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NITROGEN, PHOSPHORUS AND POTASSIUM ACCUMULATION IN WATERMELON CULTIVARS IRRIGATED WITH SALINE WATER

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KEYWORDS

Citrullus lanatus, plant nutritional status, water management

ABSTRACT

The use of saline water in agriculture has increased in the Brazilian semiarid due to low availability of good quality water for irrigated agriculture, being the selection of salt tolerant hybrids an alternative to reduce the effect of salinity on nutritional status of plants. So, the objective of this work was to evaluate the effect of salinity of irrigation water in the accumulation and partition of nutrients in the vegetable tissue of watermelon cultivars, in the region of Mossoro in the State of Rio Grande do Norte, Brazil. The treatments studied consisted of applying irrigation water with five electrical conductivities (EC1 = 0.57, EC2 = 1.36, EC3 = 2.77, EC4 = 3.86 and EC5 = 4.91 dS m^{-1}), two watermelon cultivars and four samplings times (15; 29; 43 and 60 days after transplanting), arranged in a scheme of split plot(5x2x4) and outlined in complete blocksrandomized with four replications.The accumulated nutrients in plants were influenced by ECw, occurring a loss in comparison with the higher ECw of 24.1 and 36.4% in the accumulationof N and P in the vegetative part of plant and 37.8 and 30.1 % in the accumulation of P and K in the aerial part. The accumulation of N, P and K in the watermelon was influenced by plant age, with reduction at the end of the cycle.

INTRODUCTION

In recent years, watermelon has been one of the most important crops cultivated in Brazil especially in the Northeast Region. In this region the culture found excellent conditions for its development due to the edapho-climatic conditions and the availability of springs water underground and on the surface (Martins et al., 2013), and it can be cultivated the whole year under irrigated conditions.

In Rio Grande do Norte and Ceara, large melon-producing companies started planting this crop targeting, above all, the external market. The Quetzali watermelon is one of the most produced by the fruit producing companies in this region and the main exported variety with seed.

Currently seedless watermelon is also a widely accepted product in the world's major markets and has emerged as an alternative crop for growers. In Mossoro region the cultivated area in recent years has grown substantially to 2000 ha (Costa et al., 2013).

The region presents not only conducive conditions to cultivation, but also availability of water. The available water in the region obtained at a compatible cost comes from a well that explores the Jandaira aquifer which has the disadvantage of having high salt contents. In this sense, water salinity has been identified as one of the main factors responsible for hindering the expansion and productivity of crops that use irrigation (Furtardo et al., 2012).

The presence of excess ions in the soil can prevent the absorption of essential elements to plant growth leading to nutritional imbalance. Salinity may promote nutritional imbalance due to excess sodium in the soil solution that causes disturbance in nutrient uptake by the plant (Wanderley et al., 2010), impairing mainly root absorption of K and interfering with its physiological functions. However, the greater demand for water led to the use of the most water sources available in the region forcing the producers to use water with different levels of salinity (Costa et al., 2012).

The use of water with high concentrations of salts in irrigation is one of the great challenges of researchers and agricultural producers, mainly due to the scarcity of good quality water, seeking to obtain economically viable productivities and quality products using water of inferior quality (Medeiros et al., 2014).

An alternative to reduce the effect of salts on plants would be the selection of salinity tolerant hybrids. The tolerance of the cultivars to the salinity is related to the ability of the plant to resist certain levels of salts which

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may vary according to the genotype, its development phase, nature and intensity of saline stress (Brito et al., 2014; Oliveira et al., 2015). The ability of plant genotypes to maintain high nutrient contents and low levels of Na within the tissue is one of the mechanisms that contribute to express greater tolerance to salinity. Due to the genetic variability of olericulture hybrids such as melon and watermelon, for example, there is a great variation in the tolerance to salinity between the cultivars of these crops (Silva et al., 2005).

Considering the above, this study was developed to evaluate the effect of water salinity irrigation on the accumulation and partition of nitrogen (N), phosphorus (P) and potassium (K) in two watermelon cultivars with different grades of tolerance to salinity.

MATERIAL AND METHODS

The experiment was carried out at the Experimental Farm “Rafael Fernandes” belonging to the Semi-Arid Federal Rural University (UFERSA), located in Alagoinha, in the municipality of Mossoro-RN, at latitude 5º03’37” S and longitude 37º23’50” W Gr, with an altitude of approximately 72 m.

The experimental area soil is classified as a Red-Yellow Argisol, according to the classification proposed by Embrapa (2006). The available irrigation water at the Experimental Farm comes from a well drilled from the Açu Sandstone aquifer with water electric conductivity (ECw) around 0.57 dS m^{-1}.

The treatments consisted in the application of water irrigation with five salt concentrations (equivalent to electrical conductivities of 0.57; 1.36; 2.77; 3.86 and 4.91 dS m^{-1}), two watermelon cultivars (Quetzali and Shadow) and four plant sampling time (15; 29; 43 and 60 days after transplanting), arranged in a 5 x 2 x 4 sub - divided plots scheme and completely randomized blocks with four replications.

The lower salinity water (S1) came from the deep artesian well and the higher one (S5) was previously produced in a 5000 L tank with the NaCl, $CaCl.2H_2O$ and $MgSO_4.7H_2O$ that the mol_c ratio of Na, Ca and Mg was 7:2:1. The proportionality used for Na: Ca: Mg is a representative approximation of the majority water sources available for irrigation in the Brazilian Northeast. The other three levels obtained of water salts were from the mixture of these two waters, being monitored daily by means of a portable conductivity meter from collected samples during irrigation in emitters distributed in the area.

The culture used in the experiment was the watermelon (*Citrulluslanatus*), cultivars Quetzali (with seeds) and Shadow (seedless). The choice of the cultivars for planting took into account the type of preferred fruit by the consumer market, their resistance to transportation, adaptation of cultivars to the region and tolerance to diseases. The commercial crops of watermelon in Brazil are cultivars of American or Japanese origin that have adapted well to our edapho-climatic conditions. Currently in the States of Rio Grande do Norte and Ceará the cultivars Shadow and Quetzali have been well cultivated.

The sowing was done in polyethylene trays for 200 seedlings filled with commercial substrate based on coconut fiber and the transplanting occurred at 14 days after sowing.

The experimental plots consisted of three rows of 20 m of plants with spacing of 2.0 m between rows and 0.5 m between plants. The arrangement of the plants was done in such way as to maintain a seeded fruit plant, in the case of the Quetzali cultivar, alternated with a seedless plant, Shadow cultivar in each line of the experimental plot. A row of plants was used to collect the material. For each cultivar we selected the plant randomly, before starting the harvest at each time, corresponding to the sub-subplot.

The irrigation system used in the experiment was drip irrigation. For each row of plant there was a lateral line of drippers, spaced 0.3 m, with mean flow of 1.3 L h^{-1} at a pressure of 80 kPa. Irrigation management was carried out based on the estimation of the maximum evapotranspiration of the crop (ETm) daily, according to the method proposed by FAO 56 (Allen et al., 2006), adding a leaching blade of 10%. Daily climatic data were from a local weather station.

Plant material collections were performed at 15, 29, 43 and 60 days after transplanting (DAT). In the 2nd, 3rd and 4th collections the leaves, stems and fruits dry matter were estimated by samples taken from the respective fresh materials which were dried in a forced circulation oven at temperature of 65 ± 5 ºC until constant mass. At the end we determined plant vegetative dry matter (leaf + stem) and total dry mass of the aerial part (leaf + stem + fruit). In the dry materials the N, P and K contents were determined according to the methodology cited by Embrapa (2009). The accumulated content of N, P and K in the different plants’ organs (leaf, stem and fruit) was obtained by the product between the nutrient content and dry phytomass of each part of the plant (g $plant^{-1}$).

Due to the quantitative data it was verified whether the requirements of the model according to the recommendations by Bardin (1994) were satisfied: model additivity, normality, independence and homogeneity of error variance. The models were chosen based on the significance of the regression coefficients, adopting the probability level of 5% and the coefficients of determination (R^2).

RESULTS AND DISCUSSION

Accumulation of nitrogen, phosphorus and potassium in the aerial part

Table 1 shows a summary of the ANOVA for nitrogen, phosphorus and potassium in the vegetative and aerial part of the watermelon plant (NVEG, PVEG, KVEG, NT, PT and KT), as a function of the electrical conductivity of the irrigation water and in different periods of evaluation. It is observed that nitrogen content (NVEG), phosphorus (PVEG) and potassium (KVEG) in the watermelon vegetative part and the content of nitrogen, (NT), phosphorus (PT) and potassium (KT) in the aerial part of the plant were significantly influenced by EC of the irrigation water. There was also a significant effect of the interaction ECw and watermelon cultivars for K accumulation in the vegetative part and N in the aerial part of the plant and the interaction days after the transplanting and cultivars for the N, P and K content in the vegetative part of the watermelon, as well as for the N, P and K content in the aerial part of the plant.

TABLE 1. Summary of ANOVA and mean values of N, P and K accumulation in the vegetative and aerial part of the watermelon plant (NVEG, PVEG, KVEG, NT, PT and KT), as a function of EC of the irrigation water in different evaluation periods.

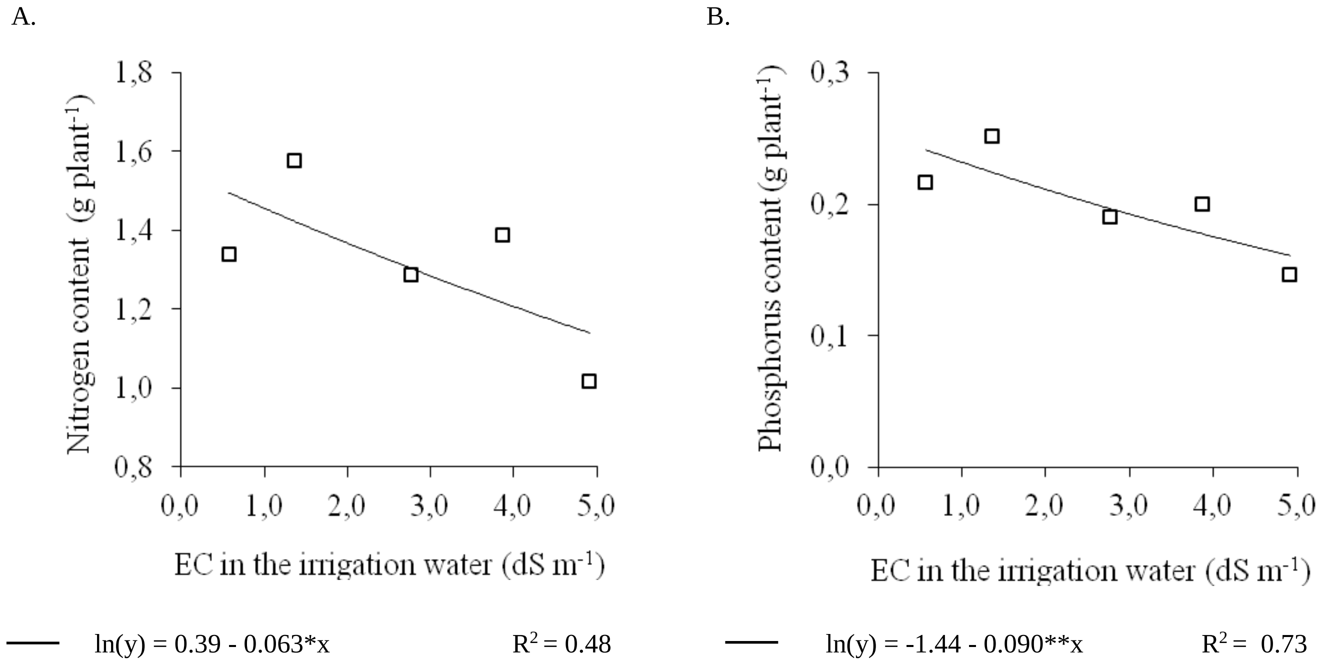
F.V.	DF	Variables					
		NVEG	PVEG	KVEG	NT	PT	KT
		----------------------------------g plant^{-1}-----------------------------					
		Statistic F					
BLOC	2	0.22^{ns}	0.82^{ns}	0.47^{ns}	0.22^{ns}	0.22^{ns}	0.56^{ns}
ECw	4	3.75^{**}	7.50^{**}	3.06^{*}	4.12^{**}	4.71^{**}	4.08^{**}
ERROR(A)	8	---	---	---	---	---	---
CULT	1	23.74^{**}	7.82^{**}	28.99^{**}	9.59^{**}	3.92^{ns}	$8,32^{**}$
CULTx ECw	4	1.46^{ns}	1.44^{ns}	2.60^{*}	2.5^{*}	0.96^{ns}	$2,12^{ns}$
ERROR(B)	10	---	---	---	---	---	---
DAT	3	437.57^{**}	366.56^{**}	581.48^{**}	1113.8^{**}	849.97^{**}	$1290,18^{**}$
DATxCULT	3	7.67^{**}	5.55^{**}	15.92^{**}	4.16^{**}	11.54^{**}	$11,14^{**}$
DATx ECw	12	1.15^{ns}	0.64^{ns}	1.16^{ns}	1.33^{ns}	1.46^{ns}	$0,97^{ns}$
DATxCULTx ECw	12	1.29^{ns}	1.08^{ns}	0.93^{ns}	1.22^{ns}	1.05^{ns}	$0,73^{ns}$
ERROR(C)	60	---	---	---	---	---	---
GENERAL AVERAGE^{II}		7.13	5.22	7.26	7.58	5.90	7.82
CV1(%)		5.74	6.49	6.28	4.14	7.10	4.56
CV2(%)		6.35	9.40	6.12	4.65	7.44	4.92

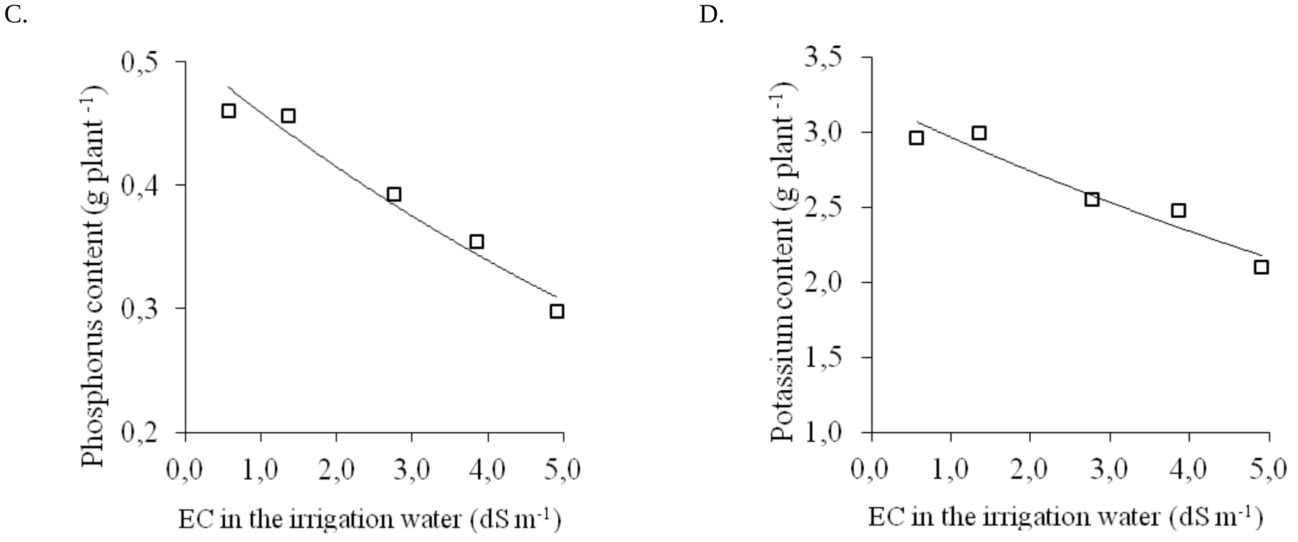
FV - sources of variation; DF – degrees of freedom - ECw - water electrical conductivity; CULT - cultivar; DAT - days after transplanting; NVEG -nitrogen in the vegetative part of the plant; PVEG - phosphorus in the vegetative part of the plant; KVEG- potassium in the vegetative part of the plant; NT - nitrogen in the aerial part of the plant; PT - phosphorus in the aerial part of the plant; KT - potassium in the aerial part of the plant; ^{ns}-not significant, *- significant at 5%, ** - significant at 1% probability by F test; II Values expressed in ln.

The effect of EC of the irrigation water on nutrients content in the watermelon, was observed with the increase of ECw there was a reduction in nitrogen accumulation and phosphorus in the watermelon vegetative part (Figures 1A and 1B) and on phosphorus and potassium accumulation (Figures 1C and 1D) in the aerial part of the plant, so that the lowest accumulation was for the plants irrigated with higher water EC (5.91 dS m^{-1}) and an average accumulation of 1.07; 0.14; 0.28; 2.07 g plant^{-1} and the highest for irrigated plants with lower water EC (0.57 dS m^{-1}) with an average accumulation of 1.41; 0.22; 0.45 and 2.96 g plant^{-1}, respectively for NVEG, PVEG, PT and KT.

The lower nutrients extraction in plants under salt stress is mainly due to the growth inhibition caused mainly by the osmotic effects and toxic of salts excess in the root zone (Neves et al., 2009).

Lucena et al. (2011) evaluated the accumulation of macronutrients in Quetzali watermelon cultivated under different levels of salinity in the irrigation water also verified that the accumulation of nitrogen in the total dry matter of the aerial part of the plants decreased linearly with the increase of the salinity in the irrigation water. The reduction in N accumulation in plants is probably due to the harmful effect of salinity on the accumulation of biomass.





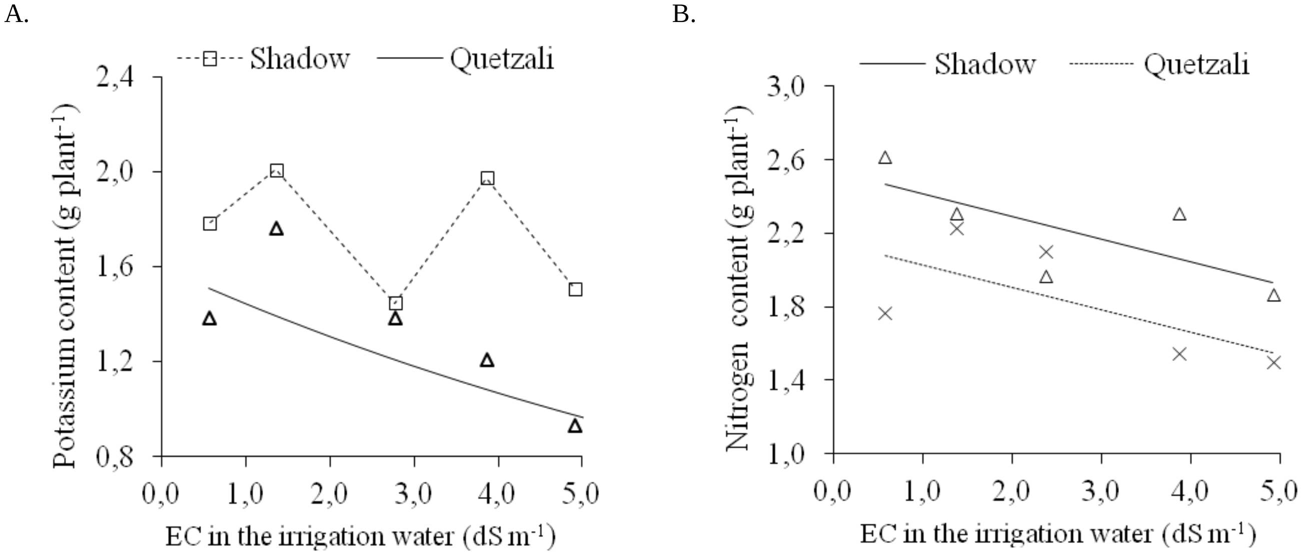
—— $\ln(y) = -0.71 - 0.10^{**}x$ $R^2 = 0.97$ —— $\ln(y) = 8.0 - 0.079^{**}x$ $R^2 = 0.93$

FIGURE 1**.** Nitrogen (A) and phosphorus (B) content in the vegetative part of the watermelon and phosphorus (C) and potassium (D) content in the aerial part of the plant, average of the cultivars Shadow and Quetzali, in function of the EC in the irrigation water.

Figure 2 represents the interaction ECw and watermelon cultivars in K accumulation in the vegetative part of the plant. Reduction in potassium accumulation was verified for Quetzali cultivar according to the increase of EC in irrigation water being the greater accumulation (1.50 g plant^{-1}) observed in the lowest ECw (0.57 dSm^{-1}) and the lowest K content (0.95 g plant^{-1}) was observed in the highest salinity (4.91 dS m^{-1}).

The absorption of K in plants grown in saline medium can be reduced by Na excess, since these ions compete for the same sites in the absorption system in the plasma membrane in the root cells (Marschner, 2012). Thus, the reduction on potassium absorption in watermelon subjected to saline stress is associated with the excess absorption by the roots and the transport to the aerial part of the Na$^+$ ion. The K accumulation in Shadow cultivar did not respond to the EC effect in the irrigation water, presenting an average value of 1.67 g plant^{-1} (Figure 2A). This may mean a higher resistance of this cultivar to salinity. Among the studied cultivars, Shadow was the one with the lowest relative loss of production.

The N content in the aerial part of the plant decreased with the increase of ECw, being the greater accumulation 2.49 and 2.03 g plant^{-1} (ECw = 0.57 dS m^{-1}) and the smaller 1.84 and 1.52 g plant^{-1} for the Shadow and Quetzali cultivars, respectively (Figure 2B). According to Lacerda et al. (2016) the lower N accumulation is due to the reduction in water absorption due to the osmotic effects of salinity and consequent reduction in growth.

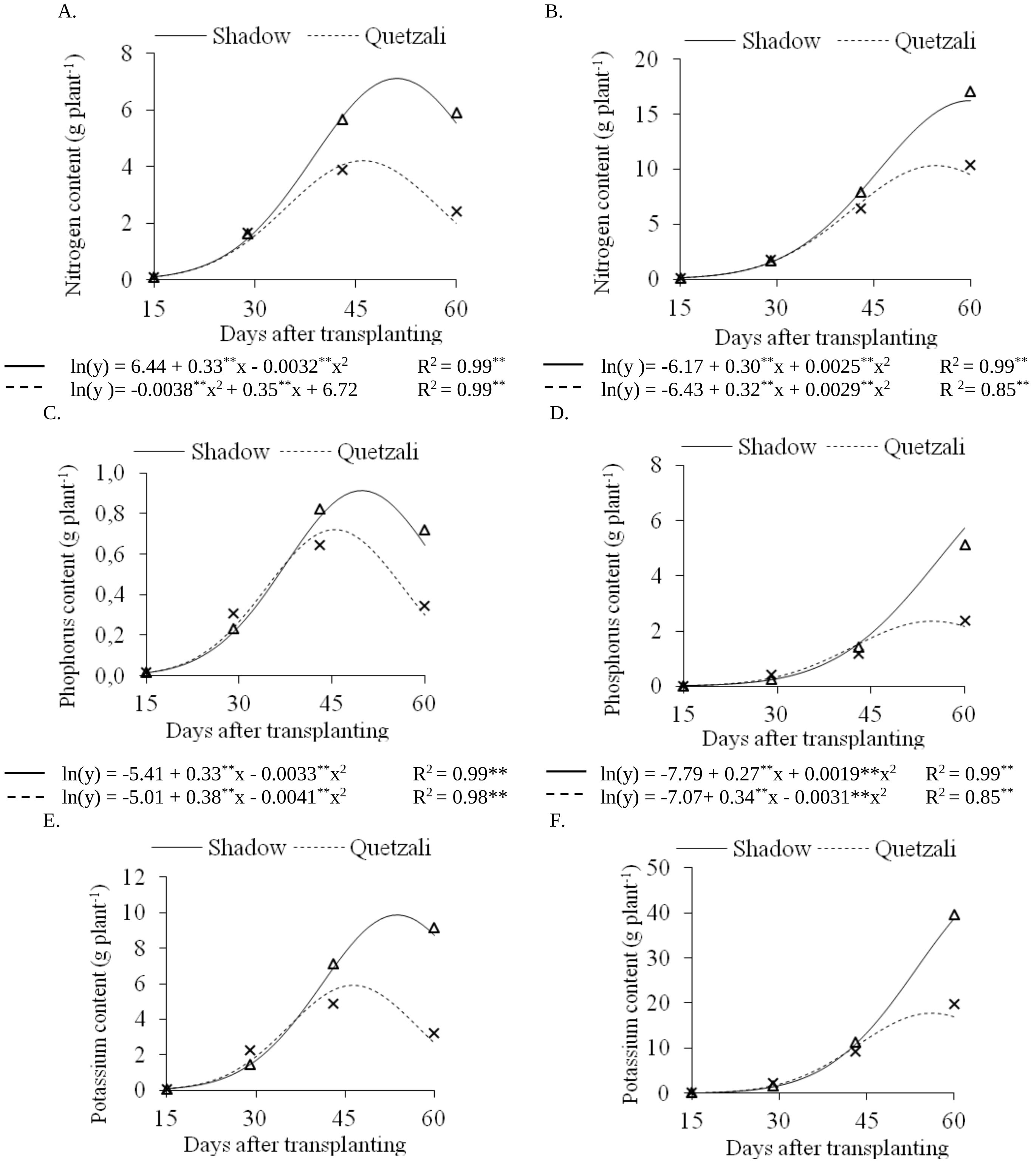


-□- y = 1.67 —— $\ln(y) = 0.95 - 0.070^{*}x$ R^2=0.58

—— $\ln(y) = 0.46 - 0.10^{**}x$ $R^2 = 0.72$ - - - $\ln(y) = 0.75 - 0.067^{*}x$ R^2=0.49

FIGURE 2**.** Potassium content (A) in the vegetative part of watermelon and nitrogen (B) in the aerial part of the plant, Shadow and Quetzali cultivars, in function of the EC in the irrigation water.

In relation to interaction days after transplanting and cultivars (Figure 3) we verified that the Shadow cultivar accumulated the maximum of N in the plant tissue at 51 days after transplanting (Figure 3A), being estimated an average accumulation of 7.12 g plant^{-1}; from 52 DAT the N accumulation began to decrease due to the translocation of this nutrient to the fruits, so that at 60 DAT the plant accumulated 5.54 g. For the Quetzali cultivar (Figure 3A) the highest requirement of the vegetative part for this nutrient occurred at 46 DAT with accumulation estimated at 4.21g plant^{1}. Almeida et al. (2012) studying the absorption of macronutrients for Crimson Sweet watermelon cultivar also observed that the N requirement of the plant is increasing until the beginning of the fruiting.



A.

—— $\ln(y) = 6.44 + 0.33^{**}x - 0.0032^{**}x^2$ $R^2 = 0.99^{**}$

- - - $\ln(y) = -0.0038^{**}x^2 + 0.35^{**}x + 6.72$ $R^2 = 0.99^{**}$

B.

—— $\ln(y) = -6.17 + 0.30^{**}x + 0.0025^{**}x^2$ $R^2 = 0.99^{**}$

- - - $\ln(y) = -6.43 + 0.32^{**}x + 0.0029^{**}x^2$ $R^2 = 0.85^{**}$

C.

—— $\ln(y) = -5.41 + 0.33^{**}x - 0.0033^{**}x^2$ $R^2 = 0.99^{**}$

- - - $\ln(y) = -5.01 + 0.38^{**}x - 0.0041^{**}x^2$ $R^2 = 0.98^{**}$

D.

—— $\ln(y) = -7.79 + 0.27^{**}x + 0.0019^{**}x^2$ $R^2 = 0.99^{**}$

- - - $\ln(y) = -7.07 + 0.34^{**}x - 0.0031^{**}x^2$ $R^2 = 0.85^{**}$

E.

—— $\ln(y) = 0.083 + 0.34^{**}x - 0.0032^{**}x^2$ $R^2 = 0.99^{**}$

- - - $\ln(y) = -0.49 + 0.40^{**}x - 0.0043^{**}x^2$ $R^2 = 0.98^{**}$

F.

—— $\ln(y) = 6.43 + 0.30^{**}x - 0.0022^{**}x^2$ $R^2 = 0.99^{**}$

- - - $\ln(y) = -7.03 + 0.35^{**}x - 0.0031^{**}x^2$ $R^2 = 0.99^{**}$

FIGURE 3**.** Nitrogen (A), phosphorus (C) and potassium (E) content in the vegetative part of the watermelon and nitrogen (B), phosphorus (D) and potassium (F) content in the aerial part of the plant, average of the Shadow and Quetzali cultivars, in function of the days after transplanting.

The highest N accumulated content in the watermelon aerial part, Shadow cultivar (Figure 3B) was observed in the last evaluation period (60 DAT) with an average accumulation of 16.7 g plant^{-1}. For the Quetzali cultivar the highest N accumulation in the aerial part of the plant occurred at 54 DAT (10.24 g plant^{-1}) reducing to 60 DAT with an average accumulation of 9.50 g plant^{-1} (Figure 3B).

According to Grangeiro et al. (2005) the absorption and nutrients accumulation in the watermelon is small in the first 30 days after transplanting, intensifying and reaching the maximum daily accumulation rate between 40 and 50 days. This determines that the soil mobile and easily leachable nutrients, such as nitrogen and potassium, should be applied in coverage to be available after the first 30 days.

The phosphorus content accumulated in the vegetative part of the plant for the Shadow and Quetzali cultivars are in Figure 3C. For the Shadow cultivar the highest accumulation (0.91g plant^{-1}) occurred at 45 DAT and for the Quetzali cultivar the highest accumulation occurred at 50 DAT and it estimated an average value of 0.72 g plant^{-1}. In relation to phosphorus accumulation in the aerial part of the plant (Figure 3D), the highest observed content in the Shadow cultivar was 5.74 g plant $^{-1}$ obtained in the last evaluation period (60 DAT) and for the Quetzali cultivar the highest accumulation (2.36 g plant^{-1}) occurred at 56 DAT from which there was a decrease reaching 60 DAT with an average value of 2.17 g plant^{-1}. Grangeiro & Cecílio Filho (2005) verified for the Mickylee watermelon hybrid that the accumulated amount of phosphorus in the plant reached maximum value at 50 DAT.

For the potassium content in the vegetative part of the watermelon (Figure 3E), we observed that the greatest accumulation of this nutrient occurred at 54 and 46 DAT for the Shadow and Quetzali cultivars, obtaining average values of 9.88 and 5.90 g plant^{-1}, respectively. In the aerial part of the plant the maximum accumulation was 38.77 g plant^{-1} at the end of the crop cycle for the Shadow cultivar and for the Quetzali cultivar the highest amount required by the crop was 17.78 g plant^{-1} at 56 DAT with a subsequent decrease in K amount in the aerial part of the plant (Figure 3F). The results indicate an increase in fruits K accumulation from the beginning of fruiting to the final development phase. Similar results were obtained by Grangeiro & Cecílio Filho (2005) who working with Mickylee watermelon verified that K was the nutrient most accumulated by the cultivar, being the greatest demand of this nutrient occurred in the period from 40 to 50 DAT.

Partition of N, P and K

Data on total accumulation and distribution of macronutrients in the vegetative part and in the fruits of the watermelon plants, Shadow and Quetzali cultivars, in the different levels of salinity are presented in Table 2.

TABLE 2. Percentage distribution of macronutrients at the end of the crop cycle of Shadow and Quetzali watermelon cultivars irrigated with water from different EC.

		Shadow			Quetzali		
Accumulation	ECw	N	P	K	N	P	K
	0.57 dS m^{-1}	g plant^{-1}					
DWT		17.38	8.36	41.75	9.12	2.06	21.14
		%					
DWVEG		28.37	8,73	14.47	26.92	19.90	17.50
DWFR		71.63	91.27	85.53	73.68	80.10	82.50
	1.36 dS m^{-1}	g plant^{-1}					
DWT		23.11	8.09	51.14	13.36	3.09	25.96
		%					
DWVEG		43.53	17.55	25.78	23.43	14.24	18.53
DWFR		56.47	82.45	74.22	76.57	85.76	81.47
	2.77 dS m^{-1}	g plant^{-1}					
DWT		12.67	5.18	32.12	10.17	1.91	18.87
		%					
DWVEG		31.25	8.50	22.07	23.11	18.85	13.94
DWFR		68.75	91.50	77.93	76.89	81.15	86.06
	3.86 dS m^{-1}	g plant^{-1}					
DWT		20.38	5.75	40.72	8.78	2.18	15.37
		%					
DWVEG		33.02	13.56	31.11	44.32	15.60	22.45
DWFR		66.98	86.44	68.89	55.58	84.40	77.55
	4.91 dS m^{-1}	g plant^{-1}					
DWT		13.91	3.65	34.87	11.07	2.88	18.89
		%					
DWVEG		39.54	15.07	25.50	10.93	7.64	11.59
DWFR		60.46	84.93	74.50	89.07	92.36	88.41

DWT- dry matter total; DWVEG - dry matter total in the vegetative part; DWFR – dry matter in the fruits of the watermelon plants.

By evaluating the nutrients distribution in the vegetative part and in the fruits of plants of the Shadow cultivar irrigated with water of lower EC, we verified that the N, P and K had the highest accumulated amounts in the fruits with about 71.63, 91.27, and 85.53%. Similar results were obtained for Quetzali cultivar that presented the highest accumulated amounts of N, P and K in the fruits with about 73.68, 80.10 and 82.50%. Similar behavior was obtained by Grangeiro et al. (2005) for the watermelon evidencing that the fruits are the main drains of the watermelon nutrients.

The nutrient requirement for the watermelon was in the following order: K> N> P, being corroborated by Grangeiro et al. (2005) with Myckylee cultivar in Mossoró-RN conditions and confirmed by Lucena et al. (2011) with watermelon Quetzali in Mossoró-RN conditions. The potassium requirement by the watermelon is superior to the nitrogen, being demanded in greater proportion after fruiting. Potassium, although is not part of any organic compound, plays an important role in regulating the opening and closing of stomata, photosynthesis, gas exchange, enzyme activation and protein synthesis (Hawkesford et al., 2012) being therefore fundamental to the plant’s growth and production.

CONCLUSIONS

1. The salinity of the irrigation water reduces the accumulation of N, P and K in watermelon, Shadow and Quetzali cultivars, and the effect is higher in the last one.
2. The order of nutrient extraction in the total dry matter of the aerial part of the watermelon cultivars is: K> N> P.
3. The age of the plant influences the accumulation of N, P and K nutrients in the aerial part of the watermelon.
4. For both cultivars the highest amounts of N, P and K accumulate in the fruits.

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