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Article

Population dynamics of stems in *Urochloa* hybrids with different harvest intensity

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Abstract

The stability of the stem population allows analyzing the variations in the rates of appearance, death and survival, so the objective of this research was to determine the effect of harvest intensity (15 and 25 cm) on the stability of the population of stems of hybrid *Urochloa* Mulato II, Cayman and Mavuno. The study was conducted from March 2020 to February 2021 in Güémez, Tamaulipas, Mexico. In established meadows, 18 experimental plots of 3 x 3 m were delimited. In each experimental unit, two areas of 100 cm^2 were placed to select the initial population of stems and count the dead stems and tillers present every four weeks. Differences were found between the intensities and sampling dates for the variables stem density, tillering rate, and stability index ($p < 0.05$). The cutting intensity of 15 cm generated the highest density of stems with 2 545, 2 996 and 2 200 stems m^2 in Mulato II, Cayman and Mavuno, respectively, as a result of tillering rates greater than 12% without showing differences in death rates and survival percentage. The cutting intensity of 15 cm averaged stability indices of 0.98 and 0.96 in Mulato II and Mavuno, while negative stability (0.93) occurred in Cayman. The cutting intensity of 15 cm allowed maintaining the stability of the population of stems of the *Urochloa* hybrids Mulato II and Mavuno over time.

Keywords: intensity, persistence, survival.

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Introduction

In Mexico, extensive cattle farming is carried out in pastures of semiarid regions (Velázquez *et al*., 2015), where the main source of food is scrubland, grasses and weeds (Romero-Paredes and Ramírez, 2003), with native and introduced plant species (Elizondo and Boschini, 2002; Quero *et al*., 2007); nevertheless, the distribution of rainfall in these sites is erratic, which ranges between 350 and 600 mm per year for the semiarid zone and less than 350 mm for the arid zone (Tarango, 2005), coupled with this, prolonged periods of drought produce a decrease in animal production (Cuartas *et al*., 2014), because plants stop their development and therefore the availability of forage decreases (Carmona-Muñoz *et al*., 2003).

In this context, species of the genus *Urochloa* have been introduced in the state of Tamaulipas, with yields of up to 10.13 t ha^{-1} of dry matter accumulated in the season of maximum precipitation, which corresponds to the months of May to October, in contrast to 1.36 t ha^{-1} present in the months of November to April with a management program at intervals of eight weeks between cuts, yields higher than *Pennisetum ciliare* H-17 (Garay-Martínez *et al*., 2018).

The hybrids derived from the genus *Urochloa* have been developed with characteristics that make them tolerant to deficit of moisture in the soil, even to reach permanent wilt without presenting changes in leaf turgor and obtain greater leaf biomass compared to their parents *U. decumbens* and *U. brizantha* (Carmona-Muñoz *et al*., 2003). However, the response of species in morphological and structural characteristics depends on various factors, such as plant age, its genetic composition, climatic conditions and agronomic management (Garay-Martínez *et al*., 2018).

With agronomic management, in addition to seeking yield and nutritional value, it is sought to increase the time of use of the area established with the genotype of interest, that is, to increase the persistence of the meadow through stability in the density of stems (Rojas *et al*., 2016), which depends on the response of the processes of formation, death and survival of these (Ramírez *et al*., 2020).

In this sense, the frequency and intensity of cutting are variables that generate changes in the composition and permanence of the meadow (Cruz-Hernández *et al*., 2017); since, as there is a higher density of stems, forage yield increases and it maintains population stability of stems (Morales *et al*., 2012). The research aimed to determine the effect of cutting intensity on the population dynamics of stems of three *Urochloa* hybrids (Mulato II, Cayman and Mavuno) under rainfed conditions.

Materials and methods

The study was conducted from March 2020 to February 2021 at the Zootechnical Post ‘Ingeniero Herminio García González’, located in the municipality of Güémez, Tamaulipas, Mexico (23° 56’ 17.55” north latitude, 99° 06’ 2.45” west longitude), at 167 masl. The climate of the place is of the semiarid type [BS1 (h’) hw with rains in summer and up to 10% in winter (Vargas *et al*., 2007)].

The soil has a clayey texture (11.3, 23.3 and 65.4% sand, silt and clay, respectively), with pH of 8.3, the sodium adsorption ratio is 0.19, 4.2% organic matter, 0.25% N and 7.4, 288.6, 1.4 and 0.5 mg kg^{-1} of P, K, Fe and Zn, respectively (Garay-Martínez *et al*., 2018). The average minimum temperature ranges between 10 and 26 °C, the maximum between 18 and 34 °C and the average accumulated precipitation of the place is 750 mm per year (Figure 1).

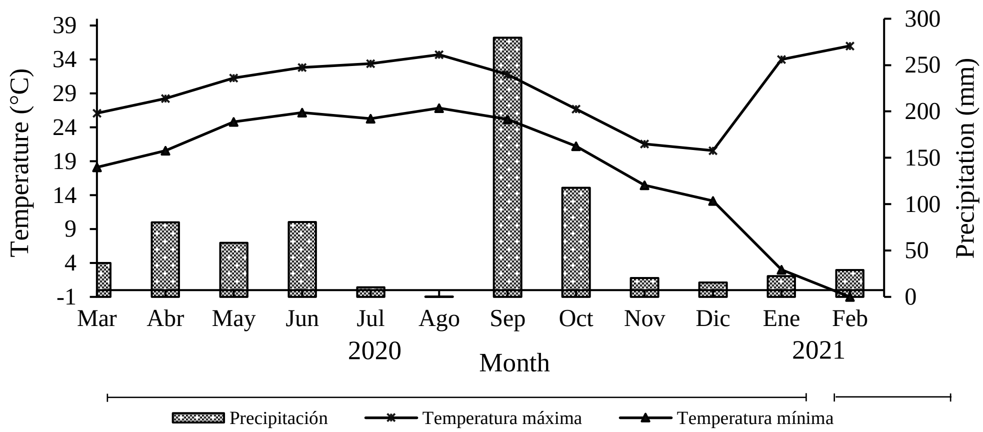

Figure 1. Maximum and minimum temperatures and precipitation of the site during the study period.

The established meadows of hybrid *Urochloa* Mulato II, Cayman and Mavuno were sown in rows 0.3 m apart and continuously within the row, at a sowing density of 5 kg ha^{-1}. There was no fertilization or irrigation during the experiment. At the beginning of the research, during the month of March 2020, a cut was made to standardize the meadows and define the areas of the treatments according to the intensity levels, 15 and 25 cm, subsequently, the stem count dates were carried out every 4 weeks and homogenization cuts were made according to the defined intensity. The six treatments defined by the three cultivars and two cutting intensities were distributed in 18 experimental plots of 3 x 3 m with three repetitions.

After making the uniformity cut (March, 2020), two fixed wire squares of 10 x 10 cm were placed in each experimental unit and the live stems present in the area were marked with rings of the same color, defining them as the initial population and every four weeks (sampling dates) the tillers were marked with a new color, each date formed a generation of stems, while the dead stems were removed from the sampling area and the data were recorded.

The data obtained were used to calculate changes in the stem population density (SPD; stems m^2), tillering rate (TR) and stem death rate (DR) between each evaluation date with the following formulas according to the formulas described by Ramírez *et al*. (2020): TR (%)= $\frac{\text{Number of tillers}}{\text{SPD previous sampling}}$ x 100. DR (%)= $\frac{\text{Number of dead tillers}}{\text{SPD previous sampling}}$ x 100. The stem survival rate (SSR) was obtained as follows: SSR (%) =100-DR. The stem population stability index (PSI) was obtained with the following formula: PSI (%)= SSR(1+TR).

Where: the PSI is the ratio between the final or current population and the previous population of stems observed, considering the stem survival rate and tillering rate. Its value indicates the effect of tillering and death of the stems in relation to the total density, for a given period, values close to or equal to 1 (0.95 to 1.05) indicate a population of stems in equilibrium and a negative and positive stability presents values less than 0.95 and greater than 1.05, respectively.

The response variables (SPD, TR, DR, SSR and PSI) were analyzed using PROC GLM (SAS, 2002) through an analysis of variance with a randomized complete block design and factorial arrangement (3 × 2 × 12) where the study factors were cultivars (Mulato II, Cayman and Mavuno), cutting intensities (15 and 25 cm) and sampling dates (12 dates), in addition, the Tukey test (p= 0.05) was performed for the comparison of means.

Results and discussion

In the *Urochloa* hybrids, differences were found between intensities and sampling dates for the variables stem density, tillering rate, and stability index (p< 0.05), while in the death rate and survival rate there were differences only between the intensities of the hybrid Mavuno, with differences between sampling dates in the six treatments (p< 0.05).

Stem population density

The average stem population density was higher at the intensity of 15 cm by 11.4, 4.7 and 11% in the hybrids Mulato II, Cayman and Mavuno, respectively, compared to the intensity of 25 cm (Table 1). In addition, there was a decrease at the end of the evaluation (February-2021), compared to the initial population (March-2020), of 31 and 51% at the intensity of 15 and 25 cm, respectively, in Mulato II, 39 and 75% for Cayman and 23 and 32% for Mavuno at the same intensities (Table 1).

Table 1. Stem population density (stems m^{-2}) of *Urochloa* cultivars at different cutting intensity with an interval of four weeks.

Sampling	Mulato II				Cayman				Mavuno			
	15 cm		25 cm		15 cm		25 cm		15 cm		25 cm	
March 20	2 683	ab	2 833	a	3 433	a	3 983	a	2 558	a	2 646	a
April 20	2 483	ab	2 650	ab	3 500	a	3 733	ab	2 050	bc	1 975	ab
May 20	2 133	ab	2 533	ab	2 800	abcd	2 967	cd	1 816	c	1 408	b
June 20	2 250	ab	2 400	ab	2 994	abc	3 100	bcd	1 991	bc	1 537	ab
July 20	2 811	a	2 250	ab	2 694	bcd	2 800	cd	2 083	abc	1 750	ab
August 20	2 717	a	2 433	ab	2 850	abcd	3 033	cd	2 408	ab	2 150	ab
September 20	2 639	ab	2 050	abc	2 616	cd	3 133	bcd	2 258	abc	2 500	ab
October 20	2 955	a	2 350	ab	2 483	cd	3 166	bc	2 291	abc	2 287	ab
November 20	2 911	a	2 227	ab	2 566	cd	3 033	cd	2 158	abc	2 050	ab
December 20	2 733	a	2 033	abc	2 700	bcd	2 483	e	2 442	ab	1 991	ab
January 21	2 383	ab	1 916	bc	2 383	cd	1 833	e	2 158	abc	1 425	b
February 21	1 847	b	1 375	c	2 094	d	983	f	1 966	bc	1 787	ab
Average	2 545	A	2 254	B	2 996	A	2 855.6	B	2 200	A	1 959	B
SEM	67.36		87.12		86.34		152.18		52.39		90.10	

Lowercase literals compare averages between sampling dates in each intensity by cultivar. Uppercase literals compare means of averages between intensities by cultivar. Different literal indicates significant differences (Tukey; p= 0.05). SEM= error standard of the mean.

The evaluation over time with established cutting interval defined the behavior in the density of stems in the three hybrids, the hybrid Mulato II showed differences between the intensities from October, with the intensity of 15 cm remaining higher by 20% on average until January (Figure 2), therefore, it is probably a function of the environmental conditions present in January and February (Figure 1). In this regard, the behavior of the stem population density with prolonged cutting interval in the cultivar Mulato II in conjunction with four cultivars of *Urochloa* presented densities greater than 4 000 stems m^{-2}; however, no significant differences were found between cultivars (Lucio *et al*., 2023), therefore, for this experiment the cutting intensity is crucial to determine the effect on the stem population density, since it has been established that, after mechanical or grazing defoliation, stem density growth is induced, which lasts until 21 and 28 days in *Andropogon gayanus*, for example (Ramírez *et al*., 2020).

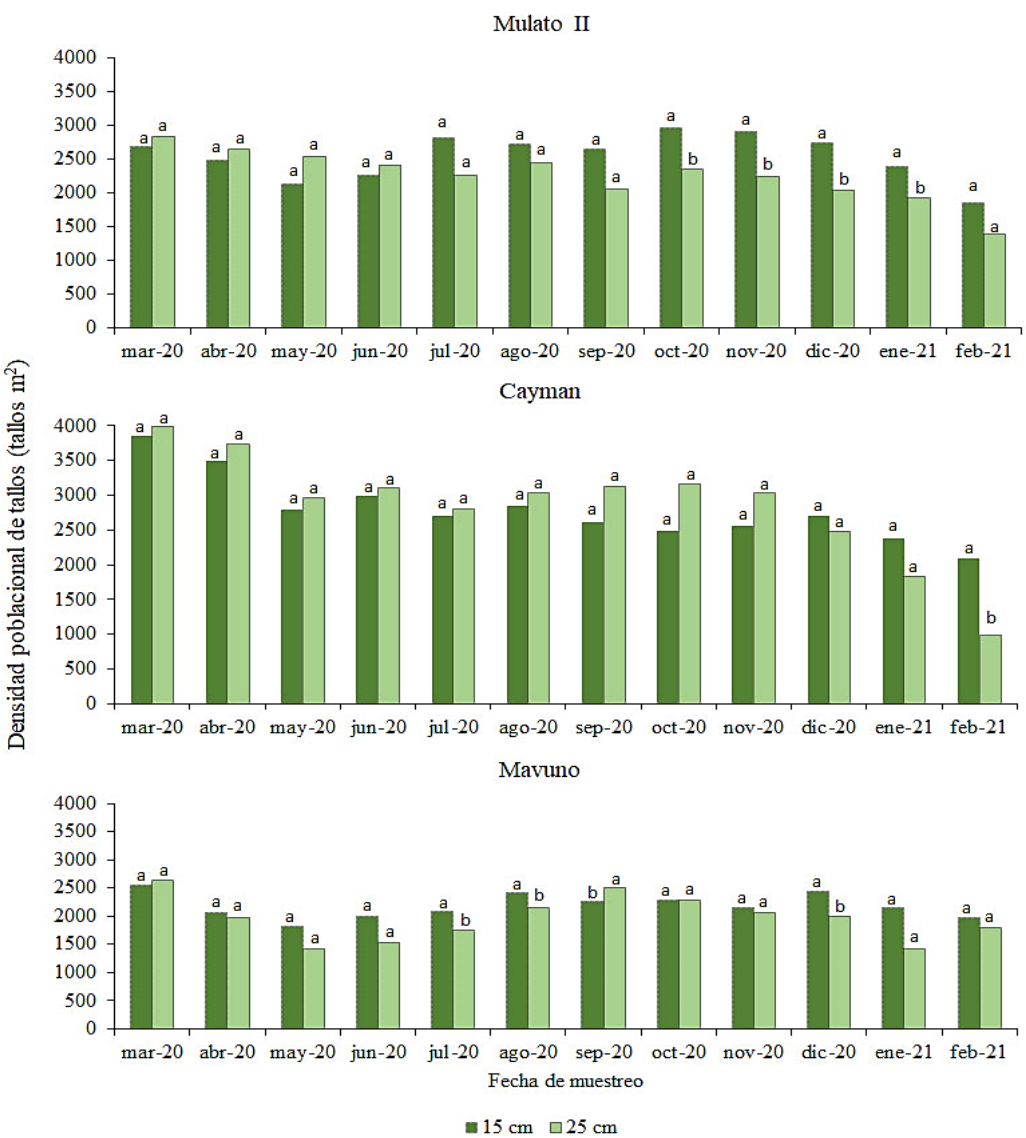

Figure 2. Effect of cutting intensity (15 and 25 cm) on stem population density (stems m^{-2}), with a fixed interval of four weeks.

Regarding the hybrid Cayman, it did not show differences between intensities ($p \leq 0.05$) during the evaluation, except for February, in which the intensity of 15 cm was 53% higher compared to the intensity of 25 cm, the same behavior occurred in another study when evaluating the cultivar Cayman in the period from June to December with a fixed intensity of 15 cm and an interval of four weeks (Lucio-Ruiz *et al*., 2021), as in this experiment there were no differences between these dates, so it is proposed that the cutting intensity for this cultivar is 15 cm without affecting the stem population density throughout the year, likewise, this intensity has been related to obtaining yields of up to 8.8 t ha^{-1} of dry matter accumulated during the season of maximum precipitation in Güémez, Tamaulipas (Garay-Martínez *et al*., 2018).

The hybrid Mavuno showed variations in stem population density in the months of July, August and December, favoring the intensity of 15 cm, while in September the intensity of 25 cm was 11% higher (Figure 2), it suggests a response to the precipitation accumulated in September, given that having lower density per area in the previous sampling and when favorable conditions are propitiated, the density of stems increases, the same response occurred in the grass Mulato (36061), when evaluated in the northerly wind, dry and rainy seasons, the highest density of stems was present in the rainy season regardless of the cutting intensity (Cruz-Hernández *et al*., 2017).

When evaluating the *Urochloa* hybrid Mulato at intensities of 10 and 14 cm in height, Cruz-Hernández *et al*. (2017) found that the intensity of 10 cm generates higher density of stems (between 3 280 and 5 729 stems m^{-2}); nevertheless, the precipitation in this place occurred in greater quantity from June to October with more than 1 400 mm, while in the place of this study there is an average annual precipitation of 750 mm, coupled with extreme temperatures, therefore, due to the ideal conditions for the emergence of tillers, it generates a higher density of stems through the regrowth stage (Ramírez *et al*., 2011). During this stage, the activation of the active meristematic zone located at the base of the stems occurs, thanks to the presence of reserve carbohydrates (Rincón *et al*., 2008).

Tillering and stem death rate

The highest tillering rates occurred at the intensity of 15 cm on average, compared to that of 25 cm, in addition, during the month of September there were the highest tillering rates at both intensities and for the three hybrids, because it is the month of maximum accumulation of precipitation, which favors the tillering of new stems (Table 2).

In this sense, during the month of August, where the phenomenon known as the dog days of summer occurs, accompanied by high temperatures, which cause greater thermal accumulation for grasses (Lucio *et al*., 2023) and the absence of precipitation (Pacheco-Hernández *et al*., 2020), the hybrids Cayman and Mavuno presented the highest tillering rate at both intensities ($p < 0.05$), possibly due to the use of carbohydrate reserves present at the base of the stems, crown and roots of plants, as a measure of perpetuation (Rincón *et al*., 2008). The opposite happened with the hybrid cultivar Cobra, which, as there was moisture restriction and temperature increase, the tillering rate decreased by 12% on average (Cámara-Acosta *et al*., 2022).

Table 2. Rates of tillering and stem death of *Urochloa* cultivars at two harvest intensities with an interval of four weeks.

Sampling	Mulato II				Cayman				Mavuno			
	15 cm		25 cm		15 cm		25 cm		15 cm		25 cm	
					Tillering rate							
April 20	2.1	d	2.1	b	8.1	bc	5.2	bc	20.2	ab	3.9	d
May 20	18.1	bcd	5.3	ab	10.7	bc	8.1	bc	9.1	bc	12.2	bc
June 20	23.2	bc	10.1	ab	20.9	ab	11.3	b	14.4	abc	9.1	bcd
July 20	27	ab	11.7	ab	14	abc	3.2	c	16.5	abc	8.8	bcd
August 20	17.5	bcd	12.7	ab	23.7	a	22.3	a	21.9	ab	29.1	a
September 20	42	a	15.8	ab	25	a	24.7	a	29	a	29.6	a
October 20	31.1	ab	4.8	ab	4.8	c	7.5	bc	25.4	a	14	b
November 20	9.4	cd	5.1	ab	8.1	c	2.7	c	18.3	abc	5.6	cd
December 20	8.5	cd	7.5	ab	9.5	bc	2.3	c	15.6	abc	6.3	cd
January 21	3.2	d	7.8	ab	2	c	3.7	c	4.5	c	11	bc
February 21	11	cd	27.5	a	4.8	c	4.8	bc	23.9	ab	3.2	d
Average	17.6	A	10	B	12	A	8.7	B	18	A	11.1	B
SEM	2.2		1.6		1.4		1.3		1.6		1.9	
					Death rate							
April 20	7.9	bc	8.8	cde	6.3	bcd	12.5	cde	24.7	abcd	28.9	ab
May20	0	c	0	e	20.4	abcd	19.3	cd	10.4	cde	6.9	bc
June 20	18.3	b	19	c	22.6	abc	7	e	0.5	e	0	c
July 20	18.7	b	18.3	cd	23.3	abc	12.4	cde	25	abc	10.3	bc
August 20	4.5	bc	8.5	de	20.2	abcd	6.4	e	5.5	de	8.1	bc
September 20	52.5	a	30.5	b	25.2	abc	19.1	cd	31.8	ab	17.4	abc
October 20	15.4	bc	7.1	e	9.6	bcd	8.5	de	5.7	cde	13.1	abc
November 20	11	bc	5.3	e	4.7	cd	5	e	15.8	bcde	21	abc
December 20	3.8	bc	1.2	e	1.2	d	21.9	bc	1.3	e	7.9	bc
January 21	21.6	b	47.2	a	26	ab	31.5	b	18.3	bcde	38	a
February 21	41.1	a	45.4	a	39.5	a	51.6	a	41.7	a	37.8	a
Average	17.7	A	17.4	A	18.4	A	17.8	A	16.4	A	17.8	A
SEM	2.8		2.8		2.2		2.4		2.85		3	

Lowercase literals compare means between sampling dates in each intensity by cultivar. Uppercase literals compare means of averages between intensities by cultivar. Different literal indicates significant differences (Tukey; p= 0.05). SEM= standard error of the mean.

The death rate showed variations across the sampling dates (p< 0.05), and February was the month which presented the highest death rate in all cultivars and cutting intensities (Table 2), as a result of the minimum temperatures present prior to the sampling date (Figure 1); it also, generated lower survival with values less than 65% in the six treatments on the same date. In the effect of the intensity for each cultivar, the intensity of 25 cm caused a 3% decrease on average compared to the intensity of 15 cm only in the survival of stems of the hybrid Mavuno, so exposing this cultivar to the intensity of 25 cm will affect the survival of the population of stems from one cutting date to another (Table 3).

Table 3. Survival rates and stability index of the stem population in *Urochloa* cultivars at two cutting intensities with an interval of four weeks.

Sampling	Mulato II				Cayman				Mavuno			
	15 cm		25 cm		15 cm		25 cm		15 cm		25 cm	
Survival rate												
April 20	91.7	abc	91.1	ab	91.4	ab	88	ab	75.25	bcde	71.1	d
May 20	100	a	100	a	85.3	bcd	89.8	ab	89.5	abc	90.9	abc
June 20	81.6	bc	82.8	b	80.2	cde	93.3	ab	99.4	a	99.5	a
July 20	83.8	bc	81.6	b	76.6	de	87.5	ab	74.9	cde	91	abc
August 20	95.4	ab	91.5	ab	89.7	ab	93.5	a	94.4	ab	91.8	ab
September 20	54	d	69.4	c	74.7	e	80.8	ab	68.1	de	82.5	bcd
October 20	87.6	abc	92.8	ab	87.3	abc	88.6	ab	94.2	abc	89	abc
November 20	88.9	abc	91.3	ab	95.2	a	93	ab	85.9	abcd	78.9	cd
December 20	96.1	ab	98.7	a	92.4	ab	79.5	bc	97.8	a	92	ab
January 21	80.5	c	63.9	cd	73.9	e	66.3	cd	81.6	abcd	56.7	e
Average	83.9	A	83.6	A	82.8	A	83.1	A	83.6	A	80.6	B
SEM	2.4		2.4		1.7		2.2		2.8		3.6	
Stability index												
April 20	0.91	bcd	0.94	ab	1	dc	0.9	ab	0.9	bcd	0.74	d
May 20	1.16	a	1.04	a	0.91	cde	0.9	ab	0.95	abc	1.02	ab
June 20	1.02	abc	0.88	abc	0.91	cd	1.05	a	1.14	a	1.09	ab
July 20	1	abcd	0.9	ab	0.84	def	0.9	ab	0.83	cd	1	bc
August 20	1.15	a	1	a	1.14	a	1.06	a	1.1	ab	1.21	a
September 20	0.69	e	0.79	bcd	0.93	cd	0.94	ab	0.88	cd	1.04	ab
October 20	1.12	ab	0.99	a	0.93	cd	0.96	ab	1.13	a	1.01	bc
November 20	1	abcd	0.97	a	1.01	bc	0.98	a	1.01	abc	0.81	cd
December 20	1.03	abc	0.97	a	1.05	ab	0.8	bc	1.12	ab	1.01	bc
January 21	0.86	cde	0.73	cd	0.74	f	0.72	cd	0.84	cd	0.63	de
February 21	0.79	de	0.63	d	0.79	fe	0.61	d	0.72	d	0.45	e
Average	0.98	A	0.89	B	0.93	A	0.89	B	0.96	A	0.91	B
SEM	0.02		0.02		0.02		0.02		0.03		0.04	

Lowercase literals compare means between sampling dates in each intensity by cultivar. Uppercase literals compare means of averages between intensities by cultivar. Different literal indicates significant differences (Tukey; p= 0.05). SEM= standard error of the mean.

Likewise, it has been reported that the intensity of 5 cm in the cultivar Mavuno has negative effects on the total population density, therefore, it is reflected in a lower survival rate and this behavior generates changes in the morphological composition, since, at intensities of 5 cm, it generates stems of greater weight, while, at intensities of 15 cm, the weight per stem decreases, however, in the total weight of dry matter, there are no differences between intensities (Rodrigues *et al*., 2021). In this sense, Cámara-Acosta *et al*. (2022) mention that to achieve the persistence of a meadow, a balance between the tillering rate and the survival of the stems is necessary to maintain the density of stems in certain situations.

On the other hand, other dates differ in the behavior of the death rate in each cultivar by cutting intensity, this behavior is attributed to competition for space, to the little or no availability of moisture and stress to exposure to temperatures below 15 °C, determined as the base temperature of tropical grasses (Lucio *et al*., 2023). In addition, it has been found that, in cuts with fixed intervals, there is a greater pressure on the death rate since the stems weaken more (Cámara-Acosta *et al*., 2022).

Survival rate and stability index of the stem population

The stability index allows establishing a relationship between survival processes and the tillering rate, since, by itself, it does not allow clarifying whether it is sufficient to replace the death rate and maintain the stem population density (Ramírez *et al*., 2011). Therefore, the cutting intensity had an effect on the stability of stems ($p < 0.05$) and the intensity of 15 cm was the one that presented the highest stability index with 9, 4 and 5% compared to the intensity of 25 cm in the three cultivars (Table 3).

However, the hybrid Cayman presented values lower than 0.95; that is, in the evaluation period, a negative stability was obtained in the meadow, so the intensities for this hybrid do not favor the permanence of the meadow, while the hybrids Mulato II and Mavuno remained in equilibrium with values of 0.98 and 0.96. In this regard, Lucio-Ruiz *et al*. (2021) when evaluating two cutting intensities defined by a fixed intensity of 15 cm and one at 50% considering the height before cutting in the hybrid Cayman, the latter intensity led to greater stability of the stem population, since the intensities were less than 15 cm of residue, therefore, it is established that for this cultivar in the established environment, greater intensity is required to increase the stability index.

In August, the six treatments presented a positive stability of stems, despite being the month where there is little or no precipitation and temperatures are maximum, due to the relationship that exists between the higher rate of tillering compared to the death rate on this date (Table 2). When evaluating *Panicum maximum* cv. Mombaza, Ramírez *et al*. (2011) found greater stability during the dry season than in the rainy season, while, when evaluating two cutting heights, Difante *et al*. (2008) found that at the 15 cm height, stem population remains more stable, with a decrease in variation in stem population density when conditions are limiting for stability.

The stability index showed the contrasts that exist between climatic conditions, given that with water deficit and high temperatures (October), there was less activity in the death rate and an increase in the tillering rate, while, during the month of September, with the ideal conditions to carry out tissue replacement, there was a higher death rate compared to the tillering rate, possibly due to plant growth and competition that exists between available resources such as radiation, soil and water (Rueda *et al*., 2018).

Conclusions

The cutting intensity of 15 cm allowed maintaining the stability of the population of stems of the *Urochloa* hybrids Mulato II and Mavuno. The density of stems was different between sampling dates according to the environmental conditions and the density present in the area, since, when favorable conditions of precipitation and temperature are present, the death rate increases, while under restricted conditions there is an increase in the appearance of tillers.

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