Initial growth of cowpea cultivars with an increase of 4.8 ° C in air temperature

Crescimento inicial de cultivares de feijão-caupi com aumento de 4,8 ° C na temperatura do ar

DOI:10.34117/bjdv7n2-592

Recebimento dos originais: 20/01/2021
Aceitação para publicação: 20/02/2021

Juliane Rafaele Alves Barros
Master in Agronomy
Universidade Estadual de Feira de Santana (UEFS), Feira de Santana, Bahia, Brazil
E-mail: juliane-ab@hotmail.com

Miguel Júlio Machado Guimarães
Phd in Agricultural Engineering
Instituto Federal de Educação, Ciência e Tecnologia do Maranhão (IFMA), São Raimundo das Mangabeiras, Maranhão, Brazil
E-mail:mjmguimaraes@hotmail.com

Rodrigo Moura e Silva
Biologist
Universidade de Pernambuco, Petrolina, Pernambuco, Brazil
E-mail: moura.pnz@gmail.com

Maydara Thaylla Cavalcanti Rêgo
Master in Plant Genetic Resources
Universidade Estadual de Feira de Santana (UEFS), Feira de Santana, Bahia, Brazil
E-mail: maydara.rego@hotmail.com

Natoniel Franklin de Melo
Phd in Biological Sciences
Embrapa Semiárido, Petrolina, Pernambuco, Brazil
E-mail: natoniel.melo@embrapa.br

Francislene Angelotti
PhD in Agronomy
Embrapa Semiárido, Petrolina, Pernambuco, Brazil
E-mail: francislene.angelotti@embrapa.br

ABSTRACT

Vigorous germination and uniform seedling establishment are determinant and dependent on the performance of cultivars in the face of rising air temperatures. Thus, the objective was to evaluate the initial development of different cultivars of cowpea against the increase of 4.8 ° C in the daily temperature regime. The experiment was carried out in growth chambers, in a 5x2 factorial scheme (cultivars x temperature regimes). It was evaluated: germination percentage, germination speed index, average germination time, average germination speed, average germination speed, the initial seedling length and the

initial seedling dry weight. The increase of 4.8 ° C in the temperature did not affect the germination percentage of the seeds, being above 90%. The germination speed index and the average germination speed were higher at temperatures of 24.8-30.8-37.8 ° C. For the germination percentage, the cultivars Pujante, Rouxinol and Tapahium presented the highest indexes, above 90%. The germination speed index and the average germination speed were higher for cv. For Rouxinol, consequently, the average germination time was shorter. The initial seedling length did not differ between cultivars, with an average value of 17.73 cm. The cv. Pujante differed among the other cultivars in terms of seedling dry mass. The initial growth and dry mass of seedlings were higher in the environment with a temperature of 24.8-30.8-37.8 ° C The 4.8 ° C increase in air temperature does not affect the initial phase of cowpea. The germinative parameters of this legume vary according to the cultivars.

Keywords: *vigna unguiculata*; heat stress; climate changes; cultivars

RESUMO
A germinação vigorosa e o estabelecimento uniforme de plântulas são processos determinantes e dependentes do desempenho das cultivares frente ao aumento da temperatura do ar. Assim, objetivou-se avaliar desenvolvimento inicial de plântulas de diferentes cultivares de feijão-caupi frente ao aumento de 4.8 ° C no regime diário de temperatura. O experimento foi conduzido em câmaras de crescimento, em esquema fatorial 5x2 (cultivares x regimes de temperatura). Avaliou-se: porcentagem de germinação, índice de velocidade de germinação, tempo médio de germinação, velocidade média de germinação, comprimento de plântula e peso seco de plântila. O aumento de 4,8 °C na temperatura não afetou a porcentagem de germinação das sementes, ficando acima de 90%. O índice de velocidade de germinação e a velocidade média de germinação foram maiores nas temperaturas de 24,8-30,8-37,8 °C. Para a porcentagem de germinação, as cultivares Pujante, Rouxinol e Tapahium apresentaram os maiores índices, superiores a 90%. O índice de velocidade de germinação e a velocidade média de germinação, foram maiores para a cv. Para o Rouxinol, consequentemente, o tempo médio de germinação foi menor. O comprimento inicial das plântulas não diferiu entre as cultivares, com um valor médio de 17,73 cm. A cv. Pujante diferiu entre as outras cultivares quanto a massa seca das plântulas. O crescimento inicial e a massa seca das plântulas, foram maiores no ambiente com temperatura de 24,8-30,8-37,8 °C. O aumento de 4,8 °C na temperatura do ar não afeta a fase inicial do feijão-caupi. Os parâmetros germinativos dessa leguminosa variam de acordo com as cultivares.

Palavras-chave: *Vigna unguiculata*; estresse por calor; mudanças climáticas; cultivares

1 INTRODUCTION

The germination of seeds and the initial development of seedlings depend on climatic conditions and are fundamental processes for the establishment of the plant in the field (Tribouillois et al., 2016). Among the various factors that influence germination, temperature is one of the most relevant because it directly influences plant growth and development (Motsa et al., 2015). Temperatures higher than the optimum reduce or

paralyze the metabolism of seeds, caused by protein denaturation and loss of enzymatic activity (Orzari et al. 2013). As a consequence, a retardation in the emergence of seedlings or the formation of small seedlings may occur (Santos and Zonetti, 2009).

As a result of global climate changes, the air temperature will alter, causing more frequent, intense and longer lasting temperature variations. (Cunha et al., 2019). According to the Intergovernmental Panel on Climate Change (IPCC), in the pessimistic scenario, the increase in air temperature could reach between 3.7 and 4.8 °C by 2100 (IPCC, 2014). This represents a danger to food security, as this increase in temperature will cause losses in the productivity of several crops. Thus, the use of cultivars with more vigorous germination and uniform establishment of seedlings will be an important strategy in the face of temperature increase (Skoufogianni et al., 2017).

Cowpea (*Vigna unguiculata* L.) is considered a key crop in the context of global climate change and food security (Carvalho et al., 2019).Because in addition to representing an accessible nutritional source, with a fundamental role in the balance of diets, due to its low fat content and high carbohydrate content (Gomes et al., 2019), it generates employment and income for family agriculture (Merwad et al., 2018; Rocha et al., 2016), especially in the Brazilian semi-arid region (Melo et al., 2018).

Semi-arid regions are the more vulnerable to climate change and extreme temperature events (Djanaguiraman et al., 2018). The Brazilian semi-arid region has an average temperature of approximately 26 °C (Angelotti et al., 2020) and according to the data described by the Rules for Seed Analysis (*Regras para Análise de Sementes* - RAS) the ideal temperature for the germination of the cowpea is 25 °C (BRAZIL, 2009), so the increase in temperature predicted by the IPCC (2014) may affect the viability of the seeds. In addition, there is no literature on the impact of the 4.8 °C increase on seed germination and establishment of seedlings of cowpea cultivars.

The existing works report only the effect of fixed temperatures or with day and night variations (Covell et al., 1986; Craufurd et al., 1996; Islam et al., 2006; Butler et al., 2014; Motsa et al., 2015; Chagas et al., 2018). These results help to explain the initial process, but do not simulate the performance of the cowpea in the face of daily temperature variations, as in the environment. Studies simulating daily temperature variations contribute to understanding how seeds of different cultivars will respond during the germination process and the establishment of seedlings in higher temperature environments, allowing the selection of tolerant materials that germinate and establish successfully, even in adverse conditions (Motsa et al., 2015).

Therefore, the objective of this study was to evaluate the initial development of different cultivars of cowpea against the increase of 4.8 ° C in the daily temperature regime.

2 MATERIAL AND METHODS

The experiment was carried out in growth chambers, of the Fitotron type, with temperature, humidity and photoperiod control. Seeds of five cowpea cultivars were used: BRS Carijó, BRS Itaim, BRS Pujante, BRS Rouxinol and BRS Tapahium. The sowing took place in pots, with a capacity of 7 L. Fertilization was carried out two days before planting, according to the results of the soil chemical analysis and the crop reccomendation (Cavalcanti, 2008).

The experiment was carried out in a 5x2 factorial arrangement (cultivars x temperature), using four replications. The temperature regimes were: T ° 1: 20-26-33 ° C (20 °C: between 8 pm and 6 am; 26 °C: between 6 am and 10 am; 33 °C: between 10 am and 3 pm; 26 °C: from 3 pm to 8 pm) for the chamber 1. For the chamber 2 the regime T ° 2: 24.8-30.8-37.8 °C (24.8 °C: from 8 pm to 6 am; 30.8 °C: from 6 am to 10 am; 37.8 °C: from 10 am to 3 pm; 30.8 °C: from 3 pm to 8 pm) was adopted. Temperature values were determined from minimum, average and maximum temperatures, ranging from 18-22, 25-27 and 32-34ºC, respectively, in the São Francisco Sub-Middle Valley, Brazil. In this study, an increase of 4.8 °C was used, based on the temperature increase scenario IPCC (2014).

For germination evaluation, four replications of ten seeds were used. The germinated seed count was daily performed. The parameters evaluated were: germination percentage (G), germination speed index (GSI), average germination time (AGT) and average germination speed (AGS). Germination percentage (G) was obtained by the daily counting of germinated seeds (Equation 1: Labouriau, 1970). The germination speed index (GSI) was calculated from the sum of the number of germinated seeds per day, divided by the respective number of days elapsed from sowing, corresponding to the number of germinated seeds over time, expressed in seed / day (Equation 2: Maguire, 1962; Santana and Ranal, 2000). The average germination time (AGT) refers to the sum of the number of germinated seeds multiplied by the incubation time in days divided by the sum of germinated seeds per day (Equation 3: Labouriau, 1983; Santana and Ranal, 2000). Average germination speed (AGS) was calculated by the inverse of the average

germination time by daily counting (Equation 4: Kotowski, 1926; Santana and Ranal, 2000).

$$\text{Equation 1 } G = \frac{\sum_{i=1}^{k} ni}{A} * 100$$

$$\text{Equation 2 } GSR = \sum_{i=1}^{k} \frac{Ni}{ti}$$

$$\text{Equation 3 } AGT = \frac{\sum_{i=1}^{k} ni.ti}{\sum_{i=1}^{k} ni}$$

$$\text{Equation 4 } AGS = \frac{\sum_{i}^{k} ni}{\sum_{i=1}^{k} ni.ti}$$

On what:

K = last day of observation;

A = Total number of seeds placed to germinate;

ni = non accumulated number of germinated seeds;

ti = number of days;

Ni = accumulated number of germinated seeds

To evaluate the initial growth, 15 days after planting proceding a cut in the bottom part of the stem. For seedling length evaluation a ruler was used. Seedlings were placed in paper bags and stored in an oven at 65 °C for ± 72 hours, to obtain the dry mass (g).

Variance analysis (ANAVA) was performed, being the means compared by Tukey's test at 5% of probability using the SISVAR Version 5.6 software.

3 RESULTS AND DISCUSSION

The interaction of cultivars x temperature was not significant for the germination of cowpea seeds and did not interfere in the initial seedlings growth (Table 1). However, the isolated effect of cultivars was observed both in seed germination and in the initial development of plants. The increase in temperature interfered in the germination speed index (GSI), average germination time (AGT), average germination speed (AGS), in the initial seedling length (SL) and in the initial seedling dry weight (DSW) (Table 1).

Table 1. Summary of the variance analysis, by the mean square, of parameters evaluated in different cowpea cultivars submitted to two temperature regimes.

Variation source	MS						
	DF	G%	GSI	AGT	AGS	SL	DSW
Cultivar (cv)	4	316.25**	2.60**	0.41**	0.01**	8.82ns	0.32**
Temperature (T)	1	202.5ns	20.49**	3.04**	0.08**	477.61**	1.19**
Cultivar x T	4	8.75ns	0.27ns	0.06ns	0.001ns	1.65ns	0.19ns
Residue	30	52.5	0.28	0.06	0.0023	6.9	0.09
CV%		7.77	12.69	9.77	10.37	14.81	15.81

DF = degree of freedom; CV = coefficient of variation; ns = not significant, ** significant at 1% of probability, * significant at 5% of probability compared by Tukey's test. Germination percentage (G), germination speed index (GSI), average germination time (AGT), average germination speed (AGS), initial seedling length (SL), the initial seedling dry weight (DSW).

The result showed that the germinative parameters may vary depending on the cultivar analyzed (Table 2). For the germination percentage, the cultivars Pujante, Rouxinol and Tapahium presented the highest indexes with a value greater than 90%. The germination speed index (GSI) and the average germination speed (AGS), were higher for cv. Rouxinol, consequently, the average germination time (AGT) for this cultivar was smaller. During the germination process, the temperature interferes with the water soaking time and chemical reactions, changing the germination speed (Gordin, 2012). This high percentage and germination speed may be related to the physiological quality of the seeds, since the greater the vigor, the greater the speed and germination rate (Padua et al., 2010). According to Melo Junior et al. (2018), rapid germination favors the establishment of species, since the seeds are exposed to adverse environmental conditions for a long time.

The initial seedling length not differ between cultivars (SL), obtaining an average value of 17.73 cm. Similar results were found in a study by Nunes et al. (2019) when evaluating the effect of temperature on cowpea genotypes, which found that there was no significant difference in the initial seedling length of the evaluated genotypes, regardless the temperature regime. The initial dry weight of the seedling was higher for cv. Therefore, different cultivars, even if they are of the same species, may present different responses to each other (Matoso et al., 2018) (Table 2).

Table 2. Germinative parameters of cowpea cultivars submitted to two temperature regimes.

Cultivar	G%	GSI	AGT	AGS	SL	DSW
Carijó	90.0 ab	4.29 ab	2.38 bc	0.43 ab	18.01	1.97 ab
Itaim	83.7 b	3.44 c	2.61 ab	0.39 bc	18.88	1.66 b
Pujante	96. 2 a	3.92 bc	2.18 c	0.36 c	17.32	2.20 a
Rouxinol	97.5 a	5.00 a	2.77 a	0.47 a	18.31	2.07 ab
Tapahium	98.7 a	4.17 bc	2.58 ab	0.39 bc	16.15	1.95 ab
Means	-	-	-	-	17,73	-
MSD	10.51	0.76	0.36	0.06	3.81	0.45

Means followed by the same lowercase letter in the column do not differ by Tukey's test at 5% probability. Germination percentage (G), germination speed index (GSI), average germination time (AGT), average germination speed (AGS), initial seedling length (SL), the initial seedling dry weight (DSW). Minimal significant difference (MSD).

An increase in 4.8 ºC of air temperature did not affect the percentage of germination of cowpea seeds. It was found that the seeds submitted to the temperature regime 24.8-30.8-37.8 °C presented higher germination speed index (GSI) and average germination speed (AGS) with less time to germinate (Table 3). The high temperatures tend to accelerate the speed of water absorption and chemical reactions (Carvalho and Nakagawa, 2012). Additionally, the increase in temperature is associated with the acceleration of the cycle, permitting plants to alter their metabolism when subjected to stress conditions so as not to prejudice development (Bergamaschi and Bergonci, 2017; Schmidt et al., 2017), which justifies the higher germination speed of seeds submitted to temperature increase.

In the temperature regime of 20-26-33 °C, the seeds took longer to germinate (Table 3).

Table 3. Germinative parameters of cowpea submitted to temperature increase.

Temperature	G%	GSI	AGT	AGS	SL	DSW
20-26-33°C	91.0	3.45 b	2.78 b	0.36 b	14.28 b	1.80 b
24.8-30.8-37.8°C	95.5	4.88 a	2.23 a	0.46 a	21.19 a	2.14 a
Means	93.25	-	-	-	-	-
MSD	4.68	0.341	0.158	0.027	1.696	0.201

Means followed by the same lowercase letter in the column do not differ by Tukey's test at 5% probability. Germination percentage (G), germination speed index (GSI), average germination time (AGT), average germination speed (AGS), initial seedling length (SL), the initial seedling dry weight (DSW). Minimal significant difference (MSD).

The increase in temperature also interfered in the initial growth of cowpea seedlings (SL and DSW). Seedlings developed in the environment with a temperature range of 24.8-30.8-37.8 °C showed an increase inlength of 32.6% and 15.9% in initial dry

weight, respectively. This result reinforces the effect of temperature in promoting the rapid seedlings development due to the interference of this element in water absorption and chemical reactions (Carvalho and Nakagawa, 2012). On the other hand, lower temperature during sowing can decrease the mobilization of reserves, reducing the growth rate (Cruz et al., 2007). This explains the shorter length and the lower shoot dry mass of cowpea cultivars at a temperature range of 20-26-33 °C.

In this way, environments with temperatures outside the optimal point can delay the emergence of seedlings, and reduce the stand because of the formation of small seedlings, confirming that environmental conditions are decisive in the process of establishing crops (Santos and Zonetti, 2009).

Based on the data obtained in this research, it is stated that the initial growth of the cultivars Carijó, Itaim, Pujante, Rouxinol and Tapahium was tolerant to an increase of 4.8 °C in air temperature, presenting an optimum performance when maintained in the regime of 24.8-30.8-37.8 °C (Table 3). However, studies will be necessary to evaluate the impact of the temperature increase on the different phenological phases of the cowpea, since each phase presents an optimal range for its growth and development.

Considering this and the future scenario of climate change, the selection of plants tolerant to temperature increase will be of great importance, especially during the germination process, as it will contribute to the establishment of seedlings and the uniformity of the crop.

4 CONCLUSION

The increase of 4.8 °C in air temperature does not affect the initial phase of the cowpea. The germinative parameters of this legume vary according to the cultivars.

ACKNOWLEDGEMENTS

The authors would like to thank the Foundation for the Support of Research of the State of Bahia (FAPESB) for funding the doctoral scholarship (Nº BOL0419 / 2017).

REFERENCE

ANGELOTTI, F; BARBOSA, LG; BARROS, JRA; SANTOS, CAF. Cowpea (*Vigna unguiculata*) development under different temperatures and carbon dioxide concentrations. *Revista Pesquisa Agropecuária Tropical*, v. 50, n.1, p.1-7, 2020. DOI: https://doi.org/10.1590/1983-40632020v5059377

BERGAMASHI, H; BERGONCI, JI. *As plantas e o clima: Princípios e aplicações*. Guaíba: Agrolivros, 2017. 352p.

BUTLER, TJ; CELEN, AE; WEBB, SL; KRSTIC, D; INTERRANTE, SM. Temperature affects the germination of forage legume seeds. *Crop Science*, v. 54, n.1, p. 1-8, 2014. https://doi.org/10.2135 / cropci2014.01.0063

BRASIL. Ministério da Agricultura, Pecuária e Abastecimento. *Regras para análise de sementes*. Ministério da Agricultura, Pecuária e Abastecimento. Secretaria de Defesa Agropecuária. Brasília: MAPA, 2009. 395p.

CALBO, AG; AROCA, SC. Medidas para mitigar os efeitos das mudanças climáticas na produção de hortaliças. In: Guedes, M. R. (Ed.). Mudanças climáticas globais e a produção de hortaliças. Brasília, DF: Embrapa Hortaliças, 2009. 95-126p.

CARVALHO, M; CASTRO, I; PEREIRA, JM; CORREIA, C; CORTINES, ME; MATOS, M; ROSA, E; CARNIDE, V; LINO NETO, T. Evaluating stress responses in cowpea under drought stress. *Journal of Plant Physiology*, v. 241, n.1, p.1-13, 2019. https://doi.org/10.1016/j.jplph.2019.153001

CARVALHO, NM; NAKAGAWA, J. Sementes: ciência, tecnologia e produção. 5.ed. Jaboticabal: FUNEP, 2012. 588p.

CAVALCANTI, FJ de A. *Recomendações de adubação para o estado de Pernambuco*. 2ª Apr. 3.ed., Recife: IPA, 2008. 212p.

CHAGAS, JTB; FARIAS, JEC; SOUZA, RF; JÚNIOR, SPF; COSTA, MGS. Germinação e vigor de sementes crioulas de feijão-caupi. *Agrarian Academy, Centro Científico Conhecer*, v.5, n.9; p.1-12, 2018. https://doi.org/10.18677/Agrarian_Academy_2018a48

COVELL, S; ELLIS, RH; ROBERTS, EH; SUMMERFIELD, RJ. The Influence of Temperature on Seed Germination Rate in Grain Legumes: I. A comparison of chickpea, lentil, soybean and cowpea at constant temperatures. *Journal of Experimental Botany*, v. 37, n.1, p. 705-715, 1986. https://doi.org/10.1093/jxb/37.5.705

CRAUFURD, PQ; SUMMERFIELD, RJ; ELLIS, RH; ROBERTS, EH. Development in cowpea (*Vigna unguiculata*) I. The influence of temperature on seed germination and seedling emergence. *Experimental Agriculture*, v.32, n.1, p.1-12, 1996. https://doi.org/10.1017/S0014479700025801

CRUZ, HL; FERRARI, CS; MENEGHELLO, GE; KONFLANZ, V; ZIMMER, PD; VINHOLES, PS; CASTRO, MAS. Avaliação de genótipos de milho para semeadura precoce sob influência de baixa temperatura. *Revista Brasileira de Sementes*, v.20, n.1, p.52-60, 2007.

CUNHA, APMA; ZERI, M; DEUSDARÁ LEAL, K; COSTA, L; CUARTAS, LA; MARENGO, JA; TOMASELLA, J; VIEIRA, RM; BARBOSA, AA; CUNNINGHAM, C; CAL GARCIA, JV; BROEDEL, E; ALVALÁ, R; RIBEIRO-NETO, G. Eventos de extrema seca no Brasil de 2011 a 2019. *Atmosfera, v.10*, n.11, p.642, 2019.

DJANAGUIRAMAN, M; PERUMAL, P; CIAMPITTI, IA; GUPTA, SK; PRASAD, PVV. Quantifying pearl millet response to high temperature stress: Thresholds, sensitive stages, genetic variability and relative sensitivity of pollen and pistil. *Plant, Cell and Environment*, v.41, n.1, p. 993-1007, 2018. https://doi.org/10.1111/pce.12931

GOMES, AMG; NHANTUMBO, N; FERREIRA-PINTO, M; MASSINGA, R; RAMALHO, JC; RIBEIRO-BARROS, A. Breeding Elite Cowpea [*Vigna unguiculata* (L.) Walp] Varieties for Improved Food Security and Income in Africa: Opportunities and Challenges, Legume Crops - Characterization and Breeding for Improved Food Security, Mohamed Ahmed El-Esawi, IntechOpen, 2019.

GORDIN, CRB; MARQUES, RF; MASETTO, TE; SCALON, SPQ. Germinação, biometria de sementes e morfologia de plântulas de *Guizotia abyssinica* Cass. *Revista Brasileira de Sementes*, v.34, n.4, p.619-627, 2012. https://doi.org/10.1590/S0101-31222012000400013

IPCC. *Climate Change Synthesis Report Contribution of Working Groups I. II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Geneva: IPCC, 2014. 151p.

ISLAM, S; CARMEN, RC; JUNIOR, JOG. Screening for tolerance of stress temperature during germination of twenty five cowpea (*Vigna unguiculata* L. Walp) cultivars. *Journal of Food, Agriculture & Environment*, v.4, n.2, p.191-195, 2006.

KOTOWSKI, F. Temperature relations to germination of vegetable seed. *Proceedings of the American Society for Horticultural Science*, v. 23, n.1, p. 176-184, 1926.

LABOURIAU, LG. *A germinação das sementes*. Washington, DC: Secretaria Geral da Organização dos Estados Unidos Americanos, 1983.

MAGUIRE, JD. Speed of germination-aid in selection and evaluation for seedling emergence and vigor. *Crop Science*, v.2, n.1, p.176-177, 1962. https://doi.org/10.2135/cropsci1962.0011183X000200020033x

MATOSO, AO; SORATTO, RP; GUARNIERI, F; COSTA, NR; ABRAHÃO, RC; TIRABASSI, LH. Sowing Date Effects on Cowpea Cultivars as a Second Crop in Southeastern Brazil. *Agronomy Journal*, v.110, n.1, p.1-14, 2018. https://doi.org/10.2134/agronj2018.01.0051

MELO JUNIOR, JLA; MELO, LDFA; ARAUJO NETO, JC; FERREIRA, VM. Germination and morphology of seeds and seedlings of Colubrina glandulosa Perkins after overcoming dormancy. *Australian Journal of Crop Science*, v.12, n.4, p.639-647, 2018. https://doi.org/10.21475 / ajcs.18.12.04.pne980

MELO, AS de. SILVA, ARF da; DUTRA, AF.; DUTRA, WAF; BRITO, MEB; SILVA, FV da. Photosynthetic efficiency and production of cowpea cultivars under deficit irrigation. *Revista Ambiente & Água*, v.13 n.5, p.1-8, 2018. https://doi.org/10.4136/ambi-agua.2133

MERWAD, ARMA; DESOKY, ESM; RADY, MM. Response of water deficit-stressed *Vigna unguiculata* performances to silicon, proline or methionine foliar application. *Scientia Horticulturae*, v. 228, n.1, p.132-144, 2018. https://doi.org/10.1016/j.scienta.2017.10.008

MOTSA, MM; SLABBERT, MM; AVERBEKE, W; MOREY, AL. Effect of light and temperature on seed germination of selected African leafy vegetables. *South African Journal of Botany*, v. 99, n.1, p.29-35, 2015. https://doi.org/10.1016 / j.sajb.2015.03.185

NUNES, LR de L; PINHEIRO, PR; PINHEIRO, CL; LIMA, AP; DUTRA, AS. (2019). Germination and vigour in seeds of the cowpea in response to salt and heat stress. *Revista Caatinga*, v.32, n.1, p.143-151, 2019. https://doi.org/10.1590 / 1983-21252019V32N115RC

ORZARI, I; MONQUERO, PA; REIS, FC; SABBAG, RS; HIRATA, ACS. Germinação de espécies da família Convolvulaceae sob diferentes condições de luz, temperatura e profundidade de semeadura. *Planta Daninha*, v.31, n.1, p.53-61, 2013. https://doi.org/10.1590/S0100-83582013000100006

PÁDUA, GP de; ZITO, RK; ARANTES, NE; RANÇA NETO, J de B. Influência do tamanho da semente na qualidade fisiológica e na produtividade da cultura da soja. *Revista Brasileira de Sementes*, v.32, n.3, p.09-16, 2010. https://doi.org/10.1590/S0101-31222010000300001

ROCHA, MM; SILVA, KJD; MENEZES JÚNIOR, JAN; HASHIMOTO, JM; NEVES, AC; SOUZA, FM; RIBEIRO, E; FERNANDES, L. *Feijão-caupi: Melhoramento genético para o avanço da cultura*. Embrapa Meio-Norte, Teresina, 2016. 6p.

SANTANA, DG; RANAL, MA. Análise estatística na germinação. *Revista Brasileira de Fisiologia Vegetal*, v.12, n.1, p.205-237, 2000.

SANTOS, GA; ZONETTI, PC. Influência da temperatura na germinação e desenvolvimento do girassol (*Helianthus annuus* L.). *Revista Iniciação Científica Cesumar*, v.11, n.1, p.23-27, 2009.

SCHMIDT, D; ZAMBAN, D; PROCHNOW, D; CARON, BO; SOUZA, VQ; PAULA, GM; COCCO, C. Caracterização fenológica, filocrono e requerimento térmico de tomateiro italiano em dois ciclos de cultivo. *Horticultura Brasileira*, v.35, n.1, p.1-8, 2017. https://doi.org/10.1590/s0102-053620170114

SKOUFOGIANNI, E; BARTZIALIS, D; GIANNOULIS, KD; KANDRI, E; DANALATOS, NG. Seed germination rates of different cool season legumes. *Agrofor International Journal*, v.2, n. p.1-6, 2017. https://doi.org/10.7251 / AGRENG1701035S

TRIBOUILLOIS, H; DÜRR, C; DEMILLY, D; WAGNER, M-H; JUSTES, E. Determination of Germination response to temperature and water potential for a wide range of cover crop species and related functional groups. *PloS one*, v.11, n.8, p.1-16, 2016. https://doi.org/10.1371 / journal.pone.0161185