Experimental Study on the Effects of Prescribed Burning on a *Quercus coccifera* L. Garrigue: Early Results

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GENERAL COMMENTS ON FIRES IN NATURAL VEGETATION IN SOUTHERN FRANCE

NATURAL succession in Mediterranean vegetation is often disturbed by fire. In France, only a few authors have studied fire and its devastating action as a factor in succession: Ribbe (1866, 1919), Flahault (1924), Braun-Blanquet (1935, 1936), Laurent (1937), Kornas (1958), Kuhnholtz-Lordat (1938, 1957, 1958). Generally, these authors only describe stages corresponding to vegetation types; they give some information about succession immediately following fire, and then compare the different stages to each other.

Nevertheless, Kuhnholtz-Lordat gives rather a complete general survey of the relation between fire and vegetation in two basic books: La terre incendiée (The Earth on Fire) (1938), and L'écran vert (The Green Screen) (1958). But it must be remembered that the results described are not data obtained from controlled or experimental conditions.

Our major goal is to study fire as a factor experimentally, in its natural habitat (the French Mediterranean area), where its impact upon the vegetation is one of the most important factors affecting the dynamics of the vegetation and the environment. The most numerous and most harmful wildfires in France occur in the Mediterranean area, an area which extends from the eastern Pyrenées, to the southern Alps, down to Corsica. For example, in 1970, about 5700 hectares of natural vegetation were consumed in this area.

Fire, natural or intentionally set, has always been a prime dynamic factor in the dissemination of seeds and invasion of soil by plants. It was the most widely used primitive tool employed by man in his conquest of virgin lands. For some decades, fire has tended to be succeeded by mechanical and chemical means.

Over many centuries fire has engendered a type of vegetation which is that of the Mediterranean garrigue or maquis. The term "garrigue" corresponds to a plant formation, usually low (less than 2 meters), composed chiefly of sclerophyllous small trees and bushes with evergreen foliage, growing on calcareous soil. "Maquis" corresponds to a compact formation, often impenetrable, of shrubs and small trees, generally on siliceous soil (Plaisance 1959). Maquis is denser and higher than garrigue (Fig. 1 and 2). Fire has contributed to the present aspect of the landscape, but it is not the sole responsible factor.

The floristic composition of these plant formations shows a great number of species which are adapted or resistant to fire, called pyrophytes. For some authors, pyrophytes are species which invade rapidly after fire has passed, while for others they are species which resist fire. In the Mediterranean area the two kinds are interspersed (Trabaud 1970). The factors determining the development of such species in burned areas is not clearly understood; some of them invade right after fire, while others pre-existed and spread out as a result of reduced competition pressure due to fire.

THE PROBLEM

What are the elements of the problem (succession in the garrigue after fire) we should consider?

FIG. 1. Aspect of the maquis. Photo by L. Trabaud.

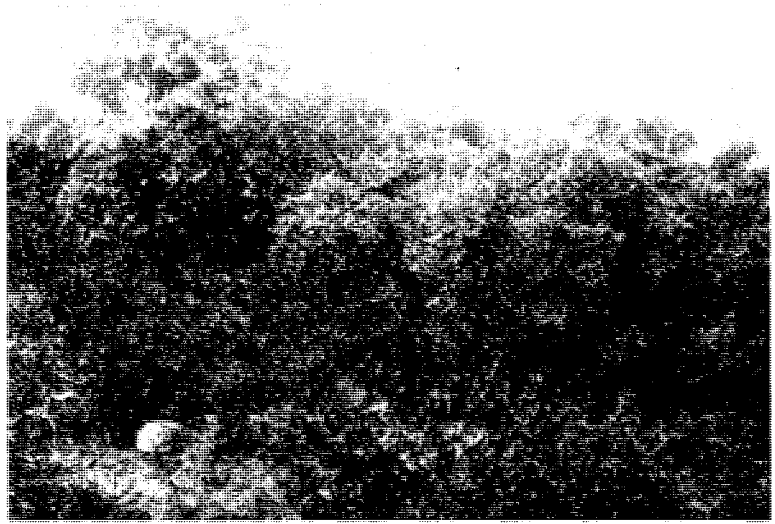


FIG. 2. Aspect of a garrigue. Photo by L. Trabaud.

1. The species of the garrigue as they presently exist.

2. The spatial and temporal arrangement of these species, due to the history of the vegetation and the environmental factors, causing different plant associations.

3. Environmental factors:

a. The water and wind factors require special attention. The quantity and rhythm of rainfall have an effect upon the vegetation; they characterize the Mediterranean climate, generally dry in summer, with heavy but short rains in autumn and in spring. In addition, the air hygrometry affects the "water factor" and the probability of fire. The flammability of the vegetation changes according to the seasonal quantities of rain and according to the dryness of the soil. The wind factor deserves particular study because it is the major factor responsible for the rate and the direction of fire spread.

b. The edaphic factors have less influence on fire. However, they affect the distribution of vegetation, and consequently, fire behavior (the open garrigues of *Rosmarinus officinalis*,* or marls, are rarely overrun by fire).

The fire problem is a research topic we have dealt with by continuous observation on a permanent plot network set in the Mediterranean Languedoc, and by experimental study plots situated in a *Quercus coccifera* garrigue (Fig. 3)

CHOICE OF A METHOD TO ESTIMATE THE PLANT DYNAMICS EXPERIMENTALLY

Generalities

To study the vegetation dynamics, it was necessary to find a method which would reveal the successive changes through the years, and which would permit the recording of these changes, the different stages of a community recovering bare ground.

The study techniques are the following:

* The specific names are those given in Les quatre flores de France, P. Fournier, 1961, Le Chavellier, 405 p.

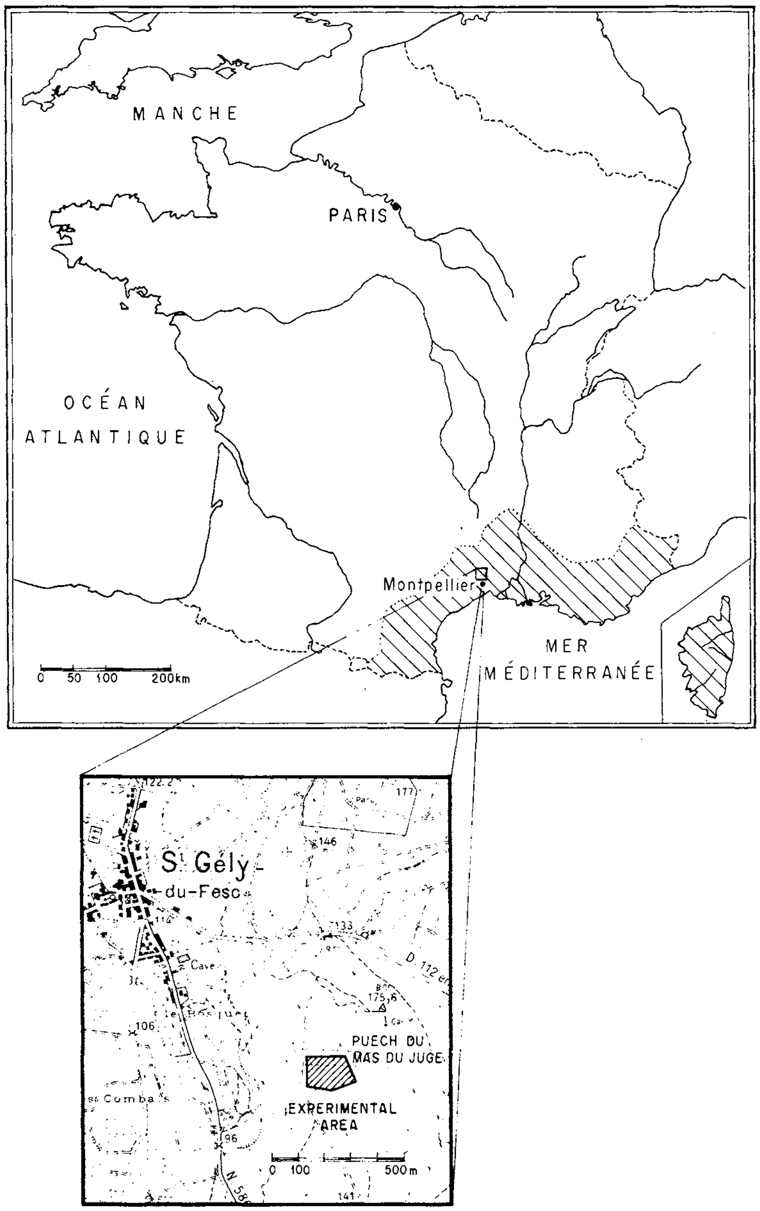


FIG. 3. Mediterranean area of southern France and location of the experimental area, near Saint-Gely-du-Fesc.

1. Permanent lines (quadrat points, presence of species under consecutive segments) (Long 1957, 1958; Gordon 1966).

2. Permanent square plots (density, cover, vigor) (Braun-Blanquet 1952).

3. Permanent transects.

4. Photography and cartography of plots.

These techniques show the progressive occupation of the stand by plants which pre-existed fire or which settle afterwards.

For all these, only the simple and inexpensive tools normally used for these types of studies are required, such as posts, frames, and measuring tapes (Long 1957, 1958).

The collected data and the resulting conclusions permit the characterization of the changes in vegetation with respect to the date and the intensity of fire. Generally, the vegetation can be characterized three ways: 1) a deeper degradation of that which was the vegetal cover before fire; 2) a recycling to the previous vegetation, after some lapse of time, and a few intermediate stages; and 3) a progressive succession towards a high garrigue, different from the former garrigue (this is improbable).

To bring about such a study, a series of simple devices must be placed at different stations, and records kept of the fires, the vegetation types and the substrate (Fig. 4).

Autoecological aspects of the problem have also been touched on in a few highly representative cases:

1. Flammability of the litter and of the constitutive particles of some garrigue species.

2. Vulnerability and fire resistant forms of plants (aerial and subterranean organs).

3. Fire effect upon the germinative capabilities of some species.

DESCRIPTION OF A COMPLEX EXPERIMENTAL DESIGN

Experimental principles

A complex experiment has been established in a *Quercus coccifera* L. (kermes scrub-oak) garrigue at Pueh-du-Mas-Du-Juge (St. Gely-du-Fesc township), about 10 km north of Montpellier (Fig. 3),

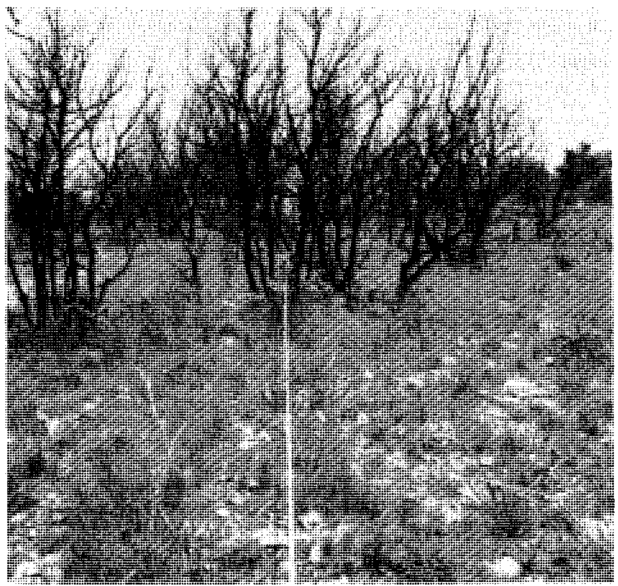


FIG. 4. Permanent plot set up to study the effect of wildfire on the vegetation (Languedoc network). Photo by L. Trabaud.

where numerous research means to study the dynamics of the Mediterranean vegetation are concentrated. The choice of the stand was motivated by the large area that this vegetation, so representative of the Mediterranean brushlands, occupies (more than 100,000 ha), and by the locality, that of previous, numerous studies (Long 1961, Trabaud 1962, Poissonet 1966, Fay *et al* 1967).

The initial stage was a garrigue of "pyrophytic" origin, about 18 years old (last known burn date: 1951). The shrubby layer, 0.5 to 1 m high, is formed almost exclusively by *Quercus coccifera;* the grass layer is dominated by *Brachypodium ramosum.* The four main species, by decreasing frequency are: *Quercus coccifera, Brachypodium ramosum, Dorycnium suffruticosum, Rubia peregrina* (Possonet 1966).

The experiment was designed to show rigorously the impact of fire upon a vegetation type. The design permits several quantitative and qualitative measurements after the predetermined burnings: vegetation changes (installation and re-installation of the species), and vegetation and soil temperatures during and after the fires.

THE DESIGN AND THE BURNING PROTOCOL

Description of the experimental design

Before giving a detailed account of the design, it is necessary to emphasize that the controlled fire experiment is one of several experiments undertaken at the same experimental area, all part of a larger project to study changes in vegetation submitted to different treatments.

During the initial period, before beginning the treatments, a vegetation inventory of each basic 50 square meter plot (10 × 5 m) was made. To do this, permanent vegetation study lines were set up. In each plot a 10 m long line is set through the longest length of the plot. Every 10 cm, observations are made along this line (i.e. 100 points for each plot). Every 10 cm we slip a sort of "needle" painted with two colors (red and white) in stripes; each color stripe corresponds to a different layer, i.e., 0–5 cm, 5–25 cm, 25–50 cm, 50–100 cm, and over. We count the number of plant contacts along these needles for every layer (Fig. 5). In addition, the occurrence of every species observed inside the plane determined by the needles and the 10 cm segment between the two needles is noted. So, we have spatially precise knowledge of the whole vegetation (biovolume and plant cover).

A light cat-walk was built to carry out observations without disturbing or modifying the in-place vegetation (Fig. 6).

The data are recorded directly in the field by means of prepunched computer cards (Fig. 7); therefore every observation is immediately punched by hand. For each vegetation layer (as previously defined) there is a card containing the information about the contacts and the occurrence of every species encountered in the layer. In addition, on the first card (corresponding to the 0–5 cm layer), are recorded the surface soil characteristics (rocks, litter, bare soil); on the last card (corresponding to the highest observed

FIG. 5. Survey of the vegetation. Point quadrat by needles along the 10 m line. Photo by G. Long.

layer. This can be extremely variable.) are recorded the vegetation height (in decimeters) and the highest species. Usually there is more than one card for each observation point.

In addition, every basic plot was the object of a detailed mapping (Fig. 8, example of plot mapping) to the one hundredth scale.

Afterwards, in spring every year, such measurements are repeated.

Parallel to our experiments, a biomass measurement was done on similar vegetation, in the same area by another team from the CEPE. The first results obtained (not published) allow a good representation of the vegetation.

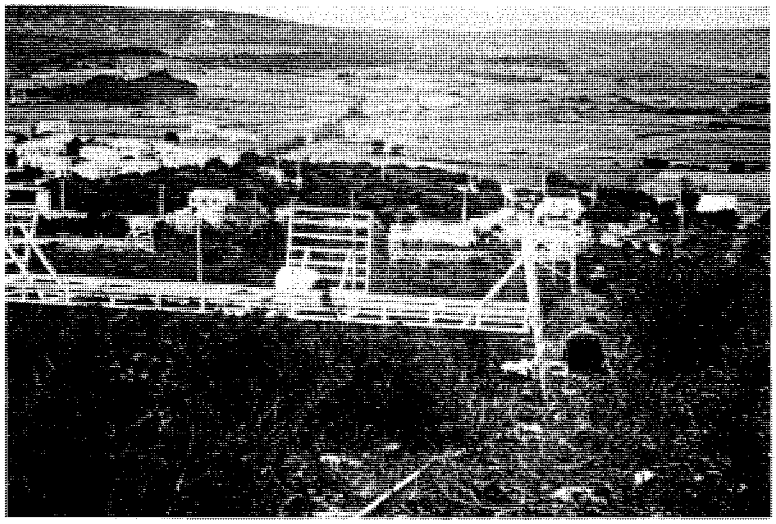


FIG. 6. Apparatus built to carry out observations without disturbing the in-place vegetation. Photo by G. Long.

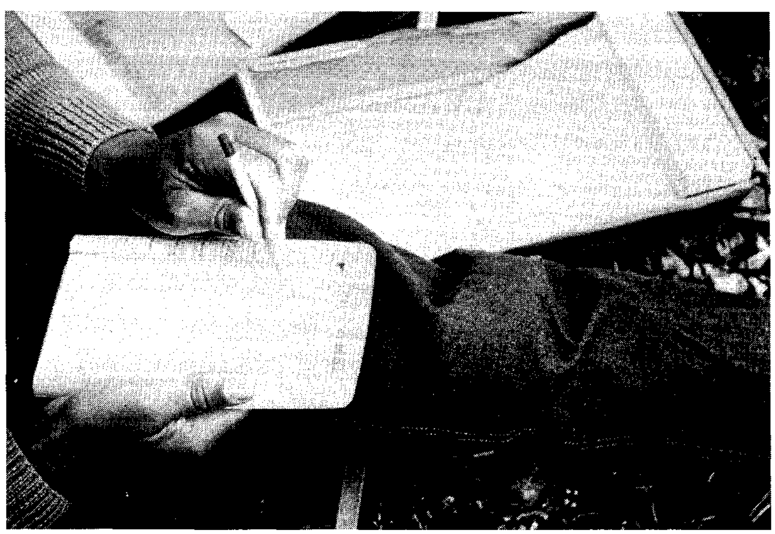


FIG. 7. Recording of the data. The data are directly recorded in the field on prepunched "perfostyl" cards. Photo by G. Long.

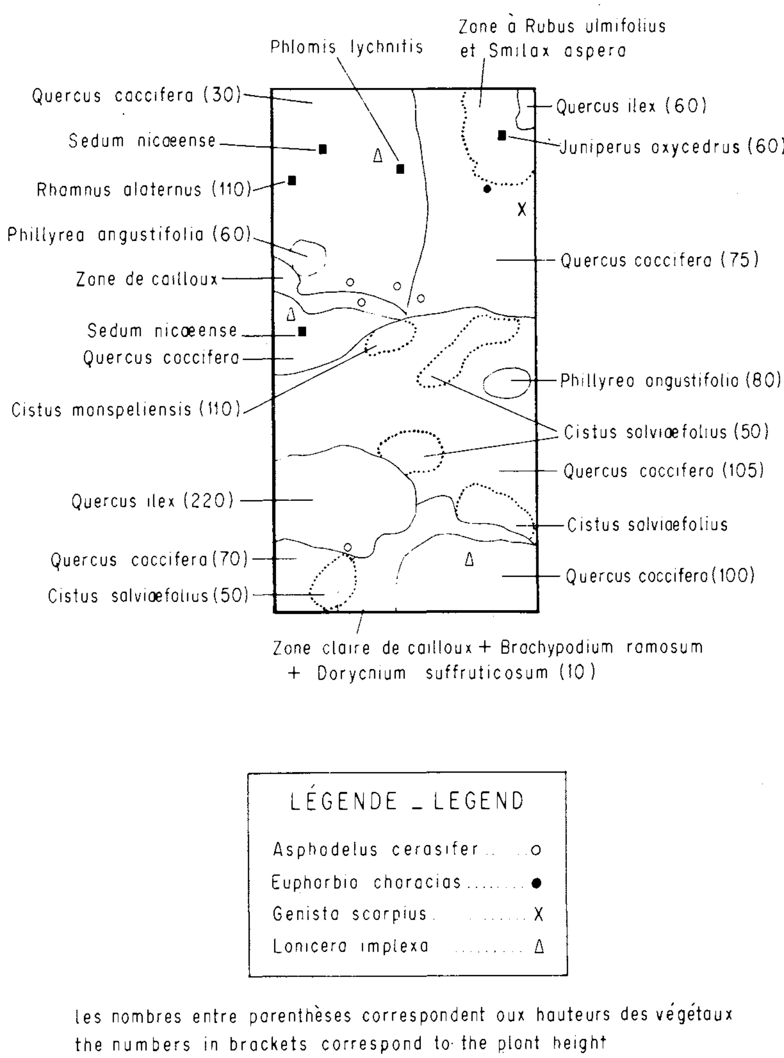


FIG. 8. Sample of vegetation mapping of elementary plots (5 × 10m). Surveyed on May 1969.

Sixty-three basic plots, each 50 sq m, have been observed as previously described and at the same periods. Afterwards, four sample strips (10 m $\times$ 1 m) were cut by means of an agricultural machine. In every basic plot the whole plant material was gathered and weighed (Fig. 9). This gives a gross plant material weight of 26 tons per ha of green material (Thiault 1972, pers. comm.). Then, on a central strip, 1 m wide and 10 m long (the central strip where the quadrat point measurements were read), the vegetation was cut by hand, square m by square m, picked out species by species, and weighed (Fig. 10). This gives a weight of 33 tons per ha of green material. Then, samples were taken off, oven dried and weighed to determine the dry weight of the plot vegetation. This gives a mean dry matter weight of 15 tons per ha (mechanized harvest) and 18 tons per ha (manual harvest) (Thiault 1972, pers. comm.).

Owing to the great amount of data collected (63 basic plots have been cut), the number of contacts of each species can be correlated with the above ground plant biomass. When this correlation is established (the computations are now in progress), we will be able to apply it to the measurements done on our plots, thereby showing the changes in above ground biomass, both total and for each species, for each different fire treatment.

Burning treatment

The fires are set at different times of the year to determine if the seasonal conditions that affect the plant phenology act together, and in what way, with the fire force, and if these conditions modify the future behavior of the different species, and the equilibrium of the vegetation.

To determine the burning dates, we have taken as criterion, some mean phenological stages of the population of *Quercus coccifera* this being the principal species.

First case: The first fire is set at the beginning of the *Quercus coccifera* flowering, when vegetative growth has really started, since the buds have already developed the first annual shoots and emitted the young leaves. The kermes scrub-oak is then in a turgid state, at

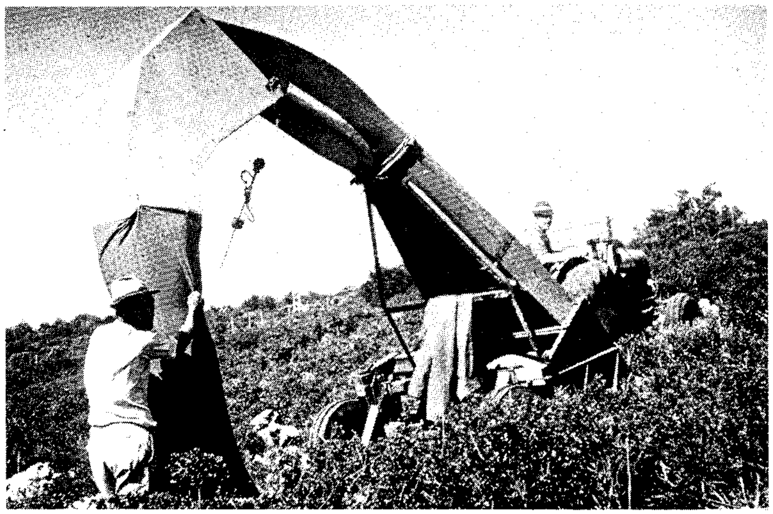


FIG. 9. Biomass measurement. In each elementary plot whole plant material was gathered and weighed from four ten sq m (10 × 1 m) sample strips. Photo by G. Long.

the maximum photosynthetic stage (ascending sap full vegetative activity, and without reserves), usually at the end of May or the beginning of June.

Second case: For the second burning period we have chosen a time at the beginning of fall, when the vegetation appears to be at rest (reserves accumulated in the rhizomes, reduced photosynthesis and ripening of twigs), always at the beginning of September.

The chosen burning periodicity is 2 years on one group of plots, 3 years on another group, and for the third group, one fire at the beginning of the experiment; these to determine if the fire frequency has an effect, and if so, what, upon the vegetation. Therefore the experimental design allows three treatments at two burning times, i.e.:

No burning

T. Control plots

"Seasonal burning" treatments

FIG. 10. Biomass measurement. On the central strip of each plot where observations were made, the vegetation was cut by hand, square meter by square meter, pulled out species by species and weighed.

P. End of spring or beginning of summer

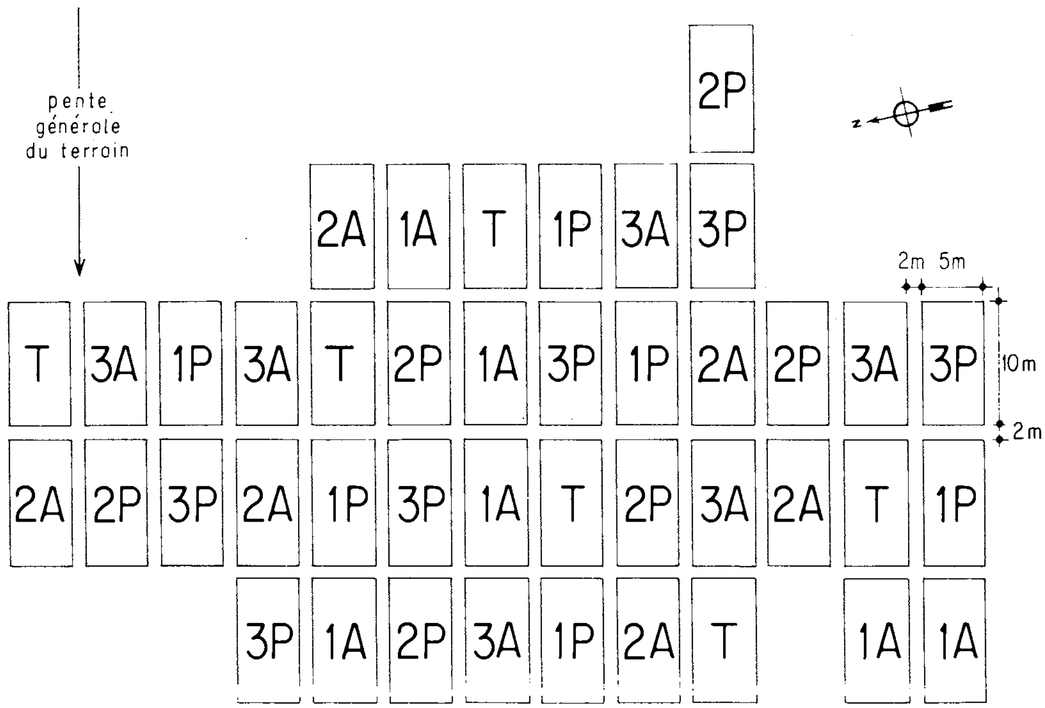
A. Fall burning

Fire frequency

1. Plots burned only one time in 6 years, the first year of the experiment.
2. Plots burned every 3 years (two fires in 6 years).
3. Plots burned every 2 years (three fires in 6 years).

The following symbols are used for these: T, 1P, 2P, 3P, 1A, 2A, 3A (Fig. 11).

Six replicates have been established for every treatment, i.e. 42 basic plots in all. The permanent observations and measurements



LÉGENDE

Traitements

T – témoins non brûlés
P – feux de fin printemps
A – feux de début automne

1 – placettes brûlées une seule fois, la première année, sur un cycle de 6 ans
2 – placettes brûlées deux fois en 6 ans
3 – placettes brûlées trois fois en 6 ans

LEGEND

Treatments

T – control plots (not burnt)
P – late spring burnings
A – early fall burnings

1 – plots burnt only one time the first year for six years
2 – plots with two burnings for six years (burnt every three years)
3 – plots with three burnings for six years (burnt every two years)

FIG. 11. Experimental design for the study of qualitative and quantitative reactions of the Garrigue of *Quercus coccifera* in which are applied controlled fires (Peuch du Mas du Juge, Herault, France).

are made only on the central strip of each 40 sq m plot. Every plot is separated by 2 meter-wide lanes.

Kinds of Observations and Measurements

Before and after fire:

—observations on the floristic composition,

—readings of permanent lines, to determine the frequency, abundance, cover of the species and the vegetation structure (a reading every 10 centimeters and consecutive 10 centimeter segments),

—a large scale mapping from aerial photographs

—soil samples (for laboratory analysis)

—a study of the thermal soil pattern

From these we can monitor the changes in the vegetation and in the soil.

During the fires our observations are about:

—the meteorological conditions at the time of burning

—the rate of spread of the fire

In addition, we measure the temperatures by means of thermocouples placed at different heights in the vegetation and in the soil. These thermocouples are connected to recorders calibrated for pyrometric measurements. Also, we use thermic indicators (Tempilaq, Fenner and Bentley 1960) to find out the temperature pattern throughout the burned plot (Fig. 12). These observations facilitate the understanding of fire mechanism and behavior.

The experimental results, compared with those studied in the field for wildfires, should permit the description of colonization stages by the plant species and the construction of the laws that govern the vegetation dynamics, in short, the understanding of the gradual development of the garrigue after fire.

EXAMINATION OF THE EARLY RESULTS

Detailed Analysis of the Evolution of the Species Occurrences and of the changes in the Floristic Composition (Table 1).

At the present state of our program, it is not possible to use all

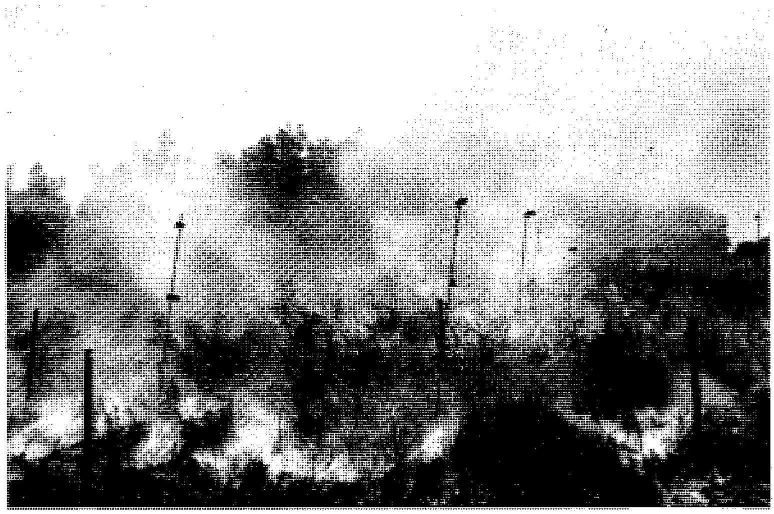


FIG. 12. A plot burning. The fire is producing flames and smoke. The thermic indicators are hung on stakes at different levels. Another kind of stake, in the foreground on the right and the left are to measure the rate of speed of the fire. Photo by L. Trabaud.

the data we intend to gather. To date there have been two fires set on the plots to be burned three times, and one fire on all the remaining plots, which we group together for the purposes of this paper.

We have put together, in a comprehensive table (Table 1), the species occurrences according to the five treatments. Only the species found at least in two different treatments have been kept. In this synoptic table the observation dates have been put together by treatments. Opposite the name of each species is written a number in the column corresponding to a coefficient (percentage). We call this the *evolution index*, representing the active occurrence of the species at the time of observation compared to the species occurrence at the beginning of the experiment, before any treatment. Indeed, in order to compare the different treatments and the floristic evolution (the degree of recovery of the species after fire) at different observation dates, we could either compare the species occurrences at the time of observation to the total in the treatment plots, or we could compare the species occurrence at the time of observation with their initial occurrence. We prefer this second method because it gives more truly the species evolution. For example, *Brachypodium ramosum*, in the plots burned once in spring (Table 1, "one fire in June"), had, in May 1970, 12 occurrences, it also had 12 occurrences in May 1969, therefore the ratio is: 12/12 = 1 (obviously, for the first observation year all the indices of the species present equals 1). On the other hand, *Cistus monpeliensis*, had 4 occurrences in May 1970, and 9 occurrences in May 1969, the ratio is thus 4/9 = 0.44, but in April 1971, the ratio became 7/9 = 0.78 (7 occurrences). This coefficient demonstrates the species evolution with respect to the beginning state. Thus, at one glance, the species that have kept the same occurrence, those that have either increased or decreased their occurrence, and those that have appeared or disappeared are immediately apparent. Species appearing in a treatment after the first observations (May 1969) are circled. In Table 1, the species are ranked according to the evolution criterion: species indifferent to the action of fire, species favored by fire, species sensitive to the action of fire, and species usually foreign to the *Quercus coccifera* garrigue which appear because of fire.

Some general conclusions are easily drawn from reading the table. The usual species of the kermes scrub-oak garrigue sprout from the rhizomes. The annual species appear very soon in rather large numbers after burning, but they do not remain (*Sonchus oleraceus*, *S. tenerrimus*, *Rapistum rugosum*, *Erigeron canadense*, etc.). Certain species which are not normally found in the garrigue (Braun-Blanquet *et al.* 1951) have the tendency to diminish if they do not disappear totally after the fire (ex. *Aphylanthe monpeliensis* and particularly *Fumana cordifolia*).

Careful observation of the comprehensive table allows the grouping of species according to their behavior with respect to fire.

In our experiment some species are not affected by fire, and hence always have the same evolution index. Others have the tendency to increase their presence under the effect of fire, others, on the contrary, have the tendency to disappear.

TABLE 1. EXPERIMENTAL AREA, PUEH DU MAS DU JUGE (HÉRAULT, FRANCE). EVOLUTION OF THE SPECIES OCCURRENCES, COMPREHENSIVE TABLE. Thin line: no fires set, thick line: separation between treatments, double line: fire set.

Treatments	Control Plots				Plots burned once in June				Plots burned once in September				Plots burned twice in June				Plots burned twice in September			
Species / years of observation	69	70	71	72	69	70	71	72	69	70	71	72	69	70	71	72	69	70	71	72
Group 1																				
Brachypodium ramosum	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Carex halleriana	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dorycnium suffruticosum	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Festuca spadicea	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Osyris alba	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1	1
Phillyrea media					1	1	1	1	1	1	1	1								
Quercus auzandi					1	1	1	1	1	1	1	1								
Quercus coccifera	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1
Quercus lanuginosa					1	1	1	1					1	1	1	1				
Rhamnus infectoria	1	1	1	1					1	1	1	1	1	1	1	1				
Rubia peregrina	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Rubus tomentosus	1	1	1	1	1	1	1	1	1	1	1	1								
Group 2																				
Avena bromoides	1	1	1	1	1	1	1	1	1	66	1	1	1	1	1	1	1	1	1	83
Carex humilis	1	1	1	1	1	1	1	1	1	1	1	1	1	80	1	1	1	1	1	1
Daphne gnidium	1	1	1	1	1	1	1	1	1	1	1	1	1	1	50	50	1	1	1	1
Hieracium pilosella	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	66	1	1	1	1
Phillyrea angustifolia	1	1	1	1	1	1	80	1	1	1	1	1	1	1	1	1	1	1	1	1
Quercus ilex	1	1	1	1	1	1	1	1	1	80	1	1					1	00	1	1
Rosa sempervirens	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	50	1	1
Rubus ulmifolius	1	1	1	1	1	1	1	1	1	1	1	1								
Group 3																				
Stachys officinalis	1	1	1	1	1	1	1	1	1	80	80	80	1	1	1	1	1	1	1	1
Teucrium chamaedrys	1	1	1	1	1	1	1	1	1	83	91	91	1	1	1	1	1	1	1	1
Group 4																				
Lonicera etrusca									1	1	1	1					1	1	1	00
Pistacia lentiscus	1	1	1	1	1	00	1	1	1	50	1	1	1	1	1	1	1	00	1	00

Table 1 continued

Group 5																				
Asparagus acutifolius	1	1	1	1	1	70	90	120	1	1	1	1	1	1	1	1	1	83	83	1
Asphodelus cerasifer	1	1	83	66	1	90	1	1	1	1	1	1	1	80	1	120	1	1	1	1
Group 6																				
Arrhenatherum elatius	1	1	1	1	1	1	110	110	1	1	1	120	1	1	1	1	1	120	120	120
Brachypodium phoenicoides	1	1	1	1	1	1	1	1	1	77	1	111	1	1	1	165	1	1	1	1
Bupleurum rigidum	1	1	1	1	1	125	150	150	1	142	142	1	1	1	80	1	1	125	125	125
Centaurea pectinata	1	1	75	75	1	1	115	115	1	109	109	109	1	1	1	1	1	1	1	1
Euphorbia characias	1	1	120	120	1	109	109	109	1	109	109	109	1	1	1	1	1	1	1	1
Galium corrudaefolium	1	1	1	1	1	500	500	500	1	128	128	128	1	1	150	1	1	200	150	250
Hieracium murorum	1	1	1	1	1	125	125	1	1	85	1	1	1	125	125	125	1	122	122	66
Lonicera implexa	1	1	1	1	1	1	1	1	1	1	110	110	1	1	1	1	1	1	1	125
Sanguisorba minor	1	150	150	1	1	116	133	133	1	166	166	150	1	1	133	133	1	1	1	150
Sedum nicaeense	1	1	1	1	1	1	200	200	1	50	1	300					1	50	50	50
Ononis minutissima	1	1	1	1	1	200	200	400												
Group 7																				
Aphyllanthes monspeliensis	1	1	1	1	1	64	36	36	1	1	62	62	1	75	75	75	1	80	80	80
Asperula cynanchica					1	1	1	1									1	1	00	00
Bromus erectus	1	1	1	1	1	1	1	129	1	90	81	81	1	1	1	60	1	80	80	80
Clematis flammula	1	1	1	1	1	00	1	1	1	66	66	66	1	1	1	50				
Fumana coridifolia	1	1	33	33	1	66	66	66	1	00	00	33	1	1	00	00	1	00	00	00
Genista scorpius	1	1	1	1	1	64	90	1	1	30	70	1	1	1	1	66	1	33	50	33
Juniperus oxycedrus	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	50	1	66	66	66
Rhamnus alaternus	1	1	1	1	1	75	75	75	1	00	00	00	1	33	33	66	1	00	1	1
Smilax aspera	1	1	1	1	1	76	88	88	1	87	87	87	1	1	1	1	1	33	66	66
Thymus vulgaris	1	1	1	66	1	00	00	50	1	00	00	33					1	00	1	1
Viola scotophylla	1	1	1	1	1	1	1	1	1	75	75	75	1	1	75	75	1	1	1	1
Group 8																				
Cephalaria leucantha	1	1	1	80	1	1	1	133	1	90	90	81	1	1	1	75	1	1	1	1
Cistus monspeliensis	1	1	1	1	1	44	78	90	1	66	111	111	1	66	1	33	1	50	50	50
Cistus salviaefolius	1	1	1	1	1	125	125	125	1	71	85	85	1	75	75	50	1	66	1	1
Group 9																				
Biscutella laevigata			①	①		①	①	①	1	1	1	1								
Convolvulus cantabricus												①					1	1	1	200
Echium pustulatum						①			1	250	200	00		①		①		③	②	②
Euphorbia nicaeensis							②	②	1	00	200	400			②	①	1	00	1	00

Euphorbia serrata				①		①	①	①					1	50	1	50		①	①	②
Filipendula hexapetala									1	1	1	00						①		
Hippocrepis comosa	1	1	1	1			①	④				①				①		①	①	②
Lagoseris sancta	1	00	00	00						⑥	④							②		②
Scabiosa maritima					1	1	50	50								②				
Silene italica			①						1	1	200	200						①	①	①
Sonchus oleraceus						⑤	②		1	700	500	00		③	①	④	1	200	00	300
Sonchus tenerrimus					1	300	00	00	1	400	00	00		①		②		④		①
Vincetoxicum nigrum						①	①	①	1	1	1	1								
Group 10																				
Bromus madritensis										①										①
Cirsium acarna						①	①			②	②	①		①		①			①	①
Crepis pulchra												①								①
Crepis taraxacifolia						②					①				①	②		①		①
Erigeron canadense						②	②			④	③			②	①	②		①		
Geranium purpureum												①		①		①				
Lactuca scariola											①									①
Lavatera cretica						①				②	②							①		②
Picris hieracoides											②	①								③
Rapistrum rugosum			①			③				⑧	③			②		①		④	①	④
Scleropoa rigida										②								①		
Senecio gallicus																①		①		①
Senecio vulgaris							②			②	③				①	③		①		
Sonchus asper						①										③		①		①
Tragopagon australis												①				③				①
Group 11																				
Aristolochia pistolochia	1	1	1	1	1	1	50	50	1	1	50	50					1	1	1	1
Festuca ovina					1	1	1	1	1	1	1	1	1	1	00	00	1	1	1	150
Allium sphaerocephalum										1	1	00	00				1	1	00	00
Limodorum abortivum	1	1	1	1					1	1	00	00								

Légende=trait fin : pas de mises à feu ; trait double : mise à feu ; trait épais : séparation entre traitements.

According to the different tendencies we might constitute 11 groups of species, of very diverse importance.

Groups of Species Apparently Indifferent to the Action of Fire

Group 1. *Brachypodium ramosum*, *Carex halleriana*, *Dorycnium suffruticosum*, *Festuca spadicea*, *Osyris alba*, *Phyllyrea latifolia* ssp *media*, *Quercus auzandi*, *Quercus coccifera*, *Quercus lanuginosa*, *Rhamnus saxatilis* ssp *infectoria*, *Rubia peregrina*, *Rubus tomentosus*. All these species are perennial and belong to the kermes scrub-oak garrigue. Though fire does not seem to have any effect on the evolution index of these species, it is not implied that, out of the well delimited plots, its action does not favor their extension. It suffices to see the areas covered by the present garrigues.

Group 2. *Avena bromoides*, *Carex humilis*, *Daphne gnidium*, *Hieracium pilosella*, *Phillyrea angustifolia*, *Quercus ilex*, *Rosa sempervirens*, *Rubus ulmifolius*. These species have exactly the same behavior as the previous group of species, but fire diminishes their evolution index slightly at one observation in one of the treatments.

Group 3. *Stachys officinalis*, *Teucrium chamaedrys*. This group is only a variant of the second group, in which, perhaps, we should put it. Only the "one September fire" treatment diminished their evolution index.

Group 4. *Lonicera etrusca*, *Pistacia lentiscus*. These two species are related to the second group. The only difference is that they disappear completely, probably temporarily, after the September 1971 burning, i.e. the second fall burning.

Groups of Species in Which the Evolution Index Has a Tendency to Increase After Fire

Group 5. *Asparagus acutifolius*, *Asphodelus cerasifer*. This is a transitional group. These two species have a tendency to increase their evolution index under the action of fire.

Group 6. *Arrhenatherum elatius*, *Brachypodium pinnatum ssp. phoenicoides*, *Bupleurum rigidum*, *Centaurea pectinata*, *Euphorbia charcias*, *Galium mollugo* spp *corrudaefolium*, *Hieracium murorum*, *Lonicera implexa*, *Sanguisorba minor*, *Sedum nicaeense*, *Ononis minutissima*. All these perennial species are favored by fire action. Their evolution indices increase, and some very notably (i.e. *Galium corrudaefolium*).

Groups of Species in which the Evolution Index has a Tendency to Decrease After Fire

Group 7. *Aphyllanthes monspeliensis*, *Asperula cynanchica*, *Bromus erectus*, *Clematis flammula*, *Fumana coridifolia*, *Genista scorpius*, *Juniperus oxycedrus*, *Rhammus alaternus*, *Smilax aspera*, *Thymus vulgaris*, *Viola alba* var. *scotophylla*. All these perennial species, usually present in the kermes scrub-oak garrigue are affected by fire. Their evolution indices diminish after fire has passed. These species regenerate slowly. The second observation year after fire (1971), the evolution index drew near its first level, without reaching it, however. Upon the second burning, the evolution index diminishes again, the most sensitive species being *Fumana coridifolia*. This could be due either to the interspecific competition or to the repeated action of fire. During observations done on fields conducive to *Fumana coridifolia*, where competition for colonization is less strong, it resows very easily after wildfires (*Rosmarinus officinalis* garrigues, *Pinus halepensis* pinewoods).

Group 8. *Cephalaria lencantha*, *Cistus monspeliensis*, *Cistus salviaefolius*. These three species constitute a particular group. They all resow by seeds, only *Cephalaria lencantha* can have root-sprouts. They seem favored by one fire (comprehensive table, first columns), but a second burning lowers their evolution index: it is possible that if fire action ceased, they would develop again.

Groups of Infrequent Occurence or Plants Foreign to the Stand which Colonize with Help of Fire

Group 9. *Biscutella laevigata*, *Convolvulus cantabricus*, *Echium vulgare ssp pustulatum*, *Euphorbia nicaeensis*, *Euphorbia serrata*, *Filipendula hexapetala*, *Hippocrepis comosa*, *Lagoseris sancta*, *Scabiosa martima*, *Silene italixa*, *Sonchus oleraceus*, *Sonchus tenerriumus*, *Vincetoxicum nigrum*. All these species, usually foreign to the kermes scrub-oak garrigue, were, at least one time, present in the plots before the beginning of the burning. All are herbaceous species, not one is ligneous. Fire increases their evolution index.

Group 10. *Bromus madritensis*, *Cirsium acarna*, *Crepis pulchra*, *Crepis vesicaria* ssp *taraxacifolia*, *Erigeron canadense*, *Geranium robertianum* ssp *purpureum*, *Lactuca scariola*, *Lavatera cretica*, *Picris hieracoides*, *Rapistrum rugosum* ssp *memausense*, *Scleropoa rigida*, *Senecio gallicus*, *Senecio vulgaris*, *Sonchus asper*, *Tragopogon porrifolius* ssp *australis*. All are annual or biennial species foreign to the kermes scrub-oak garrigue. They appear with the help of fire, and they remain only owing to the fire action, without which, they disappear.

It is interesting to note, that generally, whereas the burning dates do not bring any notable floristic variations, some species from the two former groups appear only after fall burnings (either one or two burnings). They are: *Bromus madritensis*, *Convolvulus cantabricus*, *Crepis pulchre*, *Filipendula hexapetala*, *Lactuca scariola*, *Lagoseris sancta*, *Picris hieracoides*, *Scleropoa rigida*, *Silene italica*. Therefore, the fall burnings induce a great amount of specific alteration.

Species with Indistinct Behavior

Group 11. *Aristolochia pistolochia*, *Festuca ovina*, *Allium sphaerocephalum*, *Limodorum abortivum*. These species have a peculiar behavior; fire seems to have no *a posteriori* action upon them. It is true that three of them are geophytes: *Aristolochia*, *Allium*, *Limodorum*. It would be possible, therefore, that they do not appear every year, and that they have an advent cycle every 3 years.

Of course, the species mentioned here are not all those encountered. Species must have been observed during at least two treatments to have been included in the table.

If we consider the whole table, we note that fire creates a disturbance among all the species present, even if this disturbance appears small. There is an increase in the uncommon plants, therefore a floristic diversification. The action of fire, and particularly the fall burnings, has, consequently reduced the occurrence of some species, and therefore has favored the introduction of a number of new species usually infrequent in this type of stand.

Only three species remain present in 100 percent of the plots and treatments during the 4 years of observation: *Quercus coccifera, Brachypodium ramosum, Dorycnium suffruticosum.* We can say that fire has little effect on them, except maybe to favor them to the detriment of other species. They might thus be true pyrophytes.

Statistical Interpretation

Variance analysis and orthogonal comparisons (Dagnelie 1970) were used to judge the effects of the treatments. We could only analyze the total occurrence number of each species. The variations due to the treatments are significant to the 90 percent level in 1970, 1971, and 1972. For 1970, the comparison between spring burned plots and fall burned plots is significant to the 95 percent level, and the comparison between the fall burned plots and the control plots is significant only to the 80 percent level. For 1971, only the comparison between the spring burned plots and the fall burned plots is significant, but at the 99 percent level. For 1972, the control plot treatment and one spring burning are different, at the 99 percent level. For 1972, the control plot treatment and one spring burning are different, at the 99 percent level, from the other treatments: one fall burning, two spring burnings and two fall burnings.

Behavior of Some Characteristic Species

As we have seen above, the behavior of each species varies according to the different treatments. If we set the occurrence number of the species during the first observation (i.e. before the first burning) equal to one, for reference, it is easy, after, to calculate and to draw a curve for each different occurrence value of the species for every observation (evolution index, Table 1). Thus, it is easy to compare their respective behavior. But, since on the whole, 104 different species have been encountered during these observations, it would be tedious to describe and to show the behavior of each. We will therefore choose only certain definite cases that reflect sufficiently the behavior of the other species classified in the previously defined groups. In addition to the regular yearly observations, we have put on the graphs observations done some months after each burning.

1. Species in which the evolution index is not modified by fire. *Brachypodium ramosum* (L) Rand S (Group 1). *Brachypodium ramosum* withstands fire imperturbably; from the first weeks after a fire, it resprouts. No burning rhythm or period disturbs it. These are roughly the same characteristics for the species which are not or little affected by fire (Groups 1, 2, 3 and 4).

2. Species in which the evolution index has a tendency to increase. *Hieracium murorum* L. (Group 6). In the control plots the evolution index of this species remains constant; usually the species of this group all have the same behavior. One burning, at any application time (spring or fall), lowers the index of this species during the first period after the burning (September 1969, January 1970). This is to be expected because the observations are made just after the burnings (2 months after) and during the bad seasons of the year. In spring of the 2 years following the first burnings, the species index increases (there was an appearance of plantlets in plots which were not colonized by the species at the beginning of the experiment). Is this expansion due to fire? But, a new series of burnings (1971, anytime) inhibits and reduces this expansion (the index lowers) much as for the first stages after the first fires. The following year, in 1972, the spring burning has no effect, since the index became equal again to that of 1970 and 1971 which was higher than the initial index. The species which belong to the same group as *Hieracium murorum* have the same general behavior. Fire action favors and increases their evolution index. Continuation of the experiment will permit us to establish what the tendency of these species is (Groups 5 and 6).

3. Species in which the evolution index has a tendency to diminish. *Genista scorpius* (L) LmK. (Fig. 13 c and Group 7). From the first burning, the evolution index of the species diminishes, when in the control plots the index remains constant. An increase seems to appear during the spring observations of 1970 and 1971, but it does not reach the initial index. Another burning series (1971) lowers the index again. It should be noted that *Genista scorpius* is very sensitive to the time of burning: the fall burns lower the evolution index con-

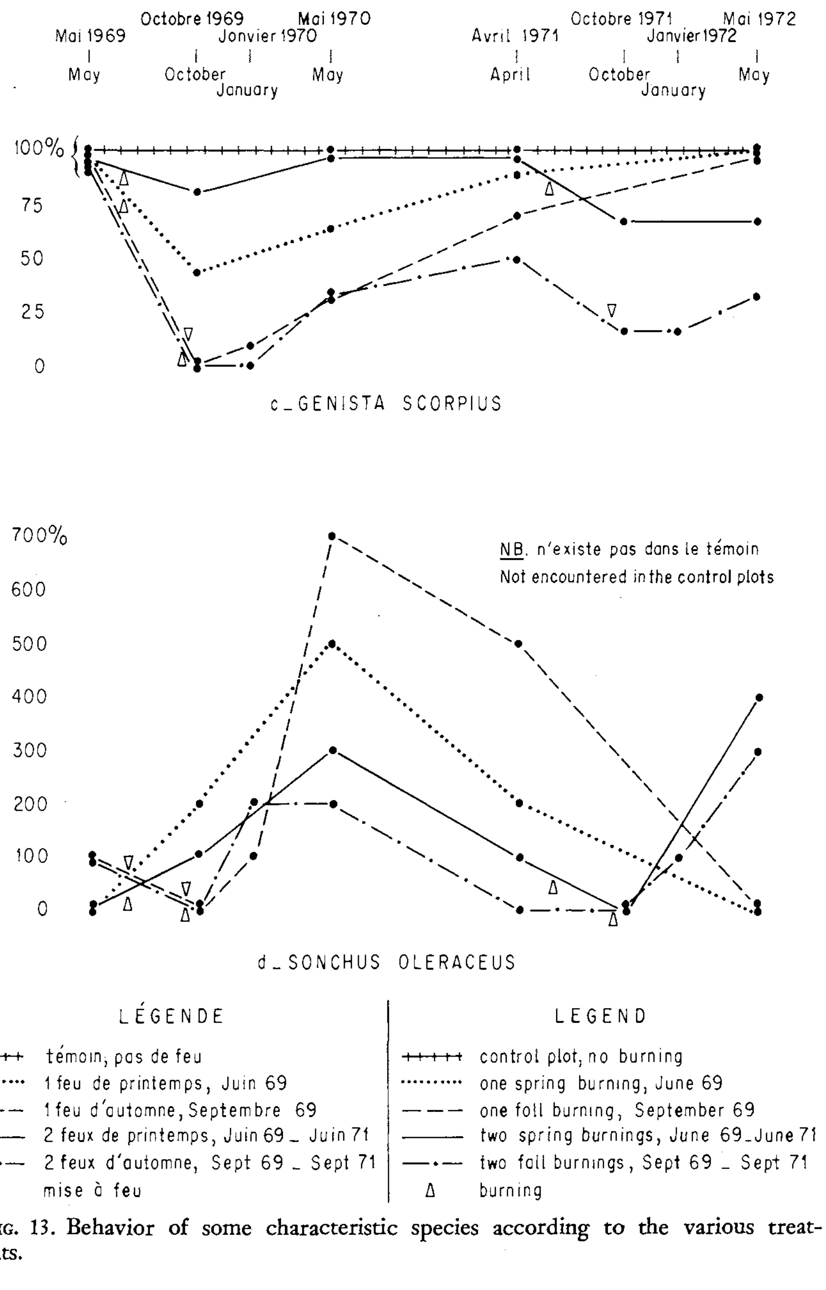


Fig. 13. Behavior of some characteristic species according to the various treatments.

siderably. The species of Groups 7 and 8 have nearly the same behavior, with, however, slight variations.

4. Annual species foreign to the stand, which have a variable behavior. *Sonchus oleraceus* L. (Fig. 13 d and Group 9). The annual species show aberrant behavior (due to their sudden appearance and disappearance). *Sonchus oleraceus*, however, does not represent all the annual species' behavior, but shows the tendency of the irregular behavior of these species, behavior closely related to the fire action. This fire action favors, first, the appearance (or the increase of the index) of the species (for example, some months after the first fall burning, the *Sonchus oleraceus* evolution index is very high, 700). When the action of fire ceases or lessens, the evolution index of all these species diminishes and even drops to zero. So, *Sonchus oleraceus* remains the first year, but, after it disappears totally (May 1970; the second burning again increases the index (Fig. 13 d). This type of behavior is common to the species of Group 9 and 10. Are these species really dependent on fire? We do not think this; they are not true pyrophytes, and besides, they can be found elsewhere when the soils are bare. The appearance of these species depends on the fact that they can scatter a great number of diaspores, usually anemophilous, and on the vegetation-bare spaces. When the particular action ceases, and the natural perennial vegetation reinstalls itself, these species disappear; fire can be one of those actions.

DISCUSSION AND CONCLUSIONS

Hence, we have undertaken a study on the action of fire upon the French Mediterranean vegetation, and more particularly upon the kermes scrub-oak garrigue; a garrigue which has been engendered by the action of fire upon the vegetation. Now, this garrigue is stable, and seems to support the periodical fires at different frequencies. The goal of our experiment, of which only the first results are herein discussed, is to establish what is the succession of this garrigue when submitted to fires set at different time intervals, and at different seasons of the year. From the first results, already we can say that these garrigues, if they are not submitted to repeated burnings, recover both their physiognomical and floristic aspect quickly. Observations made on wildfire-burned areas permit us to say that, about 2 years after a fire, the tendency is to return towards the previous garrigue, and 5 years after the fire, the differences between a burned garrigue and an unburned garrigue are very difficult to distinguish. Only the charred stems emerging from the plant mass testify to the passage of fire. This tendency appears also during our experiment, but with some slight modifications. Thus, the fall burnings seem to have a certain influence upon the species appearance; indeed, this species appearance is later after the fall burnings than after the other burns (the plots with fall burns have a tendency to return towards the previous stage 1 year later than the other plots), besides, there is a greater number of annual species. Thus, fall burns have a tendency to favor the herbaceous species to the detriment of the woody species.

Some species, such as *Brachypodium ramosum*, are totally indifferent to the general fire treatment, on the other hand, other species which are not in their optimum environment, such as *Aphylanthes monspeliensis* (cf. Braun-Blanquet *et al* 1951) have a tendency to disappear under the impact created by the passage of fire. Others also are very sensitive to fire and recover their former place very slowly (*Gerista scorfius*). Finally fire brings with it always, after it occurs, a number of annual species (*Sonchus* spp., *Erigeron*, *Cirsium*, etc.), species that will disappear quickly, probably due to competition, since the influence of fire will lessen (Trabaud 1970).

These first results show us the impact of fire upon the vegetation of the kermes scrub-oak (*Quercus coccifera*) garrigue, but surely it will be yet more interesting to find out the evolution of their biomass, after the definitive protocol will have been established. It is that which we are trying to do now. But, henceforth, we can say that the fall burns favor the herbaceous species to the detriment of the woody species, and the more burnings there are, the more this tendency is increased (Fig. 14, 15, 16).

In conclusion, many basic fire ecology studies are now in progress at Montpellier to find out the behavior of the Mediterranean vegetation after fire; but it is quite obvious that fire has many additional

FIG. 14. Elementary plot with only one spring burning. Three years after the fire the main species is *Quercus coccifera*. Photo by G. Long.

FIG. 15. Elementary plot with two spring burnings. One year after the second burning. The main species are *Dorycnium suffruticosum* and *Quercus coccifera*, and in the background *Brachypodium ramosum*. Photo by G. Long.

FIG. 16. Elementary plot with two fall burnings. Eight months after the second fire. The main species are *Brachypodium ramosum* and, in *flower, Asphodelus cerasifer.* Photo by G. Long.

potential uses in the multiple use management of garrigues. Its utility will depend in large measure on learning its impacts on ecosystems, and learning how to use it to obtain desirable results while minimizing undesirable impacts.

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