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MEDITERRANEAN SHRUBLANDS GROWTH RESPONSES TO WARMING AND DROUGHT CONDITIONS

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1. INTRODUCTION

Evergreen sclerophyll shrubland is a prominent feature of Mediterranean Basin. Elevated temperatures and extended drought period are predicted to have a large influence on the functioning of natural and semi-natural environments both directly and through interactions with land management and pollutant loading (Larcher, 2000; Llorens et al., 2003). Climatic changes may have particular strong effects on vulnerable ecosystems, which are already subjected to other stresses such as elevated N deposition, intensive grazing or the risk of fire (Sala et al., 1998).

An experimental manipulation of climatic conditions at field scale was conducted employing a newly developed "night-time warming" technique and an automated covering system to extend summer drought (Beier et al., 2002).

The objective of this study was to test how a future extended drought period and an increase in temperature could affect plant response in terms of plant cover and biomass, plant growth and reproductive effort. In this paper preliminary results obtained during the two first years of experiment (2002 and 2003) are shown.

2. MATERIALS AND METHODS

Study site and species description

The study site is located within a nature reserve in north-western Sardinia, Italy (40° 37' N, 8° 10' E). The climate is semi-arid with a remarkable water deficit from May through September and a mean annual rainfall amount of 640 mm. The mean annual temperature value is 16.8 °C.

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Maximum and minimum air temperatures result milder due to sea vicinity (10 °C in January and 24 °C in August). Even winter season can be dry and temperature not so low to determine vegetation break. The most common soils are Luvi and Litosoils, neutral, with depth hardly exceeding 20-30 cm.

The experimental plots are located in a firebreak strip constructed in 1973 and cleared by fire until 1990. In 1991 and 1992, the firebreak strip was cleared mechanically and from 1993 a natural recolonization process started. The plots are covered by vegetation with a maximum height of 1.0 m including sclerophyll species (*Cistus monspeliensis*, *Dorycnium pentaphyllum* and *Helichrysum italicum*), some scattered shrubs (*Pistacia lentiscus*, *Cistus incanus*, *Daphne gnidium*, etc.) and several herbaceous plants (*Carlina* spp., *Asphodelus* spp., *Brachipodium ramosus*, *Ammoides pusilla*, etc.). Vegetation covers about 80% of the plot surface.

Experimental system

The set-up of the experimental site was completed on summer 2001. 20-m^2 plots were manipulated by night-time warming and extending summer drought, and the responses to the treatments were compared to control plots. Each type of manipulation was replicated 3 times.

Extended summer drought was induced by covering the plots with waterproof plastic curtains, transparent to infrared radiation, during rain events over two annual growing seasons. The drought treatment was carried out for a 3-month period in autumn (September- November) and for 45 days in spring (1 May – 15 June).

Passive night-time warming was induced by covering the vegetation and soil with automated 1.5-m-tall aluminum curtains at night. This method allows retaining a portion of energy accumulated in the ecosystem during the light period, simulating the mechanism of global warming. Warming treatment started on winter

2001 and it has been working all nights throughout the study.

A micrometeorological monitoring station equipped with 69 sensors (rainfall, wind speed and direction, radiation, air and soil temperature, relative humidity, soil water content) was installed to obtain data from each plot on the microclimatic changes determined by the treatments.

Plants response

The response of the plants to the treatments was monitored measuring plant cover and biomass, plant growth, and reproductive effort. Pre-treatment measurements were done in summer 2001 to identify variability between plots. The pin point method was used for measuring plant frequency, and estimating plant cover, biomass and plant growth. Species, contact types, and height above the ground for each contact were recorded along four transect in each plot. At least 300 measurement points were used for each experimental plot. Two different contact types were identified: (1) vegetative parts (green and dead); (2) reproductive structures (flowers, inflorescences, and fruits). In addition, the pin point measurements were calibrated by means of destructive biomass sampling outside the plots. Allometric regressions were calculated for the main species to estimate the values of biomass, and the Relative Growth Rate (RGR) was determined. Moreover, a direct measurement of plant growth was performed by marking and sampling 10 terminal shoots of *Cistus monspeliensis* in each plot, and measuring for each shoot: length, basal diameter, number of leaves, fresh weight, dry weight, and leaf area. Finally, the percentage of flowering shoots or flowering plants, calculated by the pin point method, was adopted as an indicator of reproductive effort. The measurements frequency of each variable was yearly during both experimental years.

A one way ANOVAs with differences between years for each measured plant parameter as dependent variable and treatments as independent factor was performed to test the effects of treatments. Significant differences between means were identified by Duncan's multiple range test.

3. RESULTS

Environmental data

Rainfall in the first year of the study was higher (599 mm) than in the second year (411 mm). A very anomalous seasonal pattern of rainfall events was observed in the months of May, June, July and August 2002. In this period the amount of rainfall was 160 mm against 10 mm registered for the same period in 2003 and 55 mm of mean climatic value. Drought treatment reduced annual rainfall by 15 % and 36 % on average, relative to control plots, in 2002 and in 2003 respectively.

The increase of daily minimum temperature of air and soil observed at 20 cm height and at 10 cm depth in the warming treatments was approximately equal to 0.5° C relative to control.

Plant response

A negative, even if not significant, effect of drought treatment was observed on total plant cover. This effect was observed for both drought and warming treatments mainly during the second year of experimentation (Fig. 1). The less evident effect of treatments observed in 2002 could be due to the unusual summer rainfall events.

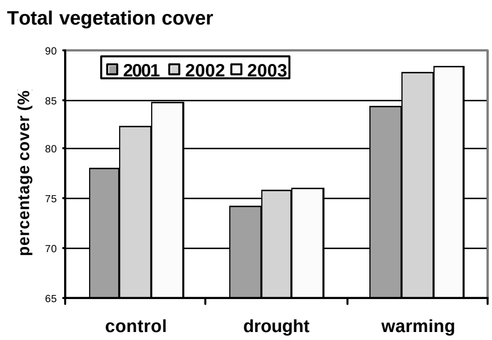

Figure 1. Observed variations of the percentage ground cover.

In relation to species-specific responses, drought treatments tended to decrease soil cover due to *Cistus monspeliensis* and *Helichrysum italicum*. Values of soil cover due to *Cistus monspeliensis* and *Helichrysum italicum* were significantly lower than those of control taking $p<0.1$ as the level of significance for *Cistus* and $p<0.08$ for *Helichrysum*. Warming treatment did not affect significantly this variable for any species (Fig. 2).

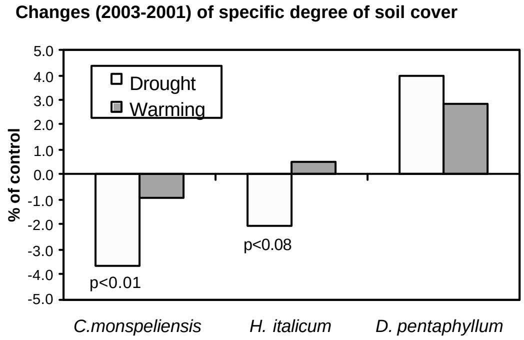

Figure 2. Changes in specific degree of soil cover resulting from the warming and drought treatments after two growing season of experimentation. Changes are expressed as differences in the number of contacts between summer 2003 and summer 2001 in relation to the control treatment.

The Relative Growth Rate in 2003 varied between 0.2 and 0.8 g g^{-1} $year^{-1}$ (Fig. 3). A negative effect on the RGR was recorded in *Cistus monspeliensis*, in both warming (-39 %, p>0.05) and drought treatment (-68 %, p<0.06). *Helichrysum italicum* was negatively affected (-70 %, p<0.05) by the drought treatment, whereas a positive but not significant increase occurred in the warming treated plots (Fig. 3)

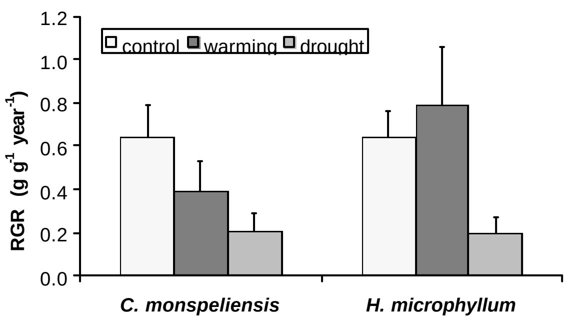

Figure 3. Relative growth ratio values for *Cistus monspeliensis* and *Helichrysum italicum* observed in 2003.

The shoot length and the shoot diameter of *Cistus monspeliensis* were not significantly affected by warming treatment (Table 1), whereas significant effects were recorded in the drought treated plots: in 2002 and in 2003 the shoot length was reduced by 21 % compared to the control (p<0.05); the shoot diameter was significantly reduced by 15 % in 2002 (p<0.05) but not in 2003 (-6 %, p>0.05).

Table 1 – Different parameters measured during the two growing seasons on the shoots sampled from *C. monspeliensis*. Each value is the mean of 30 values. The letters in bold mean significant differences (p<0.05) between treatments by year.

		Control	Drought	Warming
Shoot length (cm)	2002	6.7 **a**	5.3 **b**	6.0 **ab**
Shoot diameter (mm)		2.0 **a**	1.7 **b**	1.8 **ab**
Shoot volume (mm^3)		141.4 **a**	87.4 **b**	110.0 **ab**
Shoot length (cm)	2003	7.8 **a**	6.2 **b**	7.8 **a**
Shoot diameter (mm)		1.8 **a**	1.7 **a**	1.9 **a**
Shoot volume (mm^3)		239.8 **a**	102.0 **b**	221.1 **a**

The percentages of reproductive structures (flowers inflorescences and fruits) measured in the pin-point campaigns were used as indicator of reproductive effort. A significant trend to increase induced by warming treatment was observed for the whole community (p<0.05), though different responses to treatments were observed for the three dominant species (Fig. 4). Significant effect of treatments were observed for *Helichrysum italicum* (P<0.001): warming treatment produced a positive significant effect on reproductive effort in *H. italicum* relative to control (p<0.002); conversely, reproductive effort values of this specie, in the drought treatment, were significantly lower than those of control (p<0.005). A positive effect of warming treatment (even if not significant p<0.15) was also observed for *Cistus monspeliensis*.

Warming and drought treatments did not produce any significant effect on reproductive effort of *Dorycnium pentaphyllum*. However a particular pattern was observed for this species that seems to be positively influenced by drought and warming treatments.

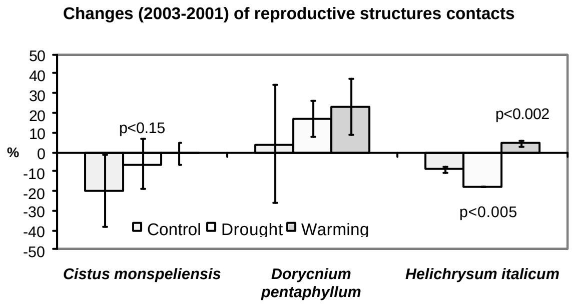

Figure 4. Changes in reproductive structure contacts resulting from the warming and drought treatments after two growing season of experimentation.

4. DISCUSSION AND CONCLUSIONS

Results show a negative effect of drought treatment in plant productivity, especially at species-specific level. Decreases of cover percentage, Relative Growth Rate and plant growth for the two dominant species (*H. italicum* and *C. monspeliensis*) were recorded.

Moreover, as expected, a positive effect of warming treatment, and a negative effect produced by drought treatment on the reproductive effort were observed.

Although an increase in plant productivity induced by warming treatments was generally hypothesized in arctic and temperate ecosystems (Hartley et al, 1999; Rustad et al, 2001), our study do not show any general effect in plant productivity due to warming treatment. The only positive, but not significant, effect on Relative Growth Ratio was observed in the specie *H. italicum*, whereas a significant negative effect of treatment on RGR was recorded for *C. monspeliensis*.

This lack of response or negative plant response to increasing temperature could be due to a decrease of soil moisture and a lower availability of nutrient resources that are often associated with warming (Rustad et al., 2001). The response to warming treatment could be probably expected greater in cold northern latitude where ecosystems are limited by temperature and nutrients, whereas Mediterranean ecosystems are typically limited by water availability (Chapin et al, 1995; Larcher, 2000; Rustad et al., 2001). Moreover, the general lack of effects of the warming treatment could be probably due to the low increase of temperature.

In conclusion, the results obtained show that in Mediterranean ecosystems an extension of drought period could decrease growth and reproduction of vegetation community, even if different responses to treatment were observed for the different species.

On the short-term time scale of the present study, some effects of treatments were detected on the fast responding processes of the ecosystem but further years of treatments are needed to verify potential effects of climatic manipulation on ecosystem functioning.

5. REFERENCES

Beier C., Spano D., Duce P., 2002: Vulcan: a European field scale manipulation project to asses the vulnerability of shrubland ecosystems under climatic changes. *Proc. 15th Conference on biometeorology and aerobiology 27 October – 1 November 2002*, Kansas City, Missouri, 265-269.

Chapin F.S. III, Shaver G.R., Giblin A.E., Nadelhoffer K.G., Laundre J.A., 1995. Response of artic tundra to experimental and observed changes in climate. *Ecology* 76, 694-711.

Hartley A.E., Neil C., Melillo J.M., Bowles F.P., 1999: Plant performance and soil nitrogen mineralization in response to simulated climatic change in subartic dwarf shrub tundra. *Oikos* 86, 331-344.

Larcher W., 2000: Temperature stress and survival ability of Mediterranean sclerophyllous plants. *Plant Biosystems,* 134, 279-295.

Llorens L., Peñuelas J., Estiarte M., 2003: Ecophysiological responses of two Mediterranean shrubs, *Erica multiflora* and *Globularia alypium*, to experimentally drier and warmer conditions. *Physiologia Plantarum*, 119, 231-243.

Rustad L.E.,Campbell J.L., Marion G.M., Norby R.J., Mitchell M.J., Hartley A.E., Cornelissen J.H.C., Gurevitch J., 2001: A meta-analysis of the response of soil respiration, net nitrogen mineralization, and aboveground plant growth to experimental ecosystem warming. *Oecologia*, 126,543-562.

Sala OE., Chapin FS., Gardner RH., Laurenroth WK:, Mooney HA., Ramakrishnan PS., 1998: Global change, biodiversity and ecological complexity In: *The terrestrial biosphere and global change: Implications for natural and managed ecosystems*. Cambridge University Press, Cambridge.