



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



Samuel Tuffa ^{a, b, *}, Dana Hoag ^c, Anna C. Treydte ^{b, d}

^a Yabello Pastoral and Dryland Agriculture Research Centre, P. O. Box 85, Yabello, Ethiopia

^b Department of Agroecology in the Tropics and Subtropics, University of Hohenheim, Garbenstr. 13, University of Hohenheim, 70599 Stuttgart, Germany

^c Department of Agricultural and Resource Economics in the College of Agricultural Sciences, Colorado State University, USA

^d Nelson Mandela African Institution of Science and Technology, Arusha, Tanzania

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ABSTRACT

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 reseeded 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.

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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).

* Corresponding author.

E-mail addresses: satukada@gmail.com (S. Tuffa), Dana.Hoag@colostate.edu (D. Hoag), anna@tretydte.com (A.C. Treydte).

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 reseeded 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 reseeded (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

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 (\pm SD) of 645 (\pm 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

clipped) and (iii) none (unclipped), each replicated ten times. In *C. ciliaris*, we had one more treatment (iv) weekly grazing (grazing), all replicated seven times.

To understand responses of newly sown grass species to herbivory and rainfall we ran two factorial experiments simultaneously in experimental field plots and pots. The levels of clipping frequencies were (i) frequent (weekly clipped), (ii) moderate (biweekly clipped), (iii) light (monthly clipped), and (iv) none (unclipped/control). We increased irrigation based on a likely increase by about 5% in mean annual rainfall predicted for East Africa (CDKN, 2014; Christensen et al., 2007; Meehl et al., 2007). Accordingly, we varied the irrigation amount as (i) an increased mean annual rainfall by 5% (“higher”), (ii) average rainfall (“mean”), which was a long-term (30 years) average April, i.e., growing season, rainfall. The long-term (1984–2013) mean rainy days for April occurred for about 15 days in Yabello district, and we used these rainy days as irrigation frequency. We further used (iii) a lower overall amount: 70% of mean annual rainfall (“lower”), which has been shown to happen in drought years (Palchaudhuri and Biswas, 2013; Sheffield and Wood, 2008) that have become more frequent over the last years (He et al., 2014). The entire pot experiment comprised 72 pots (6 blocks \times 3 irrigation \times 4 clipping) per species. The pots were set up in the lath house in a 3×4 factorial experiment in a completely randomized block design. In the field plots, we set up a blocked design in factorial experiment following a similar layout to that of pot experiment, but with 7 blocks, and hence 84 field plots per species.

2.3. Data collection

We measured every regrowth with a ruler before each clipping event. All clipped parts were oven dried at 60 °C for 48 h (Adesogan et al., 2000; Holub et al., 2013). Each clipping was cumulated for AG_B per treatment. The sampling method was destructive (Tackenberg, 2007) and all grass roots were removed at the end of the experimental period to estimate BG_B per grass individuals (Jensen et al., 1990). We estimated BG_B by excavating all root parts, washing and filtering them through a 1 mm mesh size strainer before drying to a constant weight. Before analyzing AG_B and BG_B of mature tufts, we carefully standardized for initial sizes of all tufts, which were estimated by measuring the circumference of each tuft at the crown (Acharya et al., 2012).

We determined nutritional composition of mature grasses using Near-Infrared Reflectance Spectroscopy (NIRS) for crude protein (CP), ash value (Ash), neutral detergent fiber (NDF), acid detergent lignin (ADL), true in vitro organic matter digestibility (TIVOMD) and acid detergent fiber (ADF) (Corson et al., 1999).

2.4. Data analysis

The AG_B, BG_B and nutritive values from mature tufts were subjected to one-way ANOVA with completely randomized block design to compare treatment effects, with irrigation and clipping as independent variables. Data generated from field plots and pots were analyzed for significant interaction by two-way ANOVA with the completely randomized block design. We used a significance level of $\alpha = 0.05$ with Fisher's least significant difference (LSD) test for significant main effects (clipping and irrigation) and Tukey's HSD test for significant interactions as post hoc test with GLM procedure of SAS (Littell et al., 2002). Analyses were done for each grass species separately and for each above- and belowground parts because species level response is essential for understanding community level response (Jobbágy and Sala, 2000). Data with non-normal residual distribution after Shapiro-Wilk test (Littell et al., 2002) were transformed before analysis.

3. Results

3.1. Aboveground biomass in mature tufts under clipping

The AG_B of mature *Cenchrus ciliaris* did not differ significantly across clipping treatments ($F_{(3,18)} = 1.81$, $p = 0.21$) but BG_B was 39% lower under no grazing compared to the other treatments ($F_{(3,18)} = 4.77$, $p = 0.013$; Fig. 1a). Weekly clipping resulted in BG_B similar to weekly grazing values, highlighting that clipping resembles the effects of grazing very well. In *C. gayana*, frequent and moderate clipping significantly reduced AG_B by 75 and 66% ($F_{(2,18)} = 17.88$, $p < 0.0001$), respectively, whereas BG_B did not significantly differ ($F_{(2,12)} = 0.33$, $p = 0.73$; Fig. 1b).

3.2. Aboveground biomass in newly established grasses under clipping

Clipping significantly increased AG_B ($F_{(3,61)} = 4.21$, $p = 0.009$) of *C. ciliaris* but only slightly increased BG_B ($F_{(3,61)} = 3.02$, $p = 0.037$; Fig. 2a) compared to no clipping in pots. In field plots, moderate and light clipping significantly increased ($F_{(3,72)} = 5.41$, $p = 0.0021$) AG_B by 24 and 17%, respectively (Fig. 2b), while frequent and no clipping led to lowest AG_B allocation. There was no significant difference observed in BG_B in the field plot experiments under the clipping treatments ($F_{(3,72)} = 0.76$, $p = 0.5224$; Fig. 2b).

3.3. Biomass allocation in grasses under irrigation

The lower irrigation amount significantly reduced AG_B in both *C. ciliaris* ($F_{(2,61)} = 8.49$, $p = 0.0006$; Fig. 3a) and in *C. gayana* ($F_{(2,61)} = 15.03$, $p < 0.0001$; Fig. 3b) in the pot experiment. Further, this irrigation decrease also significantly reduced BG_B in *C. ciliaris* ($F_{(2,61)} = 9.55$, $p = 0.0002$) and *C. gayana* ($F_{(2,55)} = 24.01$, $p < 0.0001$) (Figs. 3a and 4a, respectively) while a slight increase in irrigation amount did not have additionally positive effects on AG_B or BG_B.

3.4. The interactive effects of clipping and irrigation on biomass

In pots, clipping and irrigation interactions were significant only for the BG_B ($F_{(6,55)} = 24.01$; $p = 0.023$; Fig. 4a) but not for AG_B ($F_{(6,55)} = 2.18$; $p = 0.059$) of *C. gayana*. Under light and no clipping, the higher irrigation significantly increased BG_B while decreased irrigation kept the BG_B significantly low at all clipping treatments (Fig. 4a).

Clipping on its own led to significant differences in AG_B ($F_{(3,61)} = 14.03$, $p < 0.0001$) and BG_B ($F_{(3,61)} = 3.42$, $p = 0.022$) in the

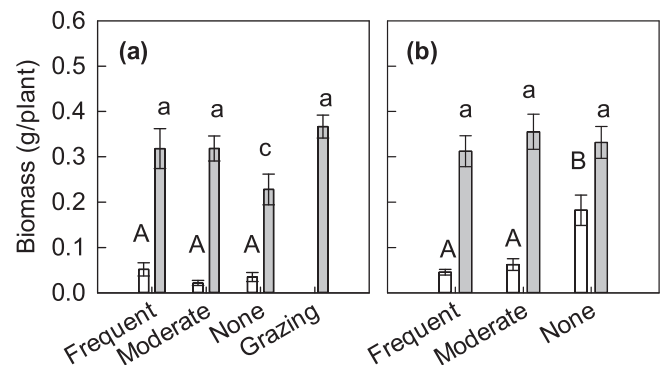


Fig. 1. Mean (\pm SE) of aboveground (white bars) and belowground (gray bars) biomass (AG_B and BG_B, respectively) across clipping frequencies of (a) mature *C. ciliaris* and (b) mature *C. gayana* tufts. Different letters denote significant difference across clipping frequencies.

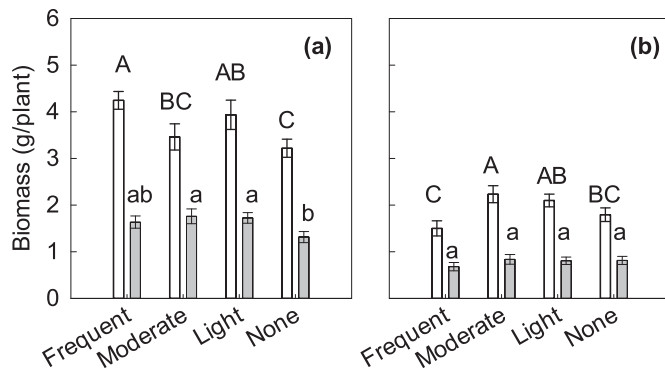


Fig. 2. Mean (\pm SE) aboveground (white bars) and belowground (gray bars) biomass (AG_B and BG_B, respectively) across clipping frequencies (frequent, moderate, light, none) of *C. ciliaris* in (a) the pot experiment and (b) the field plot experiment. Means in white bars followed by different upper case letters are significantly different. Means in gray bars followed by different lower case letters are significantly different across treatments.

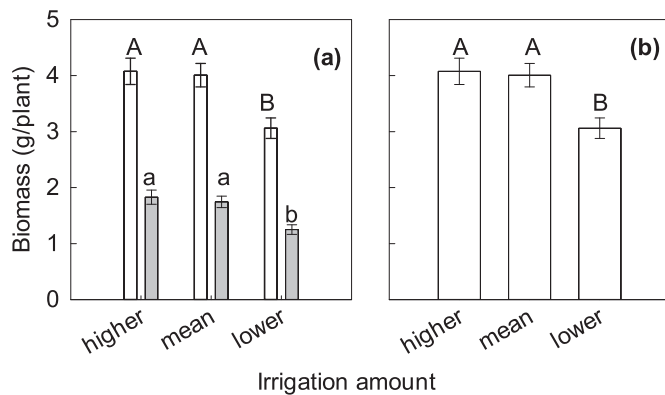


Fig. 3. Mean (\pm SE) aboveground (white bars) and belowground (gray bars) biomass (AG_B and BG_B, respectively) across irrigation amounts (higher, mean, lower) of (a) *C. ciliaris* and (b) mean (\pm SE) AG_B of *C. gayana* in the pot experiment. In the latter figure, we omitted the BG_B to avoid the ambiguity of presenting the same data twice since we present it in Fig. 4a as an interactive factor. Different letters denote significant difference across treatments.

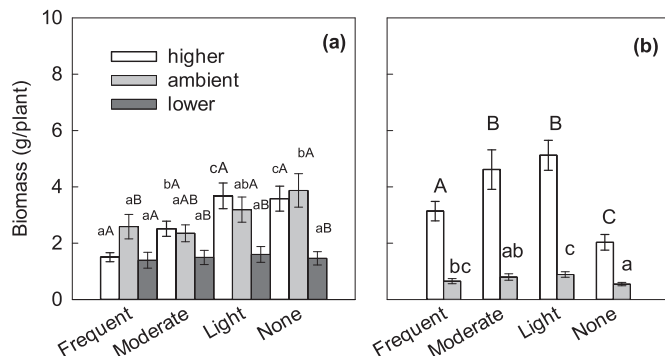


Fig. 4. (a) Interactive effect of clipping (frequent, moderate, light, none) and irrigation (higher, mean, lower) on belowground biomass (BG_B) of *C. gayana* in the pot experiment. Bar graphs with whiskers represent mean (\pm SE) BG_B across clipping frequencies and irrigation amounts. (b) Mean (\pm SE) aboveground (white bars) and belowground (gray bars) biomass (AG_B and BG_B, respectively) of *C. gayana* across clipping frequencies in the field plot experiment. Means of bars followed by different letters are significantly different.

field plot experiment while irrigation amount alone did not ($F_{(2,72)} = 2.92$, $p = 0.06$; $F_{(2,72)} = 1.12$, $p = 0.33$, respectively). In the

field plot experiment, the AG_B of *C. gayana* was by 127 and 152% significantly higher under moderate and light clipping, respectively (Fig. 4b).

3.5. Nutritive values of mature tufts under clipping

The nutritive values of the two study species showed similar patterns across our treatments. Clipping significantly increased CP and TIVOMD contents and (Fig. 5c and e, respectively) while crude ash significantly decreased with increased clipping (Fig. 5b). The ADL significantly decreased with increasing clipping frequencies in *C. gayana* but not in *C. ciliaris* (Fig. 5d) while ADF significantly increased with increasing clipping frequencies in *C. ciliaris* only (Fig. 5f).

4. Discussion

4.1. Aboveground biomass in mature tufts under clipping

The significantly reduced aboveground biomass (AG_B) of mature *Cenchrus ciliaris* and *Chloris gayana* under clipping was mainly caused by the removal of photosynthetic tissues, which was also reported by others (Bai et al., 2015; Gilbert and Fraser, 2013; Leriche et al., 2003; Shahzad et al., 2012). On the other hand, the enhanced belowground biomass (BG_B) under clipping and grazing compared to the unclipped control is in accordance with reports that grazing exclusion leads to reduced BG_B, which might be attributed to a lower demand of nutrients for growth under no defoliation (Shi et al., 2013; Stevens and Gowing, 2014). As such, reduced root growth reduces grass ability to compete for available water and nutrients (Engel et al., 1998) and, hence, becomes a survival challenge for grasses during drought (Hoogenboom et al., 1987). Therefore, grazing is an important factor for increasing belowground biomass and, thus, forage resources, which further increases grassland ecosystem services such as carbon sequestration (Larreguy et al., 2014). We found that grazing and clipping had a similar effect on biomass allocations, suggesting that clipping can be used as a proxy to identify grazing pressure effects on vegetation (Cuykendall and Marten, 1968). This result has paramount importance because the responses of dominant mature grass species help to understand ecosystem resilience in the face of climate change (Nippert et al., 2009).

4.2. Aboveground biomass in newly established grasses under clipping

The higher AG_B under moderate clipping frequencies compared to non-clipping highlights that controlled grazing can strongly enhance biomass in a newly established pasture. This might be attributed to the fact that plants have the capacity to compensate or even overcompensate for herbivory at low levels of grazing pressure (Mei et al., 2014; Veen et al., 2014).

The freshly reseeded grasses reacted more strongly with enhanced production to defoliation than already established grasses, which might be due to the high photosynthetic capability of young leaves (Nowak and Caldwell, 1984). In Contrast experiments using *Holcus lanatus* and *Lolium perenne* grasses showed that clipping stimulated older grasses more strongly than younger ones in producing clonal propagation (Aarssen and Turkington, 1987), which might be species specific artifact. Our findings have a paramount importance in the management of rangelands of different ages in areas such as Borana rangelands, where our study species have recently been recommended for reseeding activities (Tebeje et al., 2014).

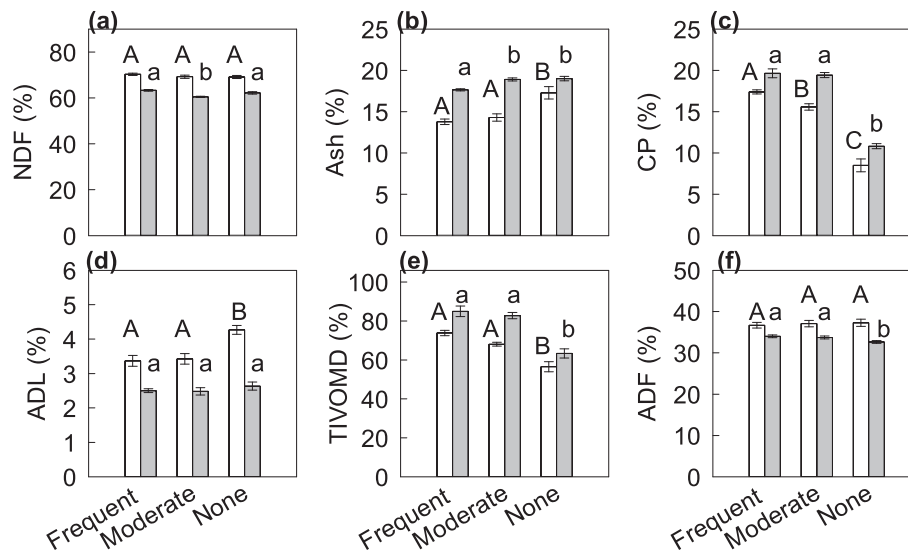


Fig. 5. Percentage (\pm SE) nutritive values (NDF, Ash, CP, ADL, TIVOMD and ADF; (a)–(f), respectively) in dry matter of *C. gayana* (white bars) and *C. ciliaris* (gray bars) across clipping frequencies (none, moderate and frequent). Means followed by different letters are significantly different across treatments. CP = crude protein, Ash = Ash value, NDF = neutral detergent fiber, ADL = acid detergent lignin, TIVOMD = true in-vitro organic matter digestibility and ADF = acid detergent fiber.

4.3. Biomass allocation in grasses under irrigation

The decreased irrigation reducing AG_B and BG_B of both grass species in our pot experiments showed that rainfall plays an overriding role in dictating productivity of grasses in semiarid environments. A 30% lower rainfall regime, a trend predicted for eastern Africa in the future climate change scenarios (Sheffield and Wood, 2008), would, therefore, lead to a 31 and 40% lower AG_B and BG_B , respectively, as water stress leads to reduced daily leaf extension (Busso and Richards, 1993). This result implies that under drought conditions grazing seems less important for grass productivity (Muthoni et al., 2014; Xu et al., 2013). Irrigation effects were not significant for both grass species in the field plot experiment. This might be attributed to potential horizontal and vertical seepages of water out of the field plots (Ochoa et al., 2009), which were not an artifact in the pot experiments.

4.4. Interactive effects of clipping and irrigation on biomass

The significant interactions between clipping and irrigation for BG_B suggested that low grazing pressure can enhance BG_B under mean or high rainfall, but not under low rainfall conditions, as reported by others in ecosystems of the Sahel (Le Houerou, 1989). These changes might be attributed to morphological, physiological and biochemical changes in moisture-stressed plants, resulting from reduced CO_2 assimilation rates due to low stomatal conductance (Anjum et al., 2011). Further, a high BG_B of *C. gayana* at high rainfall in unclipped compared to clipped treatments indicated that under controlled grazing high rainfall can greatly enhance grass productivity. This might be an opportunity for some east African regions, where higher rainfall is predicted under the future climate change scenarios (Christensen et al., 2007). An increase in BG_B under clipping and irrigation combined at light and no clipping and a reduction under frequent and moderate-clipping might be attributed to slow elongation and decreased production of new roots (McInenly et al., 2010) as well as a reduced leaf extension rate due to water stress and biomass removal (Busso and Richards, 1993). Future grazing management should consider resting times of grazing areas for better biomass allocation and grass survival as BG_B plays a significant role in the long-term sustainability of

rangelands (Engel et al., 1998; Hoogenboom et al., 1987). With our experiments that combined above- and belowground biomass allocation as grass species responses to herbivory are useful in order to understand grazing land ecosystem functions and resilience (Bardgett and Wardle, 2003). Restoration of degraded rangelands with perennial grasses plays an increasingly important role in rangeland sustainability (Christensen et al., 2005; Haddad et al., 2015; Mapfumo et al., 2002). Particularly, lowlands (highly productive areas and fallback pockets), which can potentially maintain the entire semiarid rangeland production system will require sufficient grass supply (Scoones, 1995). This supply could be a combination of reseeded and mature perennial grasses. While it has already been established that cropping of staple food is unsustainable in rangeland systems (Angassa and Oba, 2008; Solomon et al., 2007), some still support cultivation (Ng'ang'a et al., 2016), which is, under current and future climatic conditions, prone to frequent crop failure (Tache and Oba, 2010; Tolera and Abebe, 2007). This current trend of cultivating lowlands (Ng'ang'a et al., 2016) will lead to an extinction of important perennial grasses (Angassa and Oba, 2010; Solomon et al., 2007) and will, consecutively, undermine the resilience of rangelands (Elias et al., 2015).

4.5. Nutritive values of mature tufts under clipping

The main feed resource of Boran cattle (*Bos indicus*), which is the most important livestock species in the region (Zander et al., 2009), is a natural pasture that shows seasonal variability not only in quantity but also in quality (Tolera and Abebe, 2007). In the Borana rangelands, grass species such as *C. ciliaris*, which has been ranked first as preferred cattle forage species by pastoralists (Keba et al., 2013), is decreasing at an alarming rate (Angassa, 2014). While it is possible to reserve grass as standing hay in enclosures (Angassa and Oba, 2010) the quality of grasses drops significantly during dry seasons (Abebe et al., 2012a, 2012b; Keba et al., 2013). However, compared to other local grass species (such as *Leptochloa fusca*, *Cynodon dactylon* and *Panicum colonum*), *C. ciliaris* *C. gayana* have higher nutritive values with low ash contents (Sultan et al., 2011). Our results, which were within the range of the study species (Abebe et al., 2012b; Keba et al., 2013), clearly indicated that clipping can significantly increase grass nutrient quality in both

C. gayana and *C. ciliaris*. Clipping decreased the ash content by 20 and 7% while it increased CP content by 105 and 82% in *C. gayana* and *C. ciliaris*, respectively. Similar findings were reported by other researchers for grazing and clipping in the same as well as other species (Georgiadis and McNaughton, 1990; Leriche et al., 2003; Pavlu et al., 2006). Clipping also improved the true in vitro organic matter digestibility (TIVOMD) by 31 and 34% in *C. gayana* and *C. ciliaris*, respectively. Therefore, we recommend that grasses should be clipped and stored for dry season or drought period supplementation, for instance, by the cut-and-carry principle or put-and-take stocking during their growth periods (Allen et al., 2011; Mekuria, 2013) to fortify the deficient forage. This can be done at an enclosure level, Kalo (Lind et al., 2016), which can provide nutritious feed for calves and attenuated cattle during the dry season or drought.

Grasses should be cut while still growing for better nutritional quality rather than waiting until maturity, the latter being a common practice in the Borana rangelands. Further, our two study grass species not only occur in Borana but also in rangelands across the world; for instance, *C. ciliaris* is the only cultivated grass in its area of origin and of potential application in other climate zones while *C. gayana* is the most important cultivated tropical grass of today (Boonman, 1993; Marshall et al., 2012). Hence, understanding their resilience towards drought and herbivore pressure has global implications.

5. Conclusions

Our findings have important implications for the management of grasses of different ages in semiarid areas such as Borana rangelands, mainly where the two study grass species are recommended for restoration of degraded rangelands. We observed different results in grass biomass allocation between mature and young grasses. As such, rangeland management should incorporate the age of dominant perennial grasses for better biomass production in the restored rangelands. Our study showed that the high biomass production of grasses was overridden by frequent clipping when irrigation was high. Hence, a resting period is recommended for years with increased rainfall for better biomass allocation of the study grass species. In contrast, reduced rainfall can also strongly reduce biomass allocation in grasses, highlighting that under climate change an even more conservative management regime of low cattle grazing should be preferred. Therefore, long-term practiced exclosures and reseeding of degraded areas should be lightly and moderately clipped or grazed to enhance the overall biomass yield of the rangelands when grasses are young. Generally, our findings provide important information for local decision makers, which might enhance the establishment and management of reseeded areas in the Borana rangelands. However, future experiments should cover long-term studies to clarify the potential of those grass species that proved to be promising within our study. The results from this study will greatly increase the available information on above- and belowground production in *C. ciliaris* and *C. gayana*. Our results very likely could be used to manage restored sites in other semiarid ecosystems reseeded by grasses of the same species. We recommend that the traditional way of pastoralism, including resting places that exclude grazing (Kalos), should be supported; and that new management alternative such as reseeding should be further explored with other potential grasses to prove if there are species-to-species differences between grasses used.

Author contributions

ST, AT conceived and designed the research; ST performed the experiments and analyzed the data; ST wrote the manuscript and

AT and DH edited the manuscript.

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