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Seasonal growth and translocation of some major and trace elements in two Mediterranean grasses (*Stipa tenacissima* Loefl. ex L. and *Lygeum spartum* Loefl. ex L.)

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ABSTRACT

The rangelands of *Stipa tenacissima* and *Lygeum spartum* (Poaceae) constitute one of the main typical ecosystems in the Iberian Peninsula and North Africa. This study examines the seasonal changes in aboveground biomass accumulation and translocation of some major (Ca and K) and trace elements (Br, Cr, Cu, Fe, Mn, Sr and Zn) from topsoil to shoots of these perennial grasses. Species, season and their interaction significantly affected the dry biomass (DW) and chemical composition of both species and their surrounding soil. The maximum DW was found in spring due to high physiological activity and was correlated positively with rainfall. A significant relationship between seasons and chemical elements was found. For both species the maximum concentrations of Ca, Cu and Zn were found in spring season. However *L. spartum* had the highest concentrations of K, Cr, Br, and Sr in autumn season, indicating exceptional ability of these species to accumulate large contents of these elements during the active growth periods. By way of contrast, in the topsoil the highest concentrations of almost all chemical elements were found in summer and autumn. Principal component analyses (PCA) showed that growth of *L. spartum* was highly associated with K, Ca, Zn, Br and Sr, whereas topsoil was correlated with Cu, Cr, Fe and Mn concentrations. Translocation factor (TF_x) of chemical elements was not identical across the two species, demonstrating inter–specific variability to uptake chemical elements. The maximum values of TF_x were recorded for K, Ca and Sr especially for *L. spartum.* To cope with arid conditions, *S. tenacissima* and *L. spartum* sprout quickly by increasing their rate of growth and nutrient uptake as soon as soil water is available after the rain.

1. Introduction

The Mediterranean grassland communities are recognized by their specific colonization patterns across edaphic gradients and the processes controlling the distribution and abundance of vegetation are directly related to soil proprieties (Garcia-Fuentes et al., 2001; Ghiloufi et al., 2017). However, rainfall is the most significant climatic factor involved in controlling the survival of perennial grasses and their distributions (Le Houérou, 2001; Slimani et al., 2010). Growth productivity and plant chemistry differ with seasons and local biotopes (Kabata-Pendias, 2011). Bioavailability of chemical elements in plants may depend on plant species rather than total element concentrations in the soil where the plants grow. Therefore, plant analysis is often undertaken in order to predict the level of absorption, deficiency or excess of chemical elements indispensible for plant nutrition (Grønflaten and Steinnes, 2005).

Nutrient extraction from soil by root systems varies significantly across seasons and harvesting periods. This finding was confirmed by previous investigations that showed that extractable chemical elements have large spatial and temporal variability in the same and between species (Munoz and Faz, 2014; Zhang et al., 2014).

Stipa tenacissima Loefl. ex L. and *Lygeum spartum* Loefl. ex L. commonly known respectively as “*Halfa*” and “*Sennagh*” (Fig. 1), are typical perennial grasses widespread in arid the Ibero-North African rangelands (Ghiloufi et al., 2017; Nedjimi, 2016a; Ramírez et al., 2006). These grasses play an important role in soil stability against erosion (De Baets et al., 2007; Nedjimi et al., 2010). They also provide a valuable source of forage for livestock during harsh conditions (Nedjimi and Beladel, 2015) and offer cellulosic fibres for paper industries (Nedjimi, 2009, 2016b).

In arid and semiarid ecosystems, the relationship between composition and occurrence of natural flora and primary productivity (biomass) is generally linked to physicochemical characteristics of soil (e.g., texture, OM %, pH, mineral content …. .) and water availability for plant growth (frequency and abundance of rainfall) (Gastine et al., 2003). Therefore, information about seasonal variation of mineral composition is required to understand the mechanisms leading to the distribution and dynamic of vegetation productivity (El-Keblawy et al., 2015).

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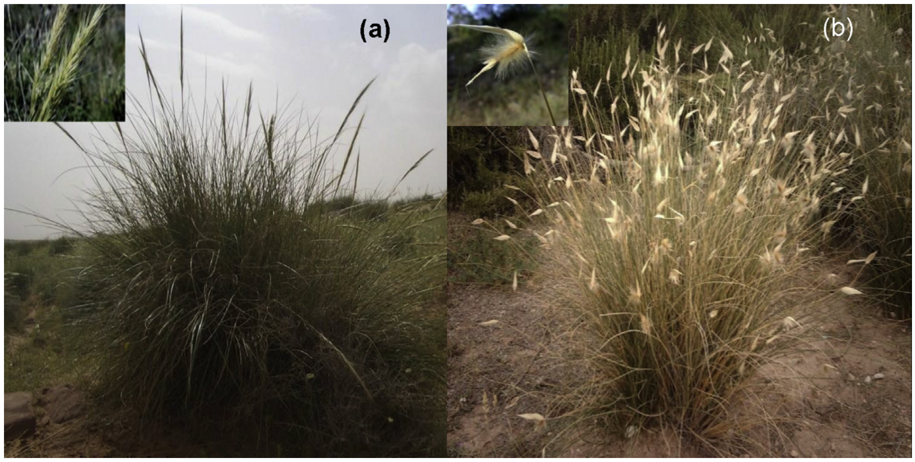

Fig. 1. *Stipa tenacissima* Loefl. ex L. "*Halfa*" (height ≈ 100 cm) **(a)** and *Lygeum spartum* Loefl. ex L. "*Sennagh*" (height ≈ 80 cm) **(b)** tussock grasses (Poaceae) from *Djelfa* rangelands (Algeria).

Plants can be used as tools of ecological control when they indicate a direct response to the environment changes (Klink et al., 2014). At low concentrations, some trace elements such as Cu, Mn, Zn are essential as micronutrients for plants, however these elements become toxic when they existent at higher levels in the soil. By assessing the level of trace elements in the plant tissues, we can obtain not only direct information about bioavailable pollutants but also detect early indications of ecological changes (Bonanno et al., 2018).

Plant mineral composition is influenced not only by naturally occurring minerals of soil, but also by transport and deposition of potentially toxic elements. There are many sources of contamination by pollutants, for example, by direct atmospheric deposition of trace elements onto the plants leaves, or indirect absorption of these elements from the soil by the root system (Bi et al., 2013). While trace elements (such as Cu, Fe, Mn and Zn) are required by plants, they are generally non–biodegradables, can be toxic and can persist in the environment producing adverse impacts to natural ecosystems, animal and human health (Kabata-Pendias, 2011). Therefore, in order to understand anthropogenic impacts on the environment, it is important to assess the levels of trace elements in the plants and soils (Tripathee et al., 2016).

In Algerian rangelands, little has been done to investigate the levels of essential and potentially toxic trace elements in the natural biotope or the environment. The use of plant species as bio–indicators or bio–monitors is a useful practice to evaluate the chemical element status of soil and/or degree of pollution in local environment (Wu et al., 2010).

Much importance has been paid to major nutrient composition among Mediterranean grasslands vegetation (Pugnaire and Haase, 1996; Haase et al., 1999; Mehdadi et al., 2008), but less importance was attributed to trace element variation within vegetation. The temporal variations in soil and plant chemistry associated with ecological and environmental factors may affect the cycling of chemical elements in ecosystem as well as determine the plant effectiveness in biomoritoning and bioindication. In this context, this study aimed to investigate the capacity of perennial grasses to translocate, accumulate and bioindicate trace elements in the field conditions, to better know the level and seasonal dynamics of trace element mobility in the rangeland ecosystems as well as to determine the effectiveness of the perennial grasses as bioindicators.

We hypothesized that: (1) the ecological characteristics and the alternative changes of environmental factors would affect growth and trace element translocation of dominant grasses in the arid rangelands, (2) the concentration of trace metals in the *S. tenacissima* and *L. spartum* grasses and their surrounding soil would be different between seasons, (3) *S. tenacissima* and *L. spartum* would accumulate trace elements in their tissues proportionally to trace elements available in surrounding soil, (4) the high translocation of chemical elements was found at the humid season to support growth of both species.

In order to achieve these objectives, the purposes of this study are: (1) to investigate the impact of rainfall fluctuations on the biomass productivity of *S. tenacissima* and *L. spartum* (2) to examine the seasonal variation of some major and trace elements in the aboveground biomass of both grasses and to compare with those of the soil below plant samples and (3) to explore the differences between the bioaccumulation capacities of chemical elements across the two species. The information about seasonal variation of elemental contents in soil as well as in natural vegetation could serve as an environment quality assessment and as a baseline for future environmental studies in the Algerian rangelands or for other Mediterranean countries with similar ecological conditions.

2. Material & methods

2.1. Field site description and sampling methodology

Stipa tenacissima and *L. spartum* and their topsoil samples were collected from *Aïn Maâbad* region at 20 km north Djelfa province, in the central rangelands of Algeria (3°13′N, 34°70′E and 934 m a.s.l.) (Fig. 2). The sampling region has a semi–arid climate dominated by Mediterranean influences with irregular rainfalls. The mean precipitation was less than 300 mm year^{-1}. According to the USDA classification, the region was dominated by the xeric calcimagnesic soil with calcareous crust (Halitim, 1988).

Fig. 3 shows the mean monthly temperatures and total precipitation recorded during 2015. This figure displays dry period exceeding four months from May to August (P = 52 mm) and mean annual precipitations (P) of 212 mm. The mean monthly minimal (m) and maximal (M) temperatures during 2015 at *Aïn Maâbad* region are m = 5.5 °C in February and M = 26.9 °C in August respectively. Two distinct humid (wet) periods occurred, a first period between January to April with P = 72.6 mm (winter–spring period) and second period from September to November with P = 69.6 mm (autumnal period).

The central rangelands of Algeria are colonized by two particular types of vegetation called "bunch grass steppe" which consists *S. tenacissima, L. spartum* and *Stipagrostis pungens* and "chamaephytic steppe" dominated by *Artemisia herba–alba*, *Noaea mucronata* and *Plantago albicans* (Aïdoud et al., 2006).

Sampling (plant and topsoil) was carried at the middle of each season (January–15, April–15, July–15, and October–15) during 2015 at the same sites, to measure seasonal trends of trace elements in