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PHYLLOCHRON VARIABILITY AND CUTTING MANAGEMENT PRACTICES ON THE AGRONOMIC POTENTIAL OF SORGHUM (*Sorghum bicolor* (L.) Moench)

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Abstract

The phyllochron is an indispensable parameter associated with the potential production of sorghum. Accordingly, management practices applied directly in the sorghum (*Sorghum bicolor* (L.) Moench) crop, such as the cutting technique, provide the ability of plants to regrowth and reestablish the performance of vegetative and reproductive development based on the stimulation of growth in the photosynthetically active area. Appropriately, the aim of this study was to evaluate the alterations in phyllochron and leaf emission rate expressed by the implementation of cutting management practices in sorghum plants from high and low-quality seeds. The study was performed in the experimental and didactic area of the Federal Institute of Rio Grande do Sul (IFRS) – Ibirubá, Rio Grande do Sul, Brazil. The experimental design was completely randomized and the treatments were plants from higher (HQS) and lower (LQS) quality seeds and two season crops (2015/16 and 2016/17) with eight replications. The mean phyllochron (°C day leaf^{-1}), height (cm), main stem diameter (cm), number of nodes, dry mass (kg ha^{-1}), and number of tillers were evaluated as a strategy to verify the performance of each treatment. Furthermore, meteorological data obtained from an automatic station was required to calculate phyllochron and the evapotranspiration (ET_c). Finally, this study indicated that the diameter of the stem and tillers is directly associated to the accumulation of a dry mass of the crop, based on the results of biomass productivity. Moreover, it was demonstrated that forage sorghum plants derived from HQS indicated a higher capacity to accumulate photoassimilates, stimulating the production of dry mass.

Keywords: biomass accumulation; dry matter; leaf area performance; leaf emergence.

VARIABILIDADE DO FILOCRONO E PRÁTICAS DE MANEJO DE CORTE NO POTENCIAL AGRONÔMICO DE SORGO (*Sorghum bicolor* (L.) Moench)

Resumo

O filocrono é um parâmetro indispensável associado ao potencial de produção do sorgo. Nesse sentido, práticas de manejo aplicadas diretamente na cultura do sorgo (*Sorghum bicolor* (L.) Moench), como a técnica de cortes, proporcionam a capacidade das plantas de rebrotar e restabelecer o desempenho do desenvolvimento vegetativo e reprodutivo das plantas a partir do estímulo do crescimento da área fotossinteticamente ativa. Apropriadamente, o objetivo deste estudo foi avaliar as alterações no filocrono e na taxa de emissão foliar expressas pela implementação do manejo de corte em plantas de sorgo a partir de sementes de alta e de baixa qualidade. O estudo foi realizado na área experimental e didática do Instituto Federal do Rio Grande do Sul (IFRS) – Ibirubá, Rio Grande do Sul, Brasil. O delineamento experimental foi inteiramente casualizado e os tratamentos foram plantas provenientes de sementes de qualidade superior (SQS) e inferior (SQI) e duas safras (2015/16 e 2016/17) com oito repetições. O filocrono médio (°C dia folha^{-1}), altura (cm), diâmetro do caule principal (cm), número de nós, massa seca (kg ha^{-1}) e número de perfilhos foram avaliados como estratégia para verificar o desempenho de cada tratamento. Além disso, dados meteorológicos obtidos de uma estação automática foram necessários para calcular o filocrono e a evapotranspiração (ETc). Finalmente, este estudo indicou que o diâmetro do caule e perfilhos está diretamente associado ao acúmulo de massa seca da cultura, com base nos resultados de produtividade de biomassa. Além disso, foi demonstrado que plantas de sorgo forrageiro derivadas de SQS apresentaram maior capacidade de acumular fotoassimilados, estimulando a produção de massa seca.

Palavras-chave: acúmulo de biomassa; matéria-seca; performance da área foliar; emergência de folhas.

Introduction

Forage sorghum (*Sorghum bicolor* (L.) Moench) has a C4 photosynthetic system, and it is cultivated for use as food, feed, fiber, and biofuel. The chemical composition of sorghum is abundant in fat, protein, polysaccharides and nutrients, and vitamins (ESPITIA-HERNÁNDEZ *et al.*, 2020). Its ability to resist water deficit makes it an important crop for cultivation in regions where rainfall is a limiting factor, it has lower soil fertility requirements and higher regrowth capacity (ABREHA *et al.*, 2022). Its most common agronomic purposes are cutting, grazing, vegetation cover, and silage (BARROS *et al.*, 2020). Furthermore, it is widely introduced in the field with the aim of producing biomass for cover and is extremely efficient in retaining, and maintaining soil moisture, increasing the organic carbon content and infiltration, and reducing surface runoff of water and erosion (MENDIS *et al.*, 2022).

Accordingly, an alternative for feeding cattle with corn forage is sorghum, since its dry mass production and nutritional characteristics are similar, an advantage for sorghum, which requires lower production costs compared to corn (FERRAZ-ALMEIDA *et al.*, 2022). The replacement of the corn grains used to feed beef cattle with sorghum is an alternative since the use of sorghum obtained a similar weight and carcass quality of the animals of the diet totally constituted by corn (AMBRÓSIO *et al.*, 2023).

Appropriately, the production cost is a limiting factor for the increase in the income of the producers, the production of cattle demands large expenses with food, reaching 80% (GREENWOOD, 2021). To avoid this situation, techniques, such as handling the disposal of the animal in the field, the application of plant by-products with a high protein and/or mineral concentration, and the use of forage crops adapted to the region and which have lower production costs than those normally explored by the producer must be adopted (CREMILLEUX *et al.*, 2022; PATERNINA-ACOSTA *et al.*, 2021; CAPPELLOZZA *et al.*, 2021).

Accordingly, forage sorghum is adapted to conditions of lower water availability, has lower production costs than corn, the main crop used in silage, and can replace in animal feed. Despite the various uses and benefits, sorghum has a low area of cultivation when compared to corn, which obtained 22.31 million hectares in the first and second harvests, while sorghum for grain reached 1.05 million hectares (CONAB, 2023). The formation of pastures is one of the most important steps to achieve the success of the livestock enterprise, in case of failure, low productivity and more susceptibility to pasture degradation can be caused, with seed quality being one of the fundamental factors for proper establishment. of culture (COSTA *et al.*, 2021). Attribution of financial resources solely used to maintain the productive potential of the cultivar, such as fertilization, phytosanitary treatment, weed control, and other cultural practices, are not capable of increasing the productivity characteristic of the genotype. Genetic advancement is essential when it comes to raising field productivity, to reach higher and higher levels, so attention must be paid to the quality of the seeds used, as they will carry the potential selected by the breeding program (LADO; MUTHOMI, 2020).

Besides, some of the benefits of using high-quality seeds are increased productivity, and more efficient use of fertilizers, irrigation, and pesticides. Furthermore, the plants will have higher uniformity of emergence and seedling vigor (BATISTA *et al.*, 2022). Other benefits are the periodic and rapid replacement of new cultivars that will have production potential and even more advanced tolerance mechanisms (CAPSTAFF; MILLER, 2018). Due to the relevance of the use of higher quality seeds, the high representativeness of cattle farming in the national economy, and the importance of forage sorghum as a food source, research is required in a way that enables the best use of resources in the agricultural sector and encourages this type of management (RANE *et al.*, 2021).

Moreover, Brazil faces serious resistance to the use of certified seeds, which can cause a series of harm to a large part of the productive chain (SCHILLING-VACAFLOR *et al.*, 2021). Moreover, the Brazilian sector suffers from serious losses such as reduced investments in research, possible reduction in productivity, field contamination, less security in the return on investment and low exploration of public-private partnerships (BAGLAN *et al.*, 2020). Low rates of use of certified seeds occur due to the use of saved seeds or seeds sold illegally. Its use ends up being worrying since a difference is observed between the favorable seed quality for certified and saved lots.

Additionally, the productive potential, resistance to diseases, insects, adverse environmental factors, product quality, response to inputs, and precocity are characteristics that influence the agronomic value of the cultivar, and this, in turn, can be interfered with by the low quality of seeds (TOSTA *et al.*, 2021). Even within a certified batch, there are seeds with different physiological qualities, the difference between the seeds is accentuated in batches of lower quality, as they are usually saved, due to the significant variability between the seeds, they will express less uniformity and speed in the field of emergency (AMORIM *et al.*, 2021).

Seeds with high vigor have desirable characteristics for faster emergence and easier adaptation, such as faster translocation from seed reserves to seedling tissues (SAHA *et al.*, 2022). Therefore, higher quality seeds can generate better establishment of plants, consecutively, the stand will be more appropriate, and this condition is capable of interfering with production (MEKASHA *et al.*, 2021). Furthermore, the use of high-quality seeds is an important parameter to increase the chance of successful cultivation (PENG *et al.*, 2020).

Accordingly, due to the relevance of the use of higher quality seeds, the high representativeness of cattle farming in the agricultural economy, and the importance of forage sorghum as a food source, research is required in a strategy that enables the exploration of resources in the agricultural sector and encourages this type of management. Correspondingly, the aim of this study was to evaluate the alterations in phyllochron and leaf emission rates expressed by the implementation of cutting management practices in sorghum plants from high and low-quality seeds in distinct agricultural years.

Material and Methods

Area characterization

The experiment was performed in the experimental and didactic area of the Federal Institute of Education, Science and Technology of Rio Grande do Sul, physiographic region of the Middle Plateau, Ibirubá, RS, Brazil (latitude (º) -28.656178, longitude (º) -53.112895, and 416 m above sea level). The Köppen climatic design is Cfa (humid subtropical) and the soil was classified as a Typical Dystroferric Red Latosol (SANTOS *et al.*, 2018). The agronomic evaluation of the collected material was conducted in the Didactic Laboratory for Research and Analysis of Seeds and Grains and in the Laboratory for Research on Annual Crops, Federal Institute of Education, Science and Technology of Rio Grande do Sul, Ibirubá, RS, Brazil.

Experimental design

In the 2015/16 crop season, the experiment was implemented in the direct seeding process using the cultivar Jumbo (Atlântica Sementes S.A.). The treatments were plants from higher (HQS) and lower (LQS) quality seeds and the 2015/16 and 2016/17 crop seasons. The experimental design applied was completely randomized, with eight replications for each seed specify in each management practice. Three plants were selected per repetition.

According to the cultivar performance, the characteristics are excellent forage quality with frequent cuts, production of straw for cover in no-tillage, rusticity, resistance to viruses, deep root system, the productivity of up to 1,200 kg ha day^{-1} of fresh mass, sowing time from September to March, the population of 300 to 400.000 plants ha^{-1}, which is equivalent to 10 to 15 kg seeds ha^{-1}.

Moreover, in the 2015/16 crop season, sorghum was sown on 11/04/2015, plants from HQS emerged on 11/11/2015, and LQS on 11/13/2015. In the 2016/17 crop season, the sorghum was sown on 10/08/2016, with the emergence of plants from HQS on 10/15/2016 and LQS on 10/17/2016. Technical indications of plant population, sowing depth, row spacing, and sowing time were used (CONAB, 2015; FILHO *et al.*, 2010). The sowing depth used was 4 cm, for all seeds, the depth control was performed at the time of sowing, performing visual evaluations.

To define the plants originating from HQS and LQS, a methodology similar to those adopted by Schuch *et al.* (2009) and Panozzo *et al.* (2009), the first seedlings emerged, approximately seven days after sowing, were considered as plants from HQS, while plants from LQS were defined as the last seedlings to emerge, which occurred approximately two days after the emergence of the HQS. This definition was possible since only one batch of certified seeds was used and in the same batch, there are both HQS and LQS. The experiment was divided, an area was destined for the evaluation of the whole plants and another one was submitted for cuts.

Agronomic evaluation

Phyllochron

To calculate the phyllochron, phenological data were used in association with climatic temperature data collected at the meteorological station of Campus Ibirubá, which is located 300 meters from the experimental area. The lower base temperature (Tb), optimal temperature (Topt), and upper base temperature (TB) of the forage sorghum were taken into account as 11, 30, and 42 °C (KIM *et al.*, 2010; SINGH *et al.*, 1998).

The determination of the average air temperature (Tave) from the data from the meteorological station was performed by calculating the arithmetic mean between the minimum (Tmin) and maximum (Tmax) air temperature on that day, with the following exceptions (ROSA *et al.*, 2009):

If $Tmin < Tb$, $Tmin = Tb$;

If $Tmax > TB$, $Tmax = TB$.

The phyllochron was determined according to the method suggested by Rosa *et al.* (2009) and obtained through the least standard deviation, using the following equations to determine the thermal sum:

If $Tb < T\text{ave} \leq T\text{opt}$, $\text{TS}d = (T\text{ave} - Tb) \times 1\text{day}$;

If $T\text{opt} < T\text{ave} \leq TB$, $\text{TS}d = (T\text{opt} - Tb) \times (TB - T\text{ave}) \div TB - T\text{opt} \times 1\text{day}$.

Since the STd was accumulated from the emergence of each plant to the beginning of its maturation, this period resulted in the accumulated thermal sum (STa): STa=∑STd. Linear regression was performed between NL and STa for the mean of each repetition and the phyllochron was estimated as the inverse of the slope of this linear regression (MENDONÇA *et al.*, 2012).

Morphological performance of plants not submitted to cuts

In the area without cutting between the emergence and beginning of flowering processes, the number of emissions of fully expanded leaves on the main stem (NL) was monitored, and the evaluations occurred three times a week. The last sheet was issued and marked with an elastic band, wrapping it, as the others developed, the marking changed. When the identified plants reached physiological maturity, they were collected individually by cutting at the height of the ground, without their structures being damaged. Subsequently, the plants were directed to the laboratories and the evaluations of the morphological characteristics were performed. According to the collected plants, the variables height (H), stem diameter (SD), the number of nodes in the main stem (NN), and dry mass (DM) were determined.

For height analysis, a tape measure was used and measurements were performed from the apex to the base (ground height) of the plants. The results were established in centimeters. Using a digital caliper, Digimess Instrumentos de Precisão Ltda., the average diameter of the main culm was determined by measuring the smallest diameter of the center of the second internode. To determine the number of nodes in the main stem, it was necessary to directly count the plants already collected, considering only the nodes above ground.

Finally, dry mass evaluations for plants destined for full development were performed by cutting at ground level when the selected plants were close to the period of physiological maturity. Afterward, the replicates were submitted to drying using a paper bag in a forced air circulation oven at an approximate temperature of 65 °C. The daily weighing was performed to observe when the sample reached constant weight. Subsequently, the repetition was destined for final weighing on an analytical balance with three decimal places of precision.

Morphological performance of plants submitted to cuts

In the area conducted simulating grazing, four and five cuts were performed. The cutting procedure was performed when the average height of the plants was between 60 cm high, after the cut the remaining height was 20 and 30 cm from the soil for sorghum (FORTANELI *et al.*, 2012). The selected plants from each replicate were cut and placed separately. In the last cut, the remaining stem and tillers were collected to determine the diameter and dry mass. After each cut, 50 kg of N was applied in the form of urea in coverage. The plant material from the cutting procedure and remaining stems were dried using a paper bag in a forced air circulation oven at a temperature of, approximately, 65 °C. The daily weighing was performed to observe when the sample reached constant weight, and when obtained, the repetition was destined for final weighing on an analytical balance with three decimal places of precision.

Additionally, after conducting the cuts and collecting the remaining stem, evaluations of stem and tiller diameter and number of tillers were performed. Using a digital caliper, Digimess Instrumentos de Precisão Ltda., the average diameter of the main stem and tillers was determined by measuring the smallest diameter of the center of the second internode. To determine the number of tillers in the main stem in the area with the performance of cuts, it was necessary to directly count the plants collected.

Water deficiency

Other data from the IFRS meteorological station INMET, Campus Ibirubá, were also required to calculate the water balance by the SISDAGRO system. In the system, the option of corn was selected as a crop, due to the availability and higher proximity to the Poaceae used in this study, with a cycle according to the period that the plants remained in the field and clayey soil due to the similarity with the experimental area, generating the value of available soil water capacity of 76.8 mm. Moreover, the water balance calculations reproduced were based on the methodology of Penman-Monteith (ALLEN *et al.*, 1998) and Thornthwaite & Mather (THORNTHWAITE; MATHER, 1955).

Statistical analysis

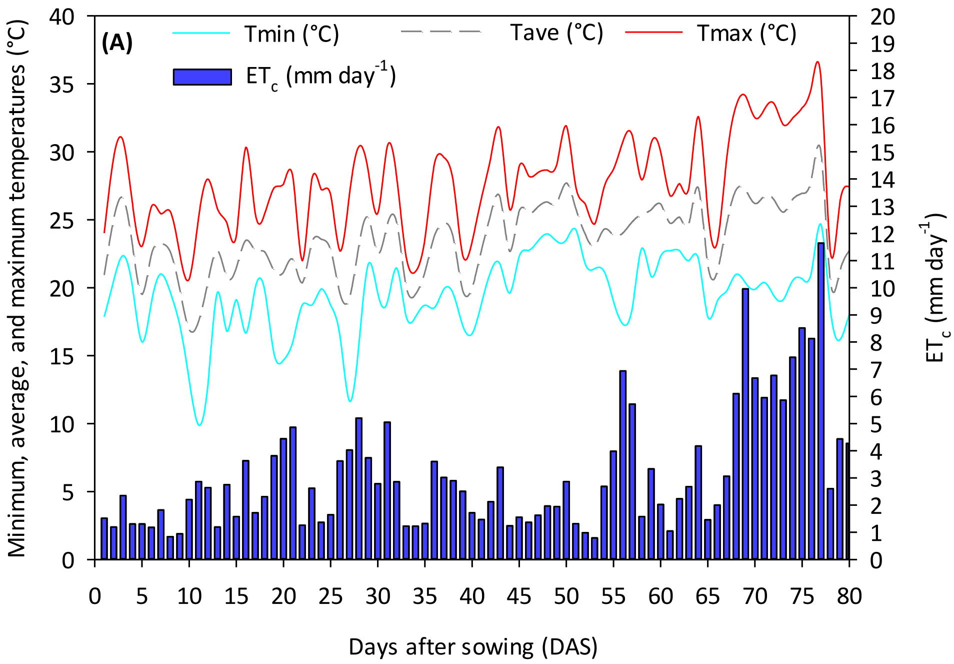
The data collected were tabulated, with the aid of the Sisvar® 5.6 statistical software package, submitted to analysis of variance, and, in case of significance, the Tukey test was applied at a 5% probability of error.

Results and Discussion

Meteorological data

In the 2015/16 crop season, on average, sorghum started its reproductive stages on 02/06/2016, 87 days after emergence (DAE) of the HQS, and dry mass collections were conducted on 04/08/2016 (149 DAE). In 2016/17 the sorghum started the reproductive period for the HQS on 01/25/2017 (102 DAE) and dry matter collection on 03/01/2017 (137 DAE).

The average daily air temperature of the 2015/16 was 23.5 °C, with a minimum temperature of 19.6 °C and a maximum of 28.1 °C. In 2016/17, the average air temperature was 23.0 °C and its minimum and maximum temperature were 18.6 °C and 27.5 °C, respectively. In the 2015/16 crop season, there was a lower amount and uniformity of water deficit throughout the crop cycle, compared to the second crop, attributing higher performance to the plants of the first season (Figure 1).



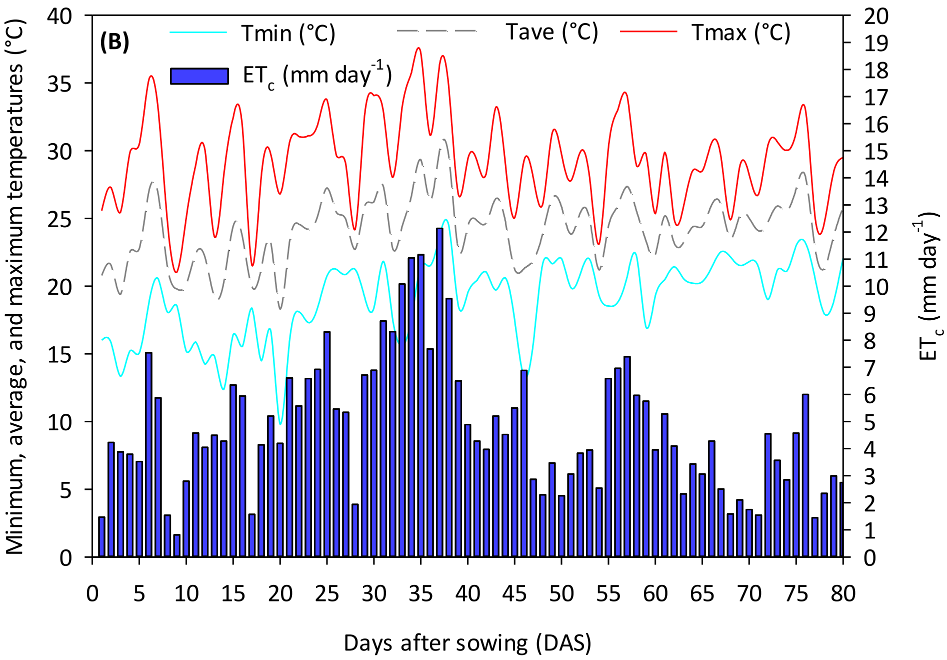


Figure 1. Minimum (Tmin, °C), average (Tave, °C), and maximum (Tmax, °C) air temperatures and crop evapotranspiration (ET_c, mm) in the (A) 2015/16 and (B) 2017/18 crop seasons.

The 2015/16 crop season required 87 DAE to start its reproductive period, during this process, it only suffered a period of severe water deficit, close to panicle emission, lasting 15 days and leaving the plants in a negative balance of 67.1 mm, which contributed to a total of 37 days and 77.9 mm of accumulated water deficit. The 2016/17 crop season ended its vegetative development at 102 DAE and, unlike the previous one, it suffered a constant water deficit, lasting 65 days and quantifying 85.7 mm accumulated.

Despite the intense lack of water for a fortnight in the 2015/16 crop season, in 2016/17, during the reproductive period, a significant water deficit was observed, which can affect the development and growth of the forage sorghum crop. The total recorded in this harvest was 28 days and 7.8 mm more accumulated water deficit than in the previous one.

The factors that most commonly affect leaf expansion rates, leaf height, and leaf area duration are temperatures outside the ideal range, water, and nutrient deficiency (ZHANG *et al.*, 2019). Rain indirectly affects the rate of photosynthesis performed by the plant, as it interferes with soil moisture, which is a regulatory factor for all the metabolic processes of the crop, including the production of photoassimilates (YANG *et al.*, 2020). With low soil moisture, the plant will be induced to stomatal closure, reducing CO_2 fixation, therefore, delaying growth and development (MONTEIRO *et al.*, 2009). The rainfall in the state of Rio Grande do Sul is variable, which impacts agricultural crops, as the irregularity of rainfall can expose plants to water deficit, reducing the performance of morphological characteristics, yield components, and grain productivity (PARIZI *et al.*, 2009).

Morphological performance of plants not submitted to cuts

In both seasons, the final plant population obtained was approximately 333.000 plants ha^{-1}. There was no interaction between plants, but differences were observed between treatments. The results obtained with the complete development of the plants in the harvests were superior for the plants from HQS, except for the number of leaves (Table 1).

Table 1. Means of phyllochron (°C day leaf^{-1}), height (cm), the diameter of the main stem (cm), number of nodes and dry mass (kg ha^{-1}) of forage sorghum plants derived from high quality seeds (HQS) and low quality seeds (LQS) in the 2015/16 and 2016/17 crop seasons without cutting, Ibirubá, RS, Brazil.

	Phyllochron	**H**	**DS**	**NN**	**DM**	**Phyllochron**	**DS**	**DM**
	2015/16					**2016/17**		
HQS	75.1 A*	354 A	0.85 A	14.2 A	19611 A	74.3 A	1.12 A	16616 A
LQS	82.5 B	300 B	0.67 B	12.0 B	11100 B	83.3 B	0.40 B	14094 B
Average	78.8	327	0.76	13.1	15355	78.8	0.76	15355
CV (%)	11.28	11.07	15.56	12.01	18.56	11.28	15.56	18.56

*Means followed by the same lowercase letter in the row or uppercase in the column did not differ from Tukey's test at 5% error probability.

The phyllochron was 7.4 °C day leaf^{-1} lower in the treatment with HQS, which demonstrates that the plants required less thermal accumulation for the emission of a new leaf in the main stem and consecutively had a more accelerated development, which also increased growth, accumulating dry mass in its structures, such as the culm, which is directly related to the total dry mass of each plant. The faster biomass accumulation allowed the HQS to produce plants with higher height, 354 cm, compared to 300 cm of the LQS. This scenario was also observed in the main stem diameter, 0.85 cm, and 0.67 cm, and the number of nodes in the main stem, 14.2 and 12.0, for HQS and HQS, respectively. The dry mass of plants from HQS was higher, reaching 19611 kg ha^{-1}, while in LQS this accumulation was 11100 kg ha^{-1}.

The results obtained by Ludwig *et al.* (2009) were similar, when corn plants from seeds of different qualities were compared, the averages obtained in the variable leaf area (cm^{-2} plant^{-1}) were 1047 and 781 in lots of HQS and LQS, respectively. Furthermore, it was observed a number of leaves plant^{-1} of 8.1 and 7.1 leaves plant^{-1}, plant height (cm) of 67.0 and 55.6 cm, and shoot dry mass (g plant^{-1}) 10.43 and 8.05 g plant^{-1}.

Accordingly, using seeds of high vigor for rice, Höfs *et al.* (2004) observed, in the 2000/2001 crop season, superior results for grain yield in the order of 9% and, in the 2001/2002 season, 10% more than in the plants from seeds with lower vigor. According to Perazzo *et al.* (2013), varieties that demonstrate higher foraging behavior are characterized by having a tall size, and a higher percentage of stem and leaf blade, therefore, they are cultivars with a higher capacity to produce dry mass. The study emphasized that the plant height is directly associated to the number of nodes and the cultivar Ponta Negra obtained both the highest results, 274 cm in height and 9.5 nodes in the main stem.

The results achieved in the study by Perrier *et al.* (2017) justified the higher productivity of dry mass in sorghum in the 2014 crop season through the high concentration of biomass in the stem, which was mainly influenced by the higher height and diameter of the stem compared to the 2013 season. Researching sweet sorghum, Almodares *et al.* (2013) arrived at the results where the maximum height growth (2.3 m) and the largest internode diameter (1.8 cm) provided the highest biomass results, reaching 58 Mg ha^{-1}.

An important morphological characteristic against lodging is the diameter of the stem, when larger, it increases the number of reserves, increasing the resistance of the stem to mechanical action (FIGUEREDO, 2019). Furthermore, despite the phyllochron being 10.2 °C day leaf^{-1} lower and the number of nodes in the stem being higher in plants from LQS, the number of leaves did not differ between the two seed qualities, with an average of 16.1 leaves per the main stem.

Each leaf originates from a node, until the V5 stage, the sorghum growth point is located below the ground, and may undergo changes by the environment or genetic characteristics, this makes the corresponding nodes to these leaves cannot be counted by the methodology applied, which considers only the nodes above the ground (CARCEDO *et al.*, 2022). Additionally, the first nodes above the ground are compressed, which makes it difficult to count directly on the plant, justifying the difference observed between the number of nodes and leaves (COELHO *et al.*, 2015).

Moreover, there was a difference for some of the variables when the plants without the presence of cuts were observed with the two crops (Table 1). The parameters height, the number of nodes, and leaves in the main stem reached averages of 327 cm, 13.1, and 16.1 respectively. Furthermore, the 2015/16 crop season obtained superior results compared to the 2016/17 season, the respective phyllochron values were 74.3 and 83.3 °C day leaf^{-1}, main stem diameters of 1, 12, and 0.40 cm, and total dry mass production of 16616 and 14094 kg ha^{-1}. The previous results indicated that the number of leaves did not differ, but there was an acceleration of the vegetative period of the plants of the 2015/16 crop season, which was confirmed by the phyllochron, resulted from the lower constancy of water deficit.

Rice crop results obtained by Crusciol *et al.* (2003), showed that in irrigated areas the extraction of nutrients can be 66% higher than in rainfed areas, influencing the higher production of dry matter and grains, which was confirmed by Mauad *et al.* (2011) who in the same culture obtained lower dry mass production in treatments with -0.5 MPa of soil water tension, compared to the treatment of -0.25 MPa. Moreover, it was verified that the 2015/16 crop season indicated a higher speed of development and growth capacity, since the stem diameter was higher, causing the forage sorghum to start the reproductive period earlier and it ended, in DAE, after 2016/17 crop season, having more time to translocate the reserves and new photoassimilates to the grains. This scenario occurred since the 2016/17 crop season suffered from water deficiency during the flowering period, which may have reduced the number of grains in the panicle, as well as an early start to the process of senescence of the lower leaves, which would impact productivity and dry mass (MAGALHÃES *et al.*, 2008).

Morphological performance of plants submitted to cuts

In both crop seasons, the final plant population obtained was approximately 333.000 plants ha^{-1}. When the averages of the two harvests were analyzed, interaction with the seed quality used and the cuts was observed, the same occurred when the separate averages of the crop seasons were related to the average yields of the distinct cuts and the remaining stem for each seed quality (Table 2).

Table 1. Average dry mass (kg ha cut^{-1}) of four cuts (I, II, III, and IV) and remaining (R) of forage sorghum plants from the 2015/16 and 2016/17 crop seasons and averages of the cuts as a function of seed quality, Ibirubá, RS, Brazil.

Quality	Dry mass (kg ha cut^{-1})						
	Cut					Crop season	
	I	II	III	IV	R	2015/16	2016/17
HQS	1172 Ab*	2590 Aa	2248 Aa	2101 Aa	1243 Ab	2619 Aa	1123 Ab
LQS	462 Bb	571 Bb	1263 Ba	722 Bb	587 Bb	966 Ba	476 Bb
Average	1296						
CV (%)	27.06						

*Means followed by the same lowercase letter in the row and uppercase in the column did not differ from Tukey's test at 5% error probability. R: Remaining cut

The interaction demonstrated the maximum efficiency of dry mass production in all cuts when the HQS was used. Among the dry mass yields according to the tested seed qualities, the HQS obtained higher results in all cuts, accounting for a general average of 1871 kg ha cut^{-1}, while the LQS produced 39% of the value of the HQS. Analyzing only the cuts, it can be concluded that for the HQS, the second, third, and fourth were the most significant. Nonetheless, in the LQS only one cut indicated more significant results when compared to the others, with 1263 kg ha^{-1} of dry mass production, the third cut was the best.

When observing the averages of all collections of the seed quality and harvest interaction, the first year and the HQS provided the highest results, both separately and together. The HQS in the 2015/16 crop season reached 2619 kg ha^{-1}, different from the second crop season with LQS, which produced 476 kg ha^{-1}. The total HQS yield was 9355 kg ha^{-1}, compared to 3605 kg ha^{-1} for the LQS, a result 160% higher for the HQS. The total dry mass productivity of the 2015/16 crop season was 8963 kg ha^{-1}, 124% higher than the 2016/17 season.

The results obtained by Scheeren *et al.* (2010) indicated that the exploration of seeds of higher physiological quality in soybean crops is more efficient in establishing the initial plant stand. In order for the plant population to be equal in distinct qualities, it was necessary to increase the amount of lower quality seeds by 47%, even with this measure, there were 11.5% losses in plant height at 21 and 75 days after sowing (DAS) and grain yield of LQS was 3495 kg ha^{-1}, 311 kg ha^{-1} more than LQS.

Furthermore, research using millet culture, performed by Torres *et al.* (2019), generated increasing results of animal load and live weight gain ha^{-1} as the dry mass productivity increased by the crop. The evaluation municipalities were Santiago and Santa Maria, Rio Grande do Sul. In Santiago, the variation in dry mass productivity was 11040 and 15494 kg ha^{-1}, and as the results increased, the animal load varied between 3067 and 4304 kg of live weight ha^{-1} day^{-1} and the weight gain was from 920 to 1291 kg ha^{-1}. The response of animal load and live weight gain in relation to dry mass productivity obtained in Santa Maria was similar to that of Santiago.

Moreover, there was a statistical difference for the variables, stem diameter, number of tillers, and tiller diameter. Nevertheless, only the third one resulted in an interaction between crops and seed quality, with no statistical difference between crops for stem diameter and number of tillers (Table 3).

Table 2. Average diameter of the main stem (cm) and average number of tillers for 2015/16 and 2017/18 crop seasons and tiller diameter (cm) as a function of seed quality, Ibirubá, RS, Brazil.

Quality	**Diameter of the main stem (cm)**	**Number of tillers**	**Tiller diameter (cm)**	
			Crop season	
	-	-	2015/16	2016/17
HQS	0.90 A*	1.71 A	0.79 Aa	0.32 Ab
LQS	0.64 B	0.56 B	0.35 Ba	0.13 Bb
Average	0.77	1.13	0.4	
CV (%)	26.16	15.25	23.99	

*Means followed by the same lowercase letter in the row and uppercase in the column did not differ in Tukey's test at 5% error probability.

The HQS indicated higher efficiency in increasing the stem width, as they obtained a diameter of 0.90 cm, while the LQS only reached 0.64 cm. The number of tillers was also higher in the HQS which on average produced 1.71, against 0.56 tillers in the LQS. Furthermore, the tiller diameter was higher in the HQS, which obtained an average of 131% more width than the LQS. The 2015/16 crop season indicated the best results, with higher proportions than the differences between seed qualities, reaching an average tiller diameter 153% higher than the 2016/17 season.

The interaction between the first crop season and plants from HQS provided the highest results for the diameter of forage sorghum tillers subjected to cuts, which was 0.79 cm, while the 2016/17 season with LQS reached 0.13 cm. The results obtained by Eichler *et al.* (2008), using *Mombasa* grass associated with different nitrogen and phosphate fertilization, showed that the highest yields of the dry mass of cuts coincided with the highest results of tillers and leaf area.

The diameter of the stem and tillers is directly associated with the accumulation of a dry mass of the culture (OLIVEIRA *et al.*, 2020). Appropriately, the results of biomass productivity of the present study were proven. It was verified that forage sorghum plants derived from HQS presented a higher capacity to accumulate photoassimilates from the stem, while their dimensions and number of tillers increased, which increased their dry mass production. Finally, due to the influence of the climatic conditions (Figure 1), there were differences in the dry mass productivity of the forage sorghum cuts, which were higher in the 2015/16 crop season, coinciding with the lower constancy and intensity of the water deficit. In wet years, the difference between the dry mass productivity of HQS and LQS is higher than in less precipitation. In the 2015/16 season, the superiority of HQS in the average productivity of cuts was 171% compared to LQS, in 2016/17 the highest value was 136%.

Conclusions

This study indicated that the exploration of higher quality seeds produced forage sorghum plants that, when submitted to cutting procedures or not, obtained improved results in terms of dry mass productivity and morphological characteristics. Furthermore, the 2015/16 crop season indicated lower intensity and constancy of water deficit and obtained the best results, regardless of the crop management. Accordingly, this study provided a rich comprehension of the growth and development behavior of sorghum in the climatic condition of Southern Brazil and promoted assertions about the magnitudes caused by agricultural practices on the growth performance of sorghum. Future scientific studies can benefit positively, mainly due to the productive potential and the management adopted in this study. The establishment of the phyllochron parameterization and plant biomass disposition are also essential factors since the influence of the culture on successor species and its advantages for the suitability of the agroecosystem.

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