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Measurements of aerial biomass of *Cenchrus ciliaris* L. under the arid bioclimate of Tunisia

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SUMMARY – The main objective of this work was to assess the above-ground biomass of *Cenchrus ciliaris* under the arid climate of Tunisia. Measurements of volume parameters (height, crown diameters and biovolume) and biomass production were made during 2003-2006. Different regression models between these parameters were tested. Results showed high significant relationships between total biomass production and mean crown diameter (R^2 varied from 0.62 to 0.71). Annual production had the lowest correlation with mean diameter (R^2 varied from 0.43 to 0.51). Linear regression between the total biomass production of *C. ciliaris* and both height and crown diameters had a high significant relationship (R^2=0.75). Whereas, linear regression between annual biomass production and these volume parameters generated a model equation with lower coefficient of determination (R^2=0.51).

Key words: Above-ground biomass, *Cenchrus ciliaris*, regression model, Tunisia.

RESUME – *"Mesure de la biomasse aérienne de Cenchrus ciliaris L. sous le bioclimat aride de la Tunisie". L'objectif du présent travail est d'évaluer la biomasse aérienne de* Cenchrus ciliaris *sous bioclimat aride de Tunisie. Les mesures des paramètres du volume (hauteur, diamètres du houppier et biovolume) et de la production en biomasse ont été réalisées durant 2003-2006. Divers modèles de régression entre la biomasse aérienne et les paramètres du volume de l'espèce ont été testés. Les résultats ont montré des relations hautement significatives entre la biomasse totale produite et le diamètre moyen de la touffe (R^2 varie entre 0,62 et 0,71). La production annuelle a montré des corrélations moins significatives avec le diamètre moyen (R^2 varie de 0,43 à 0,51). La régression linéaire reliant la production totale en biomasse de* C. ciliaris *à la hauteur et aux diamètres des individus a produit une corrélation hautement significative (R^2=0,75). Cependant, la régression linéaire reliant la production annuelle à ces paramètres a généré un modèle d'équation présentant un coefficient de détermination moins important (R^2=0,51).*

Mots-clés : *Biomasse aérienne,* Cenchrus ciliaris*, modèle de régression, Tunisie.*

Introduction

In Tunisia, intensified exploitation of the natural environment in arid regions was the cause of floristic changes, decreasing production, water and wind erosion (Bendali *et al.*, 1990; Nefzaoui and Skouri, 2002). During last decades, the population of these zones was faced with a vital problem related to the availability of a sufficient forage resource for their livestock which was incessantly increasing. In addition, the climatic precariousness had a great influence on the quality of rangelands. At this level, where the yearly precipitations do not exceed 200 mm, the vegetation state depends closely on the availability of the water resources (Floret and Pontanier, 1982; Nefzaoui and Skouri, 2002). At the same time, soil, and especially superficial layers, became more affected by the erosion factors (especially wind and water). In view to this regressive vegetation dynamics formerly of forest nature (Le Houerou, 1969; Bendali *et al.*, 1990), we are actually in face of a steppic vegetation. The great human activity at different times, had contributed to this steppisation which was traduced by a rarefaction of the vegetation cover and a modification of the flora composition.

Nowadays, the climatic instability associated with an irrational use of lands (overgrazing, cereals, cutting (M'timet, 1996; Jauffret, 2001), constitute a serious threat to the southern Tunisian rangelands.

Establishment of mathematical models relating the biomass production of shrub species is one of the well adopted methods to evaluate the species productivity under arid climate (Abdelkader *et al*., 2007). This method was suggested by several researchers (Johnson *et al*., 1988; Thomson *et al*., 1998).

The present work was concerned with a Poaceae of high range value, *Cenchrus ciliaris*, with the aim to establish some mathematic models which could explain its ecological behaviour and allow predicting its biomass production according to the species dimension.

Material and methods

Experiments were conducted in the National Park of Bou Hedma in the arid area of Tunisia (34° 15′ N and 9° 15′ E). This study site was characterized by a savanna vegetation, dominated by *Acacia raddiana* and *Ziziphus lotus* associated with a chamaephytic vegetation. Perennial grasses are the dominant species in this site. The major ones are *Cenchrus ciliaris*, *Digitaria nodosa*, *Stipagrostis ciliata*, *Heteropogon contortus* and *Tricholaena teneriffae*. The soil is a calcareous plain with clay-alluvium and sandy deposits. The area has a mean annual precipitation of 180 mm, predominantly in autumn and winter. The average monthly temperatures vary between 3.8°C in January and 37.5°C in July. Experiments had been carried out during four years (2003-2006). Fifty two individuals of *C. ciliaris* were selected for measurements. These individuals were randomly sampled. The plant height (H) and the canopy diameters taken at the widest part of the tuft (longest diameter (d_1) and the greatest diameter (d_2) perpendicular to d_1) were measured.

Subsequently, each individual plant was clipped and separately weighed. Fresh matter was then dried in the laboratory at 70°C to a constant dry weight. The dried plant biomass was related to: (i) the mean diameter (MD) (as the average of the two canopy diameters), and (ii) the plant height (H). Different regressions were tested statistically, using SPSS 10.0 computer program, and the best significant relationships were retained.

Results and discussion

The range in the height, mean canopy diameter and biomass (total and annual) of sampled individuals of *C. ciliaris* were, respectively, 7-40 cm (mean: 13.25 cm, standard deviation (SD): 7.16 cm), 9-45 cm (mean: 22.48 cm, SD: 7.68 cm), 1.15-41.49 g (mean: 12.86 g, SD: 8.73 g) and 0.77-16.10 g (mean: 6.32 g, SD: 4.16 g).

Summary goodness-of-fit statistics from the most three relevant modelling approaches (linear, power and exponential equations), relating total biomass (TB) to the mean canopy diameter (MD), applied for all species are provided in Table 1. All established models fitted high significant relationships (R^2 varied from 0.62 to 0.71). Concerning the annual production (AB), model equations established fitted low relationships (R^2 varied from 0.43 to 0.49) (Table 2).

Table 1. Regression models between total biomass production (TB) and mean canopy diameter (MD) of studied individuals

Model*	r^2	d.f.	F	Sigf	b_0	b_1
Linear	0.71	52	127.29	000	-8.6501	0.9573
Power	0.68	52	108.04	000	0.0474	1.7599
Exponential	0.62	52	83.01	000	2.0324	0.0722

*Regression models were: 1: Linear ($TB = b_0 + b_1 MD$); 2: Power ($TB = b_0 . MD^{b1}$); and 3: Exponential (Exponential $TB = b_0 e^{b1 MD}$).

Table 2. Regression models between annual biomass production (AB) and mean canopy diameter (MD) of studied individuals

Model*	R^2	d.f.	F	Sigf	b_0	b_1
Linear	0.48	52	48.78	000	-2.1438	0.3769
Power	0.49	52	49.30	000	0.0453	1.5387
Exponential	0.43	52	39.55	000	1.2343	0.0624

*Regression models were: 1: Linear (AB = b0 + b1 MD); 2: Power (AB = b0. MD b1); and 3: Exponential (AB = b0 e b1 MD).

Even when correlated to both the height and the canopy diameters (d_1 and d_2), the biomass production fitted high significant relationships. The following mathematic equations were obtained:

$TB = -0.360\ H + 0.352\ d_1 + 0.878\ d_2 - 8.403;\ R^2 = 0.75$
$AB = -0.110\ H + 0.049\ d_1 + 0.370\ d_2 - 1.802;\ R^2 = 0.51$

According to all above cited results, the aboveground biomass of *C. ciliaris* was strongly correlated to the mean canopy diameter. Regression models (linear and non linear) fitted high significant relationships. Concerning the total biomass, it appeared well correlated to the mean canopy diameter. The most significant relationship was linear regression.

Linear regressions relating the biomass production of the studied species and its volume parameters (H, d_1 and d_2) also produced significant relationships.

The biomass production was well correlated to the mean diameter and it evolved positively with the plant dimension. This method permits to predict, with a high degree of accuracy, the aboveground biomass production. It is fast, very suitable and non destructive (only in first time). It was applied to assess the biomass production of trees such as *Acacia* sp. (Laamouri *et al*., 2002; Abdelmoula *et al*., 2004) and shrub species (Sicot, 1980; Floret, 1988; Abdelkader *et al*., 2007) and even for the evaluation of foliar biomass (Armand, 1994). Further investigations could provide more accurate regression models.

Conclusions

The prediction of the aboveground biomass production of plant species is beneficial to the suitable estimation of species productivity. Establishing mathematical equations could contribute to fast and non destructive estimation of the aerial biomass of these species.

Based on all cited results, it appeared that the biomass production of *C. ciliaris* was well correlated with its volume parameters. This could be beneficial for understanding the species behaviour. Such result could contribute to assess the species productivity under arid bioclimate. Evaluation of aboveground biomass production of *C. ciliaris* could be illustrated at different degrees of significance. Various models linking individual biomass production and its crown dimension were produced. Biomass production seemed well correlated to both height and mean crown diameter.

The mean diameter could be a sufficient parameter which could predict, with a high degree of significance, the aboveground biomass production of plant species.

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