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Effect of long-term storage on viability of buffel grass (*Cenchrus ciliaris* L.) seeds

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ABSTRACT: Prolonged storage of seeds may lead to decreases in seed quality, negatively affecting germination and vigor and preventing the obtaining of a promising stand. Seed quality is a critical factor, and the performance of the lot can be altered by vigor, dormancy and, mainly, by the time and conditions in which the seeds were stored. In the experiment, the physiological quality of seeds 14 genotypes of buffel grass (*Cenchrus ciliaris* L.) genotypes stored for a period of thirteen years in cold conditions was evaluated. The seeds were subjected to germination induction treatment with potassium nitrate (KNO_3) and evaluated to identify seeds with presence and absence of embryos. The seed storage period affected their germination capacity and the use of KNO_3 did not increase seed germination. A low number of full seeds was found for genotype 613 (12%). The relative germination percentages did not underestimate the buffel grass seed germination potential, as it is usually calculated, providing an improved distinction between the evaluated genotypes. The use of KNO_3 increased the seedling root and shoot weights of some genotypes, as well as the dry matter weight of seedlings, an important characteristic for forage production. The prolonged storage affects the physiological quality of buffel grass seeds. The production of seeds without embryo is a problem found for this species, which affects the final quality of the seed lots produced.

Index terms: forage grass species, genotypes, physiological quality, seed production, storage.

RESUMO: O armazenamento prolongado pode levar a perda da qualidade das sementes, influenciando negativamente na germinação e vigor e impedindo a obtenção de um estande promissor. A qualidade das sementes é um fator crucial, e o desempenho do lote pode ser alterado pelo vigor, dormência e principalmente, pelo tempo e condições em que as sementes ficaram armazenadas. No experimento foi avaliada a qualidade fisiológica de sementes de 14 genótipos de capim-bufel (*Cenchrus ciliaris* L.) armazenados por treze anos em câmara fria. As sementes foram submetidas a tratamento para indução da germinação com nitrato de potássio (KNO_3), e posteriores avaliações para identificação da presença e ausência de embrião. O período em que as sementes ficaram armazenadas afetou sua capacidade de germinação e o KNO_3 utilizado não induziu aumento na germinação das sementes. Baixo número de sementes cheias foi verificado para o genótipo 613 (12%). As porcentagens de germinação relativa não subestimaram o potencial de germinação das sementes de *C. ciliaris*, como usualmente é calculada, fornecendo distinção melhorada entre os genótipos avaliados. O KNO_3 incrementou positivamente nas partes das plântulas de alguns genótipos, bem como na biomassa seca destas, sendo uma característica importante para a forragicultura em geral. O armazenamento prolongado afetou a qualidade fisiológica das sementes de *C. ciliaris*. A produção de sementes sem embrião é um problema encontrado nessa espécie, interferindo na qualidade final dos lotes produzidos.

Termos para indexação: gramínea forrageira, genótipos, qualidade fisiológica, produção de sementes, armazenamento.

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INTRODUCTION

Buffel grass (*Cenchrus ciliaris* L.) is among the most cultivated forages in tropical and subtropical arid grasslands in the world due to its easy adaptation to climatic conditions, high drought tolerance and ability to withstand heavy grazing (Marshall et al., 2012). This grass is a perennial species, with variable growth and a well-developed root system, capable of withstanding prolonged periods of drought, and has a high nutritional value for ruminants (Marshall et al., 2012; Burson et al., 2015). Buffel grass is recommended for growing in degraded areas or in intercropped pastures, as it has long flowering, rapid growth and maturation, and high seed production (Martin et al., 2015).

The creation of tropical forages is important for the Brazilian livestock sector. In the 1970s, an Active Germplasm Bank of forage species was implemented in the Caatinga experimental unit of the *Empresa Brasileira de Pesquisa Agropecuária* (Embrapa Semiárido), including several buffelgrass genotypes, which was the most outstanding among the evaluated species, due to its greater potential for forage production (Oliveira et al., 1999). Based on this, an Active Germplasm Bank was implemented for Cenchrus species and, in 2009, it integrated the National Platform of Genetic Resources, in the Vegetal Genetic Resources Network – Vegetal Network (Embrapa Cenargen, 2009; Jank et al., 2021). The improvement of these plants is essential to obtain information and develop cultivars that present desirable characteristics considering local needs.

The seeds of this species have an orthodox character, with the presence of physiological dormancy in their seeds, leading to germination asynchrony, mainly demonstrated when the seeds are freshly harvested, but the seeds may have their dormancy suppressed during storage. The quality of the seeds will depend on the period in which the seeds will be stored, which can interfere with their germination, and this will depend on several factors such as temperature conditions, relative humidity of the environment in which these seeds are stored and the time they will remain in a storage environment (Saeed et al., 2020). Adequate storage is one of the determining factors for the production of high quality seeds; even if the storage period does not improve its quality, it prolongs the maintenance time of the seeds.

Seeds that have spent many years in storage, it is necessary to make evaluations to know what situation they are in, and with increasing storage time there is also an increase in deterioration and consequently a significant reduction in the percentage of germination and vigor. Evaluations of seed germination and vigor are important to monitor the physiological potential of seeds and occurrence of dormancy, and to establish vigorous and homogeneous populations in the field (Marcos-Filho, 2015a).

Another way of evaluating seed quality is relative germination, which is little studied by seed technologists, who consider that the final germination (G%) is enough to evaluate the quality of seed lots. This evaluation is more used to evaluate botanical families that present problems with non-embryonic (without embryo) and non-viable seed production, such as Asteraceae, Cyperaceae, Melastomataceae, and Poaceae (Dayrell et al., 2016). Santana et al. (2018) reported this problem in *Lychnophora ericoides* seeds and explained that this adversity during the seed development is important to understand the reproduction potential of a species, and should be considered in statistical analyses as well as germination evaluations for species that produce large quantities of seeds without embryo.

Thus, aim of this work was to evaluate the effect of prolonged storage on the physiological quality of buffelgrass seeds stored for 13 years in a germplasm bank and to examine the occurrence of seeds without embryo in the studied lots.

MATERIAL AND METHODS

Seeds of 14 genotypes (123, 129, 144, 147, 148, 149, 151, 199, 476, 570, 591, 613, Pusa Giant and Biloela) of *C. ciliaris*, harvested in 2006 and stored for 13 years in a cold chamber at a temperature of 10 ± 2 °C and 40% UR.

Preliminary evaluations

The seeds were first evaluated for 1000-seed weight, using 8 replications of 100 seeds; and water content, determined by the oven method (105 ± 3 °C for 24 hours) (Brasil, 2009). The seed water content was obtained based on the mean weight of samples and expressed in percentages.

Germination (G%)

Germination was evaluated in a completely randomized experimental design, with a 14×2 factorial arrangement, consisting of the 14 genotypes described above and 2 imbibition solutions, with four replications. Fifty (50) seeds were sown in 11x11x3.5 acrylic boxes containing two sheets of blotting paper moistened with distilled water (H_2O) or a 0.2% potassium nitrate (KNO_3) aqueous solution at the proportion of 2.5-fold the substrate paper dry weight. The seeds were maintained in a germination chamber at a 30 °C with a photoperiod of 12 h (Brasil, 2009). The evaluations were carried out at every 7 days for 21 days. These data were used to calculate the final germination percentage (G%).

Relative germination (GR%)

After the germination test, the percentage of empty seeds in each lot was evaluated; non-germinated seeds were cut in half with the aid of a scalpel to determine the number of seeds with and without embryo. The number of germinated seeds divided by the number of seeds with embryo was used to calculate the relative germination percentage. Dead seeds were counted at the end of the experiment and added to the number of seeds with embryo. These data were used to calculate the relative germination percentage, considering GR% = germinated seeds at the end of the experiment × 100 / number of full seeds (Santana et al., 2018).

Normal and abnormal seedlings (NS% and AS%)

Normal and abnormal seedlings were evaluated 21 days after sowing by individually analysing seedlings and its essential structures present for normal growth (Brasil, 2009).

Seedling root and shoot lengths (SRL / SSL)

The roots and shoots of ten normal randomly chosen seedlings of each replication were measured after the final counting of the germination test with the aid of a ruler, and the results were expressed in centimeters per seedling.

Seedling root and shoot dry matter weights (SRDW / SSDW)

The same seedlings evaluated for length were placed in paper bags and taken to a forced air-circulation oven at 65 °C until constant weight (72 hours); then, their weights were determined in analytical balance with precision of 0.001 g, and the results were expressed in grams per seedling. These tests were carried out together with the germination test, following the Brazilian procedures for seed analysis (Nakagawa, 2020).

Statistical analyses

The data were firstly analyzed to verify the assumptions of analysis of variance. The Shapiro-Wilk test was used to evaluate the normality of residues for the response variables (Shaíro and Wilk, 1965); the Levene test was used for the homogeneity of variances (Levene, 1960); and the *d* statistic of Durbin-Watson was used for the independence of residues (Durbin and Watson, 1950); all tests were carried out at 0.05 probability level.

The distribution and link function were chosen for each response variable according to the variable results and it's better fit to these parameters. The germination (G%), relative germination (GR%), normal seedling (NS%), and abnormal seedling (AS%) data were analyzed using the quasibinomial distribution with the logit link function (Agresti, 2007). The seedling root (SRL) and shoot (SSL) length data were analyzed using gamma distribution (Thom, 1958) with the log link function. Gamma distribution was used for the seedling root (SRDW) and shoot (SSDW) dry matter weight data, with

the identity and inverse link functions, respectively. An adjustment procedure using generalized linear models (GLM) was used due to the violation of the assumptions of ANOVA and the option of not using angular transformation for the response variable.

The deviances were calculated for each factor alone, for the interaction, and for the null models. The inferences of analysis of deviance (ANODEV) were based on the qui-square (x^2) statistic for the quasibinomial distribution, and based on the *F* statistic for the gamma distribution.

After the GLM analysis, significant differences within each genotype, treatment, and variables studied were evaluated by comparisons of pairs of means by the post-hoc Tukey's test at 5% significance. The means followed by confidence intervals were fitted by the Šidák method (Šidák, 1967). The analyses were carried out using the R program (R Core Team, 2020).

RESULTS AND DISCUSSION

According to the assumptions of the analysis of variance, the Shapiro-Wilk tests indicated residues with normal distribution only for relative germination (0.4565) and shoot length (0.1094). The analysis of independence of residues by the Durbin-Watson test to assess the experiment randomization showed that all studied variables met the assumption; contrastingly, the homogeneity of variances found by the Levene test showed that none of the variables met the assumption.

The percentage of germination was statistically significant ($p < 0.05$) only among the access factor (Table 1), where seeds from accession 144 had a higher percentage of germination (68%) when germinated in distilled water (Table 2). Accession 147 did not differ statistically from 144, regardless of whether germination occurred in distilled water (60%) or KNO_3 solution (55%). The accessions that showed the lowest germination in distilled water were 613 (14%), followed by 570 (27%) and Pusa Giant (28%). As with distilled water, the seeds of accessions 613, Pusa Giant and 570 showed the lowest percentages of germination when the seeds were hydrated with KNO_3.

The relative germination percentages did not underestimate the germination potential of *C. ciliaris* seeds, as it is usually calculated, providing a better separation between the evaluated accessions. Seeds germinated in distilled water showed the highest percentage of relative germination when compared to those that were hydrated in KNO_3 solution (Tables 1 and 2). The lowest percentages of relative germination in distilled water were for accession 613 (18.1%), followed by accessions 570 (36.2%), Pusa Giant (37.5%) and 129 (45.5%). Using KNO_3 hydration, the lowest percentages of relative germination were for accessions 613 (12.1%), Pusa Giant (26.8%), 476 (33.6%) and 570 (33.6%). The only accessions that showed significant interaction were Pusa Giant, 199 and 476 (Table 2).

Table 1. Analysis of deviance (ANODEV) for buffelgrass (*Cenchrus ciliaris* L.) seeds stored for 13 years, treated with potassium nitrate (KNO_3) and distilled water (H_2O).

SV	DF	G%	GR%	NS%	AS%	SRL (cm)	SSL (cm)	SRDW (g)	SSDW (g)
Treatment (T)	1	3.00ns	455.56**	1.35ns	18.44ns	3.1416**	1.6978**	0.318ns	1.6978**
Genotypes (G)	13	481.34**	605.11**	440.07**	102.228**	9.2481**	5.4201**	67.079**	5.4201**
T*G	13	15.99ns	433.7**	35.93ns	73.193**	12.0369**	2.7005**	5.103**	2.7005**
Shapiro-Wilk		< 0.05	0.4565	< 0.05	< 0.05	< 0.05	0.1094	< 0.05	< 0.05
Levene		< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Durbin-Watson		0.664	0.158	0.264	0.005	0.418	0.262	0.922	0.738
CV%		22.3	21.74	24.44	68.95	51.28	27.01	21.93	25.37

* = significant at 1% probability level by the F test of Snedecor. ns = not significant. SV = source of variation. DF = degrees of freedom; G% = germination percentage; GR% = relative germination percentage; NS% = normal seedlings; AS% = abnormal seedlings; SRL = root length; SSL = shoot length; SRDW = root dry matter weight; SSDW = shoot dry matter weight. CV% = coefficient of variation.

Table 2. Germination (G), relative germination (GR), normal (NS) and abnormal (AS) seedlings formed from *C. ciliaris* seeds stored for 13 years and treated in potassium nitrate (KNO_3) and distilled water.

Genotypes	G (%)		GR (%)	
	H_2O	KNO_3	H_2O	KNO_3
Pusa Giant	28 d	20 e	38 dA	27 dB
123	50 b	50 b	67 bA	66 bA
129	34 c	40 b	46 cA	54 bA
144	68 a	67 a	91 aA	89 aA
147	60 a	55 a	80 aA	74 aA
148	39 b	38 c	52 bA	51 bA
149	46 b	53 b	61 bA	71 aA
151	35 c	34 c	47 cA	46 cA
199	48 b	37 c	64 bA	50 cB
476	33 c	25 d	44 cA	34 dB
570	27 e	25 d	36 dA	34 dA
591	39 b	39 c	53 cA	52 bA
613	14 f	9 f	18 eA	12 eA
Biloela	32 c	29 d	43 cA	38 dA
Genotypes	NS (%)		AS (%)	
Pusa giant	24 cA	19 dA	3 dA	1 cA
123	44 bA	42 bA	7 cA	8 bA
129	18 dB	37 bA	19 aA	6 bB
144	59 aA	58 aA	10 bA	9 bA
147	55 aA	48 aA	2 dA	8 bA
148	34 bA	32 cA	5 cA	7 bA
149	31 cA	41 bA	15 aA	12 aA
151	32 bA	23 cA	3 dB	11 aA
199	34 bA	35 bA	10 bA	3 cA
476	18 cA	19 dA	15 aA	7 bB
570	17 dA	23 cA	11 bA	2 cB
591	28 cA	34 bA	10 bA	6 bA
613	10 eA	9 eA	4 dA	0 dA
Biloela	18 cA	22 cA	15 bA	7 bB

Means fitted by Šidák method followed by different lowercase letters in the columns are different from each other; Means followed by the same uppercase letter in the rows are not statistically different from each other by the Tukey's test at 0.05 probability. Fitting model: GLM with quasibinomial distribution and logit link function.

Some accessions presented low germination (G%) and relative germination (GR%), as was the case of accession 613 (Table 2), which presented a low number of full seeds, resulting in a lower percentage of germination.

The accessions that obtained the highest percentages of normal seedling formation were 144 and 147, both in distilled water and in KNO_3 (Tables 1 and 2). Accession 613 showed the lowest percentage of normal seedlings in distilled water and in KNO_3 solution, 10% and 9%, respectively. There was a significant difference between the hydration

treatments only for accession 129, where KNO_3 provided greater formation of normal seedlings (NS = 37%), (Table 2).

Seeds germinated in distilled water had a higher percentage of abnormal seedling formation compared to seeds hydrated in KNO_3 solution (Tables 1 and 2). The accessions that showed the highest formation of abnormal seedlings when the seeds were hydrated in distilled water were 129 (19%), 149 (15%) and Biloela (14%). The KNO_3 provided a lower formation of abnormal seedlings for the accessions evaluated, mainly 149 (12%) and 151 (10%). There was a significant difference between hydration in distilled water and KNO_3 for accessions Biloela, 570, 476, 151 and 129, and of these genotypes only 151 showed higher formation of abnormal seedlings when the seeds were hydrated in KNO_3 solution (Table 2).

For some accessions, germination in distilled water favored the growth of the main root (SRL) of the seedlings, as can be observed for accessions 199 (4.38 cm), 144 (4.36 cm), 147 (3.58 cm) and 151 (2.91 cm) (Tables 1 and 3). In this same context, hydration with KNO_3 also favored root growth in some accessions, such as 149 (4.60 cm), 147 (2.82 cm) and 199 (2.27 cm). There was a difference between the hydrations only for accessions 144, 149, 151 and 199, where only accession 149 with the seeds hydrated in KNO_3, presented a root length greater than that of distilled water (Table 3).

For shoot length (SSL) the accessions that developed the best were 144 (4.53 cm), 147 (4.14 cm), Biloela (4.01 cm), 613 (3.88 cm) and 476 (3.85 cm) in distilled water (Table 3). For seeds germinated in KNO_3, the highest values were for accessions 149 (6.8 cm), 129 (6.35cm), 147 (5.76 cm), 148 (3.79 cm) and 199 (3.61 cm). Accessions 149, 129, 147, 148 and 199 showed a statistical difference between the hydrations, where the seeds germinated in the KNO_3 solution provided seedlings with greater shoot length compared to those that germinated only in distilled water (Table 3).

The accessions with the highest incorporation of biomass in the root when the seeds were hydrated with distilled water were 123 (0.0095 g) and 476 (0.0089 g). These same accessions also showed superior results when their seeds were hydrated with KNO_3 (Tables 1 and 3). The accessions that showed a statistical difference between the hydrations were 570, 199, 151 and 129, however the only one that showed better incorporation of biomass in the root when the seeds were hydrated with H_2O was 151 (0.0028 g).

Table 3. Length of taproot (SRL) and shoot (SSL), dry biomass of root (SRDW) and shoot (SSDW) of *C. ciliaris* seedlings formed from seeds stored for 13 years and treated in nitrate of potassium (KNO_3) and distilled water.

Genotypes	SRL (cm)		SSL (cm)	
	H_2O	KNO_3	H_2O	KNO_3
Pusa giant	1.29 bA	1.28 bA	2.89 bA	3.36 cA
123	2.35 bA	1.35 bA	3.83 aA	3.21 cA
129	1.38 bA	1.99 bA	3.45 aB	6.35 aA
144	4.36 aA	1.25 bB	4.53 aA	4.92 bA
147	3.59 aA	2.83 aA	4.14 aB	5.76 aA
148	2.30 bA	1.43 bA	2.27 bB	3.79 cA
149	1.04 bB	4.60 aA	3.00 aB	6.80 aA
151	2.91bA	0.91 cB	2.80 bA	3.05 cA
199	4.39 aA	2.28 aB	2.05 bB	3.61 cA
476	1.58 bA	1.91 bA	3.85 aA	4.78 bA
570	2.31 bA	1.41 bA	2.33 bA	2.55 cA
591	2.35 bA	0.94 cA	3.34 aA	4.54 bA
613	2.71 bA	1.24 bA	3.88 aA	2.65 cA
Biloela	1.99 bA	1.29 bA	4.01 aA	3.94 cA

Continue...

Table 3. Continuation.

Genotypes	SRL (cm)		SSL (cm)	
	H_2O	KNO_3	H_2O	KNO_3
Genotypes	SRDW (g)		SSDW (g)	
Pusa giant	0.0014 eA	0.0018 dA	0.0023 dA	0.0049 dA
123	0.0098 aA	0.0098 aA	0.0163 aA	0.0125 bB
129	0.0055 cB	0.0072 bA	0.0163 bB	0.0148 bA
144	0.0019 eA	0.002 dA	0.0060 cA	0.0084 cA
147	0.0027 dA	0.0018 dA	0.0057 cA	0.0081 cA
148	0.0009 fA	0.0009 dA	0.0016 dB	0.0048 dA
149	0.0078 bA	0.0084 bA	0.0095 aB	0.0216 aA
151	0.0028 dA	0.0013 dB	0.0055 cA	0.0047 dA
199	0.0011 eB	0.0027 dA	0.0017 dB	0.0063 cA
476	0.0089 aA	0.0094 aA	0.0116 aB	0.0156 bA
570	0.001 fB	0.0024 dA	0.0019 dA	0.0038 dA
591	0.0037 dA	0.0044 cA	0.009 bA	0.0068 cA
613	0.0012 eA	0.0023 dA	0.0026 dA	0.003 eA
Biloela	0.0075 bA	0.0080 bA	0.0108 aA	0.0126 bA

Means fitted by Šidák method followed by different lowercase letters in the columns are different from each other; Means followed by the same uppercase letter in the rows are not statistically different from each other by the Tukey's test at 0.05 probability. Fitting model: GLM with quasibinomial distribution and logit link function.

For the dry biomass weight of the aerial part, the accessions that presented better results when the seeds were hydrated in distilled water were Biloela (0.0107 g), 476 (0.0116 g), 149 (0.0094 g) and 123 (0.0163 g), (Table 3). When the seeds were hydrated with the KNO_3 solution the only accession that presented greater incorporation of biomass and that was statistically different from the others was accession 149. Hydration with KNO_3 provided greater incorporation of biomass to the aerial part of *C. ciliaris* seedlings (Table 3) for accessions 476, 199, 148 and 129, as it showed significant differences and superior results in relation to seedlings originating from seeds hydrated with distilled water (Table 3).

There was no significant difference between the treatments used to induce germination and the germinated seeds, there was a significant difference only between the genotypes (Table 2), which may be linked to the wide variation in the physiological potential of the seeds. Considering factors such as humidity 40%, temperature 10 °C and storage time of 13 years for all accessions evaluated in this study, it can be inferred that the genetic characteristics and quality of the lots may have been decisive in the performance variations observed between the hits. According to Marcos-Filho (2015b), the physiological quality of seeds has its basis established in the genotype and that of some cultivars are less prone to deterioration, but the proportion of more vigorous seeds gradually decreases as storage time is increased. Thus, the intensity of seed deterioration will depend on the characteristics of the species, their chemical composition and genetic differences, seed quality and environmental conditions in which they are stored (Marcos-Filho, 2015b).

The KNO_3 at different soaking times did not induce an increase in germination in *Bouteloua dactyloides* seeds. A fact also observed in annatto seeds (*Bixa orellana*) stored for more than 10 years. However, in both cases, improvement was observed in the other germination variables when using this salt (Kreuser et al., 2016; Fernandes et al., 2021). The use of KNO_3 is generally indicated for promoting germination and overcoming dormancy in different types of seeds, including forage (Bareke, 2018; Golmohammadzadeh et al., 2020; Ali et al., 2021; Pereira et al., 2021).

Seeds of the Poaceae family usually produce large quantities of empty seeds (Dayrell et al., 2016), as well as dormant seeds, which is noticed mainly when recently harvested. The evaluation of the relative germination showed that the

seed lots presented a large number of empty seeds (Table 2), decreasing even more the obtaining of quality seeds.

A trade-off can occur when there is a limitation in pollen and the effect of genetic load, i.e., an exchange between sexual and asexual reproduction (Oliveira et al., 2015; Hewitt, 2020). These factors may affect seed development, increasing the number of empty seeds. Seeds without embryos are resulted from phylogenetic lines and can occur in different families (Dayrell et al., 2016). Therefore, the low seed germination found may be due to other factors and not by this reason.

Although the KNO_3 solution had no significant effect on the germination of the buffel grass seeds, it significantly increased normal seedlings, root and shoot lengths, and roots and shoot dry matter weights (Tables 2 and 3), respectively. Potassium is absorbed mainly at the vegetative growth stage; several physiological processes are affected by potassium nitrate, such as: meristematic growth, water distribution, photosynthesis, and long-distance transport (Grimme et al., 1974). A different result was found when the seeds were treated with water, as there was an increase in the percentage of abnormal seedlings (Table 2). This high percentage may be justified, since the seed initial reserves were probably used during the germination period for the initial establishment of the seedlings. In addition, the seed's physiological integrity is important for their satisfactory performance (Marcos-Filho, 2015b).

Differences in seed vigor can lead to the formation of seedlings with greater unevenness, due to the reduced capacity to use the reserves present in the embryo's structures, in fact affecting the growth rate and dry mass production, due to the inequality in the issue of growth of the plant between the different vigor levels (Meneguzzo et al., 2021). Only one of the 14 seed lots presented a significant response in the percentage of normal seedlings to KNO_3 (Table 2); these seeds probably had low vigor due to the storage time. Seed deterioration is an irreversible process during the storage period (Moncaleano-Escandon et al., 2013).

The treatments used were favorable and the parts of the normal seedlings evaluated showed rapid and uniform growth, with little different lengths, even those from seed lots that showed low germination, in addition to presenting significant and satisfactory responses for root and root lengths shoots and dry matter weights of some genotypes (Table 3). KNO_3 application is highly recommended for physiological quality evaluations of grass seeds, due to its easy absorption by plant tissues.

A significant effect in seedling length was found when using KNO_3 in Johnson grass (*Sorghum halepense* L.) seeds, with increases in seedling root length of up to 31.8% (Baličević et al., 2016). Similarly, positive effects were found in root and shoot lengths and seedling weight for redroot pigweed (*Amaranthus retroflexus* L.) treated with KNO_3 (Ravlić et al., 2015). The seedling root and shoot length test is carried out considering that more vigorous seeds originate from more developed seedlings, with fast and homogeneous establishment in the field and more effective water and nutrient absorption from higher soil depths.

The storage condition in a relatively dry and cold environment in which the seeds were kept made it possible to maintain their viability even after so long. It was observed that genotype 144 presented a better conservation status with a higher germination rate compared to the other evaluated genotypes. Our results demonstrate that storing them under suitable conditions can reduce the speed and intensity of seed deterioration and maintain their physiological integrity longer.

CONCLUSIONS

The treatment adopted with KNO_3 for the stored buffel grass (*C. ciliaris*) seeds did not increase the germination percentage in this experiment due to deterioration and storage time. The time in which the seeds were stored affected the quality of the lots, reducing the germination capacity of the evaluated genotypes. A high number of seeds without embryos (empty) was observed with the relative germination evaluation, reinforcing the importance of including evaluations like this in the germination test.

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