



## Seed size affects productive parameters in Sudan grass

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**ABSTRACT:** *The use of larger seeds may improve the initial development, plant stand, and mass productivity in forage crops. The present study aimed to evaluate the effect of the size of seeds of Sudan grass (*Sorghum sudanense* L.), standardized on density, on parameters of physiological quality and crop productivity. Seeds were processed in a gravitational table in order to become uniform in terms of density and then submitted to sieves with apertures of 1.75 or 2.00 mm. Three different treatments (seeds without size classification, seeds with diameter between 1.75 mm and 1.99 mm, and seeds with diameter above 2.00 mm) were compared. This study consisted of a laboratory stage for the analysis of physiological variables of seed, and a stage in field plots under a randomized block design and 3 replicates. Larger seeds presented better physiological and productive performance and had a higher germination rate, seedling growth, and forage yield at the first cut. Both the sieve with opening of 1.75 mm and that of 2 mm were suitable for processing of seeds of this species.*

**Key words:** sieves, seed processing, forage yield, physiological quality.

## O tamanho da semente afeta parâmetros produtivos em capim Sudão

**RESUMO:** *O emprego de sementes maiores pode melhorar o desenvolvimento inicial, o estande de plantas e a produtividade de massa em cultivos forrageiros. Este trabalho visou avaliar o efeito do tamanho da semente de capim sudão (*Sorghum sudanense* L.), padronizada quanto à densidade, sobre parâmetros da qualidade fisiológica e de produtividade da cultura. As sementes foram processadas em mesa gravitacional, para serem uniformizadas em termos de densidade, e depois submetidas ou não a peneiras com abertura de 1,75 ou 2,00 mm. Assim, foram comparados três tratamentos (sementes sem classificação por tamanho; sementes com diâmetro entre 1,75 mm e 1,99 mm; e sementes com diâmetro acima de 2,00 mm). O trabalho consistiu de uma fase laboratorial, para análise de variáveis fisiológicas da semente, e uma fase em parcelas a campo, sob delineamento em blocos casualizados e três repetições. Sementes maiores apresentaram melhor desempenho fisiológico e produtivo, sendo superiores na taxa de germinação, crescimento de plântula e rendimento de forragem ao primeiro corte. Tanto a peneira com abertura de 1,75 mm quanto a de 2 mm mostraram-se adequadas para o processamento de sementes da espécie.*

**Palavras-chave:** peneiras, processamento de sementes, produtividade forrageira, qualidade fisiológica.

## INTRODUCTION

The quality of a seed is defined by the interaction between genetic, physical, physiological and health aspects. Physiological quality is associated with essential functions of the seed such as longevity, germination, rapid and uniform emergence as well as tolerance to environmental adversities (ZUCARELI et al., 2016). Seeds with a high germination rate and excellent seedling vigor are pursued in order to establish high stands of vegetation (WILLENBORG et al., 2005).

Some physical quality parameters cause a response in terms of the physiological potential of development such as mass – commonly referred to

as weight – of seed (MOLES & WESTOB, 2004; GARDARIN et al., 2016). Two parameters of great relevance are density and size of the seed since both parameters are closely related to mass. Effect of density on the physiological performance of seeds of some species was presented by BASKIN (1990). Conversely, the effect of the seed size is highlighted by ZAREAIN et al. (2013) and AMBIKA et al. (2014) and has been demonstrated in forages, including *Panicum virgatum* L., *Pennisetum glaucum* (L.) Leeke, and *Sorghum bicolor* L. (MORTLOCK & VANDERLIP, 1989; AIKEN & SPRINGER, 1995; SMART & MOSER, 1999; GASPAR & NAKAGAWA, 2002; VALADEZ-GUTIÉRREZ et al., 2007; SUGRI et al., 2011) and in cereals used to

produce grains and/or fodder, such as *Avena sativa* L., *Hordeum vulgare* L., *Triticum aestivum* L., and *X Triticosecale* Witm. (WILLENBORG et al., 2005; KAYDAN & YAGMUR, 2008; MUT & AKAY, 2010; FARAHANI et al., 2011; GHAROOBI, 2011; ZAREIAN et al., 2013).

LAWAN et al. (1983) carried out a study on *Pennisetum glaucum* (L.) Leeke in which they showed the interactive effect between density and seed size, presenting that the influence of one factor is greater when faced with a low level of the other. The search for seeds that simultaneously meet the criteria of density and size is of major importance. It should be noted, however, that in many studies evaluating the effect of seed size, including many of the above, this variable was not adequately dissociated from the density. Thus, there may have been some confusion and misunderstanding (FONTELLES, 2012) on the effects of these factors as a seed of a certain size may have a higher or lower density, and this can be the determining factor of seed performance, not size. Among seeds of the same density, the larger seeds have more mass and; therefore, possibly higher reserves. Thus, it is necessary to isolate the effect of each of these factors.

For the forage seed industry, this aspect is of undeniable importance since seed classification is done through specific procedures for density and size (MELO et al., 2016). Prioritizing one or the other feature, or associating them, is a decision that have an impact on the final cost of the product and should be properly established. Based on the aforementioned scenario, the present study aimed to evaluate the effect of seed size of Sudan grass (*Sorghum sudanense* L.) standardized on density on parameters of physiological quality and crop productivity.

## MATERIALS AND METHODS

This study consisted of different processing methods of Sudan grass seeds in search for differences in the diameter of these seeds. Initially, seeds were passed through a gravimetric table in order to obtain homogeneity in terms of density. Then, part of the seeds was processed in sieves with different mesh diameters (1.75 mm and 2.00 mm). Three seed lots were then formed and 3 different treatments were evaluated as follows: I. control, which represents the conventional method of classification of forage seeds; i.e. only use of the gravimetric table generating seeds of various sizes (CT treatment); II. seeds with

diameters ranging between 1.75 mm and 1.99 mm (treatment P1); III. seeds with diameter above 2.00 mm (treatment P2).

Operationally, the experiment was divided into two stages. In the first stage, which was carried out in the laboratory, samples of commercial seeds were subjected to purity analysis following the standard norms established by the regulations and guidelines on seed analysis (BRASIL, 2009). Subsequently, these samples remained for 5 days at a temperature of  $10 \pm 0.5$  °C as a treatment for dormancy break. Then treatments were compared for the germination and initial development of seedlings following the indications of BRASIL (2009), adopting a completely randomized design with 4 replicates per treatment, each corresponding to 100 seeds. Seeds were placed on paper towels and placed into a germination chamber in which they remained sufficiently moist for 10 days at alternating temperatures of 20 °C and 30 °C ( $\pm 0.5$  °C). At the end of this 10-day period, seeds that originated seedlings classified as normal were counted, generating the germination percentage index. Then aerial parts and primary roots were extracted and subjected to drying for 5 days in a forced ventilation oven at  $65 \pm 0.5$  °C with subsequent weighing of the samples.

The second stage of the study was conducted at an experimental field located in the Municipality of Canoinhas, north of the state of Santa Catarina, south Brazil, corresponding to the coordinates 26°16'37" south latitude, and 50°28'18" west longitude, in an altitude of 764 m asl. According to the Köppen climate classification, the climate of the region is of the Cfb type, i.e. humid subtropical, without a dry season and with a temperate summer (ALVARES et al., 2013). The soil is classified as a dystrophic humic cambisol (SANTOS et al., 2013). Analysis performed prior to the implementation of the experiment indicated the following characteristics for the 0 to 20 cm layer: 36% clay; pH in water 5.9; 22.4 mg/dm<sup>3</sup> of phosphorus; 242 mg/dm<sup>3</sup> of potassium; 4.8% of organic matter; CTC = 15.06 Cmol/dm<sup>3</sup>; base sum 79.5%; and absence of exchangeable aluminum. Correction of soil fertility followed the recommendation of the Manual of Liming and Fertilization for the states of Rio Grande do Sul and Santa Catarina, south Brazil (COMISSÃO DE QUÍMICA E FERTILIDADE DO SOLO, 2004).

A randomized block design with 3 replicates was used. Each experimental plot consisted of five 6 m long lines spaced 0.4 m apart. Sowing was done manually on December 4, 2015, aiming to

establish a stand of 400 plants per linear meter. Once plants reached an average height of 80 cm, the 3 central lines of each plot were sampled at a cutting height of 20 cm from the soil. The first cut was performed on January 6, 2016; i.e. 33 days after sowing, and the second cut was done on January 19, 2016, i.e. 13 days after the previous cut. Samples were weighed and put into a forced circulation stove oven at  $65 \pm 0.5$  °C for 48 h for dry matter analysis. Weight obtained in each of the samples was extrapolated to yield per hectare.

The Shapiro-Wilk test was used in order to assess if the data had a normal distribution. Once the normality was evaluated, the data were analyzed using the software Statistical Analyses System (SAS). Since a significant difference ( $P < 0.05$ ) between the treatments was detected, the averages of these were compared to one another with the Tukey test.

## RESULTS AND DISCUSSION

The effect of the processing method of Sudan grass seeds on physiological variables is presented in table 1. Use of sieve sorters according to the seed size resulted in a significantly higher germination index ( $P < 0.01$ ) than that observed in the control treatment, in which no sieves were used. This result is in agreement with those obtained by MORTLOCK & VANDERLIP (1989), SMART & MOSER (1999), GASPAS & NAKAGAWA (2002), WILLENBORG et al. (2005), MUT & AKAY (2010), FARAHANI et al. (2011), and SUGRI et al. (2011). However, there was no difference between treatments P1 and P2. AIKEN & SPRINGER (1995) noted a non-linear effect of the size of the seeds of *Panicum virgatum* L. on the germination index and there was an increment within a range of size increase. However, from a given size, this effect no longer occurred.

Similar results were reported in the present study. GHAROOBI (2011), GIORDANO et al. (2013), and ZAREIAN et al. (2013) did not show any effect of seed size or mass on the germination rate, whereas VALADEZ-GUTIÉRREZ et al. (2007) noted better performance of small seeds.

The highest seed size assessed in the P2 treatment showed an advantage ( $P < 0.01$ ) in terms of shoot mass (seedling), exceeding the P1 treatment by 25%, which did not differ from the control treatment (table 1). This finding is in accordance with those published by SMART & MOSER (1999), KAYDAN & YAGMUR (2008), FARAHANI et al. (2011), GHAROOBI (2011), and ZAREIAN et al. (2013). In *Pennisetum glaucum* (L.) Leeke, larger seeds resulted in a higher growth rate as evidenced by the shorter time to reach the five-leaf stage (SUGRI et al., 2011). Similar effect was recorded on the length of the seedling by KAYDAN & YAGMUR (2008), MUT & AKAY (2010) and FARAHANI et al. (2011).

The main root mass after a 10-day period in the germination chamber was also affected by treatments. Seeds from P2 treatment produced 16% heavier rootlets in comparison with the seeds from P1 treatment ( $P < 0.01$ ) as shown in table 1. The seeds of the control treatment produced radicles significantly smaller than those verified in the treatments submitted to the action of sorting sieves. This result is in accordance with those obtained by VALADEZ-GUTIÉRREZ et al. (2007) and KAYDAN & YAGMUR (2008), whereas SMART & MOSER (1999) noted this effect in one year but not in other year. In a study on the root length of *Avena sativa* L., MUT & AKAY (2010) observed the advantage of large and medium seeds on small seeds. However, this observation was not confirmed by GHAROOBI (2011) in a study on *Hordeum vulgare* L.

Table 1 - Index of germination and initial growth in Sudan grass (*Sorghum sudanense* L.) in correlation with different seed sizes.

|  | -----Treatments----- |         |         | s.e.m. | P     |
|--|----------------------|---------|---------|--------|-------|
|  | CT                   | P1      | P2      |        |       |
| Germination index (%)                                | 86.75 b              | 96.50 a | 97.25 a | 0.90   | <0.01 |
| Bulk mass (g plant <sup>-1</sup> )                   | 0.320 b              | 0.335 a | 0.420 a | 0.01   | <0.01 |
| Mass of the primordial root (g plant <sup>-1</sup> ) | 0.420 c              | 0.475 b | 0.550 a | 0.01   | <0.01 |

CT: seeds without size classification (seeds of various sizes);

P1: seeds with diameter between 1.75 mm and 1.99 mm;

P2: seeds with a diameter above 2.00 mm.

Means followed by unequal letters in the row differ from each other by the Tukey test at the 1% probability level;

s.e.m.: standard error mean.

Effect of the seed diameter – which in the present study was directly related to the seed mass – on the physiological parameters, such as those presented here, is linked to the content of organic reserves (BOCKUS & SHROYER, 1996; BREDEMEIER et al., 2001; SUGRI et al., 2011; GIORDANO et al., 2013; ZAREIAN et al., 2013; AMBIKA et al., 2014; GARDARIN et al., 2016). Larger (heavier) seeds have a higher content of carbohydrates and nitrogen compounds (BREDEMEIER et al., 2001), which guarantees better nutrition to the developing plant embryo, providing a greater initial early growth. The effect on germination is less pronounced since even small seeds have sufficient reserves for the process. It should be considered that larger seeds require increased volume of water to germinate (ZAREIAN et al., 2013).

MORTLOCK & VANDERLIP (1989), KAYDAN & YAGMUR (2008) and FARAHANI et al. (2011) showed that the physiological advantage of larger seeds is more pronounced under unfavorable environmental conditions. In general, heavier seeds promote the emission of larger coleoptiles, with rapid emergence and greater possibility of overcoming problems such as deep seeding, lightly compacted surface soil layer, water deficiencies, shade, competition with weeds or existing vegetation in the area (MOLES & WESTOBY, 2004; MUT & AKAY, 2010; CARÁMBULA, 2013), extending the possibility of a proper establishment when conditions are not ideal (AIKEN & SPRINGER, 1995). However, a number of studies showed that this advantage would be limited to the earlier stages of the plant development (SMART & MOSER, 1999; FARAHANI et al., 2011) and would not be available once all reserves are consumed (MOLES & WESTOBY, 2004).

Table 2 shows the effect of the treatments on dry matter production in the field. With regard to the first cut, it was noted that the use of sieves proved effective in order to produce plants with higher growth potential; and therefore, mass accumulation, since treatments P1 and P2 exceeded by more than 120% the production of CT ( $P < 0.01$ ). No difference was observed between treatments P1 and P2. This result is in agreement with those noted for *Triticum aestivum* L. by BOCKUS & SHROYER (1996), BREDEMEIER et al. (2001), and STOUGAARD & XUE (2004). The higher production of biomass in the early phase of the vegetative cycle accelerates the development of plants. SUGRI et al. (2011) carried out a study on *Pennisetum glaucum* (L.) Leeke and noted a negative association between seed size and time required to reach the three- and five-leaf phenological stages. A practical consequence of this finding is the anticipation of the first cut of forage, which results in better and faster return to the producer.

As for mass production relative to the second cut, treatments had no effect ( $P > 0.05$ ) as shown in table 2. This result confirmed the fact that the size of the seed exerts influence during the initial periods which in the present study was extended until the first cut. Regrowth after a cut is conditioned by a number of aspects, especially those of environmental nature and exogenous to the plant. As a result, the effect of seed size on productivity at the second cut is minimal to none and is; therefore, overcome by other factors.

Higher dry matter yields using larger seeds are related to two factors: individual plant growth or the largest plant population per area (or both). The first concept is based on the fact that larger seeds result in a faster and more vigorous development of root systems and aerial part of the

Table 2 - Dry matter yield in the first and second cuttings in Sudan grass (*Sorghum sudanense* L.) according to seed diameter.

| Dry matter yield (kg ha <sup>-1</sup> ) | -----Treatments----- |       |       | s.e.m. | P     |
|---|----------------------|-------|-------|--------|-------|
|   | CT                   | P1    | P2    |        |       |
| First cut                               | 339 b                | 772 a | 787 a | 71.6   | <0.01 |
| Second cut                              | 1364                 | 1280  | 1447  | 189    | NS    |

CT: seeds without size classification (seeds of various sizes);

P1: seeds with diameters between 1.75 mm and 1.99 mm;

P2: seeds with diameter above 2.00 mm.

Means followed by unequal letters in the row differ from each other by the Tukey test at the 1% probability level;

s.e.m.: standard error mean.

NS: non-significant.



plants as demonstrated in the present study, which favors the absorption of more nutrients and the early establishment of photosynthetic processes (STOUGAARD & XUE, 2004). In this sense, there is an effect on the size and mass of the first leaves and number of tillers (BREDEMEIER et al., 2001) as well as on the mass of the plant (STOUGAARD & XUE, 2004; ZAREIAN et al., 2013).

The second explanation, which states that increased forage production is linked to an increase in plant population per area, is based on the direct correlation between seed diameter and emergency capacity (AIKEN & SPRINGER, 1995) since the size of the seed affects the emergence rate more than the germination rate (ZAREIAN et al., 2013). Thus, seed size is directly related to the survival of seedlings in the field (MOLES & WESTOBY, 2004) and makes crops grown with larger seeds to offer stands with higher plant density and greater soil cover (BOCKUS & SHROYER, 1996), which is reflected in higher mass productivity per area (STOUGAARD & XUE, 2004).

The present results corroborated those of KAYDAN & YAGMUR (2008) and MUT & AKAY (2010). Based on these findings, the authors concluded that large seed selection may be an appropriate measure to increase crop productivity. However, the impact of the use of larger seeds will depend on the reference used to determine the seed density to be implemented. BOCKUS & SHROYER (1996) showed that when the sowing criterion is the number of seeds per area, the option for larger seeds tends to be advantageous due to the greater development of the resulting plants. However, if the criterion is seed weight, as it is usually adopted by Brazilian producers, then this advantage can be reduced or eliminated. In the case of the use of small seeds, this means a greater number of seeds which leads to a higher density of plants per area and compensates for an occasional lower individual production.

Results confirmed that industrial classification of seeds by density using a gravitational table (HESSEL et al., 2012) may be accompanied by significant positive effects if sieves are used in seed size classification (MELO et al. 2016).

## CONCLUSION

In *Sorghum sudanense* L., larger seeds have better physiological and productive performance and have a higher germination rate, higher seedling growth, and increased forage yield at the first cut. Combining seed classification by specific weight and the seed selection by size provides advantages

in the performance of the crop. Sieves with openings (apertures) of 1.75 mm or 2 mm were ideal for *Sorghum sudanense* L.

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## DECLARATION OF CONFLICT OF INTERESTS

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

## AUTHORS' CONTRIBUTIONS

The authors contributed equally to the manuscript.

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