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Post-fire successional recovery of a phryganic (East Mediterranean) ecosystem

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ABSTRACT

Post-fire regeneration of plant species in a phryganic (East-Mediterranean) ecosystem occurs through stem crown resprouting and seed germination. Post-fire succession starts with a preludium of herbaceous vegetation, a situation which is gradually changed, so that by the end of the seventh post-fire growth period the percentage contributions of woody and herbaceous species are almost as before. At this period above-ground biomass attains the half of the pre-fire one, while the photosynthetically active tissues (leafy biomass) contribute equally to the total above-ground biomass in the unburned and the burned sites. Furthermore, soil cover is much more in the burned site than in the unburned one. This fact may mean that the danger of soil erosion due to the denudation of soil cover is less than commonly considered.

Key-words: *Fire - Regeneration - Mediterranean ecosystems*

RÉSUMÉ

La régénération après incendie des espèces végétales d'une phrygane (écosystème de la Méditerranée orientale)s'effectue par rejet de souches et germination de graines. La succession après incendie commence par un stade de végétation herbacée; cette situation change graduellement, de telle sorte qu'à la fin de la septième année de croissance après le feu, les pourcentages des contributions des espèces ligneuses et des espèces herbacées sont pratiquement ceux d'avant le feu. A cette époque, la phytomasse aérienne atteint la moitié de celle qui existait avant l'incendie, mais les tissus photosynthétiquement actifs (phytomasse foliaire) de la végétation totale aérienne des zones brûlées et non brûlées présentent des pourcentages égaux. En outre, le recouvrement est beaucoup plus élevé dans la zone brlûée que dans celle non brûlée. Ce fait pourrait indiquer que le danger d'érosion du sol dû à la dénudation est moins grand que ce que l'on croit communément.

Mots-clés : *Feu - Régénération - Écosystèmes méditerranéens.*

INTRODUCTION

Mediterranean type climate is characterized by an alternation of mild, humid winters with warm and dry summers. This type of climate prevails in several distinct regions of the world, that is California, Central Chile, South and Southwest Australia, and Mediterranean basin, all found between 32°-42° North and South of the Equator.

The development of the severe summer drought combined with high temperatures leads to high frequency fires in Mediterranean climates. Therefore, Mediterranean type ecosystems are often characterized as fire-induced or fire-adapted (Shantz, 1947).

Mediterranean-type ecosystems of Greece occupy about 40 % of its total area and are very often subjected to recurring fires (LIAKOS, 1973). In our effort to identify the ecological role of fire in the xerophytic Mediterranean vegetation of Greece, we undertook in Attica a study which started in 1976. Part of the aim of this study was the evaluation of the adaptation mechanisms shown by the producer organisms of a phryganic ecosystem in opposing fire's action.

Two major types of plant regeneration can be distinguished: vegetative resprouting from undisturbed dormant buds and seed germination (NAVEH, 1975; ARIANOUTSOU, 1979). Fire regeneration behaviour through resprouting is closely linked with season and water availability. Resprouting in seasonal dimorphic plants (phrygana) begins after the first autumn rains when soil moisture becomes available (PLUMB, 1963; ARIANOUTSOU-FARAGGITAKI & MARARIS, 1981 *a*) and is probably related to the carbohydrates available in the plant at the moment of fire burst (JONES & LAUDE, 1960).

Vegetative regeneration is very fast and can be attributed to the new leaves of the resprouts which are both larger and richer in chlorophyll than those of the unburned shoots. (The percent increase was 70 % for the *Phlomis fruticosa* and 150 % for *Euphorbia acanthothamnos*, considering the mg of chlorophylls per g of leaf dry weight) (ARIANOUTSOU-FARAGGITAKI & MARGARIS, 1981 *a*).

Seed germination is greatly stimulated after fire. The possible mechanisms through which this stimulation occurs may be (*a*) the mechanical rupture of seed coats, (*b*) the inactivation of heat sensitive inhibitors present in the soil, (*c*) the activation of the phytochromic system as a result of the foliage removal (see review by MARGARIS, 1981).

Herbaceous vegetation which normally grows in the patches formed between the woody species is also adapted to recurring fires (NAVEH, 1974; ARIANOUTSOU-FARAGGITAKI & MARGARIS, 1981 *a*) and recovers either through resprouting and/or through seed germination forming thick carpets the first two post-fire years. Among these herbs, the relative abundance of Papilionaceae nitrogen-fixing species is marked, especially considering the possibilities offered in nitrogen replenishement.

This paper presents the results of a follow-up study which was based on data collected for a period of 5 years (1979-1983). It also discusses in more detail the characteristic trends shown by the ecosystem during its post-fire succession.

STUDY SITE

A phryganic ecosystem located at Mount Hymettus (Attica) was burnt accidentally in late July 1976. It is found at a height of 400 m above sea level and its terrain is moderately steep with slopes of 10-15°. The flora of the mountain is well known (ZERLENTIS, 1965). The parent rock is limestone, while the soil is characterized as clayloam.

Climatic data for the study site are shown in figure 1.

Full description of the situation during the first and second post-fire years was given by ARIANOUTSOU-FARAGGITAKI & MARGARIS (1981 *a*, *b* and *c*) while information for the adjacent unburned site, used as control, was given by MARGARIS (1976).

METHODS

Throughout a five years period (1979-1983) burned and control sites were frequently surveyed. Measurements on above ground biomass were done by cropping it at the end of the growing period.

each year, in 10 randomly spaced 1 m^2 quadrats. The dry weight was measured after oven-drying at 60° C for 48 hours. By the end of 1983, plant species composition was counted in 3 plots. Each plot was 100 m^2. Plant cover was estimated in 25 transects each having an area of 4 m^2.

Nomenclature follows the Flora Europaea (1-5, 1964-1980).

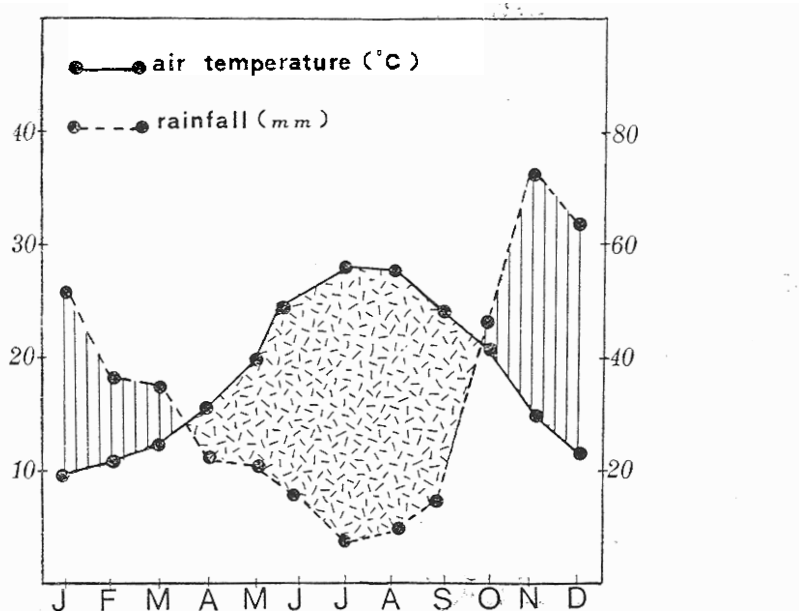

FIG. 1. — Climadiagram of the study site. Data are the mean values of a ten years period

RESULTS AND DISCUSSION

From the woody species *Phlomis fruticosa* L., *Euphorbia acanthothamnos* Heldr. & Sart. ex Boiss., *Sarcopoterium spinosum* (L.) Spach., *Cistus* spp. and *Thymus capitatus* (L.) Hoffmans & Link, which were dominant before fire and accounted an above-ground phytomass of about 1,000 $g.m^{-2}$ (MARGARIS, 1976), *P. fruticosa*, *S. spinosum* and *E. acanthothamnos* regenerated from dormant buds located at the crown, while *C. incanus* Rchb. and *T. capitatus* did not resprout at all. Most of the other woody species (*Teucrium polium* L., *T. divaricatum* Sieber ex Boiss., *Phagnalon graecum* Boiss. et Heldr., *Helianthemum numularium* L. Miller) regenerated through resproutings quite successfully. From the above listed species *S. spinosum* regenerated also through stimulated seed germination, which is the only way for survival in the case of *C. incanus*. Fire greatly promotes seed germination of the latter species and this is very important since in unburned sites its seedlings are not more than 20 per m^2. *C. incanus* seedlings in the burned site were risen up to 300 per m^2.

Results concerning the above-ground plant biomass are inserted in figure 2. Seven years after fire the system has attained half of its prefire biomass (about 1,000 $g.m^{-2}$).

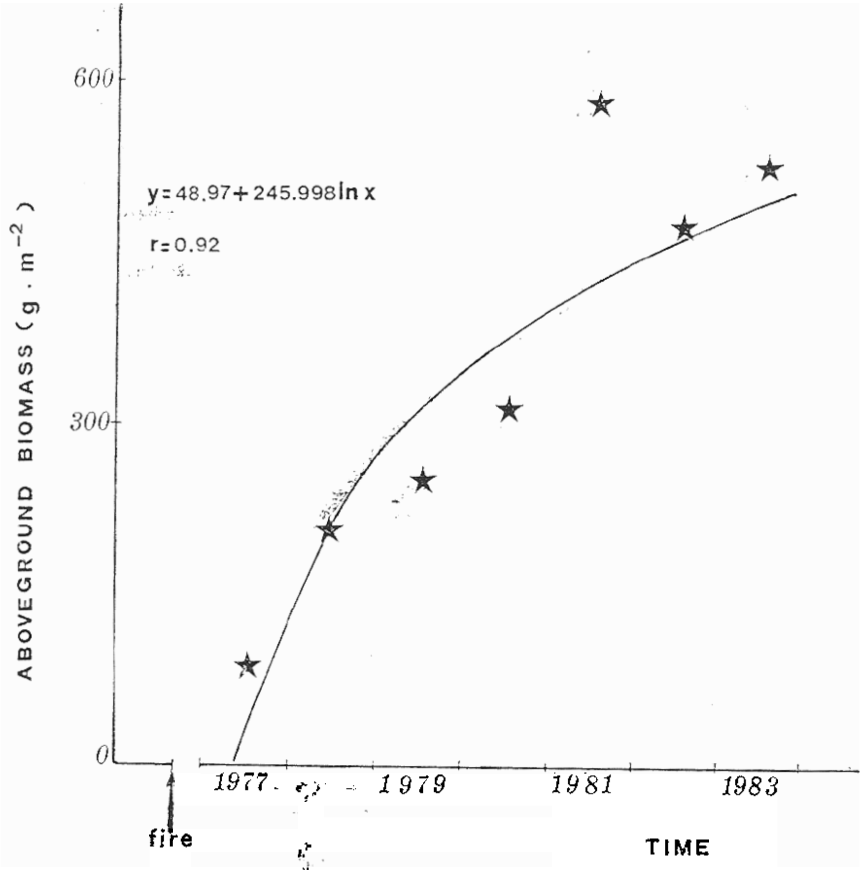

FIG. 2. — Post-fire above-ground plant biomass for the years 1977 up to and 1983
Fire's outbreak on late July 1976.

The relative percentage contribution of the woody and the herbaceous species, in this biomass, is shown in table I. During the first two post-fire years, there is an apparent dominance of herbs. The woody vegetation is only 54 % of the total above-ground biomass. This situation is gradually changed. By the end of the 7th growth period the percentages are 92 % and 8 % for the woody and herbaceous vegetation respectively.

This fact reveals that post-fire succession starts with a preludium of herbaceous vegetation, which is gradually diminishing till a situation more or less similar to the prefire one is reestablished.

Comparison between the burned and unburned sites (table II) as regards percent cover by each species, at the end of the observation period, shows that *S. spinosum* has a very high participation. This may be explained by the fact that this species regenerated from seeds as well as from buds which is a definite advantage over the others.

TABLE I. — *Percentage of woody and herbaceous vegetation in the above-ground biomass.*

Year (*)	Biomass of woody vegetation		Biomass of herbaceous vegetation	
	%	$g.m^{-2}$	%	$g.m^{-2}$
1977	16	14.88	84	78.12
1978	54	113.40	46	96.60
1979	78	195.00	22	55.00
1980	80	244.00	20	61.00
1981	85	497.25	15	87.75
1982	90	423.00	10	47.00
1983	92	487.60	8	42.40

(*) All estimations have been done on biomass data of the peak growth period (May).

TABLE II. — *Percent cover of plant species of burned and unburned sites at the end of the observation period in the phryganic ecosystem.*

Species	Unburned site	Burned site (1983)
Phlomis fruticosa	13.31	2.60
Euphorbia acanthothamnos	12.86	4.76
Sarcopoterium spinosum	6.22	33.20
Cistus incanus	4.41	16.48
Thymus capitatus	1.90	0.12
Micromeria juliana	1.00	0.01
Olea europea	0.90	1.60
Fumana thymifolia	0.54	0.02
Helianthemum numularium	0.45	2.28
Asparagus acutifolius	0.36	1.08
Ballota acetabulosa	0.32	0.01
Phagnalon graecum	0.32	0.03
Inula candida	0.32	—
Osyris alba	0.14	0.01
Teucrium polium	0.13	0.20
T. divaricatum	0.09	0.01
Quercus coccifera	0.05	0.02
Sedum sediforme	0.02	—
Anthyllis hermaniae	0.01	—
Hypericum empetrifolium	0.01	0.16
Satureja thymbra	0.01	0.01
Globularia alypum	0.01	—
Total pover s	43.38	62.60

In sites which were recently exposed to fire's action, this plant is usually a dominant one. For instance, in Rodopos (Certe) it occupies approximately 27 % of the total coverage of woody species, while in Karystos (Euboia), it reaches 34 % (DIAMANTOPOULOS, 1983). These sites were exposed to fire quite recently (about 10-15 years ago).

Great difference also appears in the case of *Cistus incanus* and *Helianthemum numularium* whose percentage coverage was risen 4 and 5 time respectively, while three others of the dominant species seem to have much lower values *i. e. Euphorbia acanthothamnos, Phlomis fruticosa* and *Thymus capitatus*. The latter species started appearing in the site long after fire's occurrence (early, 1982) and it is probable that its seedlings originated from seeds dispersed to the burned site from the adjacent unburned area.

The most important post-fire effect observed on the phryganic ecosystem studied is that the bare ground is much less than before: 57 % before fire and 37% after it. Considering that in these figures herbaceous plant coverages have not been taken into account, the final ones will be even lower. In case this result is found to hold also true for other phryganic ecosystems it may mean that the danger of soil erosion due to the denudation of soil cover by fire is less than commonly considered (provided of course that the burned areas are well protected from other human perturbations, like overgrazing, construction activities etc.).

Table III gives results on species above-ground biomass. It is apparent that the species relative contribution has changed. Some species have been restricted while some others overdominate. For instance *S. spinosum* and *C. incanus* contribute much more in the above-ground biomass. Bur despite this change, the important thing is that the total green, photosynthetically active, biomass is comparatively the same (table IV). Considering that the post-fire above-ground biomass is about half of the prefire one, it is of great significance the fact that the photosynthetically active organs through which the system reconstitution is established, consist 20 % of the total biomass, exactly as before fire. This means that the ecosystem is quite well recovering by possessing those functioning structures, which are the first steps towards rapid recovery process, in the same percentage as before even if it is more young. This also might mean that from a point of view fire is necessary in keeping the ecosystem in a young and vigorous productive stage.

TABLE III. — *Species above-ground biomass.*

Species	$g.m^{-2}$ Pre-fire 1976	$g.m^{-2}$ Post-fire 1983
Phlomis fruticosa	336.5	13.7
Euphorbia acanthothamnos	270.0	36.0
Sarcopoterium spinosum	143.5	216.0
Cistus incanus	83.5	169.0
Helianthemum numularum	80.3	30.7
Thymus capitatus	36.0	—
Others	130.7	64.3
Total	1,110.5	529.7

TABLE IV. — *Total pre- and post-fire green (leaves) and non-green (shoots and flowers) biomass in the phryganic ecosystem.*

	Pre-fire (1976)		Post-fire (1983)	
	$g.m^{-2}$	%	$g.m^{-2}$	%
Leaves	209	19	109	20
Shoots	886	80	413	78
Flowers	16	1	8	2
Total	1,111	100	530	100

Alternation of plant number within species and of species composition 6 years after fire has been reported for chaparral vegetation in Southern California (HANES & JONES, 1967), but the overall shrub composition of chaparral was relatively stable. In general, the same conclusion can be drawn for the phryganic ecosystem under study. The minor changes occurred can be attributed to (1) reduced numbers of some species (in coverage); (2) increased numbers of some species; (3) occurrence of some new ones. Furthermore, regardless of the more or less significant change in woody species biomass and coverage after fire, if we consider the ratio of these two developmental parameters (B/C) (table V) we may say that there is not such a great difference in how each species is favoured by the larger space offered. For example while biomass of *P. fruticosa* is about 14 $g.m^{-2}$ and its relative coverage is about 3 % and those of *S. spinosum* are 216 $g.m^{-2}$ and 33 % respectively, their ratios, B/C are 5.27 and 6.51. This small difference may signify that these two species have a similar ability to exploit available resources, either by increasing their canopy, getting thus favour of larger space or increasing their biomass in lesser area.

TABLE V. — *Woody species' biomass to coverage ratio.*

Species	Unburned site	Burned site (1983)
Phlomis fruticosa	27.53	5.27
Euphorbia acanthothamnos	20.99	7.56
Sarcopoterium spinosum	23.07	6.51
Cistus incanus	18.93	10.25
Thymus capitatus	18.95	—

It is also characteristic, that species sprouting vigorously from root-crowns, either maintained their dominance, or they were in the process of attaining their pre-fire dominance, especially when they also regenerate through seedlings. Anyway, the potential resprouting is a genetically controlled characteristic and varies widely from species to species, and very possibly even among subspecies or ecotypes (WESTMAN, 1981). Thus, a fire of lower intensity might be followed by less resprouting than a site of higher intensity burn, if the colonizer species are less heat tolerant and inherently less vigorous resprouters. The latter may be in the case for *Thymus capitatus*.

In conclusion we may say that post-fire succession in phrygana is a dynamic process, which proceeds through species dominance and retrieval to a more or less stable state, which may be characterized as the climax one, the fire-climax.

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