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Original Article

Salicylic acid and polymer on the quality of cowpea seeds grown under water deficit[1]

Ácido salicílico e polímero na qualidade de sementes de feijão-caupi cultivado sob déficit hídrico

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HIGHLIGHTS:

0.29 to 2 mM of salicylic acid and HumigelPlus® polymer improve the quality of cowpea seeds grown under water deficit.
0.29 and 1.71 mM of salicylic acid and HumigelPlus® polymer improve the physical quality of cowpea seeds under water deficit.
1 to 2 mM of salicylic acid and HumigelPlus® polymer increase the physiological vigor of cowpea seeds under water deficit.

ABSTRACT: Cowpea is the third most cultivated legume in the world, and its cultivation can be intended for both grains and seeds. Plants intended for seed production, when exposed to water deficit, may compromise their physical and physiological quality, necessitating the development of strategies to minimize their damage, such as the application of salicylic acid and HumigelPlus® polymer. The objective of this study was to evaluate salicylic acid and HumigelPlus® polymer concentrations to reduce the effects of water deficit on the physical and physiological quality of cowpea seeds. The landrace cowpea seeds used in this study were sourced from two field experiments (Summer and spring). The treatments consisted of five concentrations of salicylic acid (0, 0.29, 1, 1.71, and 2 mM) and five concentrations of HumigelPlus® polymer (0, 0.29, 1, 1.71, and 2%) combined according to the Central Composite Design and a control group (absence of water deficit and application of salicylic acid and HumigelPlus® polymer). The values of electrical conductivity, germination, emergence, weight, and water content of cowpea seeds were higher with the application of salicylic acid (mM) and HumigelPlus® polymer (%) concentrations between 0.29 and 2, regardless of the season. The application of salicylic acid (mM) and HumigelPlus® polymer (%) concentrations between 0.29 and 2, both in summer and spring cultivation, reduces the effects of water deficit on the physical and physiological quality of cowpea seeds.

Key words: *Vigna unguiculata* (L.) Walp., water scarcity, phytohormones, monomers

RESUMO: O feijão-caupi é a terceira leguminosa mais cultivada no mundo, seu cultivo pode ser destinado tanto para grãos quanto para sementes. As plantas para a produção de sementes quando expostas a déficit hídrico, pode comprometer suas qualidades físicas e fisiológicas, necessitando do desenvolvimento de estratégias que minimizem seus danos, como a aplicação de ácido salicílico e de polímero HumigelPlus®. Objetivou-se com este estudo avaliar a aplicação de concentrações de ácido salicílico e polímero HumigelPlus® para reduzir os efeitos do déficit hídrico na qualidade física e fisiológica de sementes de feijão-caupi. As sementes crioulas de feijão-caupi utilizadas neste estudo foram provenientes de dois experimentos de campo (verão e primavera). Os tratamentos foram compostos por cinco concentrações de ácido salicílico (0; 0,29; 1; 1,71 e 2 mM) e cinco concentrações de polímero HumigelPlus® (0; 0,29; 1; 1,71 e 2%) combinadas de acordo com a matriz experimental Composto Central de Box e uma testemunha (ausência de déficit hídrico e de aplicação de concentrações de ácido salicílico e polímero HumigelPlus®). Os valores da condutividade elétrica, germinação, emergência, peso e teor de água de sementes de feijão-caupi foram maiores com a aplicação de concentrações de ácido salicílico (mM) e de polímero HumigelPlus® (%) entre 0,29 e 2, independentemente da estação do ano. A aplicação de concentrações de ácido salicílico (mM) e de polímero HumigelPlus® (%) entre 0,29 e 2, tanto no cultivo de verão, como no cultivo de primavera, reduz os efeitos do déficit hídrico na qualidade física e fisiológica de sementes de feijão-caupi.

Palavras-chave: *Vigna unguiculata* (L.) Walp., escassez de água, fitohormônios vegetais, monômeros

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Introduction

Cowpea (*Vigna unguiculata* (L.) Walp.) is one of the most important species globally, as it constitutes a significant component of the diet for millions of people in less developed tropical countries due to its extensive nutritional benefits (Cardona-Ayala et al., 2020; Uzoh & Babalola, 2020). Its production is primarily intended for marketing in the form of both grains and seeds (Afutu et al., 2017).

Many cowpea cultivars show high yields under adequate water management; however, they are highly susceptible to water deficit. This susceptibility significantly reduces seed production, as it is directly related to reduction in plant development (Ravelombola et al., 2018). Predicting water scarcity at specific times or locations remains a challenge, even with advancements in meteorological forecasting (Verbree et al., 2015). This underscores the necessity of developing strategies to mitigate the damage caused by water constraints on crops (Sun et al., 2020).

Salicylic acid is considered an essential phytohormone to reduce the effects of abiotic stresses in plants due to its association with phenolic compounds and the regulation of plant defenses (La et al., 2019), as observed in millet and wheat crops exposed to sat and water stress (Yadav et al., 2020). Another potential stress-mitigating agent developed in recent decades are polymers, which induce tolerance to water deficit, as in corn cultivation with application of chitosan at concentrations of 140 mg L^{-1} (Almeida et al., 2020). Additionally, they have been shown to enhance production under suitable water management conditions, as demonstrated in cowpea cultivation (El-Hadidi et al., 2020). In light of the aforementioned, the objective of this study was to evaluate the application of salicylic acid concentrations and HumigelPlus® polymer concentrations to reduce the effects of water deficit on the physical and physiological quality of cowpea seeds.

Material and Methods

The cowpea seeds from the landrace cultivar Pingo-de-Ouro used in this study were sourced from two field experiments conducted under no-till planting systems. These experiments were carried out at Boqueirão Farm, Catolé do Rocha, Paraíba state, Brazil, across two crop cycles. The first cycle occurred from December 2019 to February 2020 (summer), and the second from September to November 2020 (spring). The experimental area is located at 6° 21'5 0" S and 37° 40' 59" W, with an altitude of 220 m.

Climate data (Figure 1) were recorded using a digital thermo-hygrometer (HT-600 Instrutherm®), installed in a shelter at the center of the experimental area, 1.5 m above ground level. Data were collected daily in the late afternoon throughout the experimental period.

Seed analyses were conducted after each cultivation period at the Seed Analysis Laboratory, belonging to the Department of Agrarian and Exact Sciences at the Universidade Estadual da Paraíba, Campus IV, located at Sítio Cajueiro, Catolé do Rocha, Paraíba state, Brazil.

The field experiment was conducted using a randomized block design with 10 treatments and four replicates. The treatments (1 to 9) used were the result from the combination of five concentrations of salicylic acid (S) and five concentrations of HumigelPlus® polymer (P), combined according to the Central Composite Design from the non-concentration (0) and the highest concentration of S, 2 mM (Silva et al., 2019)

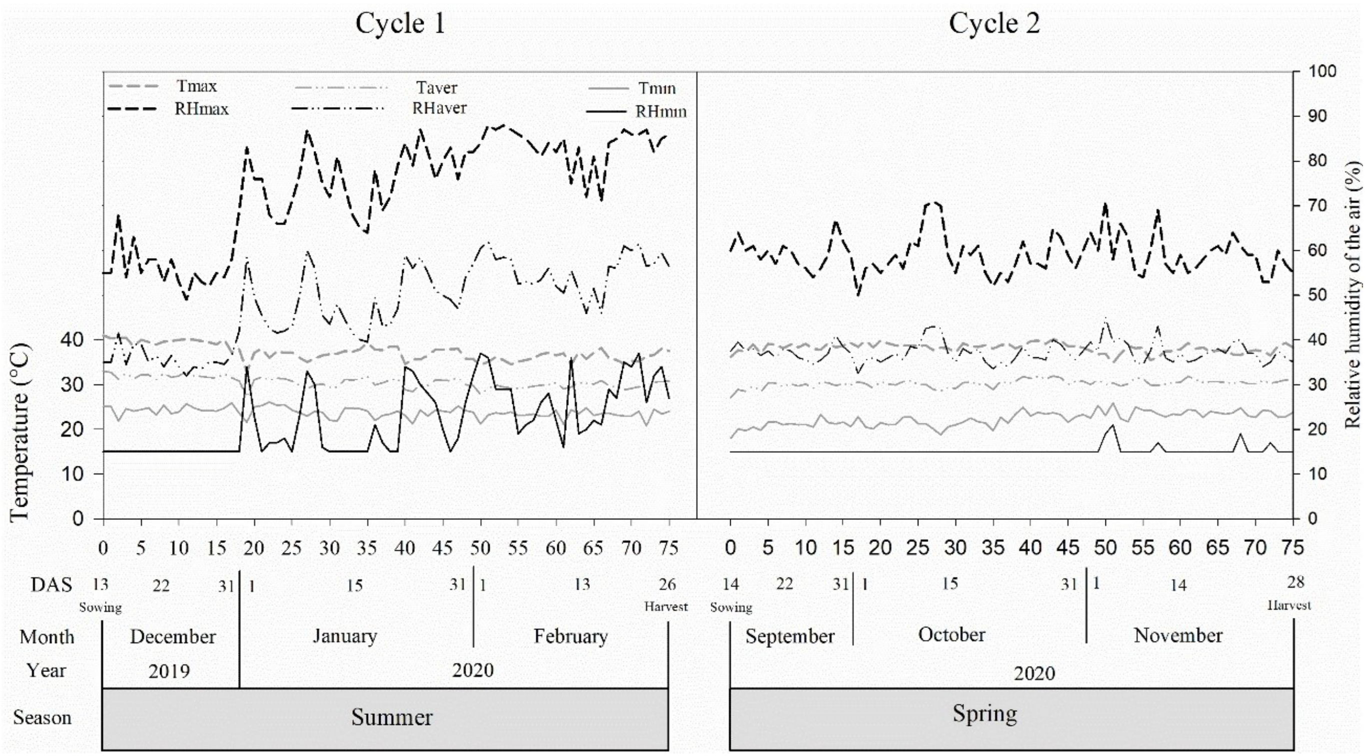


Figure 1. Maximum (Tmax), average (Taver), and minimum (Tmin) air temperatures in ºC and maximum (RHmax), average (RHaver), and minimum (RHmin) relative air humidity in %, during the experimental period in summer (Cycle 1) and spring (Cycle 2) of 2020 in the Catolé do Rocha region, Paraíba state, Brazil

and P, 2% (Tecniferti, [n.d.]), resulting in the following treatments: T1 - 0.29 and 0.29 (S0.29P0.29); T2 - 1.71 and 0.29 (S1.71P0.29); T3 - 0.29 and 1.71 (S0.29P1.71); T4 - 1.71 and 1.71 (S1.71P1.71); T5 - 1.00 and 0.00 (S1P0); T6 - 1.00 and 2.00 (S1P2); T7 - 2.00 and 1.00 (S2P1); T8 - 0.00 and 1.00 (S0P1); and T9 - 1.00 mM and 1.00% (S1P1). For comparison purposes, an additional treatment (T10) was included, involving the absence of water interruption and the absence of salicylic acid and HumigelPlus® polymer concentrations (control) (S0P0).

The plants were subjected to water interruption when the water deficit causes greater damage to the crop's yield, 25 days after emergence (DAE), stage V4, until the soil matric potential (Ψm) at a depth of 0.40 m indicated the absence of available water, as described by Ribeiro et al. (2019), which occurred at the beginning of flowering (40 DAE), stage R5. The applications of salicylic acid and HumigelPlus® polymer were carried out with a manual sprayer on the plant leaves at 25 and 26 DAE, respectively.

The salicylic acid concentrations were diluted in 20 mL of ethyl alcohol and water with 0.05% neutral detergent (surfactant). The HumigelPlus® polymer concentrations were diluted in water with 0.05% neutral detergent (surfactant). The polymer HumigelPlus® is composed of 2% nitrogen, 4% CaO, 2.2% MgO, and 1.4% fulvic acids (Tecniferti, [n.d.]).

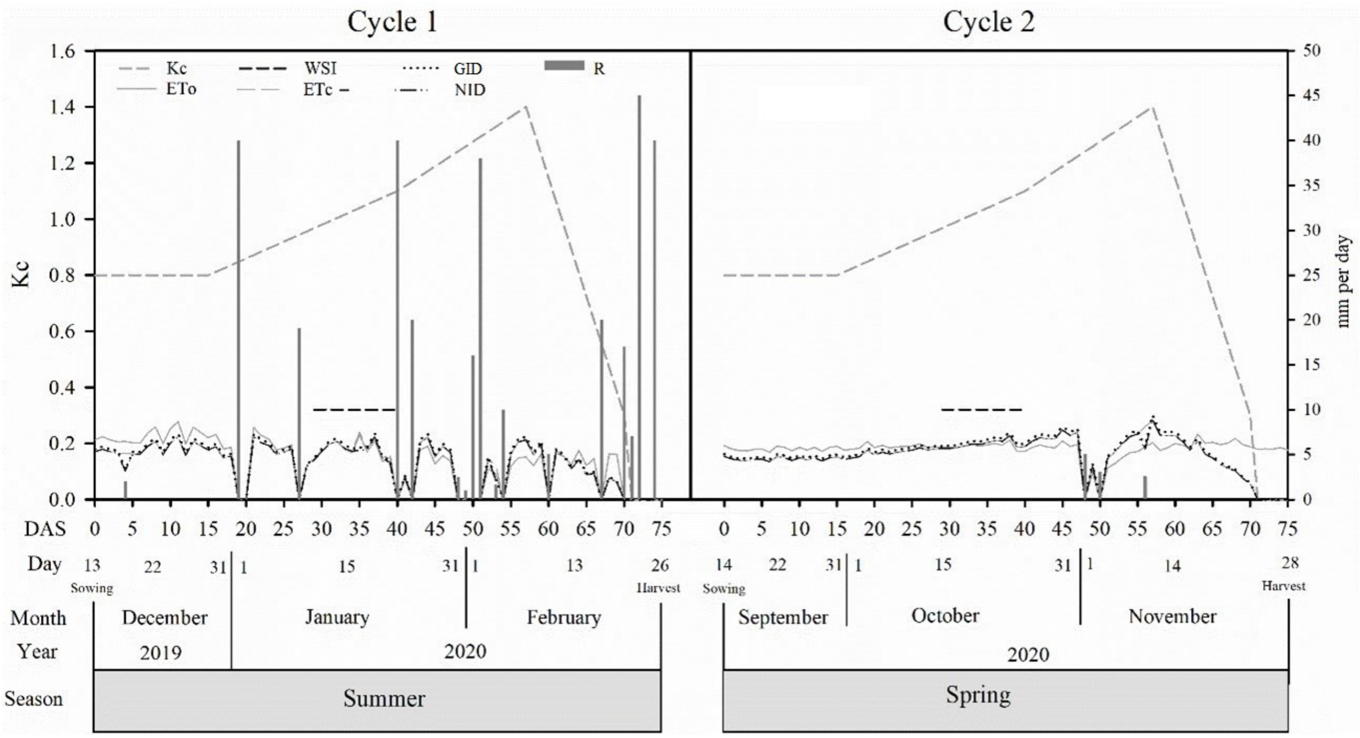
The experimental plot consisted of 12 single rows (6 double rows), each measuring 4 m, corresponding to an area of 21.6 m^2. To define the effective area of the plot, two rows from each side (borders) and 0.5 m from the front ends of the plot (borders) were excluded, resulting in an effective area of 10.8 m^2, comprised of the eight central rows.

The cowpea seeds used were from the landrace cultivar Pingo-de-Ouro cultivated in a no-tillage system. After desiccation of the previous crop (corn) and weeds using glyphosate (N-[phosphonomethyl]-glycine) at a dose of 4.075 kg ha^{-1}, recommended for areas with the occurrence of *Portulaca oleracea*, the seeds were mechanically sown, with 10 seeds per linear meter in double-row spacing of 0.60 x 0.30 x 0.20 m. After emergence stabilization, thinning was performed, leaving five plants per linear meter, resulting in a population density of 111,111 plants per hectare.

For water management, the localized irrigation method was employed using a drip system installed between the rows with a narrower spacing (30 cm). The drip tape had a diameter of 16 mm, a wall thickness of 200 microns, emitter spacing of 20 cm, and a maximum emitter flow rate of 3.8 L h^{-1}, although its operational flow rate was 3.32 L h^{-1}. These characteristics generated a wetted area percentage (P) of 50%.

Regarding water management (Figure 2), the calculation of the gross irrigation depth (GID) considered, first, the reference evapotranspiration (ETo, mm per day), the product of daily evaporation from the Class A pan and its coefficient (Kp = 0.75). By multiplying the ETo value by the crop coefficient (Kc) recommended by Bastos et al. (2008) and subtracting values for any precipitation, the net irrigation depth (NID, mm per day) was calculated. This value was then divided by the irrigation system efficiency (Ef = 0.95), resulting in the gross irrigation depth (GID), applied daily in the early hours of the day, except during the period and plots subjected to water interruption treatments.

Both the planting and top-dressing fertilization, for both summer and spring planting, were based on soil chemical analysis (Table 1) and fertilization recommendation (IPA, 2008). Planting fertilization was broadcast using doses of 20, 20, and 20 kg ha^{-1} of N, P_2O_5, and K_2O, respectively. Top-dressing fertilization was applied using a broadcast method with a dose of 20 kg ha^{-1} of N at 20 days after planting. The sources of N, P_2O_5, and K_2O were urea (for both planting and top-dressing), single superphosphate, and potassium chloride, respectively.



Kc - Crop coefficient; ETo - Reference evapotranspiration; ETc - Crop evapotranspiration; R - Rainfall; NID - Net irrigation depth; GID - Gross irrigation depth; WSI - Water stress interval

Figure 2. Water management for cowpea crops subjected and not subjected to water stress over the days after sowing (DAS)

Table 1. Chemical, physical and physical-hydraulic characteristics of the soil used in the experiment in the 0 to 20 cm depth layer

Chemical characteristics of the soil												
pH	P	K^+	Na^+	H+Al	Al^{+3}	Ca^{+2}	Mg	SEB	CEC	V	m	OM
	(mg dm^{-3})		(cmol$_c$ dm^{-3})							(%)		(g kg^{-1})
7.25	5.35	183.77	2.56	0.00	0.00	4.88	2.18	10.09	10.09	100	0.00	1.67

Physical and physical-hydraulic characteristics of the soil									
Bd	Pd	TP	FC	PWP	Sand	Silt	Clay	Textural classification	
(g cm^{-3})		(m^3 m^{-3})	(g kg^{-1})					- Embrapa -	- Atterberg -
1.61	2.72	0.40	131.1	48.2	700.8	221.2	78	Medium	Sandy loam

pH - Water: 1:2.5; P, K, Na - Mehlich extractor; H+Al - 0.5 M Calcium acetate extractor, pH 7.0; Al, Ca, Mg - 1 M KCl extractor; SEB - Sum of exchangeable bases; CEC - Cation exchange capacity; V - Base saturation; m - Aluminum saturation; OM - Organic matter; Bd - Bulk density; Pd - Particle density; TP - Total porosity; FC - Field capacity; PWP - Permanent wilting point

Preventive control of aphids (*Aphis craccivora*) and pod borers (*Michaelus jebus*) was carried out using the insecticides Imidacloprid and Methomyl at doses of 150 g 100 kg^{-1} of seeds and 215 g ha^{-1}, respectively. Although there was an occurrence of *Fusarium oxysporum*, it did not reach the control threshold. Weed control was performed 15 days after emergence (DAE) using the herbicide ethofumesate at a dose of 82.5 g ha^{-1}.

Partial pod harvests in both cycles occurred between 60 and 80 days after sowing. Upon reaching the physiological maturity of the seeds, verified from the change in color from green to the color characteristic of the species (red), the pods were manually harvested, threshed, cleaned by ventilation, sun-dried, and then stored in a refrigerator with a constant temperature of 10 °C.

Seed quality variables from the field experiments were assessed with four replicates of 50 seeds each, except for the thousand-seed weight. Moisture content (MC - %) was determined using the oven method at 105 ± 3 °C for 24 hours (Brasil, 2009). The germination test involved sowing the seeds between three sheets of paper towels moistened with distilled water in an amount equivalent to 2.5 times the weight of the dry paper. Subsequently, the seeds were placed in a germination chamber at a constant temperature of 25 °C.

The first germination count (FGC) was performed concurrently with the germination test. It involved recording the percentages of germinated seeds (radicles with 2 mm) on the fifth day after sowing. This was calculated as the ratio of the number of germinated seedlings to the total number of seeds, multiplied by 100 (BRASIL, 2009). The final germination percentage (GP) was determined on the eighth day after sowing, using the same calculation as described above (BRASIL, 2009).

The seedling emergence test on a sand substrate was conducted in a greenhouse. Seeds were sown in a sand bed with longitudinal furrows measuring one meter in length and spaced 0.10 m apart. Irrigation was applied twice a day through drainage lysimetry until the start of water runoff at the base of the bed, seeking to preserve moisture in the sand bed. Daily counts were conducted at a specified time (5:00 p.m.) from the fifth to the eighth day after sowing (BRASIL, 2009).

The first emergence count (FEC) was performed simultaneously with the emergence test. It involved recording the percentages of normal seedlings on the fifth day after sowing. This was calculated as the ratio of the number of emerged seedlings to the total number of seeds, multiplied by 100 (BRASIL, 2009). The final emergence percentage (FEP) was determined using the same calculation as described above (BRASIL, 2009). The results were expressed as a percentage of normal seedlings.

Electrical conductivity (EC) and the amount of water absorbed by the seed (AWA) were determined by weighing the seeds and placing them in disposable plastic cups with a capacity of 150 mL, each containing 75 mL of distilled water. These cups were kept in an air-conditioned room with a constant temperature of 25 °C for 24 hours. After the aforementioned time, the electrical conductivity of the seeds was measured using a benchtop conductivity meter (Digimed CD-21 brand), with the results expressed in μS cm^{-1} g^{-1} of seed.

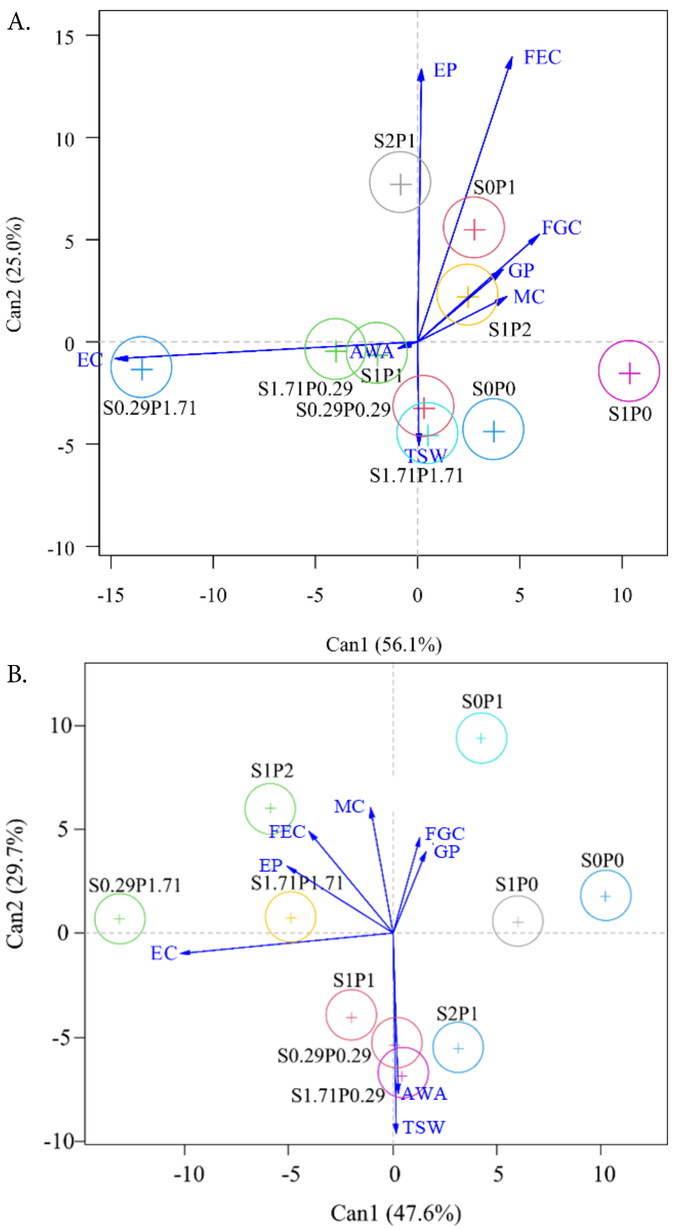
For the calculation of AWA, the methodology used was adapted from Sampaio et al. (2016). This involved using the mass of soaked seeds and subtracting it from the mass of seeds before immersion in water (non-soaked seeds), with the results expressed in g per seed. To determine the thousand-seed weight (TSW), eight replicates of 100 seeds from each plot were separated and weighed using an analytical balance. TSW was calculated by multiplying the average weight of the eight replicates of 100 seeds from each plot by 10, considering that the coefficient of variation was less than 4% (BRASIL, 2009).

The data were subjected to canonical variables and confidence ellipses ($p \leq 0.01$) to explore the interrelationships between variables and the evaluated factors using the candisc package (Friendly & Fox, 2017). Pearson's correlation analysis was performed using the corrplot package (Wei & Simko, 2017). The R statistical software (R Core Team, 2021) was employed for conducting the statistical analyses.

Results and Discussion

Seed electrical conductivity (EC) exhibited higher values when plants were subjected to water deficit and the application of 0.29 mM of salicylic acid (S) and 1.71% of HumigelPlus® polymer (P) (S0.29P1.71), both during the summer cultivation (Figure 3A) and the spring cultivation (Figure 3B). Water deficit in the vegetative stage causes greater electrolyte leakage in the seed, indicating that the plants exposed to water deficit suffer an impact on the structure and cell membrane of the produced seed, which leads to an increase in electrical conductivity in seeds of reduced quality (Dehghan et al., 2020), since one of the principles of electrical conductivity in seeds is the increase in the permeability of cell membranes as the seed undergoes some type of membrane deterioration (Tunes et al., 2008).

The amount of water absorbed by the seed (AWA) was superior and similar in the treatments in which the plants were subjected to water deficit and the application of 1.71 mM of salicylic acid and 0.29% of HumigelPlus® polymer (S1.71P0.29)



MC - Moisture content; FGC - First germination count; GP - Final germination percentage; FEC - First emergence Count; EP - Final emergence percentage; EC - Electrical conductivity; AWA - Water imbibition by the seed; TSW - Thousand-seed weight. 0.00 and 0.00 (S0P0); 0.29 and 0.29 (S0.29P0.29); 1.71 and 0.29 (S1.71P0.29); 0.29 and 1.71 (S0.29P1.71); 1.71 and 1.71 (S1.71P1.71); 1.00 and 0.00 (S1P0); 1.00 and 2.00 (S1P2); 2.00 and 1.00 (S2P1); 0.00 and 1.00 (S0P1); 1.00 mM of salicylic acid and 1.00% of HumigelPlus® polymer (S1P1), respectively

Figure 3. Canonical variables (Can) and confidence ellipses between variables related to the physical and physiological quality of cowpea seeds in summer (A) and spring (B) cultivation without and with water deficit and application of different concentrations of salicylic acid (S) and HumigelPlus® polymer (P)

and 1 mM of salicylic acid and 1% of HumigelPlus® polymer (S1P1) in seeds from the summer cultivation (Figure 3A). Similar trends were observed in treatments with 1.71 mM of salicylic acid and 1.71% of HumigelPlus® polymer (S1.71P1.71) and 0.29 mM of salicylic acid and 0.29% of HumigelPlus® polymer (S0.29P0.29) in the spring cultivation (Figure 3B). The imbibition phase is an essential step in germination process, as it reactivates enzymes involved in mobilizing seed reserves to support the growth of the embryo in the germination process (Moles et al., 2019). With this study, it was identified that the imbibition process is affected by different concentrations of salicylic acid and antitranspirant polymer, with behavioral variations between seeds from summer and winter crops. Among the concentrations, the use of 0.29 to 1.0 mM salicylic acid and 0.29 to 1.71% HumigelPlus® polymer proved to be efficient in increasing seed imbibition for the initial germination processes.

The first emergence count (FEC) showed the highest values in the treatment where plants were subjected to water deficit and the application of 0 mM of salicylic acid and 1% of HumigelPlus® polymer (S0P1) in seeds from the summer cultivation (Figure 3A) and in the treatment with 1 mM of salicylic acid and 2% of HumigelPlus® polymer (S1P2) in the spring cultivation (Figure 3B). The final emergence percentage (EP) exhibited the highest values in the treatment where plants were subjected to water deficit and the application of 2 mM of salicylic acid and 1% of HumigelPlus® polymer (S2P1) in seeds from the summer cultivation, as well as in the treatment with 1 mM of salicylic acid and 2% of HumigelPlus® polymer (S1P2) in the spring cultivation. The first germination count (FGC) and final germination percentage (GP) showed the highest values in the treatment where plants were subjected to water deficit and the application of 1 mM of salicylic acid and 2% of HumigelPlus® polymer (S1P2) in seeds from the summer cultivation, as well as in the treatment with 0 mM of salicylic acid and 1% of HumigelPlus® polymer (S0P1) in the spring cultivation. Salicylic acid enhances the distribution of photoassimilates to reproductive parts and developing seeds, thus increasing the physiological quality of the seeds (Mahboob et al., 2015). In peas, seed vigor produced by plants originating from seeds treated with salicylic acid through imbibition was superior to that of untreated seeds (Anjum et al., 2020).

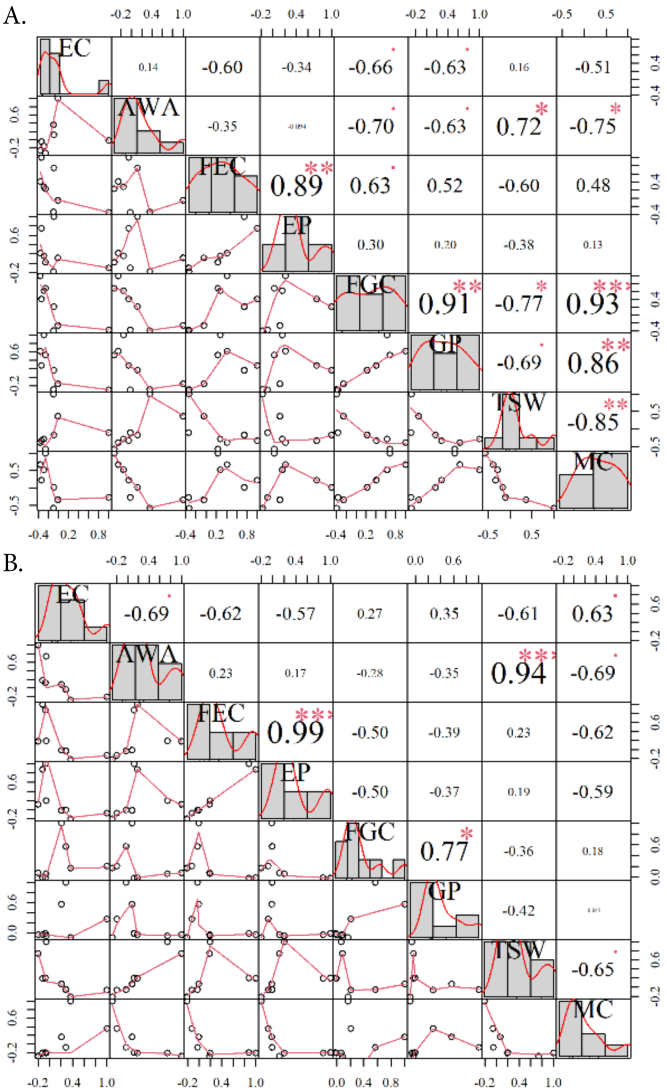
The thousand-seed weight (TSW) exhibited the highest values in the treatment where plants were not subjected to water deficit (S0P0) and in similar treatments where plants were subjected to water deficit and the application of 0.29 mM of salicylic acid and 0.29% of HumigelPlus® polymer (S0.29P0.29) and 1.71 mM of salicylic acid and 1.71% of HumigelPlus® polymer (S1.71P1.71) in seeds from the summer cultivation (Figure 3A). Similar trends were observed in treatments with 0.29 mM of salicylic acid and 0.29% of HumigelPlus® polymer (S0.29P0.29) and 1.71 mM of salicylic acid and 0.29% of HumigelPlus® polymer (S1.71P0.29) in the spring cultivation (Figure 3B). The seed mass of most cowpea genotypes decreases with the severity of water deficit due to the partitioning of carbohydrates and photoassimilates in the developing seed, as under adequate conditions, seeds develop properly due to high assimilation and carbohydrate accumulation, resulting in the maximum seed mass that the genotype can express (Yahaya et al., 2019).

The moisture content (MC) showed the highest values in the treatment where plants were subjected to water deficit and the application of 1 mM of salicylic acid and 2% of HumigelPlus® polymer (S1P2) in seeds from both summer (Figure 3A) and spring (Figure 3B) cultivation. Seed moisture content can decrease when plants are exposed to water deficit at any stage of crop development (Thakur & Thakur, 2018). The use of salicylic acid can mitigate the effects of water deficit on the plant and provide greater resistance to seed moisture loss, as observed in the case of tomato crops treated with salicylic acid priming (Galviz-Fajardo et al., 2020).

The treatment where plants were not subjected to water deficit (S0P0) and the treatment where plants were subjected to water deficit and the application of 1 mM of salicylic acid and 0% of HumigelPlus® polymer (S1P0) showed no significant relationship with any of the variables studied in the summer cultivation (Figure 3A). Similarly, these treatments, along with the treatments involving 1 mM of salicylic acid and 1% of HumigelPlus® polymer (S1P1) and 2 mM of salicylic acid and 1% of HumigelPlus® polymer (S2P1), exhibited no significant relationship with any of the variables studied in the spring cultivation (Figure 3B).

Regarding Pearson's correlation analysis between variables related to the physical and physiological quality of cowpea seeds (Figure 4), in the summer cultivation (Figure 4A), the strongest positive correlations (synergistic effects) were observed between the variables FGC and MC (ρ = 0.93), FGC and GP (ρ = 0.91), FEC and EP (ρ = 0.89), GP and MC (ρ = 0.86), and AWA and TSW (ρ = 0.72). The strongest negative correlations (antagonistic effects) were observed between the variables TSW and MC (ρ = -0.85), FGC and TSW (ρ = -0.77), and AWA and MC (ρ = -0.75).

In the spring cultivation (Figure 4B), the strongest positive correlations (synergistic effects) were observed between the variables FGC and GP (ρ = 0.77), AWA and TSW (ρ = 0.94), FEC and EP (ρ = 0.99), EC and MC (ρ = 0.63), and FGC and GP (ρ = 0.77). The strongest negative correlations (antagonistic effects) were observed between the variables EC and AWA (ρ = -0.69), AWA and MC (ρ = -0.69), FEC and MC (ρ = -0.62), TSW and MC (ρ = -0.65), and EP and MC (ρ = -0.59).



MC - Moisture content; FGC - First germination count; GP - Final germination percentage; FEC - First emergence Count; EP - Final emergence percentage; EC - Electrical conductivity; AWA - Water imbibition by the seed; TSW - Thousand-seed weight; *, **, and *** - Significant at p ≤ 0.05, p ≤ 0.01 and p ≤ 0.01 by the t-test, respectively

Figure 4. Pearson's correlation between variables related to the physical and physiological quality of cowpea seeds in summer (A) and spring (B) cultivation without and with water deficit with the application of concentrations of salicylic acid and HumigelPlus® polymer

In general, important effects of the application of salicylic acid and HumigelPlus® polymer on cowpea plants subjected to water stress were identified, which justifies their use in plantations under adverse conditions of water availability, as long as at appropriate concentrations. According to Araújo et al. (2018), in BRS Guariba cowpea plants, the use of salicylic acid reduces the harmful effects of abiotic stress and leads to an increase in the percentage of germination, seedling height and chlorophyll a, chlorophyll b, and carotenoids, in addition to playing an important role in adjusting cellular electrolyte leakage and increasing proline content under conditions of induced water stress, especially at a concentration of 1 mM.

Regarding the use of antitranspirant polymers, Cadorin et al. (2016) highlight that their efficiency is directly linked to the reduction in stomatal conductance promoted by these products, which must be applied at varying concentrations depending on the species subjected to water stress. In *Corda trichotoma* seedlings, the authors indicate that the use of 1.5% promotes lower water losses in plants subjected to water stress.

Conclusions

1. Application of salicylic acid and HumigelPlus® polymer, both in summer and spring cultivation, mitigates the effects of water deficit on the physical and physiological quality of cowpea seeds.
2. Physical quality of cowpea seeds cultivated under water deficit is improved with the application during cultivation of 0.29 to 1.71 mM of salicylic acid and 0.29 to 1.71% of HumigelPlus® polymer.
3. Physiological vigor of cowpea seeds cultivated under water deficit was positively influenced by the application during cultivation of 1 to 2 mM salicylic acid and 1 to 2% of HumigelPlus® polymer.

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