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Management for grain sorghum cultivation under saline water irrigation[1]

Manejo da irrigação para o cultivo de sorgo granífero com água salina

Miguel J. M. Guimarães[2*], Welson L. Simões[3], Alessandra M. Salviano[3], Anderson R. de Oliveira[3], Jucicléia S. da Silva[3], Juliane R. A. Barros[3] & Lilia Willadino[4]

[1] Research developed at Embrapa Semiárido, Petrolina, PE, Brazil
[2] Instituto Federal de Educação, Ciência e Tecnologia do Maranhão/Campus São Raimundo das Mangabeiras, São Raimundo das Mangabeiras, MA, Brazil
[3] Empresa Brasileira de Pesquisa Agropecuária/Embrapa Semiárido, Petrolina, PE, Brazil
[4] Universidade Federal Rural de Pernambuco/Departamento de Biologia, Recife, PE, Brazil

HIGHLIGHTS:

Application of leaching fractions promotes better distribution of electrical conductivity in soil.
Leaching fractions of up 15% with saline water increase production of sorghum grains.
Applying leaching fractions up to 12% increases water use efficiency in sorghum.

ABSTRACT: In order to obtain an efficient cultivation of grain sorghum in production systems that use saline water, an adequate management becomes necessary for maximizing its production. The present study aimed to evaluate the effect of the application of leaching fractions in the saline water irrigation management on the production of sorghum varieties and on the distribution of water and salts in the soil profile, under semiarid conditions. The study was carried out in the municipality of Petrolina, semiarid region of Brazil. The experimental design was randomized blocks, with four replicates, in split-split plots; four leaching fractions (LF): 0, 5, 10, and 15% with saline water from artesian well in the plots, three varieties of grain sorghum: 1011-IPA, 2502-IPA and Ponta Negra in the subplots, and two crop cycles (1st and 2nd cut) in the sub-subplots. The evaluated variables were distribution of water and salts in the soil profile, biometric variables, fresh biomass, dry biomass, and grain yield. Application of leaching fractions of up 15% in saline water irrigation promotes better distribution of salts in the soil profile, with increments of up to 60% in the grain yield of the sorghum varieties evaluated. The production of the varieties 1011-IPA and Ponta Negra is a feasible alternative in systems irrigated with saline water with average electrical conductivity of 4.19 dS m^{-1}, in Ultisol, under semiarid conditions.

Key words: *Sorghum bicolor* (L.) Moench, leaching fraction, salt distribution

RESUMO: Para se obter um cultivo eficiente de sorgo granífero em sistemas de produção que utilizam água salina, torna-se necessário um manejo hídrico adequado para maximizar sua produção. Com isto, o presente estudo teve como objetivo avaliar o efeito da aplicação de frações de lixiviação no manejo da irrigação com água salina na produção de variedades de sorgo granífero e na distribuição de água e sais no perfil do solo, em condições semiáridas. O estudo foi realizado no município de Petrolina, região semiárida do Brasil. Foi utilizado o delineamento experimental em blocos casualizados, com quatro repetições, em parcelas subdivididas; sendo as parcelas quatro frações de lixiviação (FL): 0; 5; 10 e 15% com água salina proveniente de poço artesiano, as subparcelas três variedades de sorgo granífero: 1011-IPA, 2502-IPA e Ponta Negra e as subsubparcelas dois ciclos de cultivo (1º e 2º corte). As variáveis avaliadas foram: distribuição de água e sais no perfil do solo, variáveis biométricas, biomassa fresca, biomassa seca e produtividade de grãos. A aplicação de frações de lixiviação na irrigação com água salina promove melhor distribuição de sais no perfil do solo, com incrementos de até 60% no rendimento de grãos das variedades de sorgo avaliadas. A produção das variedades 1011-IPA e Ponta Negra é uma alternativa viável em sistemas irrigados com água salina com condutividade elétrica média de 4,19 dS m^{-1}, em Argissolo Vermelho Amarelo, sob condições semiáridas.

Palavras-chave: *Sorghum bicolor* (L.) Moench, fração de lixiviação, distribuição de sais

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* Corresponding author - E-mail: miguel.guimaraes@ifma.edu.br
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Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is a tolerant/resistant crop to several abiotic constraints (Gois et al., 2019; Safdar et al., 2019; Shankar & Evelin, 2019; Castro & Santos, 2020). Its agricultural exploitation in semiarid regions is subject to several adverse environmental factors, potentially capable of causing negative effects on growth, development, production, and quality (Guimarães et al., 2019; Simões et al., 2019; Guimarães et al., 2020).

In these regions, saline water is often the only source of water. According to Calone et al. (2020), sorghum tolerance to soil saturation extract and water salinity is up to 6.8 and 4.5 dS m^{-1} of electrical conductivity, respectively. Above these limits, a yield reduction of 16% is expected for each unit increase in soil or water salinity.

Irrigation with saline water requires extra application of water to leach salts from the root zone to avoid excessive accumulation of these salts (Guimarães et al., 2016; Simões et al., 2016). This technique constitutes an important management strategy in crops irrigated with saline water, since it aims to achieve a balance between the salts accumulated in the root zone and the salts leached from the soil profile (Manzoor et al., 2019; Ning et al., 2020; Simões et al., 2021).

Promising results of the application of various leaching fractions in crops using saline water in irrigation have been observed by several authors (Santos et al., 2012; Guimarães et al., 2016; Simões et al., 2016; Guimarães et al., 2018). Therefore, with the use of this technique, grain sorghum has production potential for cultivation with saline water in semiarid regions.

The present study aimed to evaluate the effect of the application of leaching fractions in the saline water irrigation management on the production of grain sorghum varieties and on the distribution of water and salts in the soil profile, under semiarid conditions.

Material and Methods

The experiment was carried out in the Caatinga Experimental Field, belonging to Brazilian Agricultural Research Corporation (Embrapa Semiarid), in Petrolina-PE, Brazil, in the sub-middle São Francisco region (9° 8' 8.9" S, 40° 18' 33.6" W, 373 m), in the period from autumn to winter seasons of 2016. The soil of the experimental area was classified as Ultisol, of medium texture, on a flat relief.

The climate of the region is classified as semiarid, BSwh' type according to Köppen's classification, with a well-defined period of rainfall, encompassing the months from November to April (Lopes et al., 2017). During the experimental period (Table 1), the average relative humidity and air temperature were 55.95% and 26.43 °C, respectively. The maximum daily reference evapotranspiration (ETo) observed during the experimental period was 6.72, with an average of 4.64 mm per day and precipitation events totaled 47.1 mm at the end of the experiment.

The experimental design was randomized blocks, with four replicates, in split-split plots; four leaching fractions (LF): 0, 5, 10 and 15% with saline water from artesian well in the plots, three varieties of grain sorghum: 1011-IPA, 2502-IPA and Ponta Negra in the subplots, and two crop cycles (1st and 2nd cut) in the sub-subplots. Each experimental unit (subplot) consisted of five 5-m-long rows, spaced by 0.50 m, totaling an area of 12.5 m^2, with 10 plants per linear meter, evaluating plants from the central rows and disregarding 1 m on both ends of each row.

The experimental area was prepared according to the requirements of the crop, with liming of 0.68 t ha^{-1} of calcitic limestone to reach 70% base saturation at 90 days before planting. Basal fertilization was carried out according to the soil analysis previously performed (Table 2), applying 30 kg ha^{-1} of nitrogen, 60 kg ha^{-1} of phosphorus and 20 kg ha^{-1} of potassium

Table 1. Mean meteorological parameters during the experimental period

Season	Month	Cut	Temperature (°C)	Relative humidity (%)	Wind speed (m s^{-1})	Total precipitation (mm)	ETo (mm)
Autumn	April	1st Cut	27.91	57.42	1.22	4.2	4.6
	May		26.73	59.75	1.28	9.4	4.1
	June		25.15	60.92	1.36	3	3.77
Winter	July	2nd Cut	24.8	57.62	1.49	3.8	4.16
	August		25.47	53.22	1.5	0.3	4.74
	September		27.03	50.73	1.57	0.1	5.48
	October		27.89	51.98	1.51	26.3	5.64

Table 2. Soil chemical and physical parameters and particle size before the experiment

Layer (cm)	ECse (dS m^{-1})	pH	OM (g kg^{-1})	P (mg dm^{-3})	K (cmol$_c$ dm^{-3})	Na	Ca	Mg	H + Al	SB	CEC	V (%)
0-20	1.33	4.6	4.6	6.14	0.23	0.27	1.6	0.6	1.5	2.7	4.2	64.0
20-40	2.20	5.7	4.1	1.22	0.16	0.68	1.4	0.6	2.7	2.8	5.6	50.9
40-60	2.41	5.0	3.7	0.55	0.15	1.12	2.4	1.5	2.5	5.2	7.7	67.4
60-80	2.50	4.5	2.3	1.69	0.11	1.40	2.8	2.2	2.3	6.5	8.8	74.3
80-100	2.60	4.5	2.1	0.21	1.18	1.18	3.2	2.0	2.3	6.5	8.7	74.2

	Density (kg dm^{-3})		Total porosity (%)	Particle size (g kg^{-1})		
	Bulk	Particle		Sand	Silt	Clay
0-20	1.49	2.59	42.40	808.1	116.9	75.0
20-40	1.37	2.51	45.41	721.7	195.3	83.0
40-60	1.23	2.55	51.84	631.3	174.6	194.1
60-80	1.20	2.59	53.54	431.9	220.7	347.4
80-100	1.20	2.59	53.42	498.2	170.1	331.7

ECse- Electrical conductivity of the saturation extract; OM - Organic matter; P - Available phosphorus extracted with Mehlich-1; Ca - Exchangeable calcium; Mg - Exchangeable magnesium; Na - Exchangeable sodium; K - Exchangeable potassium; Al - Exchangeable acidity; CEC – Cation exchange capacity at pH 7.0; V - Base saturation

Table 3. Chemical characteristics of the irrigation water from the artesian well

Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	pH	EC 25 °C	Hardness $CaCO_3$	SAR
($mmol_c\ L^{-1}$)						($dS\ m^{-1}$)	($mg\ L^{-1}$)	
15.83	14.49	14.8	0.52	55.79	7.37	4.19	140.65	3.8

EC - Electrical conductivity; Ca - Calcium; Mg - Magnesium; Na - Sodium; K - Potassium; Cl^- - Chloride; SAR - Sodium adsorption ratio ($mmol\ L^{-1}$)$^{0.5}$

(Cavalcanti, 2008). At 30 days after planting (DAP) and 15 days after the first cut, top-dressing nitrogen fertilization was performed with 30 kg ha^{-1} each. Sowing was carried out in April/2016, and the emergence occurred at 7 DAP.

The irrigations were performed daily by surface drip, through a drip tube, nominal diameter (ND) of 16 mm, with emitters with discharge rate of 1.6 L h^{-1}, spaced by 0.30 m. The chemical characteristics of irrigation water were determined in weekly evaluations before and during the experiment, showing the averages described in Table 3.

Irrigation management began after all the plots were at field capacity, which comprises the maximum water retention capacity of the soil, (19.8% soil moisture). For this, a 10 mm irrigation depth was applied 2 days before planting. From this moment, the water depths applied by irrigation were calculated according to the crop evapotranspiration measured in the period between irrigations, using the method proposed by FAO 56 (Allen et al., 1998), applying the dual-Kc method, using basal Kc of 0.15, 0.95, and 0.35, and Kl of 0.5, 0.9, and 1.0, respectively, for the initial, mid-season, and late-season phenological stages, according to the water application efficiency of the system and the leaching fractions tested, according to Eq. 1.

$$\mathrm{Li} = \frac{\left[\left(\mathrm{ETo}\cdot\mathrm{Kc}\cdot\mathrm{Kl}\right)-\mathrm{P}\right]}{\left[\mathrm{Ef}\cdot\left(1-\mathrm{LF}\right)\right]} \quad (1)$$

where:

Li - irrigation depth, mm;

ETo - reference evapotranspiration measured in the period, mm;

Kc - crop coefficient;

Kl - localized irrigation coefficient;

P - precipitation measured in the period, mm;

Ef - efficiency of the irrigation system, 0.9; and,

LF - leaching fraction applied, decimal.

Soil moisture in the profile was monitored using PR2 probes (Profile Probe PR2, Delta-T Devices Ltda), which are based on the Frequency Domain Reflectometry (FDR) principle, previously set to measure soil moisture at depths of 0.10, 0.20, 0.30, 0.40, and 0.60 m, at 0.05 m from the plants (Figure 1). Moisture readings were taken every week, about two hours after each irrigation.

In the period of sorghum harvest (81 and 70 days of 1st and 2nd cuts, respectively) of each cycle, disturbed soil samples were collected in the layers of 0-0.10, 0.10-0.20, 0.20-0.30, 0.30-0.40, 0.40-0.50, and 0.50-0.60 m, at 0.1 m from the dripper, to determine the electrical conductivity of the soil saturation extract (ECse), using the saturated paste method (Figure 1). Samples of 250 g of air-dried fine earth (ADFE) were placed in appropriate containers, and distilled water was added until it reached the saturation paste point, as described by Richards (1954). The ECse was determined using a benchtop digital conductivity meter.

Harvests were carried out when the grains of the central portion of the panicle exhibited a dry appearance. Plants of the useful plot were cut at five cm height from the soil and separated into culm, leaf, panicle and grains. The following parameters were evaluated: fresh biomass, total leaf area (TLA),

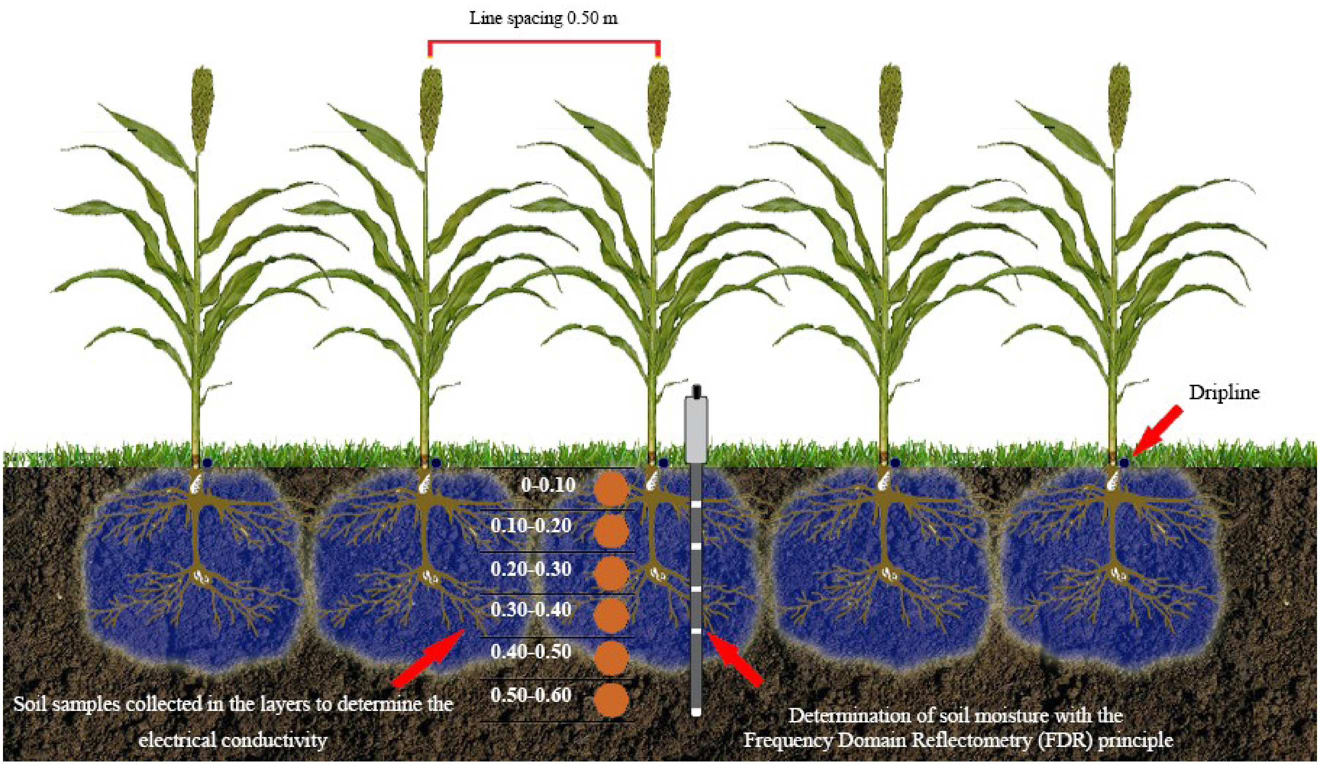


Figure 1. Soil sampling diagram for determining the electrical conductivity and installation of the FDR soil moisture sensor

plant height and culm diameter. Subsequently, the material was placed in an oven to dry at 60 °C to determine the dry biomass. The yields of fresh biomass (FBY), dry biomass (DBY), and grains (GY) were calculated by the ratio between the quantity harvested and the harvested area, being expressed in t ha^{-1}.

Water use efficiency (WUE) was calculated by the ratio between grain yield (GY) and the total amount of water consumed (WC), represented by irrigation plus precipitation, according to Eq. 2.

$$WUE = \frac{GY}{WC} \tag{2}$$

where:

WUE - water use efficiency, kg ha^{-1} mm^{-1};
GY - grain yield, kg ha^{-1}; and,
WC - irrigation depth plus precipitation, mm.

The obtained data were subjected to Shapiro-Wilk normality test and analysis of variance (ANOVA), using the program Sisvar 5.0. First- and second-order regression models, when significant at 0.01 or 0.05 probability levels, were evaluated for comparison between leaching fractions. Tukey test at 0.05 probability level was used for comparison between sorghum varieties (Ferreira, 2014).

Results and Discussion

The 2502-IPA and Ponta Negra varieties required greater volumes of water per crop cut than required by the same treatments for the 1011-IPA variety (Table 4). The differences in water volume for irrigation between the varieties may be explained by the duration of the cycle, which was different for the cultivars studied. The varieties 2502-IPA and Ponta Negra had longer cycles in the two cuts evaluated, and consequently, higher total depth applied.

The application of leaching fractions (LF) with saline water led to lower values of electrical conductivity of the soil saturation extract (ECse) in all soil layers evaluated ($p \leq 0.01$). It can be observed that the plots irrigated with 15% leaching fractions had lower values of ECse than plots under no leaching fraction (0) (Table 5). However, there was an increase in soil salinity to values close to the electrical conductivity of irrigation water in all evaluated plots when compared to the measurement performed before sowing (Table 1).

Table 4. Irrigation depth plus precipitation and cut time in cultivation of grain sorghum varieties irrigated with saline water

Variety	Cut time (days)		Leaching fraction (%)	Irrigation depth plus precipitation (mm)	
	1st cut	2nd cut		1st cut	2nd cut
1011-IPA	81	70	0	271.3	316.9
			5	284.8	332.8
			10	298.4	348.6
			15	312.0	364.5
2502-IPA	102	78	0	363.9	386.8
			5	382.1	406.1
			10	400.3	425.4
			15	418.5	444.8
Ponta Negra	102	78	0	363.9	386.8
			5	382.1	406.1
			10	400.3	425.4
			15	418.5	444.8

Table 5. Electrical conductivity of the saturation extract (dS m^{-1}) of the soil cultivated with grain sorghum varieties subjected to leaching fractions of 0, 5, 10, and 15%

Leaching fraction (%)	Layer (m) Electrical conductivity of the soil saturation extract					
	0- 0.10	0.10-0.20	0.20-0.30	0.30-0.40	0.40-0.50	0.50-0.60
0	7.47 a	5.69 a	5.92 a	6.12 a	6.48 a	6.14 a
5	5.33 b	4.84 a	4.36 b	4.62 b	4.62 b	5.43 ab
10	4.95 b	5.34 a	4.48 b	4.80 b	4.58 b	4.96 ab
15	4.25 b	3.48 b	3.98 b	3.99 b	4.58 b	4.28 b
LSD	1.189					
CV (%)	19.68					

*Means followed by the same letter in the columns do not differ by Tukey test at 0.05 probability level

The principal factors affecting soil salinity of the root zone in drip irrigation are the location of the emitter, the hydraulic characteristics of the soil, the salinity of the irrigation water, the frequency of irrigation, and the irrigation depth applied (Hanson & May, 2011).

For an efficient management of irrigation with saline water, a volume of water above the maximum value that the soil can retain (field capacity) is applied at a frequency of three times a week to promote the leaching of salts in its profile. According to Wang et al. (2017), the beneficial effects of this technique can be achieved after several irrigations because, with the application of the leaching fraction in the irrigation depth, the salts are displaced to the edges of the wet bulb, in which the root system of the crop is distributed.

This effect can be observed with the data presented in Table 5, which shows a reduction in soil ECse with the increase of LF. Similar result has been observed by several authors in forage sorghum (Guimarães et al., 2016), beet (Simões et al., 2016), peanuts (Santos et al., 2012), and pepper (Qiu et al., 2017), confirming that leaching is an effective practice to reduce excess salts in the root zone of crops.

One of the main effects of the reduction of ECse is the increase in the exploration area for the roots, thus decreasing the stress caused by the accumulation of salts. Increase in biometric parameters of plants subjected to leaching fractions with saline water has already been observed in plants of maize (Carvalho et al., 2012) and sorghum (Guimarães et al., 2016), and these results were associated with the reduction of salinity in the cultivated soil.

Plots subjected to leaching fractions of 5, 10 and 15% showed increase in soil moisture in the 0-0.60 m layer, with values above field capacity (FC) (Figure 2). The results demonstrate reduced water movement in the soil, which may be related to the increase of clay content in the 0.60-0.80 m layer (Table 2), which causes a reduction in the rate of water infiltration in the soil, consequently delaying drainage.

There were no significant interactions between the factors variety × leaching fraction × cycle, and no significant interactions between cycle × variety and cycle × leaching fraction.

Plant height, culm diameter, total leaf area (TLA), and water use efficiency (WUE) showed significant differences among the varieties and leaching fractions applied ($p \leq 0.01$). In relation to cycles, the variables plant height (H), TLA, and fresh biomass yield (FBY) showed significant differences

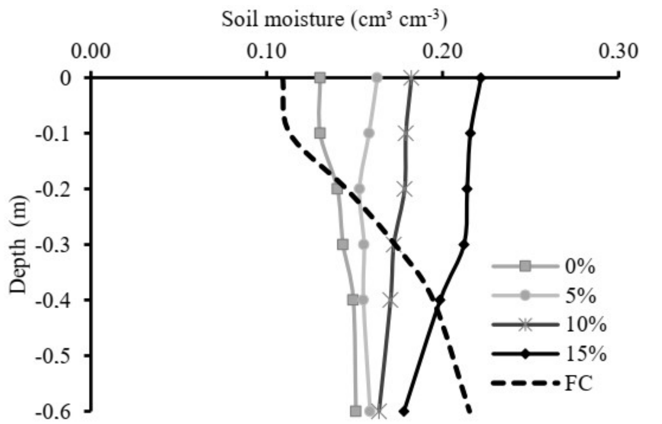


Figure 2. Mean moisture distribution in a soil profile during cultivation of grain sorghum varieties and irrigated with saline water, subjected to leaching fractions of 0, 5, 10 and 15%, where FC is the soil moisture content at field capacity

($p \leq 0.01$). For the interactions sorghum variety × leaching fraction, only the variables related to crop yield (FBY, DBY, and GY) showed significance ($p \leq 0.05$).

There were progressive linear increments for the variables plant height, culm diameter and TLA with increase in the LF applied. The WUE showed a quadratic effect of the increase in LF, with maximum values at LF of 12.25% (Figure 3).

Plants of the variety 1011-IPA were the tallest ones, followed by Ponta Negra, and 2502-IPA. As for the culm diameter, TLA and WUE, higher values were observed for the varieties 1011-IPA and Ponta Negra, which significantly differed from 2502-IPA (Table 6).

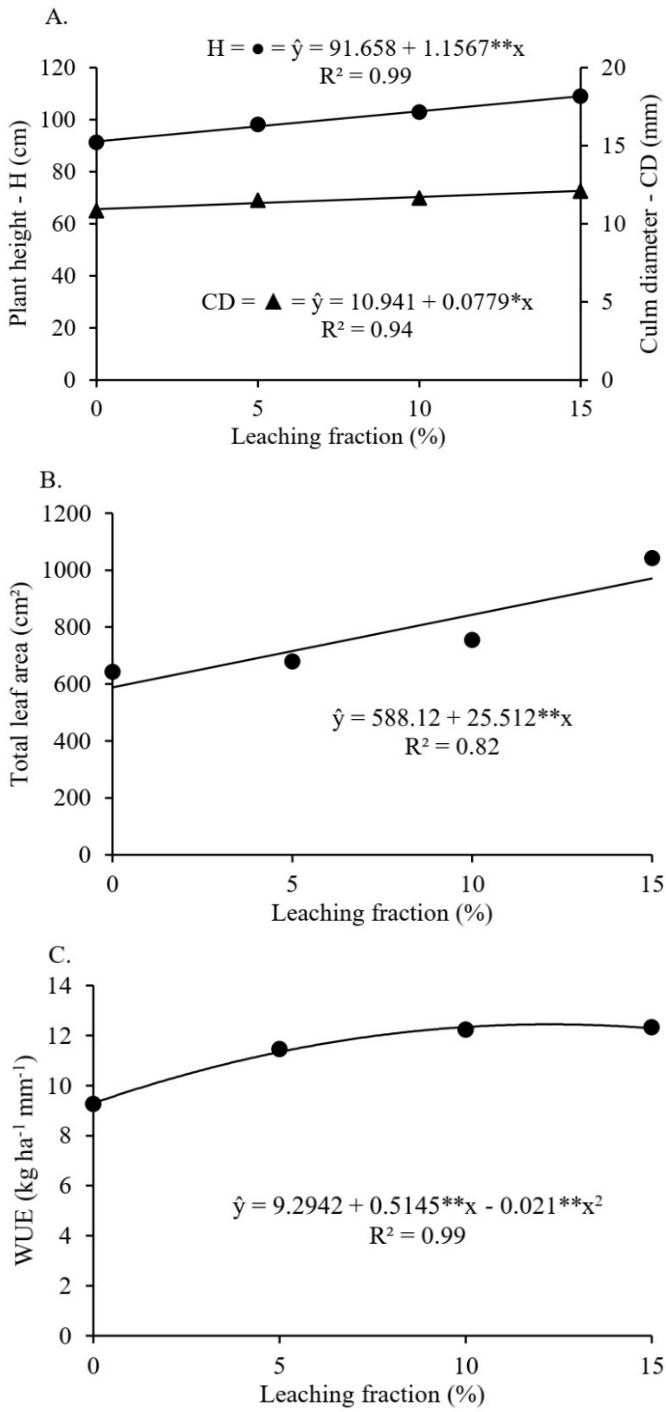
Thus, associated with the low WUE of the variety 2502-IPA, it is possible to observe higher potential for grains in the varieties 1011-IPA and Ponta Negra, which, despite being taller, have larger diameter, a characteristic that can promote higher physical resistance for the plants.

For sorghum cultivation, plant size and culm resistance are characteristics that should be taken into consideration in the selection of grain varieties. Varieties with shorter plants, associated with higher culm resistance, as the Ponta Negra variety, are less susceptible to lodging or breakage of plants (Silva et al., 2009).

Several authors report the increase of yield with the application of leaching fractions with saline water. Similar results were observed by Guimarães et al. (2018) in forage sorghum, Santos et al. (2012) in peanuts, Simões et al. (2016) in beet and Qiu et al. (2017) in pepper plants. However, it is worth pointing out that high leaching fractions may cause reduction in the yields of crops due to the decrease in the availability of indispensable ions for their mineral nutrition, as observed by Carvalho et al. (2012), when evaluating the yield of maize irrigated using saline water (ECse = 3.3 dS m^{-1}) with LF of 20%, and in the yield of the variety 1011-IPA.

The reduction of soil ECse due to the application of leaching fractions led to an increase in the grain yield of the evaluated varieties. The development of reproductive organs is directly related to the salinity of the cultivation medium.

Increased yield with the application of LF interferes directly with the WUE of plants. Considering that the WUE represents the amount of grains produced for every mm



Coefficients significant at $p \leq 0.01$ (**) and $p \leq 0.05$ (*)

Figure 3. Plant height and culm diameter (A), total leaf area (B), and water use efficiency – WUE (C) of grain sorghum plants irrigated with saline water, subjected to different leaching fractions

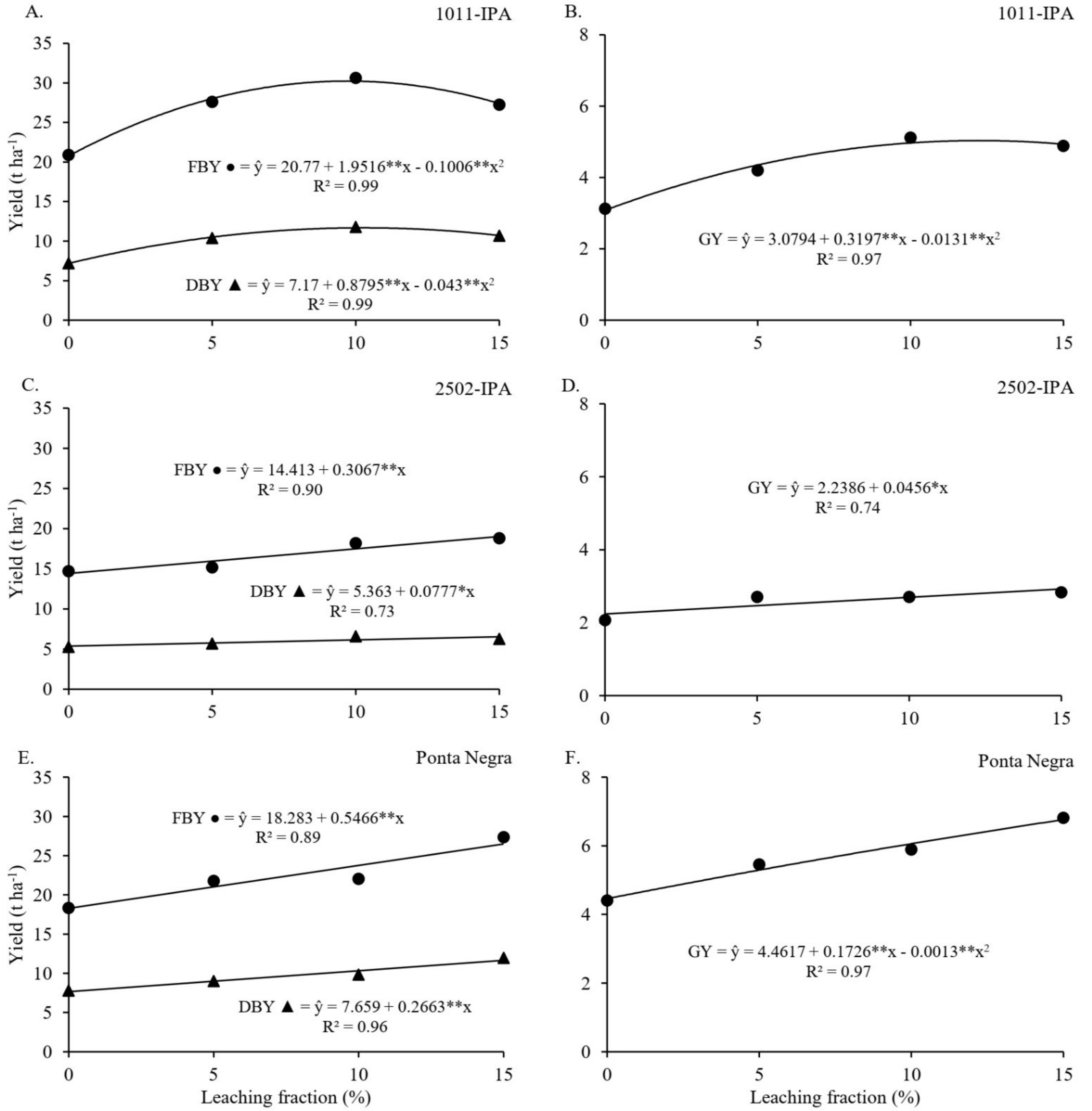
Table 6. Plant height, culm diameter, total leaf area, and water use efficiency (WUE) of grain sorghum varieties irrigated with saline water

Variety	Plant height (cm)	Culm diameter (mm)	Total leaf area (cm^2)	WUE (kg ha^{-1} mm^{-1})
1011-IPA	110.90 a	12.61 a	812.57 a	13.64 a
2502-IPA	89.53 c	9.56 b	671.34 b	6.39 b
Ponta Negra	100.56 b	12.39 a	854.46 a	13.92 a
LSD	6.39	1.05	140.22	1.22
CV (%)	8.17	12.53	30.86	17.35

*Means followed by the same letter in the column for each variable do not differ by Tukey test at 0.05 probability level of water supplied along the crop cycle, the observed values indicate that LF application promotes a more efficient use of water by plants. Assuming that soil salinity decreases with the increment in the LF applied, it can be concluded that plants exposed to a less saline environment have higher values of WUE, corroborating the findings of Guimarães et al. (2019), who observed significant reductions of WUE with increased salinity in the cultivation of grain sorghum varieties.

In general, there is a reduction in the biometric and yield parameters of sorghum plants from the 1st to the 2nd cut, which was reported by some authors when evaluating different sorghum varieties under different cultivation conditions (Botelho et al., 2010; Silva et al., 2017). In the case of cultivation under saline conditions, these reductions may be associated with the time of exposure to the applied stress, which, together with its intensity, directly reflects the morphological responses of the plants (Willadino & Camara, 2010).

The evaluated varieties showed different behaviors of yield under irrigation with saline water with increasing leaching fractions (Figure 4). 1011-IPA showed quadratic behavior, with maximum yields of 30.23 t ha^{-1} of fresh biomass (FBY) with LF of 9.7%, 11.68 t ha^{-1} of dry biomass (DBY) with LF of 10.25% and a grain yield (GY) of 5.03 t ha^{-1} with LF of 12.20%. Compared to plants under no LF application, these values represented increases of 44.6, 61.8, and 61.2% in FBY, DBY and GY, respectively.



Coefficients significant at $p \leq 0.01$ (**) and $p \leq 0.05$ (*)

Figure 4. Fresh biomass yield (FBY), dry biomass yield (DBY), and grain yield (GY) of grain sorghum varieties irrigated with saline water, subjected to different leaching fractions

Table 7. Mean values of plant height, culm diameter, total leaf area, yield, and water use efficiency (WUE) of grain sorghum varieties in two production cycles (1st and 2nd cut)

Cut	Plant height (cm)	Culm diameter (mm)	Total leaf area (cm^2)	Yield ($t\ ha^{-1}$)			WUE ($kg\ ha^{-1}\ mm^{-1}$)
				FBY	DBY	GY	
1st	119.81 a	11.19 a	887.45 a	24.06 a	8.64 a	4.08 a	11.53 a
2nd	80.85 b	11.85 a	671.47 b	19.73 b	8.44 a	4.29 a	11.10 a
LSD	4.004	0.679	64.953	1.348	0.471	0.275	0.82
CV (%)	8.17	12.53	30.86	12.26	13.31	16.6	17.35

*Means followed by the same letter in the columns for each variable do not differ by Tukey test at 0.05 probability level. DBY - Dry biomass yield; FBY - Fresh biomass yield; GY - Grain yield

For the varieties 2502-IPA and Ponta Negra, there was a linear increase of yield with the increase in the leaching fractions applied. There were increments of 27.9, 19.08, and 36.4% in the FBY, DBY, and GY of the variety 2502-IPA with the application of a LF of 15%, with values of 18.8, 6.26, and 2.83 $t\ ha^{-1}$, respectively. These values were lower than those observed in the variety Ponta Negra, which showed increments of about 50% in all evaluated yields, with values of 27.35, 11.96, and 6.81 $t\ ha^{-1}$ for FBY, DBY, and GY, respectively.

The present study found lower values of plant height compared to the results obtained by several authors for different varieties of grain sorghum (Botelho et al., 2010). However, the reduction of size in the evaluated plants is a consequence of the saline environment in which they were cultivated, because one of the main effects of salinity on plant growth is due to the increase in the osmotic pressure of the cultivation medium, which negatively affects the physiological processes of the plants, reducing the absorption of water and nutrients by the roots, thus inhibiting meristematic activity and cell elongation (Ayers & Westcot, 1999).

The results obtained in this study denote that, despite being of the same species (*Sorghum bicolor* L.), different varieties respond in a specific way regarding the magnitude of the effects of salinity on their growth and production.

The average data of the biometric variables and grain yield of the sorghum varieties for the two production cycles evaluated are shown in Table 7. In general, the varieties showed taller plants and with higher TLA in the first cut. Regarding the data of yield, only the variable FBY was significantly different between the 1st and 2nd cuts, decreasing by about 18%.

A reduction only in the FBY of sorghum plants in the 2nd cut may be related to their water status, because changes in the osmotic potential are the first effect of salts on plants, which causes reductions in water absorption and, consequently, in fresh weight. Willadino & Camara (2010) also report that such reduction is intensified by the time of exposure to salt stress, since plants evaluated in the 2nd cut were exposed to the saline environment for a longer period.

Besides the deleterious effects of the time of exposure to salt stress in second-cut plants, some authors relate reductions in FBY to the ideal stand because, in the regrowth, due to tillering, there may be an increase in the final stand. Hence, in first-cut sorghum, there may have been greater capture of light by the plant due to the higher values of TLA, enhancing its development, possibly through the increase of photosynthetic capacity, increasing the yield of green matter (Botelho et al., 2010).

Although significant reductions in plant height, TLA and FBY were observed between the evaluated cycles, the same behavior was not observed for DBY and grain yield. These results show more accentuated reductions in the production of culms (plant height) and leaves (total leaf area) between cycles, corroborating those obtained by Botelho et al. (2010), who found significant reductions in the proportions of leaves and culms in varieties of grain sorghum between production cycles, 1st and 2nd cut.

Conclusion

The application of leaching fractions in irrigation of 15% with saline water leads to grain sorghum yield increments up to 60% in the variety 1011-IPA, 36% in 2502-IPA and 50% in Ponta Negra. The production of the varieties 1011-IPA and Ponta Negra is a viable alternative in systems irrigated with saline water with average electrical conductivity of 4.19 $dS\ m^{-1}$ in area with Ultisol under semiarid conditions.

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