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Changes in floristic composition of *Quercus coccifera* macchia after fire in the Çukurova region (Turkey)

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We studied the floristic changes in *Quercus coccifera* macchia after a fire that occurred in 1986. Floristic changes in the study area were observed during the first five years and the fourteenth year after the fire. Most of the pre-fire species (98.6%) returned back within the first three years after the fire. In the fifth year, the species similarity in the burned and unburned areas was 93.8%, and the vegetation nearly reached the pre-fire physiognomy. At the end of the fourteenth year, no significant differences in terms of floristic composition and physiognomy were observed.

Key words: ecology, fire, floristic composition, macchia, succession

Introduction

Fire is one of the most important ecological factors in the Mediterranean forest ecosystems. Most of the natural vegetation in the Mediterranean region is composed of woodland in various stages of degradation as secondary succession created by the long history of man's activities (Le Houreou 1974, Naveh 1975, Trabaud 1982, Hadjibiros 2001, Tarrega *et al*. 2001). Pine forest communities are more flammable than the pine itself: litter is very flammable during drought periods and gives a high, persistent flame, which spreads easily into the shrub layer, which is often rich in species containing resins or essential oils (Trabaud *et al*. 1985). Fire impact, associated with grazing and cutting, has led to the destruction of many pine forest communities, referred to as "macchia" (Trabaud 1981, Lucchesi & Giovannini 1992).

Fires in Turkey are responsible for the destruction of the largest portion of forests. The main causes of fire are: (1) a large number of fires of unknown origin, negligence or arson, (2) the Mediterranean type of climate in the region with long, hot and dry summers, and (3) accumulation of flammable vegetation and litter. The vegetation type in the area is highly flammable and combustible due to the preponderance of species with a high content of resins or essential oils. Most current fires in the Mediterranean basin are caused by human activities. In prehistoric times, however, lightning and volcanoes certainly played a major role causing fires in vegetation (Komarek 1973, Le Houreou 1977, Trabaud 1982).

Today in Turkey lightning causes only 1% of the fires, while fires mainly set off as a result of either the carelessness or deliberate action of men. The effects of fire on vegetation are various: after

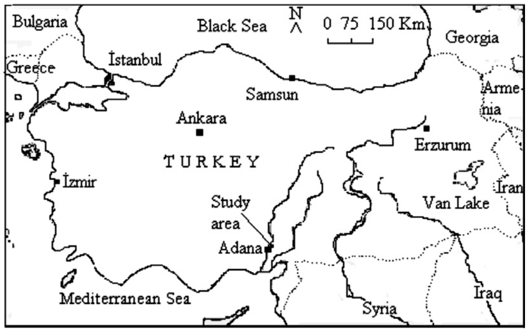

Fig. 1. Location of the study area in Turkey.

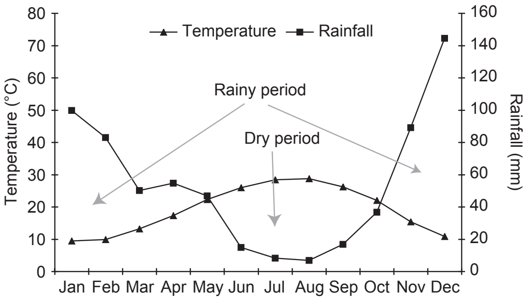

Fig. 2. Climatic diagram of the study area.

the fire, the biomass of the area decreases, various individuals are killed, extrinsic species having a great availability of resources as sunlight, nutrients and water come out. As opposed to this reduction in the number of individuals, fire creates special conditions favorable to the germination and establishment of seedlings. On the other hand, fire leads to erosion of soil and some nutrients through volatilization (Calvo *et al*. 1992).

Forty-eight percent (9 732 840 ha) of forests in Turkey are susceptible to fire due to the Mediterranean climate, and the flammable and combustible vegetation. An average of 23 127 ha/year of natural vegetation in Turkey burned in fires between 1937–2003, in which period 72 316 fires took place and 1 549 506 ha of forest was burned (unpubl. data of Turkish Ministry of Environment and Forestry).

The post-fire succession has not been previously studied in Turkey, although some studies on this subject were conducted in other countries with Mediterranean-type ecosystems, such as the United States (Hanes 1970, Keeley 1987), France (Trabaud & Lepart 1981, Trabaud 1982), Israel (Naveh 1975), Italy (Mazzoleni & Esposito 1992), and Greece (Arianoutsou-Faraggitaki 1989, Thanos *et al*. 1989, Troumbis 1992, Böhling & Gerold 1995). The aim of the present study is therefore to determine the succession stages developing after a fire and to determine the role of fire in the floristic composition of *Quercus coccifera* macchia in Turkey.

Material and methods

The study area is located on a hillside near the city of Adana (37°21´N, 35°10´E), Turkey, 170 m above sea level and 70 km from the Mediterranean Sea (Fig. 1).

Generally, the soils of the study area are lightly basic and formed of very calcareous and soft clay materials originating from the Pliocene, and of conglomerates, which formed the old alluvial terraces in the Pleistocene. The soil, mainly of limestone, is characterized by low concentration of nutrients (Özbek *et al*. 1974).

The Mediterranean climate in the study area is characterized by long summer droughts and mild and rainy winters. The mean annual precipitation is about 646.6 mm, while the monthly precipitation approximates 6.9 mm in July and 144.4 mm in January. The mean maximum temperatures range from 14.8 °C in January to 34.6 °C in August and the mean minimum temperatures from 5.1 °C in January to 22.9 °C in July. According to the average climatic data for 14 years obtained from the Meteorological Station of Adana, the dry period for the study area is from May to October (Fig. 2).

The natural vegetation of the study area has been under protection since 1970. It is a typical Mediterranean macchia plant community mainly composed of *Quercus coccifera*, *Calicotome villosa*, *Cistus creticus*, *Phillyrea latifolia*, *Pistacia terebinthus* ssp. *palaestina*, *Rhamnus oleoides* ssp. *graecus*, *Olea europaea* var. *sylvestris*, *Daphne sericea* and *Lithodora hispidula*. Of these, only a few individuals of *Quercus coccifera* and *Olea europaea* var. *sylvestris* reach 2.5 m. There is a macchia area of about 126 689 ha in Adana province (viz. Çukurova; Tükel & Hatipoğlu 1990), but most of it is disturbed by humans for various reasons and purposes.

A part of the vegetation in the research area was intensely burned down in early autumn 1986 as a result of negligence by a shepherd. In order to analyze the changes in composition and physiognomy of the plant community in this area, four permanent plots were established in the burned area and the adjacent unburned area, which was known to be floristically similar to the pre-fire vegetation (cf. also Türkmen & Düzenli 1990). Each plot was 100 m^2 (10 m × 10 m). The burned and unburned plots were treated as single plots. All floristic records were carried out monthly, every year from September 1986 to September 1991, and in 2000. The Sørenson's similarity equation was used to compare the floristic richness values of the burned and unburned areas.

Sørenson similarity = $2C/(A + B)$, where A and B are the richness values of each of the areas in the comparison and C is the number of the common taxa shared by the two areas.

Determinations of the species are based on Davis (1965–1985).

Results and discussion

Floristic composition was measured in terms of the number of taxa found on the burned and unburned plots on each observation date. The evolution of the floristic composition of vegetation after the fire was different from the re-colonization of places, which are devoid of plants, where the taxa around the site have a tendency to establish themselves. The empty areas coming out as a result of fire permitted the invasion of different taxa compared and contrasted with those of the original vegetation, but they are rapidly inhibited by the reappearance of species that existed before the fire (Table 1). Trabaud (1981) and Espirito-Santo *et al*. (1992) also made the same observation.

In addition to the extrinsic species (nonexistent species before the fire), surviving species in the burned areas continued their existence in the new habitats, either vegetatively or generatively, although the vegetation cover had been completely destroyed during the fire.

Table 1. Plant species that appeared in the study area (LF = life form: S = shrub, aH = annual herb, pH = perennial herb, bH = biennial herb; RS = reproductive strategy: V = vegetative, G = generative, VG = both generative and vegetative. Presence of species in terms of time after fire: 4m = first four months; 1 = first year; 2 = second year; 3 = third year; 4 = fourth year; 5 = fifth year; 14 = fourteeth year. + = recorded; – = not recorded).

Scientific name	Family	LF	RS	4m	1	2	3	4	5	14
Resident species										
Ainsworthia trachycarpa	Apiaceae	aH	G	–	–	+	+	+	+	+
Allium flavum ssp. *tauricum* var. *tauricum*	Liliaceae	pH	V	–	+	+	+	+	+	+
Anagallis arvensis var. *caerulea*	Primulaceae	aH	G	–	+	+	+	+	+	+
Artedia squamata	Apiaceae	aH	G	–	–	+	+	+	+	+
Asparagus acutifolius	Liliaceae	S	V	+	+	+	+	+	+	+
Asphodelus aestivus	Liliaceae	pH	VG	+	+	+	+	+	+	+
Brachypodium pinnatum	Poaceae	pH	V	–	+	+	+	+	+	+
Bromus intermedius	Poaceae	aH	G	–	+	+	+	+	+	+
Calicotome villosa	Fabaceae	S	VG	–	+	+	+	+	+	+
Capparis spinosa var. *spinosa*	Capparaceae	S	VG	+	+	+	+	+	+	+
Carex flacca ssp. *serrulata*	Cyperaceae	pH	V	+	+	+	+	+	+	+
Centarium erythrea ssp. *turcicum*	Gentianaceae	aH	G	–	–	+	+	+	+	+
Chrysopogon gryllus ssp. *gryllus*	Poaceae	pH	G	–	–	+	+	+	+	+
Cistus creticus	Cistaceae	S	G	–	+	+	+	+	+	+
Cistus salviifolius	Cistaceae	S	G	–	+	+	+	+	+	+
Colchicum stevnii	Liliaceae	pH	G	–	–	–	+	+	+	+
Crocus cancellatus ssp. *cancellatus*	Iridaceae	pH	G	–	–	+	+	+	+	+
Crocus graveolens	Iridaceae	pH	V	–	+	+	+	+	+	+
Crucianella latifolia	Rubiaceae	aH	G	–	–	–	+	+	+	+
Cyclamen persicum	Primulaceae	pH	VG	+	+	+	+	+	+	+
Cytisopsis dorycniifolia ssp. *dorycniifolia*	Fabaceae	S	G	–	–	+	+	+	+	+

Continued

Table 1. Continued.

Scientific name	Family	LF	RS	4m	1	2	3	4	5	14
Dactylis glomerata ssp. *hispanica*	Poaceae	pH	V	–	+	+	+	+	+	+
Daphne sericea	Thymelaeaceae	S	G	–	–	–	+	+	+	+
Dianthus strictus var. *strictus*	Caryophyllaceae	pH	V	–	+	+	+	+	+	+
Echium plantagineum	Boraginaceae	pH	G	–	+	+	+	+	+	+
Ephedra campylopoda	Ephedraceae	pH	G	–	–	+	+	+	+	+
Eryngium creticum	Apiaceae	H	VG	–	+	+	+	+	+	+
Euphorbia apios var. *lamprocarpa*	Euphorbiaceae	pH	V	+	+	+	+	+	+	+
Gagea fibrosa	Liliaceae	pH	V	–	+	+	+	+	+	+
Gladiolus italicus	Iridaceae	pH	VG	–	+	+	+	+	+	+
Helianthemum salicifolium	Cistaceae	aH	G	–	+	+	+	+	+	+
Helianthemum stipulatum	Cistaceae	S	G	–	+	+	+	+	+	+
Hordeum bulbosum	Poaceae	pH	V	–	+	+	+	–	–	–
Hyparrhenia hirta	Poaceae	pH	VG	+	+	+	+	+	+	+
Hypericum lydium	Hypericaceae	pH	G	–	–	–	+	+	+	+
Jasminum fruticans	Oleaceae	S	VG	–	+	+	+	+	+	+
Lithodora hispidula	Boraginaceae	S	V	+	+	+	+	+	+	+
Malabaila secacul	Apiaceae	pH	V	–	+	+	–	–	–	–
Medicago minima var. *minima*	Fabaceae	aH	G	–	+	+	+	+	+	+
Melica minuta	Poaceae	pH	G	–	–	–	+	+	+	+
Michauxia campanuloides	Campanulaceae	bH	G	–	+	+	+	+	+	+
Micromeria myrtifolia	Lamiaceae	S	G	–	+	+	+	+	+	+
Misopates orontium	Scrophulariaceae	aH	G	–	+	+	+	+	+	+
Muscari comosum	Liliaceae	pH	VG	–	+	+	+	+	+	+
Muscari parviflorum	Liliaceae	pH	VG	+	+	+	+	+	+	+
Olea europaea var. *sylvestris*	Oleaceae	S	V	+	+	+	+	+	+	+
Onobrychis caput-galli	Fabaceae	pH	G	–	+	+	+	+	+	+
Ophrys umbilicata ssp. *umbilicata*	Orchidaceae	pH	G	–	–	–	–	+	+	+
Osyris alba var. *serotina*	Santalaceae	S	G	–	–	–	+	+	+	+
Pallenis spinosa	Asteraceae	aH	G	–	+	+	+	+	+	+
Phillyrea latifolia	Oleaceae	S	V	+	+	+	+	+	+	+
Piptaherum miliaceum ssp. *miliaceum*	Poaceae	pH	V	–	+	+	+	+	+	+
Pistacia lentiscus	Anacardiaceae	S	V	+	+	+	+	+	+	+
Pistacia terebinthus ssp. *palaestina*	Anacardiaceae	S	V	+	+	+	+	+	+	+
Psoralea bituminosa	Fabaceae	pH	V	+	+	+	+	+	+	+
Quercus coccifera	Fagaceae	S	V	+	+	+	+	+	+	+
Ranunculus millefolius	Ranunculaceae	pH	G	–	–	–	+	+	+	+
Rapistrum rugosum	Brassicaceae	aH	G	–	–	+	+	+	+	+
Rhamnus oleoides ssp. *graecus*	Rhamnaceae	S	V	+	+	+	+	+	+	+
Rubia tenuifolia ssp. *brachypoda*	Rubiaceae	S	V	–	+	+	+	+	+	+
Salvia viridis	Lamiaceae	aH	G	–	+	+	+	+	+	+
Scabiosa chalocephala	Dipsacaceae	aH	G	–	+	+	+	+	+	+
Scilla autumnalis	Liliaceae	pH	VG	+	+	+	+	+	+	+
Scorzonera phaeopappa	Asteraceae	pH	V	+	+	+	+	–	–	+
Stipa bromoides	Poaceae	pH	G	–	–	+	+	+	+	+
Teucrium polium	Lamiaceae	pH	VG	–	+	+	+	+	+	+
Themeda triandra	Poaceae	pH	VG	+	+	+	+	+	+	+
Trifolium berytheum	Fabaceae	aH	G	–	+	+	+	+	+	+
Urginea maritima	Liliaceae	pH	VG	+	+	+	+	+	+	+
Valerianella vesicaria	Valerianaceae	aH	G	–	–	+	+	+	+	+
Ziziphora capitata ssp. *orientalis*	Lamiaceae	aH	G	–	+	+	+	+	+	+
Extrinsic species										
Allium ampeloprasum	Liliaceae	pH	G	–	+	+	+	+	–	–
Althaea hirsuta	Malvaceae	aH	G	–	+	+	–	–	–	–
Alyssum desertorum var. *desertorum*	Brassicaceae	aH	G	–	–	+	+	–	–	–

Continued

Table 1. Continued.

Scientific name	Family	LF	RS	4m	1	2	3	4	5	14
Anthyllis tetraphylla	Fabaceae	aH	G	–	+	+	+	+	+	+
Avena sterilis ssp. *ludoviciana*	Poaceae	aH	G	–	+	+	–	–	–	–
Buglossoides arvensis	Boraginaceae	aH	G	–	–	+	–	–	–	–
Calendula arvensis	Asteraceae	aH	G	–	+	+	–	–	–	–
Capsella bursa–pastoris	Brassicaceae	aH	G	–	–	+	–	–	–	–
Carthamus dentatus	Asteraceae	aH	G	–	+	+	+	+	–	–
Centaurea aggregata	Asteraceae	aH	G	–	+	+	–	–	–	–
Cichorium pumilum	Asteraceae	aH	G	–	–	+	–	–	–	–
Cnicus benedictus var. *kotschyi*	Asteraceae	aH	G	–	+	+	–	–	–	–
Consolida axilliflora	Scrophulariaceae	aH	G	–	–	+	+	–	–	–
Convolvulus cantabrica	Convolvulaceae	pH	G	–	+	+	+	+	+	–
Conyza canadensis	Asteraceae	aH	G	–	–	+	+	–	–	–
Coronilla parviflora	Fabaceae	aH	G	–	+	–	–	–	–	–
Crepis sancta	Asteraceae	aH	G	–	+	+	+	+	+	+
Cynoglossum creticum	Boraginaceae	aH	G	–	–	+	–	–	–	–
Daucus guttatus	Apiaceae	aH	G	–	+	+	–	–	–	–
Erodium cicutarium ssp. *cicutarium*	Geraniaceae	aH	G	–	+	+	–	–	–	–
Euphorbia peplus var. *peplus*	Euphorbiaceae	aH	G	–	+	–	–	–	–	–
Filago eriocephala	Asteraceae	aH	G	–	+	+	–	–	–	–
Geropogon hybridus	Asteraceae	aH	G	–	+	+	–	–	–	–
Gynandriris sisyrinchium	Iridaceae	pH	G	–	+	+	–	–	–	–
Heliotrophium europaeum	Boraginaceae	aH	G	–	+	+	–	–	–	–
Hymenocarpus circinnatus	Fabaceae	aH	G	–	–	+	+	–	–	–
Lactuca serriola	Asteraceae	bH	G	–	+	+	–	–	–	–
Lamium amplexicaule	Lamiaceae	aH	G	–	+	+	–	–	–	–
Lapsana communis ssp. *adenophora*	Asteraceae	aH	G	–	–	+	–	–	–	–
Lathyrus sativus	Fabaceae	aH	G	–	+	–	–	–	–	–
Linaria chalepensis var. *chalepensis*	Scrophulariaceae	aH	G	–	+	+	–	–	–	–
Lotus peregrinus var. *peregrinus*	Fabaceae	aH	G	–	–	+	+	+	–	–
Malva parviflora	Malvaceae	aH	G	+	+	–	–	–	–	–
Medicago turbinata var. *chiotica*	Fabaceae	aH	G	–	+	+	+	+	+	+
Melilotus elegans	Fabaceae	aH	G	–	+	+	–	–	–	–
Mercurialis annua	Euphorbiaceae	aH	G	–	+	+	–	–	–	–
Ononis reclinata	Fabaceae	aH	G	–	+	+	–	–	–	–
Onopordum boissieri	Asteraceae	bH	G	–	+	+	–	–	–	–
Origanum laevigatum var. *laxum*	Lamiaceae	pH	G	–	–	+	–	–	–	–
Papaver rhoeas	Papaveraceae	aH	G	–	+	+	–	–	–	–
Phleum exeratum ssp. *exeratum*	Poaceae	aH	G	–	+	–	–	–	–	–
Polygonum aviculare	Polygonaceae	aH	G	–	+	+	+	+	+	–
Rumex conglomeratus	Polygonaceae	pH	G	–	–	+	–	–	–	–
Scolymus hispanicus	Asteraceae	aH	G	–	–	+	+	–	–	–
Scorpiurus muricatus var. *subvillosus*	Fabaceae	aH	G	–	+	+	–	–	–	–
Scrophularia trichopoda	Scrophulariaceae	pH	G	–	+	+	–	–	–	–
Senecio vernalis	Asteraceae	aH	G	–	–	+	+	–	–	–
Sideritis perfoliata var. *condensata*	Lamiaceae	pH	G	–	+	+	+	–	–	–
Silene aegyptiaca ssp. *aegyptiaca*	Caryophyllaceae	aH	G	–	+	+	–	–	–	–
Silybum marianum	Asteraceae	bH	G	–	+	+	–	–	–	–
Sinapis arvensis	Brassicaceae	aH	G	–	+	+	–	–	–	–
Sonchus oleracus	Asteraceae	aH	G	–	+	–	–	–	–	–
Stachys sparsipilosa	Lamiaceae	aH	G	–	+	+	+	–	–	–
Thlaspi perfoliatum	Brassicaceae	aH	G	–	+	+	+	+	+	+
Trifolium campestre	Fabaceae	aH	G	–	+	+	+	–	–	–
Trifolium purpureum var. *purpureum*	Fabaceae	aH	G	–	+	+	–	–	–	–
Trigonella kotschyii	Fabaceae	aH	G	–	–	–	+	+	–	–
Verbascum sinuatum var. *adenosepalum*	Scrophulariaceae	bH	G	–	–	+	–	–	–	–

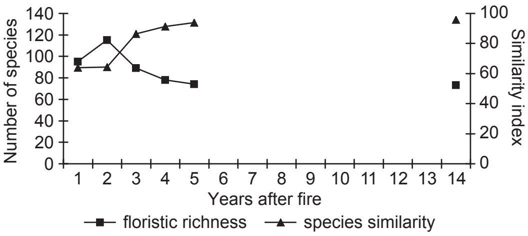

Fig. 3. Development and similarity of floristic composition after the fire.

The flora of the unburned area (400 m^2) consisted of 71 species, and it did not change (floristically) during the fourteen years after the fire. In the burned area (400 m^2), the presence of plant species changed throughout the observation period as follows: 95 species in the first year, 115 species in the second year, 89 species in the third year, 78 species in the fourth year, 74 species in the fifth year, and 73 species in the fourteenth year (Table 1).

The community corresponding to *Quercus coccifera* coppices went through four phases in terms of changes in the floristic richness after fire. In the first phase, during the first two months, there was no vegetative re-sprouting; in the second phase, during the following two years, there was a rapid increase of taxa (in this phase the floristic richness reached the maximum value); in the third phase, during the third and the fourth years after the fire, there was a slow decrease of taxa; and in the fourth phase, the fifth year, the number of taxa was stable (Fig. 3). In the last phase the shrubs also reached adult size and maturity.

98.6% of the species, which belong to the pre-fire vegetation, reappeared in the three years after the fire (Table 2). The return towards a metastable state was quite rapid. It is known that some Mediterranean ecosystems evolve with fire and that most plant species have developed adaptive mechanisms (Trabaud 1987a). These mechanisms could be associated with the strategies of persistence after a fire (e.g. species that regenerate well or disseminate numerous seeds after a fire).

Many herbaceous re-sprouters having subterranean root organs (rhizomes, bulbs, or tubers) such as *Themeda triandra*, *Hyparrhenia hirta*, *Asphodelus aestivus* and *Urginea maritima* regenerated easily in the first year after the fire. These results agreed with those presented by other authors (Daubenmire 1968, Trabaud 1973).

The subterranean woody re-sprouters (*Quercus coccifera*, *Olea europaea* var. *sylvestris*, *Rhamnus oleoides*, *Phillyrae latifolia*, *Lithodora hispidula*), which dominated the vegetation before the fire, re-dominated and reached the previous situation in the fifth year. Sprouting of perennials after the fire depends on the survival of buds having vascular connections with the subterranean organs. Subterranean organs are protected from fire by the soil, which is a good isolator and conducts little heat produced by the burning vegetation (Packmann 1971, Aston & Gill 1976). Mooney and Dunn (1970) found that nearly 50% of small woody shrubs in California and Chile sprouted after a fire. Kruger (1977) suggested that approximately 65% of South African fynbos species behaved in the same manner. Naveh (1975) in

Table 2. Appearance proportions of resident and extrinsic species, and the floristic similarity between burned and unburned areas after fire.

Time after the fire	Burned sites				Sørenson similarity index
	No. of resident species	%	No. of extrinsic species	%	
4 months	20	28.1	1	1.7	43.5
1 year	33	46.5	41	69.5	63.9
2 years	10	14.1	16	27.1	64.3
3 years	7	9.9	1	1.7	86.3
4 years	1	1.4	0	0.0	91.3
5 years	0	0.0	0	0.0	93.8
14 years	0	0.0	0	0.0	95.8
Total	71	100	59	100	–

Israel and Trabaud and Lepart (1980) in southern France found that nearly all the woody species of these regions sprouted after a fire within 3–5 years.

The successive observation during the first five years and the fourteenth year showed that the reappearance of the taxa that were frequent before the fire progressively dominated the floristic composition of the vegetation. Returning back to a stable situation was faster in the *Quercus coccifera* scrubland and the floristic diversity was seen to be unchanged. These results indicate that the impact of the fire on the studied vegetation was similar to that observed by Trabaud and Lepart (1980) for the vegetation of Bas-Languedoc and by Thanos *et al*. (1989) for *Pinus brutia* forest ecosystems of the Samos Island.

Among the extrinsic species, the most prolific families were Fabaceae and Poaceae. It was observed that these families were more abundant in the first three years after the fire than in the pacific stage. Later (in the fifth year), they increased to pre-fire levels.

As regards *Cistus creticus* and *C*. *salviifolius*, our results disagree with some previous studies (Le Houreou 1974, Trabaud 1982, Thanos *et al*. 1989). Those species were regarded as pyrophytic by Naveh (1975) and Keeley (1987), as opportunistic seeders by Trabaud (1987b) and, because of their capacity to develop in the absence of strong competitors, as helophytic pioneer species by Greig-Smith (1979) and Mazurek and Romane (1986). In our study, however, their abundance did not change similarly.

As a result, there was no real succession in the burned *Quercus coccifera* macchia, where different communities appeared, but a progressive reappearance of the previous vegetation. Auto-succession, i.e. the reconstitution of the former community, is a widespread phenomenon in the Turkish macchia vegetation.

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