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Fire-Induced Nutrient Losses in a Phryganic (East Meditteranean) Ecosystem

by

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ABSTRACT. — After a fire in a phryganic ecosystem, the nutrient losses in above-ground plant biomass, in nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) were quantitatively different. The most important is that of nitrogen (96%), followed by magnesium (59%), potassium (54%) and calcium (36%) while phosphorus content remained constant. Removal of these elements took place through fire's smoke.

INTRODUCTION

According to Aschmann's (1973) definition of the "Mediterranean type" climate, Greece is, in general, a typical representative. Two major mediterranean ecosystem-types can be distinguished (Eyre, 1968): maquis at the wet end of the precipitation gradient and phrygana at the dry end. Maquis (synonyms: macchia-Italy, chorech-Israel, monte bajo-Spain, matöral-Chile, chaparral-California, mallee-Australia, fynbosch-S. Africa) are dense evergreen scrub communities, while phrygana (tomillares-Spain, batha-Israel, gariga-Italy, coastal sage-California, renosterbos-S. Africa) are open ones.

The available information on the nutrients changes after forest and grassland fires is quite numerous (Biswell, 1972; Daubenmire, 1968; DeBell and Ralston, 1970; Dix, 1960; Dix and Butler, 1954; Grier, 1975; Knight, 1966; Lewis, 1974; Lloyd, 1971; Sharow and Wright, 1977; Vogl, 1965). There is also information on chaparral and heathland fires (Allen, 1964; Christensen, 1973; Depano and Conrad, 1978; Debano, Dunn and Conrad, 1977; Gimingham, 1970; Kenworthy, 1964; St. John, 1941). However, for the Mediterranean basin itself there are no published data up to now. In this paper, the data concern plant nutrient changes during and after fire in a phryganic ecosystem in Greece. This study consists of a part of a research program on the structure, function and management of phryganic ecosystems (Adamantiadou, Siafaca and Margaris, 1978; Margaris, 1975, 1976, 1977a, b; Margaris and Papadogianni, 1978).

EXPERIMENTAL SITE

A phryganic ecosystem located near Athens, in the SW of Mt. Hymettus on an altitude of 400 m, is the area under study; it neighbours with an unburnt area of the same structure, in which experiments were carried out for comparison. The dominant plant species in the

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biomass of the ecosystem are (Margaris, 1976): *Phlomis fruticosa* (33%), *Euphorbia acanthothamnos* (26.5%), *Sarcopoterium spinosum* (12%), *Cistus* spp. (7.5%) and *Thymus capitatus* (3%).

MATERIALS AND METHODS

Chemical analysis was carried out on samples consisting of the above-ground parts of the dominant plant species of the ecosystem, cropped in July 1977. A part of the cropped material was spread on a metal tray and ignited. As the fire proceeded more material was added. The plant ash thus obtained was further analysed.

Nitrogen was estimated by a combination of Kjeldahl procedure, using $CuSO_4$—K_2SO_4— Se as a digestion accelerator, and Varley's method (1966) in the Technicon autoanalyser.

For phosphorus, potassium, calcium and magnesium analysis, the procedure used is the following; samples of oven-dried plant material and the ash obtained were incinerated twice at 540°C for 8 h. After every incineration the ash was taken with 5ml HCl-H_2O (1:4) and filtered through a filter paper (Whatman No 42). Phosphorus was estimated in a spectrophotometer using vanadomolybdate yellow procedure (Chapman and Pratt, 1961) and potassium with a flame photometer. Calcium and magnesium were estimated with an atomic absorption spectrophotometer.

RESULTS AND DISCUSSION

Chemical analysis of intact plant material and of the ash obtained through burning in the laboratory gives us results on the percentage losses of each element, removed in the fire's smoke. Analytical data are shown in Tables 1 to 5.

According to Table 1 from a total amount of 5.050 g/m^2 of nitrogen only 0.089 g/m^2 remained after fire what means that 96% of this nutrient is lost in smoke, probably due to the high volatilization of the compounds formed.

Table 1. Loss in nitrogen (N) of the aboveground plant parts of the ecosystem because of fire

Species	Plant biomass before fire (g/m^2)	Nitrogen in unburned plants (‰)	Nitrogen before fire (g/m^2)	Ash in the site (g/m^2)	Nitrogen in ash (‰)	Nitrogen after fire (g/m^2)
Phlomis fruticosa	385	6.600	2.540	33.100	0.311	0.103
Euphorbia acanthothamnos	302	3.770	1.140	14.700	0.188	0.028
Sarcopoterium spinosum	148	4.020	0.590	9.700	0.257	0.025
Cistus sp.	95	6.530	0.620	7.200	0.432	0.031
Thymus capitatus	35	4.640	0.160	1.300	0.161	0.002
Mean			1.010			0.088
Loss due to fire (%)						96

Table 2. Loss in phosphorus (P) of the aboveground plant parts of the ecosystem because of fire.

Species	Plant biomass before fire (g/m²)	Phosphorus in unburned plants (‰)	Phosphorus before fire (g/m²)	Ash in the site (g/m²)	Phosphorus in ash (‰)	Phosphorus after fire (g/m²)
Phlomis fruticosa	385	0.559	0.231	33.100	4.590	0.152
Euphorbia acanthothamnos	302	0.146	0.044	14.700	7.222	0.106
Sarcopoterium spinosum	148	0.324	0.035	9.700	4.781	0.046
Cistus sp.	95	0.774	0.074	7.200	11.008	0.079
Thymus capitatus	35	0.351	0.012	1.300	8.465	0.011
Mean			0.079			0.079
Loss due to fire (%)						

Table 3. Loss in potassium (K) of the aboveground plant parts of the ecosystem because of fire

Species	Plant biomass before fire (g/m²)	Potassium in unburned plants (‰)	Potassium before fire (g/m²)	Ash in the site (g/m²)	Potassium in ash (‰)	Potassium after fire (g/m²)
Phlomis fruticosa	385	4.870	1.875	33.100	28.800	0.953
Euphorbia acanthothamnos	302	3.610	1.090	14.700	26.640	0.392
Sarcopoterium spinosum	148	1.490	0.220	9.700	18.820	0.182
Cistus sp.	95	4.820	0.458	7.200	27.250	0.198
Thymus capitatus	35	6.050	0.212	1.300	36.960	0.048
Mean			0.771			0.355
Loss due to fire (%)						

On the contrary, phosphorus (Table 2) was not lost, but it was deposited in the ash-bed covering the soil surface. Potassium and the divalent cations, calcium and magnesium (Tables 3, 4 and 5) showed moderate losses: 54%, 36% and 59% respectively.

Table 6 shows qualitative data of fire effects on nutrients in three ecosystem types: forests, grasslands and shrublands. As we can see, in all cases the most important loss in

Table 4. Loss in calcium (Ca) of the aboveground plant parts of the ecosystem because of fire.

Species	Plant biomass before fire (g/m²)	Calcium in unburned plants (‰)	Calcium before fire (g/m²)	Ash in the site (g/m²)	Calcium in ash (‰)	Calcium after fire (g/m²)
Phlomis fruticosa	385	12.320	4.743	33.100	75.600	2.502
Euphorbia acanthothamnos	302	12.040	3.636	14.700	151.200	2.223
Sarcopoterium spinosum	148	9.240	1.367	9.700	181.440	1.760
Cistus sp.	95	13.760	1.307	7.200	99.760	0.718
Thymus capitatus	35	13.440	0.470	1.300	108.800	0.141
Mean			2.305			1.469
Loss due to fire (%)						36

Table 5. Loss in magnesium (Mg) of the aboveground plant parts of the ecosystem because of fire.

Species	Plant biomass before fire (g/m²)	Magnesium in unburned plants (‰)	Magnesium before fire (g/m²)	Ash in the site (g/m²)	Magnesium in ash (‰)	Magnesium after fire (g/m²)
Phlomis fruticosa	385	1.500	0.577	33.100	5.400	0.179
Euphorbia acanthothamnos	302	2.240	0.676	14.700	18.000	0.265
Sarcopoterium spinosum	148	1.680	0.249	9.700	18.820	0.182
Cistus sp.	95	2.580	0.245	7.200	12.380	0.089
Thymus capitatus	35	1.680	0.059	1.300	14.080	0.018
Mean			0.361			0.147
Loss due to fire (%)						59

smoke was that of nitrogen. Nitrogen deserves special consideration because of its importance in all ecosystems and especially in Mediterranean-type shrublands as far as:

(1) It is easily volatilized by heating (Grier, 1975; White, Thompson and Gartner, 1973).
(2) Soil heating and combustion transform nitrogen into forms readily available to plant growth and to subsequent mineralization (Christensen, 1973).
(3) Soil enrichment in nitrogen after fire takes place through the activity of nitrogen fixing bacteria and with precipitation which contains some nitrogen also.

Table 6. Effect of fire on aboveground plant nutrient losses in different ecosystem types.

Ecosystem type	N	P	K	Na	Ca	Mg	Author
Shrublands							
1.	101	9	90	5	147	14	Debano and Conrad* (1978)
2.	60						Allen** (1964)
3.	96	0	54		36	59	Present work**
Forests							
1.	62						Debell and Ralston** (1970)
2.	64						Knight** (1966)
3.	39		35	83	11	15	Grier* (1975)
Grasslands							
1.	73	25	39				Lloyd* (1971)
2.	36						Sharrow and Wright* (1977)

* Loss in kg/ha
** Loss in %

Since fire consumes high nitrogen quantities, the ecosystem must be capable to replace; or else it would quickly become completely devoid of it. Rain undoubtedly contains some nitrogen, but this input is low, not more than two kilograms/ha/year (DeBano and Conrad, 1978). The most important mechanism seems to be the activity of nitrogen-fixing bacteria, such as the symbiotics in the nodules of *Papilionaceae*. We can for example refer to the herbal genera *Lotus, Lupinus* and *Trifolium*, abundant in chaparral (Dunn and DeBano, 1977) and phrygana (Economidou, 1969; Papatsou, 1977) in the nodules of which nitrogen is fixed.

The presence of these genera is very important in the first growth periods after fire and is especially typical in sites with recurring fires, e.g., as we follow the North-South direction in Greece, we can see more and more representative species of *Papilionaceae*. It is so illustrated how important is the rapid symbiotic nitrogen fixation by resident legume species after fire. Some nonherbaceous nitrogen fixers in Greek phryganic ecosystems are *Genista acanthoclada*, typical in South Peloponnese, *Anthylis hermaniae, Calycotome villosa* and *Spartium junceum*.

Data from California show that nodules of *Ceanothus gregii* produce such a nitrogen quantity that covers 25% of its own nitrogen needs; and *Ceanothus integerrimus* root nodules (Vlamis et al., 1958) are capable of fixing up to 60 kg/ha of nitrogen annually under optimum conditions (Delwich, Zinke and Johnson, 1965).

About 0.355 g/m^2 (54%) of potassium were lost in smoke. The rest of it will be deposited with the ash on the soil surface. From the total amount of calcium, 1.468 g/m^2 were lost in the fire smoke, while 0.836 g/m^2 returned to the soil surface. Respectively, magnesium losses, attained 0.147 g/m^2 (59%).

The data as a whole show that burning of plant cover releases large amounts of readily soluble nutrients such as K, Na, Ca, Mg. These nutrients were bound in plant tissues, therefore useless to plant growth. Fire converts them into readily available forms for the plant community. From this aspect, it can be considered as a quick decomposer. If these nutrients are not used either because there are no plants, or the soil cannot hold them, they will be lost with erosion (DeBell and Conrad, 1976) and the subsequent regeneration will be slow (Viro, 1974).

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