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Original Article

Accumulation and exportation of macronutrients by peanut crops under pulse irrigation with brackish water[1]

Acúmulo e exportação de macronutrientes pelo amendoim irrigado por pulsos e água salobra

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HIGHLIGHTS:

Nutrient accumulation and exportation by peanut crops decrease under high salinity levels.
High salinity levels increase Na^+ and Cl^- accumulation in peanut leaves.
Pulse irrigation mitigates the harmful effects of nutritional disorders caused by saline water.

ABSTRACT: High salinity levels trigger harmful effects on plant mineral nutrition, causing production losses. The objective of this study was to evaluate effects of using pulse or continuous drip irrigation with brackish water on the accumulation and exportation of nutrients in peanut (*Arachis hypogaea*) crops. A randomized block experimental design with four replications was used, in a 6×2 factorial arrangement consisting of six levels of electrical conductivity of irrigation water (ECw: 0.2, 1.6, 2.8, 4.0, 5.2, and 6.4 dS m^{-1}) and two irrigation regimes (pulse and continuous). Accumulation and exportation of macronutrients, sodium, and chloride were quantified at 63 days after sowing. Pulse irrigation mitigated the harmful effects of high salinity levels on peanut crops and promoted greater nutrient accumulation by plants compared to continuous irrigation. The descending order of nutrient accumulation by plants under pulse and continuous irrigation was: K > N > Ca > Mg > P > S. Pulse irrigation is effective in mitigating the detrimental effects of using brackish water on peanut crops.

Key words: *Arachis hypogaea*, salinity, nutritional disorder, water management, nutritional management

RESUMO: A salinidade desencadeia uma série de efeitos nocivos na nutrição mineral das plantas, o que causa perda na produção. O objetivo deste estudo foi avaliar os efeitos do uso de água salobra com irrigação por gotejamento por pulso e contínua no acúmulo de nutrientes na cultura de amendoim (*Arachis hypogaea*). O delineamento experimental utilizado foi o de blocos casualizados sob esquema fatorial (6 × 2), constituído por seis níveis de condutividade elétrica da água de irrigação (CEa: 0,2; 1,6; 2,8; 4,0; 5,2 e 6,4 dS m^{-1}) e dois tipos de manejo da irrigação (por pulsos e contínua) com quatro repetições. Após 63 dias de semeadura, o acúmulo e a exportação de macronutrientes, sódio e cloro foram quantificados. A irrigação por pulso mitigou os efeitos deletérios da salinidade sobre a cultura do amendoim e proporcionou um maior acúmulo de nutrientes pela cultura em relação a irrigação contínua. A ordem decrescente de acúmulo de nutrientes pelas plantas sob irrigação por pulso e contínua foi: K > N > Ca > Mg > P > S. A irrigação por pulso é eficaz para mitigar os efeitos do uso de água salobra na cultura do amendoim.

Palavras-chave: *Arachis hypogaea*, salinidade, desordem nutricional, manejo de água, manejo nutricional

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Introduction

Peanut (*Arachis hypogaea* L.) is native to South America and one of the four most widely cultivated oilseed crops; it is an important source of nutrients, especially for populations at risk of food insecurity (USDA, 2020). The use of brackish water negatively affects plant physiology and development (Figueiredo et al., 2019). According to Ayers & Westcot (1991), the soil salinity threshold for peanut crops is 3.2 dS m^{-1}. Nutritional disorders in plants can be caused by impacts on nutrient availability, competitiveness, and transport in the plant, as well as the physiological inactivation of nutrients caused by high salinity levels in the soil solution (Ferreira et al., 2005).

Pulse drip irrigation is a recently developed irrigation method that optimizes water and fertilizer applications (Menezes et al., 2020). This method has been used worldwide, as it has positive effects, such as increasing crop yields, improving plant quality, saving water by reducing emitter clogging, and consequently, reducing energy consumption (Cruz et al., 2021).

In pulse irrigation, soil moisture is maintained for a longer time compared to other methods, resulting in lower salinity levels in the crop rhizosphere and mitigating the deleterious effects of salts (Assouline et al., 2006). Recent studies have shown positive results of pulse drip irrigation for agricultural production and the nutritional status of crops (Menezes et al., 2020; Zamora et al., 2021). Thus, the objective of this study was to evaluate effects of using pulse or continuous drip irrigation with brackish water on nutrient accumulation and exportation in peanut (*Arachis hypogaea*) crops.

Material and Methods

The study was conducted from September to November 2019, in an open field of the experimental area of the Departamento de Engenharia Agrícola of Universidade Federal Rural de Pernambuco, Sede campus, Recife, PE, Brazil (08° 01’ 05” S and 34° 56’ 48” W, and an average altitude of 6.5 m). The region’s climate was classified as As” or Ams”, tropical rainy, according to the Köppen classification, with a rainy season from April to July (Silva et al., 2012).

Meteorological data (Figure 1) of the experimental area during the experiment were collected from an automatic weather station at an adjacent area. The accumulated rainfall depth from crop sowing to harvest totaled 103.7 mm.

The soil used in the lysimeters was classified as a Spodosol, according to the United States Department of Agriculture (USDA, 1999), and as Espodossolo, according to the Brazilian Soil Classification System (SIBICS) (Santos et al., 2013). The analysis of the 0-40 cm soil layer before implementing the experiment showed a sandy texture, bulk density of 1.50 kg dm^{-3}, and particle density of 2.65 kg dm^{-3}.

Soil water storage limits were measured in a Richards pressure chamber. The values obtained were 0.033 m^3 m^{-3} and 0.022 m^3 m^{-3} for field capacity (10 kPa) and permanent wilting point (1,500 kPa), respectively.

A chemical characterization of the soil used in the experiment was carried out before the experiment was implemented (Table 1). The water used in the experiment had a pH of 6.3, electrical conductivity of 0.2 dS m^{-1}, and was classified as C_1S_1 (good quality water) (Richards, 1954).

Soil fertilizers (N, P, K) were applied for planting the peanut crops, applying 15 kg ha^{-1} of N, using ammonium sulfate as source (partial saline index of 3.25); 80 kg ha^{-1} of P_2O_5, using

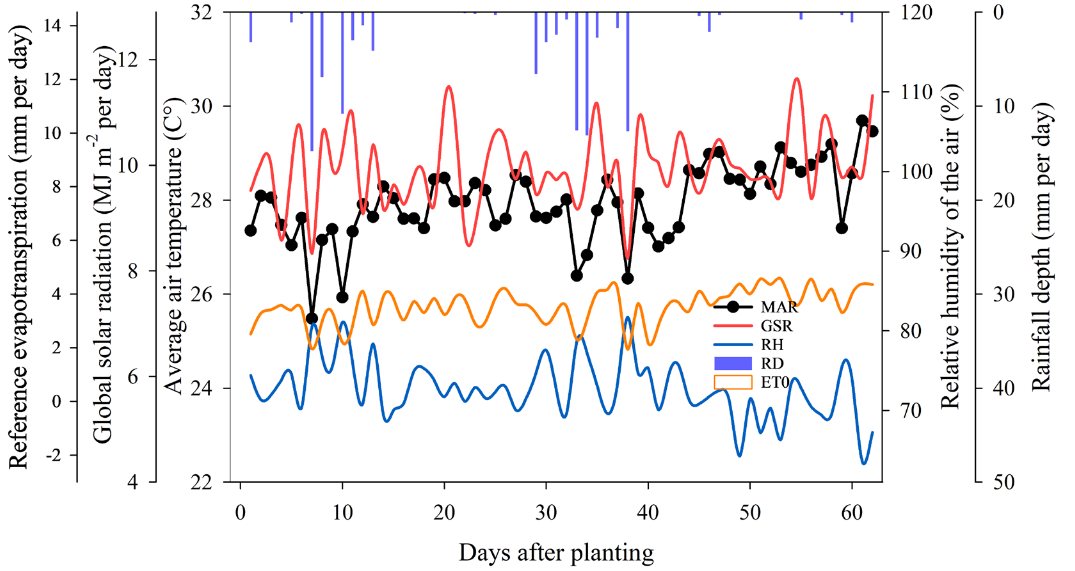


Figure 1. Rainfall depth (RD), mean air temperature (MAR), relative air humidity (RH), reference evapotranspiration (ET0), and global solar radiation (GSR) in the experimental area from September 12 to November 14, 2019

Table 1. Chemical characterization of the soil used in the experiment

pH	P	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Al^{+3}	$H^{+}+Al^{+3}$	SB	CEC	CECe	Cu	Fe	Mn	Zn	BS	OM
H_2O	(mg dm^{-3})	($cmol_c$ dm^{-3})									(mg dm^{-3})				(%)	(g kg^{-1})
6.5	5.03	1.75	0.55	0.08	0.07	0	0.69	2.45	3.14	2.45	0.1	4	4.1	1.3	78.03	5.53

SB - Sum of bases; CEC - Cation exchange capacity; CECe - Effective cation exchange capacity; BS - Base saturation; OM - Organic matter simple superphosphate as source (partial saline index of 0.43); and 30 kg ha^{-1} of K_2O, using potassium chloride as source (partial saline index of 1.94).

Fifteen days after emergence of the plants (DAE), fertilizers were applied to the soil surface layer, using 15 kg ha^{-1} of N and 30 kg ha^{-1} of K_2O. Micronutrients were supplied through application of a foliar fertilizer (Amino Agross; 150 mL $100L^{-1}$ water) at 20 days after sowing, following the manufacturer's recommendations for peanut crops. The composition of this product was (g L^{-1}): 79.80 organic carbon; 2.66 B, 13.3 Ca, 10.64 P, 6.65 Mg, 66.5 N, 66.5 K, 2.66 Cu, 10.2 Fe, 7.98 Mn, and 13.3 Zn.

A randomized block experimental design with four replications was used, in a 6 × 2 factorial arrangement consisting of six levels of electrical conductivity of irrigation water (ECw: 0.2, 1.6, 2.8, 4.0, 5.2, and 6.4 dS m^{-1}) and two irrigation regimes (pulse and continuous), totaling 48 experimental plots. The ECw levels were arranged to provide equidistant intervals up to the highest ECw. The highest ECw established was two-fold the water salinity threshold (Ayers & Westcot, 1991), which is 3.2 dS m^{-1}.

The experimental area measured 38 m in length and 10.5 m in width, comprising 48 drainage lysimeters with a capacity of 240 L each. The lysimeters arranged in equidistant rows with 1.0 m spacing between them. The drainage system consisted of a half-inch water hose adapter at the bottom of each lysimeter. The established ECw levels were obtained by adding sodium chloride (NaCl) to the public supply water (ECw = 0.2 dS m^{-1}) and measured using a conductivity meter. The control treatment (0.2 dS m^{-1}) consisted of only public supply water.

A drip irrigation system was utilized, with applications every two days. The depth of irrigation water applied was determined for each treatment based on the water requirements of the plants, focusing on maintaining the soil at field capacity (0.033 m^3 m^{-3}). In treatments with pulse irrigation, applications were divided into five equal parts with 1-hour intervals between applications, achieving 90% efficiency. The applications of brackish water began 12 DAE when the plants were fully established.

The evaluated peanut cultivar was BR-1. Six seeds were sown per lysimeter at a depth of 5 cm to ensure germination. Thinning was conducted 10 DAE, leaving one plant per lysimeter. Phytosanitary monitoring and cultural treatments were performed after planting, as recommended by EMBRAPA (2009). Harvest was carried out at the crop physiological maturity, which occurred 63 days after sowing.

Shoots and pods were evaluated and separated after harvest to determine the accumulation and exportation of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), and sodium (Na), and chloride (Cl^-). All plant material, i.e., shoots and kernels (in-shell), were taken to laboratory and washed with deionized water.

The plant materials were then packed in paper bags, labeled, and dried in an oven at 65 °C to a constant weight. Subsequently, the dry material was weighed on an electronic scale (0.0001 g) to quantify their dry weights, and then ground in a Willey mill with a 2 mm sieve.

Open digestion was used for N extraction, using a digester block as a heat source and a mixture of sulfuric acid (H_2SO_4), hydrogen peroxide (H_2O_2), and a digester mixture to digest the dry matter. The digestion of the nutrients P, K, Ca, Mg, S, and Na was carried out in a closed system, using a microwave oven as the heat source and concentrated nitric acid (HNO_3) to digest the dry matter (Silva, 2009). Chloride was extracted using hot water, as described by Bezerra Neto & Barreto (2011).

Total N was quantified by the Kjeldahl method; K and Na were determined by the flame photometry method; P was measured using the colorimetry method, with the molybdate-vanadate reagent; S was analyzed through turbidimetry, using barium sulphate; Cl was assessed using the Mohr method; and Ca and Mg were analyzed by atomic absorption spectrophotometry (Bezerra Neto & Barreto, 2011).

The exportation of nutrients was obtained by multiplying nutrient contents by the dry matter accumulated in the kernels. Total nutrient accumulation was determined by summing the nutrients accumulated in both the kernels and shoots of the plants.

All statistical analyses were conducted using the SISVAR program (Ferreira, 2019). The obtained data were subjected to analysis of variance using the F test. Means showing significant effects were further analyzed through regression analysis (for salinity levels) and comparison of means (for irrigation regimes) using the F test at 0.05 probability level. The model that best fitted the data was determined based on four analyses: non-significant effect of regression deviation; significance of the parameters of the fitting equation ($p \leq 0.05$); the highest value of coefficient of determination (R^2); and explanation of the evaluated treatments by each variable.

Results and Discussion

According to the analysis of variance (Table 2), the interaction between irrigation regimes (pulse and continuous drip irrigation) and electrical conductivity of irrigation water (ECw) significantly affected the accumulations of P, Ca, and Na. Additionally, the individual factors had significant effects on the accumulations of N, K, Mg, S, and Cl.

According to the analysis of variance for exportation data (Table 3), the interaction between irrigation regime and ECw was significant for K. The individual factors had significant effects on the exportations of N, P, Ca, Mg, Cl, and Na. Sulfur (S) exportation was affected only by the irrigation regime factor.

N accumulation in plants decreased by 0.18 g per plant for each increase in ECw (dS m^{-1}) (Figure 2A). The maximum N accumulation was 2.37 g per plant, at an ECw of 0.2 dS m^{-1}. The ECw of 6.4 dS m^{-1} resulted in a 48.1% decrease in N accumulation (1.23 g per plant). N exportation by peanut kernels reduced by 0.0742 g per plant for unit increase in ECw (dS m^{-1}). Regarding the effects of irrigation regimes, pulse drip irrigation promoted increases of 38 and 32.19% in N accumulation and exportation, respectively (Figure 2A and B).

Sousa et al. (2022) found decreases in N concentrations in maize leaves as the salinity level increased. Reductions in N accumulation under high salinity conditions can be attributed to increased concentrations of chloride (Cl^-), the

Table 2. Analysis of variance for accumulation of macronutrients, Cl and Na in peanut plants (cultivar BR-1) as a function of irrigation regimes and salinity levels

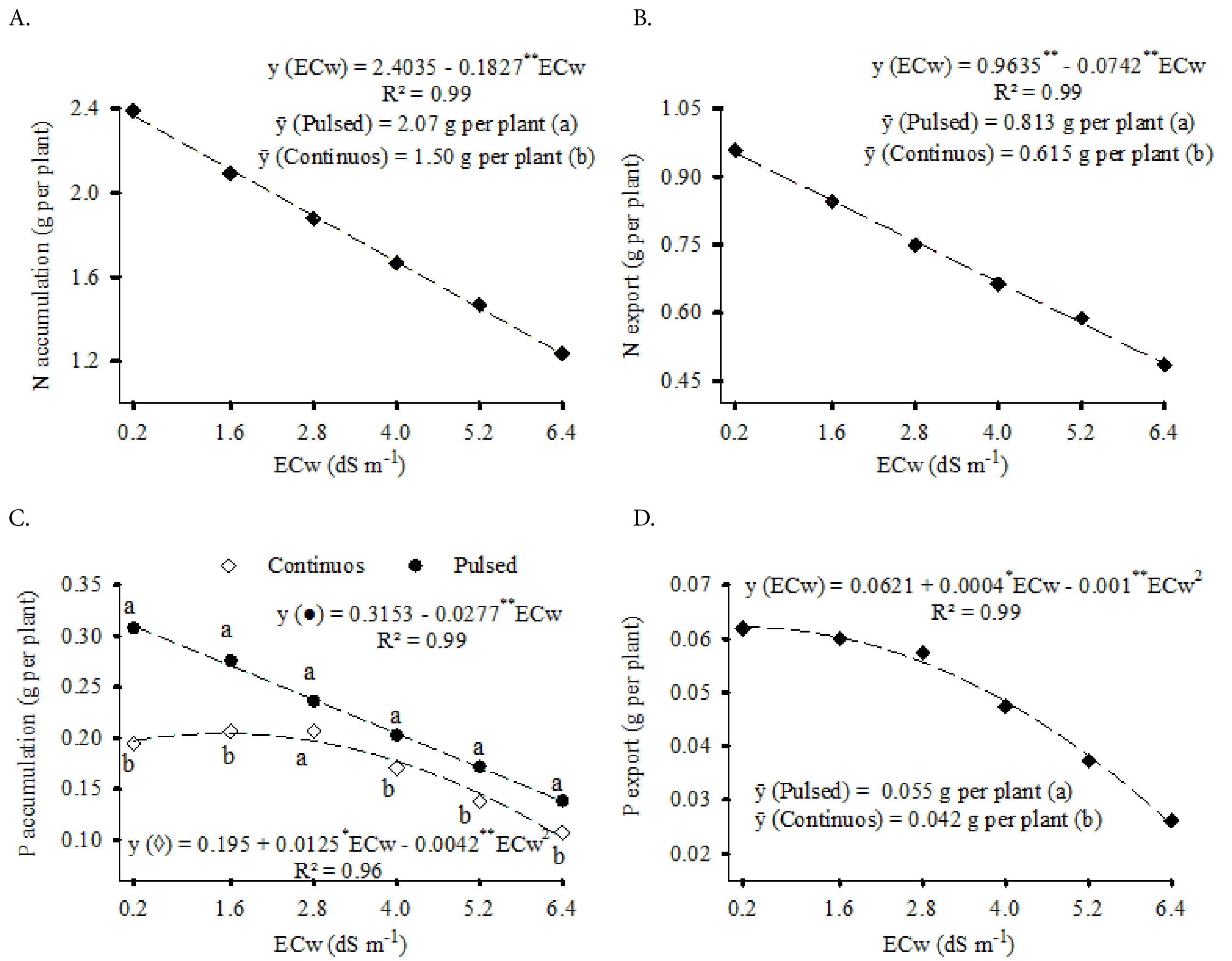
Source of variation	DF	Mean squares							
		Macronutrients						Elements	
		N	P	K	Ca	Mg	S	Cl	Na
Regime (R)	1	3.888**	0.032**	6.429**	0.032**	0.070**	0.010**	26.29×10^{5}**	10.087**
Salinity (S)	5	1.414**	0.020**	1.079**	0.020**	0.016**	0.004**	4.13×10^{5}**	3.218**
R × S	5	0.010^{ns}	0.002**	0.009^{ns}	0.002**	$5\times10^{-4\ ns}$	$6\times10^{-6\ ns}$	$2.82\times10^{4\ ns}$	0.447**
Block	3	0.027^{ns}	$7\times10^{-4\ ns}$	0.310**	19.783*	0.003^{ns}	0.001**	5.23×10^{5}*	0.166^{ns}
Residue	33	0.022	4×10^{-4}	0.060	4×10^{-4}	0.001	2×10^{-4}	21899	0.098
CV (%)		8.26	10.27	12.21	0.75	11.10	10.34	14.55	20.76

CV - Coefficient of variation; DF - Degrees of freedom; ** - Significant at 0.01 probability level, * - Significant at 0.05 probability level, and ns - Not significant by the F test

Table 3. Analysis of variance for the exportation of macronutrients, Cl, and Na in peanut crops (cultivar BR-1) as a function of irrigation regimes and salinity levels

Source of variation	DF	Mean squares							
		Macronutrients						Elements	
		N	P	K	Ca	Mg	S	Cl	Na
Regime (R)	1	0.470**	0.002**	1.674**	2×10^{-4}**	0.005**	0.006**	42,061.001**	0.091**
Salinity (S)	5	0.238**	0.002**	0.425**	5×10^{-5}*	5×10^{-4}*	3×10^{-4ns}	11,866.20**	0.016**
R × S	5	0.006^{ns}	0.001^{ns}	0.096**	2×10^{-6ns}	6×10^{-5ns}	4×10^{-6ns}	$11,76.272^{ns}$	0.097^{ns}
Block	3	0.003^{ns}	0.001^{ns}	0.0316**	9×10^{-6ns}	3×10^{-6ns}	0.001^{ns}	7,680.093*	0.010^{ns}
Residue	33	0.010	$8x10^{-5}$	0.008	1×10^{-5}	2×10^{-5}	$1x10^{-4}$	951.889	0.001
CV (%)		14.120	18.43	11.37	30.57	24.75	29.55	30.62	22.97

CV - Coefficient of variation; DF - Degrees of freedom; ** - Significant at 0.01 probability level, * - Significant at 0.05 probability level, and ns - Not significant by the F test



Means comparing irrigation regimes (pulse and continuous) followed by different letters are significantly different by the F test ($p < 0.05$); * and ** - Significant at $p \leq 0.05$ and $p \leq 0.01$ by the F test, respectively

Figure 2. Nitrogen accumulation (A) and exportation (B) as a function of effects of salinity levels of irrigation water and irrigation regimes, individually; interaction between these factors on phosphorus accumulation (C) and effects of these factors, individually, on phosphorus exportation (D) in peanut plants as a function of salinity levels and irrigation regimes.

dominant anion which directly competes with NO_3^- absorption (Marschner, 1995).

The difference between irrigation regimes (pulse and continuous) was significant for P accumulation (Figure 2C). Pulse drip irrigation resulted in linear decreases in P accumulation, equivalent to 0.0277 g per plant for unit increase in ECw (dS m^{-1}). The highest estimated P accumulation (0.31 g per plant) was found at an ECw of 0.2 dS m^{-1}. This accumulated P decreased by 55.5% at the highest ECw (6.4 dS m^{-1}). Pulse drip irrigation resulted in a P exportation 30.9% higher than continuous drip irrigation (Figure 2D).

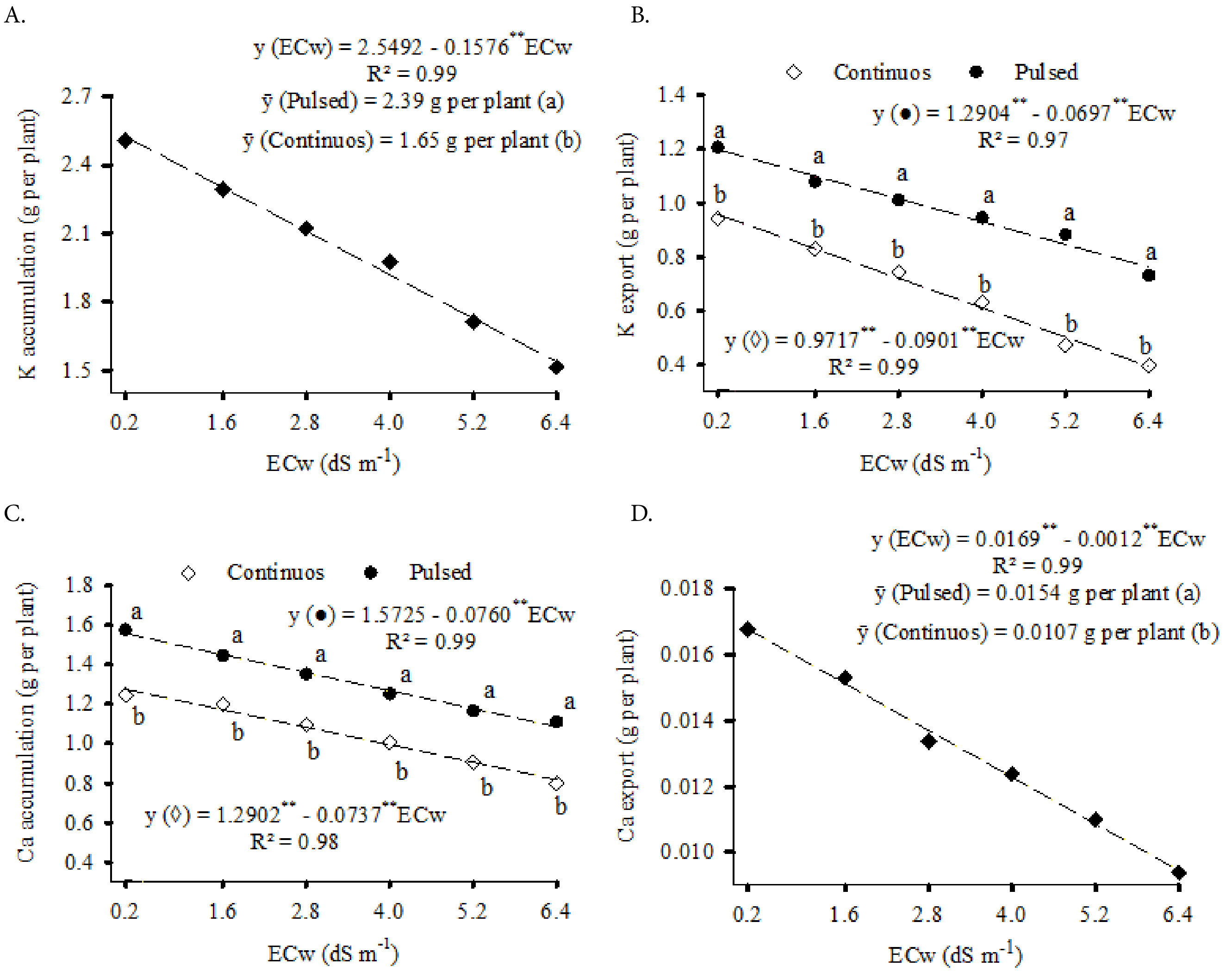
The polynomial model that best fitted the data of P accumulation in continuous drip irrigation was the quadratic model (Figure 2C). The highest estimated P accumulation was 0.20 g per plant at an ECw of 1.49 dS m^{-1}, which showed a 48.5% decrease at the ECw of 6.4 dS m^{-1}. P accumulation in kernels was significantly higher in pulse drip irrigation (0.055 g per plant) compared to the continuous management (0.042 g per plant), except for the ECw of 2.8 dS m^{-1}, at which continuous irrigation resulted in similar P accumulation.

P accumulation at the highest ECw (6.4 dS m^{-1}) in both irrigation regimes (continuous and pulse) was higher than the mean P accumulation (0.09 g per plant) found by Nandi et al. (2020). High salinity levels decrease P concentration in plant tissues due to effects of ionic strength, and P solubility decreases with increasing NaCl levels in the soil (Garcia et al., 2005).

Increases in ECw resulted in decreased K accumulation and exportation (Figure 3A and B). K accumulation decreased by 0.16 g per plant for unit increase in ECw (dS m^{-1}). The highest estimated K accumulation (2.52 g per plant) was found at the ECw of 0.2 dS m^{-1}, which was 63.3% higher than that found at the ECw of 6.4 dS m^{-1} (1.54 g per plant) (Figure 3A).

Regarding the effect of drip irrigation regimes on K accumulation (Figure 3A), pulse drip irrigation mitigated the effects of ECw, resulting in a 44.8% higher K accumulation compared to continuous drip irrigation. The analysis of irrigation drip regimes within ECw levels (Figure 3B) showed that pulse drip irrigation had increases in K exportation of 33.85, 42.46, 52.24, 65.48, 84.42, and 113.72% at ECw levels of 0.2, 1.6, 2.8, 4.0, 5.2, and 6.4 dS m^{-1} compared to continuous drip irrigation, respectively.

K accumulation was 1.54 g per plant at the highest ECw (6.4 dS m^{-1}) (Figure 3A); this mean was higher than that found



Means comparing irrigation regimes (pulse and continuous) followed by different letters are significantly different by the F test ($p < 0.05$); * and ** - Significant at $p \le 0.05$ and $p \le 0.01$ by the F test, respectively

Figure 3. Potassium accumulation (A) as a function of effects of irrigation regimes and salinity levels, individually; interaction between these factors on potassium exportation (B) and calcium accumulation (C); and effects of these factors, individually, on calcium exportation (D) in peanut plants as a function of salinity levels of irrigation water and irrigation regimes

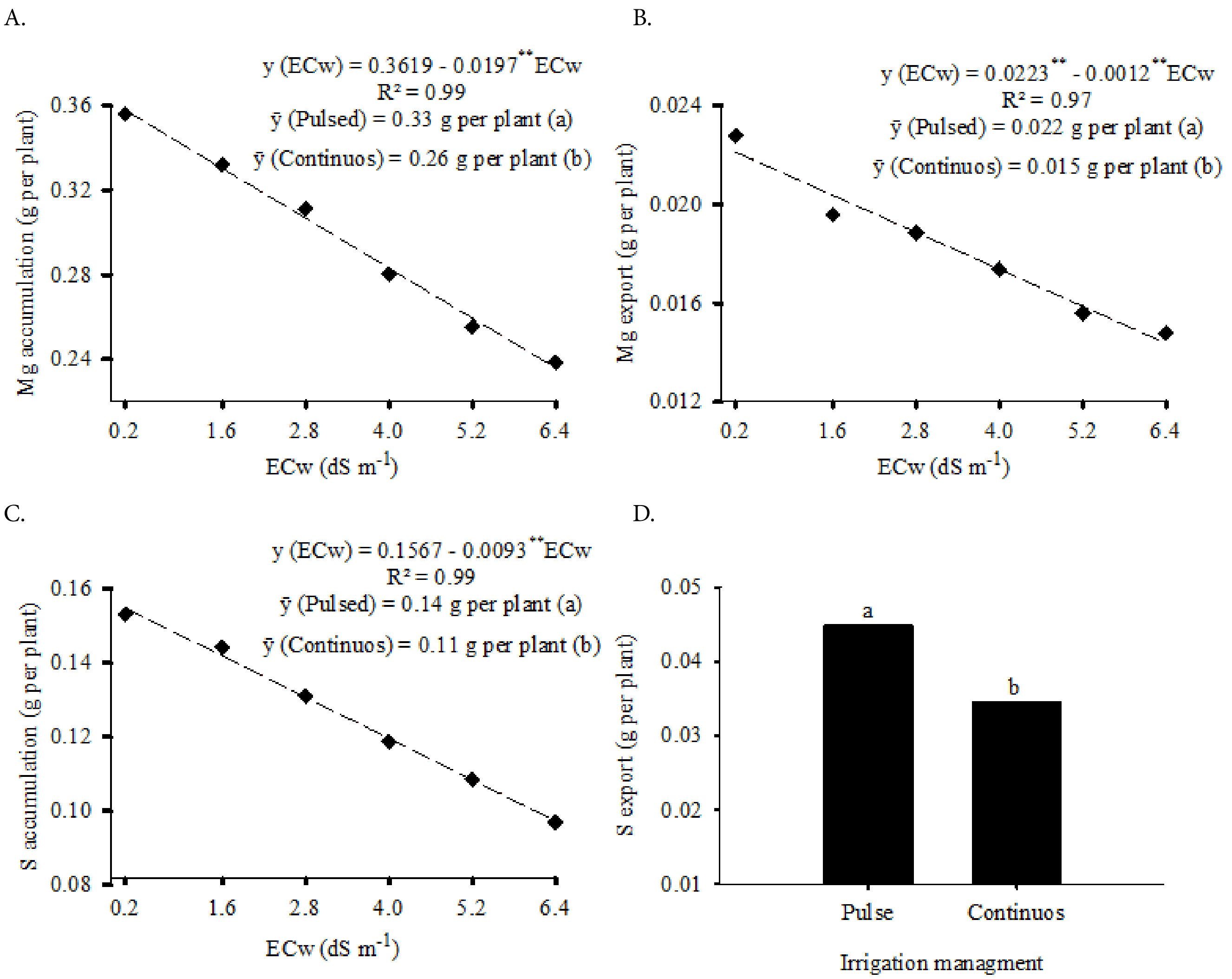
by Nandi et al. (2020) for peanut crops (0.44 g per plant) using irrigation water with salinity of 0.5 dS m^{-1}. Decreases in K accumulation under high salinity levels may be attributed to competition between K^+ and Na^+ for absorption, as Na^+ competes with K^+ for binding sites of high affinity (KUP and HKT) K^+ channels, as well as low affinity non-selective cation channels (Sharmin et al., 2021).

Increases in ECw resulted in decreased Ca accumulation (Figure 3C) in both irrigation regimes. Ca accumulation decreased by 0.076 g per plant for unit increase in ECw (dS m^{-1}) under pulse drip irrigation. Ca accumulation increased by 22.10, 23.77, 25.45, 27.44, 29.81, and 32.69% at ECw levels of 0.2, 1.6, 2.8, 4.0, 5.2, and 6.4 dS m^{-1} under pulse drip irrigation compared to continuous drip irrigation (Figure 3C). The higher efficiency of pulse drip irrigation in mitigating the adverse effects of brackish water is due to its longer maintenance of soil moisture than other methods, resulting in lower salinity levels in the plant rhizosphere, reducing deleterious effects of salts (Assouline et al., 2006).

The low Ca accumulation and exportation by peanuts found in the present study can be attributed to Na accumulation. High Na accumulation decreases the absorption and distribution of Ca; much of this Na can be transported by non-selective ion channels that stimulate Na flow from the depolarization of the membrane potential, resulting in Ca influx (Maathuis, 2014). Sá et al. (2021) evaluated cowpea (*Vigna unguiculata*) crops and found that irrigation waters with electrical conductivities higher than 2.5 dS m^{-1} increase soil salinity and sodium content in tissues to toxic levels, reducing Ca contents in plant tissues.

Magnesium accumulation and exportation decreased by 0.0197 and 0.0012 g per plant for unit increase in ECw (dS m^{-1}) (Figure 4A and B). The highest Mg estimated accumulation and exportation were 0.36 and 0.02 g per plant at the ECw of 0.2 dS m^{-1}. These values correspond to increases of 51.78 and 51.36% compared to those estimated for the ECw of 6.4 dS m^{-1} (0.24 and 0.015 g per plant), respectively.

Pulse drip irrigation resulted in increases in Mg accumulation and exportation of 26.9 and 46.66%, respectively, compared to continuous drip irrigation (Figure 4A and B). Mg accumulation and exportation at the highest ECw (6.4 dS m^{-1}) decreased by 34.12 and 33.72%, respectively (Figure 4A and B) compared to those found at the lowest ECw (0.2 dS m^{-1}). A study on soybean plants showed that irrigation water with ECw levels of 6.5 and 8.5 dS m^{-1} decreased leaf Mg contents by 40 and 64.9%, respectively (Essa, 2002).



Means comparing irrigation regimes (pulse and continuous) followed by different letters are significantly different by the F test ($p < 0.05$); * and ** - Significant at $p \leq 0.05$ and $p \leq 0.01$ by the F test, respectively

Figure 4. Magnesium accumulation (A) and exportation (B) and sulfur accumulation (C) as a function of effects of salinity of irrigation water and irrigation regime, individually; and sulfur exportation under irrigation regime (D) in peanut plants (cultivar BR-1)

The increases in ECw linearly decreased S accumulation (Figure 4C). Pulse drip irrigation mitigated the effects of ECw, as it increased S accumulation by 27.3% (Figure 4C) and S exports by 42.03% compared to continuous drip irrigation (Figure 4D), which presented mean S accumulations of 0.049 and 0.0345 g per plant for continuous and pulse drip irrigation regimes, respectively.

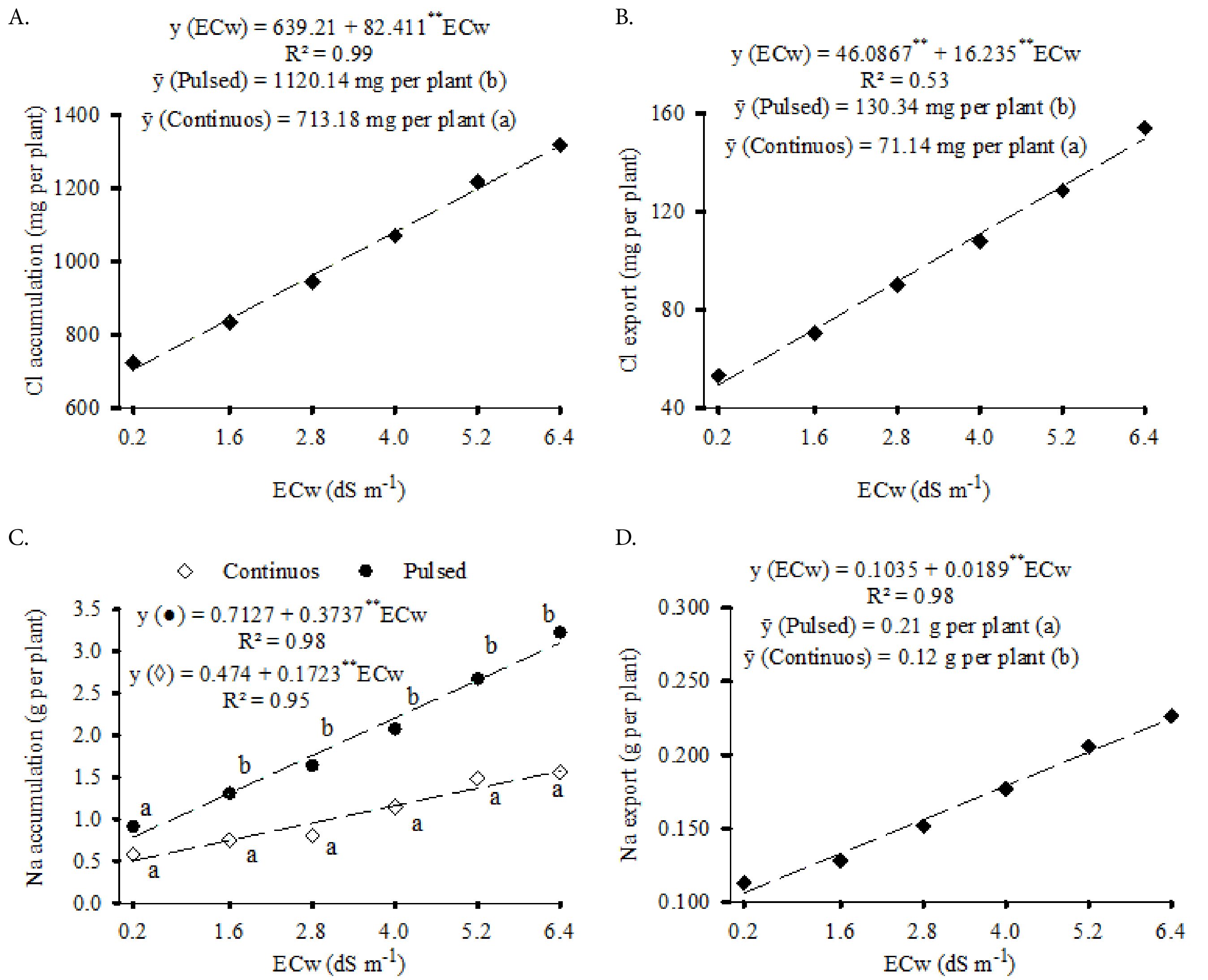
The decreases in S accumulation due to the ECw may be connected to the competitive effect between Cl^- and SO_4^{2-}, as high levels of one of these nutrients can reduce the absorption of the other (Malavolta et al., 1997). An experiment with garlic (*Allium sativum*) grown under 200 mM NaCl showed reductions of approximately 50% in total S contents compared to the control treatment (Aghajanzadeh et al., 2019).

Cl accumulation and exportation increased by 82.411 and 16.235 mg per plant, respectively, for unit increase in ECw (dS m^{-1}) (Figure 5A and B). Pulse drip irrigation increased Cl accumulation by 57.06% and Cl exports by 83.22% compared to continuous drip irrigation. Souza et al. (2019) found that chloride concentrations in leaves of noni (*Morinda citrifolia*) increased as the salinity of irrigation water was increased.

The irrigation regimes with different ECw levels (Figure 5C) had significant effect on Na accumulation. The differences between pulse and continuous drip irrigation regimes at ECw levels of 1.6, 2.8, 4.0, 5.2, and 6.4 dS m^{-1} showed increases of 74.82, 83.92, 89.79, 93.87, and 96.89%, respectively, for the use of pulse drip irrigation. Na exportation per plant increased by 0.0189 g for unit increase in ECw (dS m^{-1}) (Figure 5D).

Na^+ and Cl^- accumulations in plant tissues are some of the harmful effects of salt stress on crops grown in soils with high levels of salts, such as NaCl. The entry of these ions into cells causes severe ionic imbalance, and excessive absorption can cause significant physiological disorders (Sousa, 2019).

Na accumulation and exportation significantly increased as the ECw was increased. However, pulse drip irrigation resulted in higher Na accumulation and exportation than continuous drip irrigation. Sousa et al. (2022) reported correlation between the use of high salinity water and Na accumulation in plants. Essa (2002) evaluated soybean (*Glycine max*) cultivars (Lee, Coquitt, and Clark) and found that increasing ECw to 8.5 dS m^{-1} increased Na contents by 300, 210, and 292%,



Means comparing irrigation regimes (pulse and continuous) followed by different letters are significantly different by the F test ($p < 0.05$); * and ** - Significant at $p \leq 0.05$ and $p \leq 0.01$ by the F test, respectively

Figure 5. Chloride accumulation (A) and exportation (B) as a function of effects of salinity levels and irrigation regimes. individually; interaction between these factors on sodium accumulation (C), and effects of these factors, individually, on sodium exportation (D) in peanut plants (cultivar BR-1)

respectively, compared to an ECw of 0.5 dS m^{-1}. A study on cabbage (*Brassica oleracea* var. capitata) showed that an ECw of 11.82 dS cm^{-1} increased leaf Na content by 58% compared to an ECw of 0.245 dS m^{-1} (control) (Sahin et al., 2018).

The descending order of nutrient accumulation found for the pulse and continuous drip irrigation regimes was: K > N > Ca > Mg > P > S. The descending order of nutrient exportation by peanut kernels was: K > N > P > Mg > Ca > S for pulse drip irrigation, and K > N > P > S > Mg > Ca for continuous drip irrigation. Cl and Na accumulation were higher under pulse drip irrigation, with increases of 57.06% for Cl^- (Figure 5A) and 96.89% for Na^+ at the ECw of 6.4 dS m^{-1} compared to continuous drip irrigation (Figure 5C).

Silva et al. (2017) evaluated peanut crops of the cultivar IAC Caiapó and found the following descending order of nutrient accumulation: N > K > Ca > Mg > S > P. Lira et al. (2019) evaluated sugarcane (*Saccharum officinarum*) crops grown under irrigation with saline water and found the following order of nutrient extraction: K > Ca > N > Mg > S > P.

Although nutrient accumulation was affected by the salinity level and irrigation regime, the order of nutrient accumulation remained consistent. Contrastingly, the order of nutrient exportation differed between irrigation regimes for S, Mg, and Ca.

According to the analysis of variance (Table 4), shoot dry weight and kernel dry weight were affected by the irrigation regime and ECw.

Table 4. Analysis of variance for shoot dry weight and kernel dry weight in peanut crops (cultivar BR-1) as a function of irrigation regimes and salinity levels

Source of variation	DF	Mean squares	
		Shoot dry weight	Kernel dry weight
Regime (R)	1	1153.07**	176.03**
Salinity (S)	5	1094.47**	87.25**
R × S	5	6.09^{ns}	0.15^{ns}
Block	3	53.68*	1.30^{ns}
Residue	33	13.59	1.33
CV (%)		6.34	9.33

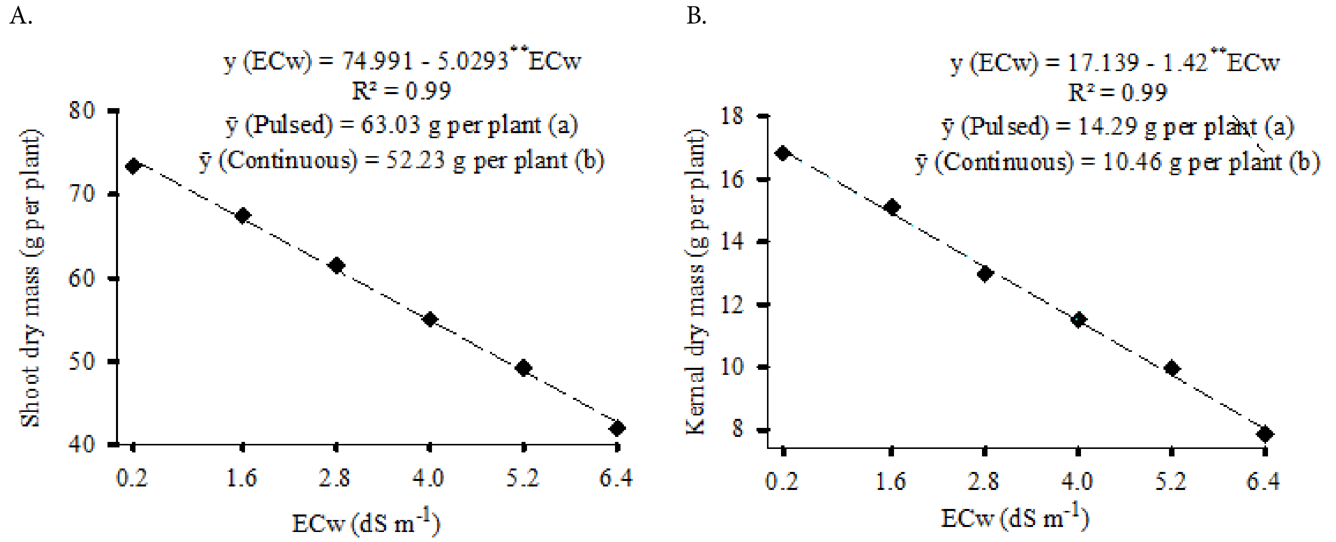
** - Significant at 0.01 probability level, * - Significant at 0.05 probability level, and ns - Not significant by the F test

Shoot dry weight decreased by 5.029 g per plant for unit increase in ECw (dS m^{-1}) (Figure 6A). The highest estimated shoot dry weight was 74.0, and the lowest was 42.8 g per plant at ECw levels of 0.2 and 6.4 dS m^{-1}, respectively. The lowest shoot dry weight (42.8 g per plant at ECw of 6.4 dS m^{-1}) represents a decrease of 42.16% compared to that (74 g per plant) at the lowest ECw. Shoot dry weight increased by 20.68% under pulse drip irrigation compared to that found under continuous drip irrigation.

Kernel dry weight data fitted to a decreasing linear regression model (Figure 6B), with decreases of 1.42 g per plant for unit increase in ECw (dS m^{-1}). The highest estimated kernel dry weight was found at the ECw of 0.2 dS m^{-1}, which was 16.86 g per plant and 109.4% higher than that at the highest evaluated ECw. Regarding the different irrigation regimes, kernel dry weight increased by 35.28% under pulse drip irrigation compared to that under continuous drip irrigation.

Pulse irrigation provided better maintenance of soil moisture; thus, this irrigation management possibly contributed to increases in shoot dry weight (Figure 6A) and kernel production (Figure 6B). According to Zamora et al. (2021), pulse irrigation maintains the wet soil area constant for a longer time due to better water availability conditions and reduced losses due to evaporation or deep percolation. Menezes et al. (2020) evaluated coriander crops grown under pulse and continuous fertigation regimes and found that pulse irrigation favored crop dry matter accumulation.

Abuarab et al. (2011) evaluated common bean crops grown in the Mediterranean region of Egypt under different irrigation regimes and found increases of 156 and 167% in shoot dry weight for pulse irrigation at the first and second crop years, respectively, compared to continuous irrigation. Losses in kernel dry weight were also found by Santos et al. (2012) when evaluating peanut crops of the cultivar BR-1 under irrigation with saline water and different leaching fractions; they found decreases in dry weight of 0.59 g for each increase in ECw (dS m^{-1}).



Means comparing irrigation regimes (pulse and continuous) followed by different letters are significantly different by the F test ($p < 0.05$); * and ** - Significant at $p \leq 0.05$ and $p \leq 0.01$ by the F test, respectively

Figure 6. Shoot dry weight (A) and kernel dry weight (B) of peanut plants (cultivar BR-1) as a function of salinity levels of irrigation water and irrigation regimes

Conclusions

1. High salinity levels of irrigation water decrease the accumulation and exportation of N, P, K, S, Ca, and Mg, while increase the accumulation of sodium and chloride.

2. Pulse drip irrigation results in increased accumulation and exportation of nutrients by peanut crops compared to continuous drip irrigation.

3. High salinity levels decrease shoot and kernel dry weights of peanut plants; however, treatments with pulse drip irrigation increase dry weight accumulation.

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