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Quercus calliprinos regrowth advantage under grazing in Mediterranean maquis and its management implications

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ABSTRACT

The post disturbance natural succession of the Mediterranean maquis, which turns open and species-rich landscapes into dense, closed stands of sclerophyllous woody vegetation is a principal threat to plant and animal diversity. Therefore, in the absence of traditional agricultural disturbance, active management regimes that include cutting and grazing are proposed to preserve biodiversity. The Mediterranean woody vegetation in Israel is strongly dominated by one species – the evergreen sclerophyllous *Quercus calliprinos* (Kermes oak). We hypothesized that under cutting and grazing, the evergreen *Q. calliprinos* has a relative regrowth advantage over other competing tree species. Here we examined the effect of grazing and the effect of tree structural traits on the regrowth after clear cutting of all trees in our study plots at Mt. Meron LTER site, Israel. All trees were removed from five blocks of 2000 m^2 and each block was divided into two plots, five of which were exposed to grazing livestock while five were wire-fenced and ungrazed. The regrowth rate of *Q. calliprinos* under grazing was higher than that of all other tree species suggesting that in the long-term, under such a conservation management regime, the dominance of the evergreen sclerophyllous *Q. calliprinos* over the deciduous tree species will increase and consequently will decrease plant and animal diversity. Therefore, we conclude that to protect landscape and species diversity in Mediterranean ecosystems dominated by evergreen oaks, when cutting and grazing are applied, special care must be paid to trees that are more negatively affected by such treatment.

Nomenclature: Danin (1998).

1. Introduction

Typical vegetation in Mediterranean-type ecosystems (MTEs) worldwide is characterized by dense forests dominated by short (2–5 m high), multi-stemmed, evergreen, sclerophyllous trees (di Castri et al., 1981). This complex vegetation type is termed 'maquis' in the Mediterranean basin. Under traditional agricultural disturbances, such as cutting and grazing, the Mediterranean maquis is a plant and animal species rich biome (Naveh and Whittaker, 1979). However, in the absence of human interference, the natural succession will turn this open landscape into closed, dense and shady woody vegetation with low biodiversity (Perevolotsky, 2005). Therefore, active management including cutting and grazing, is proposed to prevent tree closure and consequent loss in biodiversity.

Since the early pre-historical period, the Mediterranean maquis has been widely affected by intensive human activities. Fires, cuttings and grazing were the traditional exploitation techniques of the natural woody vegetation, which greatly affected the evolution of plants and the landscape (Naveh, 1990). With the beginning of agriculture, about 10,000 years ago, cutting and grazing became the dominant human activities (Naveh and Carmel, 2004).

Rapid resprouting and regrowth from secondary buds is the main adaptation of Mediterranean trees to major disturbances such as fire, cutting and grazing (Naveh, 1975; Bond and Midgley, 2001). The regrowth rate is commonly affected by tree age, size, aboveground biomass and stem density (Ehleringer and Mooney, 1983; Danell et al., 1985; Malanson and Trabaud, 1988; Bellingham and Sparrow, 2000). Tsiouvaras et al. (1986) showed that as response to repeated clipping of Kermes oak (*Q. coccifera*) canopies, growth rate of twigs had increased and the growth period was extended into the summer, a season in which Kermes oak trees do not normally grow. Carrión et al. (2000) studied the distribution of the evergreen *Q. suber* (cork oak) and concluded that the dense monospecific forests of cork oak in the Iberian Peninsula are the result of human selection and, that in the absence of human intervention, *Q. suber* would develop into mixed forests with other evergreen and deciduous oaks.

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The Mediterranean maquis covers most of the northern and central mountainous region (300–900 m a.s.l.) in Israel. This vegetation includes about 15 evergreen and 15 deciduous tree species (Danin, 2010; Shmida, personal communication), but is strongly dominated by the evergreen sclerophyllous *Quercus calliprinos* Webb, which accounts for 80–90% of the tree coverage (Zohary, 1973). In this paper, we posit the hypothesis that under a management regime that includes cutting and grazing, the evergreen *Q. calliprinos* has a relative advantage in regrowth over its accompanying tree species. We studied the effect of grazing on the regrowth rate after canopy removal of *Q. calliprinos* and three deciduous tree species. We also examined the influence of pre-treatment tree structure on the regrowth rate of *Q. calliprinos* and five deciduous tree species. Our specific predictions were P1: The evergreen *Q. calliprinos* will have a higher regrowth rate than deciduous trees. P2: Cattle grazing will have a smaller negative effect on *Q. calliprinos* than on the deciduous species. P3: Regrowth is species-specific and, in each species regrowth rate will be connected with different structural traits.

2. Materials and methods

2.1. Study site and experimental design

We carried out the research at the Mt. Meron Long-Term Ecological Research site, which was established as part of the Israeli LTER network to study the effect of woody species as landscape modulators along the rainfall gradient in Israel (Shachak et al., 2008; Agra and Ne'eman, 2009). The site is located in northern Israel (35.25°E, 33.15°N), 850 m a.s.l., with mean annual precipitation of 900 mm, falling mainly during the short winter (December to February). The bedrock is limestone covered with terra-rossa soil. The vegetation is a dense maquis, subject to moderate cattle grazing of 0.3 cows ha^{-1} $year^{-1}$, a typical grazing intensity in such areas. The average total vegetation cover was ca. 95%, of which 60% was trees, 15% shrubs, 10% dwarf-shrubs and 10% open patches of herbaceous plants. The dominant tree species *Quercus calliprinos* Webb (constitutes 75% of the individuals and 80% of their coverage), is accompanied in the study area mainly by the following deciduous trees: *Q. boissieri* Reuter (4% of trees and 7% of tree cover), *Pistacia palaestina* Boiss. (5% of trees and 5% of tree cover), *Crataegus aronia* (L.) DC. (7% of trees and 4% of tree cover), *Pyrus syriaca* Boiss. (4% of trees and 2% of tree cover), *Stirax officinalis* L. (2% of trees and 1% of tree cover) and *Prunus ursina* Kostchi (2% of trees and 1% of tree cover).

All trees were removed down to ground from five blocks of 2000 m^2. Each block was divided into two equal (1000 m^2) plots, five of which were exposed to grazing livestock while five were wire-fenced and ungrazed. The research plots were located near hilltops with little or no slope, and heterogeneous in their aspect, vegetation and rock cover.

2.2. Effect of grazing on regrowth rate

To examine the effects of grazing, three growing seasons after canopy removal, we measured the regrowth of randomly sampled *Q. calliprinos* trees and trees of the three other most common species growing in the experiment plots: *Q. boissieri*, *P. palaestina* and *C. aronia*. Sampling effort for each species was determined by analyzing the coefficient of variation (CV) against sample size in the plots.

For each tree, we determined three parameters of the re-growing canopy: (1) canopy height- the highest re-growing shoot; (2) canopy diameter – the average of two diameters (north/south and east/west) of the re-growing canopy; (3) relative horizontal regrowth – canopy diameter divided by the average pre-removal diameter of the species in the plot (according to the data collected before treatment application). Relative horizontal regrowth was calculated to correct the data for the differences in initial canopy size among the various species on their regrowth rates. As grazing was applied at the plot scale, to examine the effect of grazing we used the average of all trees in a plot to test each parameter. Since not all species were present in all blocks, we applied a within-subject two-way mixed model ANOVA (SPSS 17: Mixed model, linear) for unbalanced data for the examination of the effects of grazing, tree species, and their interactions on the three tested parameters (West et al., 2007). We used the block as the independent subject, grazing and tree species as the two within-subject fixed factors.

2.3. Effect of tree structure on regrowth rate

This part of the research was done only in the ungrazed plots. During canopy removal, we permanently numbered all tree stumps with aluminum discs and recorded for each tree, the following data: species, canopy diameter, average of two perpendicular stem diameters and number of stems (>4 cm diameter). One growing season after canopy removal, we randomly selected 182 trees from all the ungrazed plots. For each tree, we determined canopy height as the highest re-growing shoot and canopy diameter as the average of two diameters (north/south and east/west) of the re-growing canopy.

Canopy height and diameter, which represent two different structural parameters of the canopy, responsible for vertical and horizontal growth respectively, were not significantly correlated. Therefore, we separately examined the correlations of canopy height and canopy diameter with number of stems, mean stem diameter, pre-removal canopy diameter, and thickest stem diameter. Because the data did not follow a normal distribution (Kolmogorov–Smirnov test) even after various transformations, we used the non-parametric Spearman correlation tests.

3. Results

3.1. Effect of grazing on regrowth rate

Without grazing, three years after canopy removal the two *Quercus* species were higher than *C. aronia* and *P. palaestina*; under grazing, *C. aronia* was the highest, followed by *Q. calliprinos* and *P. palaestina* was the lowest (Fig. 1a). canopy height was significantly affected by grazing and tree species with no interaction between them (Table 1).

Without grazing, *Q. calliprinos*, *Q. boissieri* and *P. palaestina* had a larger canopy diameter than *C. aronia* trees, while under grazing *Q. calliprinos* had larger canopy diameter than the other three species (Fig. 1b). Canopy diameter was significantly affected by grazing and tree species, with no significant interaction between them (Table 1).

P. palaestina had the largest Relative horizontal regrowth in grazed and in ungrazed plots, but also had the largest decrease under the grazing relative to no-grazing treatment (Fig. 1c). Relative horizontal regrowth of *Q. calliprinos* and of *C. aronia* trees was less negatively affected by grazing than that of *Q. boissieri* and *P. palaestina* (Fig. 1c). Relative horizontal regrowth was significantly affected by grazing and tree species, with no significant interaction between them (Table 1).

3.2. Effect of tree structure on regrowth rate

One year after canopy removal, regrowth parameters of *Quercus calliprinos* trees were positively and significantly correlated with most of their pre-removal parameters (Table 2). canopy diameter