


Cutting Date Impact on the Herbaceous Layer in Sahelian Rangeland During the Wet Season

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Abstract:

Annual herbaceous vegetation is a crucial source of forage for pastoral livestock in the Sahel region. These species grow during the wet season, which coincides with the peak grazing period. Understanding the impact of disturbances on annual herbaceous vegetation is then essential. This study focuses on the temporal aspects of disturbance.

In northern Senegal, we established nine different plots and cut them weekly during the wet season and returned to each plot at the end of the season to create a gradient of cutting dates. We measured the plant's phenology, height, dry biomass, and fodder quality.

Our results indicated that vegetation growth occurs in three phases: establishment, growth, and flowering. The impact of cutting varied across these phases. Plots cut during the establishment phase exhibited vegetation characteristics similar to those of uncut plots. Plots cut during the growth phase had reduced vegetation height but all individuals completed their growth cycle. Plots cut during the flowering phase had significantly lower biomass at the end of the season and experienced a slight delay in phenological development and increase the quality of the fodder at the end of the season. These findings highlight the importance of cutting timing on vegetation dynamics.

Keywords: Phenology; Dry mass; Fodder quality; seasonality

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1. Introduction

The Sahel belt is the southern fringe of the Sahara Desert, extending from Senegal in the west to Somalia in the east. The climate of this region is characterized by a short rainy season, with annual rainfall ranging between 150 mm and 600 mm (Nicholson, 2013). Rainfall is highly seasonal, with a wet period from June to October, followed by a dry season for the remainder of the year. Pastoral livestock farming is the predominant agricultural activity, with approximately 292 million an-

imals (donkeys, horses, cattle, sheep, goats, and camels) in the region (FAO, 2020). This livestock primarily depends on natural vegetation for grazing.

The Sahelian vegetation is dominated by an annual herbaceous layer, interspersed with scattered perennial species (e.g., perennial grasses, shrubs, and trees) (Hiernaux & Le Houérou, 2006). Livestock rely on this vegetation for grazing throughout both the wet and dry seasons. While animals also feed on tree foliage, their primary source of nutrition during the wet season comes from annual grasses (Assouma et al., 2018; Schlecht et

al., 1999). During the wet season, the intake of green herbaceous biomass constitutes nearly half of the animals' annual forage intake. This period also sees a higher density of grazing animals compared to the dry season. Livestock in the Sahel are highly mobile, moving between areas depending on feed availability. They are present in the region during the wet season but migrate elsewhere when the dry season begins.

Herbaceous species in the Sahel are heavily influenced by grazing pressure. Previous studies have documented the long-term effects of grazing intensity (Hiernaux, 1998), cutting frequency (Hiernaux & Turner, 1996), and nutrient inputs (Hiernaux et al., 1995) on biomass production and species composition in rangelands. Globally, species diversity is greater in the grazed areas than in the protected (fenced) sites (Wieczorkowski & Lehmann, 2022), suggesting that grazing can enhance species composition through seed dispersal by animals. However, to our knowledge, no studies have yet examined the temporal aspects of these management practices on herbaceous vegetation. The growth of annual herbaceous species in the Sahel is closely tied to rainfall patterns during the wet season (Diatta et al., 2021). Germination occurs with the first rains, though some species are able to germinate with lower rainfall amounts, while others require more substantial precipitation (Hérault & Hiernaux, 2003). After germination, growth remains slow during the establishment phase (characterized by tillering and root system development). Vegetative growth accelerates as plants mature, culminating in the flowering phase (Diatta et al., 2023a). Throughout this growth period, fodder quality typically declines (Diatta et al., 2023b), with the highest fodder quality observed during the early stages of growth, followed by a decrease in nutritional content, such as nitrogen levels.

Our hypothesis is that the response of herbaceous vegetation in terms of biomass production, fodder quality and phenology to cutting depends on the phenological stage at which the vegetation is cut. The objective of this study was to investigate the impact of cutting timing on herbaceous vegetation in the Sahel. To achieve this, we conducted weekly cutting of different herbaceous vegetation plots during the growing phase and revisited these plots at the end of the growing season.

2. Material and methods

2.1 Localization of the experiments

The experiments were conducted at the Centre de Recherches Zootechniques of the Institut Sénégalais de Recherches Agricoles (ISRA) in Dahra Djoloff, located in northern Senegal (15°21' N; 15°26' W). The center covers an area of 6,800 ha, including 5,000 ha of natural rangeland (Ndiaye et al., 2014; 2015). The rangeland is neither sown nor plowed and contains only spontaneous species. Approximately 800 ha of this rangeland is enclosed by fencing. These fields provide forage for the center's 160 Gobra zebu cattle during the dry season.

Rainfall was measured near the experimental plots.

Total rainfall during the 2017 wet season amounted to 316 mm (rainfall events are detailed in the supplementary material). The first rain event occurred on June 24, and the last on October 11. Between June 29 and July 29, only a single rainfall event was recorded, with 3.5 mm of rain. This period thus marked a significant break in rainfall during the wet season.

2.2 Sampling design

Measurements were conducted in a fenced area to eliminate grazing effects on our surveys. Three 400m² (20 × 20m) plots on sandy soil, devoid of tree cover, were selected. In 2017, the vegetation in the first two plots (P1 and P2) was predominantly dominated by the legume species *Zornia glochidiata*, while the third plot was primarily dominated by the forb *Diodella sarmentosa* (Rubiaceae). Both species are annual species with short phenology. *Diodella sarmentosa* is an invasive species that is inedible and is ultimately consumed. A complete list of species for each plot is provided in the supplementary material.

During the growing season, vegetation was cut weekly, beginning one week after the first rainfall event (July 3) and continuing until September 30. In each of the three plots, three 1m² (1 × 1m) subplots were randomly positioned each week (the subplots were marked by randomly throwing a square). Various measurements were taken on the herbaceous vegetation in each subplot (see the measurement section for details). The entire herbaceous biomass within these subplots was cut and collected (Akpo & Grouzis, 2000). To minimize any buffering effects, we also cut the surrounding 50 cm on each side of the subplots. The position of each subplot was marked with metal labels.

At the end of the rainy season (between October 10 and 24), we revisited the 1m² subplots using the metal labels for orientation. On each plot that had been cut during the growing season, we come back on the different plots and did the same measurements. This way we obtained a cutting date gradient starting with plot cut 9 days after the first rain to plot cut 98 days after the first rain.

2.3 Vegetation measurements

During the growing season monitoring and at the end of the season, we made the same measurements on the vegetation.

2.4 Plant Height

In each quadrat, 10 plant individuals were randomly selected. We measured plant height following the random individual sampling method proposed by Lavorel et al. (Lavorel et al., 2008). Vegetative height (H) was recorded (in cm) from the ground level to the highest leaf. Reproductive height (RH) was measured as the distance from the ground level to the apex of the flower or fruit. Reproductive height was recorded only for individuals in the flowering stage. Both heights were measured on the standing plants.

2.5 Phenology

The phenological stages of each individual were assessed using the Zadok scale (Zadoks et al., 1974). The Zadok scale is divided into nine main stages (ranging from 1 to 9), representing the primary phenological phases, with stage 1 corresponding to the germinative stage and stage 9 to senescence. Each stage is further subdivided (e.g., for monocotyledons, stage 1.1 corresponds to a plant with one leaf, and stage 1.2 corresponds to a plant with two leaves). However, due to the difficulty related to evaluating these subcategories over the entire 1m² subplot, we estimated the average phenological stage of the 10 randomly selected plant individuals measured for the height.

2.6 Vegetation cover

Additionally, we assessed the ground cover within the 1m² quadrat, categorizing the vegetation into the nine general Zadok stages (Z1 to Z9). The overall vegetation cover within each subplot was also estimated and recorded as cover.

2.7 Forage dry matter yield

The herbaceous layer was harvested from each 1m² quadrat, with all plant material collected. Fresh biomass (FM) was measured immediately after the cut, while dry mass (DM) was determined after drying the fresh biomass at 60 °C for 48 hours. The dry matter content (DMC) was calculated as the ratio of dry mass to fresh mass.

2.8 Forage Quality

We assessed several forage quality parameters from the dried biomass samples using Near-Infrared Reflectance Spectroscopy (NIRS). NIRS is a non-destructive method used to estimate the chemical composition of plant biomass.

Reflectance spectra were collected using an ASD Lab-Spec Pro spectrometer (ASD, Boulder, CO, USA) over a wavelength range of 350–2500 nm. Spectra were taken from ground samples sieved through a 1 mm mesh and placed in ring cells with quartz glass. Duplicate measurements (from two separate cup fillings) were averaged for each sample.

For calibration purposes, existing models from CIRAD (Montpellier, France) were adapted to our samples. A subset of the samples was analyzed using reference methods in the laboratory. NIR calibration was performed using modified Partial Least Squares (PLS) regression with the WINISI software (Version 4, Infrasoft 185 International, Port Matilda, PA, USA).

Total ash (MM) was determined by ashing at 550°C. Crude protein (CP) content was measured using the Kjeldahl method. Fiber content was analyzed using the Van Soest sequential method (Van Soest et al., 1991), providing measurements of Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), and Acid Detergent Lignin (ADL).

In vitro digestibility of dry matter (IvDMD) and or-

ganic matter (IvOMD) were measured using an in vitro enzymatic method with pepsin and cellulase (Aufrère et al., 2007).

2.9 Statistical Analysis

To examine the trends of variation in vegetation growth during the season, an analysis of variance (ANOVA) was performed to compare the different vegetation variables across different measurement dates. The ANOVA was followed by a Tukey HSD post hoc test to identify significant differences between groups. Similarly, the effects of the cutting date on vegetation variables measured at the end of the season were analyzed using ANOVA. Tukey HSD post hoc tests were again used to identify significant differences between the cutting dates.

2.10 Cumulative Dry Mass

At the first cut during the growing season, biomass was collected to estimate primary production. To assess seasonal production, we combined the measurement made during the season (first cut) and the measurements made at the end of the season (second cut), providing a measure of total seasonal primary production.

Additionally, digestible organic matter (DOM) was calculated by the multiplication of dry mass DM, Organic matter content (1-Ash) and digestibility of organic matter (IvOMD). We used it to evaluate the total amount of feed produced throughout the season that could be utilized by the livestock.

3. Results

3.1 Phenological Stages

Z1, the germination stage of the Zadok scale, was the only phenological stage present throughout the entire growing season. It was the predominant stage (100%) on the first sampling date (9 days after the first rainfall). This percentage declined to 3% by the final measurement (98 days after the first rainfall) (Figure 1a).

Z2, the tillering stage, appeared between days 16 and 65 after the first rain, with the percentage of tillering coverage consistently below 10% (Figure 1b).

Z3, the elongation stage, first appeared on day 16 and covered approximately 80% of the vegetation from day 39 to day 65, after which it nearly disappeared for the remainder of the season (Figure 1c).

Z5, beginning and Z6, full flowering stages, reached a maximum of 5% coverage (on day 77 for Z5 and day 90 for Z6).

Z7, the beginning of the fructification stage, was predominantly present on day 77, with an average coverage of 28% (Figure 1d).

Z8, the full fructification stage, appeared on day 77 with 46% coverage, peaking at 63% on day 81, and then sharply declining towards the final measurement (Figure 1e).

Z9, the senescence stage was first observed on day 77 with 1.4%, reaching 85% by the last sampling date (day 99) (Figure 1f).

Based on ANOVA results (Table 1), three distinct periods of growth can be identified:

1. **Early Growth (Days 9–44):** During this period, the growth was minimal, with dry mass around 10 g/m^2 , vegetation covers at approximately 30%, and plant height averaging 5 cm. Biomass quality was high, with crude protein (CP) content stabilizing at around 20% dry matter (DM), total fiber (NDF) slightly increasing from 30% to 33%, and in vitro digestibility (IvDOM) stabilizing around 75% after initially reaching 80%.
2. **Mid-Growth (Days 56–81):** From day 56 to day 81, the dry mass increased substantially, reaching around 217 g/m^2 , accompanied by an increase in vegetation cover (85%) and height (approximately 33 cm). However, biomass quality declined sharply, with CP dropping to 12%, NDF increasing to 46%, and IvDOM decreasing from 75% to 59%.
3. **Late Growth and Senescence (End of Season):** By the end of the season, dry mass remained stable at 200 g/m^2 , with cover at 80% and height at 34 cm. Biomass quality continued to decline, with CP falling to 9%, NDF rising to 53%, and IvDOM decreasing by another 10%, ending at 48%. Lignin (ADL) content increased from 1% to 12%.

3.2 Impact of Cutting Periods

At the end of the season, we come back on the different subplot to assess the vegetation after different regrowth timing.

*plots that had been cut during the growing season were predominantly in the senescence stage (Z9), with coverage exceeding 80% for subplots cut between days 9 and 65. This percentage dropped to 27% for subplots cut on day 98. The fruiting stage (Z8) remained present at the end of the season, especially in plots cut after day 44, with a percentage greater than 10%. This stage peaked at 50% in plots cut on day 90. In contrast, the flowering stage (Z6) was still prominent in plots cut on day 98 (25.8%) (Figure 2).

ANOVA results between plots with different cutting dates (Table 2) revealed three distinct trends, reflecting differences in vegetation dynamics at the end of the season based on cutting timing.

Height, Dry Mass, and Fodder Quality

- **Early Cuts (Days 9–44):** Subplots cut early in the season had a similar dry mass (around 130 g/m^2), vegetation cover (around 75%), and plant height (around 30 cm) compared to the uncut plots at the end of the season (Table 1). Biomass quality was low, with CP around 9%, NDF around 55–60%, and IvDOM around 45%.
- **Mid-Season Cuts (Days 56–65):** Subplots cut during the mid-season showed lower dry mass (around 85 g/m^2), vegetation cover (65%), and plant height (around 20 cm) at the end of the season. However, biomass quality improved compared to the early

cuts, with CP averaging 11% and IvDOM around 50%.

- **Late Cuts (Days 77–98):** Subplots cut later in the season showed a further decline in dry mass, from 60 g/m^2 on day 77 to only 5 g/m^2 by day 98. Vegetation cover and height also decreased (from 65% to 4% and 18 cm to 8 cm, respectively). In contrast, the quality of the remaining biomass increased, with CP levels rising from 14% to 16%, NDF decreasing from 45% to 41%, and IvDOM increasing from 60% to 65%. ADL content decreased from 12% in early-cut subplots to 7% in those cut late.

3.3 Cumulative Dry Mass

To assess the impact of cutting on yearly herbaceous biomass production, we combined the dry mass data from both the growing and end of the season (Table 3). ANOVA results revealed that cumulative dry mass in plots cut early in the season (day 9) was lower (around 150 g/m^2) compared to plots cut in the middle of the season (day 65), which had a cumulative dry mass of around 200 g/m^2 . Plots cut at the end of the season had the highest cumulative dry mass (around 260 g/m^2), although the last-cut plots had lower values. Despite differences in digestibility, the amount of digestible organic matter followed the same trend as cumulative dry mass (Table 3), with the highest value observed on day 81.

4. Discussion

4.1 Vegetation trends during the season

The growth dynamics of the herbaceous layer during the wet season can be divided into three main periods. The first phase, the “establishment stage”, begins with plant germination following the first rainfall event. In our study, this stage was relatively prolonged, lasting almost a month. One possible explanation for this is the rainfall break in the 2017 wet season. Between June 29 and July 28 in 2017, there was only one rainfall event on July 7, which amounted to just 13 mm (see Appendix). During this time, both the tillering (Z2) and elongation (Z3) stages were observed (Figure 1).

The second phase was the growth phase, characterized by an increase in biomass. This phase began with a return of frequent and substantial rainfall at the end of July, leading to an increase in vegetation cover, dry mass, and plant height. The final phase, the reproductive stage, saw most plants flowering between days 77 and 81, and most becoming senescent between days 90 and 98. This reproductive pattern was consistent with observations in 2018–2019 at the same experimental station (Diatta et al., 2021; 2023a; 2023b). Thus, the 2017 season is the representative of the general dynamics observed in the Ferlo region of northern Senegal.

The phenology of herbaceous species in this region is adapted to the local rainfall patterns (Cissé, 1986). However, reproductive events of Sahelian herbaceous

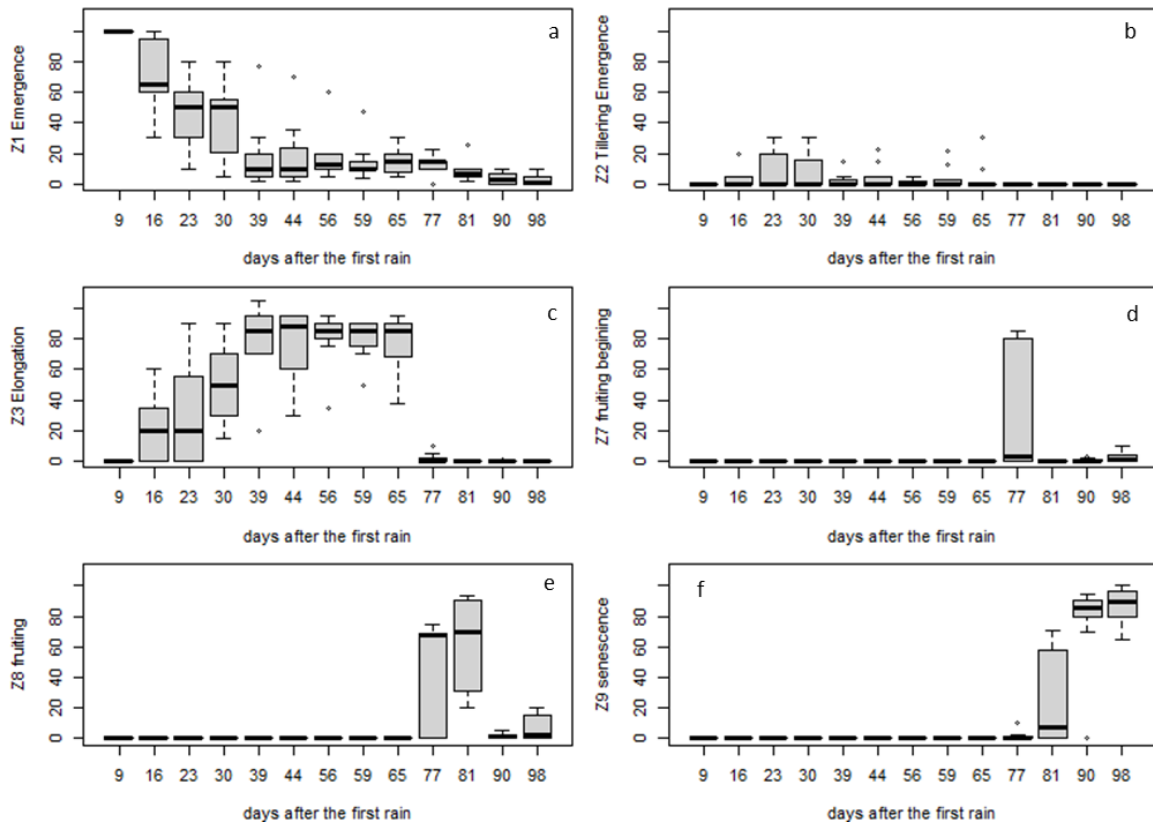


Figure 1. Dynamics of the different Zadok stages each week during the growing season. The percentage of cover was estimated visually. The x-axis corresponds to the date of the different measurements. We used the number of days after the first rainfall events to describe the dates of the measurement

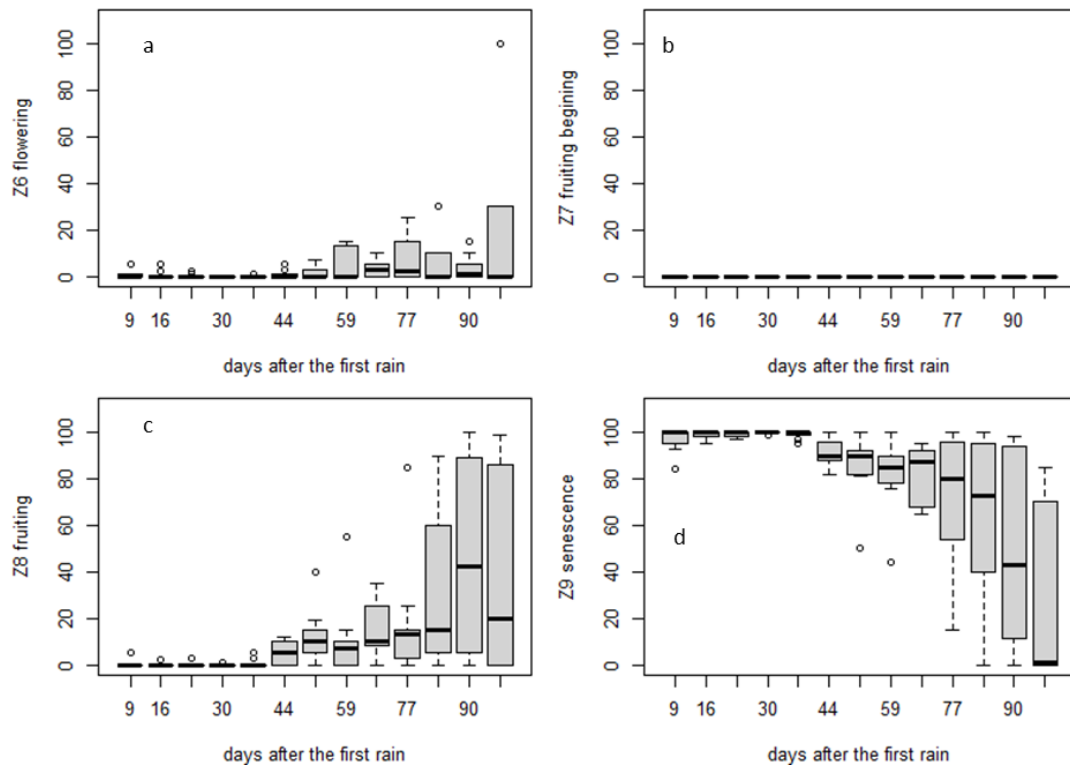


Figure 2. Dynamics of the different Zadok stages regarding the date of the cut.. The percentage of cover was estimated visually. The x-axis corresponds to the cutting dates. We used the number of days after the first rainfall event to describe the cutting date.

Table 1. Comparison of the vegetation variable between the different dates during the growing season (first cut)

Growth stage	Cutting dates	DM g.m ⁻¹	DMC %	Cover %	H cm	HR cm	CP %	Ash %	IvOMD %	IvDMD %	ADF %	NDF %	ADL %
Early Growth	9	1.61a	0.54a	27.22a	2.83a	-	19.87b	15.64e	84.07g	71.66ef	14.62a	29.50a	1.55a
	16	7.82a	0.38b	23.56a	4.70ab	-	20.2b	14.14e	80.01fg	72.72f	17.60ab	29.56a	3.62ab
	23	11.13a	0.36b	31.44a	5.63ab	-	20.24b	13.9de	76.90eg	69.62ef	19.38ac	31.63ab	4.99ac
	30	11.43a	0.36b	34.5a	5.69ab	-	18.82b	13.06de	75.67eg	71.61ef	21.77bcd	34.97abc	5.67acd
	39	11.72a	0.36b	26.11a	5.33ab	-	19.63b	14.51e	75.43eg	67.99ef	20.34ad	32.26ab	5.86bcd
	44	9.12a	0.36b	28.33a	5.4.00ab	6.00a	21.71b	13.15de	75.25eg	69.71ef	20.27ad	32.65ab	5.83bcd
	56	58.09ab	0.36b	50.11b	10.01bc	10.73a	20.57b	13.75e	75.07ef	65.81def	20.71ad	34.46abc	5.24ac
Mid-Growth	59	82.39b	0.36b	47.89b	13.95cd	11.15a	17.59b	12.98bce	68.66de	61.36ce	24.94cde	39.95bd	6.29bcd
	65	107.55b	0.36b	76.67c	19.26d	16.54a	17.61b	13.05ce	64.64cd	56.71bcd	26.87df	41.63cd	7.91ce
	77	183.65c	0.36b	87.83c	29.36e	31.3b	12.39a	9.79acd	58.26bc	53.68acd	32.70fg	46.83de	8.26ce
	81	216.77c	0.36b	85.56c	33.08e	33.89b	12.02a	8.95ac	58.87bc	54.01ac	31.5efg	45.79de	8.31ce
Senescence	90	238.06c	0.36b	82.56c	34.72e	35.92b	10.53a	8.33a	53.84ab	49.62ab	35.00gh	48.59de	9.80de
	98	201.33c	0.36b	81.56c	34.22e	36.01b	9.23a	8.76ab	48.41a	45.94a	39.70h	53.11e	11.51e

for each variable, the mean value is at one date, and the letter corresponds to the Tukey (HSD). DM (Dry matter), DM content (dry matter content, Cover (estimated vegetation cover), H height, RH reproductive Height, CP crude protein content, IvOMD: In Vitro DM digestibility, IvOMD (In Vitro OM digestibility

Table 2. Comparison of the vegetation variable between the different cutting dates at the end of the season (second cut)

Cutting dates	Cutting dates	DM g.m ⁻¹	DMC %	Cover %	H cm	Rh cm	CP %	Ash %	IvOMD %	ADF %	NDF %	ADL %
Early Cuts	9	134.00df	0.36a	84.44e	29.74eg	31.09de	9.39a	8.71a	47.77ac	41.20de	55.61de	12.17a
	16	126.89df	0.47ab	74.44de	30.71eg	32.67de	8.99a	8.01a	46.93ac	41.61de	55.84de	12.00a
	23	139.44ef	0.62b	78.56de	31.11fg	32.28de	8.68a	8.71a	42.17a	45.51e	61.93e	12.82a
	30	137.00df	0.59b	81.11de	33.52g	33.83e	9.46a	9.35a	45.57ab	43.49e	55.64de	12.46a
	39	163.78f	0.46ab	79.44de	33.97g	34.37e	9.90ab	8.79a	45.48ac	44.13e	57.64de	12.98a
	44	136.33df	0.46ab	75.56de	30.61eg	31.49de	8.61a	9.99a	43.31ab	44.53e	57.74de	13.54a
Mid-Season Cuts	56	82.33bd	0.45ab	61.11cd	23.48def	24.21cd	11.6abc	9.26a	49.70bc	38.97ce	52.54bce	10.82ab
	59	90.78cde	0.45ab	63.89ce	22.68ce	23.82cd	10.76ab	8.76a	49.60bc	38.88ce	53.50ce	11.50ab
	65	88.44bde	0.52ab	65.00ce	18.59bcd	19.60bc	11.38abc	10.74a	53.22cd	36.36bcd	48.81acd	10.14ab
Late Cuts	77	60.00abc	0.48ab	49.44bc	14.44ac	15.60ac	14.09bd	9.19a	60.10de	32.92ac	44.93ac	9.70ab
	81	47.56abc	0.59b	38.89b	16.04acd	16.14ac	14.10bd	10.57a	61.41e	31.63ab	43.72ac	9.76ab
	90	33.22ab	0.61b	29.33b	12.48ab	12.63ab	15.40cd	11.53a	62.51e	32.51ac	43.46ab	9.69ab
	98	4.89a	0.60b	4.22a	8.51a	8.27a	16.220d	11.56a	65.42e	27.86a	41.23a	7.49b

(for each variable, the mean value at one date and the letter corresponding to the Tukey HSD. DM (Dry matter), DM content (dry matter content, Cover, (estimated vegetation cover) H height, RH reproductive Height, CP crude protein content, MM mineral matter content IvOMD; In Vitro DM digestibility, IvOMD (In Vitro OM digestibility

Table 3. Dry mass (DM), digestible organic matter (DOM) and protein quantity (CPM) during the growing season at the end of the season and the sum of both (cumulative production).

Days after rain	Growing season			End of the growing season			Sum of two measurements		
	DM yield	DOM yield	CPM yield	DM yield	DOM yield	CPM yield	DM yield	DOM yield	CPM yield
9	1.61	1.08	0.34	134.00	53.63	12.41	135.61	54.7	12.75
16	7.82	5.1	1.65	126.89	51.42	11.27	134.71	56.52	12.92
23	11.13	6.69	2.25	139.44	48.70	11.75	150.57	55.4	14.00
30	11.43	6.57	2.07	137.00	50.45	12.72	148.43	57.02	14.79
39	11.72	7.19	2.49	163.78	64.26	15.44	175.5	71.45	17.93
44	9.12	5.32	1.95	136.33	46.47	10.53	145.45	51.8	12.48
56	58.09	34.59	12.02	82.33	33.96	9.54	140.42	68.55	21.56
59	82.39	43.03	13.84	90.78	35.95	9.71	173.17	78.98	23.55
65	107.55	53.64	18.47	88.44	37.65	9.86	195.99	91.29	28.33
77	183.65	86.81	21.98	60.00	28.53	7.60	243.65	115.34	29.58
81	216.77	105.6	24.58	47.56	23.90	6.37	264.33	129.5	30.94
90	238.06	106.5	23.47	33.22	16.81	5.08	271.28	123.31	28.55
98	201.33	81.34	16.53	4.89	2.62	0.82	206.22	83.95	17.35

species are also closely tied to the photoperiod (Penning de Vries & Djitéye, 1982), with flowering typically occurring by the end of August (Seghieri et al., 1995), followed by fructification by the end of September (Bille & Poupoun, 1974). Interestingly, germination was observed throughout the entire season. This continuous germination has been documented in previous studies on Sahelian species (Hérault & Hiernaux, 2003). Such a pattern has significant implications for fodder quality, which declines as the season progresses (Diatta et al., 2021). Younger plants tend to have higher nitrogen and lower fiber content compared to older or senescent plants. Therefore, grazing during the wet season is critical not only for the quantity of biomass removed by livestock but also for the nutritional quality of the forage.

4.2 Impact of Cutting Date

Our study design included a gradient of cutting dates, providing insights into how cutting at different phenological stages affects vegetation dynamics. Interestingly, the response to cutting was consistent within plots cut at similar stages (establishment, growth, or fructification), highlighting the importance of phenology in determining the effects of disturbance.

Subplots cut during the establishment phase exhibited vegetation characteristics similar to those found at the end of the season in uncut plots (Table 2). These subplots had a vegetation cover of around 80% and a plant height of approximately 30 cm, consistent with the end-of-season conditions (Table 1). This suggests that the vegetation had a strong capacity to regenerate after disturbance. Notably, the season itself included a rainfall break, and it is possible that the cutting combined with this break induced mortality, further emphasizing the potential influence of timing and disturbances.

Regarding biomass and forage quality, we observed differences between the dry mass collected during the last measurement of the season and the second measure-

ment taken from plots cut early in the season. This discrepancy may be due to the two-week interval between the measurements. The final measurement was taken in late September (day 98), while the second measurement occurred in mid-October when herbaceous biomass had already started to decline rapidly due to seed dispersal and the onset of natural decomposition (Diawara et al., 2018; Hiernaux et al., 2013). Since we cut all above-ground biomass, the plants in these plots were likely from new germinations, as the germinative stages persisted throughout the season.

For subplots cut during the middle of the season, biomass at the end of the season was lower than that of plots cut early. These subplots also had a lower plant height (around 10 cm), as they were already transitioning into senescence, with no significant phenological differences observed compared to the early-cut plots.

Plots cut at the end of the fructification stage had the lowest dry mass at the end of the season, with a delayed phenological response. However, many of the plants in these plots had already flowered by the time of cutting, even in those cut only two weeks before the final measurement. The reproductive height of these plants was reduced to around 10 cm, only about one-third of the height observed in subplots cut earlier. These findings highlight the remarkable adaptability of Sahelian vegetation to disturbances (Seghieri et al., 1995). The decrease in reproductive height following disturbance such as grazing or cutting is a well-documented response in grasslands (Díaz et al., 2001).

Regarding cumulative dry mass production, we observed the highest values in the plots with the latest cuts. Herbaceous vegetation appeared to resume the growth toward the end of the season with the final rainfall events. This suggests that cutting during the season did not increase the total biomass production, consistent with previous studies indicating that the grazed or cut plots typically show lower biomass production (Cissé, 1986; Pen-

ning de Vries & Djitèye, 1982). A key factor here is that we performed the ground-level cutting, which differs from many other cutting scenarios. A recent study by N'goran et al. (N'goran et al., 2024) suggests that cutting at a height of 5 cm may have a different impact compared to cutting at the ground level.

In this study, cutting was used as a proxy for grazing. However, the effects of grazing and cutting are not identical. Grazing is selective, with animals exhibiting preferences for certain species (Ayantunde et al., 1999), and during the wet season, they generally do not graze plants down to the ground level. Moreover, grazing animals return nutrients to the soil through manure, which is an important factor in nutrient cycling in this nutrient-limited region. Our work indicates that cutting later in the season reduces biomass availability at the end of the season, which could decrease fodder for the dry season. However, this practice may also have positive effects, such as reducing fire risks and competition between herbaceous plants and tree saplings (Vadigi & Ward, 2014). Controlled grazing or cutting could be useful for fire management or to support tree regeneration in the context of initiatives like the Great Green Wall (Cesaro et al., 2022a; 2022b).

5. Conclusions

This study demonstrates that the impact of cutting on herbaceous Sahelian species varies depending on the timing of cutting, particularly about plant phenology. The results underline the strong adaptability of annual species to disturbances. Optimal dry mass production occurred when cuts were made at the peak of vegetation growth. Late cutting or grazing may have additional benefits such as aiding fire control and promoting the regeneration of tree layers in restoration projects. Future research should explore the impact of grazing at different times during the wet season to determine if similar results are observed.

Authors contributions

All the authors have participated sufficiently in the intellectual content, conception and design of this work or the analysis and interpretation of the data (when applicable), as well as the writing of the manuscript.

Availability of data and materials

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Conflict of interests

The author states that there is no conflict of interest.

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Appendix: Supplementary Tables

Table A. Rainfall events that occurred in Dahra During the 2017 wet season.

Date of the event	Days after the first event	Rainfall in mm
24/06/2017	0	1 0
26/06/2017	2	47
28/06/2017	4	30
29/06/2017	5	1.5
07/07/2017	13	3.5
28/07/2017	34	1.5
29/07/2017	35	8
01/08/2017	38	7
08/08/2017	45	13.4
12/08/2017	49	18
13/08/2017	50	12
18/08/2017	55	18
19/08/2017	56	13.7
26/08/2017	63	32
04/09/2017	72	16
08/09/2017	76	37
18/09/2017	86	13
24/09/2017	92	23
04/10/2017	102	15
11/10/2017	109	20

Table B. List of species, abundance and frequency.

List of species	Abundance	Frequency
<i>Alysicarpus ovalifolius</i>	2.1%	59.3%
<i>Aristida mutabilis</i>	0.3%	12.0%
<i>Bulbostylis hispidula</i>	0.0%	1.4%
<i>Cenchrus biflorus</i>	0.3%	13.9%
<i>Ceratoteca sesamoides</i>	0.2%	14.8%
<i>Chloris prierii</i>	1.3%	20.8%
<i>Citrus colocynthis</i>	0.0%	0.5%
<i>Corchorus tridens</i>	0.0%	2.3%
<i>Cynodon dactylon</i>	0.0%	1.4%
<i>Cyperus sp</i>	0.1%	2.3%
<i>Dactyloctenium aegyptium</i>	1.5%	28.2%
<i>Dicliptera verticillata</i>	0.0%	0.5%
<i>Digitaria gayana</i>	0.1%	9.3%
<i>Diodella sarmentosa</i>	29.9%	51.4%
<i>Dipcadi viride</i>	0.0%	0.5%
<i>Eragrostis ciliaris</i>	0.0%	0.9%
<i>Eragrostis tremula</i>	0.5%	24.5%
<i>Gisekia pharnaceoides</i>	0.0%	9.3%
<i>Poacea sp</i>	1.6%	17.1%
<i>Indigofera pilosa</i>	0.4%	14.8%
<i>Ipomoea coptica</i>	4.6%	48.1%
<i>Ipomoea vagans</i>	1.5%	39.4%
<i>Merremia hederacea</i>	0.9%	28.7%
<i>Portulaca foliosa</i>	0.0%	2.8%
<i>Schoenefeldia gracilis</i>	0.0%	0.5%
<i>Senna obtusifolia</i>	0.3%	11.6%
<i>Sesamum alatum</i>	0.0%	0.5%
<i>Spermacoceae sp</i>	0.3%	6.9%
<i>Tephrosia purpurea</i>	0.5%	21.8%
<i>Tephrosia sp</i>	0.0%	0.5%
<i>Tragus berteronianus</i>	0.0%	2.8%
<i>Tribulus terrestris</i>	0.0%	0.5%
<i>Xenostegia pinnata</i>	1.3%	32.4%
<i>Zornia glochidiata</i>	47.9%	95.8%