Revista de Agricultura Neotropical

Physiological quality of mung bean seeds according to the plant density

Edvan da Costa Silva[1], Nei Peixoto[2], Natália Arruda[3], Natália Cássia de Faria Ferreira[2], Luís Augusto Batista de Oliveira[2]

[1] Universidade Estadual do Oeste do Paraná, Campus Marechal Cândido Rondon, Marechal Cândido Rondon, Paraná, Brasil. E-mail: edvan_costa@outlook.com. Parte da dissertação de mestrado do primeiro autor.

[2] Universidade Estadual de Goiás, Campus Ipameri, Ipameri, Goiás, Brasil. E-mail: nei.peixoto48@gmail.com, natcassiadefaria@gmail.com, luisaugusto-1993@hotmail.com

[3] Universidade Estadual de Maringá, Campus Regional de Umuarama, Umuarama, Paraná, Brasil. E-mail: nathy.a@hotmail.com

Received: 27/05/2019; Accepted: 15/10/2019.

ABSTRACT

Mung beans (*Vigna radiata* L.) are of Asian origin and have gained national importance with the production of *moyashi*. The study aimed to evaluate the seed physiological quality of mung beans according to the row spacing and number of plants per meter. The experiment was conducted at Goiás State University, Ipameri Campus. Tests were performed to determine the water content, germination, and vigor to evaluate the physiological quality of the seeds. The experimental design was completely randomized, with the treatments arranged in a 2 x 6 factorial scheme, having as factors the row spacing (25 and 50 cm) and the number of plants per meter (4, 8, 12, 16, 20, and 24 plants) with four replications. Based on the results of the analysis of variance, germination, first germination count, and emergence speed index were not influenced by row spacing and number of plants per meter. The shoot length of seedlings was significative affected by row spacing and the number of plants per meter. For root length, seedling dry mass and thousand-seed weight there was significant interaction between the studied factors. There was significant effect of row spacing on accelerated aging and seedling emergence. The mung bean plant density affected seed quality. Seeds produced with a row spacing of 50 cm with 24 plants per meter had the best physiological potential.

Keywords: *Vigna radiata*, Plant arrangement, Germination and Seed vigor.

Qualidade fisiológica de sementes de feijão mungo em função de densidade populacional de plantas

RESUMO

O feijão mungo (*Vigna radiata* L.) é de origem asiática e tem ganhado importância nacional com a produção de moyashi. O objetivo desse trabalho foi avaliar a qualidade fisiológica das sementes em função de espaçamentos entre linhas e o número de plantas por metro linear de feijão mungo. O experimento foi conduzido na Universidade Estadual de Goiás, Câmpus Ipameri. Para avaliação da qualidade fisiológica das sementes, foram realizados testes para determinação do grau de umidade, germinação e vigor. O delineamento experimental utilizado foi inteiramente casualizado, com os tratamentos dispostos em esquema fatorial 2 x 6, tendo como fatores os espaçamentos entre linhas (25 e 50 cm) e números de plantas por metro linear (4, 8, 12, 16, 20 e 24 plantas), com quatro repetições. Com base nos resultados da análise de variância, a germinação e a primeira contagem de germinação e índice de velocidade de emergência não foram influenciados pelos espaçamentos entre fileiras e números de plantas por metro linear. O comprimento da parte áerea de plântulas apresentou efeito significativo para os espaçamentos entre linhas e números de plantas por metro linear. Para comprimento da raiz, massa seca de plântulas e massa de mil sementes houve interação significativa entre os fatores estudados. Para envelhecimento acelerado e emergência de plântulas em areia houve efeito significativo isolado apenas para os espaçamentos entre linhas. A densidade populacional de feijão mungo afetou a qualidade das sementes. Sementes produzidas no espaçamento entre fileiras de 50 cm com 24 plantas por metro linear apresentaram melhor potencial fisiológico.

Palavras-chave: *Vigna radiata*, Arranjo de plantas, Germinação e Vigor de sementes.

1. Introduction

Mung beans (*Vigna radiata* (L.) R. Wilczek) is an Asian grain legume. The growth of its production in Brazil is due to its excellent quality to produce bean sprouts (*moyashi*), which arise soon after seed germination (Araujo et al., 2011).

Morphologically, the seeds are identical to commercial grains. However, by definition, seeds are produced for sowing purposes, requiring knowledge related primarily to technical standards, procedures, and standards set by legislation. For this, the farmers must know very well the species and variety with which they are working, the desirable field and laboratory patterns of seeds and the characteristics of other cultivars, undesirable wild plants, and factors that may influence production, especially affecting seed quality (França-Neto et al., 2016).

High-quality seed should have high sanitary, physical, genetic, and physiological characteristics, as these attributes guarantee agronomic performance directly linked to yield (Dutra et al., 2012; Zucareli et al., 2015; Marcos-Filho, 2015). The physiological quality is related to the ability to perform the vital functions of seeds, characterized by longevity, germination, and vigor.

Factors such as spatial arrangement and plant density are determinant concerning the intensity of competition since the determination of density guarantees benefits to the efficiency of shoot development and, consequently, a higher capacity of radiation interception by plants (Valeriano et al., 2019). Amaro et al. (2014), evaluating the physiological quality of seeds of different bean cultivars as a function of plant density, found that increasing sowing density does not affect the physiological quality of seeds of bean cultivars, except for Madrepérola cultivar, where population up to 290 thousand plants ha^{-1} is suitable for the production of high-quality seeds under the conditions studied.

According to Ghassemi-Golezani et al. (2012), the average seed weight of brindle beans cultivars decreased significantly as plant density increased; however, the physiological potential of seeds, measured by germination rate and seedling dry mass, was not affected by the plant density.

Although there are studies about the influence of plant density on grain yield for mung beans, there are no reports on the proper management of this parameter when evaluating the physiological quality of seeds. Thus, the study aimed to evaluate the physiological quality of freshly harvested mung bean (*Vigna radiata*) seeds according to the row spacing and number of plants per meter.

2. Material and Methods

Tests were performed to determine the water content, germination and seed vigor to evaluate the physiological quality of mung bean seeds, in the Multidisciplinary II Laboratory of the Goiás State University, Ipameri Campus, between February and August 2018.

According to the Koppen classification, the climate of the region is tropical (Aw) with two well-defined seasons, dry winter and rainy summer, with periods of drought during the rainy season (summer). The average air temperature in all months of the year is above 18 ºC. The soil of the experimental area is classified as Latossolo Vermelho-Amarelo distrófico (Santos et al., 2013), or Oxisol (Soil Survey Staff, 2014).

The chemical properties of 0-20 cm soil layer was: pH in $CaCl_2$ = 4.91; Available P (Mehlich 1 extractor) = 8.6 mg dm^{-3}; Available K = 0.3 $cmol_c$ dm^{-3}; Ca = 1.7 $cmol_c$ dm^{-3}; Mg = 1.0 $cmol_c$ dm^{-3}; Al = 0.0 $cmol_c$ dm^{-3}; H+Al, 4.0 $cmol_c$ dm^{-3}; CTC 7.06 $cmol_c$ dm^{-3}; and base saturation of 43.0%. Data about rainfall (mm) and average temperature (ºC) during the experiment conduction are shown in Figures 1 and 2.

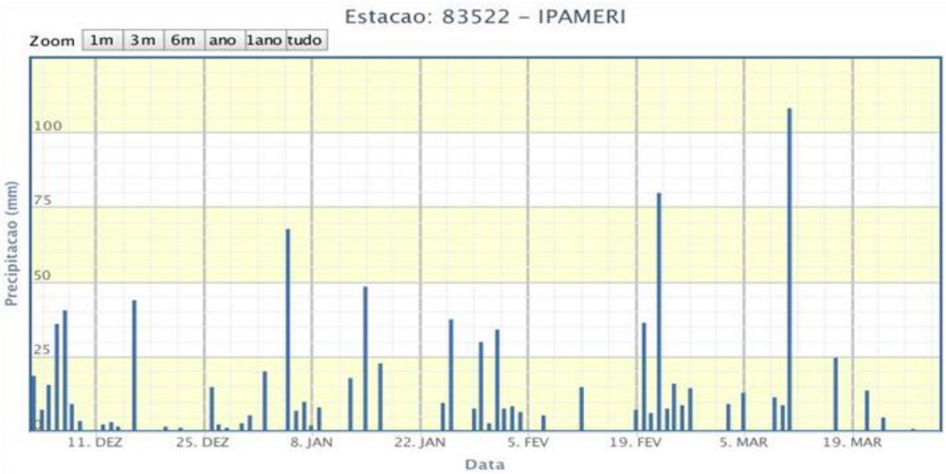

Figure 1. Rainfall (mm) during the experiment conduction, from December 2017 to March 2018. **Source**: INMET, 2018.

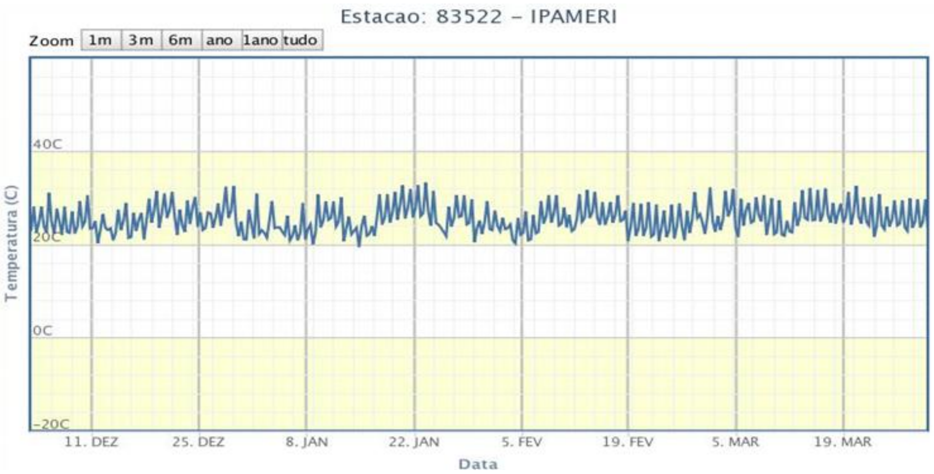

Figure 2. Average temperature (°C) during the experiment conduction, from December 2017 to March 2018. **Source**: INMET, 2018.

The experimental design used for both experiments was completely randomized, with the treatments arranged in a 2 x 6 factorial scheme, having as factors the row spacings (25 and 50 cm) and the number of plants per meter (4, 8, 12, 16, 20 and 24 plants), with four replications. Seeds from cultivar MGS Esmeralda, produced in Ipameri-GO, were used. The experimental units had 4.0 m long, and 2.5 m wide, with 4.0 m^2 of useful area. Plots with 50 cm row spacing were composed of four rows, the two central ones being considered as useful area and the two lateral ones as borders. Plots with 25 cm row spacing consisted of eight rows, the four central rows were considered as useful area and the two lateral rows of each side as borders.

Sowing was done with 50% more seeds for each density to ensure the desired plant density. On the tenth day, the adjust of densities was done. The sowing took place on December 15, 2017. Rows were demarcated with a tractor, and the seeds were manually sown at 4 cm depth. At sowing, 600 kg ha^{-1} of the formulated fertilizer 5-25-15 were manually applied, and at 20 DAE (days after emergence), 150 kg ha^{-1} of urea was applied.

Two harvests were carried out, the first on February 23, 2018, and the second on March 10, 2018. The seeds were harvested after reaching the physiological maturity point, in which they presented high water content (16-19%). They were dried in a shaded environment until the water content was 11-13% for each treatment.

The seed quality evaluation was performed through the following tests and/or determinations:

1 - Water content: the greenhouse method was used with forced air circulation, at 105 ± 3 ºC, for 24 h, according to the methodology described in Rules for Seed Analysis - RAS (Brasil, 2009). Two sub-samples of 20 seeds were taken per treatment. First, the forced air oven was set at 105±3 °C, and the containers were dried for 30 minutes; later, they were weighed with their covers and then with the seeds on a digital scale with three decimal places. The samples were kept in the forced air oven for 24 hours, and after this period were removed and kept in a desiccator to reduce the temperature and to be weighed. Results were expressed as % water content (wet basis).

2 - Germination test: it was conducted with four replicates of 50 seeds per treatment, which were placed on two sheets of paper towel, moistened with distilled water (2.5 times the weight of dry paper) and placed to germinate in germination chamber (BOD) with constant temperature of 25°C, estimating the percentage of normal seedlings at seven days after sowing. The evaluation was performed according to the Rules for Seed Analysis (Brasil, 2009). Results were expressed as the percentage of normal seedlings per treatment (%).

3 - First germination count: it was conducted simultaneously with the germination test, estimating the percentage of normal seedlings at five days after sowing, and the results expressed as a percentage of normal seedlings (%) (Brasil, 2009).

4 - Shoot and root length of seedlings: ten normal seedlings were used after the germination test for each replication. Shoot and root were measured with the aid of a graduated ruler. Results were expressed in centimeters (cm).

5 - Seedling dry mass: ten normal seedlings obtained from the germination test were evaluated, excluding cotyledons. The replications of each treatment were placed in identified paper bags and placed in the forced air circulation oven, kept at 80 ºC for 24 hours. After this period, each replication had the weight evaluated on a scale with a precision of 0.001g, and the average results expressed in grams per seedling.

6 -Thousand-seed weight: was determined according to the recommendations of the Rules for Seed Analysis (Brasil, 2009). Eight replications of 100 seeds from the pure seed portion of each treatment were used, where

each sample was weighed individually. Replications that fell within the standard were multiplied by 10, and the results expressed in grams.

7 - Electrical conductivity: was conducted with four replications of 50 seeds for each treatment, which were weighed, immersed in 75 mL of distilled water, and kept for 24 hours in seed germinator at 25 ºC. After this period, the electrical conductivity of the solution was evaluated by a conductivity meter, and the result was expressed in μS cm^{-1} g^{-1}.

8 - Accelerated aging: 200 seeds were used per treatment. The seeds were placed in a single layer on an aluminum screen inside plastic boxes "gerbox type", containing 40 mL of distilled water in the bottom and kept at 41 ºC for 48 hours. The germination test evaluation was performed on the fifth day after the beginning of the test, and the results were expressed as percentage of normal seedlings, following the methodology described by Jianhua and McDonald (1996).

9 - Seedling emergence test: carried out in plastic boxes containing as substrate 725 g of washed and screened sand (autoclaved at 120 °C for 2 hours) and moistened with distilled water to achieve 60% retention capacity (Brasil, 2009). Four replications of 50 seeds per treatment were distributed. The evaluation was performed within 14 days of installation. Results were expressed as a percentage of emerged seedlings.

10 - Emergence speed index (ESI): was performed concurrently with the seedling emergence test. Evaluations were performed daily, from the first day after sowing to the 14th day. From the emerged seedling daily values, the emergence speed index was calculated according to Maguire (1962).

The data were subjected to analysis of variance and regression. The comparison of the averages obtained in the tests was performed by the Tukey test at 5% probability. For row spacing and the number of plants per meter regression analysis was performed. Statistical analyses were processed using SISVAR statistical software (Ferreira, 2011).

3. Results and Discussion

Table 1 shows the average values of water content. There was variation between 11.5 and 12.6%. It is noteworthy that these values are within the standards considered ideal for harvesting and storing bean seeds (Vieira and Yokoyama, 2000).

For root length (RL), seedling dry mass (SDM), and thousand-seed weight (TSW), there was significant interaction between row spacing and number of plants per meter (Table 2). A significant effect of row spacing and the number of plants per meter on shoot length (SL) was observed. Germination (G) and first germination count (FGC) were not influenced by row spacing and number of plants per meter. For the root length, the row spacing had a significant effect, verifying that the row spacing of 50 cm differed statistically as the best, presenting a higher average than the row spacing of 25 cm (Table 2).

For the number of plants per meter in the row spacing of 25 cm (Figure 3), it is observed that the data adjusted to the quadratic regression model, increasing the results up to 4.02 cm, with the maximum point of 17 plants m^{-1}. For the row spacing of 50 cm, the data were adjusted to the increasing linear regression model (Figure 3), reaching the highest result of 5.52 cm with 24 plants m^{-1}, being 66.76% longer than the length observed for 4 plants m^{-1} (3.31 cm).

For the shoot length, it is noted that the row spacing of 50 cm differed statistically as best, presenting a higher average than row spacing of 25 cm (Table 2). There was also a significant effect of the number of plants per meter whose values adjusted to the increasing linear regression (Figure 4), reaching the highest result of 10.55 cm with 24 plants m^{-1}, being 39.37% longer than the shoot length of 4 plants m^{-1} (7.15 cm).

The evaluation of seedling length and / or its parts is an important feature in seed lot differentiation, where the highest values correspond to the most vigorous seed lots, and the seedling length is sensitive to classify lots with subtle differences in physiological potential (Guedes et al., 2009).

The row spacing of 50 cm had a significant effect on the seedling dry mass of mung bean. The row spacing of 50 cm was statistically different and had a higher average than the row spacing of 25 cm (Table 2).

For the number of plants per meter in the row spacing of 25 cm, the data were adjusted to the quadratic regression model (Figure 5), increasing the results up to 0.27 g $seedling^{-1}$, with the maximum point of 17 plants m^{-1}. For row spacing of 50 cm, the data were adjusted to the decreasing linear regression model (Figure 5), reaching the point of 0.27 g $seedling^{-1}$ with 24 plants m^{-1}, being 11.11% lower than the dry mass observed for 4 plants m^{-1} (0.30 g $seedling^{-1}$).

The vigorous seeds provide greater reserve transfer to the embryonic axis during the germination phase, resulting in higher weight seedlings due to the greater accumulation of dry matter (Carvalho and Nakagawa, 2012). Achieving improvements in the development of mung bean plants in the field is dependent on the appropriate sowing method since plant density directly influences the crop yield (Birhanu et al., 2018). It is worth considering that knowledge about ideal row spacing and plant density are factors that corroborate to the increase in production, as they vary according to size and habit of development and plant architecture (Bezerra et al., 2009).

Row spacing had a significant effect on a thousand-seed weight. The row spacing of 50 cm was statistically different, presenting a higher average than row spacing of 25 cm (Table 2). Only the row spacing of 25 cm was significant and adjusted to the increasing linear regression model (Figure 6), reaching the highest thousand-seed weight (57.26 g) with 24 plants m^{-1}, being 5.26% greater than the thousand-seed weight observed for 4 plants m^{-1} (54.40 g).

The physiological quality of seeds may be associated with changes in the thousand-seed weight, since seeds with smaller size or thousand-seed weight may show inferiority in physiological quality (Barbieri et al., 2013).

Contrary results were found by Ghassemi-Golezani et al. (2014), who, in studies with mung bean plant density, found a reduction in seed weight with increasing plant density. This is possible due to increased competition for water, nutrients, and other resources between plants (Ghassemi-Golezani et al., 2012).

For the electrical conductivity (EC) data, there was an interaction between row spacing and the number of plants per meter (Table 3). For accelerated aging (AA) and seedling emergence (SE), there was a significant isolated effect only for row spacing. Moreover, the emergence speed index (ESI) was not influenced by the factors studied.

Table 1. Water content (%) of mung bean seeds produced according to the row spacing and number of plants per meter. Ipameri-GO, 2019.

Treatments	Number of plants per meter					
Row spacing	4	8	12	16	20	24
25 cm	11.9	12.4	12.1	11.7	12.5	12.6
50 cm	11.5	12.2	12.0	11.8	12.3	12.2

Table 2. Average results of germination (G), first germination count (FGC), shoot length (SL), root length (RL), seedling dry mass (SDM) and thousand-seed weight (TSW) of mung bean seeds produced according to the row spacing and the number of plants per meter. Ipameri-GO, 2019.

Treatments	G (%)	FGC (%)	RL (cm)	SL (cm)	SDM (g seedling^{-1})	TSW (g)
Row spacing (A)						
25 cm	96.00 a	95.00 a	3.45 b	8.42 b	0.26 b	55.83 b
50 cm	96.00 a	96.00 a	4.41 a	9.71 a	0.29 a	57.04 a
N^{o} of plants m^{-1} (B)						
4	96.00	95.00	---(1)	---(2)	---(1)	---(1)
8	95.00	94.00	---	---	---	---
12	96.00	96.00	---	---	---	---
16	96.00	96.00	---	---	---	---
20	96.00	96.00	---	---	---	---
24	97.00	96.00	---	---	---	---
F-values						
A	0.79^{ns}	0.74^{ns}	30.68**	17.68**	17.59*	12.04**
B	0.81^{ns}	0.72^{ns}	16.25**	13.99**	1.62^{ns}	0.88^{ns}
A x B	2.01^{ns}	2.43^{ns}	2.98*	2.44^{ns}	6.54*	5.85**
CV (%)	2.53	2.82	15.22	11.74	7.44	12.04

Means followed by the same lowercase letter in the column for each factor studied do not differ from each other by the Tukey test at 5% probability. ** = Significant at 1% probability; * = Significant at 5% probability; ns = not significant. (1) = Significant regression for row spacing and the number of plants per meter. (2) = Significant regression for the number of plants per meter.

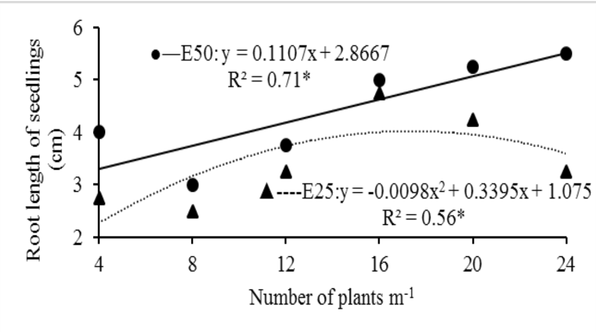

Figure 3. Root length of seedlings of mung bean seeds produced according to the row spacing and number of plants per meter. Ipameri-GO, 2019.

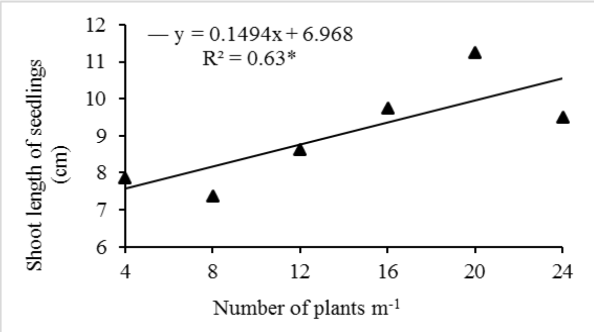

Figure 4. Shoot length of seedlings of mung bean seeds produced according to the row spacing and number of plants per meter. Ipameri-GO, 2019.

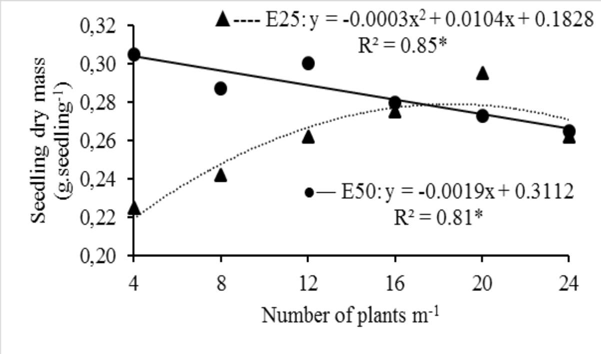

Figure 5. Seedling dry mass of mung bean seeds produced according to the row spacing and number of plants per meter. Ipameri-GO, 2019.

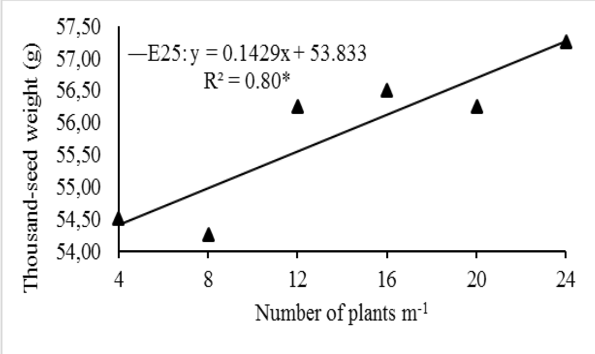

Figure 6. Thousand-seed weight of mung bean seeds produced according to the row spacing and number of plants per meter. Ipameri-GO, 2019.

Table 3. Average results of accelerated aging (AA), electrical conductivity (EC), seedling emergence (SE), and emergence speed index (ESI) of mung bean seeds produced according to the row spacing and the number of plants per meter. Ipameri-GO, 2019.

Treatments	AA	EC	SE	ESI
	(%)	(μS.cm^{-1}.g^{-1})	(%)	(%)
Row spacing (A)				
25 cm	83.00 b	108.25 b	78.00 b	7.04 a
50 cm	88.00 a	89.25 a	83.00 a	7.29 a
N^{o} of plants m^{-1} (B)				
4	85.00	---(1)	86.00	7.38
8	80.00	---	74.00	6.38
12	88.00	---	77.00	7.13
16	89.00	---	83.00	7.50
20	86.00	---	84.00	7.38
24	86.00	---	80.00	7.25
		F-values		
A	11.22**	38.73*	7.44**	1.41^{ns}
B	3.40^{ns}	1.58^{ns}	2,.63^{ns}	2.51^{ns}
A x B	3.19^{ns}	4.87*	2.12^{ns}	1.41^{ns}
CV (%)	5.29	10.71	7.44	1.41^{ns}

Means followed by the same lowercase letter in the column for each factor studied do not differ from each other by the Tukey test at 5% probability. ** = Significant at 1% probability; * = Significant at 5% probability; ns = not significant. (1) Significant regression for row spacing and the number of plants per meter.

For the electrical conductivity test, the row spacing had a significant effect, and the row spacing of 50 cm had better results than row spacing of 25 cm (89,25 μS.cm^{-1}.g^{-1} and 108,25 μS.cm^{-1}.g^{-1}, respectively) (Table 3). Only the row spacing of 25 cm had significant data, adjusting to the decreasing linear regression model (Figure 7), reaching the lowest electrical conductivity value of 98.75 μS.cm^{-1}.g^{-1} with 24 plants m^{-1}, being 19.24% lower than the electrical conductivity observed for 4 plants m^{-1} (117.75 μS.cm^{-1}.g^{-1}).

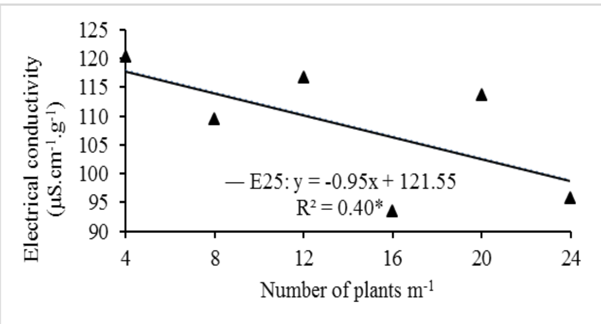

Figure 7. Electrical conductivity of mung bean seeds produced according to the row spacing and number of plants per meter. Ipameri-GO, 2019.

The present study obtained different results from those found by Costa et al. (2008) when they evaluated the physiological quality of common bean seeds as a function of three plant populations. The authors state that there was no influence of plant populations on the electrical conductivity test.

In common bean seeds, the electrical conductivity test at temperatures of 30 and 35 °C indicates increases in the seed imbibition process, a factor probably explained by the intense release of exudates in the seed imbibition solution, due to the influence of temperature on increased of water absorption speed, and thus favors gains in the amount of solutes leached by seeds in the soaking process (Silva et al., 2013). In mung beans, the maximum seed vigor measured by the electrical conductivity test was found when the seeds obtained moisture content equivalent to 20%, a factor that reveals the high capacity and vigor of mung bean seeds under different plant densities; however, considering the humidity value around 20% (Ghassemi-Golezani et al., 2014). The seeds produced in the row spacing of 50 cm with 24 plants per meter had better physiological potential, evidenced by the shoot length of seedlings, root length of seedlings, electrical conductivity, and thousand-seed weight.

In general, the knowledge of appropriate crop management for mung beans is essential regarding the answers on the physiological performance of seeds when subjected to different row spacing and plant numbers per linear meter since there are few studies in the literature for these parameters.

4. Conclusions

Mung bean plant density influenced seed quality.

Seeds produced with a row spacing of 50 cm and 24 plants per meter presented the best physiological potential.

Bibliographic References

Amaro, H.T.R., David, A.M.S.S., Carvalho, J., Vieira, N.M.B., Aspiazú, I., Assis, M.O., 2014. Qualidade fisiológica de sementes de cultivares de feijão em função de densidades populacionais. Semina: Ciências Agrárias, 35(3), 1241-1248.

Araujo, R.F., Zonta, J.B., Araujo, E.F., Heberle E., Zonta, F.M.G., 2011. Teste de condutividade elétrica para sementes de feijão-mungo-verde. Revista Brasileira de Sementes, 33(1), 123-130.

Barbieri, A.P.P., Martin, T.N., Mertz, L.M., Nunes, U.R., Conceição, G.M., 2013. Redução populacional de trigo no rendimento e na qualidade fisiológica das sementes. Revista Ciência Agronômica, 44(4), 724-731.

Bezerra, A.A.C., Távora, F.J.A.F., Freire Filho, F.R., Ribeiro, V.Q., 2009. Características de dossel e de rendimento em feijão-caupi ereto em diferentes densidades populacionais. Pesquisa Agropecuária brasileira, 44(10), 1239-1245.

Birhanu, A., Tadesse, T., Tadesse, D., 2018. Effect of inter- and intra-row spacing on yield and yield components of mung bean (*Vigna radiata* L.) under rain-fed condition at Metema District, northwestern Ethiopia. Agriculture & Food Security, 7(1), 1-7.

Brasil. Ministério da Agricultura, Pecuária e Abastecimento, 2009. Regras para análise de sementes. Secretaria de Defesa Agropecuária. Brasília, DF, Mapa/ACS.

Carvalho, N.M., Nakagawa, J., 2012. Sementes: ciência, tecnologia e produção, quinta ed. Jaboticabal, FUNEP.

Costa, R.S.S, Sá, M.E., Orioli Júnior, V., Bertolin, D.C., 2008. Qualidade fisiológica de sementes de feijão em função da população de plantas e nitrogênio em plantio direto. Nucleus, 5(2), 335-344.

Dutra, A.S., Bezerra, F.T.C., Nascimento, P.R., Lima, D.C.L., 2012. Produtividade e qualidade fisiológica de sementes de feijão caupi em função da adubação nitrogenada. Revista Ciência Agronômica, 43(4), 816-821.

Ferreira, D.F., 2011. Sisvar: a computer statistical analysis system. Ciência e Agrotecnologia, 35(6), 1039-1042.

França-Neto, J.B., Krzyzanowski, F.C., Henning, A.A., Pádua, G.P., Lorini, I., Henning, F.A., 2016. Tecnologia da produção de sementes de soja de alta qualidade. Londrina, Embrapa.

Ghassemi-Golezani, K., Abriz, S.F., Hassanpour-Bourkheili, S., 2014. Development of mung-bean seed vigour under different irrigations and plant densities. International Journal of Plant, Animal and Environmental Sciences, 4(3), 208-211.

Ghassemi-Golezani, K., Akbari, H., Bandeh-Hagh, A., 2012. Effects of plant density and pod position on seed vigour of pinto bean cultivars. Research on Crops, 13(2), 529-533.

Guedes, R.S., Alves, E.D., Gonçalves, E.P., Viana, J.S., Medeiros, M.S., Lima, C.R., 2009. Teste de comprimento de plântula na avaliação da qualidade fisiológica de sementes de Erythrina velutina Willd. Semina: Ciências Agrárias, 30(4), 793-802.

INMET, 2018. Estações Convencionais - Gráficos. http://www.inmet.gov.br/portal/index.php?r=h_estacoes_conv_graf (acessado 23 de agosto de 2018).

Jianhua, Z., Mcdonald, M.B., 1996. The saturated salt accelerated aging test for small seed crops. Seed Science and Technology, 25(1), 123-131.

Maguire, J.D., 1962. Speed of germination aid in selection and evaluation for seeding and vigour. Crop Science, 2(2), 176-177.

Marcos-Filho, J., 2015. Seed vigor testing; an overview of the past, presente and future prespective. Scientia Agrícola, 72(4), 363-375.

Santos, H.G., Almeida, J.A., Oliveira, J.B., Lumbreras, J.F., Anjos, L.H.C., Coelho, M.R., Jacomine, P.K.T., Cunha, T.J.F., Oliveira, V.A., 2013. Sistema Brasileiro de Classificação de Solos, terceira ed. Brasília, Embrapa.

Silva, S.S.D., Vieira, R.D., Grzybowski, C.R.D.S., Carvalho, T.C.D., Panobianco, M., 2013. Electrical conductivity of different common bean seeds genotypes. Journal of Seed Science, 35(2), 216-224.

Soil Survey Staff, 2014. Keys to Soil Taxonomy, twelfth ed. Washington, USDA.

Valeriano, T.T.B., Borges, R.M., Almeida, F.S., Silva Neto, O.F., Santana, M.J., Silva, K.A., 2019. Desempenho agronômico de cultivares de feijão caupi em função da densidade de plantas. Revista Inova Ciência & Tecnologia/Innovative Science & Technology Journal, 5(1), 12-17.

Vieira, E.H.N., Yokoyama, M., 2000. Colheita, processamento e armazenamento, in: Vieira, E.H.N., Rava, C.A, décima ed. Sementes de feijão: produção e tecnologia. Santo Antônio de Goiás, Embrapa Arroz e Feijão, p. 233-248.

Zucareli, C., Brzezinski, C.R., Abati, J., Werner, F., Ramos Júnior, E.U., Nakagawa, J., 2015. Qualidade fisiológica de sementes de feijão carioca armazenadas em diferentes ambientes. Revista Brasileira de Engenharia Agrícola e Ambiental, 19(8), 803-809.