



Interaction of plant functional traits of *Stipa tenacissima* L. in arid montane rangelands and grazing frequency.

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Abstract

Mediterranean biotic and abiotic conditions, with severe drought, high temperatures, decreasing rainfall and increasing human disturbances are expected to have negative impacts on vegetation. Functional traits can be used to understand the relationship between plants and the environmental conditions, including grazing, under which they grow. Plant traits of *Stipa tenacissima* L., the most abundant and multi-used species in North African montane arid rangeland, are studied under three grazing regimes (full exclusion, seasonal and continuous grazing). Results confirmed that *S. tenacissima* traits are strongly affected by the grazing regimes. Leaf water content, bio-volume (the volume occupied by the above ground biomass) and the specific contribution of *Stipa* (the proportion of the species among the total plants founded) are higher under seasonal grazing. Hence this last management is recommended for the sustainability of both plant and rangelands.

Introduction

The functional traits of species are the resulting evolutionary and adaptive responses to the specific conditions of their environment (Reich et al. 2003). Climate change and human disturbances, particularly grazing, are considered among the most challenges confronting our world (Mikhaylov et al. 2020). They affect key habitat elements critical for the maintenance of species (Krichen et al. 2019). To evaluate vegetation behaviour and highlight adaptation to grazing and climate change, it is important to understand the plant's responses through their functional traits such as those associated with their colonization, survival, growth, and mortality (Reich et al. 2003).

Stipa tenacissima L. is a dominant perennial Poaceae in southern Tunisia, particularly in the montane rangeland chain of Matmata. It is subject to a wide range of climate and soil stresses. *Stipa* helps to prevent soil erosion by its developed root system and its adaptability to environmental shifts (Yang et al. 2024). *Stipa* constitutes an integral part of local economies according to its multiple uses as artefacts (baskets, strings, shoes) and for livestock feeding in summer (Ben Salem 2012).

Methods

Study area

Three sites located in the region of Toujane (south-east Tunisia) in the Matmata Mountain Chain are studied (Fig. 1). The mean annual precipitation is approximately 150 mm. The three sites have similar soil substratum, topography and geology, but differ in altitudinal range and grazing regime. Zmerten (33°26'07.20" N, 10°07'29.02" E, 3000 ha) has been protected from grazing for 44 years. Its natural vegetation is dominated by *Juniperus phoenicea* L., *S. tenacissima* and *Rosmarinus officinalis* L. Brighith (33°29'23.40" N, 10°12'02.88" E, 100 ha) is dominated by *S. tenacissima* and is devoted to seasonal grazing. The control (33°29'14.95" N, 10°11'58.24" E) is dominated by *S. tenacissima* and continuously open to grazing.

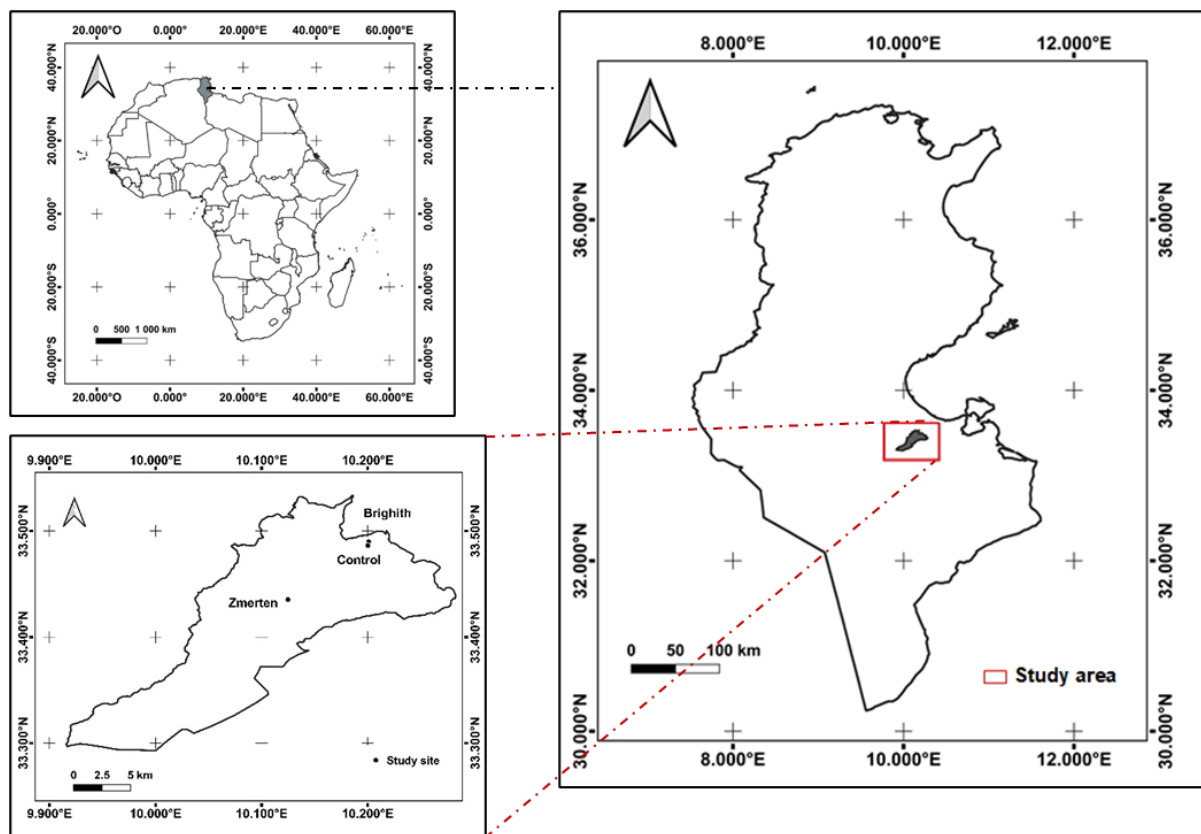


Fig. 1 Geographical location of the three study sites.

Methodology

At each site, nine tufts of different sizes (three big, three medium and three small) are measured in each altitude (low, medium and high) and aspect (south and north expositions to sunlight). The methodological approach is a pseudo replicated-nested design, with the three grazing treatments confounded with site. In total, 54 measurements are made within each site. Five leaves are collected from each tuft to measure the leaf traits. They were placed in moistened paper, and put in a refrigerator to prevent dehydration. In the laboratory, the leaves were weighed (to obtain their fresh matter (FM)), flattened, fixed and photographed. The photos are then analyzed using 'Image J' software to calculate the leaf area (LA). The sampled leaves are then oven dried for 48 hours at 60°C to obtain their dry matter content (DM). The leaf water content

(LWC), as a percentage of FM, was then calculated. The leaf dry matter content (LDMC), in mg g^{-1} FM, is DM/FM . Specific leaf area (SLA), in $\text{cm}^2 \text{g}^{-1}$ DM, is LA/DM . The biovolume (in m^3) is calculated as $\text{BV} = ((4/3) \pi r^3)/2$, where r is the average radius of the tuft and it is obtained as $r = ((D/2) + (d/2) + h)/3$, with: D is the largest diameter, d is the smallest diameter and h is the height of tuft. The canopy cover (CC in m^2) is the area covered by the aerial organs of *S. tenacissima* and it is calculated as $\text{CC} = \pi r^2$.

To characterize the whole plant community of the sites, three 20 m line-transects, 100 m apart, are installed at each level and aspect (in total, 18 lines per site). Data are collected using the quadrat point method. A metal fine pin is entered vertically into the vegetation every 20 cm along the transect (100 hits per line). The plant species touching pin are recorded. The total vegetation cover (Vc in %) is calculated as: $\text{Vc} = (n/N) \times 100$ where n is number of points where the vegetation is present and N is the total number of the measured points along the line.

The specific contribution (Sc in %) reflects the proportion of the species in the vegetation cover and was calculated as $\text{Sci} = \text{FSi} / \Sigma \text{FS} \times 100$, where FSi is the specific cover of the species and ΣFS the sum of the cover of all species. All these measurements are taken during the springs of 2019, 2020 and 2021.

Results

To summarize and investigate the patterns of the studied functional traits, a principal component analysis (PCA) is used (Fig. 2). PCA showed two principal components explained together 76.27% of the total variance. PC1 explained 53.36% of variation, while PC2 explained 22.91%. PC1 displayed a high positive association with BV, CC, Vc, Sc and LWC while it had high negative association with LDMC, SLA and LA. PC1 indicated a grouping of sites that exhibited high BV, CC, Vc and LWC. PC2 showed a positive loading with LDMC and a negative one with SLA, LA and LWC.

As showed in Figure 2, three site-groups are identified according to the hierarchical clustering. The first group included ZN1, ZS1, ZS2, ZS3, CS1 and CS2. Higher LDMC characterizes this group. The second one contained ZN2, ZN3, CN1, CN2, CN3, CS3. It is distinguished by a high LA and SLA. The last group contained all the seasonally grazed sites (BN1, BN2, BN3, BS1, BS2 and BS3) and it is characterized by a higher BV, CC, Vc, Sc and LWC. This distribution clearly proved the positive correlation of seasonal grazing on both functional traits of *Stipa* (BV, CC, Sc and LWC) and on the whole community (Vc).

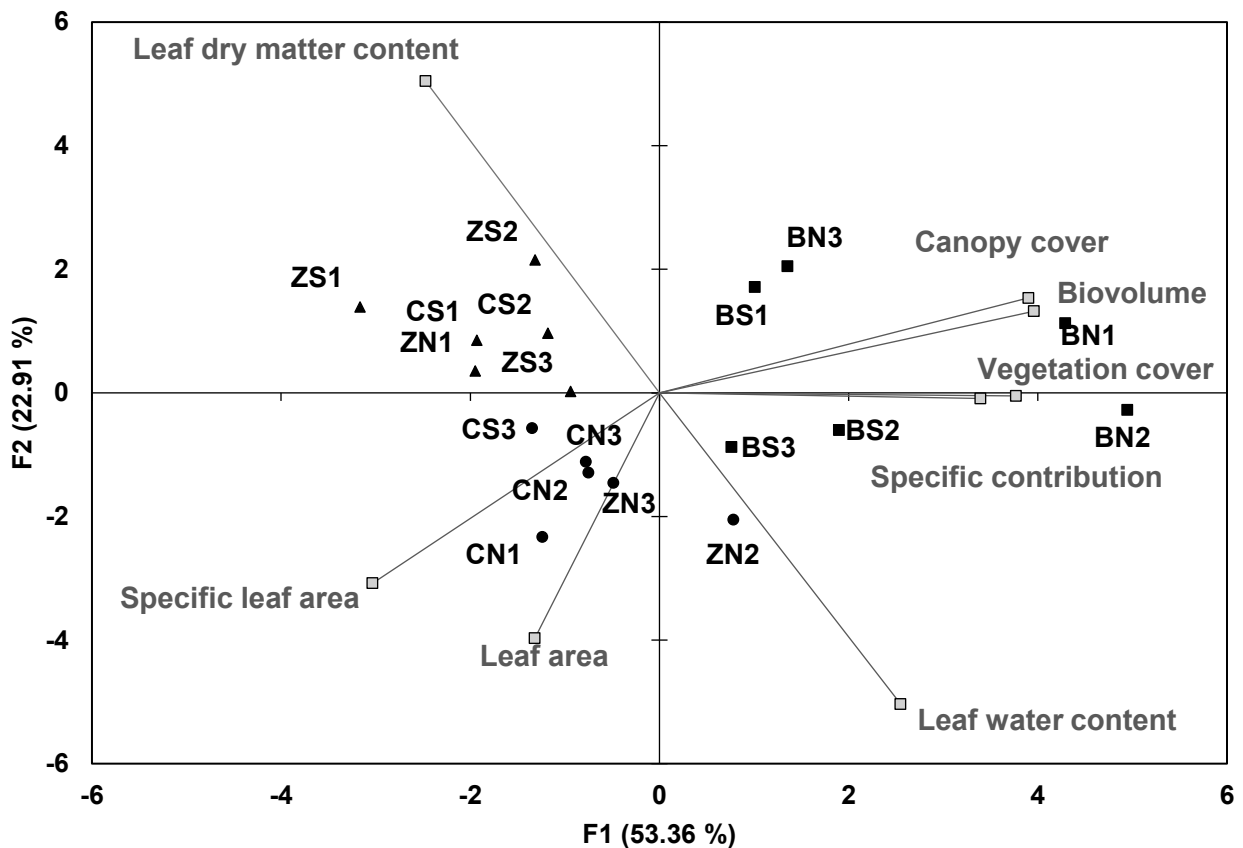


Fig. 2. Principal component analysis applied on the data of eight variables in 18 locations, meaned over the springs of 2019, 2020 and 2021. B: Brighith (seasonally grazed), C: control (continuously grazed) and Z: Zmerten (Livestock exclusion). N: northern aspect, S: southern aspect, 1: low elevation, 2: medium elevation, and 3: high elevation. For example: BN1 is Brighith North, low elevation.

Discussion

The CC, BV and Sc at the site under seasonal grazing are higher than those of the fenced and control sites. These may relate to improvements in soil characteristics. Seasonal grazing with controlled animal numbers has increased soil organic matter content and improved its physical and chemical conditions in Argentina (Vecchio et al. 2018).

Leaves are the most appropriate indicators of plant water status (Hamdani et al. 2019). SLA and LWC are closely linked to the productivity and water status of plant (Chirino et al. 2017). Hence, the low SLA with high LWC in the seasonal grazing site shows the adaptive capacity of *Stipa* to moderate grazing compared with the fenced and continuously grazed plants.

The Vc in the protected site is lower than the one in seasonal grazing. Thus, short grazing periods alternated with fencing during the growing season, seems better than strict protection (Msadek et al. 2021). Some grazing will temporarily decrease the aerial organs and allow the root systems to revitalize the remaining

plant materials. Thus, individual plants are reinvigorated and vegetation cover increases (Louhaichi et al. 2012).

In conclusion, these experiments, revealed that seasonal grazing, with a controlled animal charge, is more beneficial for species and plant communities than grazing exclusion and continuous grazing. Seasonal grazing is rehabilitating degraded rangelands using selected local plants adapted to different biotic and abiotic constraints.

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