Universidade Federal Rural do Semi-Árido
Pró-Reitoria de Pesquisa e Pós-Graduação
https://periodicos.ufersa.edu.br/index.php/caatinga
ISSN 1983-2125 (online)

http://dx.doi.org/10.1590/1983-21252025v3812672rc

Scientific Article

Cowpea yield under salt stress and use of biofertilizers and *Trichoderma harzianum*

Produtividade do feijão-caupi sob estresse salino e uso de biofertilizantes e *Trichoderma harzianum*

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ABSTRACT - The use of biofertilizers associated with the use of *Trichoderma harzianum* applied to the soil can mitigate salt stress and maximize cowpea yield. In this context, the objective was to evaluate the use of brackish water and biofertilizers on the yield of the cowpea crop in soil with and without application of *T. harzianum*. The experiment was carried out between October and December 2022 in the field, in the experimental area of Piroás Farm, belonging to the University for International Integration of Afro-Brazilian Lusophony, in Redenção, Ceará, Brazil. The experimental design was randomized blocks, in a split-split-plot scheme, with four replicates, with two electrical conductivities of irrigation water (0.8 and 4.0 dS m^{-1}) in the plots, two types of biofertilizers of animal origin (cattle and poultry) in the subplots, and with and without application of *T. harzianum* in the sub-subplots. At 90 days after sowing, the dry pods were harvested and the following variables were evaluated: number of pods per plant, number of grains per pod, pod mass, mass of 100 grains, pod length and yield. The poultry biofertilizer partially mitigated the deleterious effects of salinity and promoted a greater number, length and mass of pods and yield of the cowpea crop. Salt stress had a negative effect, while poultry biofertilizer was more efficient for the mass of 100 grains. Application of *T. harzianum* mitigated salt stress and increased the number of grains per plant, pod length and yield of cowpea crop.

Keywords: *Vigna unguiculata* (L.). Salinity. Organic fertilizer. Microorganisms.

RESUMO - O uso de biofertilizantes associado ao uso de *Trichoderma harzianum* aplicado ao solo pode mitigar o estresse salino e maximizar a produtividade do feijoeiro. Neste sentido, objetivou-se avaliar o uso de água salobra e biofertilizantes na produtividade da cultura do feijão-caupi em solo com e sem aplicação de *T. harzianum*. O experimento foi realizado entre outubro e dezembro de 2022 em campo, na área experimental da Fazenda Piroás, da Universidade da Integração da Lusofonia Afro-Brasileira, Redenção, Ceará. O delineamento experimental foi em blocos ao acaso, em esquema de parcelas subsubdivididas, com quatro repetições, sendo as parcelas, duas condutividades elétricas na água de irrigação (0,8 e 4,0 dS m^{-1}), a subparcela, dois tipos de biofertilizantes de origem animal (bovino e aves) e a subsubparcela, com e sem *T. harzianum*. Aos 90 dias após a semeadura foi realizada a colheita das vagens secas e avaliadas as seguintes variáveis: número de vagens por plantas, número de grãos por vagens, massa de vagens, massa de cem grãos, comprimento de vagem e produtividade. O biofertilizante de aves amenizou parcialmente os efeitos deletérios da salinidade e proporciona maior número, comprimento e massa de vagens e produtividade da cultura do feijão-caupi. O estresse salino afetou negativamente, enquanto o biofertilizante de aves foi mais eficiente para a massa de cem grãos de feijão. A aplicação do *T. harzianum* atenuou o estresse salino e elevou o número de grãos por planta, o comprimento de vagem e a produtividade do feijão-caupi.

Palavras-chave: *Vigna unguiculata* (L.). Salinidade. Fertilizante orgânico. Microrganismos.

Conflict of interest: The authors declare no conflict of interest related to the publication of this manuscript.

Received for publication in: May 7, 2024.
Accepted in: July 25, 2025.

Editor in Chief: Aurélio Paes Barros Júnior
Section Editor: João Everthon da Silva Ribeiro

Data Availability: The data that support the findings of this study can be made available, upon reasonable request, from the corresponding author.

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INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp) is a legume crop native to the African continent, with great socioeconomic importance, being a direct source of employment for low-income populations in the North and Northeast regions of Brazil (ROCHA et al., 2019). It is a crop rich in proteins, fibers, and minerals, being of great social and economic importance, which makes it one of the most cultivated in the world (OLIVEIRA et al., 2023). The total cultivated area in Brazil in the 2024/25 season was approximately 2,784.8 ha, with a total production of 3,172 t and a national average yield of 1,139 kg ha^{-1}. In the state of Ceará, the average production was 3,229 thousand tons, with an average yield of 1,156 kg ha^{-1} (CONAB, 2025).

However, in semi-arid regions, as in the case of the Brazilian Northeast, which are characterized by low rainfall, insufficient to supply the potential evapotranspiration rate of plants (OLIVEIRA et al., 2023). For this reason, irrigation plays a fundamental role in the development of agriculture, in many situations becoming the only way to ensure security for agricultural production (HOLANDA et al., 2016); however, in some situations it is necessary to use brackish water to enable cultivation in these areas (GOES et al., 2021).

According to Minhas et al. (2020), the salinity of irrigation water is one of the main constraints on the global production of food and other products from agriculture, as its effects are particularly critical in semi-arid and arid regions. Excess salts in the soil solution reduce osmotic and water potential, physiological processes, and ion absorption, leading to a reduction in the yield of cultivated plants (SOUSA et al., 2023).

It should be noted that cowpea is considered moderately tolerant to salinity, with a threshold of 3.3 and 4.9 dS m^{-1} for the electrical conductivity of water and soil, respectively (AYERS; WESTCOT, 1999).

Some studies have been conducted to alleviate the deleterious effects of salt stress on plants. One strategy that has been shown to be efficient is the use of fertilization through liquid biofertilizers of animal origin (SOUSA et al., 2024). Santos et al. (2024) describe that bovine biofertilizer attenuated the effects of salts on soybean crop yield. Similarly, Sousa et al. (2023) found an increase in water use efficiency in peanut crop under salt stress, when using fertilization with bovine biofertilizer, demonstrating a mitigating effect against water salinity.

In addition, recent studies demonstrate that the use of microorganisms can also be an alternative to relieve salt stress (SANTOS et al., 2024; OLIVEIRA et al., 2024). The fungus *Trichoderma harzianum* associated with the use of organic fertilizers can favor greater translocation and solubility of mineral nutrients and promote improvements in crop yield (BARBOSA et al., 2024). Oliveira et al. (2024) reported mitigation of damage in peanut cultivation under salt stress (4.0 d S m^{-1}) with organic (bovine biofertilizers) and mineral (50 and 100% phosphorus) fertilizations associated with *Bacillus sp.*, which promoted greater water use efficiency and stem diameter.

In this context, the objective of this study was to evaluate the use of brackish water and biofertilizers on cowpea yield in soil with and without *T. harzianum* application.

MATERIAL AND METHODS

The experiment was carried out under field conditions between October and December 2022, at the Piroás experimental farm, belonging to the University for International Integration of Afro-Brazilian Lusophony (UNILAB), located in Redenção (4º9'19.39" S and 38º47'41.48" W), Ceará, Brazil. The climate of the region is BSh' type, with very high temperatures and rainfall predominating in the summer and autumn seasons (ALVARES et al., 2013).

Rainfall and maximum and minimum air temperatures were recorded daily throughout the experiment, as well as the average relative humidity (Figure 1), monitored by means of a data logger (HOBO® U12-012 Temp/RH/Light/Ext).

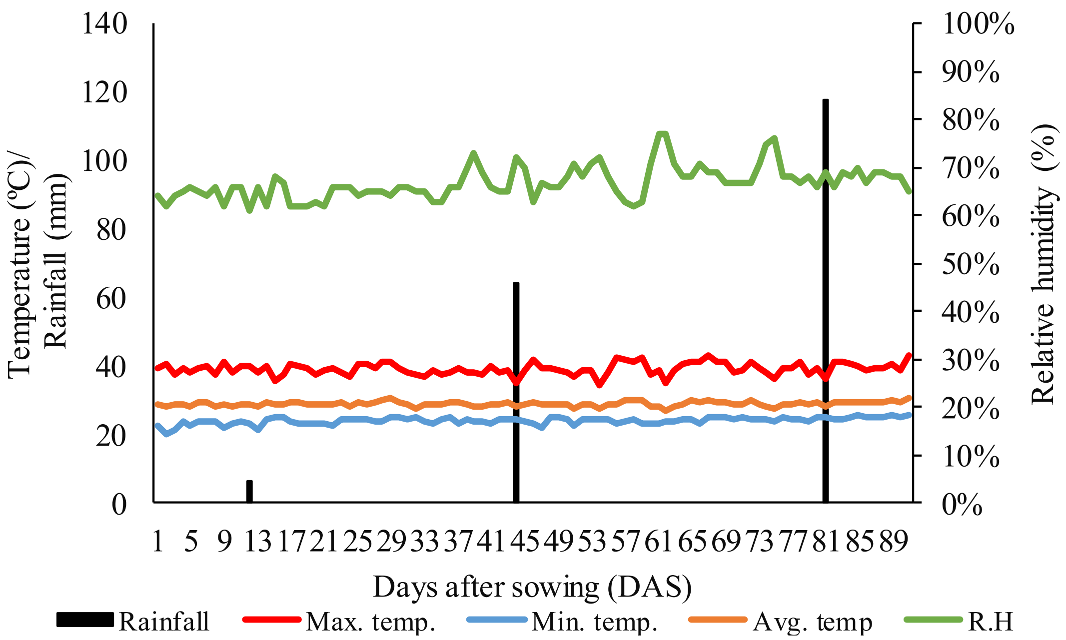

Figure 1. Mean values of temperature and relative humidity during the experimental period.

The experimental design was randomized blocks, in a split-split-plot scheme, with four replicates, with two electrical conductivities of irrigation water (0.8 and 4.0 dS m^{-1}) in the plots, two types of biofertilizers of animal origin (cattle and poultry) in the subplots, and with and without application of *T. harzianum* in the sub-subplot.

The soil present in the study area is classified as *Argissolo vermelho-amarelo* (Ultisol) with a sandy loam texture (SANTOS et al., 2018). Before the experiment, soil samples were collected to form a composite sample, which was sent to the laboratory to determine the chemical attributes (Table 1), following the methodology described by Silva (1999).

Table 1. Chemical attributes of the soil used before application of the treatments.

Chemical characteristics									
OM	N	P	K	Mg	Ca	Na	pH	ESP	ECse
g kg^{-1}	g kg^{-1}	mg kg^{-1}	g kg^{-1}	------------ cmol$_c$ dm^{-3} ------------				%	dS m^{-1}
12.52	0.79	14	0.14	2.5	5.2	0.18	5.6	2	0.9

OM = Organic matter. ESP = exchangeable sodium percentage. ECse = electrical conductivity of soil saturation extract.

Cowpea (*Vigna unguiculata* (L)) seeds, from a native variety of the region (Rabo de Soin), were sown manually by planting four seeds per hole, at a spacing of 1.0 x 0.3 m between planting rows and between plants, respectively. At 10 days after sowing (DAS), thinning was carried out with the established plant stand, leaving one plant per hole.

Cowpea plants were fertilized using organic sources (poultry and bovine biofertilizers), which were prepared using fresh cattle and poultry manure, adding water in the proportion of 1:1 (volume/volume ratio) for each biofertilizer, stored in plastic reservoirs and left to ferment aerobically for 30 days. Samples were collected and sent to the laboratory for chemical characterization, following the methodology of Silva (1999) (Table 2).

Table 2. Chemical characterization of the biofertilizers used.

	N	P	K	Ca	Mg	Fe	Cu	Zn	Mn
Biofertilizers	------------------------------ (g L^{-1}) ------------------------------					---------------------- (mg L^{-1}) ------------------------			
Poultry	0.23	0.03	3.83	0.06	0.08	17.90	0.96	2.88	2.54
Cattle	0.20	0.11	2.30	0.07	0.07	11.87	0.83	3.34	5.02

Fertilization with organic sources was complemented with the maximum recommendation of chemical fertilization by Melo and Cardoso (2017) for cowpea, which corresponded to 30 kg ha^{-1} of N, 60 kg ha^{-1} of P_2O_5 and 30 kg ha^{-1} of K_2O, considering the results of soil analysis (Table 1) and analysis of the biofertilizers (Table 2).

According to the spacing used (0.3 m x 1.0 m), with a stand of 33,333 plants ha^{-1}, the maximum nutrient dose per plant^{-1} cycle^{-1} was: 0.9 g of N, 1.8 g of P_2O_5 and 0.9 g of K_2O, respectively. The biofertilizers were applied manually in an open furrow 15 cm away from the planting row.

The microorganism used in the experiment was *T. harzianum* (ESALQ 1306 strain), a commercial product (Trichodermil). The product was applied via soil, according to the manufacturer's recommendation (2 kg ha^{-1}), always in the late afternoon.

Public-supply water (control treatment – 0.8 dS m^{-1}) was stored in 500 L water tanks and used to prepare the 4.0 dS m^{-1} saline solution, which was prepared with sodium chloride (NaCl), calcium chloride ($CaCl_2.2H_2O$) and magnesium chloride ($MgCl_26H_2O$), maintaining an equivalent ratio of 7:2:1 (RHOADES; KANDIAH; MASHALI, 2000), following the relationship between ECw and the molar concentration (mmol$_c$ L^{-1} = ECw x 10).

Irrigation was applied by a drip system, with drippers spaced 0.3 m apart, which corresponded to one dripper per plant with a flow rate of 8 L h^{-1}. The distribution uniformity coefficient (DUC) was 92%. Irrigation management was estimated daily by reference evapotranspiration, using data from a Class A evaporation pan. Crop evapotranspiration, in mm day^{-1}, was calculated from the evaporation measured in the Class A pan, according to Equation 1.

$$ETc = ECA \ x \ Kp \ x \ Kc \qquad (1)$$

Where:
ETc - Crop evapotranspiration, in mm day^{-1};
ECA - Evaporation measured in the Class A pan, in mm day^{-1};
Kp - Coefficient of the Class A pan, dimensionless; and
Kc - Crop coefficient, dimensionless.

The following crop coefficients (Kc) were adopted: 0.71 (up to 12 days after sowing - DAS); 0.81 (from 13 to 33 DAS); 1.22 (from 34 to 54 DAS) and 0.77 (from 55 DAS to the end of the cycle) (SOUZA; BEZERRA; TEÓFILO, 2005). Irrigation time was obtained from Equation 2:

$$\mathrm{Ti} = \frac{ETc \ x \ Sp}{Ea \ x \ q} x \ 60 \qquad (2)$$

Where:
Ti - Irrigation time (min);
ETc - Crop evapotranspiration in the period (mm);
Sp - Spacing between drippers;
Ea - Application efficiency (0.92);
q - flow rate (L h^{-1}).

A leaching fraction of 0.15 was added to the applied depth (AYERS; WESTCOT, 1999) and, until the establishment of the plant stand, the experiment was irrigated daily with public-supply water from the farm (0.8 dS m^{-1}). After this period, at 10 DAS, brackish water of 4.0 dS m^{-1} began to be applied.

At the end of the crop cycle, the harvested pods were subjected to natural drying and the following variables were evaluated: number of pods per plant (NPP) and number of grains per pod (NGP), obtained by direct counting the units; pod dry mass (PDM, g) and mass of 100 grains (M100g), determined on a 0.01 g precision scale; and yield (YLD - expressed in kg ha^{-1}).

To assess normality, the data were subjected to the Kolmogorov-Smirnov test ($p \leq 0.05$). Next, the data were subjected to analysis of variance (ANOVA) and, when significant by the F test, they were subjected to means comparison test, Tukey test ($p \leq 0.05$), using ASSISTAT 7.7 Beta software (SILVA; AZEVEDO, 2016).

RESULTS AND DISCUSSION

There was an interaction between the combined treatments of irrigation water and biofertilizers for the following variables: number of pods per plant (NPP), pod dry mass (PDM) and yield (YLD). On the other hand, the mass of 100 grains (M100g) was individually affected by irrigation water and biofertilizers, while the number of grains per pod (NGP) and yield (YLD) were influenced by the interaction between irrigation water and *T. harzianum* (Table 3).

Table 3. Summary of the analysis of variance for yield components (number of pods per plant (NPP), pod dry mass (PDM), number of grains per pod (NGP), mass of 100 grains (M100g), pod length (PL) and yield (YLD) in cowpea irrigated with brackish water and under the use of *Trichoderma harzianum* and biofertilizers.

SV	DF	Mean square					
		NPP	PDM	NGP	M100g	PL	YLD
Blocks	3	18.00^{ns}	91.82^{ns}	16.47^{ns}	3.39^{ns}	3457.38^{**}	280461.05^{*}
Salinity (S)	1	48.00^{ns}	377.29^{ns}	72.52^{**}	50.93^{*}	5380.28^{ns}	10168911.82^{*}
Residual (S)	3	13.6	66.75	3.57	4.62	184.64	64170.63
Plots	7						
Biofertilizer (B)	1	14.08^{*}	36.60^{ns}	11.02^{ns}	21.36^{*}	84.22^{ns}	47363.38^{ns}
S x B	1	24.08^{**}	86.57^{*}	13.02^{ns}	11.28^{ns}	5275.48^{ns}	5789498.82^{*}
Residual (B)	6	1.58	7.76	3.62	3.42	515.07	204797.11
Subplots	15						
Trichoderma (T)	1	10.08^{ns}	20.18^{ns}	13.02^{ns}	3.33^{ns}	684.53^{ns}	356410.79^{ns}
S x T	1	0.75^{ns}	15.67^{ns}	28.52^{*}	5.78^{ns}	3999.15^{ns}	1956976.15^{**}
B x T	1	8.33^{ns}	47.70^{ns}	2.52^{ns}	0.81^{ns}	317.73^{ns}	729357.36^{ns}
S x B x T	1	0.33^{ns}	4.87^{ns}	11.02^{ns}	2.70^{ns}	311.33^{**}	358814.51^{ns}
Residual (T)	12	4.03	17.05	5.27	4.13	591.57	78854.68
Total	31						
CV - S (%)		27.05	75.8	17.82	18.81	27.4	10.43
CV - B (%)		22.88	25.84	17.94	16.18	32.46	18.64
CV - T (%)		26.48	28.31	21.65	17.78	26.94	11.57

SV – source of variation; DF – degrees of freedom; CV – coefficient of variation; ns – not significant; ** and * – significant at 0.01 and 0.05 by Tukey test, respectively.

For the number of pods per cowpea plant, there was no significant difference between the biofertilizers used when plants were irrigated with lower-salinity water (0.8 dS m^{-1}); however, the treatment with brackish water and poultry biofertilizer showed an increment of 76.92% when compared to the use of bovine biofertilizer (Figure 2A).

This superiority may be related to the higher supply of nutrients (N and K) of the poultry biofertilizer, as shown in Table 2, directly assisting in the osmotic and stomatal adjustment of plants under salt stress, that is, possibly causing greater accumulation of organic solutes by plants and less water loss through transpiration (BARBOSA et al., 2024), favoring the absorption of water and nutrients in a saline environment.

Pod dry mass followed the same trend as the number of pods per plant, with an increase of 76.91% obtained with the poultry biofertilizer compared to the bovine biofertilizer, when associated with water of higher salinity (4.0 dS m^{-1}) (Figure 2B). This result may be associated with the greater nutritional supply of the poultry biofertilizer, in addition to the ability to improve the environment through a possible greater capacity to release humic substances, mitigating salt stress more satisfactorily (FREIRE et al., 2022), promoting greater pod mass.

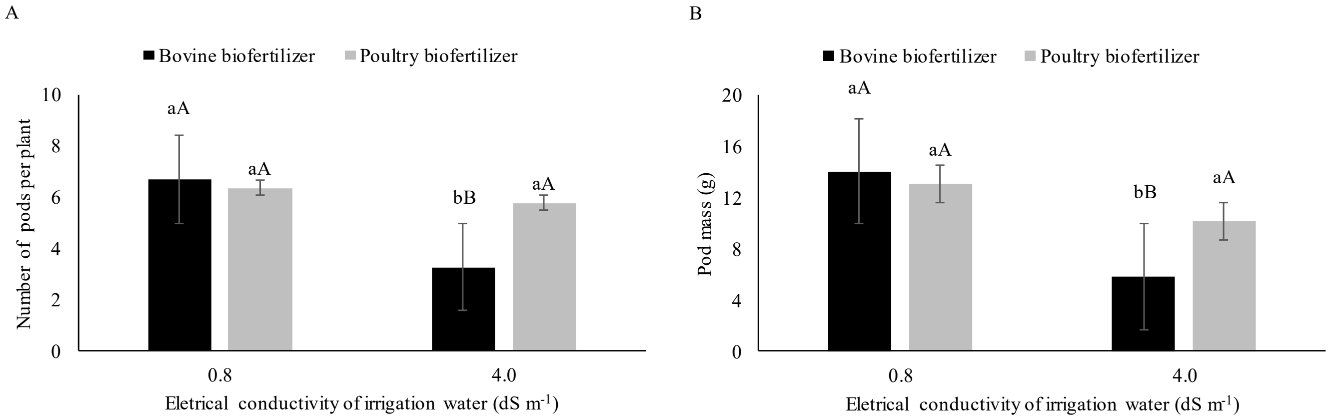

Figure 2. Number of pods (A) and pod mass (B) per plant of cowpea under levels of electrical conductivity of irrigation water and biofertilizer. Uppercase letters compare means between biofertilizers for the same electrical conductivity, while lowercase letters compare means between electrical conductivities for the same biofertilizers, using Tukey test ($p \leq 0.05$); vertical bars represent standard error (n=4).

A result contrasting with that of the present study was reported by Sousa et al. (2023), who found a higher pod mass in peanut crop irrigated with brackish water of 5.0 dS m^{-1}, under fertilization with bovine biofertilizer (1.0 L/plant weekly). Santos et al. (2024), when using bovine biofertilizer for fertilization in soybean crop under salt stress (4.0 d S m^{-1}), also found higher pod mass compared to treatment with 100% fertilization for NPK recommendation.

For the number of grains per pod, there was an effect of the interaction between different electrical conductivities of irrigation water in the presence and absence of *T. harzianum*. Irrigation water with a concentration of 0.8 dS m^{-1} led to no significant difference, but under irrigation water with a salt concentration of 4.0 dS m^{-1}, the presence of *T. harzianum* led to higher values (11 grains per pod) and differed statistically from the control treatment (Figure 3).

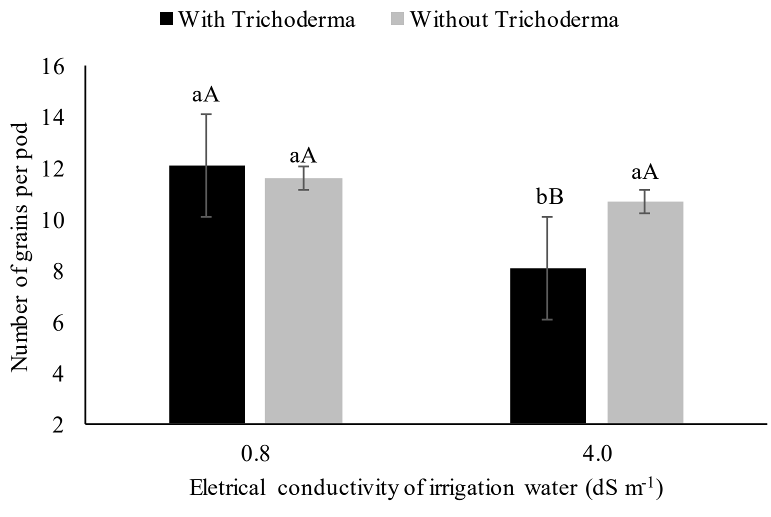

Figure 3. Number of grains per pod in cowpea plants under different levels of electrical conductivity of irrigation water and use of *T. harzianum*. Uppercase letters compare means between the treatments with and without *T. harzianum* for the same electrical conductivity, while lowercase letters compare means between electrical conductivities for the same treatment with or without *T. harzianum*, by Tukey test ($p \leq 0.05$); vertical bars represent standard error (n=4).

This decrease in the number of grains stood out for the deleterious effect of water salinity caused by osmotic imbalance, making it difficult to absorb water and nutrients due to the increase in salts in the soil, which reduces the external water potential (SOUSA et al., 2022). Li et al. (2024) state that fungi of the genus *Trichoderma* can promote the release of macronutrients such as nitrogen by the process of nitrification and nitrogen fixation, which plays a fundamental role in the performance of the number of grains.

Oliveira et al. (2023), in a study evaluating the use of inoculants containing the strains of different lines (BR 3267 (SEMIA 6462) and BR 3262 (SEMIA 6464)) of rhizobia recommended for cowpea in a semi-arid environment, recorded 11.46 for the number of grains of the BRS Tumucumaque cultivar in the first harvest.

Plants irrigated with water of 0.8 dS m^{-1} had statistically superior values (12.46 g), compared to those irrigated with saline water of 4.0 dS m^{-1} (10.4 g) for the mass of 100 grains (Figure 4A). Salt stress causes a reduction in the photosynthetic rate, resulting in a lower production of photoassimilates, which would be transferred and accumulated in the pods, resulting in grains with lower mass (RIBEIRO et al., 2022). A similar trend to that found in the present study was described by Veras et al. (2018), who observed a reduction in the mass of 100 grains in cowpea plants subjected to salt stress (4.0 d S m^{-1}).

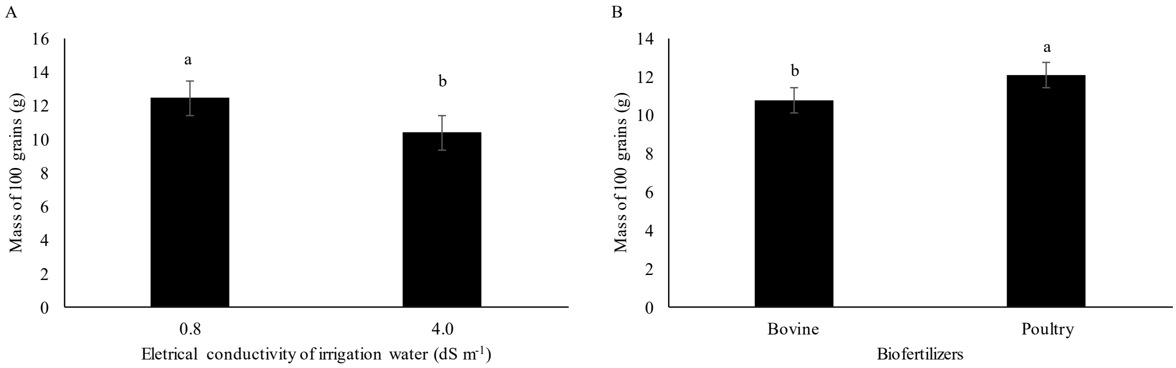

Figure 4. Mass of 100 grains of cowpea under levels of electrical conductivity of irrigation water (A) and bovine and poultry biofertilizers (B). Means followed by different letters differ from each other by Tukey test, at 5% probability level; vertical bars represent standard error (n=4).

Regarding the use of biofertilizers, poultry biofertilizer promoted higher mean values of mass of 100 grains (12.1 g), differing statistically from bovine biofertilizer (10.77 g) (Figure 4B). This effect may be related to the nutritional support contained in this organic input, especially in N and K (Table 2), essential for a higher production performance of cowpea crop grown under field conditions (PRADO, 2020). During the reproductive phase, N contributes to the synthesis of proteins and substances in which they are translocated for the formation and development of new reserve organs that increase the individual weight of grains (GONZAGA et al., 2024). Potassium helps in the activation of enzymes that participate in the processes of photosynthesis and respiration and in the synthesis of proteins and carbohydrates, growth and seed formation, contributing to the magnitude of the increment and the quality of the grains (COSTA et al., 2023).

The use of bovine biofertilizer associated with the use of water with lower salinity, 0.8 dS m^{-1}, and with application of *T. harzianum* led to higher pod length (18.64 cm), being statistically superior to poultry biofertilizer (16.82 cm). However, under salt stress (4.0 dS m^{-1}), the bovine biofertilizer in the presence of the microorganism was inferior (16.23 cm) to the absence (17.67 cm), and the poultry biofertilizer together with *T. harzianum* led to higher pod length (18.18 cm) (Figure 5).

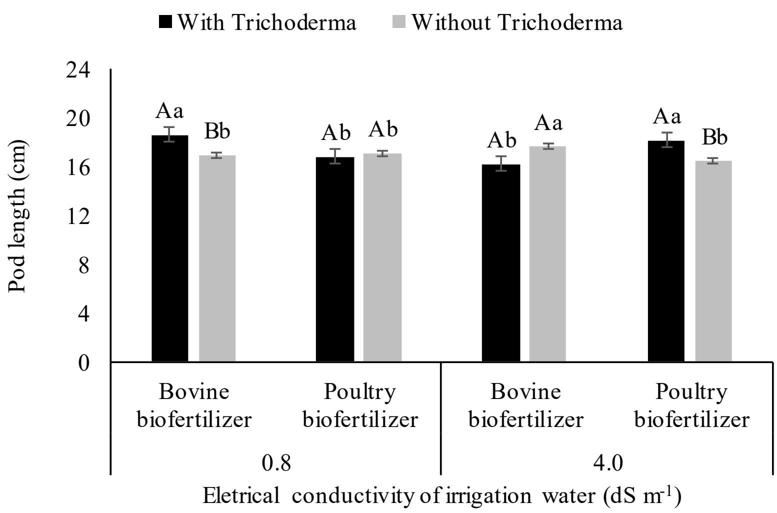

Figure 5. Pod length of cowpea under levels of electrical conductivities of irrigation water, use of biofertilizers, with and without *T. harzianum*. Uppercase letters compare means between the treatments with or without *T. harzianum* for the same electrical conductivity and biofertilizer, while lowercase letters compare means between biofertilizers for the same electrical conductivity and with or without *T. harzianum* by Tukey test (p≤ 0.05). Vertical bars represent the standard error (n=4).

Oliveira et al. (2015), in a study carried out with cowpea crop, verified a quadratic fit for pod length under the irrigation water salinity factor, whose highest value (17.5 cm) was obtained at salinity level of 1.25 dS m^{-1} and showing a decrease as the levels increased. These same authors found a reduction in pod length, but with less intensity in the presence of bovine biofertilizer, demonstrating a mitigating effect. Similarly, Santos et al. (2024) also recorded a higher mean length of soybean pod when using irrigation water with electrical conductivity of 0.3 dS m^{-1}, under fertilization with bovine biofertilizer.

The use of water with a salinity level of 0.8 dS m^{-1} associated with bovine biofertilizer promoted the highest yield, corresponding to 3378.59 kg ha^{-1}, compared to poultry biofertilizer, 2604.84 kg ha^{-1}, which was statistically superior to bovine biofertilizer, 1400.46 kg ha^{-1}, when using water with salinity level of 4.0 dS m^{-1}, promoting yield of 2328.09 kg ha^{-1} (Figure 6A). This organic input can provide favorable conditions for the development of microorganisms during its fermentation and release them into the soil solution and thus attenuate the effect of salts (FREIRE et al., 2022).

In line with the present study, Sousa et al. (2024) reported that, although brackish water of 5.0 dS m^{-1} reduced yield components of the peanut crop, fertilization with 100% bovine biofertilizer led to higher yield (93.78 g pot^{-1}) compared to the other treatments (100% NPK; 100% vegetable ash, 50% NPK + 50% bovine biofertilizer and 50% NPK + 50% vegetable ash), reinforcing the beneficial effect of fertilization with bovine biofertilizer. Similarly, Santos et al. (2024) also found a beneficial effect of bovine biofertilizer on the productive aspect of soybean crop, evidenced with the use of water with lower salinity (0.3 d S m^{-1}).

Irrigation using water with electrical conductivity of 0.8 d S m^{-1} associated with the use of *T. harzianum* promoted higher yield (3133.47 kg ha^{-1}) compared to the treatment without the microorganism with a salinity level of 4.0 dS m^{-1} (1511.45 kg ha^{-1}) (Figure 6B). In contrast to this study, Barbosa et al. (2024) obtained higher efficiency of yield and quality of beet crop under the lowest electrical conductivity of water (0.5 dS m^{-1}), and absence of *T. harzianum*.

Similarly, Sheta et al. (2024) found higher grain yield in cowpea plants irrigated with lower salinity water (0.75 dS m^{-1}). On the other hand, Guimarães et al. (2023) found reduction in the grain yield of cowpea cultivars with the increase in irrigation water salinity levels, equal to 18.97 and 56.92% at 1.5 and 4.5 dS m^{-1}, respectively.

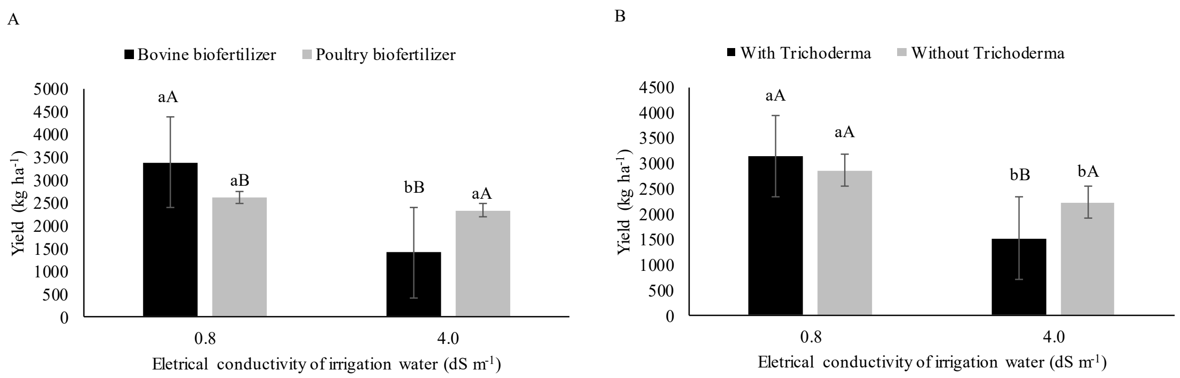

Figure 6. Yield of cowpea under levels of electrical conductivity of irrigation water and use of biofertilizers (A) with and without *T. harzianum* (B). Uppercase letters compare means between biofertilizers for the same electrical conductivity, while lowercase letters compare means between electrical conductivities for the same biofertilizers, using Tukey test ($p \leq 0.05$) (A); Uppercase letters compare means between the treatments with and without *T. harzianum* for the same electrical conductivity, while lowercase letters compare means between electrical conductivities for the same treatment with or without *T. harzianum* (B), by Tukey test ($p \leq 0.05$); vertical bars represent standard error (n=4).

CONCLUSIONS

Poultry biofertilizer mitigated the deleterious effects of salinity and promoted a higher number of pods per plant, pod length, pod mass and yield of cowpea crop.

Salt stress of 4.0 dS m^{-1} negatively affected cowpea, while poultry biofertilizer was more efficient for the mass of 100 grains.

Application of *Trichoderma harzianum* attenuated salt stress and increased the number of grains per plant, pod length and yield of cowpea.

Under salt stress (4.0 dS m^{-1}), poultry biofertilizer showed a superior mitigating effect compared to *Trichoderma harzianum*, promoting higher yield of cowpea, being recommended for the crop in saline environments.

REFERENCES

ALVARES, C. A. et al. Köppen's climate classification map for Brazil. **Meteorologische Zeitschrift**, 22: 711-728, 2013.

AYERS, R. S.; WESTCOT, D. W. **A qualidade da água na agricultura**. Campina Grande, PB: UFPB. Tradução de GHEYI, H. R.; MEDEIROS, J. F.; DAMASCENO, F. A. V., 1999. 153 p. (Estudos FAO: Irrigação e Drenagem, 29. Revisado 1).

BARBOSA A. S. et al. Brackish water, phosphate fertilization and *Trichoderma* in the agronomic performance of beet crops. **Agronomy**, 14: 1306, 2024.

CONAB - Companhia Nacional de Abastecimento.

Acompanhamento da Safra Brasileira de Grãos, Brasília, DF, v. 12, safra 2024/25, n. 9 nono levantamento, junho 2025. Available at: https://www.gov.br/conab/pt-br/atuacao/informacoes-agropecuarias/safras/safra-de-graos/boletim-da-safra-de-graos/9o-levantamento-safra-2024-25/9o-levantamento-safra-2024-25. Access on: Jun. 19, 2025.

COSTA, K. S. Q. et al. Growth and production of cowpea beans under potassium doses in soil of cerrado in Amapá, Brazil. **Brazilian Journal of Biology**, 83: e273777, 2023.

FREIRE, M. H. C. et al. Organic fertilization and salt stress on the agronomic performance of maize crop. **Revista Brasileira de Engenharia Agrícola e Ambiental**, 26: 848-854, 2022.

GOES, G. F. et al. Produtividade da cultura do amendoim sob diferentes supressões da irrigação com água salina. **Irriga**, 26: 210-220, 2021.

GONZAGA, A. C. O. et al. Late additional application of nitrogen in common bean genotypes affecting grain yield and quality. **Revista de Ciências Agro-Ambientais**, 22: 99-105, 2024.

GUIMARÃES, D. G. et al. Efeito da salinidade na água de irrigação em cultivares de feijão-caupi. **Revista em Agronegócio e Meio Ambiente**, 16: 1-18, 2023.

HOLANDA, J. S. et al. Qualidade da água para irrigação. In: GHEYI, H. R. et al. (Eds.). **Manejo da salinidade na agricultura**: estudos básicos aplicados. Fortaleza, CE: INCTSal, 2016. s/v, cap. 4, p. 43-59.

LI, Y. et al. *Trichoderma* Rhizosphere Soil Improvement: regulation of nitrogen fertilizer in saline–alkali soil in semi-arid region and its effect on the microbial community structure of maize roots. **Agronomy**, 14: 2340, 2024.

MELO, F. B.; CARDOSO, M. J. **Feijão. Cultivo de feijão caupi: solo e adubação**. Brasília, DF: Embrapa Informação Tecnológica, 2017. 9 p.

MINHAS, P. S. et al. Coping with salinity in irrigated agriculture: Crop evapotranspiration and water management issues. **Agricultural Water Management**, 227: 1-22, 2020.

OLIVEIRA, F. A. et al. Produção de feijão caupi em função da salinidade e regulador de crescimento. **Revista Brasileira de Engenharia Agrícola e Ambiental**, 17: 1049-1056, 2015.

OLIVEIRA, G. S. et al. Phosphate fertilization biofertilizer and *Bacillus* sp. in peanut cultivation under salt stress. **Revista Brasileira de Engenharia Agrícola e Ambiental**, 28: e279003, 2024.

OLIVEIRA, P. R. H. et al. Agronomic performance of cowpea cultivars inoculated with rhizobia in the brazilian semiarid region. **Revista Caatinga**, 36: 785-793, 2023.

PRADO, R. M. **Nutrição de plantas**. 2. ed. São Paulo, SP: UNESP, 2020. 416 p.

RHOADES, J. D.; KANDIAH, A.; MASHALI, A. M. **Uso de águas salinas para produção agrícola**. Campina Grande, PB: UFPB, 2000. 117 p. (Estudos FAO Irrigação e Drenagem, 48).

RIBEIRO, R. M. R. et al. Irrigation strategies with saline water and phosphate fertilization in cowpea culture. **Revista Brasileira de Ciências Agrárias**, 17: e2572, 2022.

ROCHA, D. F. et al. Desempenho do feijão-caupi a densidades de plantas na região Norte da Bahia. **Agropecuária Técnica**, 40: 48-54, 2019.

SANTOS, H. G. et al. **Sistema brasileiro de classificação de solos**. 5. ed. Brasilia, DF: Embrapa Informação Tecnológica, 2018. 355 p.

SANTOS, S. O. et al. *Bacillus* sp., fertilization forms, and salt stress on soybean production. **Revista Brasileira de Engenharia Agrícola e Ambiental**, 28: e272029, 2024.

SHETA, M. H. et al. Green synthesis of zinc and iron nanoparticles using Psidium guajava leaf extract stimulates cowpea growth, yield, and tolerance to saline water irrigation. **Horticulturae**, 10: 15, 2024.

SILVA, F. A. S.; AZEVEDO, C. A. V. The Assistat Software Version 7.7 and its use in the analysis of experimental data. **Africal Journal of Agriculture Research**, 11: 3733-3740, 2016.

SILVA, F. C. **Manual de análises químicas de solos, plantas e fertilizantes.** Brasília, DF: Embrapa Comunicação para Transferência de Tecnologia, 1999. 370 p.

SOUSA, G. G. et al. Organomineral fertilization and salt stress on the agronomic performance of peanut crop. **Revista Brasileira de Ciências Agrárias**, 19: e3478, 2024.

SOUSA, H. C. et al. Gas exchange and growth of zucchini crop subjected to salt and water stress. **Revista Brasileira de Engenharia Agrícola e Ambiental**, 26: 815-822, 2022.

SOUSA, J. T. M. et al. Desempenho agronômico de genótipos de amendoim sob estresse salino e diferentes formas de adubação. **Revista em Agronegócio e Meio Ambiente**, 16: 1-17, 2023.

SOUZA, M. S. M.; BEZERRA, F. M. L.; TEÓFILO, E. M. Coeficientes de cultura do feijão caupi na região litorânea do Ceará. **Irriga**, 10: 241-248, 2005.

VERAS, M. L. M. et al. Morphophysiological responses of cowpea to irrigation with saline water and application of bovine biofertilizer. **Comunicata Scientiae**, 9: 509-518, 2018.