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Effect of fire on flowering of *Hyparrhenia hirta* (L.) Stapf (C_4), *Merxmuellera disticha* (Nees) Conert (C_3) and *Themeda triandra* Forsskal (C_4) on the Signal Hill, Cape Town, South Africa

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Flowering in *Merxmuellera disticha* was more strongly stimulated by fire in summer. Flowering tillers produced between 9 and 11 months after fire were significantly more abundant than those produced 21 to 24 months thereafter. Growth in terms of size of individuals was considered insignificant for analysis. Neighbored *Hyparrhenia hirta* showed, to a certain degree, an out-of-season growth, production and reproduction, whilst *M. disticha* and *Themeda triandra* on the same plots did not. The xylem water potential of *H. hirta* [-10.9(±0.29)], *M. disticha* [-14.6(±0.80)] and *T. triandra* [-13.8(±0.29)] on one stand differed significantly from one another (p < 0.0001), and that of *H. hirta* [-19.7(±0.81] and *M. disticha* [-34.5(±1.26)] on the other stand also differed significantly from each other (p < 0.0001). One way analysis of variance (ANOVA) thereof produced the following (F-ratio = 13.893; degrees of freedom = 29, p < 0.0001), and for *H. hirta* versus *M. disticha*, (F-ratio = 97.605; degrees of freedom = 23, p < 0.0001). Multiple range analysis tests revealed a significant difference between xylem water potentials of *H. hirta* from that of *M. disticha* and *T. triandra* but not between *M. disticha* and *T. triandra*.

Key words: South Africa, Signal Hill, fire, flowering plants, impact.

INTRODUCTION

Veld burning has unquestionably been a feature of the African landscape since time immemorial. Periodic or planned burning of the veld is thought to preserve pasture grass communities (Scott, 1970). The beneficial effect of veld burning may be merely the removal of excess cover, since where the veld has been grazed short or excess grass had been removed by mowing, there was no need to burn (Scott, 1951). Many studies in various parts of Southern Africa, such as the Eastern Cape, Natal, and the North-eastern Transvaal have confirmed the necessity for regular/frequent fires for the maintenance of grassland communities (Acocks, 1966; Rethman and Booysen, 1986; Tainton et al., 1970; Downing, 1974; Friedel and Blackmore, 1988). But there are studies by the scientists who have reported the persistence of grasses on unburned treatment (Bowman et al., 1988). In general, however, fire appears to be a key factor in maintaining South African grasslands. The role of fire in preventing bush encroachment has also been demonstrated.

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(Trollope, 1974). To date, many studies on fire have shown it to be the most important agent for improving grassland ecosystems (Tolsma et al., 2010; Smith and Nelson, 2011). Grass species richness improved when burnt annually, and decreased when veld was protected from fire for at least 5 years (Yeaton et al., 1988). Season of veld burning might also play an important part in maintaining South African grasslands. Rethman and Booysen (1986) found that production of *Themeda triandra* and its regrowth potential were significantly influenced by the season of defoliation. Opperman and Roberts (1978) on their study of *T. triandra*, *Elyonurus argenteus* and *Heteropogon contortus* suggested an optimum disturbance (burning, grazing, cutting, or drought) time to prevent damage to the shoot apices because that may have a detrimental effect on leaf, shoot and seed production. System processes such as nutrient recycling and water relations have been proved to be fire dependent (Raison, 1979; Van Wilgen and Le Maitre, 1981; Stock and Lewis, 1986).

It was the aim of this project of the study to compare the effect of fire on growth and flowering of *Hyparrhenia hirta* (C_4), *Merxmuellera disticha* (C_3) and *T. triandra* (C_4) in 9 months, 21 months and 15 years after burning the veld on Cape Town's Signal Hill.

MATERIALS AND METHODS

Study site

The study area was Signal Hill, Cape Town, South Africa (Altitude: 300 to 350 m, latitude: 33°54' and longitude: 18°23'). The study site was chosen for the presence of *H. hirta*, *M. disticha* and *T. triandra* associations, the accessibility and proximity of the site to a representative weather station (Kloofnek), which, however, only keeps limited weather records.

Experimental sites were established on both the east-and west-facing slopes. Both the two areas on the two slopes (east- and west-facing slopes) considered for analysis were each about 500 × l500 m, and the plots used for the different facets of this study were randomly located in the two areas. All sample sites were located on the mid- and upper-elevations of the sites.

The climate of the area is typically Mediterranean. For temperature, precipitation and relative humidity, data for City Hospital station-Cape Town was considered suitable to represent Signal Hill. Most of the annual total falls in winter and little, falls in spring and summer. Local topography clearly plays an important role in influencing temperature and precipitation. Soils at the two sites seemed heterogeneous because of discrete monospecific and mixed stands of grasses and shrubs on both the slopes.

A survey of fire effects was carried out after a wildfire which burned an area approximately 50 × 150 m of the topmost section of Signal Hill's west-facing slope. The fire burned in late February, 1988 (Clive May -Kloofnek station supervisor - personal communication). Other plots on the east-facing slope studied here are all known to have had their last fire in 1975.

The Signal Hill plant communities comprise grasses, shrubs and herbs, but only the localized patches dominated by grass (*H. hirta*, *M. disticha* and *T. triandra*) were the focus for this study.

The role of fire in the 1988 burn was assessed by counting the number of flowering tillers 11 months (on January, 1989) after fire, and another count of the same individuals was performed on December, 1989 and January/February, 1990. Two plots, a monospecific stand of *M. disticha*, and a mixed stand of *H. hirta* and *T. triandra* were used. At least 20 individuals were monitored. Wire rods with numbered tags were used to mark the individuals monitored. It was not possible to compare *M. disticha* versus itself between the 1988 burn and the 1975 one, because *M. disticha* on the 1975 burn failed to produce any flowering tillers. Flowering tillers were also counted on *H. hirta* and *T. triandra* in the 1988 burn. Growth in terms of individual species' sizes and leaf greening were slightly observed for both the 1975 and 1988 burn. The data thereof were not analyzed.

Xylem water potential measurements of the three grass species on two unaltered plots in the 1975 burn (east-facing slope) were done on the following 2 days: 05/10/1988 and 21/02/1989. The aim was to use the measurements to explain the differences in the vigor of growth and reproduction of the three grass species.

RESULTS

Flowering in *M. disticha* was more strongly stimulated by fire in the summer of 1988/1989 than that of 1989/1990 (Wilcoxon test by ranks: $Z = 3.214$, $p < 0.005$, total pairs = 25). Flowering tillers produced between 9 and 11 months after fire were significantly more abundant than those produced 21 to 24 months thereafter.

H. hirta and *T. triandra* species on a 1988 burn showed leaf greening flowering longer than those on the 1975 burn. Growth in terms of size of individuals was considered insignificant for analysis. Neighbored *H. hirta* on a 1975 burn showed, to a certain degree, an out-of-season growth, production and reproduction, whilst *M. disticha* and *T. triandra* on the same plots did not. The xylem water potential of *H. hirta* [-10.9(±0.29)], *M. disticha* [-14.6(±0.80)] and *T. triandra* [-13.8(±0.29)] on one stand differed significantly from one another ($p < 0.0001$), and that of *H. hirta* [-19.7(±0.81)] and *M. disticha* [-34.5(±1.26)] on the other stand also differed significantly from each other ($p < 0.0001$). One way analysis of variance (ANOVA) thereof (1975 burn) produced the following (F-ratio = 13.893; degrees of freedom = 29, $p < 0.0001$), and for *H. hirta* versus *M. disticha*, (F-ratio = 97.605; degrees of freedom = 23, $p << 0.0001$). Multiple range analysis tests revealed a significant difference between xylem water potentials of *H. hirta* from that of *M. disticha* and *T. triandra* but not between *M. disticha* and *T. triandra*.

Normal annual flowering for *H. hirta* (C_4), and *T. Triandra* (C_4) (to a lesser degree relative to that of *H. hirta*) was observed in the 1975 burn. There was insignificant or no flowering for *M. disticha* (C_3) in the same aged veld.

DISCUSSION

Flowering was more abundant in a 1 year burn than in 2 years burn for all species. An increase in flowering frequency following fire has been noted on, the Florida Lake Wales Ridge for a number of grass species (*Aristida stricta*, *Panicum abscissum* and *Andropogon* spp.). Late spring and summer fire stimulated a vigorous flowering response, whereas winter fires encouraged only a vegetative response (Abrahamson, 1984). Frequent burning has been reported to stimulate flowering (Daubenmire, 1968; Rowley, 1970; Vogel, 1973; Dickingson and Dodd, 1976; Christensen, 1981; Gill, 1981; Gunderson et al., 1983; Whelan, 1986). Within species, both timing of flowering (Curtis and Partch, 1950; Gill and Ingwerson, 1976; Abrahamson, 1984), and number of flowering stems produced (Burton, 1944; Stone, 1951; Kucera and Ehrenreich, 1962) change following the fire. Though there are reports of a number of studies on flowering phenologies in fire-dominated habitats (Parrish and Bazzaz, 1979; Anderson and Schelfhout, 1980; Tepedino and Stanton, 1980; Rabinowitz et al., 1981), the significance of fire upon flowering of coexisting species is still not yet fully established.

The fact that all the three grass species on the 1988 burn produced out-of-season flowering tillers, regardless of whether neighbored or non-neighbored, suggests a possible post-fire improvement in soil nutrients (Christensen and Muller, 1975).

Growth improvement and out-of-season leaf greening observed on 1 year burn, compared to 2 and 15 years after fire, signifies the importance of fire on, these aspects. Many C_3 and C_4 plants have been reported to show both an out-of-season growth and leaf greening as a consequence of fire (Perce and Cowling, 1984). Some studies (White, 1983; Bowman et al., 1988) have shown that grass cover is dependent upon frequent burning. Seasonal variation of fire effects (Gill, 1981; Henderson et al., 1983; Lovel et al., 1983; Snyder, 1986, in Platt et al., 1988) has been reported. Foliage increase on burned plots and retrogression on unburned plots was witnessed. The current study has demonstrated the role of fire as "space creator", and as a stimulant of plants' production and reproduction on Signal Hill.

Elimination of *T. triandra* from pasture has been linked to the absence of fire, and repeated defoliations (Downing, 1974); thus, suggesting periodic burning for maintaining *T. triandra* vigor. On Signal Hill, unburned tussocks of *T. triandra* have become moribund. Downing (1974) found a similar phenomena, and suggested such tussocks would die eventually if fire could be withheld for long enough. Moribund T*. triandra* tussocks on Signal Hill will eventually die out if no effective management (for example, periodic burning) could be exercised. Other grass communities of Signal Hill and elsewhere might be similarly affected.

H. hirta on unaltered plots on a 1975 burn continued to grow and flower, whilst their *M. disticha* and *T. Triandra* counterparts did not. This might be linked to *H. hirta* having shown highest xylem water potentials relative to the other two species. However, xylem water potentials in this instance were measured once on each of the two plots. Neither sizes nor distances of neighbors of the measured individual species were considered. The number of neighboring plants per pressure bombed individual was also not recorded. This might have affected the xylem water potentials of the monitored plants.

The fact that the two C_4 grass species still flowered in a 1975 burn, whilst their *M. disticha* counterparts did not, appears to suggest a "generalist" strategy by them (C_4) of coping with both warm and cool temperature.

Whether February was the appropriate time for burning the three grass species is in doubt because numerous herbs and shrubs proliferated, and a year after fire most of the spaces formerly occupied by grasses were dominated by herbs and shrubs. In this case (Western Cape), the suitable time for burning could be winter because it is rainy and hence wet, thus, fire would not easily exceed predetermined boundaries. Seeds and re-sprouters will have enough moisture for germination and establishment. Flowering could also be encouraged under sufficient soil moisture content. However, it could not be verified which season is best for veld burning.

In conclusion, fire was found to enhance growth, production and reproduction of both C_3 and C_4 plants. The C_3 species differ, however, in being completely dependent on fire for flowering and seed production. In other words, C_3 species does not flower at all in old unburnt veld, whereas C_4 species do. It would, therefore, be interesting to determine whether C_4 species successfully produce seed in older veld and whether this seed is capable of establishment. The further investigation on the importance of low versus high fire intensity will throw more light of the impact of fire on flowering plants.

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