PHYSIOLOGICAL PERFORMANCE OF SEEDS OF *Phaseolus vulgaris* L. AS A FUNCTION OF ZINC AND PHYSIOLOGICAL MATURITY

DESEMPENHO FISIOLÓGICO DE SEMENTES DE *Phaseolus vulgaris* L. EM FUNÇÃO DE DOSES DE ZINCO E PONTO DE MATURIDADE FISIOLÓGICA

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Abstract: The objective of this study was to study the physiological quality of bean treated with levels of zinc during the physiological maturation stage. The work was carried out at Fazenda Ponte da Braúna and at the Seed Analysis Laboratory of the Center for Agricultural Sciences and Engineering at the Federal University of Espírito Santo. Bean seeds of the cultivar Peanut were treated with Zn at concentrations of 0; 2.5; 5.0; 7.5 and 10 g kg^{-1} of seeds and sown in the field. The variables analyzed were seed moisture, 1000-seed weight, length, width and thickness of pods and seeds, germination, germination speed index, shoot length, root length, shoot and root dry matter. The experimental design used was completely randomized, in the factorial 5 x 7 (zinc doses x maturation periods), with four replications of 25 seeds. The seeds of the bean cultivar Amendoim treated with zinc at 10 g kg^{-1} seeds showed the highest values of pod length, thickness, and width. The seeds of the bean cultivar Amendoim showed the highest germination means and GSI after 35 days from anthesis. The treatment of seeds of the bean cultivar Amendoim with zinc does not influence the seedling characteristics. Seed treatment with zinc does not interfere with the seed maturation time of the bean cultivar Amendoim. The physiological maturation of seeds of the bean cultivar Amendoim occurs after 42 days from anthesis. The seed water content of the bean cultivar Amendoim at the stage of physiological maturation is 19%.

Keywords: germination; maturation; nutrition; peanut bean; seedling growth.

Resumo: Objetivou-se com o presente trabalho estudar a qualidade fisiológica de sementes de feijão do cultivar Amendoim, tratadas com doses de zinco, durante o período de maturação fisiológica. O trabalho foi conduzido na Fazenda Ponte da

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Braúna e no Laboratório de Análise de Sementes do Centro de Ciências Agrárias e Engenharias da Universidade Federal do Espírito Santo. Foram utilizadas sementes de feijão do cultivar Amendoim tratadas com Zn nas concentrações de 0; 2,5; 5,0; 7,5 e 10 g kg^{-1} de sementes e semeadas no campo. As variáveis analisadas foram: comprimento, largura e espessura de vagens e sementes, germinação, índice de velocidade de germinação, comprimento de parte aérea e raiz, massa fresca e seca da parte aérea e raiz. O delineamento experimental utilizado foi o inteiramente casualizado, no fatorial 5 x 7 (doses de zinco x períodos de maturação), com quatro repetições de 25 sementes. Sementes de feijão cv. Amendoim tratadas com zinco na dose de 10 g kg^{-1} sementes apresentam maiores comprimento, espessura e largura das vagens na maturação. Sementes de feijão amendoim apresentam maiores médias de germinação e IVG após 35 dias da floração. O tratamento das sementes de feijão cv. Amendoim com zinco não influenciou nas características de plântulas. O tratamento das sementes com zinco não interfere no tempo de maturação das sementes de feijão cv. Amendoim. A maturação fisiológica de sementes de feijão cv Amendoim ocorre após 42 dias da antese. O teor de água de sementes de feijão cv. Amendoim na maturação fisiológica é de 19%.

Palavras-chave: germinação; maturação; nutrição; feijão amendoim; crescimento de plântulas.

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1 INTRODUÇÃO

Common bean (*Phaseolus vulgaris* L.) stands out among grain legumes due to its importance in human consumption attributed to its high nutritional value as a source of vegetable protein, B-complex vitamins, and mineral salts such as iron, calcium, and phosphorus. It is a nutrient-demanding crop due to its small and shallow root system and short cycle, allowing planting in up to three moments during the growing season. Beans have three cultivation cycles within the season, the expectation is that the second harvest will have an increase of 18.4% in production, with an estimated harvest of 1.5 million tons. This good performance contributes to the internal supply of an important product consumed by Brazilians, since the current estimate for the legume is a total production of 3.2 million tons (Companhia Nacional de Abastecimento, 2024). It is a widely cultivated species worldwide, standing out among economically relevant crops (Pitura & Arntfield, 2019).

From 60 to 80% of the bean produced in Brazil is of the carioca (pinto) type, although the black, brindle, jalo, red, *bolinha*, and cowpea types are also grown, suggesting the need for continuous research investments aiming at the development of new pest-resistant varieties, the tropicalization (adaptation) of varieties of interest for importing countries, and the stability of final prices for the consumer in the internal market, whose per capita consumption ranges from 16 to 17 kg (Ministério da Agricultura, 2018). However, there is a great preference for landrace bean seeds, which is mostly attributed to characteristics such as adaptability, flavor, quality of traditional varieties, and low production costs, constituting a source of some vitamins and minerals rich in proteins (34%), carbohydrates, and micronutrients that are valuable in developing countries, being traditionally and widely consumed by the Brazilian population (Pelwing et al., 2008; Campos-Vega et al., 2013; Nemli et al., 2017).

Landrace seed cultivars are varieties that have been selected and conserved through natural or artificial selection by smallholder farmers throughout time, regardless of their place of origin (Bevilaqua, 2012). Therefore, it is highlighted that the knowledge of the characteristics of landrace seeds regarding their productivity, vigor, germination, and nutrient availability is extremely important to promote their use and conservation by smallholder farmers (Coelho et al., 2010), with the cultivation environment and the genotype used resulting in greater reflections on the yield and physiological quality of bean seeds (Michels et al., 2014). For the bean crop, seed quality stands out in the obtainment of high yields and is extremely important in maximizing the remaining inputs (Souza et al., 2007; Amaro et al., 2015). However, seed yield and physiological quality are directly dependent on nutrient availability, which is associated with their harvest at the stage of physiological maturity (Carvalho & Nakagawa, 2012). From this point of maximum quality, a reduction in seed quality tends to occur, which is why the time of seed permanence and exposure to adverse environmental conditions should be reduced as much as possible (Minuzzi et al., 2010; Marcos Filho, 2015; Follmann et al., 2017).

However, the identification of the physiological maturity point depends on the analysis of a series of morphological, physical, physiological, and biochemical alterations aiming at establishing grounds for safely determining the moment for harvest in which the seeds will have greater vigor, with well-structured embryos and greater reserve amounts (Carvalho & Nakagawa, 2012; Marcos Filho, 2015). At this stage, the germination test is highlighted as one of the main mechanisms used to assess seed physiological quality as it allows knowing the germination potential of a seed lot under favorable conditions (Carvalho and Nakagawa, 2012). Germination is a complex process in which the seed rapidly and intensely resumes its metabolism, completing essential cellular events in order to allow the embryo to emerge and prepare for the subsequent seedling growth (Nonogaki et al., 2010).

Several studies on seed maturation conducted with a range of species point out the maximum dry matter content as the best and safest indication that the seeds reached physiological maturity, such as in seeds of *Cucurbita moschata* (Marrocos et al., 2011) and *Crambe abyssinica* (Oliveira et al., 2014).

The zinc content found in the plants also undergoes great variation, especially as a function of soil factors and of the species and/or cultivars. However, the activity of this element is essential in important processes in the physiological and nutritional plant homeostasis, acting as an activator or as a structural component of enzymes, such as in the synthesis of tryptophan, a precursor amino acid for indoleacetic acid, an auxin that participates in the maintenance of membrane integrity and nitrogen metabolism (Taiz et al., 2017). Consequently, the seeds produced by these plants show low zinc levels and, when sown, in case of nitrogen deficiency in the soil, the plants produced will have lower vigor, with chlorosis in the new leaves due to disturbances in chloroplast formation and chlorophyll degradation. Foliar zinc application promotes a linear increase of its content in the leaves of bean plants; therefore, the increase in zinc concentration in the seeds determines a positive effect on the yield (Genc et al., 2000; Teixeira et al., 2008). Besides, similar to zinc, iron and selenium deficiencies are associated with food production (Broadley et al., 2012).

In view of this, this study aimed to assess the physiological quality of seeds of the bean (*Phaseolus vulgaris* L.) cultivar Amendoim treated with levels of zinc during the physiological maturation stage.

2 MATERIAL AND METHODS

Plant material

The study was conducted using landrace bean seeds (*Phaseolus vulgaris* L.) of the cultivar Amendoim from March 6 to June 15, 2018, in a dystrophic Red-Yellow Latosol (Oxisol) at the Ponte da Braúna Farm, located in the Rive district, municipality of Alegre, Espírito Santo, 20º 75’ S and 41º 49’ W, with an elevation of 129 m, a tropical climate with hot and humid summers, and an annual rainfall of 1,200 mm year^{-1} (Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural [Incaper], 2020).

Before the installation of the experiment, soil samples were collected at 0-20 cm depth and the chemical analyses were performed according to the recommendations by Empresa Brasileira de Pesquisa Agropecuária (Embrapa 1997), revealing: pH (CaCl2) = 6.6; O.M. = 44 g dm^{-3}; P = 6 mg dm^{-3}; H+Al = 29 mmolc dm^{-3}; K = 4.5 mmolc dm^{-3}; Ca = 33 mmolc dm^{-3}; Mg = 12 mmolc dm^{-3}; SB = 44 mmolc dm^{-3}; CEC = 69 mmolc dm^{-3}; and V% = 58. Regarding micronutrients, the analysis revealed, in mg dm^{-3}: B = 0.16; Cu = 4.7; Fe = 11; Mn = 22.1; and Zn = 1.8.

Soil preparation was performed conventionally, and fertilization was carried out according to the interpretation of the soil chemical analysis by applying 200 kg ha^{-1} of NPK 10-30-10, not requiring nitrogen topdressing. Weed control was performed by manual hoeing, according to the need of the crop (stages V_2 and V_4), and insect control was performed with the insecticide Pirate®; disease control was not performed.

Seed treatment with zinc

The experimental design adopted was in randomized blocks, composed of four blocks with five treatments and four replications, totaling 20 plots. The plots were formed by four rows 9.0 m long. Sowing was performed in the field on March 06, 2018, using three seeds per hole in a 0.50 x 0.30 m spacing, maintaining one plant (the most vigorous) per hole at 15 to 20 days after emergence, coinciding with stages V_2, referring to the unfolding of the primary leaves, and V_3, characterized by the emission of the first trifoliate leaf. Seed collection was performed in the two central rows of each plot at 7, 14, 21, 28, 35, and 42 days after anthesis. The seeds of the bean (*Phaseolus vulgaris* L.) cultivar Amendoim were treated with zinc for 60 minutes at the concentrations of 0.0, 2.5, 5.0, 7.5, and 10 g kg^{-1} of seeds, washed with distilled water, and dried in the shade on *germitest* paper sheets for 24 hours, prior to sowing. Between stages R_5 and R_6, coinciding with flower bud formation and flowering, the flowers were labeled, and three replications of ten flowers were collected to determine the water content (stage zero). At each period, in stages R_7 (pod formation) and R_8 (pod filling), 30 pods per plot were collected until stage R_9

(pod maturation stage), at 7, 14, 21, 28, 35, and 42 days after anthesis (flower marking).

Physiological quality of the seed

The pods were collected from the useful area of the plot and immediately taken to the Laboratory of Seed Analysis of the Department of Agronomy of the Center of Agricultural Sciences and Engineering (CCAE) of the Federal University of Espírito Santo (UFES), in Alegre-ES, where the following variables were characterized: seed water and dry matter content, number of pods per plant, and number of seeds per pod. The biometry of pods and seeds was assessed by measuring their length (mm), width (mm), and thickness (mm) using a millimeter ruler and a digital caliper with 0.1 mm precision. The length was measured from the base to the apex, and width and thickness were measured at the median line of pods and seeds. Seed removal from the pods was performed manually using a blade. Subsequently, the following variables were determined:

Germination – conducted with four replications of 25 seeds for each treatment, sown on Petri dishes covered with *germitest* paper sheets moistened with distilled water at a proportion of three times the weight of the dry paper, and kept in a BOD type germination chamber with temperature regulated at 25 ºC. The evaluations were conducted nine days after sowing by counting the percentage of normal seedlings (Brasil 2009), and the results were expressed as germination percentage.

Germination speed index (GSI) – determined along with the germination test by daily counting, until the 9th day, the number of seeds with primary root protrusion equal to or greater than 2 mm (Maguire 1962).

Shoot length – determined nine days after sowing with the aid of a millimeter ruler by measuring the length between the base of the plant and the apex of the last leaf of each seedling in the sample, with results expressed in cm seedling^{-1}.

Root length – determined nine days after sowing with the aid of a millimeter ruler by measuring the distance from the base of the plant to the tip of the longest root, with results expressed in cm seedling^{-1}.

Shoot and root dry matter – determined nine days after sowing with an analytical balance (0.0001 g); the seedlings were put in Kraft paper bags and kept in a forced air circulation oven at 60 ºC for 72 hours (constant weight), with results expressed in g seedling^{-1}.

Statistical analysis

The experimental design used was completely randomized, in a 5 x 7 factorial arrangement (zinc levels x maturation periods) with four replications of 25 seeds. The zinc concentrations were 0, 2.5, 5.0, 7.5, and 10 g kg^{-1} seeds, and the evaluation periods were 0, 7, 14, 21, 28, 35, and 42 days after anthesis. Regression analysis was used for the quantitative factor. All statistical analyses were performed using the software R (R CORE TEAM 2022).

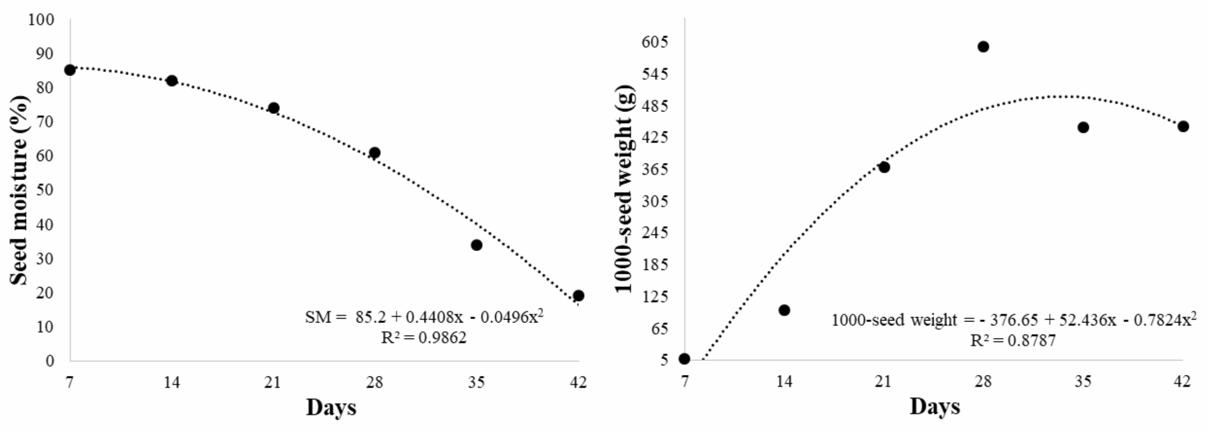
3 RESULTS

Seed moisture and 1000-seed weight of the bean cultivar Amendoim

The water content of fruits and seeds throughout maturation showed a progressive and gradual reduction as a function of the harvest periods. During seed formation, in stages R_5/R_6, from flower bud formation to anthesis, the initial water content was close to 95%, reducing to 90.65 ± 0.56 in stage R_6, when the flower was completely open. After this stage, a progressive and gradual decrease was verified as the seeds grew within the pods, with values close to 80% in stage R_7, while in stage R_8, with pod filling, there was a greater reduction in these values, culminating in 21.49 ± 1.46 in stage R_9 of pod maturation. However, at this maturation stage, although reaching high dry matter values through the accumulation of reserve substances, the seeds were kept in dry environments protected by screens to ensure maturation in the field, when they were then harvested, and the water content reached 19%. The seeds were subsequently dried, and their moisture content was reduced to 14 ± 0.42%, which is considered suitable for storage.

Considering the 1000-seed weight at this maturation stage, there was an increase in this variable with the accumulation of reserve substances until 28 days after anthesis (6.38 g to 596 g after 28 days). There was a reduction in the 1000-seed weight after this period, reaching 445 g at 42 days after anthesis (Figure 1).

Figure 1 - Seed moisture and 1000-seed weight of the bean cultivar Amendoim at 7; 14; 21; 28; 35 and 42 days after anthesis.

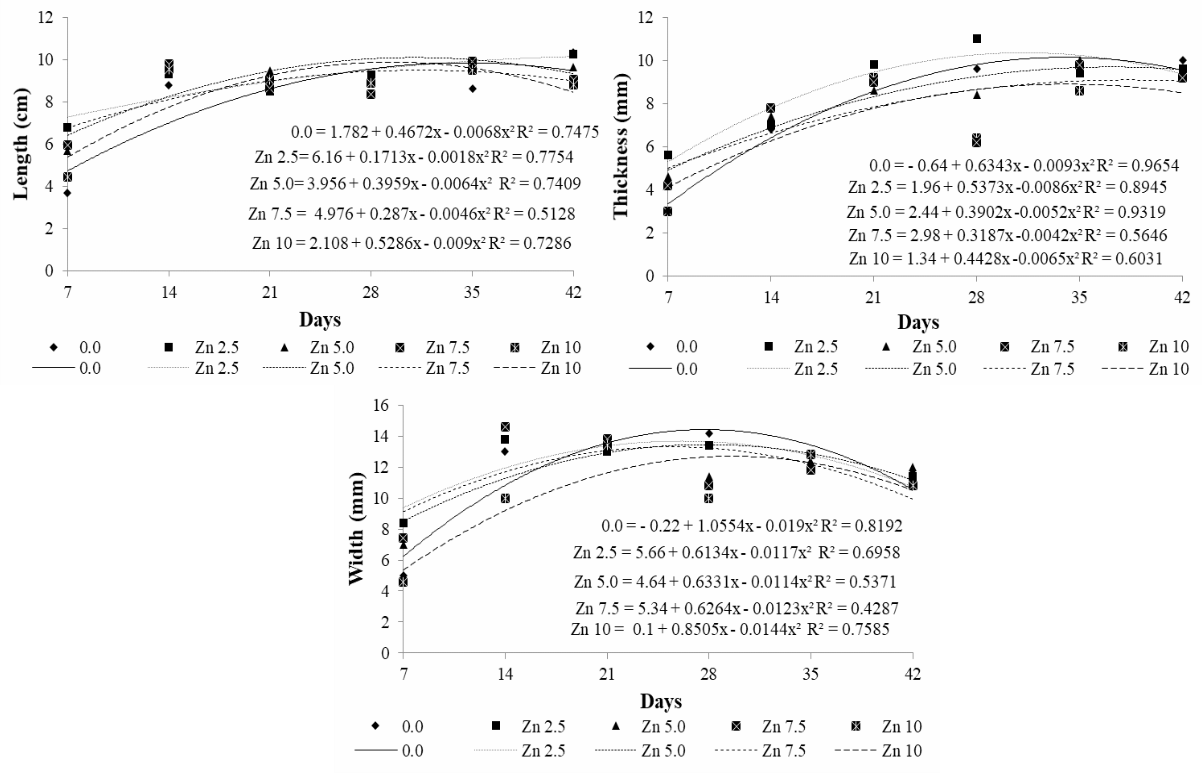


Source: authors, 2023.

Characteristics biometric of pod and seeds

In Figure 2, an increasing logarithmic behavior can be observed as a function of the harvest days of bean seeds for the variables of pod length, width, and thickness regardless of the treatment used. There was a gradual increase in pod length, width, and thickness in the initial evaluations until the 28th day, suggesting that the pods are under formation and the seeds are accumulating dry matter. At the 35th after anthesis, the pod length, width, and thickness were reduced.

Figure 2 - Pod length, thickness, and width of the bean cultivar Amendoim not treated (0,0) and treated with zinc at the concentrations of 2.5; 5.0; 7.5 and 10 g kg^{-1} seeds at 7; 14; 21; 28; 35 and 42 days after anthesis.

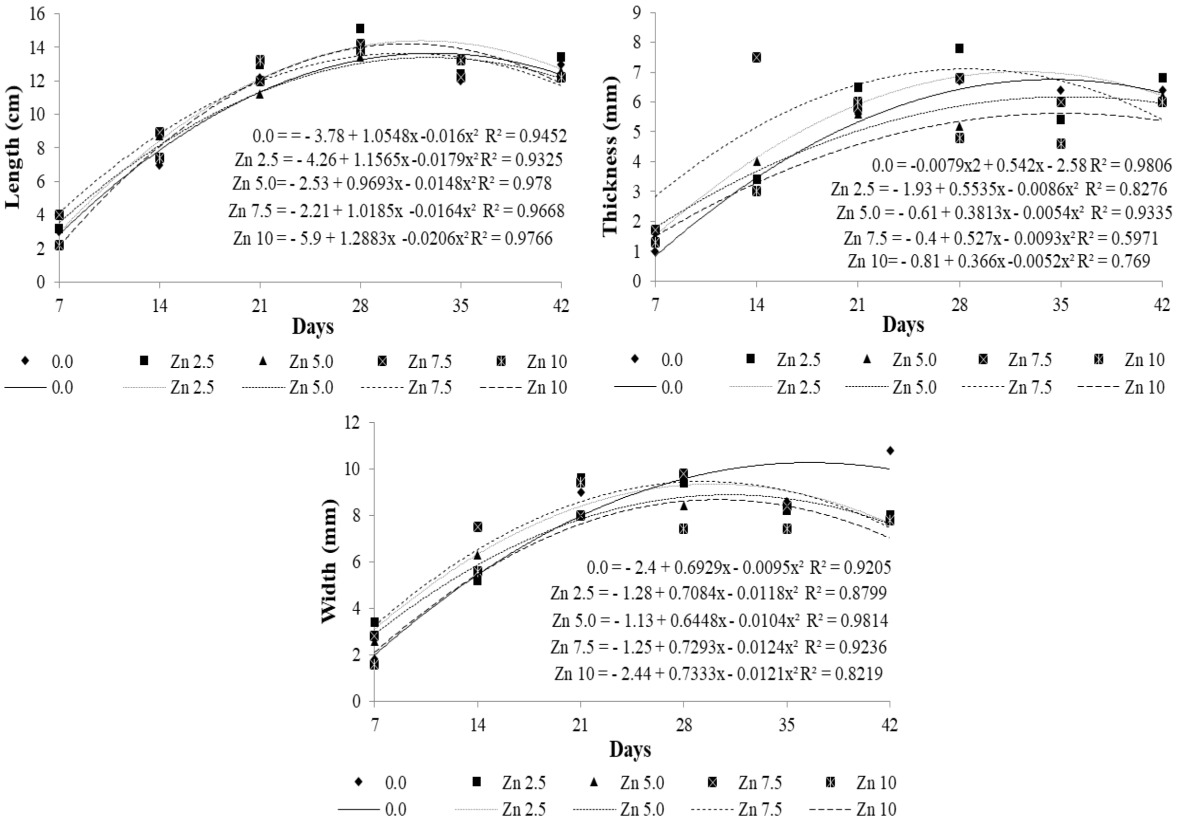


Source: authors, 2023.

According to Figure 3, the length, width, and thickness of the seeds were reduced from the 35th day onwards, that is, at the end of the cycle, as a consequence of the process of seed dehydration that naturally occurs at this maturation stage.

The seeds of the bean cultivar Amendoim treated with zinc at the concentration of 10 g kg^{-1} seeds showed better length, thickness, and width means (Figure 2).

Figure 3 - Seed length, thickness, and width of the bean cultivar Amendoim not treated (0,0) and treated with zinc at the concentrations of 2.5; 5.0; 7.5 and 10 g kg^{-1} seeds at 7; 14; 21; 28; 35 and 42 days after anthesis.

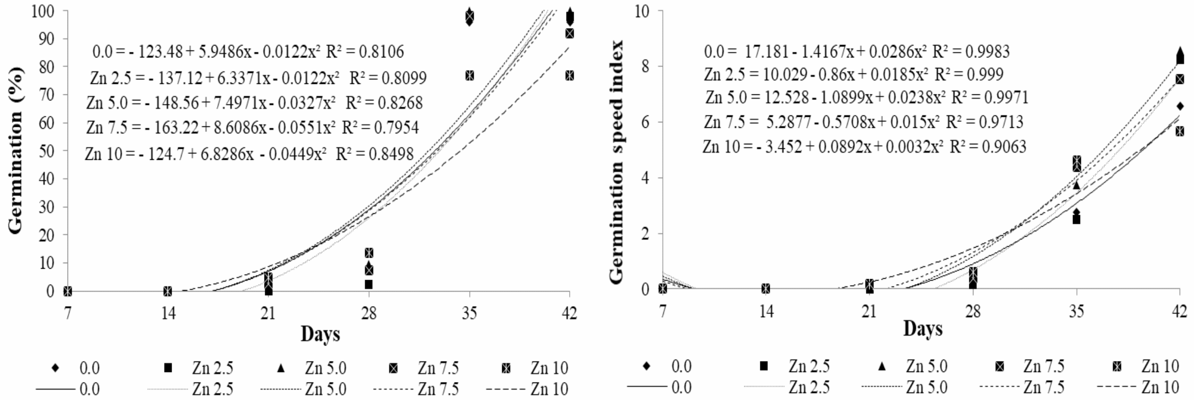


Source: authors, 2023.

Germination and vigor of seeds translated with zinc during physiological maturation

The means at the early maturation stage were low; however, throughout maturation, these values increased progressively and slowly, reaching the highest means at the later maturation stages, after 35 days from anthesis, observing a linear increasing behavior as a function of the time of seed harvest regardless of zinc application (Figure 4).

Figure 4 - Germination and germination speed index (GSI) of seeds of the bean cultivar Amendoim not treated (0.0) and treated with zinc at the concentrations of 2.5; 5.0; 7.5 and 10 g kg^{-1} seeds at 7; 14; 21; 28; 35 and 42 days after anthesis.



Source: authors, 2023.

The germination percentage reached its maximum after 35 days from anthesis, in stage R8, when physiological maturation occurred, coinciding with germination values above 95%.

Although they germinated when harvested from 21 days after anthesis, the seeds of the bean cultivar Amendoim did not result in normal seedlings, that is, the seedlings did not present a developed aerial part and root, and the same was observed when the seeds were harvested at 28 days., 35 and 42 days after anthesis.

According to Tables 1 and 2, there was no significant interaction between the evaluation days (35 and 42 days) and the studied treatments (0.0, 2.5, 5.0, 7.5, 10 g kg^{-1}seeds) for the variables analyzed.

The variables of shoot length (SL), root length (RL), shoot fresh matter (SFM), root fresh matter (RFM), shoot dry matter (DM), and root dry matter (RDM) of the seedlings produced from seeds of the bean cultivar Amendoim showed no significant difference with respect to the zinc levels studied.

Table 1 - Shoot length (SL), root length (RL), shoot fresh matter (SFM), root fresh matter (RFM), shoot dry matter (DM), and root dry matter (RDM) of seedlings produced from seeds of the bean cultivar Amendoim not treated (0.0) and treated with zinc at the concentrations of 2.5; 5.0; 7.5 and 10 g kg^{-1} seeds at 35 and 42 days after anthesis.

Zinc (g kg^{-1})	**SL (cm)**	**RL (cm)**	**SFM (g)**	**RFM (g)**	**DM (g)**	**RDM (g)**
0.0	6.9 a⁽¹⁾	6.8 a	0.81 a	0.14 a	0.18 a	0.02 a
Zn 2.5	5.9 a	8.0 a	0.74 a	0.13 a	0.16 a	0.02 a
Zn 5.0	5.3 a	7.3 a	0.63 a	0.12 a	0.15 a	0.03 a
Zn 7.5	5.6 a	9.1 a	0.64 a	0.14 a	0.15 a	0.03 a
Zn 10	6.4 a	8.7 a	0.80 a	0.16 a	0.15 a	0.03 a

(1)Means followed by the same lowercase letter in the column do not differ from each other by Tukey's test at 5% probability.
Source: authors, 2023.

There was no significant difference for the variables of shoot length, root length, and root dry matter when the seeds were harvested at 35 and 42 days after anthesis. However, the variables of shoot and root fresh matter and root dry matter showed the highest means when the seeds were harvest at 42 days after anthesis regardless of seed treatment with zinc.

Table 2 - Shoot length (SL), root length (RL), shoot fresh matter (SFM), root fresh matter (RFM), shoot dry matter (DM), and root dry matter (RDM) of seedlings produced from seeds of the bean cultivar Amendoim not treated (0.0) and treated with zinc at the concentrations of 2.5; 5.0; 7.5 and 10 g kg^{-1} seeds harvested at 35 and 42 days after anthesis.

Days	**SL (cm)**	**RL (cm)**	**SFM (g)**	**RFM (g)**	**DM (g)**	**RDM (g)**
35	6.20 a	8.30 a	0.48 b	0.11 b	0.11 b	0.03 a
42	5.60 a	7.70 a	0.97 a	0.21 a	0.20 a	0.20 a

Means followed by the same lowercase letter in the column do not differ from each other by t de Student test.
Source: authors, 2023.

4 DISCUSSION

Seed moisture and 1000-seed weight of the bean cultivar Amendoim

After the harvest and processing step, the seed water content was reduced to 14%, which is considered ideal for storage, considering that seeds with a reduced and uniform water content are indispensable for maintaining vigor and obtaining an adequate plant stand. High moisture levels and uncontrolled temperature and moisture conditions increase the risks of deterioration as they increase seed metabolism and respiration and facilitate the attack by microorganisms and insects, consuming the reserve materials of the seeds (Baudet & Vilela, 2006; Carvalho & Nakagawa, 2012; Zucareli et al., 2015).

The reduction in the water content during ripening is associated with the accumulation of reserve substances, which stabilized after 42 days with a dry matter of 0.44 g seed^{-1}, being especially controlled by factors such as the characteristics of the species or cultivar, chemical composition, and tegument composition, in addition to environmental factors. During the maturation stage, the occurrence of variation until stabilization in the water content, dry matter accumulation, and 1000-seed weight, which are dependent on the water content and seed dry matter at the time of analysis, has been reported by several authors (Carvalho and Nakagawa, 2012; Marcos Filho, 2015; Leite et al., 2019). The several stages involve physiological, morphological, and functional transformations from the moment when the ovule is fertilized, culminating in the point when the seeds reach the maximum dry matter content and a marked reduction in the water content (Carvalho and Nakagawa, 2012).

Characteristics biometric of pod and seeds

The logarithmic and increasing behavior as a function of the days of harvest of the bean seed for the dimensions of the pod, may be due to dehydration of pods and seeds that naturally occurs with the accumulation of reserve substances during the stage of maturity. Water loss occurs slowly throughout maturation, while there is an upward accumulation of nutrient reserves until reaching maximum values when dehydration is then accentuated (Marcos Filho 2015).

To the seeds had a high moisture content that reduced throughout maturation, highlighting its importance in seed formation and maturation and showing a marked reduction when the seeds reached maximum dry matter, reducing the process of accumulation of photosynthates (Marcos Filho 2015).

Best grain growth and filling performance which is associated with nutritional factors, considering that improvement occurs in the nutritional status of the plant (Magalhães et al., 2017). In plants, zinc is involved in controlling the plant growth regulator indoleacetic acid (Taiz et al., 2017). In soybean seeds cultivated in soils with zinc levels above that demanded by the crop, there was a response to nutrient application, especially considering that leaf fertilization can increase the zinc levels in the plant (INocêncio et al., 2012). Although no influence of leaf fertilization was verified on the seed mass of the bean crop (Lopes et al., 2014), in seeds of *Mimosa caesalpiniifolia,* pre-germination treatments at the first germination count determined a slight increase in the germination percentage throughout the maturation stages studied (Nogueira et al., 2013). On the other hand Biscaro et al. (2013), studying the use of liquid fertilizer rich in NPK and with small concentrations of micronutrients (Mg, Ca, S, Zn, B, Fe, Mo, Cu, and Mn) in maize, observed that it provided higher grain yields.

Germination and vigor of seeds translated with zinc during physiological maturation

The increase in averages in the final stages of maturation can be justified by the accumulation of reserve substances as a function of water availability and suitable temperatures that favor the translocation of photoassimilates and grain filling, from fertilization until the stage of physiological maturation (Nonogaki et al., 2010; Marcos Filho, 2015; Taiz et al., 2017).

High physiological quality, defined through dry matter accumulation, is indispensable to define the ideal harvest moment, which coincides with maximum germination and vigor, suggesting the ideal moment for seed harvest. However, variations in the water content, vigor, and dry matter accumulation of seeds are variable and may oscillate according to the species and environmental conditions during seed maturation (Carvalho and Nakagawa, 2012; Mata et al., 2013; Nogueira et al., 2013; Marcos Filho, 2015).

However, except for the seed treatment with 10 g kg^{-1} of zinc, which, in the same period, resulted in maximum germination of 85%, the lowest germination may be related to insufficient seed development, which can be corroborated by the analyses referring to seed width and thickness as well as by the biometry of pod thickness, thus suggesting that the seeds, at this development stage, were still immature, possibly because the high zinc concentration caused toxic effects for the species. A similar behavior was observed with tomato seeds, to which the possibility of zinc toxicity was attributed due to growth reduction, with lower fresh and dry matter accumulation in the seedlings (Guirra et al., 2015). Although zinc is a necessary micronutrient for the synthesis of auxin, a phytohormone that acts in the process of cell division and elongation (Taiz et al., 2017), it causes toxicity in plants when in excess, reducing the production of both shoot and root dry matter, causing root necrosis and seedling death (LI et al., 2011).

Similar results regarding the relationship between the application of zinc doses and the growth characteristics evaluated in this work, corroborate the work developed with wheat (Delgado et al., 2017). However, Dörr et al. (2018), studying the treatment of bean seeds with zinc, observed an increase in the expression of the physiological quality of bean seeds and also an increase in the leaf content of the micronutrient. Zinc participates in seedling growth by its role in the activation of peptidases, resulting in higher hydrolysis of reserve proteins, increasing the supplementation of carbon skeletons in the embryonic axis. Furthermore, zinc deficiency could lead to plant growth reduction as this element controls the formation of indoleacetic acid, a plant growth regulator (Taiz et al., 2017).

Considering the results of the germination test, the reduction in the seed water content, and the analysis of the vigor variables, the seeds can be collected after 35 days from anthesis, when they show higher dry matter accumulation. At this stage, the seeds still have a high water content, which needs to reduce until they reach field maturation, which, in this case, coincided with the beginning of pod dehiscence, but with higher germination and GSI, expressing their physiological potential characterized by the ability of the seed to perform vital functions with longevity, germination, and vigor (Nonagaki et al., 2010; Carvalho and Nakagawa, 2012).

5 CONCLUSIONS

The seeds of the bean cultivar Amendoim treated with zinc at 10 g kg^{-1} seeds showed the highest values of pod length, thickness, and width.

The seeds of the bean cultivar Amendoim showed the highest germination means and GSI after 35 days from anthesis.

The treatment of seeds of the bean cultivar Amendoim with zinc does not influence the seedling characteristics.

Seed treatment with zinc does not interfere with the seed maturation time of the bean cultivar Amendoim.

The physiological maturation of seeds of the bean cultivar Amendoim occurs after 42 days from anthesis, whit water content of 19%.

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