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Maternal environment on seed germination and viability in cowpea

Ambiente materno na germinação e viabilidade de sementes de feijão-caupi

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ABSTRACT
Seed quality is determined by the environmental conditions to which they were exposed during their formation. Thus, the objective of this study was to evaluate the seed viability and seedling formation of cowpea cultivars produced in a high-temperature environment. Seeds of the cowpea cultivars Carijó, Itaim and Tapahium produced in growth chambers under temperature regimes T°1: 20-26-33 °C and T°2: 24.8-30.8-37.8 °C were used. The experimental design was completely randomized, with four replicates of 25 seeds, placed to germinate at a temperature of 25 °C in B.O.D chambers. Increase in air temperature during seed production did not hamper germination percentage. However, the 4.8 °C increase in air temperature reduced the vigor of seeds of the cultivar Tapahium, resulting in an increase in the number of abnormal seedlings. Seeds of the cultivars Carijó and Itaim produced under temperature regime 24.8-30.8-37.8 °C showed higher performance.

Keywords: climate change, initial growth, parent plant, *Vigna unguiculata* L.

Brazilian Journal of Development

RESUMO

A qualidade das sementes é determinada pelas condições ambientais as quais as mesmas foram expostas durante sua formação. Desta forma, o objetivo do trabalho foi de avaliar a viabilidade de sementes e a formação de plântulas de cultivares de feijão-caupi, produzidas em ambiente com alta temperatura. Foram utilizadas sementes de feijão-caupi das cultivares Carijó, Itaim e Tapahium produzidas em câmaras de crescimento, sob regime de temperatura T°1: 20-26-33 °C e T°2: 24,8-30,8-37,8 °C. O delineamento experimental foi inteiramente casualizado, com quatro repetições de 25 sementes, colocadas para germinar em temperatura de 25 °C em câmaras tipo B.O.D. O aumento da temperatura do ar durante a produção das sementes não prejudicou a porcentagem de germinação. Contudo, o incremento de 4,8°C na temperatura do ar reduziu o vigor das sementes da cultivar Tapahium, resultando no aumento do número de plântulas anormais. As sementes das cultivares Carijó e Itaim produzidas em regime de temperatura 24,8-30,8-37,8°C apresentaram maior desempenho.

Palavras-chave: crescimento inicial, germinação, mudanças climáticas, planta mãe, *Vigna unguiculata* L.

1 INTRODUCTION

Temperature is one of the climatic elements that will undergo changes in the face of climate change. For exerting direct influence on crops, from seed germination to final production, temperature is an element that needs to be considered for the final yield of crops (Martinez et al., 2015). According to future scenarios predicted by the Intergovernmental Panel on Climate Change (IPCC), there may be an increase between 3.7 and 4.8 °C in air temperature by 2100 (IPCC, 2014).

This can pose a threat to food security, since the increase in temperature can slow or inhibit the development of flower buds and cause falls of pods in formation, resulting in a substantial reduction in the production of cowpea, which is a target crop in the face of climate changes (Nidso et al., 2016; Carvalho et al., 2019). In addition, seed vigor is reduced by the stress of increased temperature, both before and after the point of physiological maturity (Finch-Savage and Bassel, 2016), and there are no studies on the viability of cowpea seeds produced in high-temperature environments.

Cowpea (*Vigna unguiculata* L.) is a legume crop of great socioeconomic importance and one of the main components of the diet of populations, especially in semiarid regions (Melo et al., 2018). According to Djanaguiraman et al. (2018), these regions are vulnerable to climate changes and extreme temperature events, so that the cultivation of species with vigorous germination and the uniform establishment of seedlings are highly desirable.

Vigorous seed germination and seedling establishment are crucial phases for plant development (Skoufogianni et al., 2017). However, the viability of the seeds depends on the prevailing climate during their formation. Thus, it can be affirmed that the quality of the seeds and the establishment of seedlings will depend on the temperature conditions at which the parent plant grew, produced and matured its seeds (Geshnizjani et al., 2019).

Thus, the success of agricultural production depends initially on seed quality, which is directly related to the environmental conditions to which the parent plant was exposed during the formation and development of these seeds (Li et al., 2017; Hampton et al., 2013). Thus, the increase in temperature on the parent plant will significantly influence the characteristics of the seeds, including their size, dormancy and germination (Penfield and MacGregor, 2017). In addition, air temperature also plays a significant role during the germination process and the establishment of seedlings (Peeters et al., 2019).

Given the above, knowing the quality of seeds produced under high-temperature conditions will be essential to indicate tolerant cultivars, since this quality is responsible for the initial development in the field, which will promote an increase in yield per season. Therefore, the objective of this study was to evaluate the seed viability and seedling formation of cowpea cultivars produced in a high-temperature environment.

2 MATERIAL AND METHODS

Seeds of the cultivars Carijó, Itaim and Tapahium produced in phytotron-type growth chambers, under the temperature regimes of T°1: 20-26-33 °C (20 °C: from 20h to 6h; 26 °C: from 6h to 10h; 33 °C: from 10h to 15h; 26 °C: from 15h to 20h); and T°2: 24.8-30.8-37.8°C (24.8 °C: from 20h to 6h; 30.8 °C: from 6h to 10h; 37.8 °C: from 10h to 15h; 30.8 °C: from 15h to 20h).

The experimental design was completely randomized, with four repetitions of 25 seeds in B.O.D (Biochemical Oxygen Demand)-type chambers equipped with white fluorescent lamps, with light regime of 12/12 hours (dark/light, respectively). The seeds were maintained at 25 °C because, according to the Rules for Seed Analysis (*Regras para Análise de Sementes* – RAS), this is the ideal temperature for the germination test of *Vigna unguiculata* seeds (Brasil, 2009).

Initially, surface of the seeds was disinfested using fungicide of the chemical group Alkylene-bis-dithiocarbamate, in a ratio of 4 g (fungicide) to 1000 g of seeds. Then the seeds were arranged on Germitest paper moistened with distilled water, in a proportion equivalent to 2.5 times the dry paper weight. The Germitest paper containing the seeds was rolled up, placed in plastic bag, and maintained in B.O.D for the evaluation of seed viability. The number of germinated seeds was determined by means of two counts: the first at four days and the second at seven days. Seeds with radicle protrusion equal to or greater than 2 mm were considered germinated. After the second count, an evaluation was performed to quantify the percentage of normal and abnormal seedlings (Brasil, 2009). Normal seedlings were considered as those that had potential to continue their development, with developed root system and shoots. On the other hand, abnormal seedlings were the ones that had absent or damaged shoots and root systems, according to the Rules for Seed Analysis (Brasil, 2009). Shoot and root lengths were measured using a millimeter ruler (cm). To evaluate shoot dry mass (SDM) and root dry mass (RDM), shoots and roots were separated, placed in paper bags and dried in an oven at 65 ºC until reaching constant weight (±72h). After this period, the materials were weighed on a scale to obtain dry weight (g).

Analysis of variance (ANOVA) was performed and means were compared by Tukey test at 5% probability level using the program SISVAR Version 5.6.

3 RESULTS AND DISCUSSION

The summary of the analysis of variance shows that the germination of seeds of the different cultivars was not significantly influenced by the temperature regime imposed to the parent plant during seed formation and development (Table 1). This result shows that even seeds produced in an environment with a 4.8 °C increase in temperature had a high percentage of germination (92%) for cowpea. Environments with high temperature during seed filling often disrupt normal seed development, which increases the proportion of shriveled, abnormal and lower-quality seeds, which may reduce seed vigor, but not necessarily germination (Hampton et al., 2013).

Table 1. Summary of the analysis of variance, by the mean square, for the variables: germination percentage (G%), normal seedlings (NS), abnormal seedlings (AS), shoot length (SL), root length (RL), shoot dry mass (SDM) and root dry mass (RDM) of the cowpea cultivars Carijó, Itaim and Tapahium, from seeds produced under two temperature regimes.

Variation source	MS							
	DF	G (%)	NS	AS	SL	RL	SDM	RDM
Temperature (T)	1	0.66ns	216.00**	210.04**	6.41**	0.59ns	0.005ns	0.0032ns
Cultivar (cv)	2	8.66ns	327.81**	301.79**	1.77ns	13.62*	0.109**	0.033**
T x cv	2	4.66ns	242.37**	226.04**	2.01ns	9.71ns	0.033**	0.00087ns
Residue	18	3.77	2.97	2.9	0.68	3.15	0.0022	0.00088
CV%		1.96	9.07	29.42	9.81	11.13	8.3	11.59

DF = degrees of freedom; CV = coefficient of variation; ns = not significant, ** significant at 1% probability level, * significant at 5% probability level by Tukey test.

Some plant species that develop under high temperatures produce seeds that have little dormancy and consequently a higher germination (Edwards et al., 2016). In addition, annual plants, such as cowpea, have a relatively short development cycle, which promotes greater

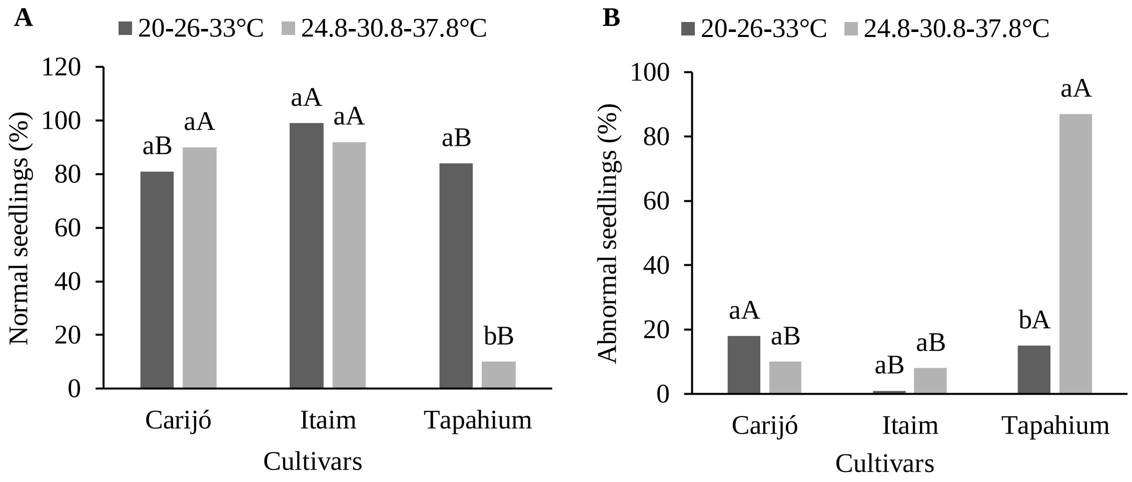
Brazilian Journal of Development

capacity to adapt to changes in the environment (Dewan et al., 2018). Such adaptation favors the germination potential of cowpea, as observed in the study conducted by Craufurd et al. (1996), where the temperature increase up to 40 °C did not prevent the germination of cowpea seeds, with a percentage above 80%.

The interaction between temperature regime of the parent plant and cultivars was significant for the numbers of normal and abnormal seedlings and for shoot dry mass. For the individual effect, the temperature regime under which the seed was produced affected shoot length. Root length, shoot dry mass and root dry mass differed between cultivars (Table 1).

For the cultivar Tapahium, the increase in temperature during seed development and growth significantly reduced the formation of normal seedlings (Figures 1A and B). However, the cultivars Carijó and Itaim had a percentage of normal seedlings higher than 80% for seeds produced under the temperature regime of 24.8-30.8-37.8 °C, in which the percentage of normal seedlings was 90% and 92%, respectively (Figure 1A).

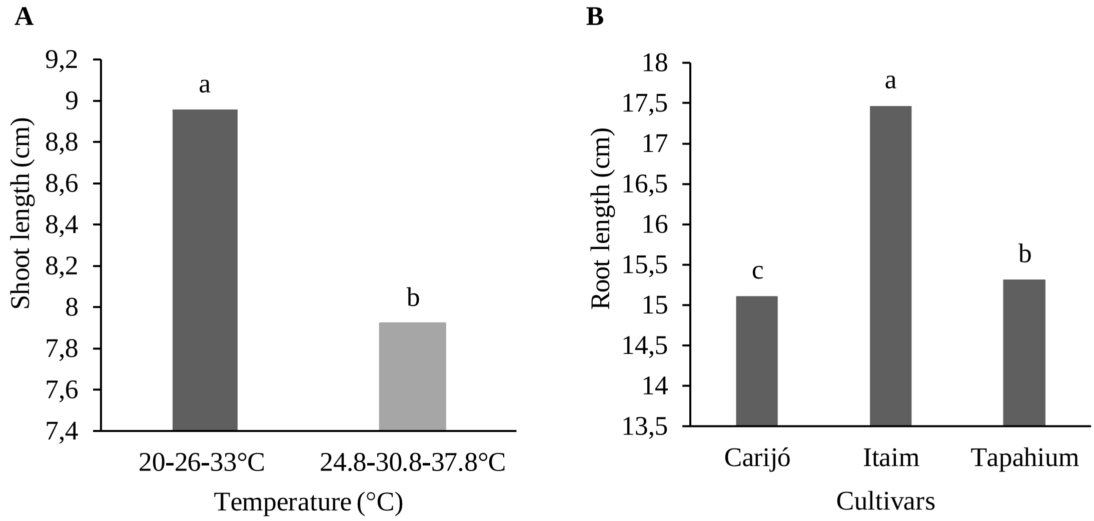
Figure 1. Number of normal seedlings (A) and abnormal seedlings (B) of cowpea cultivars, from seeds produced under two temperature regimes. *Lowercase letters for temperature and uppercase letters for cultivars.



The cultivars may show different responses regarding their adaptability to the environment (Matoso et al., 2018). This explains the reduction in the percentage of normal seedlings of the cv. Tapahium, indicating its sensitivity to temperature increase during seed formation. High temperatures can reduce seed vigor due to the formation of shriveled, abnormal and lower-quality seeds, resulting in the formation of abnormal seedlings, reducing the possibility of establishment in the field (Krzyzanowski et al., 2018). This is because, during seed production, high temperatures increase the proportion between respiration and photosynthesis, reducing the plant’s ability to provide photoassimilates for the seeds, which are necessary to synthesize the storage compounds during germination (Taiz et al., 2017). Thus, even if the seeds can germinate, as observed in the present study, they may lead to problems during seedling establishment due to the influence of environmental conditions during the development of the parent plant.

Shoot length was longer for seedlings grown from seeds produced under the temperature regime of 20-26-33 °C (Figure 2A), with an average value of 8.95 cm. For seeds formed under 24.8-30.8-37.8 °C, seedlings had an average length of 7.92 cm.

Figure 2. Shoot length (cm) (A) and root length (cm) (B) of cowpea cultivars from seeds produced under two temperature regimes.

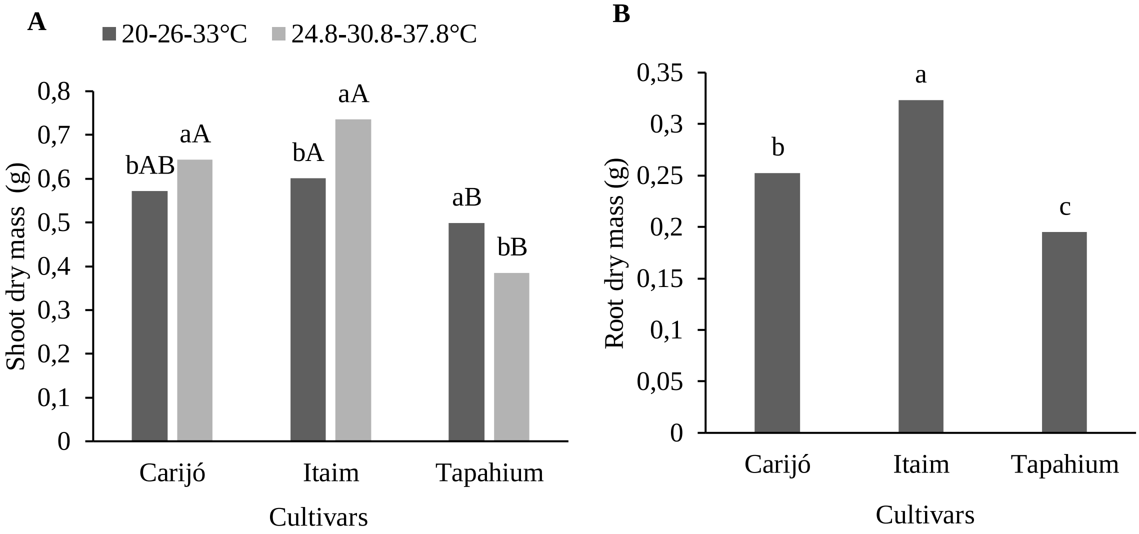


The impact of thermal stress depends on the duration, intensity and plant development stage (Ndiso et al., 2016). In the present study, plants were exposed to temperature increase throughout their development. Thus, the temperature had a direct impact on seed formation, which influenced seedling growth.

For root length, regardless of the temperature regime under which the seeds were produced, the cv. Itaim obtained a longer length of the root system compared to the others, with an average of 17.46 cm (Figure 2B). Roots play a crucial role in the establishment and performance of plants, mainly due to the abiotic stresses (Koevoets et al., 2016). According to these authors, the presence of deep root systems enables plants to access water in deeper layers, benefiting their production and survival under adverse conditions. This is an important characteristic, especially for the semi-arid region, because it has climate with high temperatures and low water availability (Melo et al., 2018). Thus, the cultivar Itaim stands out because, despite being produced under increased temperature conditions, it produces vigorous seeds, with better establishment of seedlings (Figures 1A and 2B).

Seedlings of the cultivars Carijó and Itaim, grown from seeds produced at a temperature of 24.8-30.8-37.8 °C, obtained higher values of shoot dry mass, 0.64 g and 0.73 g, respectively, compared to seeds produced at lower temperature, with averages of 0.57 for Carijó and 0.60 for Itaim (Figure 3A). For the cv. Tapahium, the increase in temperature during seed formation reduced shoot dry mass. This can be explained by the fact that thermal stress compromises the accumulation of various seed constituents by inhibiting the enzymatic processes of starch and protein synthesis (Farooq et al., 2017). Moreover, as verified in this study, the seeds of this cultivar developed under the temperature regime of 24.8-30.8-37.8 °C had a higher number of abnormal seedlings, with absent or damaged shoots (Figure1B).

Figure 3. Shoot dry mass (g) (A) and root dry mass (g) (B) of cowpea cultivars produced under two temperature regimes. *Lowercase letters for temperature and uppercase letters for cultivars.



Grain filling is a crucial stage for the development of all crops, as it involves processes of mobilization and transport of various constituents necessary for the synthesis of proteins, carbohydrates and lipids in seeds (Farooq et al., 2017). This process is highly sensitive to environmental changes and influences the qualitative and quantitative characteristics of the final yield of seeds (Yang and Zhang, 2006). Therefore, the increase of temperature imposed on the parent plant will significantly influence the characteristics of the seeds (Li et al., 2017), hence affecting the growth and weight of seedlings, as observed in the present study.

Regardless of the temperature regime under which the seed was produced, root dry mass was also higher for the cv. Itaim, with an average of 0.33 g (Figure 3B), hence evidencing that, despite being of the same species, the response of the different genotypes may vary as a function of the increase in temperature, confirming their sensitivity (Matoso et al., 2018)

In general, we found that the seeds of the cultivars Carijó and Itaim produced in an environment with a 4.8 °C increase of temperature showed higher seed viability during germination and seedling development. This indicates that these cultivars will perform better for initial development in the face of climate change. Thus, knowing the environmental conditions to which cowpea seeds were produced will be important for the recommendation of cultivars tolerant to thermal stress.

4 CONCLUSIONS

The increase in temperature during seed production will not affect the germination percentage of cowpea. However, the 4.8 °C increase in air temperature reduces seed vigor, resulting in an increase in the number of abnormal seedlings of the cultivar Tapahium. Seeds of the cultivars Carijó and Itaim produced under temperature regime of 24.8-30.8-37.8 °C showed higher viability during the processes of germination and seedling development.

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REFERENCES

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.

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

DEWAN, S; MIJNSBRUGGE, KV; FRENNE, P; STEENACKERS, M; MICHIELS, B; VERHEYEN, K. Maternal temperature during seed maturation affects seed germination and timing of bud set in seedlings of European black poplar. *Forest Ecology and Management*, v.410, n.1, p.126-135, 2018. https://doi.org/10.1016/j.foreco.2018.01.002

DJANAGUIRAMAN, M; PERUMAL, R; 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.5, p.993-1007, 2018. https://doi.org/10.1111/pce.12931

EDWARDS, BR; BURGHARDT, LT; ZAPATA-GARCIA, M; DONOHUE, K. Maternal temperature effects on dormancy influence germination responses to water availability in *Arabidopsis thaliana*. *Environmental and Experimental Botany*, v.126, n.1, p. 55-67, 2016. https://doi.org/10.1016/j.envexpbot.2016.02.011

FAROOQ, M; GOGOI, N; BARTHAKUR, S; BAROOWA, B; BHARADWAJ, N; ALGHAMDI, SS; SIDDIQUE, KHM. Drought stress in grain legumes during reproduction and grain filling. *Journal of Agronomy and Crop Science*, n.203, v.2, p.81-102, 2017. https://doi.org/10.1111/jac.12169

FINCH-SAVAGE, WE; BASSEL, GW. Seed vigour and crop establishment: extending performance beyond adaptation. *Journal of Experimental Botany*, n.67, v.1 p. 567-591, 2016. https://doi.org/10.1093/jxb/erv490

GESHNIZJANI, N; KHORAMI, AS; WILLEMS, LAJ; SNOEK, BL; HILHORST, HWM; LIGTERINK, W. The interaction between genotype and maternal nutritional environments affects tomato seed and seedling quality. *Journal of Experimental Botany*, v.70, n.10 p. 2905-2918, 2019. https://doi.org/10.1093/jxb/erz101

HAMPTON, JG; BOELT, B; ROLSTON, MP; CHASTAIN, TG. Effects of elevated CO_2 and temperature on seed quality. *Journal of Agricultural Science*, v.151, n.1, p.154-162, 2013. https://doi.org/10.1017/S0021859612000263

IPCC. Intergovernmental Panel on Climate Change. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects*. Contribution of working group II to the fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press, 2014.

KOEVOETS, IT; VENEMA, JH; ELZENGA, JT; TESTERINK, C. Roots Withstanding their Environment: Exploiting Root System Architecture Responses to Abiotic Stress to Improve

Crop Tolerance. *Frontiers in Plant Science*, v.7, n.1, p.1-19, 2016. https://doi.org/ 10.3389/fpls.2016.01335

KRZYZANOWSKI, FC; FRANÇA-NETO, JB; HENNING, AA. *A alta qualidade da semente de soja: fator importante para a produção da cultura*. Circular Técnica 136, 2018.

LI, R; CHEN, L; WU, Y; ZHANG, R; BASKIN, CC; BASKIN, JM; HU, X. Effects of Cultivar and Maternal Environment on Seed Quality in *Vicia sativa*. *Frontiers in Plant Science*, v.8, n.1, p. 1411, 2017. https://doi.org/**10.3389 / fpls.2017.01411**

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

MARTINEZ, CA; OLIVEIRA, EAD; MELLO, TRP; MARIN, ALA. Respostas das plantas ao incremento atmosférico de dióxido de carbono e da temperatura. *Revista Brasileira de Geografia Física*, v.8, p.635-650, 2015. https://doi.org/10.26848 / rbgf.v8.0.p635-650

MELO, AS; SILVA, ARF; DUTRA, AF; BRITO, MEB; SILVA, FV. 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

NDISO, JB; OLUBAYO, F; CHEMINING'WA, GN; SAHA, HM. Effect of Drought Stress on Canopy Temperature, Growth and Yield Performance of Cowpea Varieties. *International Journal of Plant & Soil Science*, v.9, n.3, p. 1-12, 2016. https://doi.org/10.9734 / IJPSS / 2016/21844

PEETERS, NPA; WILLICK, IR; NABBERN, RHM; WATERER, DR; VERHOEVEN, TMO; TNINO, KK. Effect of location on dwarf French bean (*Phaseolus vulgaris* L.) seed production and seedling vigour. *Acta Agriculturae Scandinavica, Section B-Soil & Plant, Science*, v.70, n.3, p.224-232, 2019. https://doi.org/10.1080/09064710.2019.1710561

PENFIELD, S; MACGREGOR, DR. Effects of environmental variation during seed production on seed dormancy and germination. *Journal of Experimental Botany*, v.68, n.4, p.819-825, 2017. https://doi.org/10.1093/jxb/erw436

TAIZ, L; MOLLER, EZIM; MURPHY, A. *Fisiologia e desenvolvimento vegetal*. 6.ed. Porto Alegre: Artmed, 2017.

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

YANG, J; ZHANG, J. Grain filling of cereal under soil drying. *New Phytologist*, v.169, n. 2, p. 223-236, 2006.