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Clipping Effect on Growth and Plant Water Use Response to Diurnal Variation of Vapor Pressure Deficit in *Cenchrus biflorus* Roxb

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Abstract

Cenchrus biflorus called Karangiya in the Hausa language is an annual pastoral grass which is a valuable herbaceous fodder in dry land region in the context of climate change. However, little is known about the plant water use under the effects of cut in West Africa Sahel like Niger where the plant is a multipurpose grass species. Therefore, this study investigated the impact of grazing (simulated by shoot cuts) on biomass production. *Cenchrus biflorus* Roxb was grown on field plots and in pots and subjected to shoot cuts at different levels (3 cm and 5 cm from soil surface). The effect of shoot cuts on drought tolerance was evaluated by assessing the response of transpiration to the diurnal variation of vapor pressure deficit (VPD). Results showed that the biomass production varied in response to shoot cuts depending on the culture system, and the level or frequency of cuts. The mean biomass production increased significantly especially in field plots for 5 cm cuts compared to those at 3 cm and the control treatment. In addition, transpiration was highly increased in response to the VPD increase. Shoot cuts significantly reduced transpiration, whatever the level, largely because they reduced leaf surface. We concluded that moderate grazing (cuts to 5cm) can improve biomass production and allow better adaptation to water deficit as they significantly reduced water loss through transpiration. The study recommends the cropping of the *Cenchrus biflorus* as climate solution as it performs better under water deficit for improving grazing resilience in Niger.

Keywords

Cenchrus biflorus, Biomass, Vapor Pressure Deficit, Cutting, Grazing

1. Introduction

Niger is a Sahelian country belonging to the semi-arid Africa, with a climate that is characterized by the alternation of two contrasting seasons: a short-wet season (2 - 3 months) and a long dry season (9 - 10 months). In recent decades, these regions have experienced high annual variability and spatial rainfall, which resulted in a trend of progressive climate aridity [1] with serious consequences particularly for animal production due to scarcity of fodder. Climate change is having a negative impact on the availability of rangeland forage resources [2] particularly herbaceous resources [3]. In recent years, they have conditioned the diversity of herbaceous resources [4]. Rangeland forage is the main source of animal feed in traditional livestock production systems [5]. Both quantitative and qualitative production of herbaceous biomass is strongly influenced in the Sudanian zone by a number of factors, such as rainfall [6]. Residual moisture due to late rains or early pre-monsoon rains contributes to the degradation of herbaceous biomass [7]. Thus, climatic changes play an important role in the seasonal degradation of herbaceous biomass in the Sahel [8], as the availability of herbaceous vegetation is conditioned by rainfall, solar radiation, air temperature and humidity [9]. These climatic changes have significantly modified crop-livestock production systems, in particular the rules of management of natural resources by the population [10]. These changes were exacerbated by a growth rate of 3.5% [11] resulting in an expansion of cropland at the expense of grazing areas. Farming is extensive, so heavily dependent on natural vegetation. The Sahelian zone is undergoing profound changes, and with drought raging there since more than a decade, there has been a gradual degradation of ecosystems and reduced grazing land surfaces [12]. In this context, particular attention should be focused on local species with good forage value and adapted to soil and climatic conditions of the Sahel. In Niger, the most rencontred plant species found in rangelands the most preferred by livestock (mainly goats, cow, and sheep), *Cenchrus biflorus*, *Eragrotus tremula*, *Alysicarpus ovalifolus*, *Zornia glochidiata*, *Chrozophora brochiana* et *Pennisetum pedicellatum*, *Dactyloctenium aegyptium*… [13] [14]. However, the use of such species requires a better understanding of their biology and their mechanisms of regeneration and growth. *Cenchrus biflorus*Roxb ex DC is very appreciated by livestock. This species has been studied by several people, but despite an excellent forage value and relative adaptation to drought, the biology of these species is not yet well known. As such, the selection of forage species is still needed to enhance the value of natural pastures or create new seeded pastures. The grass *Cenchrus biflorus* is also an excellent forage plant because of its very high content of mineral substances (protein, fat, Ca, K …) and amino acids which are very important for animal feed [15]. The objective of this study was to investigate the response of *Cenchrus biflorus* to simulated grazing and diurnal variation of VPD in order to better understand the resistance of this species to grazing and adaptation to drought.

2. Material and Methods

2.1. Plant Material and Experiment Management

Seeds of *Cenchrus biflorus* were kindly provided by the National Institute for Agricultural Research of Niger (INRAN/Maradi). The experiment was conducted in a randomized block design on a field of 112 m^2 (8 m × 14 m), in which three blocks of six plots of 2 m^2 (1 m × 2 m) were conducted with nine replicates for each genotype in two months during a rain free period using irrigation. The same amount of water was put in each pot during irrigation. In addition, the soil used in the experiment was thoroughly mixed before filling the pots. The experimental site is 10 km from the town Maradi, Niger, located in latitude 13˚41' and longitude = 7˚14') in altitude. For each plot seeds were sown in four lines 0.20 m apart. Regarding the pots experiment, 15 plastic pots with a capacity of 5L were used. These pots were drilled at the bottom to latex cess water to drain after watering. They were filled with sandy soil collected around the University. The sowing was done with 5 seeds per pots. Two weeks later the seedlings were thinned to one per pot until the end of the experiment. Grazing simulation was done by cutting the plant shoot at 3 cm or 5 cm from soil surface with pruning shears, in a 20-day interval between cuts. Threats were used to mark the cut plants for easy identification.

2.2. Parameters Measured

Shoot and root biomass:

- Biomass was measured by weighing shoot and roots with a 0.1 g HCB 6001 precision balance (Adam Equipment Inc., Fox Hollow Road, Oxford, USA).
- Estimated leaf area using image analysis software (WinRhizo); Transpiration (measured gravimetrically): Transpiration was assessed by measuring the weight loss of the potted plant, taking the precaution of covering the pot surface with white plastic to leave only the stem to prevent evapotranspiration of water.
- Vapor pressure deficit calculated using temperature and relative humidity [16]; *i.e.*: The vapor pressure deficit (VPD, kPa) was subtracted from the values for relative humidity (RH, %) and air temperature (T, ˚C).

3. Data Analysis

As our data were not normally distributed, Friedman test was used for to detect the effects of cut on biomass and compare the differences between means on the basis of the standard error using Genstat (9.0) software.

4. Results

4.1. Effect of Shoot Cuts on Biomass Production

- Field plots

The results showed that the response varied depending on the level and frequency of cuts (**Figure 1(a)**). With the first cut, the biomass produced did not show any significant difference between the cut plants. By contrast, shoot cuts at 5 cm increased the biomass produced by twice the biomass produced in those cut at 3 cm. At harvest, the data showed that biomass production has not significantly changed between control plants and those cut twice to 3 cm of the soil (**Figure 1(b)**). Other hand, for plants cut at 5 cm, the biomass increased by more than three times compared to control plants.

- Pots experiment

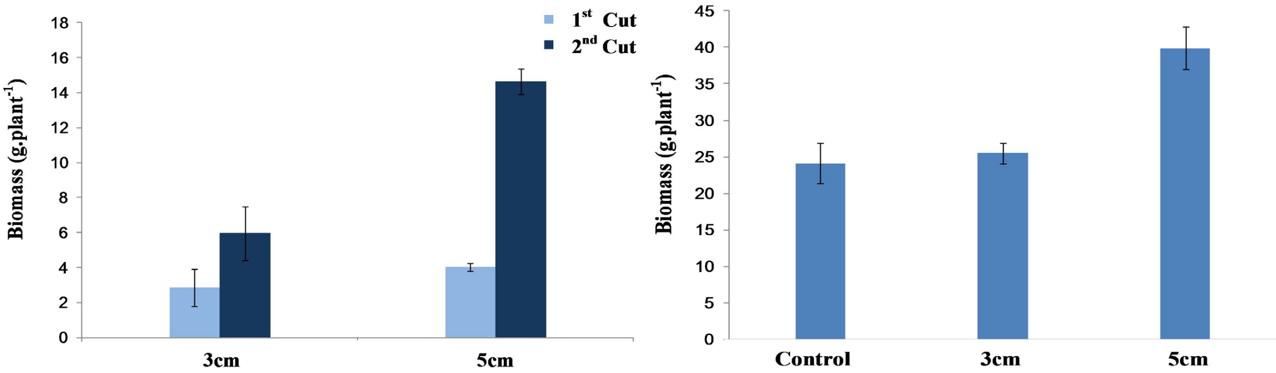
The same type of treatment was used for the plants grown in pots. Data showed the same trend as for the field experiment (**Figure 2(a)**). Thus, biomass production was significantly higher with cuts at 5 cm compared to those made at 3cm. However, at harvest, plants cut at 3 cm produced less biomass than the control plants. For plants cut to 5 cm f biomass production tended to be greater than that of the control plants (**Figure 2(b)**).

4.2. Transpiration Response to the Diurnal Variation of Vapor Pressure Deficit

During the first day of the experiment, the vapor pressure deficit (VPD) showed a slight increase between 07 h and 13 h, the maximum value being 2.25 kPa (**Figure 3(a)**). Beyond 13 h, the VPD presented gradual decrease and pointed to a value of 1.4 kPa at 19 h. Unlike the first day, the VPD exhibited a strong variation during day 2 (**Figure 3(b)**). From 7 am to 1 pm, it increased rapidly and reached its highest value of about 4 kPa between 1 pm - 2 pm. This was followed by a decrease that fell to 2 kPa late in the afternoon (7 pm).

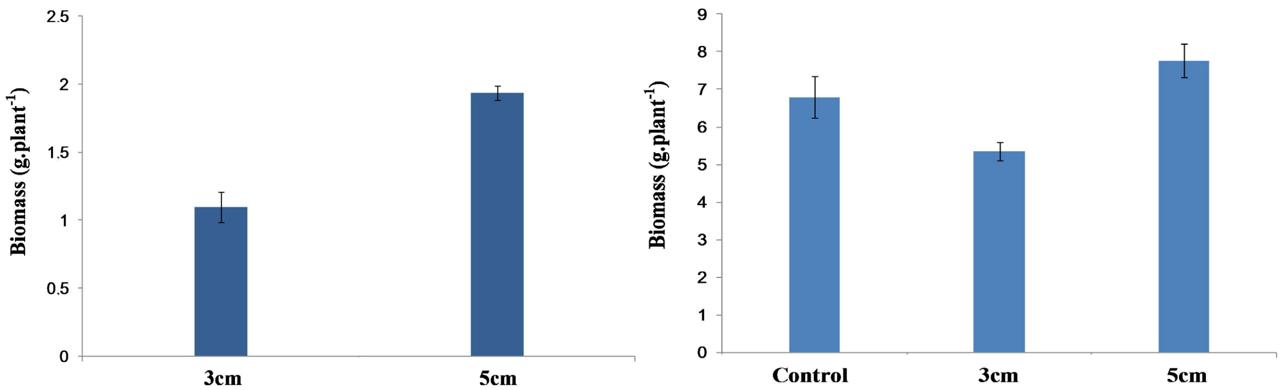
Figure 4 A shows the variation of transpiration during the day 1. The transpiration was low throughout the day regardless of the treatment. In the early morning, the cutting level showed no significant effect on transpiration. Besides, in late morning, the cut plants presented a trend to a lower transpiration compared to control plants. The rest of the day transpiration was quite similar for all treatments (**Figure 4(a)**).

Regarding day 2, results contrasted with those of day 1 (**Figure 4(b)**). Earlier in the day, no difference was observed between the different treatments. By contrast, in the late morning, the control plants showed a high transpiration that reached 90 mg·plant^{-1}. The cuts have had a significant negative effect on transpiration. Indeed, transpiration in cut plants was less than one-third that of control plants. In plants cut at 5 cm, transpiration presented a significant increase compared to that recorded in the early morning and it was significantly higher than that of plants cut at 3 cm. In the early afternoon, the transpiration differences between control plants and those cuts were still very important because



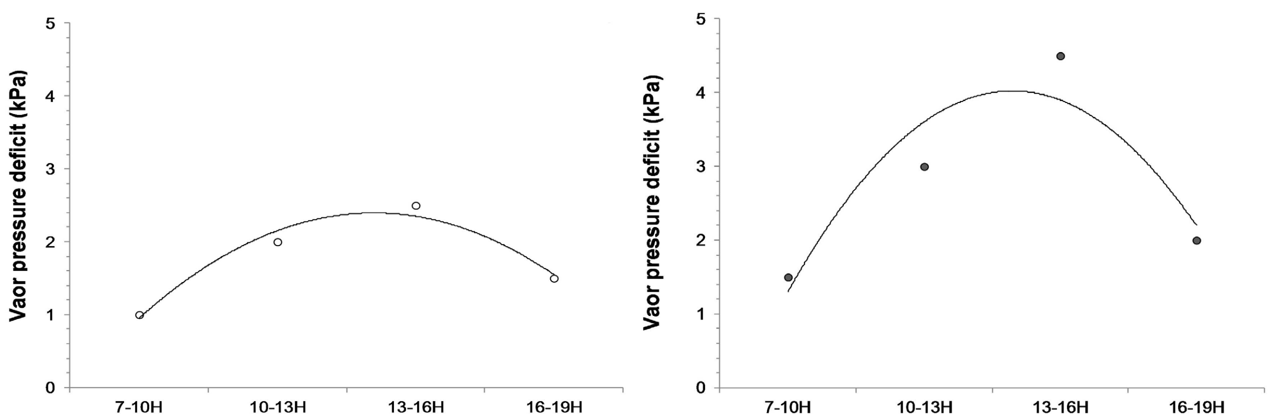
(a) (b)

Figure 1. Biomass production of *Cenchrus biflorus* subjected to shoot cuts at 3 cm et 5 cm from soil surface (a) and Total biomass production in *Cenchrus biflorus* plants subjected to shoot cuts at 3 cm et 5 cm from soil surface (b).



(a) (b)

Figure 2. Biomass production in *Cenchrus biflorus* plants subjected to shoot cuts at 3 cm et 5 cm from soil surface (a) and Total biomass production in *Cenchrus biflorus* plants subjected to shoot cuts at 3 cm et 5 cm from soil surface (b).



(a) (b)

Figure 3. Variation of vapor pressure deficit per hour (H): (a) during a cloudy day and (b) in a very sunny day. The data were recorded at the site of Dan Dicko Dankoulodo University of Maradi.

the transpiration of control plants was twice that of cut plants. In late afternoon, transpiration was low regardless of treatment, but slightly higher in cut plants (**Figure 4(b)**).

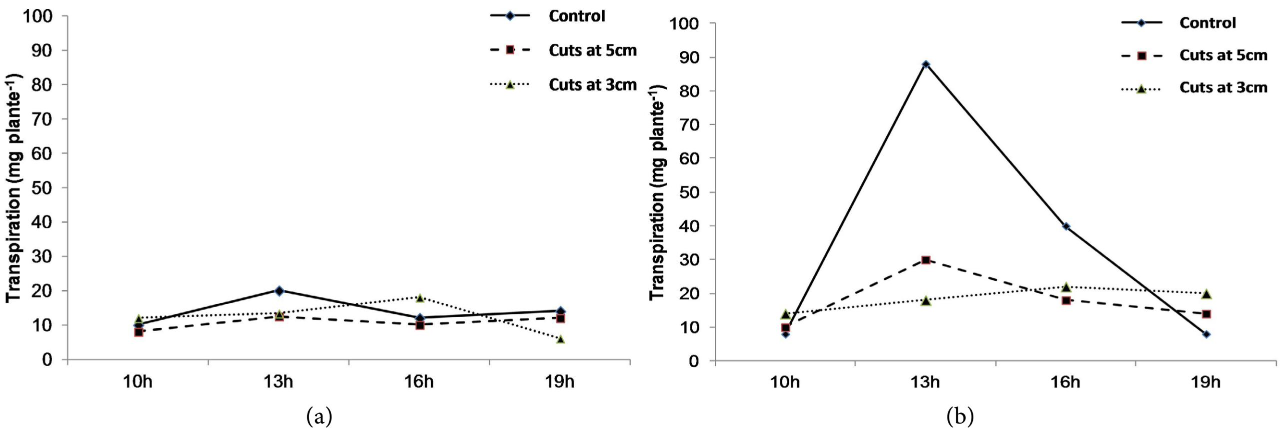


Figure 4. Diurnal variation of transpiration in Cenchrus per hour (h): (a) during a cloudy day and Diurnal variation of transpiration in C. biflorus and (b) during a sunny day.

5. Discussion

In general, among forage species, biomass is the parameter most often used to characterize the production. The grazing simulation done in *Cenchrus biflorus* in-situ on fields and in pots culture gave different results depending on the cutting level (3 cm and 5 cm) and the number of cuts. In most cases, the cuts have favored the production of biomass. These results are similar to those published by [17] which showed that the repeated cuts in the same place are a stimulus that increases biomass production. Biomass production in response to 5 cm cuts was higher on plots than in pots. This is largely related to fact that *Cenchrusb iflorus* prefers an open environment because of its very long and branched roots. The pot that provides only limited space, and unfavorable conditions for the expression of the potential of plants due to the confinement of the root system.

Low biomass production in the case of 3 cm cuts on both culture systems is an indication that this level simulates relatively severe grazing which does not allow rapid biomass regeneration. This low production observed is due to the reduction in leaf area, which compromises photosynthesis and growth. Limited photosynthesis reduces plant growth, which in turn reduces biomass. For this cut level, plants had even shown a negative effect on biomass compared to control plants, reflecting a high sensitivity to severe grazing *Cenchrus biflorus*.

The effect of VPD on transpiration in control plants showed a slight increase during the cloudy day regardless of the treatment. By contrast, during the sunny day, transpiration showed a significant increase as a result of the increasing VPD during the day. Indeed, an increase in the VPD, causes stomatal opening [18], with a subsequent increase in transpiration. The transpiration of cut plants was significantly lower due to smaller leaf surface. Therefore, the restriction of transpiration under increasing VPD, at different thresholds of VPD, can be a means of adaptation to water limiting condition. This can be an advantage in drought conditions for the plant to manage the little water available in the soil. As shown in **Figure 4(b)**, lower transpiration at high VPD is an important water conservation for which genotypic variation has been reported in other species such as pearl millet (*Pennisetum glaucum* L.,) [19], sorghum (*Sorghum bicolor* L,) [20], soybean (*Glycine max* L, Merr) [21] [22], peanut (*Arachis hypogaea* L.) [23], cowpea (*Vigna unguiculata* L,) [18] and recently on maize (*Zea mays* L.) [24] [25] [26].

Figure 4(b) shows lower transpiration at high VPD in plants cut mainly at 3 cm. This implies that the reduction in leaf area combined with partial or total closure of the stomata will limit the photosynthetic activity of the plants by reducing the supply of atmospheric CO_2. Stomatal closure would explain the low biomass produced by the species. This explains the low production recorded for these plants.

The results of the present study suggested clearly that grazing (simulated by cuts) can have positive and negative effects on biomass production depending on its intensity (cutting level). A severe grazing reduces the photosynthetic leaf surface so much that the plant is no longer able to ensure regeneration of biomass. Besides, moderate grazing stimulates the production of biomass that in most cases exceeds that of non-grazed plants. In addition, by reducing transpiration al water loss in plants, grazing may allow them to better tolerate water deficit.

6. Conclusion

The results of this study showed that implies that good pasture management can promote successful biomass regeneration and a significant reduction of drought effect. This management will be improved by involving all rangeland stakeholders in the development and implementation of climate change mitigation and adaptation measures. This work is a preliminary study which deserves to be pursued by the analysis of a large number of forage species to select those with the best ability to withstand the combined effects of grazing pressure and drought.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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