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# Yield and physiologic potential of pods bean seeds according to organic compost doses

**Rogério Lamim Silva Junior[1], Natália Arruda[1], Luciana Maria da Silva[2], Cecília Leão Pereira Resende[3], Katiane Santiago Silva Benett[1], Cleiton Gredson Sabin Benett[1]**

[1] Universidade Estadual de Goiás, Campus Sul, Ipameri, Goiás, Brasil. E-mail: rogeriolamimj@gmail.com, nataliaarruda.engagro@gmail.com, katiane.benett@ueg.br, cleiton.benett@ueg.br

[2] Instituto Federal Goiano, Campus Rio Verde, Rio Verde, Goiás, Brasil. E-mail: luy.mari@hotmail.com

[3] Universidade Federal de Uberlândia, Campus Glórias, Uberlândia, Minas Gerais, Brasil. E-mail: cecilialpr@hotmail.com

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## ABSTRACT

The production of high-quality pods bean seeds in the organic production system is a challenge for farmers because there is little information on the appropriate doses of organic compounds to be recommended in the literature. This study aimed to evaluate the yield and physiologic potential of pods beans according to the application of doses of organic compost (earthworm humus). The experimental design used was completely randomized, and the treatments were different doses of organic compost (0, 30, 60, 90, and 120 t ha$^{-1}$), with four replications. Different yield components were evaluated, and the seed quality was analyzed by the main vigor and germination tests. Organic compost doses influenced most of the seed yield components; however, the physiologic potential and organic fertilization influenced only 1000-seed weight and seedlings dry matter. It is concluded that the doses of organic compost promote the increase in pods bean yield but do not influence the physiologic potential of seeds.

**Keywords:** *Phaseolus vulgaris* L., Organic agriculture, Hummus, Fertilizing.

## Produção e potencial fisiológico de sementes de feijão-vagem em função das doses de composto orgânico

## RESUMO

A produção de sementes de feijão-vagem de alta qualidade no sistema de produção orgânico é um desafio para os agricultores, pois na literatura há poucas informações sobre as doses adequadas de compostos orgânicos a serem recomendadas. O objetivo deste estudo foi avaliar a produção e o potencial fisiológico de sementes de feijão-vagem em função da aplicação de diferentes doses de composto orgânico (húmus de minhoca). O delineamento experimental utilizado foi inteiramente casualizado e os tratamentos foram as diferentes doses de composto orgânico (0, 30, 60, 90 e 120 t ha$^{-1}$), com quatro repetições. Avaliaram-se diferentes componentes de produção e para avaliação do potencial fisiológico das sementes analisou-se: germinação e os principais testes de vigor. As doses de composto orgânico influenciaram na maioria dos componentes de produção de sementes, porém no potencial fisiológico das sementes a adubação orgânica influenciou apenas na massa de mil sementes e massa seca de plântulas. Conclui-se que as doses de composto orgânico promovem o incremento na produtividade de feijão-vagem, porém não influenciam na qualidade fisiológica das sementes.

**Palavras-chave**: *Phaseolus vulgaris* L., Agricultura orgânica, Húmus, Fertilizantes.

## 1. Introduction

Pods bean (*Phaseolus vulgaris* L.) is a vegetable of high economic and social importance, mainly produced by small farmers (Carvalho et al., 2014). It is an important protein source, iron, calcium, magnesium, and other nutrients (Montanari et al., 2010). The crop is extremely diverse in terms of production and used methods. It can be sown in different environments and grown from sea level to altitudes above 3,000 meters, both in monoculture and intercropped or in rotation with other species (Krause et al., 2012).

Because of Brazilian agriculture's intensification, there is a need to study new agroecological production models (Souza et al., 2019). In this scenario, the organic production system presents itself as an alternative. Organic fertilization promotes improvements in the physical structure and the chemical and biological composition of the soil. When applied according to the soil analysis and respecting the recommended doses to supply the crop's need, it provides sufficient amounts of nutrients for the plants to produce and under the effect of chemical fertilization (Mueller et al., 2013).

Seeds produced in organic systems must meet the same quality standard obeyed by seeds produced in the conventional system, where germination, vigor, sanitary conditions, and purity are evaluated (Brito et al., 2013). However, according to the literature, there are still doubts about the recommended doses of organic compost for pods bean production and the physiologic potential of seeds. Thus, the study aimed to evaluate pods bean yield and physiologic potential according to the application of organic compost doses.

## 2. Material and Methods

The study was carried out in a greenhouse of the Goiás State University, located in Ipameri-GO, whose geographical coordinates for 2017 were 17º42'40" S and 48º 08'13" W, and 2018, 17º43'04" S and 48º 07'55" W, with an average altitude of 759 m. The region climate, according to the Köppen Geiger classification (Cardoso et al., 2014), is defined as a tropical climate (Aw-type) with a dry season in winter (Figure 1), and the soil used was classified as a Latossolo Vermelho-Amarelo distrófico (EMBRAPA, 2018).

Pods bean seeds (*Phaseolus vulgaris* L.) of the Manteiga cultivar with determined growth were used. A completely randomized experimental design (CRD) was used, and the treatments consisted of a control and four doses of organic compost equivalent to 0, 30, 60, 90, and 120 t ha$^{-1}$. Each plot consisted of six pots (10 L) with four replications.

Before the installation of the experiment, chemical analysis of the soil was carried out in the 0-20 cm layer, which presented the following results: 0.5 mg dm$^{-3}$ of P; 30.2 mg dm$^{-3}$ of $K^+$; 0.2 mg dm$^{-3}$ of $Ca^{2+}$; 8 g dm$^{-3}$ of O.M .; 4.64 g dm$^{-3}$ of C; 0.2 g dm$^{-3}$ of Cu; 5.2 pH ($CaCl_2$); 0.1 of $Mg^{+2}$, 0.0 $Al^{3+}$, 1.6 of $H+Al^{3+}$ cmolc dm$^{-3}$, 28.2 mg dm$^{-3}$ of Fe; 3.0 mg dm$^{-3}$ of Mn; 0.9 mg dm$^{-3}$ of Zn, and 19.55% base saturation. The soil liming was carried out thirty days before sowing. The applied dose was calculated based on the soil chemical analysis, increasing the base saturation to 69.8%.

Fifteen days before sowing, the organic compost application was carried out, with the doses being applied according to each treatment. The chemical analysis of the organic compost, which presented the following results: 17.0 g Kg$^{-1}$ of N; 23.0 g Kg$^{-1}$ of $P_2O_5$; 0.8 g Kg$^{-1}$ of $K_2O$; 18.0 g Kg$^{-1}$ of Ca; 0.3 g Kg$^{-1}$ of Mg; 2.6 g Kg$^{-1}$ of S; 110.0 mg Kg$^{-1}$ of Cu; 600.0 mg Kg$^{-1}$ of Mn; 290.0 mg Kg$^{-1}$ of Zn; 30.0 mg Kg$^{-1}$ of Mo; 40.0 mg Kg$^{-1}$ of Co; 80.0 mg Kg$^{-1}$ of B; 40,5% of M.O. (Dry matter); 5.9 pH ($H_2O$). The compost was incorporated manually, and to meet the need for phosphorus, thermophosphate (YOORIN Master®) was applied at a dose of 4 t ha$^{-1}$ in all pots. Sowing was carried out with four seeds per pot, and the support for plants was installed immediately after seedling emergence. Irrigation was performed daily by hand as required by the crop.

Phytosanitary management was carried out with organic products, based on milk, orange peel, neem, and cow urine, being weekly applied to prevent diseases and pests (Lima et al., 2011). The seeds were harvested seventy-three days after sowing when the seeds reached the physiological maturity point with a water content of around 15%, and more than 50% of the plants had yellow leaves and dry pods (Nascimento, 2016).

Some variables were analyzed to evaluate plant development and seed yield. For the plant height, the distance was measured from the stem base to the end of the main branch, with the results being expressed in centimeters (cm). The stem diameter was measured at the stem base with a digital caliper aid, and the results were expressed in millimeters (mm). The relative chlorophyll index was measured in the middle third leaf of the plant, at the R5 development stage (full bloom) with the aid of a portable chlorophyll meter (chlorophyll LOG model CFL 1030 Falker®), expressing the results in Chlorophyll Falker Index (CFI). After the seeds had been harvested, the plants were weighed to determine the fresh matter. They were dried in an air-forced circulation oven at 65 °C for 72 hours (Bianco et al., 2012). The results were expressed in grams per plant (g pl$^{-1}$).

The number of pods per plant was determined by counting pods in each plant. This value was then divided by the number of seeds per pod obtained from the count of all plant seeds, determining the yield based on all plants grown per experimental plot with water content corrected to 13% and expressed in ton per hectare (t ha$^{-1}$).

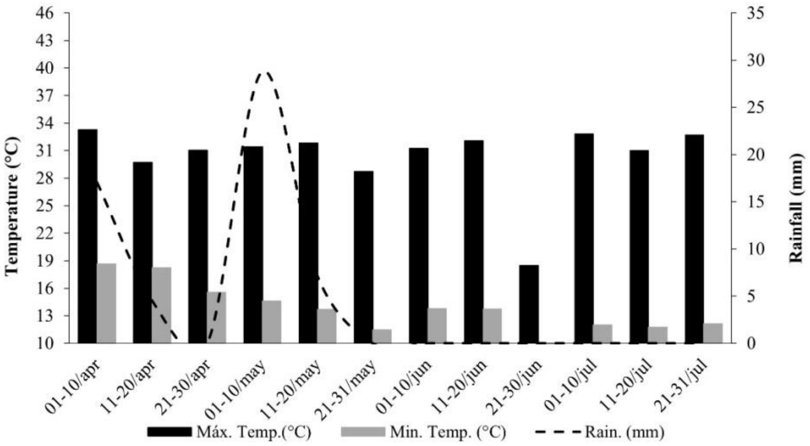


**Figure 1**. Maximum and minimum temperature and rainfall at the Goiás State University in 2018 off-seasons.

Soil samples from each treatment were also taken to evaluate the soil chemical characteristics. Before assessing seed quality, the water content was determined with two replications for each treatment, using the oven method at 105 °C ± 3 °C, for 24 hours, according to the Rules for Seed Analysis - RAS (Brasil, 2009).

Germination was analyzed to evaluate seed quality, performed with four replications of fifty seeds for each treatment, arranged in paper towel rolls moistened with distilled water equivalent to 2.5 times the paper mass, packed in a BOD at 25 ºC. The evaluation was carried out on the ninth day after the test was installed. According to the criteria established by the Rules for Seed Analysis (Brasil, 2009), the results were expressed as a normal seedlings percentage.

The main vigor tests were also carried out, such as a) first germination count: conducted concomitantly with the germination test, with the percentage of normal seedlings being evaluated on the fifth day after the test was installed (Brasil, 2009); b) 1000-seed weight: obtained through eight samples of 100 seeds of each treatment, being weighed individually, in a precision scale according to the recommendation of Brasil (2009), with the average results values being expressed in grams; c) seedlings emergence in the sand was carried out in a plastic tray with four replications of 50 seeds for each treatment, the substrate was moistened with water, 60% of the substrate capacity (Brasil, 2009), before sowing and there was water replacement when necessary, fourteen days after sowing, the evaluation of the emerged seedlings was carried out, the results being expressed in percentages of seedling emergence.

The seedling emergence index in the sand was performed concurrently with the seedling emergence test in the sand using the number of seedlings that emerged daily until the fourteenth day after sowing. The index was calculated according to the equation proposed by Maguire (1962). To determine the dry matter of seedlings, they were submitted to drying in an oven with air circulation, at 65 °C for 72 h, according to Nakagawa (1999). The dry matter was obtained on a digital scale with three decimal places, and the result was expressed in milligrams per seedling (mg plant$^{-1}$).

For electrical conductivity, the methodology described by Vieira and Krzyzanowski (1999) was used, where four replications of 25 seeds of each treatment were previously weighed and immersed in 75 mL of distilled water for 24 hours, were stored in BOD at 25 ºC. The electrical conductivity of the solution was evaluated with the aid of a digital conductivity meter. The readings values were divided by the initial mass; the results were expressed in µS cm$^{-1}$ g$^{-1}$ of seed. As for accelerated aging, the methodology described by Binotti et al. (2008) was followed. 300 seeds were distributed on a wire mesh attached to a plastic box containing 40 ml of deionized water. The plastic boxes were packed in BOD, where they remained at 40 ºC for 72 h. At the end of this period, the water content in the seeds, previously described, was determined. Subsequently, the germination test described above was performed. The accelerated aging test was evaluated five days after the test was installed, and the results were expressed as a percentage of normal seedlings.

The results were subjected to analysis of variance ($p < 0.05$), and regression analysis was performed for the different doses of organic compost. However, due to the fitting process to the equation with a low coefficient of determination ($R^2$) for the dry plant matter and electrical conductivity, it was decided to compare these treatments using the Tukey test at 5% probability. Statistical analyzes were performed using the SISVAR 5.1 program (Ferreira, 2014).

## 3. Results and Discussion

Table 1 shows the values of the soil chemical characteristics after the production of pods bean seeds.

It is possible to note that with the increase in the doses of organic compost, there was an increase in the levels of phosphorus (P), potassium (K), calcium ($Ca^{2+}$), magnesium ($Mg^{2+}$), iron (Fe), manganese (Mn), and zinc (Zn) in the soil, relevant macro, and micronutrients for plant development. Also, there is an increased base saturation (V%) and organic matter content (OM). These results agree with Cardoso et al. (2011), who observed an increase in the soil chemical characteristics according to the increase in organic compost doses.

The results referring to the analysis of yield and its components of the bean plants according to organic compost doses are shown in Table 2. There is a significant effect on plant height, number of pods per plant, number of seeds per pod, yield, and non-significant effect for stem diameter and relative chlorophyll index. For plant height (PH) and seedling fresh matter (FM), it is observed that the data adjusted to increasing linear equations (Figure 2a and 2b).

In common beans, organic compost action can increase the total plant height and number of pods per plant. One of the factors explaining this fact is the organic compost's ability to make humic acid available to the soil, consequently promoting plant growth improvements (Islam et al., 2016). This finding was observed in the results obtained in this study, showing the positive action of the organic compost in developing the plants and consequently in seed yield.

**Table 1.** Results of soil chemical analysis (0-20 cm layer in each pot) after pods beans seed production according to the doses of organic compost.

| **Doses** | **pH** | **P** | **K** | **$Ca^{+3}$** | **$Mg^{+2}$** | **$Al^{3+}$** | **$H^{+}$ + $Al^{3+}$** |
|---|---|---|---|---|---|---|---|
| **(t ha$^{-1}$)** | **$CaCl_2$** | **------mg dm$^{-3}$------** | | **---------------------cmol dm$^{-3}$---------------------** | | | |
| **0** | 5.6 | 44.2 | 47 | 2.1 | 1.3 | 0.07 | 1.5 |
| **30** | 5.8 | 67.5 | 54 | 2.8 | 1.8 | 0.08 | 1.5 |
| **60** | 5.8 | 53.3 | 44 | 3.1 | 1.8 | 0.06 | 1.6 |
| **90** | 5.9 | 71.8 | 48 | 3.7 | 2.1 | 0.08 | 1.6 |
| **120** | 5.9 | 138.5 | 78 | 4.8 | 2.6 | 0.06 | 1.6 |
| **Doses** | **BS** | **C** | **OM** | **Cu** | **Fe** | **Mn** | **Zn** |
| **(t ha$^{-1}$)** | **%** | **------g dm$^{-3}$-------** | | **-------------------mg dm$^{-3}$-------------------** | | | |
| **0** | 69.8 | 7.5 | 12.9 | 4.3 | 182 | 46.7 | 39.1 |
| **30** | 76.6 | 9.2 | 15.8 | 4.4 | 202 | 59 | 57.7 |
| **60** | 75.8 | 7.8 | 13.4 | 3.3 | 148 | 55.5 | 38.3 |
| **90** | 78.9 | 10 | 17.3 | 3.6 | 157 | 71.9 | 53.5 |
| **120** | 82.4 | 17.2 | 29.6 | 4.2 | 231 | 96.9 | 69.2 |

BS: base saturation; OM: Organic matter

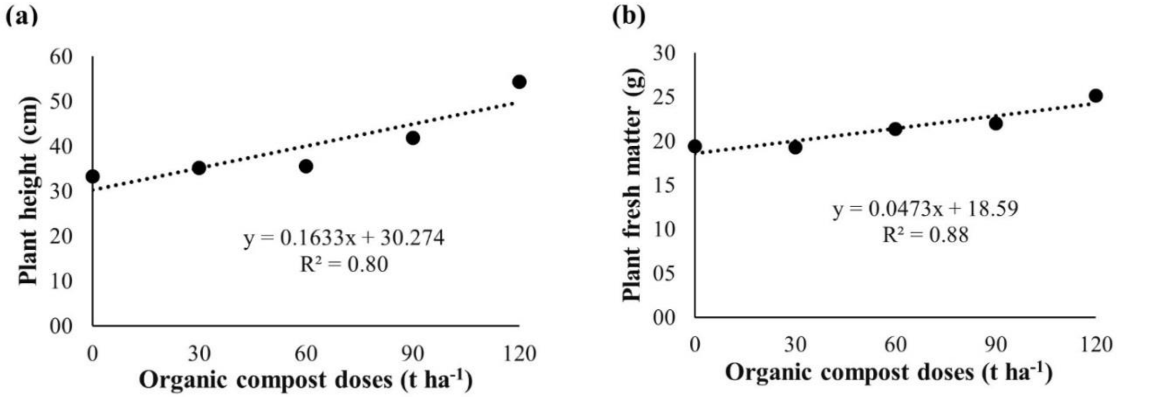


**Figure 2**. Plant height (a) and shoot fresh matter (b) of pods beans according to organic compost doses.

The plant dry matter differed statistically but did not fit any equation with $R^2$ of 9.71%, so the means of treatments were compared using the Tukey test (Table 2.). It is observed that the means of the doses of organic compost of 60 and 120 t $ha^{-1}$ showed higher values, still without differing from the other treatments. The highest rate of dry matter found in pods beans is due to the soil's physical-chemical improvements. These changes were promoted by the organic matter present, which influences the greater capacity of water retention in the soil and can be corroborated with increases in production and plant dry matter accumulation (Silva et al., 2016). As for the number of seeds per pod (NSP), the data fitted the quadratic equation with an estimated maximum value of 101.5 t $ha^{-1}$ (Figure 3). Organic compost in the bean production maximizes the number of seeds per pod since nutrients become available because of the soil's organic matter increase. The nutrients such as nitrogen, phosphorus, potassium, magnesium, and calcium are gradually released, responsible for seed formation (Magalhães et al., 2018).

**Table 2.** Plant height (PH), stem diameter (SD), relative chlorophyll index (CLOR), fresh plant matter (FM), dry plant matter (DM), number of seeds per pod (NSP), number of pods per plant (NPP), and grain yield (YIELD) of the pods beans according to doses of organic compost.

| **Doses** | **PH** | **SD** | **CLOR** | **FM** | **DM** | **NSP** | **NPP** | **YIELD** |
|---|---|---|---|---|---|---|---|---|
| **(t $ha^{-1}$)** | **Cm** | **mm** | **---** | **-------g------** | | **----------** | | **t $ha^{-1}$** |
| **0** | --- | 4.14 | 27.36 | --- | 3.96 ab | --- | --- | --- |
| **30** | --- | 4.20 | 31.67 | --- | 3.65 ab | --- | --- | --- |
| **60** | --- | 3.92 | 27.92 | --- | 4.49 a | --- | --- | --- |
| **90** | --- | 4.57 | 30.17 | --- | 3.76 ab | --- | --- | --- |
| **120** | --- | 4.63 | 28.15 | --- | 4.26 a | --- | --- | --- |
| **F-value** | $3.47^{*}$ | $0.94^{ns}$ | $0.65^{ns}$ | $5.89^{*}$ | $3.09^{*}$ | $3.67^{*}$ | $12.88^{*}$ | $7.33^{*}$ |
| **[1]Regression** | (L) | --- | --- | (L) | --- | (Q) | (L) | (L) |
| **CV (%)** | 23.16 | 14.51 | 15.47 | 9.18 | 9.86 | 7.21 | 8.14 | 11.64 |

*Significant at 5% probability, $^{ns}$ not significant and [1]significant regression, (L) significant for the linear equation and (Q) quadratic equation.

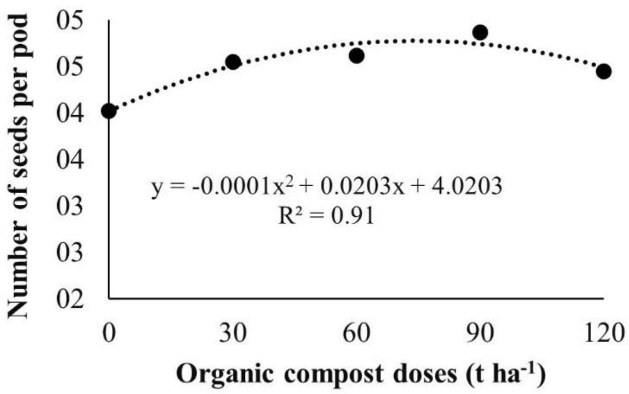


**Figure 3**. Number of seeds per pod of pods beans according to doses of organic compost.

For the number of pods per plant (NPP) and yield (YIELD), it is observed that the data adjusted to the increasing linear equation. The higher the dose of organic compost, the greater the result obtained for these variables (Figure 4a and 4b). It is worth mentioning that organic compost provides nodulation and nitrogen fixation in the soil and the production of secondary metabolites by the action of bacteria (Saikia et al., 2018), thus creating favorable conditions for plant development. Given these results, due to the increasing doses of organic compost (Table 1), there was an improvement in soil fertility, providing greater availability of nutrients for the plant, positively influencing the development and production of pods beans and consequently the increase in yield (Table 2, Figures 2, 3 and 4) Therefore, the cultivation of pods beans in the organic system shows good results. Faiyad et al. (2019) observed an improvement in the soil's physical properties, greater water retention, and nutrient accumulation, which increased cowpea development and yield, similar to what was observed in the current study.

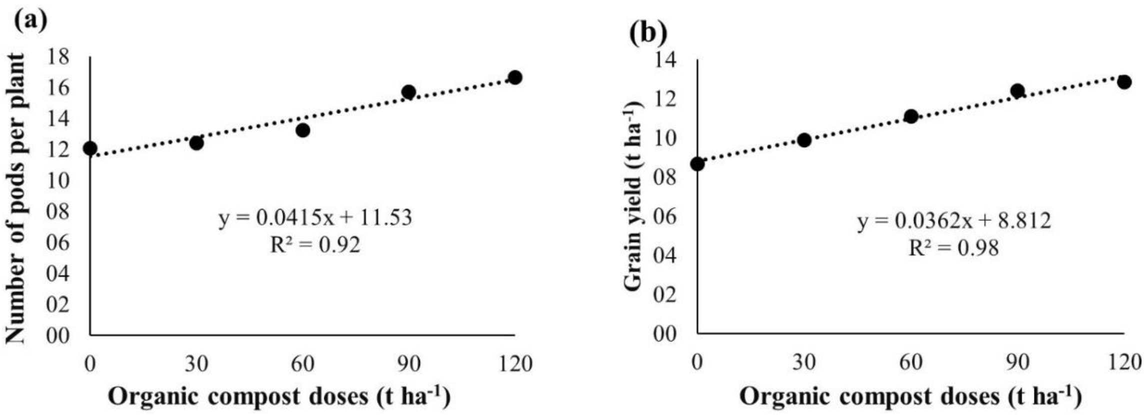


**Figure 4.** Number of pods per plant (a) and grain yield (b) of pods bean according to organic compost doses.

The results for 1000-seed weight, germination, first counting of germination, seedling emergence in the sand, emergence speed index, seedling dry matter, electrical conductivity, and accelerated aging are shown in Table 3. There was a significant difference for the 1000-seed weight (1000W), and the data were adjusted using an increasing linear equation (Figure 5a). This result differs from those observed by Silva et al. (2019), who claim that the 1000-seed weight has little influence from organic fertilization. Thus, these results suggest the need for further research related to pods beans' production and physiologic potential using different doses of organic compost. There were no statistical differences between treatments for germination (GER), first counting of germination (FCG), seedling emergence in the sand (SES), emergence speed index (ESI), and accelerated aging (AA) (Table 3).

These results demonstrate that seeds produced organically present a high percentage of germination (values above 96%) and high vigor regardless of the dose of organic compost used. As expected, the first counting of germination count, emergence of seedlings in the sand, emergence speed index, and accelerated aging showed high values regardless of the applied dose.

**Table 3.** 1000-seed weight (1000W), germination (GER), first counting of germination (FCG), seedling emergence in the sand (EPA), emergence speed index (ESI), seedling dry matter (SDM), electrical conductivity (EC), and accelerated aging (AA) of pods bean seeds produced with doses of organic compost.

| **Doses** | **1000W** | **GER** | **FCG** | **SES** | **ESI** | **SDM** | **EC** | **AA** |
|---|---|---|---|---|---|---|---|---|
| **(t ha$^{-1}$)** | **g** | **----------%------------** | | | **---** | **mg plant$^{-1}$** | **µS cm$^{-1}$** | **%** |
| **0** | --- | 97 | 97 | 98 | 23.5 | --- | 20.3 ab | 92 |
| **30** | --- | 100 | 100 | 99 | 24.7 | --- | 27.2 b | 96 |
| **60** | --- | 96 | 96 | 99 | 23.8 | --- | 26.2 ab | 90 |
| **90** | --- | 99 | 99 | 93 | 25.1 | --- | 15.6 a | 92 |
| **120** | --- | 99 | 99 | 97 | 25.3 | --- | 25.2 ab | 89 |
| **F-value** | 4.04* | 0.82$^{ns}$ | 0.82$^{ns}$ | 1.93$^{ns}$ | 1.33$^{ns}$ | 10.03** | 3.46* | 0.97$^{ns}$ |
| **[1]Reg** | (L) | --- | --- | --- | --- | (Q) | --- | --- |
| **CV (%)** | 9.79 | 3.68 | 3.68 | 3.68 | 5.46 | 24.34 | 22.86 | 5.93 |

*Significant at 5% probability, $^{ns}$ not significant, and [1]significant regression for the effect of doses of the organic compost, (L) significant for the linear equation.

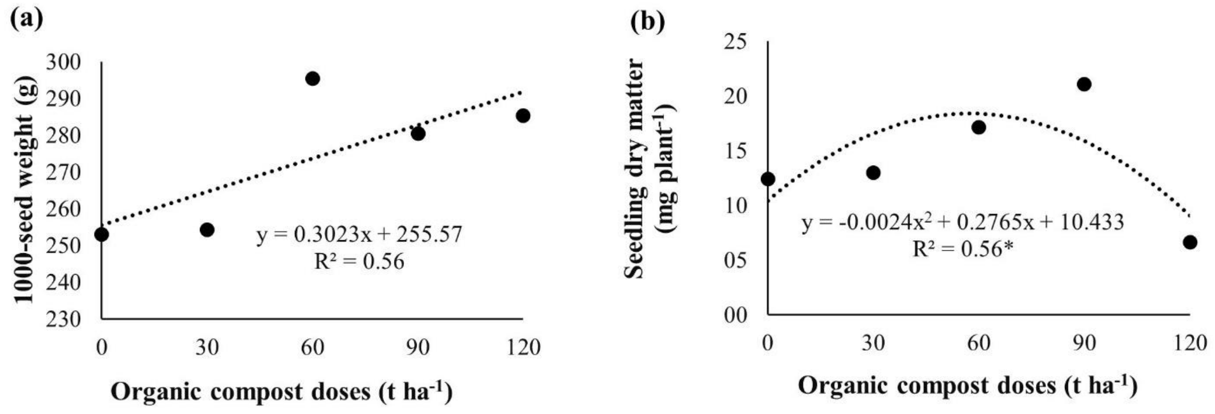


**Figure 5**. 1000-seed weight (a) and seedling dry matter (b) of pods bean according to organic compost doses.

There was a statistical difference with the results fitting to the quadratic equation for the seedling dry matter, with the maximum value estimated at 57.6 t $ha^{-1}$ of organic compost (Figure 5b). The electrical conductivity (EC) differed statistically, but there was no adequate adjustment ($R^2$ = 1.62%). Therefore, the treatment means were compared using the Tukey test (Table 3). The electrical conductivity test is related to the integrity of the cell membrane; that is, lots of high-quality seeds have low values of electrical conductivity due to the seeds' low concentration of solutes exudates in the solution caused by the fast organization of their membranes (Silva et al., 2014). The results obtained (Table 3) show that the dose of 90 t $ha^{-1}$ showed the lowest value of electrical conductivity, differing only from the treatment on 30 t $ha^{-1}$.

Organic fertilization increases organic matter in the soil providing benefits to plant development since they act as inducers of several microorganisms, stimulating the production of plant hormones, which help plant growth. These soils also have good physical-chemical and biological characteristics and decreased nutrient leaching (Hassan et al., 2015).

Due to innumerable advantages provided by the use of organic compost, the results of this study show that the organic seed production system guarantees increased yield of high-quality seeds, ensuring that organic products can be originated from organic seeds.

## 4. Conclusions

It is concluded that the increasing doses of organic compost promote the increase in the growth, development of the plants, and yield of seeds of beans of determined growth habit. Still, they do not influence the physiologic potential of the culture seeds.

## Authors' Contribution

Prof. Dr. Katiane Santiago Silva Benett, Natália Arruda and Rogério Lamim Silva Junior were responsible for study design and revising. Rogério Lamim Silva Junior, Luciana Maria da Silva, Cecília Leão Pereira Resende e Natália Arruda were responsible for data collection. Prof. Dr. Katiane Santiago Silva Benett, Natália Arruda and Rogério Lamim Silva Junior drafted the manuscript and Prof. Dr. Katiane Santiago Silva Benett, Prof. Dr. Cleiton Gredson Sabin Benett and Natália Arruda revised it. All authors read and approved the final manuscript.

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