ISSN 1808-8546 (ONLINE) 1808-3765 (CD-ROM)

ESTRATÉGIAS DE IRRIGAÇÃO COM DÉFICIT HÍDRICO NOS ESTÁDIOS FENOLÓGICOS DO FEIJÃO-CAUPI SOB ADUBAÇÃO POTÁSSICA

LAURIANE ALMEIDA DOS ANJOS SOARES[1]; THAMARA LAYSE FREITAS MEDEIROS[2]; VICTORIA CRISTINA GOMES COLMAN[3]; IRLAN VICTOR DE SOUSA PALMEIRA[4]; IDELVAN JOSÉ DA SILVA[5] E ROMULO CARANTINO LUCENA MOREIRA[6]

[1] Unidade Acadêmica de Ciências Agrárias, Universidade Federal de Campina Grande, UFCG, Rua Jario Vieira Feitosa, 1770, Bairro dos Pereiros, Pombal, PB, Brasil. E-mail: laurispo.agronomia@gmail.com
[2] Unidade Acadêmica de Ciências Agrárias, Universidade Federal de Campina Grande, UFCG, Rua Jario Vieira Feitosa, 1770, Bairro dos Pereiros, Pombal, PB, Brasil. E-mail: thamaraamedeiross@gmail.com
[3] Unidade Acadêmica de Ciências Agrárias, Universidade Federal de Campina Grande, UFCG, Rua Jario Vieira Feitosa, 1770, Bairro dos Pereiros, Pombal, PB, Brasil. E-mail: vikcolman@gmail.com
[4] Unidade Acadêmica de Ciências Agrárias, Universidade Federal de Campina Grande, UFCG, Rua Jario Vieira Feitosa, 1770, Bairro dos Pereiros, Pombal, PB, Brasil. E-mail: irlan7764@gmail.com
[5] Unidade Acadêmica de Engenharia Agrícola, Universidade Federal de Campina Grande, UFCG, Rua Aprígio Veloso, 882 -Universitário, Campina Grande, PB, Brasil. E-mail: idelvan3@hotmail.com
[6] Unidade Acadêmica de Engenharia Agrícola, Universidade Federal de Campina Grande, UFCG, Rua Aprígio Veloso, 882 -Universitário, Campina Grande, PB, Brasil. E-mail: romulocarantino@gmail.com

1 RESUMO

Em regiões semiáridas, a deficiência hídrica é o principal fator ambiental que influencia o rendimento das plantas, nestas regiões o manejo adequado dos recursos é imprescindível a fim de garantir a sustentabilidade do sistema de produção. Assim, objetivou-se com o presente trabalho avaliar a morfologia e a partição de fitomassa do feijão-caupi (*Vigna unguiculata* L.), cultivar BRS Marataoã, quando submetido a estratégias de manejo do déficit hídrico nos diferentes estádios fenológicos da cultura e doses de adubação potássica. Utilizou-se o delineamento estatístico em bloco ao acaso, em esquema fatorial 5 x 5, com três repetições, sendo os tratamentos definidos em função das cinco doses de adubação potássica (50, 75, 100, 125 e 150% de K_2O) associadas a cinco estratégias de manejo do déficit hídrico nos diferentes estádios fenológicos da cultura. A aplicação do déficit hídrico associado às doses de potássio favoreceu o crescimento e o acúmulo de fitomassa na fase de floração. Doses crescentes de potássio quando associadas ao déficit hídrico nas fases de floração e frutificação comprometem o número de vagens e comprimento de vagens. Nas fases iniciais do desenvolvimento do feijão-caupi, pode ser aplicada irrigação com déficit hídrico sem que haja perdas significativas nos componentes de produção.

Palavras-chave: *Vigna unguiculata* L., tolerância à seca, nutrição mineral

SOARES, L. A. dos A.; MEDEIROS, T. L. F.; COLMAN, V. C. G.; PALMEIRA, I. V. de S.; SILVA, I. J. da; MOREIRA, R. C. L.

IRRIGATION STRATEGIES WITH WATER DEFICIT IN THE PHENOLOGICAL STAGES OF THE COWPEA UNDER POTASSIC FERTILIZATION

Recebido em 17/01/2017 e aprovado para publicação em 09/03/2021
DOI: http://dx.doi.org/10.15809/irriga.2021v26n1p111-122

2 ABSTRACT

In semi-arid regions, water deficiency is the main environmental factor that influences the yield of plants, in these regions the proper management of resources is essential in order to guarantee the sustainability of the production system. Thus, this study aimed to evaluate the morphology and phytomass partition of cowpea (Vigna unguiculata L.), to cultivate BRS Marataoã, when submitted to water deficit management strategies in different phenological stages of the crop and fertilization doses potassium. A randomized block design was used, in a 5 x 5 factorial scheme, with three replications, with the treatments being defined according to the five potassium fertilization doses (50, 75, 100, 125, and 150% of K2O) associated with five water deficit management strategies at the different phenological stages of the crop. The application of water deficit associated with potassium doses favored the growth and accumulation of phytomass in the flowering phase. Increasing doses of potassium when associated with water deficit in the flowering and fruiting stages compromise the number of pods and pod length. In the early stages of the development of cowpea, irrigation with water deficit can be applied without significant losses in the production components.

Keywords: *Vigna unguiculata* L., drought tolerance, mineral nutrition

3 INTRODUCTION

Cowpea (*Vigna unguiculata* L.), a legume native to the African continent, is widely used in several Brazilian regions because of the high nutritional value of its grains, which are a source of vegetable protein, iron, zinc, carbohydrates, vitamins, and amino acids. It is widely produced in the semiarid region of Brazil due to its climatic adaptation and productive potential for both family farming and the corporate sector (NASCIMENTO et al., 2011; FREIRE FILHO et al., 2011).

In Brazil, cowpea had an average yield of 551 kg ha $^{-1}$ in the 2019/20 harvest (FEIJÃO, 2020). In the state of Paraíba, in 2017, an average cowpea productivity of 250 kg ha $^{-1}$ was estimated; however, such productivity is considered low, with water deficit conditions being among the factors that commonly reduce cowpea productivity in this region (MENDES et al., 2007).

Water stress causes considerable changes both in the short term, with an increase in the sucrose/starch ratio due to recently fixed carbon, and in the long term, owing to the pool of low-molecular-weight organic solutes, also called compatible solutes, in a process known as osmotic adjustment, in which both changes are part of a regulatory response of the plant to maintain leaf turgor under low water availability (FAROOQ et al., 2009). In common beans, water deficiency during the phenological phases of the crop causes significant reductions in leaf area, plant height, number of pods per plant, and number of grains per pod (SOUSA; LIMA, 2010).

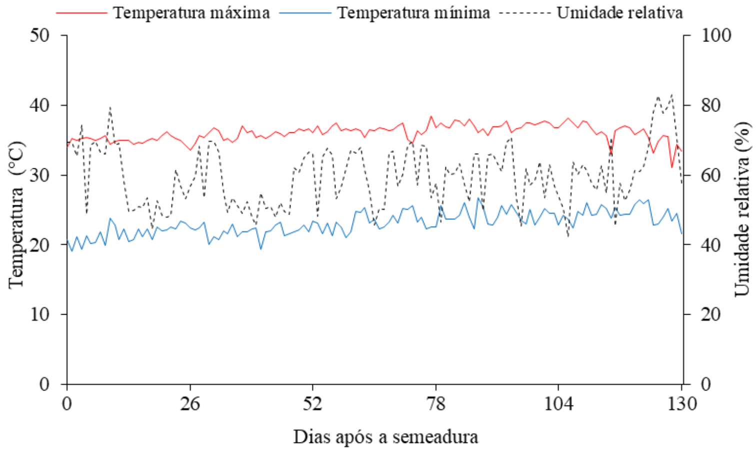
However, the water requirements of cowpea vary depending on its development stage and genotype (NASCIMENTO et al., 2011; COELHO et al., 2013). Furthermore, several management practices can improve the accessibility of soil moisture, minimizing water scarcity conditions (MOSTAFAZADEH-FARD et al., 2009). Nutritional management stands out as the most viable and economical method for inducing drought tolerance in common beans since free nutrients or nutrients structurally bound to essential complexes can regulate their osmotic potential (TAIZ; ZEIGER, 2013).

Potassium plays a fundamental role in osmosis and stomatal opening mechanisms, which are important for supporting plant water relations and cell expansion (PETTIGREW, 2008). The benefits of potassium supplementation in plants under water stress have been reported in several studies, such as increases in dry matter, water potential, the photosynthetic rate, the chlorophyll content, the leaf area, and the stem diameter (FAROOQ et al., 2009). Therefore, the objective of this study was to evaluate the morphology and phytomass partitioning of cowpea, cultivar BRS Marataoã, when subjected to water deficit management strategies at different phenological stages of the crop and potassium fertilizer rates.

4 MATERIALS AND METHODS

The experiment was conducted in a protected environment at the Center for Agrofood Science and Technology of the Federal University of Campina Grande (CCTA/UFCG), which is located in the municipality of Pombal-PB and is located at geographic coordinates of 6°47'20" south latitude and 37°48'01" west longitude and an altitude of 194 m. Figure 1 shows the meteorological data collected during the experiment between August 4, 2018, and December 13, 2018.

Figure 1. Climatic data on the maximum and minimum temperatures (°C) and relative humidity (%) during the experiment.



The experimental design used was a randomized block design with treatments arranged in a 5 × 5 factorial scheme, referring to five potassium fertilization rates (50, 75, 100, 125 and 150% of K), with the 100% rate corresponding to 150 mg K_2O kg $^{-1}$ of soil, as described by Novais, Neves and Barros (1991) for pot tests, associated with five management strategies defined according to the time of induction of water deficit in the different phenological stages of cowpea: vegetative, i.e., the period between the emergence of the first trifoliate leaf with separate and completely open leaflets and the opening of the first flower; flowering, i.e., opening of the first flower until the beginning of maturity of the first pod; and production, i.e., from the maturation of the first pod until the final harvest, with three replicates and one plant per plot, totaling 60 plants.

Cowpea cv. BRS Marataoã was irrigated with 100% actual evapotranspiration (ETr) and 50% ETr, which were applied via four management strategies: SE - plants irrigated with 100% ETr throughout the cycle; VE - plants under deficit (50% ETr) in the vegetative phase;

FL - plants subjected to water deficit (50% ETr) in the flowering phase; FR - irrigation with 50% ETr in the production formation phase; and FL/FR - irrigation with 100% ETr in the vegetative phase and irrigation with 50% ETr in the flowering and production formation phases.

The plants were grown in plastic containers adapted as lysimeters with a 20-L capacity, which received a 3-cm layer of gravel at the base and a geotextile blanket to prevent obstruction of the drainage system by the soil material. A 4-mm-diameter transparent hose was installed at the base of each container to facilitate drainage, and this hose was connected to a plastic container to collect the drained water. Then, 24 kg of a sandy-loam Fluvic Neosol from the rural area of the municipality of São Domingos, Paraíba, was placed. The soil characteristics were determined according to the methods of Claessen (1997) before sowing and are described in Table 1.

Table 1. Physical and chemical characteristics of the soil used in the experiment

Características químicas							
pH (H_2O)	MO	P	K^+	Na^+	Ca^{2+}	Mg^{2+}	EC_{is}
(1:2,5)	g kg^{-1}	(mg kg^{-1})	....	cmol $_c$ kg^{-1}	....		dS m^{-1}
5.58	2.93	39.2	0.23	1.64	9.07	2.78	2.15
Physical characteristics							
Granulometric fraction (g kg^{-1})			CT	Humidity (kPa)			
Sand	Silt	Clay	$cmol_c$ kg^{-1}	33.42 kPa[1]		1519.5 kPa[2]	
572.7	100.7	326.6	0.67	25.91		12.96	

pH – Potential of hydrogen, MO – Organic matter: Walkley-Black Wet Digestion; Ca^{2+} and Mg^{2+} extracted with 1 M KCl pH 7.0; Na^+ and K^+ extracted using 1 M NH_4OAc pH 7.0; $Al^{3+}+H^+$ extracted using 0.5 M CaOAc pH 7.0; CEes - Electrical conductivity of the saturation extract; CEC - Cation exchange capacity; RAS - Sodium adsorption ratio of the saturation extract; PST - Percentage of exchangeable sodium; [1,2] referring to field capacity and permanent wilting point.

Foundation fertilization with NPK was carried out on the basis of recommendations for pot tests (N OVAIS; NEVES; BARROS, 1991), applying amounts of 100, 300, and 150 mg kg^{-1}, respectively, in the forms of urea (N), simple superphosphate (P_2O), and potassium chloride (K_2O). The full recommendation for phosphorus and only 1/3 of that for nitrogen and potassium were applied, with the remaining two-thirds being applied via irrigation water at 45 and 65 days after sowing (DAS).

Sowing occurred after the soil moisture was increased to the maximum retention level in all the experimental units, and low-salinity water (0.8 dS m^{-1}) was used. Five seeds were placed in each pot at a depth of 3 cm. Thinning was performed 30 days after sowing, with only one plant per pot.

Irrigation was carried out daily at 5 pm, and the volume applied in each irrigation event was estimated through water balance, as expressed in Equation 1:

$$CH = (Va - Vd)/(1 - FL) \quad (1)$$

where CH is the water consumption (L), considering the volume of water applied to the plants – Va (L) on the previous day; Vd (L) is the drained volume, quantified on the morning of the following day; and FL is the leaching fraction, estimated at 20% every 15 days.

The volume of water applied in each water deficit management strategy was determined by plant consumption under 100% ETr via the drainage lysimetry method (BERNARDO et al., 2019). For irrigation in the treatment with 50% ETr, the ETr value obtained was multiplied by the evapotranspiration percentage of the treatment. The values of the water depths applied to cowpea crops throughout the cycle according to the water deficit management strategies are shown in Table 2.

Table 2. Values of water depth applied to cowpea cv. BRS Marataoã under different water deficit management strategies

Management strategies	Number of days	Water depth (mm)
IF	150	402.98
VE	20	362.45
FL	10	380.03
FR	55	264.96
FL/FR	65	242.01

At 65 days after sowing (DAS), the following parameters were evaluated: plant height (AP) in cm, stem diameter (DC) and number of leaves (NL). In NL, leaves with a length greater than 3 cm were considered. Plant height was measured considering the distance between the plant collar and the apical bud of the main branch, and the stem diameter was determined 2 cm from the plant collar.

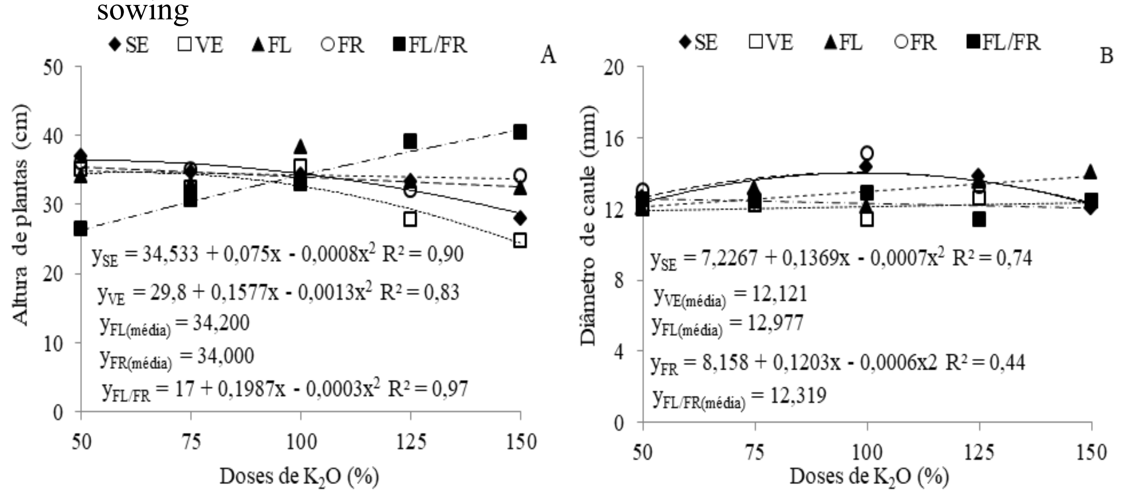
At the end of the crop cycle (90 DAS), the plants were collected and separated into leaves, stems, and roots. Each part was then placed in paper bags, which were then dried in an air-circulating oven maintained at 65 °C until a constant weight was reached. The material was subsequently weighed on a 0.0001 g precision scale to obtain the dry mass of the leaves (FSF), stems (FSC), and roots (FSR). During this same period, at harvest, the number and length of pods per plant were determined for each plot.

The data obtained were evaluated through analysis of variance via the 'F' test. In cases of significance, the Tukey test of means ($p<0.05$) was performed for the water deficit management strategies, and linear and quadratic regressions ($p<0.05$) were performed for the potassium doses via Sisvar 5.6 software (FERREIRA, 2011).

5 RESULTS AND DISCUSSION

There was a significant effect of the interaction between the factors of water deficit management strategies and potassium fertilizer doses on the plant height and stem diameter of cowpea, and the significant interaction between these factors is shown in Figure 2. With respect to the effects of the K dose on AP, in the SE and VE management strategies, decreases of 23.42% and 30.00%, respectively, were observed when the plants were fertilized with 125% K in relation to the supply of 50% K. However, the increase in potassium fertilization had a positive effect when the K dose was applied to plants under water deficit during the successive flowering and fruiting phases, indicating an increase in plant height, which is indicative of a way for cowpea to overcome the water stress to which it was subjected. Therefore, as a result of the 150% K supply, the cowpea response to water stress was equal to that of the FL/FR management strategy, with an average plant height of 33.61 cm, not differing from that of plants without water stress throughout the cycle, which had an average height of 33.35 cm (Figure 2A). The increase in potassium fertilization during the flowering and fruiting phases minimized the effects of water stress, conferring drought resistance to the plants via stomatal regulation processes and cellular water relations (BAHRAMI-RAD; HAJIBOLAND, 2017).

Figure 2. Interaction effects of water deficit management strategies and potassium fertilizer doses on the plant height (A) and stem diameter (B) of cowpea at 65 days after sowing

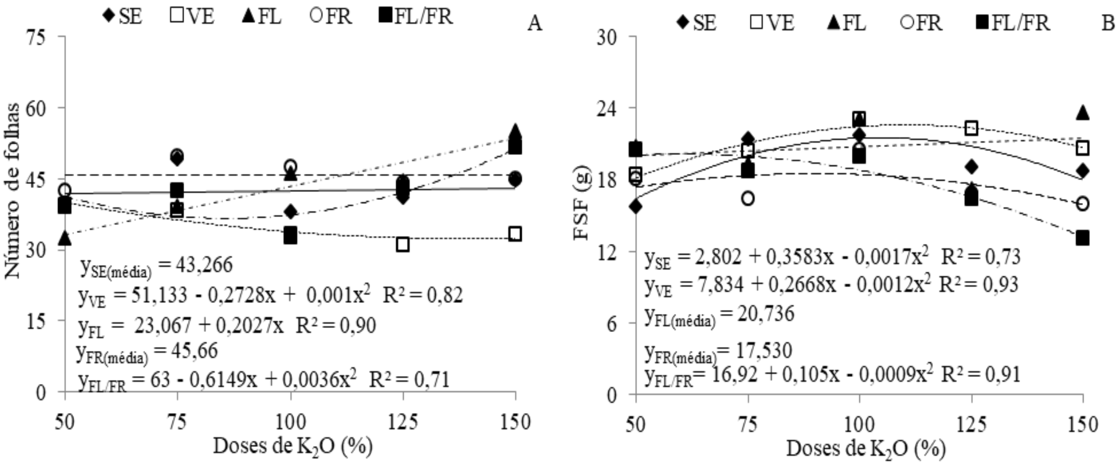


SE: plants irrigated with 100% ETr throughout the cycle; VE, FL, FR, and FL/FR: plants under deficit (50% ETr) in the vegetative, flowering, production and flowering/production formation phases, respectively.

The potassium fertilizer rate affected plant diameter under the SE and FR water deficit management strategies (Figure 2B), with maximum diameters of 13.92 and 14.18 mm, respectively. For these strategies, increases were observed up to the estimated potassium rate of 98% K2O and a quadratic relationship. However, for plants subjected to the VE, FL, and FL/FR strategies, no significant effects were observed; an average DC increase of 12.46 mm was observed, regardless of the potassium rate applied. Prazeres et al. (2015), evaluating the growth and physiology of two cowpea cultivars irrigated with saline water and subjected to different levels of K in the form of KCl (0.5, 1.0, 2.0 and 4.0 g of KCl per pot), also reported reductions in the growth of cowpea cultivars caused by increased potassium fertilization.

The effect of the water deficit management strategy on the potassium fertilization dose at 65 DAS (Figure 3A) revealed that the number of leaves differed according to the management strategy adopted. Water deficit was imposed in the vegetative phase (VE). As a result, a reduction in NF was observed, with the lowest value estimated for plants fertilized with 150% K_2O, which presented 32.71 leaves, corresponding to a reduction of approximately 18.20% in relation to plants fertilized with the lowest dose (50% K_2O), which presented 39.99 leaves (Figure 3A). In contrast, under management, in which water deficit was applied during flowering and successively in the flowering and fruiting phases of the common bean, increases in NF of 20.30% and 38.24%, respectively, were observed in plants subjected to 150% K in relation to those that received 50% K. This finding shows that the requirement for potassium fertilization differs in relation to the maturation period and growth habit of the crop (CLEMENT-BAILEY and GWATHMEY, 2007).

Figure 3. Interaction effects of water deficit management strategy and potassium fertilizer dose on the number of leaves (A) and dry matter content of leaves and the FSF (B) of cowpea at 65 and 90 days after sowing



SE: plants irrigated with 100% ETr throughout the cycle; VE, FL, FR, and FL/FR: plants under deficit (50% ETr) in the vegetative, flowering, production and flowering/production formation phases, respectively.

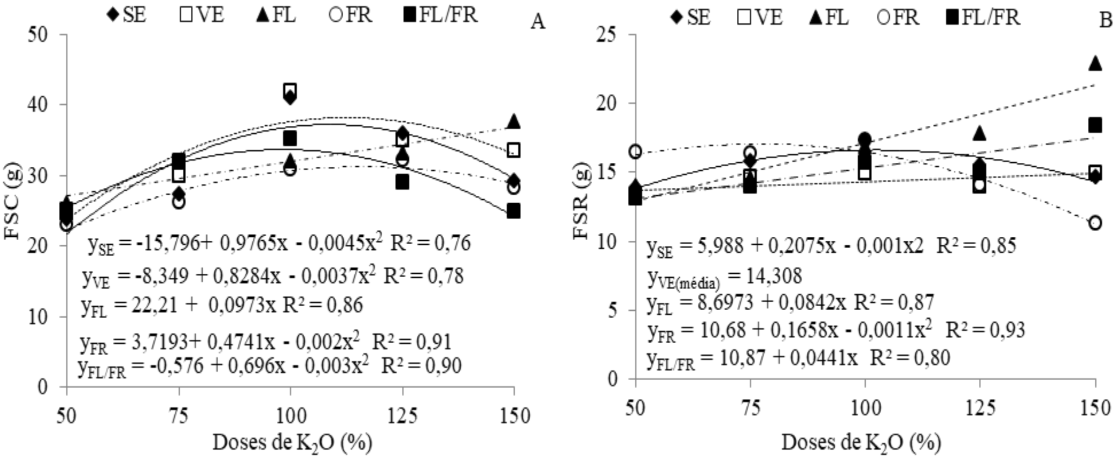
According to the regression equations (Figure 3B), the quadratic model best fit the leaf dry matter data. The SE and VE water deficit management strategies, which were under estimated potassium doses of 105% and 111% K_2O, respectively, promoted greater FSF accumulation (21.68 and 22.66 g, respectively). The lowest FSF values were obtained when the plants were subjected to water deficit successively during the flowering and fruiting phases of the crop (FL/FR). Compared with the lowest potassium dose, the accumulation of leaf dry matter decreased with increasing potassium dose, resulting in a 37.65% reduction in the FSF of plants under 150% K2O fertilization.

At the end of the cycle, the dry matter content of the leaves of the plants under water stress in the vegetative phase was similar to that of the unstressed plants, demonstrating that despite the stress in the initial crop phase, there was a resumption of leaf emission (Figure 3B). In contrast, the more significant decrease in plants subjected to water deficit during the flowering and fruiting phases than in those subjected to the other management strategies may have occurred as a consequence of osmotic adjustment, which may have developed slowly in response to dehydration. The osmotic adjustment process may not have developed in cowpea because of the longer period of water deficit, which could explain the lack of relief from the effects of water stress associated with potassium fertilization (SÁ et al., 2014).

Analyzing the regression equations (Figure 4A), there is an increasing linear behavior of the strategy with water deficit at flowering (FL) with increasing potassium doses, with an increase of 10.25% for each 25% increase in K_2O, that is, an increase of 26.44% in the dry phytomass of the stem of plants subjected to the dose of 150% K_2O, in relation to those fertilized with 50% K_2O. According to Guo et al. (2007), there is a positive correlation between water uptake and K absorption in common bean (*Phaseolus vulgaris* L.), with potassium being responsible for maintaining xylem hydraulic conductance, cell turgor, stomatal movement and gas exchange as part of adaptation to drought, helping to maintain the water balance in plants (Oddo et al., 2011).

For plants grown with the SE, VE, FR, and FL/FR strategies, the model that best fit the data were the quadratic model. The plants receiving K doses of 108%, 112%, 119%, and 116% K2O presented the highest FSC accumulation, with values of 36.83, 38.01, 31.81, and 39.79 g per plant, respectively (Figure 4A). In general, these management strategies increased the FSC with the addition of increasing doses of K to the soil up to the value corresponding to the recommended dose for obtaining maximum production. Furthermore, the reduction in water availability during these phases caused a decrease in the water potential in the cells, reducing cell and internode elongation and resulting in lower accumulation of plant phytomass (NEZAMI et al., 2008).

Figure 4. Breakdown of the interaction effects of water deficit management strategies and potassium fertilizer doses on stem dry matter (FSC) (A) and root dry matter (FSR) (B) in cowpea at 90 days after sowing

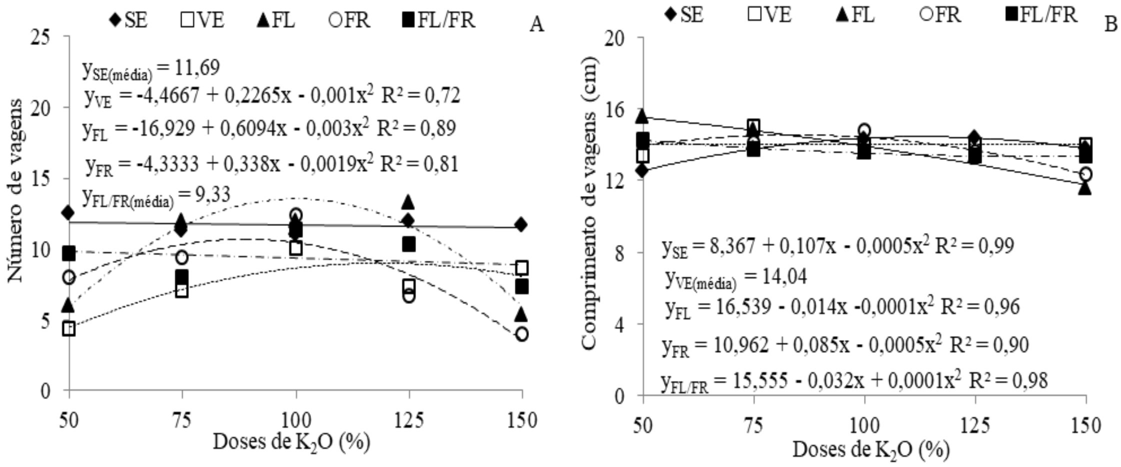


SE: plants irrigated with 100% ETr throughout the cycle; VE, FL, FR, and FL/FR: plants under deficit (50% ETr) in the vegetative, flowering, production and flowering/production formation phases, respectively.

The interaction effect between water deficit management strategy and potassium dose also had a significant effect on root dry matter (Figure 4B), with an increasing linear effect on the FSR of plants subjected to water deficit during the flowering phase and subsequently during flowering and fruiting, with increases of 24.00% and 10.14%, respectively, per 25% increase in potassium dose. On the basis of the regression equation, the data corresponding to the SE and FR strategies were fitted to a quadratic model, and the highest FSR values (16.75 and 16.92 g) were obtained in plants fertilized with 104% and 76% K_2O, respectively. Among the strategies, the highest accumulation of RSF was observed with water deficit in the flowering phase, with a value of 17.12 g, whereas the lowest accumulation was obtained in plants under the SE and VE strategies, with average values of 15.33 and 14.30 g, respectively (Figure 4B). This may be associated with the lack of soil water in the shallow layers under water deficit conditions; cowpea plants may have extended their roots to absorb water from deeper soil layers. This phenomenon was reported by Römheld et al. (2010), who associated the increase in root surface area under water deficit conditions with adequate doses of potassium, which resulted in greater efficiency in water uptake by plant cells.

An analysis of the regression equation for the number of pods as a function of the VE, FL and FR management strategies (Figure 5A) revealed that the data fit the quadratic model ($p<0.05$), with the maximum estimated values (8.35, 14.01 and 10.69 pods) obtained when fertilized with doses of 113%, 102% and 89% K2O, respectively. From these doses onward, reductions in the number of pods per plant occurred, with the lowest value (3.61 pods) being reached in cowpea plants under water deficit in the fruiting phase fertilized with the highest dose of potassium (150% of K_2O). With respect to the plants subjected to the SE and FL/FR strategies, regression studies (Figure 5A) revealed no significant effect on NV, with average values of 11.69 and 9.33 pods, respectively. According to Karam et al. (2005), the reproductive phase of beans is more vulnerable to soil water deficit; any relative reduction in water supply reflects a decrease in productivity, causing not only embryo abortion but also leaf and fruit loss (ENDRES et al., 2010).

Figure 5. Interaction effects of water deficit management strategy and potassium fertilizer dose on the number of pods (A) and pod length (B) of cowpea at 90 days after sowing



SE: plants irrigated with 100% ETr throughout the cycle; VE, FL, FR, and FL/FR: plants under deficit (50% ETr) in the vegetative, flowering, production and flowering/production formation phases, respectively.

Among the water deficit management strategies based on different potassium fertilization rates at 90 DAS (Figure 5B), when conducted without water stress throughout the crop cycle (SE), the estimated dose of 107% K2O resulted in the longest pod length (14.09 cm). For the FL, FR, and FL/FR strategies associated with potassium rates estimated at 50%, 85%, and 50%, greater pod lengths were observed (15.58, 14.57, and 14.20 cm, respectively), and higher potassium rates intensified the effects of water deficit in these phenological stages of cowpea. The negative effects of high potassium rates on plants subjected to water deficit in these stages, as observed in the present study, were also reported by Ribeiro et al. (2001), who associated these reductions with the high salinity index of the fertilizer used (KCl), which can affect water absorption and plant growth due to the reduction in the water potential of the external solution through the osmotic effect.

6 CONCLUSIONS

The application of water deficit associated with potassium doses favored growth and phytomass accumulation in the flowering phase.

When associated with water deficit in the flowering and fruiting phases, increasing doses of potassium compromise the number of pods and pod length.

In the initial stages of cowpea development, the cultivar BRS Marataoã, water deficit irrigation can be applied without significant losses in production components.

7 REFERENCES

BAHRAMI-RAD, S.; HAJIBOLAND, R. Effect of potassium application in drought-stressed tobacco (*Nicotiana rustica* L.) plants: Comparison of root with foliar application. **Annals of Agricultural Sciences** , Cairo, v. 62, no. 2, p. 121-130, 2017.

BERNARDO, S.; MANTOVANI, EC; SILVA, DD; SOARES, AA **Irrigation Manual** . 9th ed. Viçosa: UFV, 2019. 545 p.

CLAESSEN, MEC (org.). **Manual of soil analysis methods** . 2nd ed. rev. and updated. Rio de Janeiro: Embrapa-CNPS, 1997. 212 p. (Documents, 1).

CLEMENT-BAILEY, J.; GWATHMEY, C. O. Effects of potassium on partitioning, yield, and earliness of contrasting cotton cultivars. **Agronomy Journal** , North Dakota, v. 99, n. 4, p. 1139-1136, 2007.

COELHO, JBM; BARROS, MFC; BEZERRA NETO, E.; CORREA, MM Water behavior and growth of Vigna beans grown in salinized soils. **Brazilian Journal of Agricultural and Environmental Engineering** , Campina Grande, v. 17, n. 4, p. 379-385, 2013.

ENDRES, L.; SOUZA, J.L.; TEODORO, I.; MARROQUIM, PMG; SANTOS, C.M.; BRITOS, JED Gas exchange alteration caused by water deficit during the bean reproductive stage. **Revista Brasileira de Engenharia Agrícola e Ambiental** , Campina Grande, v. 14, no. 1, p. 11-16, 2010.

FAROOQ, M.; WAHID, A.; KOBAYASHI, N.; FUJITA, D.; BASRA, SMA Plant drought stress: effects, mechanisms and management. **Agronomy for Sustainable Development** , Paris, see 29, no. 1, p. 185-21, 2009.

FERREIRA, D. F. Sisvar: A computer statistical analysis system. **Science and Agrotechnology** , Lavras, v. 35, no. 6, p. 1039-1042, 2011.

BEANS. **Monitoring the Brazilian Harvest** : grains, Brasília, DF, v. 7, n. 4, p. 23-24, Jan. 2020. 2019/2020 Harvest. Fourth survey. Available at: https://www.conab.gov.br/info-agro/safras/graos/boletim-da-safra-de-graos/item/download/30348_aa345b3df6694e420f12eedc8ffb970d. Accessed on: Jan. 15, 2020.

FREIRE FILHO, FR; RIBEIRO VQ; ROCHA, MM; SILVA, KJD; NOGUEIRA, MS; RODRIGUES, EV **Production, genetic improvement and potential of cowpea in Brazil.** Teresina: Embrapa Mid-North, 2011. 84 p.

GUO, S.; KALDENHOFF, R.; UEHLEIN, N.; SATTELMACHER, B.; BRUECK, H. Relationship between water and nitrogen uptake in nitrate- and ammonium-supplied

Phaseolus vulgaris L. plants. **Journal of Plant Nutrition and Soil Science** , Landau, vol. 170, n. 1, p. 73-80, 2007.

KARAM, F.; MASAAD, R.; SFEIR, T.; MOUNZER, O.; ROUPHAEL, Y. Evapotranspiration and seed yield of field grown soybean under deficit irrigation conditions. **Agriculture Water Management** , Auckland, vol. 75, no. 3, p. 226-244, 2005.

MENDES, RMS; TÁVORA, FJAF; PITOMBEIRA, JB; NOGUEIRA, RJMC Source–sink relationships in cowpea subjected to water deficit. **Agronomic Science Journal** , Fortaleza, v. 38, n. 1, p. 95-103, 2007.

Mostafazadeh-Fard, B.; MANSOURI, H.; MOUSAVI, SF; FEIZI M. Effects of different levels of irrigation water salinity and leaching on yield and yield components of wheat in an arid region. **Journal of Irrigation and Drainage Engineering-ASCE** , Reston, v . 135, n. 1, p. 32-38,

BIRTH, SPD; BASTOS, EA; ARAÚJO, EC; FREIRE FILHO, FR; SILVA, EMD Tolerance to water deficit of cowpea genotypes. **Brazilian Journal of Agricultural and Environmental Engineering** , Campina Grande, v. 15, n. 8, p. pp. 853–860,

NEZAMI, H.; KHAZAEI, R.; BOROUMAND REZAZADEH, Z.; HOSSEINI, A. Effect of drought stress and defoliation on sunflower (*Helianthus annuus* L.) under controlled conditions. **Desert** , Terhran, v. 12, n. 1, p. 99-104,

NOVAIS, RF; NEVES, JCL; BARROS, NF Controlled environment test. *In* : OLIVEIRA, AJ **Soil fertility research methods** . Brasília, DF: EMBRAPA-SEA, 1991. p. 189-253.

ODDO, E.; INZERILLO, S.; LA BELLA, F.; GRISAFI, F.; SALLEO, S.; NARDINI, A. Short-term effects of potassium fertilization on the hydraulic conductance of *Laurus nobilis* L. **Tree Physiology** , Edmonton, v. 31, no. 2, p. 131-138, 2011.

PETTIGREW, WT Potassium influences yield and quality production for corn, wheat, soybean, and cotton. **Physiologia Plantarum** , Lund, v. 133, n. 4, p. 670-681, 2008.

PRAZERES, SS; LACERDA, CF; BARBOSA, FEL; AMORIM, AV; ARAUJO, ICS; CAVALCANTE, LF Growth and gas exchange of cowpea plants under saline irrigation and potassium doses. **Agro@mbiente Magazine** , Boa Vista, v. 9, n. 2, p. 111-118, 2015.

RIBEIRO, MCC; MARQUES, BM; AMARRO FILHO, J. Effect of salinity on seed germination of four sunflower cultivars (*Helianthus annuus* L.). **Brazilian Seed Journal** , Viçosa, v. 23, n. 1, p. 281-284, 2001.

RÖMHELD, V.; KIRKBY, EA Potassium research in agriculture: Needs and perspectives. **Plant and Soil** , Beijing, v. 335, n. 1, p. 155-180, 2010.

SÁ, AFL; VALERI, SV; CRUZ, MCP; BARBOSA, JC; REZENDE, GM; TEIXEIRA, MP Effects of potassium application and soil moisture on the growth of *Corymbia citriodora* plants. **Cerne** , Lavras, v. 20, n. 4, p. 645-651, 2014.

SOUSA, MA; LIMA, MDB Influence of irrigation suppression on development stages of common bean cv. Carioca. **Bioscience Journal** , Uberlândia, v. 26, n. 4, p. 550-557, 2010.

TAIZ, L.; ZEIGER, E. **Plant physiology** . 5. ed. Porto Alegre: Artemed, 2013. 954 p.