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Light Quality as the Environmental Trigger for the Germination of the Fire-promoted Species *Sarcopoterium spinosum* L.

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Summary

High germination percentage after fires is usually thought to result from heat scarification or dispersal of seeds. Foliage removal by fire causes changes in light quality and soil temperature fluctuations. Here we show that a change in light quality enhances germination of the fire-promoted species *Sarcopoterium spinosum* L.: A change in the red to far-red ratio from 0.3 to 1.1 increases the germination percentage ten-fold. The seeds do not have a red light requirement but are inhibited by far-red radiation. Germination of *S. spinosum* was not enhanced by heat nor by an increase in temperature fluctuations.

Introduction

Since competitors are destroyed and nutrient availability is increased, conditions for successful seedling establishment are particularly favourable after a fire. In ecosystems where fire is a main ecological factor, fire stimulates germination in many species (Naveh 1975; Arianoutsou & Margaris 1981). The seed bank can perceive fire occurrence by different means. Best documented is that heat generated by fire allows seed dispersal or meets the scarification requirement of seeds of some species (see review in Naveh 1975 and Rundel 1981). Muller et al. (1968) and Christensen & Muller (1975) suggested that heat also destroys germination inhibitors present in the soil. Margaris (1981) proposed that changes in light spectrum due to foliage removal may promote germination of post-fire species. Germination control by light quality (red to far-red ratio) through phytochrome conversion is well established (Kendrick 1976; Frankland 1981; Smith 1982) and germination inhibition by leaf canopies has been shown for many species (Gorski et al. 1978). However this phenomenon has not yet been shown to belong to the suite of physiological characteristics of fire-promoted species. Foliage removal also increases soil temperature fluctuations and these fluctuations can enhance germination in some species (Thompson et al. 1977). It is not known if this may be the case in post-fire species.

The effects of heat, light quality and temperature fluctuations on the germination of *Sarcopoterium spinosum* L. were investigated. This dwarf rosaceous shrub is an important constituent of the vegetation in Eastern Mediterranean countries (Litav & Orshan 1971). After a fire it resprouts and reseeds (Papanastasis 1977; Arianoutsou-Faraggitaki & Margaris 1981). Its germination is usually ten times higher on burned sites compared to unburned ones (Arianoutsou & Margaris 1981). Each fruit contains several seeds but usually only one seedling per fruit successfully germinates. For convenience, the fruits are referred to as seeds hereafter.

Material and Method

Seeds were harvested in August 1981 and September 1982 in phrygana (plant communities found in Greece under arid Mediterranean climate) on Mount Hymettus, Greece. Since new seeds are dormant (LITAV & ORSHAN 1971), they were stored at room temperature in paper bags until the end of the following winters. *S. spinosum* seed do not require vernalisation (LITAV & ORSHAN 1971). Seeds were germinated in 9 cm Petri dishes which contained a single layer of Macherey-Nagel 640 W filter paper placed on top of a single layer of 6 mm glass beads. 20 cm^3 of distilled water was added to each dish at the beginning of the experiment and two weeks later. Heat treatments (30, 80, 120 °C) were applied on dry seeds in open Petri dishes for 10 min (TRABAUD 1979) showed that the duration of the heat wave due to Mediterranean shrublands fire is no longer than 10 min).

In the germination chamber, white light was provided by two 25 W fluorescent lamps (Circolux, Osram) and the required amount of far-red was added by changing the voltage of the power supply of a 40 W red coloured incandescent lamp (Claude) surrounded by a blue filter (Altuglas S300, Altulor). Photon fluence rate was maintained constant (32 μmol m-2 s-1 between 400 and 700 nm) using neutral filters. Quantum flux ratio (red : far-red, R : FR) was measured using an optical device described in MÉTHY (1977) and equipped here with two 10 nm bandwidth, 50 % transmission, interference filters centered on 663 and 730 nm respectively (B40 Balzer). The R : FR given by this device was checked against a spectroradiometer calibrator (ISCO). The day and night length and temperatures were 10 and 14 h and unless otherwise stated 15 and 9 °C respectively.

Germination was defined as occurring when the emergent radicle was visible and was assessed at the end of the experiment, one month after sowing. Each Petri dish contained 50 seeds. Results are the mean of 5 dishes for the first figure and 13 for the second figure and the table.

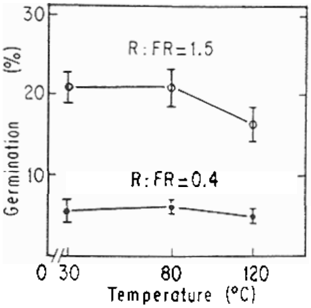
Results and Discussion

Results presented in Fig. 1 show that the heat treatments did not enhance the germination of *S. spinosum* regardless of light quality. PAPANASTASIS & ROMANAS (1977) found a slight increase in the germination percentage of *S. spinosum* seeds when heated at 100 °C for 30 min, the higher germination percentage being 14 % for a population from Northern Greece and 65 % for a population from Crete. Optimum temperatures promoting seed germination in other fire-promoted species are between 80 and 120 °C depending on time of exposure, and temperatures higher than 130 °C kill the seeds of most species (CHRISTENSEN & MULLER 1975; NAVEH 1975; ARIANOUTSOU & MARGARIS 1981; VUILLEMIN & BULARD 1981). Increasing the temperature difference between day and night along with the day fluctuations does not significantly increase the germination rate (Table 1).

Light quality (R : FR) strongly affects germination as shown on Fig. 1. This was confirmed by experiments done the following year (Fig. 2). Germination rate at R : FR = 1.1 (Fig. 2) is higher than germination percentage at R : FR = 1.5 (Fig. 1)

Table 1. Effects of temperature fluctuations and light availability on the germination percentage of *S. spinosum*. (Temperatures are mean values followed by the amplitude of fluctuation; germination percentages are means followed by standard errors).

Light condition	Temperature °C	Germination %
R : FR = 1.6	day 15 ± 0.75 night 9 ± 0.75	22.8 ± 1.8
R : FR = 1.6	day 20 ± 2.5 night 5 ± 0.8	27.8 ± 1.8
no light	day 15 ± 0.75 night 9 ± 0.75	19.2 ± 2.2



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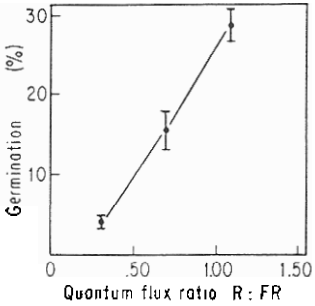

Fig. 1. Effect of the temperature of a 10 min heat treatment on the germination percentage of *S. spinosum*. Results are shown for two red to far-red quantum flux ratios during germination. (Seeds harvested in 1981; vertical bars represent standard errors of the means).

Fig. 2. Effect of light quality (red to far-red quantum flux ratio) on the germination percentage of *S. spinosum*. (Seeds harvested in 1982; vertical bars represent standard errors of the means).

probably because the experiments were done with seeds harvested in different years. R : FR values around 1.1 are typical of unfiltered solar radiation while values below 0.5 are found under dense vegetation canopies (HOLMES 1981; SMITH & MORGAN 1981). The ten-fold increase in germination percentage from 0.3 to 1.1 R : FR values in Fig. 2 is of the same magnitude as the germination increase observed in phryganic sites after fire.

Since *S. spinosum* seeds are dark germinating (Table 1), germination is not red light requiring, and the results of Fig. 1 and 2 suggest that germination is inhibited by far-red radiation. During seed maturation under high R : FR values, any phytochrome synthesised is converted to the active form and can persist as such in dry seeds (KENDRICK 1976; CRESSWELL & GRIME 1981). Imbibition under low R : FR values converts part of the phytochrome to its inactive form and subsequently reduces germination (FRANKLAND 1981).

The efficiency of such a system in inducing germination only in the absence of vegetation cover is difficult to assess because it applies only to seeds lying on the surface. Since buried seeds are not subjected to the unfavorable light spectral composition they might be expected to germinate readily. However it is probably not the case since it has been shown (WESSON & WAREING 1969) that seed which previously germinate in the dark acquire a light requirement after a period of burial. Also GORSKI (1975) and FENNER (1980) found that seeds whose germination is inhibited by canopy shade also acquire a light requirement when they are subjected to leaf transmitted light.

Conclusion

We found that in *S. spinosum*, increased post-fire germination is not a consequence of fire-generated heat nor of the increase in day-night soil temperature fluctuations. Instead it results from an increase in the red to far-red ratio of the light incident on the seeds and is mediated by the phytochrome system. The occurence of such an environmental trigger for germination has not yet been tested on other fire-promoted species. A better knowledge of the germination requirement of these species would be useful for the management of the ecosystems which evolved under the selective pressure of fire (ZEDLER 1977).

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