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Clipping and irrigation enhance grass biomass and nutrients: Implications for rangeland management

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Increasing frequency of drought and high herbivore pressure significantly affect individual grass functions in semiarid regions. Reseeding of degraded rangelands by native grass species has been recommended as a tool for restoration semiarid rangelands. However, how grass species used for reseeding respond to stressors has not been fully explored. We examined biomass allocation and nutrient contents of Cenchrus ciliaris and Chloris gayana in the semiarid Borana rangelands, Ethiopia. We tested clipped mature tufts of the same species for biomass allocation and nutritive values. Further, shifts in rainfall and herbivory were simulated by three irrigation and four clipping treatments, respectively, for newly established grasses in pot and field plot experiments. Aboveground biomass (AG_B) significantly declined by up to 75% under increased clipping in mature tufts. In contrast, clipping significantly stimulated up to 152% higher AG_B of newly established grasses. Lower irrigation reduced the AG_B by 24 and 42% in *C. ciliaris* and in *C. gayana*, respectively. Clipping, further, significantly enhanced grass nutrients in grass tufts by up to 82 and 105% in *C. ciliaris* and *C. gayana*, respectively. Hence, management should focus on balancing this trade-off in mature grasses for nutritious rangeland production by clipping and storing for later supplemental feeding when grass nutrients drop. Further, young pastures should be moderately clipped/grazed for better establishment and biomass allocation. Additionally, our experiments established the first interactive effect of clipping and irrigation frequencies on the biomass allocation of native grasses in the semiarid Borana rangelands, Ethiopia. Knowledge of these interacting factors is deemed essential for policy makers to enhance productivity of degraded rangelands such as the Borana rangelands.

1. Introduction

Maintaining productivity of rangelands requires extensive knowledge on how vegetation responds to the dominant environmental factors such as grazing and climate variability. Rangelands across the world are facing increasing pressure due to overgrazing and climate change (Chimner and Welker, 2011); drought and herbivory are the primary savanna stressors (Baruch and Jackson, 2005). Particularly in eastern Africa, drought and overgrazing have led to deteriorated rangelands and a subsequent die-off of livestock populations after severe droughts (Catley et al., 2014). Generally, climatic stresses account for about 63% of all stressors on land degradation in Africa (Porto, 2014) while overgrazing causes 49% of soil degradation, mainly in semiarid and arid regions of Africa (WRI et al., 1992). Hence, sound management of rangelands including reducing livestock numbers (Abusuwar and Yahia, 2010; Zhang et al., 2015), letting the pasture vegetation recover (Angassa and Oba, 2010), and reseeding with perennial grasses (Mganga et al., 2011; Tebeje et al., 2014) is required. However, often, intensive management activities have been neglected as little is known on the resilience of the existing grass species and which grass species would be most suitable for reseeding (Mganga et al., 2013).

The effects of herbivory on biomass production have been controversial. Many findings indicated that herbage dry matter yield decreases with increasing herbivory (Kramberger et al., 2014; Yan et al., 2012) but Martin and Chambers (2001) claimed that

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clipping had no effect on total biomass. Yan et al. (2012), observed that rotational, i.e., moderate grazing reduced aboveground biomass and increased belowground biomass whereas Gao et al. (2008) observed a decrease of belowground biomass with increasing grazing intensity. Further, responses of reseeded grasses to grazing at different age class have rarely been compared under variable rainfall amount, which is a dominant driver that governs primary productivity (Schönbach et al., 2012).

In semiarid rangelands, 90% of plant productivity occurs belowground but grass root responses to clipping are not as well understood as shoot responses (Balogianni et al., 2014; Zhou et al., 2012) due to the difficulty of estimating belowground net primary productivity (Gao et al., 2008). Yet, to successfully manage rangelands under herbivore and climatic pressure, there is an urgent need to understand resource allocation of grasses in response to such stress factors. Up till now, little is known about how grazing and water availability interactively affect the native above- and belowground productivity of grass species in reseeded semiarid rangelands.

In addition to forage biomass, the determination of plant nutrient contents is fundamental for rangeland management (Arzani et al., 2012) as livestock production is limited by forage nutritional yield (Ren et al., 2016). Thus, improvement in grass quality and quantity through reseeding with native, perennial grass species directly contributes to a sustainable cattle production (Homann et al., 2004). Cattle have been shown to select for high-quality grass (de Vries and Schippers, 1994), and under heavy grazing, it has been shown that dry matter has low nutritional values (Allison, 1985). In the Borana rangelands, not only grass quantity but also the quality of foraging sites showed significant spatiotemporal heterogeneity (Abebe et al., 2012a, 2012b; Keba et al., 2013; Teka et al., 2012). While it is known that grazing frequency greatly influences the nutritional value of grasses (Georgiadis and McNaughton, 1990), and thus, cattle production (Takele et al., 2014) empirical management recommendations are lacking particularly for Ethiopia's reseeded rangelands, which have paramount importance in protecting genetic erosion of the highly productive Boran breed (*Bos indicus*) (Homann et al., 2003).

Our experiments were aimed at resembling the two main pressures, herbivory and changes in rainfall regime, and their interactions in different intensities on two common rangeland grasses (*Cenchrus ciliaris* and *Chloris gayana*) in Ethiopian rangelands (Jorge et al., 2008). These grasses are widely used for reseeding (Tebeje et al., 2014) owing to their high digestibility and rapid growth (Angassa, 2005; Keba et al., 2013).

We aimed at answering the following research questions:

1. Will grazing influence both above- and belowground biomass of *C. ciliaris* and *C. gayana* similarly?
2. Will the two main rangeland grasses, *C. ciliaris* and *C. gayana*, vary in response to grazing at different ages?
3. What are the responses of grass biomass to increased or decreased irrigation amount?
4. Are the effects of clipping and irrigation interactive?
5. Will clipping decrease the digestibility and nutrient values of grasses?

2. Materials and methods

2.1. Study area

Our study area was located at Yabello Pastoral and Dryland Agriculture Research Centre (04°52′34″N and 038°08′48.0″E) in the Borana rangelands, southern Ethiopia. The annual rainfall of Yabello ranges from 327 to 1343 mm with a mean (±SD) of 645 (±232) mm, and is bimodal with 52% of rain occurring during the main rainy season (from March to May) and 31% occurring during the short rainy season (from September to November). The mean annual temperature is 20 °C with average maximum and minimum temperatures of 26 and 14 °C, respectively (National Meteorological Agency and Yabello weather station, Pers. Comm.). Textural class of the soil of communal Borana rangelands is sandy loam (Tefera et al., 2007b); and we selected sites with 17% clay, 14% silt and 69% sand for our experiments.

The Borana rangelands, which were once known for their outstanding rangeland management in Eastern Africa (Homann et al., 2003), are recently facing severe production problems. The rangelands' pasture vegetation has rapidly declined over the last decades due to increased cropping, bush encroachment, population increase and recurrent drought (Catley et al., 2014; Gemedo-Dalle et al., 2006). Consecutively, feed shortage has become the major challenge for animal production in the area (Tolera and Abebe, 2007). Reseeding of these grazing lands is recommended (Tebeje et al., 2014), and both *C. ciliaris* and *C. gayana* are native to the study area and highly suitable (Tefera et al., 2007a).

2.2. Experimental layout

We conducted a clipping experiment (3) under natural rainfall conditions during the rainy season (March to June of 2013) on already established grass tufts of both *Cenchrus ciliaris* and Chloris gayana species in the field to test grass biomass and nutrient allocation. Further, we tested grass regrowth in terms of aboveground biomass (AG_B) and belowground biomass (BG_B), across four levels of clipping frequencies (simulating herbivory) and three levels of irrigation (simulating rainfall regime) in the pot (1) and field plot (2) experiments from November 2013 to February 2014. For pot and field plot experiments, seedlings were grown in a seedbed in a lath house and then transplanted to the pots and field plots. The seeds used for seedling establishment were collected from the same locations where clipping experiments on the mature tufts were carried out.

Characteristics of the two study species are appropriate for the environmental conditions of our study area: *C. ciliaris* grows at an altitude below 2000 masl with more than 250 mm mean annual rainfall and can be found in areas of heavy grazing pressure (Mengistu, 2002). This species establishes well from seed and is suited for restoration of degraded areas. *Chloris gayana* is found at altitudes below 2400 masl with more than 600 mm annual mean rainfall, tolerating heavy grazing (Mengistu, 2002).

To evaluate biomass and nutrient allocation responses of already established study grass species to different clipping frequencies, we investigated mature individuals of *C. ciliaris* and *C. gayana* at locations where the grasses were found naturally under ambient rainfall conditions. We cut all grass tufts selected to an equal height of 10 cm, a height at which dry matter intake by livestock begins to decline (Chacon and Stobbs, 1976; Phillips, 2001), to have similar starting conditions. We considered tufts of equal circumferences in similar soil type (sandy loam) located at least 1 m apart from each other (Cahill, 2003). We clipped 28 and 30 tufts *of C. ciliaris* and *C. gayana*, respectively, based on grass species dominance. Further, *C. ciliaris* was grazed by cattle of the research centre to test whether hand clipping and animal grazing had similar effects on grasses (Acharya et al., 2012). Hence, we erected cage enclosures around all grass tufts to exclude uncontrolled animal herbivory throughout the experimental period. Cattle were allowed to graze from the specific tufts by removing the cages every week at the same time with tufts of weekly clipping. The treatments were (i) frequent (weekly clipped), (ii) moderate (biweekly