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Quality of Grain Sorghum Seeds Coated with Different Combinations of Materials

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Authors' contributions

This work was carried out with the collaboration of all authors. Author VAPB elaborated the study, conducted all the experiments, performed the statistical analysis and wrote the first version of the manuscript with the supervision and guidance of the author HDV. Authors JICP and DFB assisted in all stages of the greenhouse, laboratory and bibliographic references complementing the research. Author FWAS assisted in the statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

Sorghum (*Sorghum bicolor*) is the fifth most cultivated cereal in the world, has high liquidity in the market due to its nutritional and edaphoclimatic characteristics, however, because it is cultivated in marginal conditions, it presents productivity below its potential. The seed coating technique appears to optimize the cultivation of sorghum. The objective of this work was to analyze the quality of graniferous sorghum seeds coated with different filling materials and proportions of glue as a cementing material. After covering, the physical and physiological characteristics of the seeds and the initial development of plants in the greenhouse were evaluated. It was found that the coating with calcium silicate provided the best physical characteristics to the seeds with the highest adherence rates, total area, maximum and minimum diameter. The coatings with dolomitic limestone and dolomitic limestone + sand provided the best physiological performance of the seeds with the highest germination values and root dry matter. The proportion of cementitious material 3: 1 provided good results in addition to being more economical. It is concluded that the combination of the filling material and the cementing material used in the coating of graniferous sorghum seeds interferes with their physiological performance and physical aspect.

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1. INTRODUCTION

Sorghum is the fifth most cultivated cereal in the world, with annual productivity estimated at 60 million tons. In Brazil, the area cultivated with sorghum is significant, reaching in the 2018 harvest a planted area of 782.2 thousand hectares with an average production of 2731 kg ha^{-1} [1].

The grain of the sorghum has high liquidity in the market because it has the same nutritional quality as corn, lower percentage of mycotoxins in the grain and lower production cost. In addition, this cereal is one of the most drought-tolerant and is considered a safety crop for the production of grains and forage in late rain plantations or seasons with erratic and poorly distributed rains [2].

Despite the increases observed in the production of sorghum from Brazilian crops, the productivity rates of this cereal are still below the potential for grain and dry matter production of hybrids found in the market [3]. This reality, in part, is due to the country's grain production system that cultivates grain sorghum normally in a late off-season period in marginal conditions and with low use of technology, taking advantage of the residual fertility of summer crops, of brazilian soils presents an acid reaction with toxic levels of aluminum or manganese and with low levels of calcium and magnesium, thus decreasing the use of fertilizers in the soil and the productivity of explored crops [4,5].

Another relevant obstacle to the productivity of the sorghum crop is the small size of the seed, which reflects in the little available reserve, directly influencing the slow initial growth of the crop, aggravating the competition with weeds, in addition to the difficulty of adjusting the density and depth in the sowing. mechanized [6].

Thus, the seed covering technique appears as an alternative to optimize the sowing of graniferous sorghum, in order to improve performance and contribute to the best initial development of plants in the soil and, consequently, in increasing productivity. With the coating there is the possibility of adhering a material that provides the filling of the irregularities of the seeds thus gaining in the speed and uniform distribution of the seed in the sowing line, besides allowing the application of nutrients, fungicides and insecticides always with the objective of improving the performance of the seed, both physiologically and economically, which represents improvements in seed health and seedling establishment [7].

However, to form a good coating it is essential to find the ideal proportions between the materials that will compose the pellet so that it does not impair gas exchange with the external environment, the absorption of water during the process of soaking the seed and neither the integrity of the coating formed. In this way, the objective of this work was to analyze the quality of grain sorghum seeds coated with different filling materials and proportions of glue as a cementing material.

2. MATERIALS AND METHODS

The experiment was developed during the months of June to September 2018. Commercial seeds of *Sorghum bicolor* of the agronomic type were used (hybrid PR40G34). To coat the seeds, the methodology used by [8] was adapted in a bench dredge N10 Newpack, equipped with stainless steel bowl with speed regulation, pressure control of the spray that sprays the cement material and drying system. The dredger was adjusted so that the steel vat rotated at a speed of 86 rpm and a pressure of 4 bar in the compressed air that activates the cement solution for 3 s, then the hot air fan was turned on at a temperature of 50ºC for 90 s.

The filling materials used for the coating were: sand (0.25 mm), calcium silicate (<0.20 mm), dolomitic limestone (0.25 mm), calcium silicate + sand and dolomitic limestone + sand in proportion 2: 1 (w / w) in relation to the seeds. For the preparation of the cementing material, glue based on polyvinyl acetate (PVA) diluted in water previously heated to 70°C was used, in three proportions (3: 1, 2: 1 and 1: 1 between water and glue, respectively).

The coating process was carried out with four repetitions per treatment with portions of 100 g of seeds each, these portions were placed in the dredger tank, then the adhesive solution spray was applied for 3 seconds and then a portion of filling material (initially 10 g of material) was added to the vat. Soon after another spray of adhesive solution (3s) was applied followed by another portion of the filling material (10 g of material) that was added on the seeds with another application of adhesive solution (3s). Right after the air blower (50ºC) was activated for

90 s. This procedure resulted in the first coating layer. For the next layer, another jet of adhesive solution was applied followed by another portion of filler material, then another jet of adhesive solution, accompanied by the second portion of filler material. Finally, another jet of adhesive solution was applied, before triggering the final hot air, which lasted another 90 s. This procedure was repeated until the 200 g of filling material was completed, totaling 10 layers of coating at the end of this process.

After coating, the seeds were evaluated for physical and physiological characteristics, in the laboratory and in a greenhouse.

2.1 Characteristics Evaluated in the Laboratory

The physical evaluations were: 1) Water Content (WC): determined by the greenhouse method, at 105 ± 3°C, for 24 hours, with two repetitions of approximately 4.5 g (Brazil, 2009), the results were expressed in percentage (wet basis); 2) Seed biometry: determined in the Seed Analysis System (Groundeye®) using four replications of 50 seeds for each treatment. The extracted variables were: maximum diameter (MAD), minimum diameter (MID) and total seed area (TSA), with the results expressed in centimeters (cm); 3) Percentage of Adhered Material (AM) that was determined using formula (I):

I) AM = PF x 100 / PI, where: PF is the final weight of the sample after coating and PI is the initial weight of the sample where the weight of the seeds and the weight of the filler material used are considered.

The physiological evaluations were: 1) Germination Test (G): conducted with four repetitions of 50 seeds, a germ-paper roll moistened with a volume of water equivalent to 2.5 times the weight of the dry substrate was used as substrate. After sowing, the rolls were kept in a germinator at 20-30°C submitted to a photoperiod of 16 hours of darkness and 8 hours of light, respectively. The evaluations were made on the 10th day after sowing, with the registration of the percentage of normal seedlings [9]; 2) Germination Speed Index (GSI): conducted together with the germination test, with daily counts being performed after the test starts. The seedlings that presented normal characteristics according to [9] were considered to be germinated, for the calculation of the GSI the formula proposed by [10] was used.

2.2 Characteristics Evaluated in a Greenhouse

The following were evaluated: 1) Emergency (E): conducted in 7 liters plastic trays containing previously washed sand. Four replications of 50 seeds per tray were used, distributed in furrows 3 cm deep and 2 cm apart. The substrate was moistened whenever necessary and the final evaluation of the seedlings was carried out at 30 days after sowing; 2) Emergency Speed Index (ESI): it was conducted together with the emergency test. The emergence speed was determined by daily recording the number of seedlings emerged with the coleoptiles above the substrate, from the beginning until 30° day after sowing. To calculate the ESI, the formula proposed by [10] was used. At the end of the test, 10 plants from each experimental unit were selected and the aerial part was separated from the root, later they were stored in paper bags, then they were placed in an air circulation oven at 65°C for 72 hours to determine the mass. dry on both sides.

2.3 Statistical Analysis

For the variables evaluated in the laboratory, the completely randomized design model was designated and for the variables evaluated in the greenhouse, a randomized block design was used, both with treatments distributed in a 5x3 + 1 factorial scheme, with five types of materials being evaluated. fillers (sand, dolomitic limestone, calcium silicate, dolomitic limestone + sand and calcium silicate + sand) applied with three proportions of glue in the cementing material (1: 1, 2: 1 and 3: 1) plus the additional treatment as a control (uncoated seed), with four replications. The data were subjected to analysis of variance by Test F at the level of 5% probability and for the variables that showed significance, Tukey's test at 5% probability was used for qualitative data. To compare the averages of the combinations of filler materials with the proportions of glue (treatments) with the control, the Dunnett test at 5% probability was used. Pearson's correlation coefficient was determined for the physical variables (MAD, MID, TSA and AM), at 5% significance.

3. RESULTS AND DISCUSSION

3.1 Laboratory Analysis

Through a descriptive analysis of the images of the coated seeds, it was observed, in Fig. 1, that all the materials used in the coating modified the shape and size of the seeds.

The addition of materials through the coating technique aims to increase the size of the seeds eliminating the roughness and deformations, so the coated seeds can be distributed with greater precision and uniformity facilitating manual and mechanized sowing [11]. The use of seed coating has several advantages, as it allows to increase the size of the seeds and to change their shape and texture, it helps the handling and distribution of the seeds, especially the smaller, hairy and rough ones. In addition to allowing the application of nutrients, fungicides, insecticides, herbicides and beneficial microorganisms, always with the objective of improving the performance of the seed, both physiologically and economically, which represents improvements in the health of the seeds and in the establishment of the seedlings [12].

A significant effect of the filling material (P≤0.05) was observed in the variables: total area (TSA), maximum diameter (MAD), minimum diameter (MID) and germination (G). There was a significant interaction effect between the filling material and proportion of glue (P≤0.05) in the variables: percentage of adhered material (AM), water content (WC) and germination speed index (GSI).

In assessing the physical quality of the coating, it was observed in Table 1 that in relation to the AM variable, only the calcium silicate and dolomitic limestone filler materials did not show significant difference between the averages obtained in relation to the proportions of glue used, these results indicate the affinity between the coating formed and the surface of the seeds may vary according to the filling material and the concentration of cement used, since the adhesives are generally viscous products and the viscosity of the solution as well as its adhesion power depends on the its concentration [11,13].

It was observed, in Table 1, that in relation to the proportion of glue only in 2: 1 there was a statistical difference between the filling materials. In this proportion of glue, the coating with calcium silicate obtained the highest average with 95.60% of adhered material, differing statistically from the materials sand and limestone + sand with 51.68%, and 63.05%, respectively.

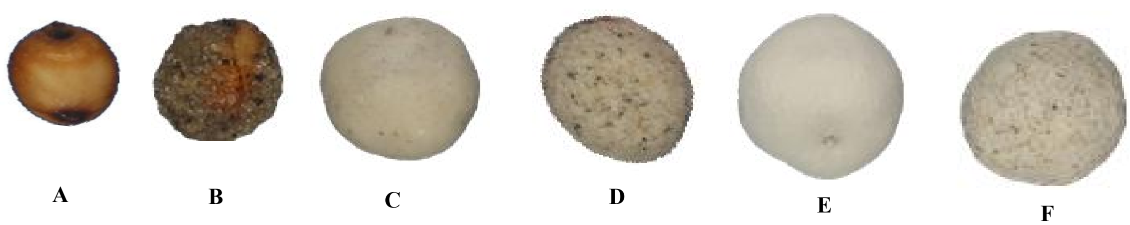

Fig. 1. Grain sorghum seed: A) Intact seed B) Sand Coating; C) Dolomitic limestone coating; D) Dolomitic limestone + sand coating; E) Calcium silicate coating ; F) Calcium silicate coating + sand

Table 1. Percentage of material adhered to the coated seeds, according to the filling material and the proportion of glue used in the cementing material. S: Sand, CS: Calcium silicate, CS + S: Calcium silicate + sand, DL: Dolomitic limestone, DL + S: Dolomitic limestone + Sand

Filling material	Proportion of glue		
	1:1	2:1	3:1
S	65.29 ABa	51.68 Bc	76.74 Aa
CS	89.52 Aa	95.60 Aa	91.40 Aa
CS + S	72.38 Ba	86.90 ABab	94.59 Aa
DL	78.68 Aa	76.55 Aab	85.90 Aa
DL + S	87.07 Aa	63.05 Bbc	69.86 ABa

Means followed by the same uppercase letters in the row and lowercase in the column, do not differ by Tukey's test at 5% probability

The results regarding the proportion of glue 2: 1 may be related to the granulometry and density of the materials. The sand has the highest density, with 2.91g cm^{-3}, ahead of dolomitic limestone and calcium silicate with 2.86 and 2.66 g cm^{-3}, respectively. The higher densities of sand and dolomitic limestone favored the formation of the coating layers due to the greater mass of the materials and also the greater granulometry, because when using materials with larger particles it is more difficult to promote their adhesion to the surface of the seeds due to their weight and greater friction with moving material. These materials must be applied in more external layers since, as the pellets are formed, the area and the weight of the seeds increase, thus allowing the use of material with heavier particles [14]. The higher rate of adherence of calcium silicate to the seeds is due to its lower density and granulometry, among the tested materials, as it has lighter and smaller particles with larger specific surfaces that adhered more easily to the seeds.

Evaluating the effect of treatments on the physical quality of the coated seeds, it was observed, in Fig. 2, that the control treatment obtained the lowest values in all the analyzed physical variables (MAD, MID and TSA) due to the non-coating of these seeds, however it did not differ from the sand treatment in the TSA variable and limestone, limestone + sand and sand treatments in the MID variable. In general, the treatments with silicate and silicate + sand differed from the control in all the physical variables evaluated, demonstrating that these treatments effectively increased the size of the coated seeds.

Among the treatments used in the coating, it was observed that silicate and silicate + sand obtained the highest averages of MAD, MID and TSA, differing statistically from the others. The sand treatment showed the lowest averages in the MAD and TSA variables, but it did not differ statistically from the limestone + sand treatment in the MAD variable (Fig. 2). These results are directly related to the AM variable (Table 1) due to the significant positive correlation between physical characteristics: total area, maximum diameter and minimum diameter (0.673; 0.678 and 0.553; respectively) and the percentage of material adhered to by the Pearson test , so it can be said that the treatments that obtained the highest total adherence averages of material (silicate and silicate + sand) resulted in a greater change in the shape of the seeds, justifying the higher values in the physical variables. In this way, the first objective of the coating process was reached, which consists of improving and modifying the shape and size of the seed, which should provide greater precision in sowing and in the application of chemicals [12].

It was observed in Table 2 that, regardless of the treatment, all coated seeds had significantly lower water contents than that presented by the control (uncoated seeds). These results corroborate with [12,15,8] who found a reduction in the water content of coated seeds when compared to the control, this is because the water used in the coating is lost more easily than that present in the seeds.

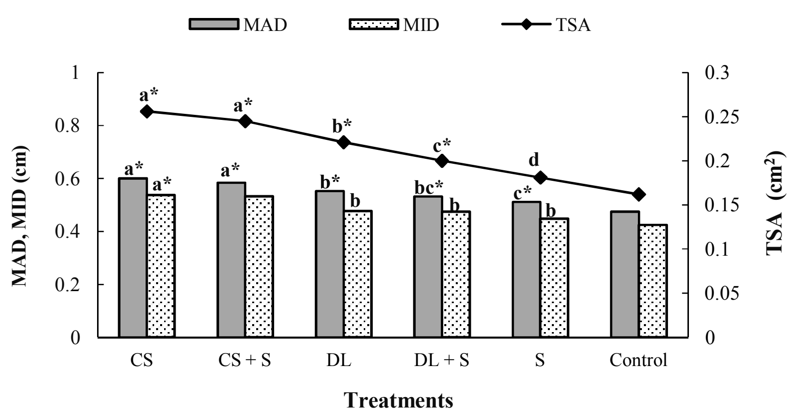

Fig. 2. Effect of treatments on grain sorghum seeds: MAD: Maximum Diameter; MID: Minimum Diameter and TSA: Total area. Treatments: S: Sand, CS: Calcium Silicate, CS + S: Calcium Silicate + Sand, DL: Dolomitic limestone, DL + S: Dolomitic limestone + Sand. Equal bars and markers followed by the same lowercase letter, do not differ by Tukey's test at 5% probability. * Significantly different from the control, by Dunnett's test, at 5% probability

Table 2. Water content in coated and uncoated seeds, according to the filling material and the proportion of glue used in the cementing material. S: Sand, CS: Calcium silicate, CS + S: Calcium silicate + sand, DL: Dolomitic limestone, DL + S: Dolomitic limestone + Sand

Filling material	Proportion of glue			Control
	1:1	2:1	3:1	
S	4.75 Ba*	7.97 Aa*	7.78 Aa*	12.44
CS	4.85 Aa*	4.54 Ad*	4.71 Ad*	
CS + S	4.22 Bb*	4.81 Ad*	4.83 Ad*	
DL	5.06 Ba*	5.30 Bc*	5.68 Ac*	
DL + S	4.72 Ba*	6.38 Ab*	6.24 Ab*	

*Means followed by the same uppercase letters in the row and lowercase letters in the column, do not differ by Tukey's test at 5% probability. * Significantly different from the control, by Dunnett's test, at 5% probability*

It can also be said that the drying temperature (50°C) used during the coating process was efficient, providing removal of part of the water used in the dilution of the cement material that is used in making the coating layers, preventing absorption by the seed. This fact is beneficial, since the high water content in the seeds can affect their quality, not only during the storage period, but also during the processing operations, often making handling difficult and reducing the efficiency of the machines used in the processing processes. In addition, by reducing the water content of the seed to 8-9%, insect activity decreases or becomes null, as they do not reproduce when the seeds have low water content [16].

Regarding the proportion of glue, it was observed that in the proportion 1: 1 only the treatment with silicate + sand differed significantly from the others, presenting the lowest water content with 4.22% (Table 2). In the remaining proportions of glue, the seeds coated with sand obtained the highest water content among the coated seeds, differing statistically from the other materials, this is due to the fact that these seeds were not fully covered due to the low adherence of the sand resulting in seeds with uncoated parts, thus obtaining less water retention by the filling material (Table 2).

The difference in humidity present in the coated seeds is basically related to the increase in the dry mass of the seeds due to the addition of the filling material, because as the formation of covering layers occurs, there is an increase in dry mass and little increase in water in the seeds, even with the spraying of cementitious material that has water in its composition [15]. In this way, the final water content in the coated seeds is the average between the water content of the seed and the water content in the coating.

When analyzing the effect of the filling material, it was observed that only the seeds coated with calcium silicate did not show significant difference between the averages obtained in relation to the proportions of glue, whereas the other materials showed the lowest water contents in the proportion of glue. 1: 1. This result indicates that the amount of water present in the cementing solution influences the final water content of the coated seeds, since the proportion of glue 1: 1 had the lowest amount of water among the tested proportions and consequently sprayed the least amount of water in the coated seeds. (Table 2).

It was observed in the germination speed index (GSI) that the control obtained the highest numerical value (23.71), this result is due to the non-coating of these seeds because this way there is no additional physical barrier that hinders the initial development of the seedling according to its vigor (Table 3). These results are in agreement with several authors [12,8], who reported that coated seeds take longer to germinate than uncoated seeds due to the coating.

However, it was observed that the seeds coated with sand in the proportions of glue 1: 1, 2: 1 and 3: 1, with silicate + sand in the proportion of glue 1: 1 and with limestone + sand in the proportion 2: 1 did not differ significantly of the GSI obtained by the control, these results may be related to the coating adherence to the seeds. The sand treatments showed low adherence rates to the seeds when compared to the other filling materials used, within each proportion of glue, in addition to not visually forming pellets that fully covered the seeds (Table 1). The treatments with silicate + sand in the proportion 1: 1 and limestone + sand in the proportion 2: 1 were those that obtained the lowest adherence of material by analyzing the respective filling material in relation to the proportions of glue (Table 1). In this way, it can be inferred that these treatments formed finer pellets that facilitated gas exchange and water absorption from the external environment and, consequently, germination.

It was observed, in Table 3, that among the filling materials used, only dolomitic limestone showed a statistical difference between the GSI averages obtained in relation to the proportions of glue, demonstrating that for the other materials the proportion of glue used did not significantly interfere in the GSI reached by the coated seeds. However, the use of the lowest proportion of glue in the cementing material, as long as it does not compromise the resistance of the coating and the physiological potential of the seed, is more economically advantageous and, in addition, the lower the proportion of cement, the less difficult it is to absorb water and oxygen [17].

Regarding the proportion of glue, it was observed that in the proportion 1: 1 the seeds coated with dolomitic limestone and limestone + sand obtained the lowest GSI, with 18.95 and 18.92 respectively, differing significantly only from the seeds coated with silicate + sand with 22.24. These results indicate that the combination of the limestone with the proportion of glue 1: 1 formed a more compact pellet depending on the material and the greater proportion of glue used in the coating, since materials such as limestone can seal the gas exchanges associated with a high rate retention of humidity imposed by the thickness of the material layer [13] and the proportion of glue 1: 1 decreases the viscosity of the solution making it difficult for water to pass and gas exchange through the pores, directly influencing the initial development of the embryo. These results corroborate with [8] who stated that coating with limestone and limestone + sand, in the proportion of glue 1: 1, increases the germination time of the seeds due to the limestone waterproofing effect.

In the proportion of glue 2:1, the seeds coated with sand obtained the highest GSI with 22.36, differing statistically only from the treatments with calcium silicate and dolomitic limestone, with indexes of 17.79 and 17.37 respectively. These results are related to the affinity between the cementing material and the granulometry of the filling material used in the covering, since, the sand has greater granulometry among the materials used, forming pellets with larger pores that facilitated the diffusion of water and gas exchange and, consequently, seed germination. Silicate and limestone, on the other hand, are materials formed by smaller particles and therefore formed firmer and more compact pellets, making the coating more consistent and impermeable due to the reduction of porous spaces [15], thus there was a decrease in the diffusion of water and gas exchange between the seed and the external environment, causing a delay in germination thus justifying the smallest GSI found.

In the proportion of glue 3: 1, the sand obtained the highest GSI value with 21.41, but it differed significantly only from the seeds coated with calcium silicate with an index of 18.03. This demonstrates that in this proportion of glue the granulometry of the material significantly influenced the obtained indexes, because due to its smaller granulometry the calcium silicate formed a more compact pellet, which delayed the germination of these seeds. These results demonstrate that the germination speed of the coated seeds depends on several factors such as the viscosity of the cement, the granulometry of the filling material and the affinity between them that can directly interfere in the exchange of the seeds with the external environment and subsequent development of the seedlings.

Table 3. Germination Speed Index of the coated seeds, according to the filling material and the proportion of glue used in the cementing material. S: Sand, CS: Calcium silicate, CS + S: Calcium silicate + sand, DL: Dolomitic limestone, DL + S: Dolomitic limestone + Sand

Filling material	Proportion of glue			Control
	1:1	**2:1**	**3:1**	
S	21.00 Aab	22.36 Aa	21.41 Aa	23.71
CS	19.55 Aab*	17.79 Ab*	18.03 Ab*	
CS + S	22.24 Aa	19.92 Aab*	20.28 Aab*	
DL	18.95 ABb*	17.37 Bb*	20.27 Aab*	
DL + S	18.92 Ab*	20.94 Aa	20.21 Aab*	

*Means followed by the same uppercase letters in the row and lowercase letters in the column, do not differ by Tukey's test at 5% probability. * Significantly different from the control, by Dunnett's test, at 5% probability*

Analyzing the germination of the seeds, it was observed that only the treatment with silicate differed from the control treatment (uncoated seeds), being statistically inferior, demonstrating that the silicate coating negatively affected the germination of sorghum seeds (Fig. 3).

Among the coated seeds, treatments with dolomitic limestone and limestone + sand obtained the highest germination averages with 85.7 and 86.5% respectively, differing significantly from the other treatments. On the other hand, seeds coated with silicate showed the lowest germination rate with 65.3%, but did not differ statistically from seeds coated with silicate + sand and sand with 71 and 71.5%, respectively.

The results presented in Fig. 3, may be related to the availability of nutrients present in the filling materials used in the coating. Calcium silicate has a greater solubilization potential when compared to dolomitic limestone, being 6.78 times more soluble [4], thus silicate makes its nutrients (silicon (Si) and calcium (Ca)) faster at roots of newly formed seedlings, however the rapid solubilization of calcium silicate may have caused nutritional imbalance, reducing the formation of normal seedlings.

In a study by [18] it was observed that the fertilization of coffee trees, with a high dose of calcium silicate (6 Mg / ha) in the soil, caused a restriction in the root growth of the plants under adequate nutritional and water conditions. The authors attribute these results to Ca, which is a nutrient that constitutes the cell wall that alters its resistance to extension, so the elevation of Ca content observed in the roots of plants treated with calcium silicate would induce greater resistance to cell wall deformation, which would explain the restriction on growth.

Although the amount of calcium silicate used in this study is much less than that used by [18], calcium silicate was applied directly to the seed where there is direct contact with the newly formed root and not to the soil where its leaching can occur and direct contact with the roots is less. Furthermore, when there is an excess of calcium in a substrate deficient in magnesium, as is the case of this work, it can cause nutritional imbalance and reduced growth of the culture mainly due to variations in the efficiency of the use of calcium in plant tissues and the mechanisms developed in plants for their absorption that differ between species [19]. In this way, the amount of silicate applied directly to the sorghum seed may have affected the root emission of the seedlings and subsequent development, resulting in decreased germination in addition to contributing to the formation of abnormal seedlings.

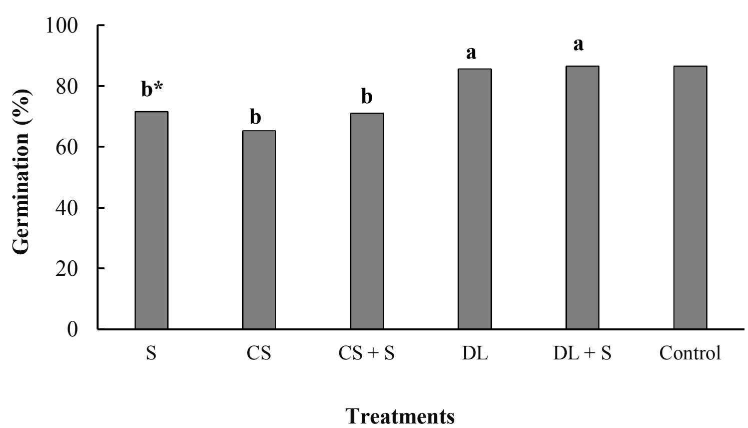

Fig. 3. Effect of coating on the germination of graniferous sorghum seeds. Treatments: S: Sand, CS: Calcium Silicate, CS + S: Calcium Silicate + Sand, DL: Dolomitic limestone, DL + S: Dolomitic limestone + Sand. Equal bars and markers followed by the same lowercase letter, do not differ by Tukey's test at 5% probability. * Significantly different from the control, by Dunnett's test, at 5% probability

The coating with dolomitic limestone was beneficial for the germination of seeds, because although it also provides calcium to the plants, this material presents a lower solubility, in relation to the silicate, so this nutrient was made available little by little, helping in the good development of the seedlings. In addition, limestone also provides magnesium (Mg) which is related to many metabolic processes and is part of essential molecules such as chlorophyll, in addition to acting on enzymatic activation and participating in a series of vital plant processes that require and provide energy as photosynthesis, respiration, macromolecule synthesis and ionic absorption [20].

These results differ from [8] who observed a reduction in the germination of limestone-coated styling seeds compared to control (uncoated) seeds. [21] found no negative effect of limestone on the germination percentage of two rice cultivars. This difference observed between the coating studies occurs depending on the filling material and the type of cementing material used during the coating process, in addition to the thickness of the layer deposited on the seeds, the absorption of nutrients and the accumulated content that varies according to species.

3.2 Greenhouse Analysis

A significant effect of the filling material ($P \leq 0.05$) was observed only in the dry root mass variable (DRMV). There was a significant interaction effect between the filling material and glue proportion ($p \leq 0.05$) factors for the variables: emergency speed index (ESI) and emergency test (E).

When analyzing the emergence speed index (ESI), it was observed that only the treatments: limestone in the proportion of glue 2: 1 and silicate in the proportion of glue 1: 1 differed significantly from the control, obtaining lower averages (Table 4). These results indicate that these treatments formed more resistant pellets that hindered gas exchange and water absorption, in addition to providing greater resistance to the root emission of these seeds, reflecting the lower emergence speed of the plants.

Among the filling materials, it was observed that only silicate + sand and limestone + sand showed a significant difference between the means in relation to the proportions of glue (Table 4). This fact may be related to the mixture of materials combined with the different proportions of glue in the composition of the pellets, since the affinity between the cement and the other filling materials is important for the structure and porosity of the pellets formed, directly influencing the relationships exchange between the seed and the external environment, mainly in a greenhouse where water availability is not as efficient as in the laboratory due to the greater evapotranspiration and leaching of water.

Regarding the proportions of glue, it was observed in the proportion 1: 1 that the seeds coated with sand reached the highest values among the coated seeds, however they did not differ statistically from the seeds coated with silicate + sand and limestone. In the 2:1 ratio, the seeds coated with sand presented the highest ESI, being statistically different from the others, and it can be said that due to the greater granulometry of the sand, the arrangement formed by its particles provided greater porous spaces allowing easier exchanges between the seeds and the medium. However for the materials of smaller particle size (silicate and limestone) there was greater adhesion of the coating to the seeds forming more compact pellets with smaller porous spaces that delayed the initial seedling development. In the proportion of glue 3:1, there was no significant difference between the coated seeds, indicating

Table 4. Index of emergence speed of coated seeds, according to the filling material and the proportion of glue used in the cementing material. S: Sand, CS: Calcium silicate, CS + S: Calcium silicate + sand, DL: Dolomitic limestone, DL + S: Dolomitic limestone + Sand

Filling material	Proportion of glue			Control
	1:1	2:1	3:1	
S	9.31 Aa	9.23 Aa	8.29 Aa	9.35
CS	6.27 Ac*	6.81 Ab	7.24 Aa	
CS + S	8.72 Aab	6.88 Bb	8.41 ABa	
DL	7.47 Aabc	6.35 Ab*	7.86 Aa	
DL + S	7.15 Bbc	6.80 Bb	9.36 Aa	

*Means followed by the same uppercase letters in the row and lowercase letters in the column, do not differ by Tukey's test at 5% probability. * Significantly different from the control, by Dunnett's test, at 5% probability*

that the lower concentration of glue provided a cementing solution with low viscosity in all coatings, this facilitated the passage of water through the pores and the gas exchange with the external environment facilitating the emergence of plants (Table 4).

In the emergency test, it was observed that the analysis of variance showed no difference (p> 0.05) between the means of the factorial and the control, inferring that the coated seeds had similar results to the control seeds (Table 5). These results are beneficial to the crop, as they state that despite the coating giving external layers to the seed coat this does not affect the emergence of sorghum plants in uncontrolled greenhouse conditions.

Among the filling materials, it can be observed that only the treatments in which there was a mixture of materials (silicate + sand and limestone + sand) showed a significant difference between their averages in relation to the proportions of glue, with the lowest averages in the proportion of glue. 2: 1, as observed in the ESI (Table 4), reaffirming that the mixture of materials combined with the different proportions of glue influences the structure of the pellets and later on the development of the plants. Regarding the proportion of glue, it was observed in the proportion 1:1 that the seeds coated with sand showed the greatest emergence, differing significantly only from the seeds coated with calcium silicate.

In the proportion 2:1 it was observed that the seeds coated with sand differed statistically from the other materials presenting the greatest emergence, these results corroborate with [15] who found the highest averages in the emergence of styling seeds coated only with sand compared to the other treatments, which are even higher than uncoated seeds. In the 3:1 ratio, there was no significant difference between the materials used in the coating, as well as in the ESI (Table 4) reaffirming that the lower concentration of glue was beneficial to the emergence of plants, these results corroborate with [8] who stated that styling seeds coated with different materials (sand and / or silicate, limestone) did not differ statistically from each other in the greenhouse emergency.

These results demonstrate that the seed response is affected by the species, the way the coating was made or the type and amount of filler and cement. In addition to the risk of the time when the study was carried out, as in a greenhouse there is no temperature and water control as efficient as in the germinator.

In the variable dry mass of the aerial part (DMAP), it was observed that the control plants reached an average value 20% higher than the average of plants originating from coated seeds, however the silicate and sand treatments differed significantly from the control by the Dunnett test obtaining averages This indicates that these treatments significantly impaired the dry matter production of the aerial part of the plants in relation to the control. Among the coated seeds, there was no significant difference (p> 0.05) between treatments for the DMAP variable (Fig. 4).

For the dry root mass variable (DRM) it was observed that only the limestone treatment differed significantly from the control, obtaining a higher average. Among the treatments used in the coating, it was observed that the seeds coated with limestone reached the highest average of DRM not differing statistically only from the treatment of limestone + sand (Fig. 4).

Table 5. Percentage of emergence in the coated seeds, according to the filling material and the proportion of glue used in the cementing material. S: Sand, CS: Calcium silicate, CS + S: Calcium silicate + sand, DL: Dolomitic limestone, DL + S: Dolomitic limestone + Sand

Filling material	Proportion of glue			Control
	1:1	2:1	3:1	
S	89.00 Aa	87.50 Aa	78.50 Aa	82.50
CS	71.50 Ab	71.00 Ab	74.50 Aa	
CS + S	84.00 Aab	68.50 Bb	78.00 ABa	
DL	79.00 Aab	68.50 Ab	79.00 Aa	
DL + S	75.50 ABab	70.00 Bb	84.00 Aa	

*Means followed by the same uppercase letters in the row and lowercase letters in the column, do not differ by Tukey's test at 5% probability. * Significantly different from the control, by Dunnett's test, at 5% probability*

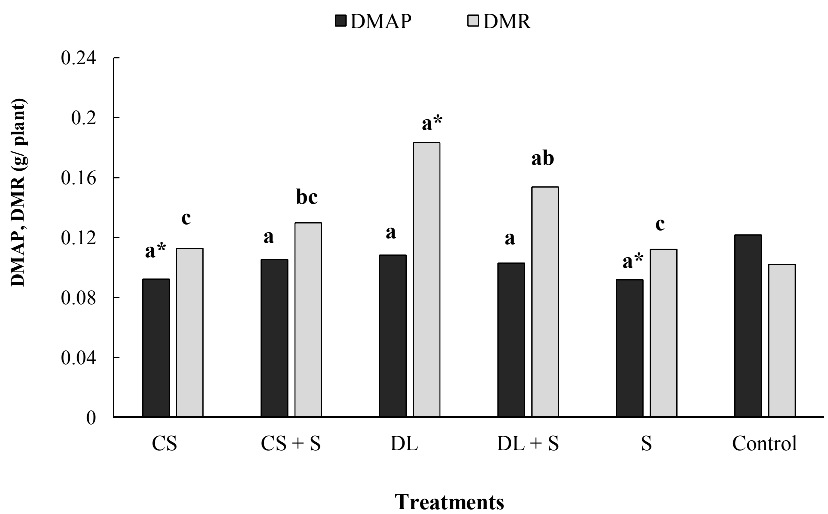

Fig. 4. Effect of treatment on grain sorghum seeds: DMAP: Aerial Dry Mass; DMR: Dry Root Mass. Treatments: S: Sand, CS: Calcium Silicate, CS + S: Calcium Silicate + Sand, DL: Dolomitic limestone, DL + S: Dolomitic limestone + Sand. Equal bars and markers followed by the same lowercase letter, do not differ by Tukey's test at 5% probability. * Significantly different from the control, by Dunnett's test, at 5% probability

The higher averages of DRM obtained by the plants covered with limestone indicates that these plants had a higher volume of roots and, consequently, a greater capacity for exploring the substrate, this is especially beneficial in field conditions as it increases the water and nutrient extraction capacity of the plant soil by these plants [22]. The increase in the root surface acts directly in the proximity between the absorptive surface of the root and the source of resource in a more economical and optimized way, thus these plants can be more efficient in the acquisition of water and nutrients per unit of carbon consumed [23].

These results demonstrate that the limestone used in the coating acted positively in the development of plant roots, this may be due to the joint action of dolomitic limestone which besides providing a neutralizing effect to the medium, provides two important nutrients, calcium and magnesium, directly to the radicles emitted by seeds. Calcium is very important in the development of roots, being a necessary nutrient in the translocation and storage of carbohydrates and proteins in addition to acting in the formation and integrity of cell wall membranes, since magnesium makes up the chlorophyll molecule in addition to participating in a series of vital processes, both nutrients act in a beneficial way in the development of seedlings [20].

4. CONCLUSIONS

1) The combination of different filling materials with different proportions of glue in the cementing material significantly interferes with the physical and physiological quality of the coated seeds.
2) The seeds coated with calcium silicate showed the best results in physical characteristics, however this material negatively affected the germination rate of the plants. The physiological characteristics of sorghum seedlings, on the other hand, benefited from the coating with limestone and limestone + sand, presenting the highest germination rates and root dry matter.
3) In the proportion of glue 3: 1, the seeds showed good results forming firm, consistent, good quality pellets that did not hinder the development of the plants, and the use of the lowest proportion of glue in the cementing material is more economically advantageous.

4) Seed coating makes it possible to add value to seeds and contributes to an increasingly demanding and competitive market.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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