Article

Population dynamics of stems and stability index of the llanero grass

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Abstract

In the tropics of Mexico, grasslands are the basis for feeding ruminants. The objective of the study was to determine the density, rate of appearance, death and survival of the population of stems of the Llanero grass (*Andropogon gayanus* Kunt) harvested at different regrowth ages (EA: 7.14, 21, 28, 35, 42 , 49 and 56 d), in two growth periods, dry season with irrigation and rainy season. The EA (treatments) were assigned to four experimental units of 3 m^2, using a randomized complete block design, with four replications. In both growth periods, the stem density increased until the 28 days of regrowth later, decreased until the end of the study with greater intensity during the dry period with irrigation compared to the rainy season (325 and 378 stems m^{-2}, respectively). There was greater appearance and death of stems in the dry period with irrigation (97 stems 100 $stems^{-1}$ $week^{-1}$). The population stability index was greater or close to one during the irrigated drought, while, in rains from the 42 days of regrowth, this was less than one. In conclusion, it was obtained that regrowth ages from 7 to 28 days do not compromise the population stability of stems and favor the persistence of the grasslands. Older regrowth ages during the rains do not allow to recover the stem population, which favors population instability.

Keywords: death rate, stem population, stem survival.

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Introduction

In Mexico, pasture grassland forms the basis of ruminant feeding in grazing systems, they provide a low cost food in relation to the food used in the stable systems. In these systems, the lack of knowledge about the proper management of grasslands can cause production systems to require more investment (Ramírez *et al*., 2011).

Grassland are made up of plant populations, which, in turn, are made up of stems, considered as growth units (Hodgson, 1990; Lemaire, 2001). In perennial grasslands, it is important to understand that the stems have a limited lifetime, generally less than one year (Matthew *et al*., 2000). In this context, the regrowth of stems presents variations in their appearance and death rates, since they depend on the management of the grassland and the season of the year (Ramírez *et al*., 2011).

There are differences between species and cultivars, to achieve stability in the population density of stems (Maldonado *et al*., 2019) and favor the persistence of the grassland, therefore, it is important to know the appearance and death rates of stems for each pasture and condition of use, which allows identifying specific management recommendations to optimize the population dynamics of stems, a basic condition to guarantee the persistence of the plant population in the grasslands; through time (Fialho *et al*., 2012).

Different authors (Portela *et al*., 2011; Rojas *et al*., 2017a) state that the evaluation in the demography of stems is associated with measurements of growth and structure of plants under cutting conditions (Giacomini *et al*., 2009; Sousa *et al*., 2010; Ramírez *et al*., 2011) or grazing (Hernández *et al*., 2014), are of importance for greater production and persistence of grasses.

The llanero grass is a perennial grass introduced to Mexico in 1986 by INIFAP (CIAT, 1989) and spread as a species resistant to low fertility soils and places that suffer from water restriction, because it has a deep root system, it also has rapid regrowth as a consequence of a high rate of stem emergence (Machado *et al*., 2010).

This grass, managed at fixed defoliation intervals and harvest intensities of 1 to 3 m, cause excessive accumulation of stems and early senescence, which reduces biomass production and hinders animal consumption; it presents higher values of stem density in spring and with defoliation intensities of 30 cm (Sousa *et al*., 2010). Therefore, the objective of the present investigation was a growth analysis and to determine the best growth rate, death, appearance and stability of the grass population of the llanero grass.

Materials and methods

Study location and period

The study was conducted at the 'Aztlan' ranch (16° 43' 26" north latitude and 99° 07' 24" west longitude), located in the municipality of Florencio Villarreal, Guerrero, Mexico. The study included two conditions: weekly irrigation by sprinkling (February 17 to April 12, 2016) and temporary (July 20 to September 13, 2016).

The climate is Awo, which corresponds to a warm subhumid with rains in summer (García, 2004), with an average annual temperature and precipitation of 27 °C and 1 100 mm, at an altitude of 40 m (CONAGUA, 2010). The monthly data on precipitation and maximum and minimum temperatures, present during the experimental period (Figure 1), were obtained from the National Water Commission (CONAGUA) located 1 000 m from the experimental area.

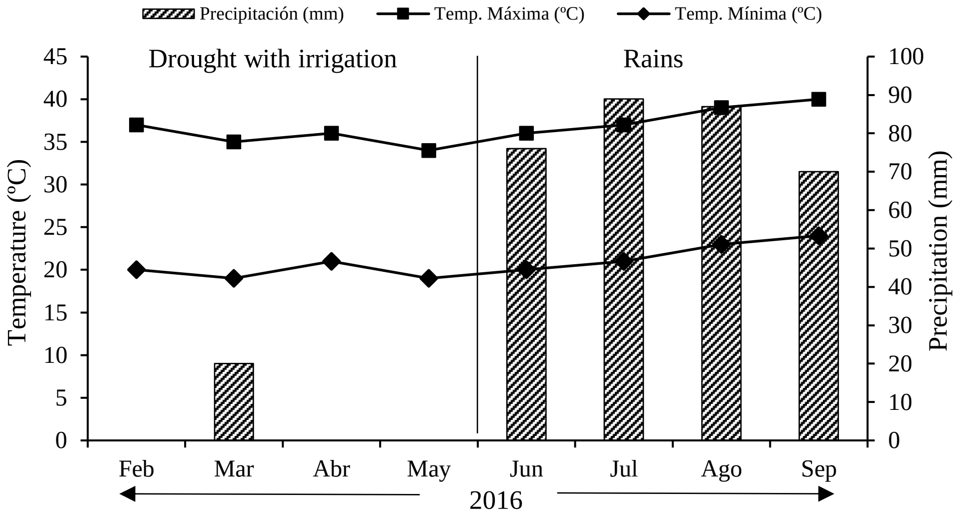

Figure 1. Monthly data on precipitation and maximum and minimum temperatures, during the study period, in the Municipality of Florencio Villareal, Guerrero, Mexico.

Grassland management

In an area of 387.75 m^{-2} of surface (23.5 x 16.5 m), four blocks of 33 m^2 (11 X 3 m) were established, 1.5 m apart. Vegetative material (young strains) was used at a rate of 2 500 kg ha^{-1}, distributed with a distance between rows and plants of approximately 50 cm. On October 3, 2015, the llanero grass was sown using a minimum tillage system, which consisted of manual cleaning to eliminate the emerged biomass, due to the uneven slope of the land the blocks were established in a completely random design, with four repetitions.

The blocks were subsequently divided into 10 experimental units of 3 m^2 (1 x 3 m). Eight regrowth ages (EA; 7, 14, 21, 28, 35, 42, 49, and 56 days) were used as treatments. At the beginning of the investigation, a uniform cut was made at a height of 10 cm. The weed was controlled by applying 2-4 D + Picloram.

Variables studied

Population dynamics

To determine the appearance and death of stems, at the beginning of each growth period, in the central part of the experimental unit, an area of 1 m^2 was delimited, in which the number of plants was recorded and a plant was selected representative in terms of average plant height, in which live stems were marked with rings of the same color and considered as initial population.

Subsequently, each week for each growth period, the new stems were marked with different colored rings, for each generation, and the rings were removed from the dead stems and counted. These values were multiplied by the number of plants per m^2, with these data the following were estimated: the population density of stems (PDS; stems m^{-2}) and their respective weekly rates of appearance (TAT) and death (TMT) (stems 100 $stems^{-1}$), using the methodology described by Rojas *et al*. (2017).

$$\text{PDS= No. of live stems existing in each sampling, TAT= TMT=}\frac{\text{No. of dead stems}}{\text{PDS of the previous sampling}}(100)$$

Stem survival rate. The Stem Survival Rate (SSR) was obtained indirectly using the equation: SSR= 100-TMT.

Stability index

To calculate the stability index of the stem population, the equation described by Bahmani *et al*. (2003), ${}^{P_f}/_{P_i}$ =TSP (1+TAP).

Where: P_f/P_i corresponds to the current or final population of stems (P_f); expressed as a proportion of the original or initial stem population (P_i) for a given period. TSP and TAP correspond respectively to the survival rate and rate of appearance of stems for the same period.

The interpretation of this index is based on the fact that the values equal to or close to one (0.95 to 1.05) indicate a stable stem population, in which the number of stems practically does not vary, although it is the result of a dynamic equilibrium. Values less than one (<0.95) indicate negative instability, where the population of stems tends to decrease over time and values greater than one (>1.05) represent the inverse condition (Bahmani *et al*., 2003).

Statistical analysis

Statistical analysis of the data was performed using the Proc Mixed procedure of the SAS statistical package (SAS Institute, 2004). To select the variance and covariance matrix, the Akaike information criterion was used (Wolfinger and O’Connell, 1993). The effects of regrowth age, growth periods and their interactions were considered fixed and the block effect was considered random.

The means of the causes of variation (treatments, study period and their interaction) were estimated with the Lsmeans procedure and the comparison between them was made using the probability of the difference (PDIFF) with the Student’s t-test, at a significance level of 5%. For the analysis of stem density, the initial population (first recorded density, after the uniformity cut) of each growth period was used as a covariate.

Results and discussion

Population dynamics

There was an effect of EA ($p< 0.0001$) for the stem density; effect of EA ($p< 0.0001$) on the rate of appearance of stems and, effect of EA ($p< 0.0001$), growth period ($p= 0.0212$) and interaction (EA x growth period; $p= 0.0306$) for the rate stem death. Averages show that stem density increased from 318 to 401 stems m^{-2} from day 7 to 35 of regrowth, then decreased until the end of the study (56 days: 352 stems m^{-2}) (Table 1).

Table 1. Density and rates of appearance and death of stems of the Llanero grass, harvested at different regrowth ages.

EA (days)	Drought with irrigation	Rain	Average
	Stem density (stems m^{-2})		
7	292 B	344 B	318 E
14	336 A	386 B	361 CD
21	360 A	427 A	394 AB
28	364 A	445 A	405 A
35	357 A	445 A	401 A
42	349 A	421 A	385 B
49	341 A	399 B	370 C
56	325 A	378 B	352 D
Average	341	405 AB	
SEM	67.9	67.9	4.6
	Occurrence rates (stems 100 $stems^{-1}$ $week^{-1}$)		
7	22.7 A	6.7 B	14.7 A
14	16.7 A	20 A	18.3 A
21	14 A	17.7 A	15.8 A
28	3 BC	5 BC	4 B
35	0 C	1 BC	0.5 B
42	0.5 C	0 C	0.2 B
49	0.2 C	0 C	0.1 B
56	0.5 C	0 C	0.2 B
Average	7.2	6.3	
SEM	4.2	2.2	2.1
	Death rates (stems 100 $stems^{-1}$ $week^{-1}$)		
7	1 Cb	8.5 Aa	4.7 A

EA (days)	Drought with irrigation	Rain	Average
14	1.2 Ca	3.7 BCa	2.5 BC
21	7.2 Aa	4.5 ABCa	5.8 A
28	2.5 BCa	1 Ca	1.7 C
35	2.2 BCa	1.2 Ca	1.7 C
42	2.7 BCa	6.2 ABa	4.5 AB
49	3 BCa	7 ABa	5 A
56	5 Aba	7 ABa	6 A
Average	3.1 b	4.9 a	
SEM	0.9	1.5	0.7

Means with equal capital letters in each column of each variable, are not statistically different (PDIFF, 0.05). Means with equal lowercase letters in each row are not statistically different (PDIFF, 0.05). EA= regrowth age; SEM= standard error of the mean.

While the highest rates of stem emergence occurred in EA 7, 14 and 21, with an average of 16.3 stems 100 stems^{-1} week^{-1}, to decrease from 35 days to the end of the study, where the appearance of stems practically ceased (0.2 stems 100 stems^{-1} week^{-1}). The stem death rate was 58% higher in the rainy season, when the 7-day EA had the highest stem death rate (8.5 stems 100 stems^{-1} week^{-1}), later, although without statistical differences, decreased to 35 days EA (1.2 stems 100 stems^{-1} week^{-1}).

As of this moment, the stem death rate was similar between regrowth ages with an average of 6.8 stems 100 stems^{-1} week^{-1}. Applying irrigation, the death rate of stems increased by varying from 7 to 21 days of regrowth with values of 1.0 and 7.2 stems 100 stems^{-1} week^{-1}, respectively, while, in the 28-day EA, the death rate decreased to 2.5 stems 100 stems^{-1} week^{-1}, from this age, stem death tended to increase up to the 56-day EA with a rate of 5 stems 100 stems^{-1} week^{-1}.

In general, the change of stems occurred in both conditions of management of the Llanero grass, since it was adjusted to the pattern of the evolution of the density of stems (the net balance between the appearance and death of stems) that occurs in a meadow in growth after mechanical defoliation (Rojas *et al*., 2017a), as happened in this study.

According to Rojas *et al*. (2017b), in a first phase of physiological growth of the plant, after defoliation, the stem density increases rapidly, while, in a second phase, it decreases and can be stopped, without necessarily reaching a complete cessation, of the rate of appearance of stems. In a third phase, stem density decreases, mainly due to stem death (Gastal *et al*., 2004).

In this study, the increase in stem density detected as the first phase occurred until the EA of 21 and 28 days, in irrigated and rainy conditions, respectively, when the appearance rates of stems exceeded the death rates of stems, in both growing conditions (Table 1 and Figure 2).

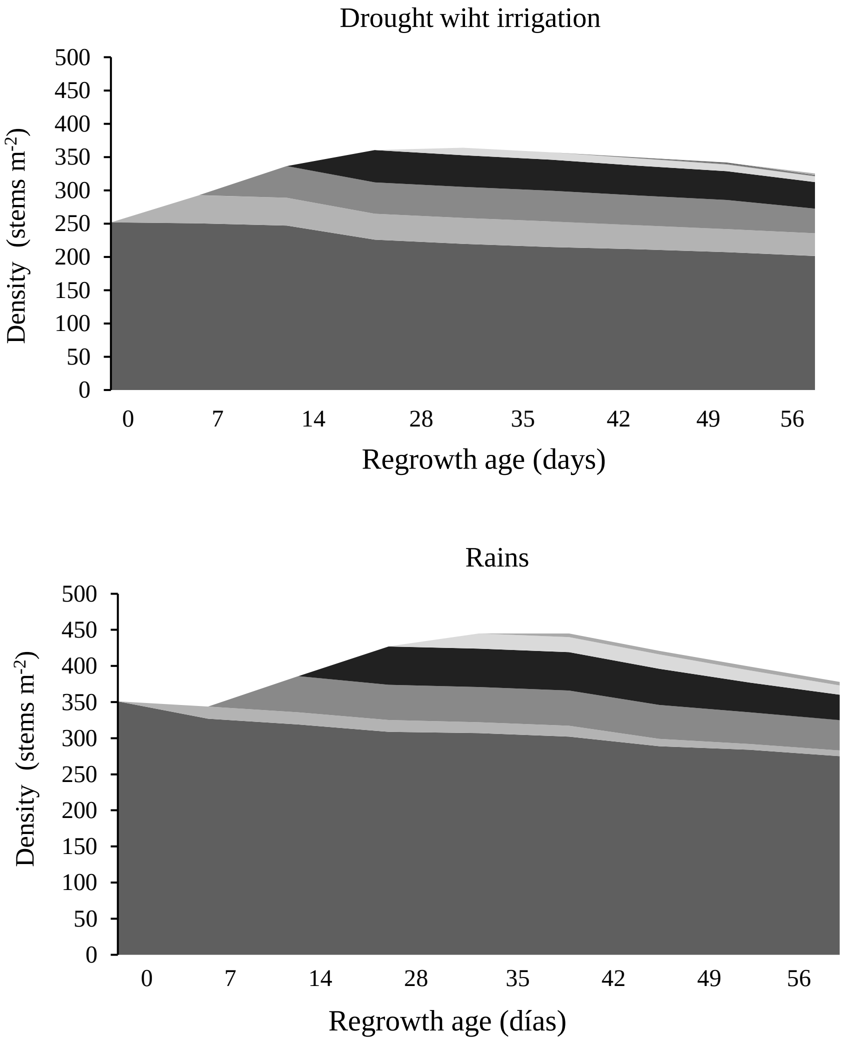

Figure 2. Weekly change in the demographics of grass stems *Andropogon gayanus* Kunt. Each gray tone stripe represents a weekly stem population and the set represents the total stem density.

The second phase occurred until the regrowth ages of 28 and 35 days for the periods of drought with irrigation and rains, respectively, and is explained by the favorable compensation between the sharp decrease in the rates of appearance of stems and the low rates of death of recorded stems, which prevented that the density of stems increased.

The third phase was presented from 35 d, until the end of the study, in both growth periods, when the insignificant or null rates of appearance of stems presented, were not able to compensate for the increasing rates of death of stems, which consequently caused the stem density to decrease (Table 1 and Figure 2).

The higher rates of stem appearance that occurred in the first phase of the llanero grass in this study were due to the good environmental conditions (Figure 1) and the effect of the beginning of each growth period, which allowed light to enter the base of the grassland and the activation of remaining axillary buds (Deregibus *et al*., 1983) and consequently, the appearance, growth and development of new stems was favored.

The decrease in the rate of stem emergence observed in the second phase was determined by the development of the plants (growth of the stems and accumulation of leaf biomass), which intercepted the incident light and gradually generated shade at the base of plants, thus inhibiting the activation of axillary buds and the appearance of stems.

As the EA and foliar biomass increased, the shade at the base of the plant also increased until the total interception of incident sunlight was achieved, which explains the insignificant or null rate of appearance of stems that occurred in the third phase and until the end of the study.

The foregoing confirms what was established by Simon and Lemaire (1987), who report that the lower rate of appearance of stems is related to the increase in the leaf area index and the advance of the regrowth cycle, once the intensity of incident light on the basal and axillary buds it is reduced.

The highest death rate of stems at 7 days of regrowth in the rainy period corresponded to stems of the initial population of the period, characterized by tall plants and consequently tall stems, so, when applying the uniformity cut, surely there was removal of apical meristems which caused the death of stems (Hernández *et al*., 1999).

Stem death shown in the third phase of regrowth is probably due to the self-shading of the same plant, on the young stems, which could not develop quickly enough during the development of the plants to maintain access to sunlight (Ong, 1978; Davies, 1988).

Similar results, in the population density of stem, to this study were reported by Rodolfo *et al*. (2015) when evaluating regrowth patterns of elephant grass (*Pennisetum purpureum*) subjected to two pre-grazing heights (90 and 120 cm) combined with two levels of defoliation (50 and 70% of the initial height), dividing the regrowth period in three states (initial, intermediate and final), where they observed 293 stems m^{-2} in the initial regrowth state, followed by a significant increase and the highest values in the intermediate state (420 stems m^{-2}) and a decrease in the final state (331 stems m^{-2}), without differences between them.

Survival rates and stability index of the stem population

The survival rate of stems is observed in Table 2 where there was an effect of EA (*p*= 0.0008), growth period (*p*= 0.0203) and interaction between EA x growth period (*p*= 0.0391). The stability index presented an effect of EA (*p*< 0.0001) and growth period (*p*= 0.012).

Table 2. Survival rate and stability index of the grassland stem population, by study period and harvested at different regrowth ages.

EA	Drought	Rain	Average
	Stem survival rate (stems 100 stems^{-1} week^{-1})		
7	99 Aa	91.7 Cb	95.3 C
14	98.7 Aa	96.2 ABa	97.5 AB
21	93 Ca	95.5 ABCa	94.2 C
28	97.7 Aa	99 Aa	98.3 A
35	97.2 Aa	98.7 Aa	98.2 A

EA	Drought	Rain	Average
42	97.2 ABa	93.7 BCa	95.5 BC
49	97 ABa	93.5 BCa	95.2 C
56	95 BCa	93 BCa	94 C
Average	96.9 a	95.1 b	
SEM	0.8	1.4	0.7
		Stability index	
7	1.2 Aa	1 B Cb	1.09 A
14	1.1 Aba	1.16 Aa	1.16 A
21	1 BCa	1.13 Aa	1.09 A
28	1 Ca	1.04 Ba	1.02 B
35	0.98 Ca	0.99 BCa	0.99 BC
42	0.98 Ca	0.94 Ca	0.96 C
49	0.97 Ca	0.93 Ca	0.95 C
56	0.96 Ca	0.92 Ca	0.94 C
Average	1.04 a	1.01 a	
EEM	0.04	0.02	

Means with equal capital letters in each column of each variable, are not statistically different ($p > 0.05$). Means with equal lowercase letters in each row are not statistically different ($p > 0.05$). EA= regrowth age; EEM= standard error of the mean.

The survival rate of stems was 2% higher during the irrigation drought, when survival rates between 97 and 99 stems were presented 100 stems^{-1} week^{-1}; through the growth period, without statistical differences between EA, except for the 21 and 56 days of regrowth, which recorded lower stem survival with similar rates between them, from 93 and 95 stems 100 stems^{-1} week^{-1}, respectively.

While, during the rainy period, the lowest survival rate occurred in the 7-day EA, subsequently and up to 35 days of regrowth this rate increased with values between 95.5 and 99 stems 100 stems^{-1} week^{-1}, with no difference between EA. Starting from the 42-day EA, the survival rate of stems decreased and at the end of the period (56-day EA) it presented a value of 93 stems, 100 stems^{-1} week^{-1}, with no differences between EA.

The stability index of the stem population during the irrigation drought period decreased as the EA also increased, changing from 1.21 to 0.96 in the 7 and 56-day EA, respectively. Values greater than 1 were observed from 7 to 21 days of regrowth, values equal to or close to 1 in the EA from 28 to 42 days and values less than 1 in the EA from 49 and 56 days, indicating that the population of stems increased, remained stable, and decreased, respectively.

During the rainy season, the 7-day EA showed an index close to 1, later, and up to the 28-day EA, the indices were higher than 1, in the 35-day EA, the index was close to 1, and from this age and until the end of the period the index was less than 1, which indicates that the population remained stable, increased, stabilized again and finally decreased. Survival rate is a variable related to the persistence of the stem population from one generation to another, that persistence depends on the death of stems that occurs between evaluations (Rojas *et al*., 2017a).

A study (Ramírez *et al*., 2011) carried out with *Panicum maximum* cv. Mombaza where they evaluated three cutting intervals (3.5 and 7 weeks) in two growing seasons (drought and rains), reported higher values of survival of stems in drought with respect to rainfall (93.5 and 67.1 stems 100 stems^{-1} month^{-1} respectively)) and greater survival in cut intervals of 3 and 5 weeks in relation to 7 weeks (82.4 and 75.6, stems 100 stems^{-1} month^{-1}), respectively.

The higher rate of stem survival (Table 2) during the irrigation drought period was a direct consequence of low death rates (Table 1), suggesting that stem survival coupled with a high rate of stem emergence during the first EA (7 to 21 days) may be an adaptation of plants to colonize the area when good environmental conditions and low plant density occur, as in this study (Matthew *et al*., 1996).

On the other hand, during the rainy season, the lower survival rate of stems (Table 2) is a consequence of a higher rate of death of stems (Table 1) than associated with a higher rate of appearance of stems during the first EA (7 to 21 days), suggest being a mechanism of adaptation of plants to favor the replacement of stems and increase the population density in the grasslands, when there are appropriate conditions for growth.

Subsequent to these EA, the highest survival rate during drought with irrigation and the lowest survival rate in rains (Table 2), associated with a minimum or no rate of appearance of stems (Table 1) in both growth periods, caused that the maximum density of stems reached, decreased until the end of the study. Despite this dynamic of stem turnover, the final stem density was higher than the initial density (Figure 2), in both growth periods.

The analysis of the stability index of the population of stems showed that the grasslands of the Llanero grass during the EA from 7 to 28 days, in both growth periods, presented indices greater than 1, indicating that the survival of stems (Table 2) associated with the appearance of stems (Table 1) was sufficient to compensate and overcome the death of stems and to cause the population of stems to increase; suggesting that in these EA the variable appearance of stems was more important than the death of stems, which should be considered in the management of *Andropogon gayanus* Kunt grass. (Ramírez *et al*., 2011).

After these EA during the period of drought with irrigation, the indices were close to one (between 0.98 and 0.96) until the end of the study, indicating that the survival of stems (Table 2) in association with a low dynamics of replacement of stems (low death rate and minimal or no appearance of stems (Table 1), favors a slight decrease in the density of stems, but allows the population of stems to be stable, guaranteeing the persistence of the grassland (Rojas *et al*., 2017b) while, during the rainy season, the stem population stability indexes were less than one (between 0.94 and 0.92).

Indicating population instability due to the fact that the appearance of new stems was not enough to compensate for the death of stems, which may compromise the persistence of the grassland; through time (Matthew *et al*., 1996). Ramírez *et al*. (2011) reported a higher population stability index (0.97) during drought than in rains (0.92) and between cut-off intervals, a higher index in the 3-week period (0.98) in relation to the 7-week index (0.9).

Conclusions

The older the regrowth age during the drought, there was a slight decrease in the density of stems because insignificant rates of appearance of stems were not sufficient to compensate for the low rates of death recorded. On the other hand, the high survival rate of stems did not allow compromising the stability of the grassland.

While, during the rainy season, the density of stems decreased with greater intensity due to high death rates and no appearance of stems, which can compromise population stability and persistence of the grassland. It is recommended to harvest the llanero grass at regrowth ages of 28 days since they do not compromise the population stability of stems and favor the persistence of the grassland.

Cited literature

Bahmani, I.; Thom, E. R.; Matthew, C.; Hooper, R. J. and Lemaire, G. 2003. Tiller dynamics of perennial ryegrass cultivars derived from different New Zealand ecotypes: effects of cultivar, season, nitrogen fertilizer, and irrigation. Australian J. Agric. Res. 54(8):803-817.

CIAT. 1989. Centro Internacional de Agricultura Tropical. Andropogon gayanus Kunth: un pasto para los suelos ácidos del trópico. Toledo, J. M.; Vera, R.; Lascano, C. y Lenné, J. M. (Eds.). ISBN 84-89206-80-5. Cali, Colombia. 406 p.

CONAGUA, 2010. Comisión Nacional del Agua-Guerrero. Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT). Gobierno de México.

Davies, A. 1988 The regrowth of grass swards. *In*: Jones, M. B. and Lazenby, A. (Eds.). The grass crop: the physiological basis of production. Chapman and Hall, London. 85-127 pp.

Deregibus, V. A.; Sanchez, R. A. and Casal, J. J. 1983. Effects of light quality on tiller production in *Lolium* spp. Plant Physiol. 72(3):900-912.

Fialho, C. A.; Silva, S. C.; Gimenes, F. M. A.; Gomes, M. B.; Berndt, A. and Gerdes, L. 2012. Tiller population density and tillering dynamics in marandu palisade grass subjected to strategies of rotational stocking management and nitrogen fertilization. Acta Scientiarum. Animal Sci. 34(3):137-139.

García, E. 2004. Modificaciones al sistema de clasificación climática de Köppen. 4^{a} (Ed.). Ciudad de México. Universidad Nacional Autónoma de México (UNAM). 97 p.

Gastal, F.; Lemaire, G. and Lestienne, F. 2004. Defolation, Shoot plasticity, sward structure and herbage utilisation. *In*: Pizarro. E.; Carvalho, P. C. F.; Da Silva, S. C. (Eds.). Symposium on Grassland Ecophysiology and Grazing Ecology, 2. UFPR, Curitiba. Anais. Curitiba. CD-ROM. 27 p.

Giacomini, A. A.; Da, Silva, S. C.; Lucena, D. O.; Zeferino, S. C. V.; Trindade, J. K.; Souza, J. S. J.; Guarda, V. D. and Nascimento, J. D. 2009. Growth of marandu palisadegrass subjected to strategies of intermittent stocking. Sci. Agric. 66(6):733-741.

Hernández-Garay, A.; Matthew, C. and Hodgson, J. 1999. Tiller size/density compensation in perennial ryegrass miniature swards subject to differing defoliation heights and a proposed productivity index. Grass Forage Sci. 54(4):347-356.

Hernández, G. A.; Euclides, V. P. B.; Silva, S. C.; Montagner, D. B.; Nantes, N. N.; Nascimento, J. D. and Soares, C. O. 2014. Herbage accumulation and animal performance on Xaraés palisade grass subjected to intensities of continuous stocking management. Tropical Grasslands-Forrajes Tropicales. 76-78 pp.

Hodgson, J. 1990. Grazing management: science into practice. New York: J. Wiley. Longman Scientific and Technical. 203 p.

Lemaire, G. 2001. Ecophysiology of grasslands: dynamic aspects of forage plant population in swards. Proceedings. *In*: XVII. International Grassland Congress. Brazil. 29-37 pp.

Machado, L. A. Z.; Lempp, B.; Valle, C. B.; Jank, L.; Batista, L. A. R.; Postiglioni, S. R.; Resende, R. M. S.; Fernandes, C. D.; Vergignassi, J. R.; Valentim, J. F.; Assis, G. M. L. and Adrade, C. M. S. 2010. Principais espécies forrageiras utilizadas em pastagens para gado de corte. *In*: bovinocultura de corte/Alexandre Vaz Pires. Piracicaba. FEALQ 1-760.

Maldonado, P. M. A.; Rojas, G. A. R.; Sánchez, S. P.; Bottini, L. M. B.; Torres, S. N.; Ventura, R. J.; Joaquín, C. S. y Luna, G. M. J. 2019. Análisis de crecimiento del pasto Cuba OM-22 (*Pennisetum purpureum* X *Pennisetum glaucum*) en el trópico seco. Agroproductividad. 12(8):17-22.

Matthew, C. 1996. Seasonal patterns of rood, tiller and leaf production in a Grassland Ruanui ryegrass sward. Proc N Z Grass Assoc. 58:73-76.

Matthew, C; Assuero, S. G.; Black, C. K.; Sackville, N. R. and Hamilton. 2000. Tiller dynamics of grazed swards. *In*: grassland ecophysiology and grazing ecology. Lemaire, G.; Hodgson, J.; Moraes, A.; Carvalho, P. C. andNabinger, F. C. (Eds.). CAB International. Wallingford, UK. 127-150 pp.

Ong, C. J. 1978. The physiology of tiller death in grasses. 1. The influence of tiller age, size and position. J. British Grassland Soc. 33(3):197-203.

Portela, J. N.; Pedreida, C. S. G. and Braga, G. J. 2011. Demografia e densidade de perfilhos de campin-braquiária sob pastejo em lotação intermitente. Pesquisa Agropec. Bras. 46(3):315-322.

Ramírez, R. O.; Da Silva, S. C.; Hernández, G. A.; Enríquez, Q. J. F.; Pérez, P. J.; Quero, C. A. R. y Herrera, H. J. G. 2011. Rebrote y estabilidad poblacional de tallos en el pasto *Panicum máximum* cv. Mombaza cosechado en diferentes intervalos de corte. Rev. Fitotec. Mex. 34(3):213-220.

Rodolfo, G. R.; Schmitt, D.; Dias, M. K. and Sbrissia, A. F. 2015. Levels of defoiation and regrowth dynamics in elephant Grass swards. Ciência Rural, Santa Maria. 45(7):1299-1304.

Rojas, G. A. R.; Hernández, G. A.; Rivas, J. M. A.; Mendoza, P. S. I.; Maldonado, P. M. A. y Joaquín, C. S. 2017a. Dinámica poblacional de tallos de pasto ovillo (*Dactylis glomerata* L.) y ballico perenne (*Lolium perenne* L.) asociados con trébol blanco (*Trifolium repens* L.). Rev. Fac. Cienc. Agrar. 49(2):35-49.

Rojas, G. A. R.; Ventura, R. J.; Hernández, G. A.; Joaquín, C. S.; Maldonado, P. M. A. y Reyes, V. I. 2017b. Dinámica poblacional de tallos de ovillo (*Dactylis glomerata* L.) solo y asociado con ballico perenne (*Lolium perenne* L.) y trébol blanco (*Trifolium repens* L.). Rev. Mex. Cienc. Pec. 8(4):419-428.

SAS Institute. 2004. SAS/STAT® 8e. User's Guide Release. Cary, NC.

Simon, J. C. and Lemaire. G. 1987. Tillering and leaf index in grasses in vegetative phase. Grass and Forage Science. 42(4):373-380.

Sousa, B. M. L.; Nacimiento, J. D.; Da Silva, S. C.; Monteiro, H. C. F.; Rodrigues, C. S.; Fonseca, D. M.; Silveira, M. C. T. and Sbrissia, A. F. 2010. Morphogenetic and structural characteristic of Andropogon grass submitted to different cutting heights. Rev. Bras. Zootec. 39(10):2114-2147.

Wolfinger, R. D. and O'Connell, M. 1993. Generalized linear mixed models: a pseudo-likelihood approach. J. Statistical Computation Simulation. 48(3-4):233-243.