September. Mean annual precipitation is 471 mm, and the majority of them (80%) falls during the winter (December–April). Frosts are infrequent, occurring only in winter and

Table 1
Mean monthly precipitation (mm) recorded at the N

Year	Month												Total (mm)
	January	February	March	April	May	June	July	August	September	October	November	December	
1968–1975	68	59	60	33	25	31	24	20	35	41	18	54	471
1994						0	9	3	2	190	64	51	
1995	236	5	74	11	6	0	46	122	66	7	39	173	785
1996	74	101	39	33	27	79	4	1	20	80	45	37	540

Marmaras Meteorological Station (1968–1975). Monthly precipitation (mm) recorded at the local meteorological station during the study (1994–1996) (Sithonia, Greece).

mostly at night. Minimum temperatures are rarely under 5 °C, while maximum temperatures reach about 30 °C. The Sithonia peninsula is one of the regions with the greatest sunlight in Greece (Livadas and Pennas, 1973). According to the classification of Köppen (1931), the climate is Csa type (or Mediterranean), and with the rain-temporal quotient of Emberger (1955); the climate is distinguished in the Mediterranean sub-dry bioclimatic type.

Two experimental plots were installed immediately after two wildfire incidents in the area. The first fire happened at the beginning of the vegetative period (Site 1 – May 1994) and the second one at the end of the growing season (Site 2 – September) of the same year. The first experimental plot is located at an altitude of about 150 m and at a distance of 1 km from the sea, while the second one is 3 km from the first, at an altitude of 200 m and 1.5 km from the coast. Both plots were deliberately selected on areas protected from any kind of post-fire disturbance (property of a local monastery), especially grazing.

The soil on both plots is shallow (15–25 cm), dry, acidic (pH 5.5–5.7) and stony, with sandy-clay textures (argil, 5–12%; clay, 22–43%; sand, 40–60%), and poor in organic matter (1.1–3.5%) and macro elements (N, 0.03–0.15%; P, 0.30–0.70 mg/100 g). Despite its low fertility and level of water and air penetration, it is suitable for the growth of a frugal Mediterranean evergreen vegetation of pines and typical sclerophyllous shrubs, such as *Q. coccifera*, *Arbutus unedo*, *Pistacia lentiscus*, *Phillyrea media*, *Erica manupiliflora*, *E. arborea*, *Olea europaea* var. *sylvestris* and *Cistus* spp.

To examine the influence of climatic variables on the growth of resprouts, data from a meteorological station, installed in 1994 (Kalabokidis et al., 2002) and located between the two experimental plots, were used during the experiment, as well as long-term climatic data from the meteorological station of N. Marmaras, 20 km away (Table 1).

2.2. Experimental sampling

A total of 100 burned kermes oak shrubs were randomly selected on each site, 25 at each of the main four aspects (north, east, south, west). The longest burned shoot of each shrub was marked, and its height and ground level diameter measured. Three months after each fire, both sites were revisited and the longest new sprout of the selected shrubs was also marked, and measurements of height and ground diameter taken. These measurements were repeated on both sites every 3 months, until December 1996, to give height and diameter growth of the sampled resprouts.

Two more plots, already installed as a research project of the Forest Research Institute, adjacent to the first ones, gave the state of the vegetation before fire. Measurements of height and diameter have also been taken on 100 randomly selected kermes oak shrubs in these plots (25 at each aspect) to serve as reference controls.

The number of resprouts influences their height and thickness (Sennerby-Forsse and Zsuffa, 1995; Riba, 1998). Therefore, care should be taken to keep the number of resprouts constant, by removing some of them. Mayor and Rodá (1993) consider 50% of the resprouts is a suitable number to be removed, while Ducrey and Turrel (1992) recommend a 75% removal. We decided to keep three resprouts as an alternative solution in case of partial destruction, while new eventual resprouts were removed. This decision was bolstered later by Espelta et al. (2003), who found that there is no statistical difference between one and three retained resprouts. In fact, after the experiment, all retained resprouts were still alive.

2.3. Statistical analysis

According to the protocol described above, the following comparisons in the two sites, with the season of fire as differentiating parameter, were done:

- Mean height and diameter of post-fire resprouts on the same date.
- Post-fire mean height and diameter of resprouts at the same age.
- Post-fire mean height and diameter of resprouts between orientations in site 1 (May fire).
- Post-fire mean height and diameter of resprouts between orientations in Site 2 (September fire).
- Correlation between maternal shoots and resprouts.

Statistical analysis of the data included standard procedures of comparison of means. Preliminary analysis showed that some groups of data, particularly diameter measurements, violated the assumptions of normality (data coming from a normal distribution) and homoscedasticity (constant variance among groups), which are prerequisite for parametric tests and consequently non-parametric tests were performed. In particular, for the comparison of mean height and diameter by site (discriminating factor: time of fire incident), the Mann–Whitney *U*-test was used. The test uses the ranks of observations in two independent samples and concludes whether the two samples come from populations having the same location or not.

To test for differences between mean height and diameter by aspect, the Kruskal–Wallis *H*-test was employed. This is the analogous to a one-way analysis of variance non-parametric test. It tests for differences of location in ranked data grouped by a single classification. To derive correlations among variables, Spearman's rank correlation coefficient was calculated.

3. Results

3.1. Initial state of vegetation

Table 2 shows the basic descriptive statistics for the 100 measurements of height and diameter in the two unburned plots. The average height of the shrubs were about 1.4 m and the average diameter around 3 cm. Mean values present small differences and Site 2 exhibits a broader range of values in both variables than Site 1. The impression that both sites comprise shrubs with similar dimensions was confirmed by the Mann–Whitney *U*-test (Table 2), which resulted in non-significant differences of initial height, as well as diameter, between the two sites.

3.2. Comparisons between sites (time of fire incident)

The average height and diameter measurement of 100 shoots taken at the same dates in the two burned plots are shown in Figs. 1 and 2, respectively. Height growth presents no particular divergence between the two sites and follows a typical sigmoid line of a tree height curve (Van Laar and Akca, 1997), with maximum height development between March and September 1995 (Fig. 1). Sprouts on both sites have a height of about 2.0 cm at the end of the first trimester, increase strongly up to 75–80 cm at the end of the second vegetative period and, thereafter growth rate decreases, reaching 90 cm height at the end of the experiment. It is worth noting that, the sprouts of the second site, despite their 3 months delay, achieve the same growth rate with the sprouts of the first site.

Table 2
Statistics and Mann–Whitney *U*-test for height and diameter of unburned shrubs in two areas adjacent to the experimental sites (Site 1 – May fire; Site 2 – September fire)

	Site	*N*	Mean (cm)	S.E.	Min (cm)	Max (cm)	Mann–Whitney *U*-test	*Z*
Height	1	100	145.39	3.8987	72.0	232.0	4468.000	-1.300^{ns}
	2	100	141.11	4.0340	68.0	265.0		
Diameter	1	100	2.86	0.0795	1.02	5.41	4788.000	-0.518^{ns}
	2	100	3.13	0.1206	1.56	7.91		

ns: not significant.

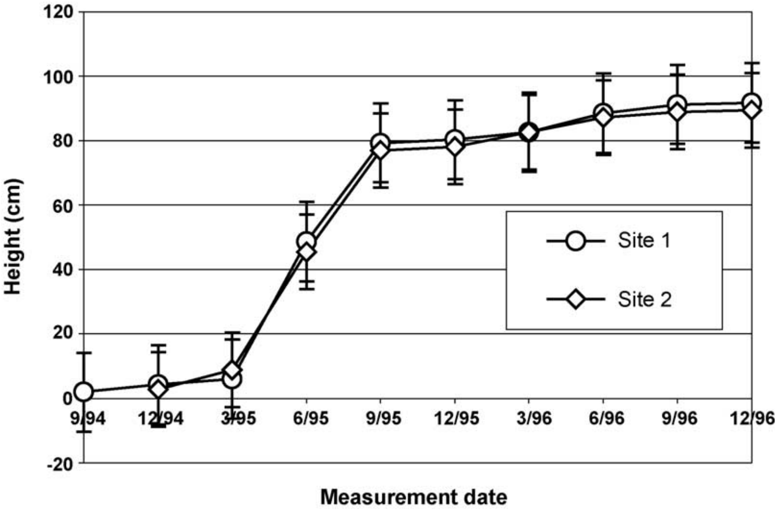

Fig. 1. Average height and measurement date of kermes oak resprouts at the two experimental sites (Site 1 – May fire; Site 2 – September fire) (Sithonia, Greece).

Diameter growth follows the same pattern in both sites (Fig. 2). Sprouts begin growing with the same average diameter (about 0.15 cm), but those on the second site (last burnt) grow faster 6 months after the fire they reached a diameter greater (0.65 cm) than the 3-month older sprouts of the first site (0.55 cm).

Mann–Whitney test for differences between the two sites in the consecutive (every three months) measurements of height and diameter resulted in highly significant differences for height only in the first two trimesters, while the differences in diameter are significant during the whole period of measurements (Table 3).

In order to compare the dimensions of resprouts of the same age, we shifted the measurements of the second site by 3 months. The average height and diameter of

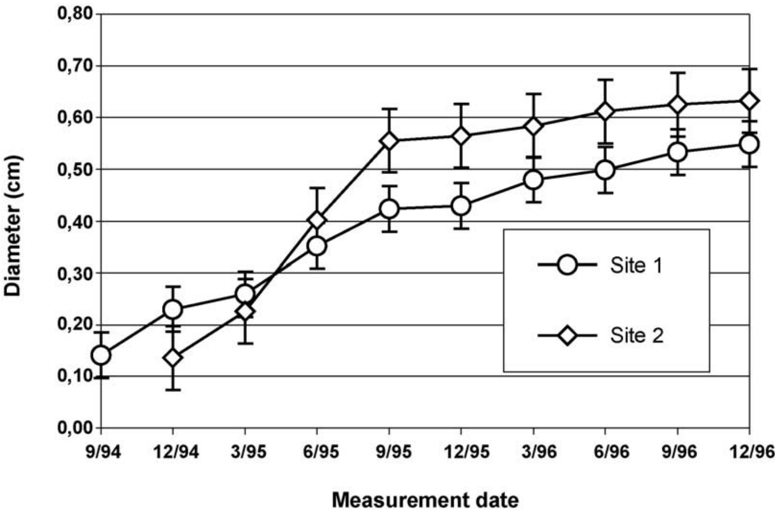

Fig. 2. Average basal diameter and measurement date of kermes oak resprouts at the two experimental sites (Site 1 – May fire; Site 2 – September fire) (Sithonia, Greece).

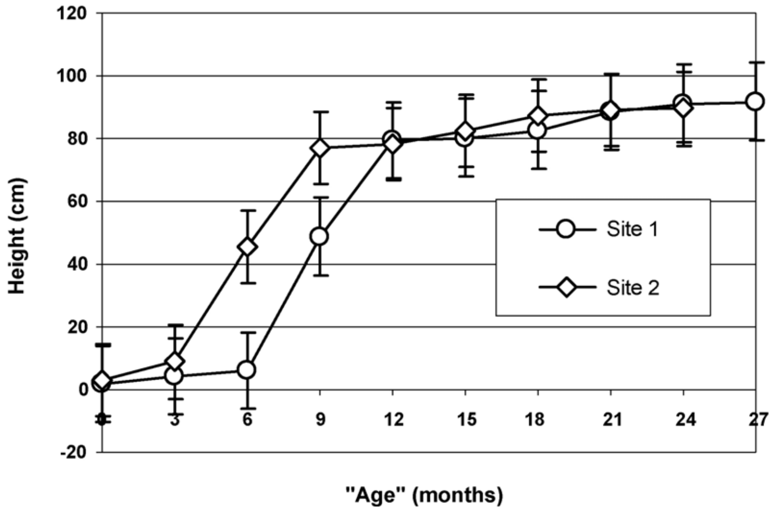

Fig. 3. Average height growth and sprout age (months since burn) of kermes oak resprouts at the two experimental sites (Site 1 – May fire; Site 2 – September fire) (Sithonia, Greece).

resprouts is shown in Figs. 3 and 4, respectively. It is clear from Fig. 3 that resprouts on the second site show a faster initial height growth than those of the first site, and after the age of 12 months height growth is more or less the same on both sites. This fact has been also confirmed by the Mann–Whitney test, which gave highly significant differences in height between sites until the age of 9 months. On the other hand, initial diameter growth is similar until the age of 3 months; differences appear afterwards with the second site showing higher growth rates (Fig. 4). Statistical tests have also confirmed this situation by giving significant differences in diameter between sites after the age of 3 months.

3.3. Comparisons among aspects

The Kruskal–Wallis test, applied to the data of both sites, resulted in significant differences among aspects

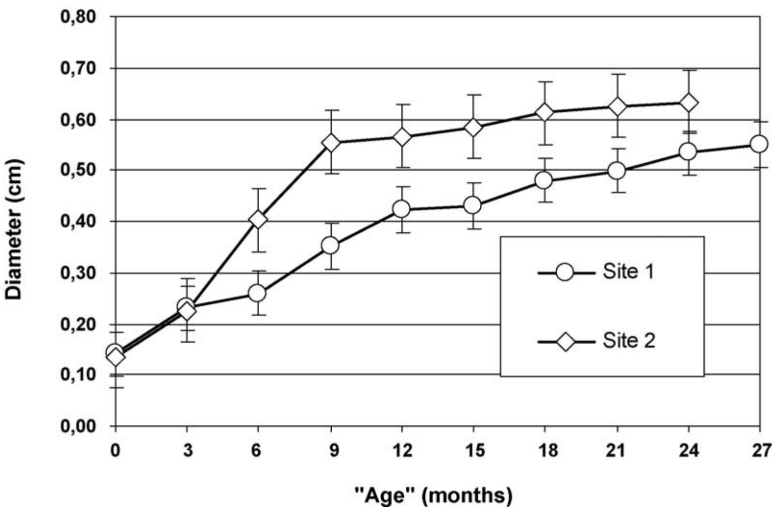

Fig. 4. Average basal diameter growth and sprout age (months since burn) of kermes oak resprouts at the two experimental sites (Sithonia, Greece).

Table 3
Mann–Whitney test for height and diameter differences in the consecutive (every 3 months) measurements at the two experimental sites

	H2	H3	H4	H5	H6	H7	H8	H9	H10	D2	D3	D4	D5	D6	D7	D8	D9	D10
Mann–Whitney *U*	3021.500	3299.000	4400.000	4664.000	4684.500	4885.500	4719.500	4590.000	4599.000	2010.000	3730.000	3550.000	2329.000	2275.000	2167.000	2327.000	2787.000	2913.500
Z	−4.903**	−4.184**	−1.466ns	−0.821ns	−0.771ns	−0.280ns	−0.685ns	−1.002ns	−0.980ns	−7.622**	−3.374**	−3.734**	−6.694**	−6.815**	−7.106**	−6.767**	−5.641**	−5.365**

Hi, Di: height and diameter measurements. H1 and D1 not included because only measurements of one site were possible. ns: not significant; i = measurement number.
** Significant at the 0.01 level.

Table 4
Kruskal–Wallis test for height and diameter differences in aspect of the unburned shrubs

	Chi-square	
	Height	Diameter
Both sites	11.830**	22.284**
Site 1 – May fire	3.920ns	1.197ns
Site 2 – September fire	18.311**	39.508**

ns: not significant.
** Significant at the 0.01 level.

in height and diameter of the shrubs in the unburned plots. Further examination of the data revealed that the differences were found on the plants of the second site, while the first site comprised plants with homogeneous dimensions among aspects (Table 4).

Similarly, resprouts of the first site did not present significant differences in height and diameter growth among the different aspects (Table 5; Figs. 5 and 6). While in the second site, significant differences in height were observed for the whole duration of the experiment. Regarding the diameter (Table 5, Fig. 6), the results did not show a clear pattern: at 3, 9, 12, 15 and 21 months, differences were significant, but in the other months non-significant differences were exhibited.

3.4. Maternal shrub

The height of the new resprouts is positively correlated to the height of maternal shrub (Table 6). Spearman's product moment correlation coefficients are highly significant for almost all height measurements. A positive correlation, though lower than that one of height (Table 6), also exists between the height of new resprouts and the diameter of maternal shrub.

A similar situation is demonstrated by the diameter of the new resprouts. It is positively correlated to height and diameter of the maternal shrub, but the correlation is higher for diameter than for height (Table 6). Here, the correlation coefficient is significant for almost all diameter measurements.

4. Discussion

Resprouting after fire (or clear-cutting) is the main regeneration mechanism of kermes oak and many

Table 5
Kruskal–Wallis test for height and diameter differences in aspect for consecutive (every 3 months) measurements

		Height									Diameter								
		H2	H3	H4	H5	H6	H7	H8	H9	H10	D2	D33	D4	D5	D6	D7	D8	D9	D10
Site 1 – May fire	Chi-Square	1.047^{ns}	1.932^{ns}	0.854^{ns}	0.085^{ns}	0.072^{ns}	1.259^{ns}	2.766^{ns}	3.777^{ns}	4.003^{ns}	1.029^{ns}	2.840^{ns}	3.140^{ns}	0.137^{ns}	0.139^{ns}	1.220^{ns}	0.851^{ns}	0.141^{ns}	0.510^{ns}
Site 2 – Sept. fire	Chi-Square	21.691**	46.345**	14.293**	11.757**	12.095**	11.142*	13.007**	10.378*	10.011*	9.239*	4.036^{ns}	14.947**	9.981*	10.495*	6.597^{ns}	9.528*	6.349^{ns}	6.691^{ns}

Hi, Di: height and diameter measurements. H1 and D1 not included because only measurements of one site were possible. ns: not significant; i = measurement number.
* Significant at the 0.05 level.
** Significant at the 0.01 level.

other characteristic shrubs that constitute important structural components in Mediterranean-type ecosystems (e.g. *A. unedo*, *P. lentiscus*, *P. media*, *O. europaea* var. *sylvestris*; Canadell et al., 1991). Sprouting ability can have a major impact on plant populations: turnover of populations is reduced and the effects of disturbance are minimized (Bond and Midgley, 2001). Resprouting occurs usually by underground buds when the aboveground part of the plant has been destroyed (Lloret and Vilà, 1997; El Omari et al., 2003). Resprouting vigor depends upon the anatomical feature of the plants (Canadell and Zedler, 1995), the status of individuals before the fire, especially plant size (Canadell et al., 1991; Pausas, 1997), the intensity of the fire (Lloret and López-Soria, 1993; Moreno and Oechel, 1994) and the environmental conditions after the fire (Schlesinger and Gill, 1980). There must also be sufficient reserves, mainly in carbon and nitrogen, from which growth of a new shoot can be supported (Malanson and Trabaud, 1988).

The two sites, where the plots were situated, comprised vegetation with similar pre-fire statistics. Therefore, differences in the post-fire development of resprouts could be attributed to environmental factors. Analysis of climatic data of the area lead to the identification of precipitation as the probable decisive factor for resprout development. As it can be seen in Table 1, the first fire was followed by a 4-month long dry period, while significant amounts of precipitation (almost five times greater than the average of the area) fell in October, 1 month after the second fire incident. The resprouts of the first site were ''waiting'' for the rainfalls (see Fig. 3), while the resprouts of the second site received it almost immediately. This behavior agrees with existent models, which demonstrate that high precipitation after wildfires are beneficial to post-fire dynamics and composition of plants, and the function of ecosystems (Vázquez and Moreno, 1995). However, there is not a general rule, such as that found by De Luis et al. (2001) where post-fire activity of *Brachypodium retusum* was influenced negatively by strong precipitations. In this case (De Luis et al., 2001), the negative effect was attributed to the significant soil erosion, with consequent root exposure and loss of nutrients.

Rapid resprouting and high growth rates are usually observed after fire (Kauffman, 1991; de Rouw, 1993;

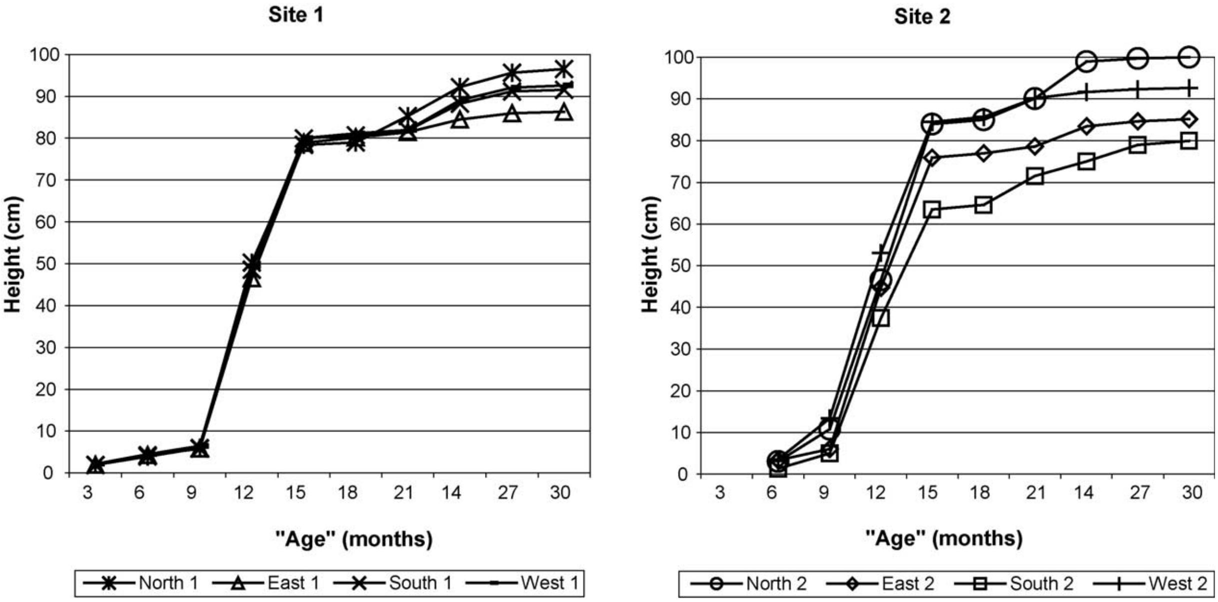

Fig. 5. Effect of orientation (aspect) on height of kermes oak resprouts (measured by age) at the two experimental sites (Site 1 – May fire; Site 2 – September fire) (Sithonia, Greece).

Goto et al., 1996; Nascimento, 1996). It seems that just after a fire, resprouts access to energy reserves are stored in underground organs (Bowen and Pate, 1993), and are used first from the pool of nutrients in the root and sprout systems. It, thus, depends mainly on soil humidity plus temperature to utilize them efficiently, and are quite independent of the degree of soil erosion. The plants use the ground humidity and high temperatures to cover their direct biological requirements (photosynthesis, new biomass, etc.); therefore, the existence of underground humidity can only play a positive role (Riba, 1998). The existence of these reserves allowed kermes oak resprouts, in our experiment, to present an immediate reaction to fire disturbance and to grow at a high rate. This was supported by favorable climatic conditions until the end of the second vegetative period and at a moderate rate afterwards, as expressed by the typical sigmoid

Table 6
Correlation coefficients between consecutive measurements of height and diameter of resprouts and height and diameter of the maternal shrub

Resprout height	Maternal shrub		Resprout diameter	Maternal shrub	
	Height	Diameter		Height	Diameter
H1	0.334**	0.349**	D1	0.426**	0.408**
H2	0.190**	0.112	D2	0.251**	0.123
H3	0.017	0.150*	D3	0.180*	0.228**
H4	0.258**	0.131	D4	0.144*	0.180*
H5	0.350**	0.168*	D5	0.078	0.116
H6	0.349**	0.160*	D6	0.077	0.094
H7	0.368**	0.169*	D7	0.100	0.117
H8	0.395**	0.149*	D8	0.128	0.145*
H9	0.416**	0.164*	D9	0.190**	0.187**
H10	0.413**	0.163*	D10	0.214**	0.184**

* Correlation is significant at the 0.05 level (two-tailed).
** Correlation is significant at the 0.01 level (two-tailed).

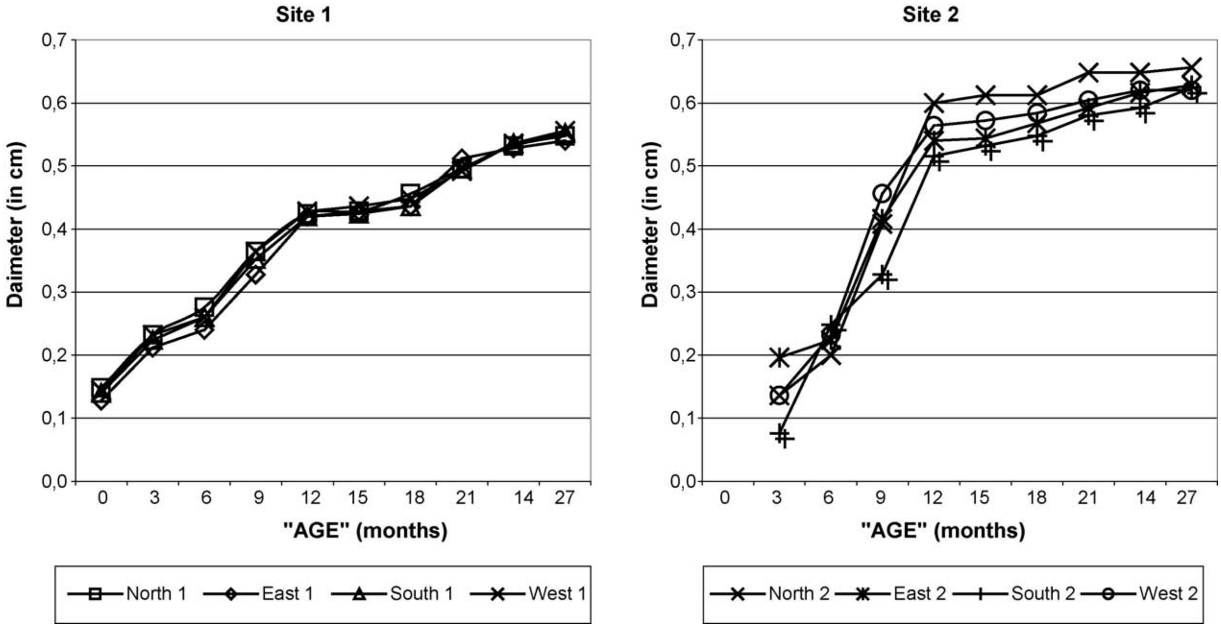

Fig. 6. Effect of orientation (aspect) on diameter of kermes oak resprouts (measured by age) at the two experimental sites (Site 1 – May fire; Site 2 – September fire) (Sithonia, Greece).

curve. The same behavior has been recorded after experimental clear-cutting of kermes oak in a fenced area of Naxos Island (Greece), where the majority of growth also occurred after the first two vegetative periods, but was reduced considerably in the third year (Tsiourlis, 1998). Moreover, Papanastasis (1986) recorded a similar development of kermes oak height after fire (80 cm at the third year). Trabaud (1974, 1984) noted, about 2 years after fire, the tendency to return towards the previous garrigue, and 5 years after the fire the differences between burned and unburned are very difficult to distinguish.

The differentiation found on the effect of orientation (aspect) in the growth of resprouts between Sites 1 and 2 could be related to season and geographic latitude, i.e. day length and intensity of sunlight. Of all the environmental parameters affecting plant activity, light is perhaps the most heterogeneous spatially and temporally (Pearcy, 1999), even if the environment is more homogeneous in open habitats (Ögren and Sundin, 1996). Depending on the aspect, plants receive different quantities of light. Analysis of the effect of aspect shows that, in a North–South orientation, variability of photosynthetically active radiation between seasons (winter and summer solstice) is reduced in a zone between 34° and 50° North (Jackson and Palmer, 1972; Tournebize and Sinoquet, 1995). The fact that terrain geomorphology is smooth in our study area implies homogeneous light conditions, and allows conclusions to be drawn on the effect of light quantity and length on resprout growth. The studied forest is located on the 40th parallel of the Northern hemisphere. Resprouts after the May fire began their growth during summertime, when the sun is moving nearest to the Tropic of Cancer. This presents only a little divergence from a vertical position for the specific studied area, providing all orientations with almost the same quantity of solar energy. As a result, no differences in height and diameter growth are observed. However, in the September fire, the plants were growing in the autumn and winter, when the sun is moved nearest to the Tropic of Capricorn. Therefore, the angle of incidence of radiation is greater, resulting in uneven distribution of solar incidence. Consequently, it seems the solar orientation plays an important role when the fire occurs at the end of the vegetative period and the resprouts grow during the autumn and winter, but not in the summer. In our case, the growth is higher in east and south orientations (Fig. 5). In other conditions, for example, in Spain, it appears the growth of the resprouts is higher in a northern orientation (López Soria and Castell, 1992; Pausas et al., 1999). On the other hand, the absence of significant effect of aspect on diameter (Fig. 6) could be attributed to the fact that thickness growth begins substantially with the start of the vegetative period. This is when plants produce vernal timber, a process that is less depended on the duration and the quantity of solar energy. So, in both periods, growth was uniform in all orientations.

The significant positive correlation of height and diameter of resprouts to the respective dimensions of the maternal shrubs indicates that plants with greater dimensions produce greater resprouts. Higher shrubs produce higher and thicker resprouts at the end of the third year. Moreover, the resprouts at this period have already reach two-thirds growth of the pre-fire shoots. It is clear that a greater root system provides a richer pool of nutrients and, in addition, offers more surface area for water and nutrient uptake, extending deep into the soil (Kennard et al., 2002). Cirne and Scarano (2001) and Pausas (1997) noted resprouting vigour was related to pre-fire individual basal area, suggesting that larger individuals accumulate more reserves and/or have more active underground buds. Auld (1990) demonstrated that resprouting vigour in *Angophora hispida* is proportional to plant size, which can be regarded as an index of resource accumulation. Hoffmann and Solbrig (2003) also found a strong positive relationship between pre-burn stem diameter and stem diameter of resprouts in savanna woody species 1 year after burning. However, other parameters such as the initial number of shoots and resprouts could also play a role in the growth of resprouts.

5. Conclusion

The results of the present study conclude that the period of occurrence of wildfire does not affect the final growth of kermes oak sprouts. However, the period of fire occurrence, in conjunction with the subsequent climatic conditions, does affect the growth rate of kermes oak sprouts. After wildfires, occurring at the end of the vegetative period, differentiation in growth rate is expected depending on aspect. Moreover, after three vegetative periods, shrubs have regained a considerable part of their pre-burn height. Thus, in *Q. coccifera* ecosystems, the best post-fire management practice would be to allow natural regeneration, without reforestation, while controlling external negative influences, such as grazing. In controlling the fuel material of mature ecosystems, predisposed to burn from any random catalyst, it appears the time of prescribed fire is not a crucial factor in the success of long-term ecosystem regeneration. However, prescribed fire in the growing season appears to be a more severe short-term disturbance on the environment than fire during the dormant season (Brockway et al., 2002).

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