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STATISTICS

Lifetime of forage grasses submitted to different water regimes using survival analysis

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ABSTRACT. Forage plants are considered one of the main factors for livestock development, for they present perennial growth, resistance to drought, adaptation to hot climate regions, and wide soil diversity. The water deficit causes changes in their anatomy, physiology, and biochemistry, which can affect all stages of development and productivity. For these reasons, it is necessary to evaluate the lifetime of forage plants under water stress conditions. The design used was a factorial scheme, consisting of two types of grasses, and five levels of water replacement, with ten replications. During the experimental period, grasses were evaluated daily, with more than 70% of leaf area in senescence being considered a dead plant the one with more than 70% of leaf area in senescence. *Urochloa mosambicensis* lifetime was of 61 days for grasses that were not irrigated, 131 and 195 days for those that received 25% and 50% of field capacity, and greater than 240 days for those that were irrigated with 75 and 100% of field capacity. *Digitaria pentzii* lifetime was of 54 days for grasses that were not irrigated, 117 and 152 days for those that received 25 and 50% of field capacity, and greater than 240 days for those that were subjected to water regime 75 and 100% of field capacity. Irrigation with 25 and 50% of field capacity doubles and triplicates, respectively, the lifetime of grasses when compared to plants that did not receive irrigation. Irrigations with 75% or more of field capacity do not promote grass mortality.

Keywords: grass survival; mortality; survival analysis; water stress.

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Introduction

Tropical forage plants are considered one of the main factors for the development of livestock throughout the world, as they act as a source of food for herds and consequently have expressive participation in the production of milk and meat. These plants have high potential for phytomass production, drought tolerance, high energy value, good acceptability and digestibility, large water reserve and easy propagation (Galvão Jr., Silva, Morais, & Lima, 2014).

Furthermore, tropical forage plants must show moderate tolerance to water deficit, especially those grown in semi-arid regions that have irregularly distributed rainfall (Silva et al., 2017). The optimization of water use in agriculture is essential, especially in areas where water is a limiting factor for production, requiring the adoption of technologies that promote increased irrigation efficiency (Santos, Santos, Silva, Santos, & Santos, 2018).

Studies applying water deficit in forage plants are of great practical importance, as certain information helps technicians and producers to choose the appropriate forage, as well as the management they should use under these conditions (Araújo Jr. et al., 2019). Cavalcante, Cavallini, and Lima (2009) found that one of the main factors causing stress in plants is water availability. So, plants can suffer damage both from excess and lack of water. However, stress caused by disability is more common, affecting, above all, their productivity and persistence.

Water stress promotes a series of damages to plant metabolism, such as reduced photosynthesis, reduced cell division, less cell differentiation, and fewer cells, compromising the expansion of plant tissues in plants, greater energy expenditure, and production of reactive oxygen species (Farooq, Hussain, Ul-Allah, & Siddique, 2019). Changes in plant anatomy, physiology and biochemistry (Araújo et al., 2010; Scalon, Mussury, Euzébio, Kodama, & Kissmann, 2011), can affect all stages of development, starting from seed germination and, consequently, stand stabilization (Cavalcante et al., 2009), even development and productivity (Yahmed et al., 2016; El-Mageed, El-Samnoudi, Ibrahim, & Tawwab, 2018). Such damages depend on the degree of stress intensity and the cultivated species (Araújo Jr. et al., 2019). These plants may develop mechanisms of tolerance or even adaptation to such conditions (Almeida et al., 2021).

The knowledge of phenological events measured on a temporal scale (lifetime, time to flowering, time to harvest, etc.) is of fundamental importance, and useful for the efficient management of crops. The lifetime of forage plants provides very useful information in the cultivation and management of natural populations, and they have great biological importance, as they enable the viability of the cultivation of a species by evaluating the growth rate.

Survival analysis is still not widespread in agricultural sciences. Such type of analysis presents a series of advantages over traditional approaches, as it allows comparing the pattern of occurrence of phenological events over time; makes it possible to estimate the probability of occurrence of events at specific intervals, which are important for planning management or marketing activities, and provides information on the percentage of phenological events; in addition to not requiring data normality or homogeneity of variances (Gienapp, Hemerik, & Visser, 2005).

In survival analysis, the response variable is, in most cases, the time until a certain event occurs. This time is called failure time and can be the time up to the death of the individual under analysis or any other event of interest (Mazucheli, Oliveira, Peralta, & Emanuelli, 2018). A characteristic resulting from these studies is, then, the presence of incomplete or partial observations. These observations, called censure, can occur for a variety of reasons, including the death of a plant during the study. and the non-occurrence of the event of interest until the end of the research.

Studies on the lifetime of forage plants under water deficit are still rare, even though this is one of the most frequent stresses. Lucena et al. (2020) evaluated the lifetime of *Pennisetum glaucum* under water and saline stress conditions through survival analysis. Given the above, this study aimed to analyze the lifespan of forage grasses *Urochloa mosambicensis* and *Digitaria pentzii* submitted to different water regimes using survival analysis.

Material and methods

This research was conducted in the forage farming sector (GEFOR) of the Federal Rural University of Pernambuco (UFRPE), Academic Unit of Serra Talhada (UAST), located in Pernambuco State, Northeast region, Brazil, which was located in the following geographic coordinates (07° 57’ 01” S and 38° 17’ 53” E) at elevation of 523 meters.

According to Koppen, the climate condition is a BS with a rainy season during the summer, starting in November and ending in April. The average annual rainfall is 632.2 mm, the average annual air temperature is 26°C, and the average air relative humidity is 60% (Lucena et al., 2021).

The design used was in a factorial scheme, consisting of two forage types of grasses [current grass (*Urochloa mosambicensis*) and pangolon grass (*Digitaria pentzii*)], and five levels of water replacement (0, 25, 50, 75, and 100% of the field capacity), with ten repetitions.

The soil used in the experiment was collected at a depth of 0-20 cm and classified as Typical Haplic Cambisol Ta Eutrophic, as described by EMBRAPA (2013). The soil sample was analysed by the soil fertility laboratory of the Instituto Agronômico de Pernambuco (IPA) and was characterized by the following chemical attributes: pH (water) = 6.80; P (extractor Mehlich I) = 40 mg dm^{-3}; K^+ = 0.45; Ca^{2+} = 5.50; Mg^{2+} = 1.60; and Al^{3+} = 0.0 $cmol_c$ dm^{-3}.

Initially, seedlings of *U. mosambicensis* and *D. pentzii* were planted in pots with a capacity of 14.41 dm^3, arranged at a spacing of 0.3 x 0.3 m and placed on brick blocks to avoid direct contact with the soil and facilitate the collection of drained water. These plants were conducted under full water supplementation during the first 30 days, considered the stand formation period. After this time, the thinning was carried out, leaving only one plant per pot. Then, the cut for uniformity and application of treatments was carried out, based on the field capacity (0, 25, 50, 75, and 100% of the field capacity). To determine the field capacity (FC) of the vessels, we followed the methodology described by Casaroli and Lier (2008).

The initial mass of the pot + soil + sand set of all pots was determined and then drinking water was added (electrical conductivity of 0.03 dS m^{-1}, sodium adsorption ratio of 0.25, classified as C1S1, low risk of salinization and sodification) until they were raised to saturation. To prevent loss of water through evaporation, the pots were covered with plastic film, and allowed to drain freely for 48 hours (time needed to reach constant mass). Thus, the irrigation depths were defined by fractioning the FC by 0 (without irrigation), 25, 50, 75, and 100%. Irrigations were carried out daily, weighing the pots and replacing the mass of water lost by the evapotranspiration process.

During the experimental period (240 days after application of treatments) the grasses were evaluated daily, being considered dead plants the ones with more than 70% of leaf area in senescence (Almeida et al., 2021). To evaluate the lifetime of grasses, the statistical methodology of survival analysis was used. In survival analysis, the response variable is, in most cases, the time until the occurrence of a certain event. This time is called failure time and can be the time until the death of the individual (plant) under evaluation or any other event of interest (Mazucheli et al., 2018).

The non-negative random variable T, usually continuous, which represents the time to failure, is usually specified in survival analysis by the survival function or by the failure rate function (risk) (Lucena et al., 2020). The survival function is defined as the probability that an observation does not fail until a certain time t, that is, the probability that an observation will survive time t. The survival function is described by:

$$S(t)=P(T\geqslant t) \quad (1)$$

In contrast, the cumulative distribution function is defined as the probability that an observation will not survive time t, that is,

$$F(t)=1-S(t) \quad (2)$$

The survival function can be obtained through non-parametric estimators, largely through the Kaplan-Meier estimator. The Kaplan-Meier estimator is an adaptation of the empirical survival function defined by:

$$S(t)= \prod_{j:\, t_j<t}\left(\frac{n_j-d_j}{n_j}\right)=\prod_{j:\, t_j<t}\left(1-\frac{d_j}{n_j}\right) \quad (3)$$

where, $t_1< t_2< \ldots < t_k$, the k times distinct and order of failure; d_j number of failures in t_j, j=1, 2,..., k and n_j is the number of plants at risk in t_j.

The graph of S(t) versus time (t) is called the survival curve (Nesi, Shimakura, Junior, & Mio, 2015). Kaplan-Meier estimates this curve based on survival times, without having to assume a probability distribution, even when there are censored data in the set of observations (Lira, Foschini, & Rocha, 2020).

The survival time (T) of forage grasses subjected to different water regimes was estimated using the survival function of the distributions: Weibull, Gumbel, log-normal and logistic (Table 1) and by the Kaplan-Meier estimator.

Table 1. Probability density and survival function for estimating millet lifetime.

Distribuitions	Density function	Survival function
Weibull	$f(t) = \frac{\gamma}{\alpha^{\gamma}} t^{\gamma-1} \exp\left\{-\left(t/\alpha\right)^{\gamma}\right\}$ $t \geq 0, \quad \alpha \text{ and } \gamma > 0$	$S(t) = \exp\left\{-\left(t/\alpha\right)^{\gamma}\right\}$
Gumbel	$f(t) = \frac{1}{\gamma}\exp\left\{\left(\frac{t-\alpha}{\gamma}\right) - \exp\left(\frac{t-\alpha}{\gamma}\right)\right\}$ $t \geq 0, \quad \alpha \text{ and } \gamma > 0$	$S(t) = \exp\left\{-\exp\left(\frac{t-\alpha}{\gamma}\right)\right\}$
Log-normal	$f(t) = \frac{1}{\sqrt{2\pi}\, t\gamma}\exp\left\{-\frac{1}{2}\left(\frac{\log(t)-\alpha}{\gamma}\right)^2\right\}$ $t > 0, \quad \alpha \text{ and } \gamma > 0$	$S(t) = \Phi\left(\frac{-\log(t)+\alpha}{\gamma}\right)$ $\Phi(*)$ is the cumulative distribution function standard normal
Logistic	$f(t) = \frac{\exp\left(\frac{t-\alpha}{\gamma}\right)}{\gamma\left\{1+\exp\left(\frac{t-\alpha}{\gamma}\right)\right\}^2}$ $t > 0, -\infty < \alpha < \infty \text{ and } \gamma > 0$	$S(t) = \frac{1}{1+\exp\left(\frac{t-\alpha}{\gamma}\right)}$

The following adequacy criteria of the survival functions defined by the models were used: Akaike information criterion (AIC), Bayesian information criterion (BIC), sum of squares of the differences between the Kaplan-Meier survival function and the model estimated survival (RMS) and model determination coefficient (R^2_{prop}), both the RMS and the R^2_{prop} were proposed by Lucena et al. (2020).

$$AIC= -2L(x;\hat{\theta}) + 2p;$$

$$\mathrm{BIC} = -2L(x;\hat{\theta}) + p\log\ (n);$$

$$R^2_{prop} = \left(1 - \frac{\sum_{i=1}^{n}(S_i - \hat{S}_i)^2}{\sum_{i=1}^{n}(S_i - \bar{S})^2}\right);$$

$$\mathrm{RMS} = \frac{\sum_{i=1}^{n}(S_i - \hat{S}_i)^2}{n - p}$$

where, $L(x;\hat{\theta})$ is the maximum likelihood function, n is the number of plants, p is the number of model parameters; S_i is the i-th survival value estimated at time T by the Kaplan-Meier estimator; $\hat{S}_i$ is the i-th survival value estimated by the model at time T; $\bar{S}$ is the mean of the survival function values of the Kaplan-Meier estimator.

All analyzes were performed using the "survival" package in the R-project software version 2.13.1 (R Core Team, 2019).

Results and discussion

The mortality rate of *U. mosambicensis* grass was 36% in the first 100 days of exposure to water deficit, 24.0% of the plants did not survive between 101st and 195th day, and 40% of the grasses survived for more than 240 days after the application of treatments (DAT) (Figure 1a). For the grass *D. pentizzi*, 40.0% mortality was observed in the 100 DAT, 20% mortality between the 101st and 152nd DAT, and 40% survival for more than 240 DAT (Figure 1b).

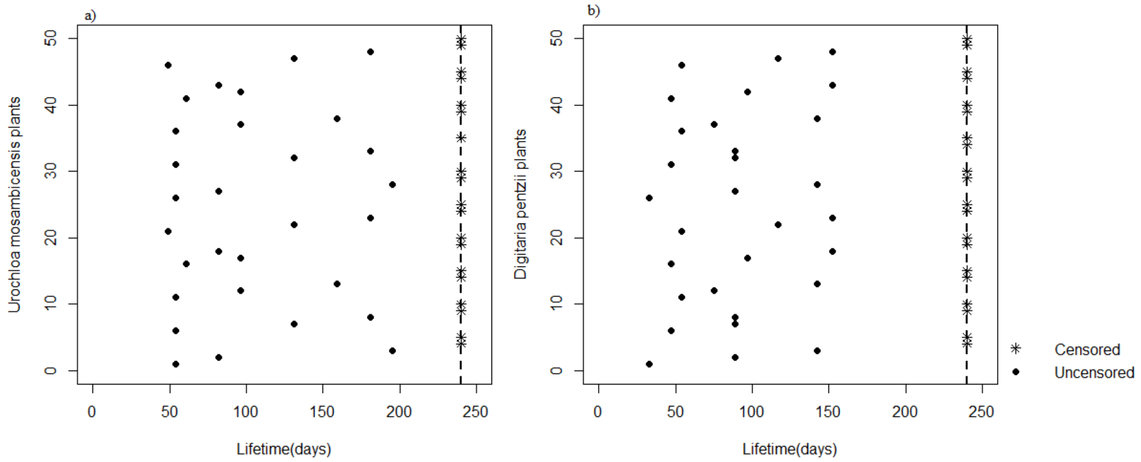

Figure 1. Lifetime *Urochloa mosambicensis* (a) and *Digitaria pentzii* (b), *censored; •uncensored.

These results suggest that the studied grasses have a similar survival rate when exposed to water deficit, however, *D. pentizzi* has a more prominent mortality rate.

Plant death begins with the senescence process of the leaves. This process begins as water availability decreases, due to reduced soil water content, decreased leaf water potential or in response to high atmospheric demand, intensifying turgor loss, leaf wilting and stomatal closure (Araújo Jr. et al., 2019).

U. mosambicensis plants began to die at 49 DAT when not irrigated (0% FC), while *D. pentzii* plants began to die at 33 DAT. *U. mosambicensis* plants in the 0% FC treatment survived more than 61 DAT, while *D. pentzii* plants under the same condition did not survive more than 54 days (Table 2).

Table 2. Lifetime of *Urochloa mosambicensis* and *Digitaria pentzii* under irrigation at 0% field capacity.

Urochloa mosambicensis				*Digitaria pentzii*			
Lifetime	Exposed plants	Dead plants	S(t)	Lifetime	Exposed plants	Dead plants	S(t)
30	10	0	100.0%	30	10	0	100.0%
49	10	2	80.0%	33	10	2	80.0%
54	8	6	20.0%	47	8	4	40.0%
61	2	2	0.0%	54	4	4	0.0%

S(t) - survival probability by the Kaplan-Meier estimator.

The results presented in Table 2 suggest that the grass *D. pentzii* is relatively more sensitive to extreme drought (lack of irrigation), being more suitable for the grass *U. mosambicensis* for longer drought conditions. Tolerance to water deficit is an intrinsic characteristic of each plant species, and plants can develop different mechanisms that act in isolation or together to live with such as situations of water limitation with an accumulation of compatible osmosolutes (Blum, 2017); morphological and anatomical adaptations (Araújo Jr. et al., 2019) and drought-resistant gene developments (Reddy et al., 2017). The performance of these mechanisms will depend on the intensity of the water deficit and the number of stressful events (Barros et al., 2018).

Plants that were irrigated with 25% of FC, regardless of species, had a longer lifetime when compared to grasses that were not irrigated (Table 3). *U. mosambicensis* plants began to die at 82 DAT, while *D. pentzii* plants began to die at 75 DAT. *U. mosambicensis* plant survived for more than 131 days, while in *D. pentzii* no plant survived for more than 117 days, confirming that the *U. mosambicensis* grass is more persistent under prolonged water deficit (Table 3).

Table 3. Lifetime of *Urochloa mosambicensis* and *Digitaria pentzii* under irrigation at 25% field capacity.

Urochloa mosambicensis				*Digitaria pentzii*			
Lifetime	Exposed plants	Dead plants	S(t)	Lifetime	Exposed plants	Dead plants	S(t)
30	10	0	100.0%	30	10	0	100.0%
82	10	2	80.0%	75	10	2	80.0%
96	8	4	40.0%	89	8	4	40.0%
121	4	0	40.0%	97	4	2	20.0%
131	4	4	0.0%	117	2	2	0.0%

S(t) - survival probability by the Kaplan-Meier estimator.

The replacement of water-based on 25% of FC doubles the lifetime of the two studied forage species, and during the first 74 DAT, no plant death of the two grass species was verified (Table 3). However, the reduction in the plant shelf under this water regime condition is still quite significant. The survival of some plants in this condition of water deficit (25% of FC) may be associated with plant defense mechanisms, such as the accumulation of compatible osmosolutes (proline, free amino acids and soluble sugar) that contribute to an osmotic adjustment, reducing the cellular water potential and facilitating water absorption by the plant even under deficit (Marviya & Vakharia, 2016).

In the water replacement based on 50% of FC, it is observed that *U. mosambicensis* plants began to die at 82 DAT, while *D. pentzii* plants began to die at 89 DAT. *U. mosambicensis* plants survived for more than 195 days, while in *D. pentzii* no plant survived for more than 152 days, confirming that the *U. mosambicensis* grass is more persistent to prolonged water deficit (Table 4).

Table 4. Lifetime of *Urochloa mosambicensis* and *Digitaria pentzii* under irrigation at 50% field capacity.

Urochloa mosambicensis				*Digitaria pentzii*			
Lifetime	Exposed plants	Dead plants	S(t)	Lifetime	Exposed plants	Dead plants	S(t)
30	10	0	100.0%	30	10	0	100.0%
82	10	2	80.0%	89	10	2	80.0%
142	8	0	80.0%	142	8	4	40.0%
159	8	2	60.0%	152	4	4	0.0%
181	6	4	20.0%	--	--	--	--
195	2	2	0.0%	--	--	--	--

S(t) - survival probability by the Kaplan-Meier estimator.

The results referring to irrigation with 50% of FC provide a threshold value, as it presents mortality of 40% in grasses even for a long period (140 days) subjected to this level of irrigation, in addition to triplicating the survival time of the two species of grasses when compared to grasses that were not irrigated. A higher survival rate found in this treatment may be related to the gradual distribution of the water deficit throughout the cycle, facilitating the occurrence of adaptations in plants caused by water stress.

Applying the water regimes of 75% and 100% of FC, it is verified that the survival rate of forage grasses *U. mosambicensis* and *D. pentzii* is 100% at 240 DAT, respectively (Table 5), indicating that water management with 75% of FC did not promote enough water stress to cause the total death of plant tissues.

Table 5. Lifetime of *Urochloa mosambicensis* and *Digitaria pentzii* under irrigation at 75% and 100% field capacity.

Urochloa mosambicensis				*Digitaria pentzii*			
Lifetime	Exposed plants	Dead plants	S(t)	Lifetime	Exposed plants	Dead plants	S(t)
30	10	0	100.0%	30	10	0	100.0%
240	10	0	100.0%	240	10	0	100.0%

S(t)- survival probability by the Kaplan-Meier estimator.

Figure 2 shows the survival curve estimated by the Kaplan-Meier method as a function of the different irrigation regimes for *U. mosambicensis* (Figure 2a) and *D. pentzii* (Figure 2b) grasses. In the survival curve of *U. mosambicensis* it is observed that all plants that were not irrigated (0% of FC) died up to 61 days (Figure 2a), while all *D. pentzii* plants died up to 54 days (Figure 2b). Plants of *U. mosambicensis* irrigated with 25% of FC did not survive more than 131 DAT (Figure 2a), while those of *D. pentzii* did not survive more than 117 DAT (Figure 2b). Plants that received 50% of FC did not survive more than 195 days for *U. mosambicensis* (Figure 2a), whereas *D. pentzii* grasses did not survive longer than 153 days (Figure 2b). Grasses that were irrigated at 75 and 100% of field capacity for more than 163 days (*U. mosambicensis*) and 156 days (*D. pentzii*) had a 100% survival rate (Figure 2a and b).

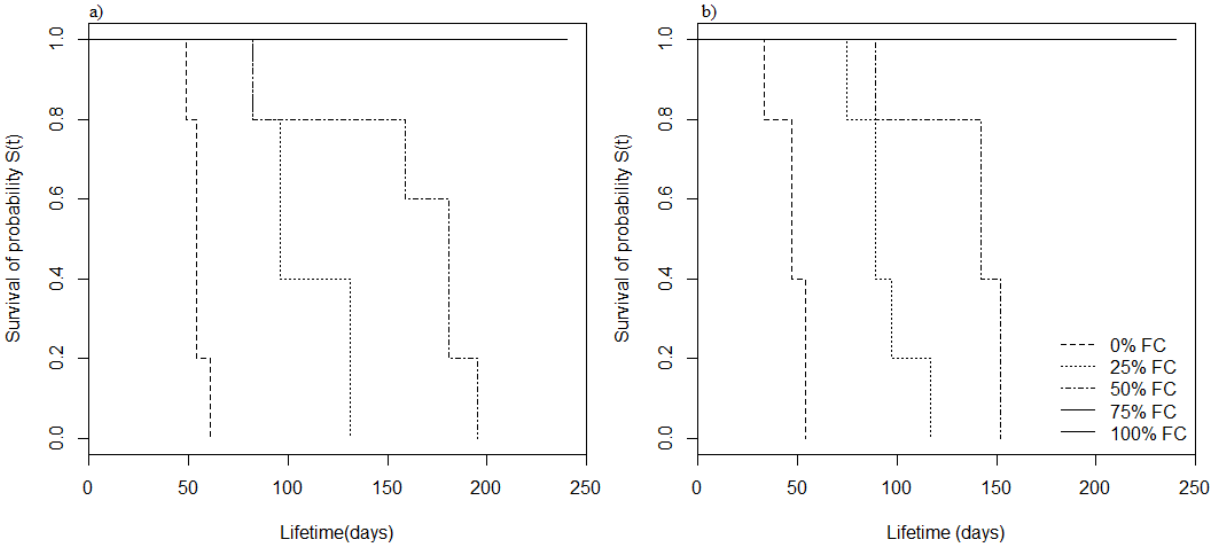

Figure 2. Survival probability of *Urochloa mosambicensis* (a) and *Digitaria pentzii* (b) grasses as a function of make-up water availability using the Kaplan-Meier estimator.

The lifetime of plant tissue may be related to the degree of damage or inhibition of vital metabolic processes in plants (especially those that need water), such as ion and nutrient transport functions, cell development and solute translocation (Zargar et al., 2017).

In addition, it should be considered that the first response of plants to water deficit (stomatic closure) leads to less CO_2 absorption, contributing to lower yields or making the survival of plants unfeasible (Tardin et al., 2013). Furthermore, lower assimilation of CO_2 promotes a reduction in the speed of the calvin cycle, resulting in a surplus of electrons from the photochemical part of photosynthesis, resulting in the production of reactive oxygen species (EROs) which promotes cell death.

Plant responses to water deficit depend on the amount of water lost by transpiration, the loss rate and the duration of the stressful condition. In addition, the effects of water stress still depend on irrigation management, and the shorter the interval between irrigation events, the smaller the effect of the water deficit (Ismail, El-Nakhalwy, & Basahi, 2018).

Plants subjected to irrigation of 0 and 25% of FC died faster comparing to other water regimes, as the stress caused by severe water deficit causes a fast reduction in leaf area, stomata closure, decrease in cellular turgor, reduction in photosynthesis and assimilate translocation, acceleration of senescence and leaf abscission (Araújo Jr. et al., 2019). In the treatments of 0 and 25% of FC these damages caused to the plants were irreversible.

Lucena et al. (2020) found that water scarcity combined with salt stress caused the death of millet plants, and that most plants do not survive more than 105 days of life, a fact that corroborates the findings of this research. The death of plants subjected to irrigation of 0.25 and 50% of FC may have occurred because water stress causes deficiency in plant development, leading to a decrease in leaf area, which impairs phytomass production, compromising the development of the root system leading to a plant death.

The decrease in leaf area directly reflects on limited light absorption, which results in acceleration of leaf senescence, inhibition of tillering and branching, rapid tiller death, as well as delaying plant growth and development. The reduction in leaf area is mainly influenced by the turgor pressure of the cells, which in turn is determined by the water content of the plant. Therefore, the lower the water content present in the plant, the lower the turgor of the cells, which leads to a lower rate of leaf growth (Araújo Jr. et al., 2019). To meet their metabolic needs, plants need to renew the water that has been transferred to the atmosphere, in order to maintain the turgor of their leaves and roots and consequently ensure their survival (Araújo Jr. et al., 2019).

Table 6 shows the regression models that were adjusted to describe the lifetime of *U. mosambicensis* and *D. pentzii* plants. Based on the adequacy criteria (AIC, BIC, RMS and R^2_{prop}) and on the estimation of the survival probability of the models, the model that best described the lifetime of *U. mosambicensis* and *D. pentzii* plants was the Weibull (Table 6 and Figures 3 and 4). Using the Weibull model, it is verified that at each 1% increase in FC, the chance of the *U. mosambicensis* and *D. pentzii* plant remaining alive is 2.4% higher, respectively.

Table 6. Estimates of model parameters to explain the lifetime of *Urochloa mosambicensis* and *Digitaria pentzii* as a function of different water regimes.

Models	*Urochloa mosambicensis*			*Digitaria pentzii*		
	Estimative	Standard error	p-value	Estimative	Standard error	p-value
			Weibull			
β_0	4.066	0.074	<0.0001	3.934	0.083	<0.0001
β_1	0.024	0.002	<0.0001	0.024	0.004	<0.0001
σ	0.163	0.013	<0.0001	0.151	0.018	<0.0001
AIC	138.2			133.4		
BIC	141.9			137.1		
RMS	0.021			0.013		
R^2_{prop}	0.770			0.746		
			Log-normal			
β_0	4.005	0.086	<0.0001	3.842	0.075	<0.0001
β_1	0.023	0.002	<0.0001	0.024	0.002	<0.0001
σ	0.223	0.021	<0.0001	0.194	0.017	<0.0001
AIC	143.2			135.7		
BIC	146.9			139.5		
RMS	0.017			0.019		
R^2_{prop}	0.755			0.703		
			Gumbel			
β_0	52.181	5.525	<0.0001	40.33	6.154	<0.0001
β_1	2.731	0.157	<0.0001	2.75	0.161	<0.0001
σ	14.7	1.244	<0.0001	17.9	1.247	<0.0001
AIC	143.97			151.4		
BIC	147.66			155.1		
RMS	0.027			0.053		
R^2_{prop}	0.611			0.605		
			Logistic			
β_0	47.695	7.621	<0.0001	33.837	8.820	<0.0001
β_1	2.724	0.190	<0.0001	2.716	0.211	<0.0001
σ	12.7	1.251	<0.0001	14.5	1.242	<0.0001
AIC		149.8			154.2	
BIC		153.5			157.9	
RMS		0.031			0.052	
R^2_{prop}		0.543			0.583	

The Weibull model will allow estimating the survival time of *U. mosambicensis* and *D. pentzii* plants, respectively, for several irrigation management conditions between 0 and 100% of FC, contributing to better management and decision-making by producers. Assessing the lifetime of millet under water and saline stress conditions, Lucena et al. (2020) found that after 121 days after sowing, plant survival was 35.0% using the exponential model, while using the Weibull model plant survival was 20.8%.

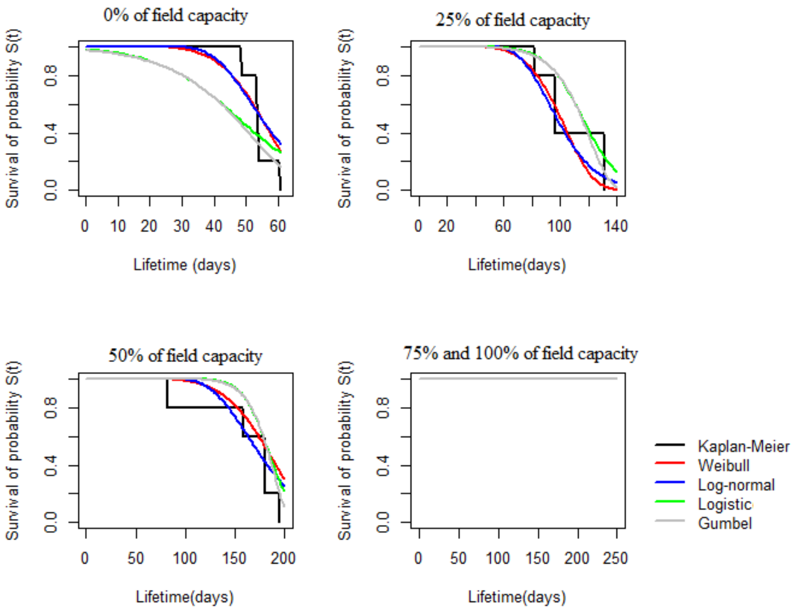

Figure 3. Estimation of the survival functions of *Urochloa mosambicensis* plants as a function of different water regimes.

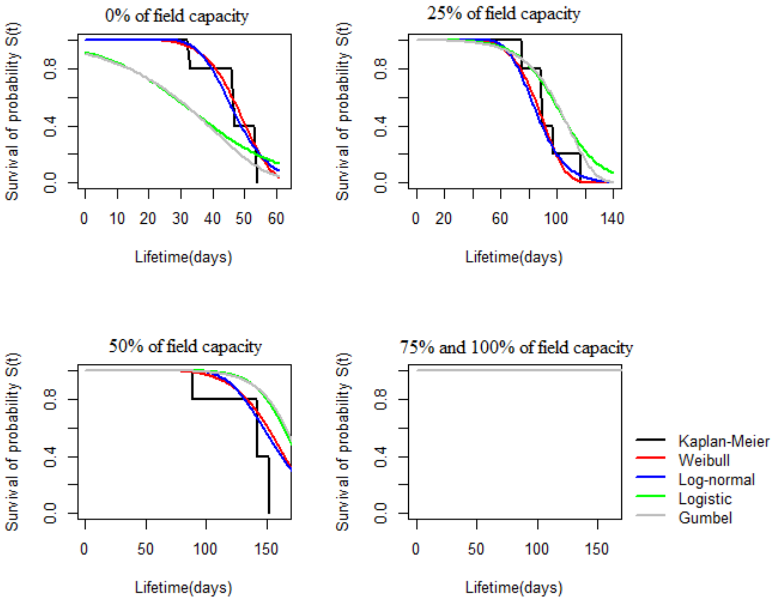

Figure 4. Estimation of the survival functions of *Digitaria pentzii* plants as a function of different water regimes.

Conclusion

Urochloa mosambicensis has a greater tolerance to water deficit, having a longer lifetime under poor irrigation conditions. Irrigations with 25 and 50% of field capacity double and triplicate, respectively, the lifespan of *Urochloa mosambicensis* and *Digitaria pentzii* plants when compared to plants that did not receive irrigation. Lifetime definition of *Urochloa mosambicensis* and *Digitaria pentzii* plants under water deficit helps rural producers in the selection, planning and decision-making in the management of these forage species, in addition to demonstrating the maximum time that forage species can remain with low water content in the soil, without causing a high mortality rate.

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