PERFORMANCE OF SALT-TOLERANT FORAGE GENOTYPES OF MILLET [*PENNISETUM GLAUCUM* (L.) R. BR.] IN EASTERN MEDITERRANEAN CONDITIONS

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ABSTRACT

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In this study the aim was to evaluate alternative crops able to tolerate thefuture rise in salinity, likely to occur in the East Mediterranean coastal areas. For this, two genotypes of pearl millet (Tall and IP13) were submitted to saline conditions (4, 8, 12 $dS.m^{-1}$ *and 2* $dS.m^{-1}$ *as control) in a field trial. Water consumption using neutron probe technique, physiological response and the production were studied. The neutron probe technique showed that 96% of consumed water originated in the upper 0.45 m. As salinity increased, water consumption became shallower, suggesting a different root distribution. Physiological aspects related to plant height, foliar potassium and uptake of nitrogen were investigated. Tallest plants were found in 4* $dS.m^{-1}$ *in Tall, and in 2* $dS.m^{-1}$ *in IP13. Foliar potassium was similar in Tall variety, while IP13 excluded the potassium, in order to reduce cellular ions. In Tall the* ^{15}N *technique showed that 40-50% of plant N originated from the fertilizers, irrespective of saline conditions. Fresh weight was not different between 4 and 8* $dS.m^{-1}$*, in three cuts out of five in 2016 and 2017. Tall produced higher dry matter, especially under saline conditions. Best water use efficiency was in 4* $dS.m^{-1}$ *(10.4* $kg.m^{-3}$ *in Tall; 8.8* $kg.m^{-3}$ *in IP13). The plotting of dry matter production against salinity gave quadratic equations, with a peak at 5.6* $dS.m^{-1}$ *for IP13 and 7.1* $dS.m^{-1}$ *for Tall. Tall can be used for phytoremediation of soils in coastal areas, and as a forage crop.*

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INTRODUCTION

Anthropogenic pressure, through industrial agriculture and tourism, is changing the composition of natural waters in many coastal areas. The interference of seawater with groundwater is leading to saline aquifers, around the Mediterranean basin in Catalonia and Sardinia (Mas-Pla et al., 2014), in Rhodes Island, Greece (Mavriou et al., 2019) and in Tripoli, Libya (Alfarrah and Malraevens, 2018). Similarly, a rise in the salinity in the coastal cities of Tripoli, Beirut and Saida (Korfali and Jurdy, 2010) and in the coastal agricultural area, south of Beirut (El Moujabber et al., 2006) had been found. Practically, growers in the coastal strip had to abandon their wells, if not mix its water with a better-quality one. This situation becomes critical in the summer when the groundwater salinity peaked (El Moujabber et al., 2006). A maximum electrical conductivity of irrigation water (ECw) of 5.4 dS m^{-1} was found in one well of the south coast (El Moujabber et al., 2013). Currently, growers of this area report ECw values exceeding 7 $dS.m^{-1}$.

A model applied to north Lebanon showed an advancement of 103 m of seawater, within the next 25 years. Climate change will be responsible for 79% of this higher demand on groundwater, while the demographic pressure will contribute by 25% only (Kaloun et al., 2018). Future climatic conditions in Lebanon would lead to a decrease in annual rainfall levels by 200 mm, and a drop in snow-covered area from 23.9% of the area of the country to less than 19% (Shaban, 2011). This would generate a higher competition between sectors for the available water, during a shorter growing season. The livestock sector could be mostly affected by the reduced vegetation cover (Hamzé et al., 2010).

To respond to this situation, salt and drought tolerant crops would be most useful, especially forage crops. Among these crops, sorghum and millet were introduced to Nebraska (Maman et al., 1999), to West Texas (Machicek, 2018) in the USA, to parts of Australia (Collett, 2004) and to central Asia (Toderich et al., 2018). Of the millet species, only proso millet (*Panicum miliaceum* L.) was known to central Asia (Toderich et al., 2013) and to parts of the eastern Mediterranean such as Syria. Pearl millet could be a suitable irrigated summer crop, especially genotypes that serve a dual purpose for grain and forage (Toderich et al., 2018). Developed with the objective of crop diversification in mixed crop-livestock farming systems, millet entries (13 of them) tolerated saline conditions between 2.6 and 8.5 dS m^{-1}, against 2.4 to 4.6 dS m^{-1} for the eight sorghum entries (Toderich et al., 2013).

In this study, the aim was to evaluate alternative crops able to tolerate the future abiotic stress conditions, likely to occur in the East Mediterranean coastal areas. For this, the performance of two genotypes of pearl millet, submitted to moderate salinity, was studied. Tolerance to salinity was evaluated in a field trial in the coastal area, by using irrigation water with levels of salinity from 2 to 12 $dS.m^{-1}$. Water consumption using neutron probe technique, physiological response and the dry matter production and quality were studied.

MATERIALS AND METHODS

Experimental set-up

The trial took place in *Sour* (Tyr) station of the Lebanese Agricultural Research Institute (LARI), south Lebanon (33° 16' 23" N, 35°11' 38" E, and 7 m above sea level), during two summer seasons in 2016 and 2017 (Table 1). Climatic data, recorded within Sour station, were typical of the sub-humid Mediterranean conditions. These included daily temperatures, relative humidity, rainfall as well as the evapotranspiration (ET0) found using the Penman-Monteith equation. Growing degree days (GDD) were calculated, with equation 1 and using10˚C as the base temperature (Machicek, 2018):

$$\mathbf{GDD\ (^{\circ}D) = \Sigma\ [(Maximum\ temperature + Minimum\ temperature)^{1/2} - 10]} \qquad \mathbf{(1)}$$

The soil was a non-saline (EC ≈ 0.27 $dS.m^{-1}$), sandy clay loam (56% sand; 26% clay); poor in organic matter (21 $g.kg^{-1}$).

Table 1. Growing degree-days and cumulative evapotranspiration (ET0), as recorded in the experimental station, and amounts of irrigation water (w.) applied to pearl millet in the 2016 and 2017 seasons.

	2016				2017			
Irrigation water	Month/ Day	Growing degree-days (˚days)	ET0 (mm)	Irrigation (mm)	Month/ Day	Growing degree-days (˚days)	ET0 (mm)	Irrigation (mm)
Well water	May 10- Jun 24	601	226	129	May 27 - Jul 3	526	145	115
Saline w.	Jun 25 - Jul 6	199	66	42	Jul 4 - Jul 20	289	136	83
First cut	**56 days**	**800**	**292**	**171**	**53 days**	**815**	**281**	**198**
Well water	one irrigation				one irrigation			
Saline w.	Jul 11 - Jul 28	**309**	-	90	Jul 31 - Aug 20	**381**	**145**	82
Second cut	**17 days**			**90**	**21 days**			**82**
Well water	Not applicable				one irrigation			
Saline w.					Aug 28 - Sept 14	**295**	**141**	80
Third cut					**18 days**			**80**

Of the entries of pearl millet developed by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), two promising genotypes - HHVBC Tall (referred to hereafter as Tall) and IP 13150 (referred to hereafter as IP13) - were multiplied by the International Center for Biosaline Agriculture (ICBA), Dubai. The

objective was to evaluate their performance under East Mediterranean conditions. Seeds were sown manually on May 10th 2016 and May 27th 2017, with a planting density close to 13 plants.m^{-2} (0.25 m x 0.30 m. plant^{-1}). Three levels of salinity were studied: 4, 8 and 12 dS.m^{-1}, in addition to the control (well water: 2 dS.m^{-1}). Saline water was obtained by mixing the well water with seawater in individual barrels. Four head units, each consisting of a pump, a water-meter and a mesh filter, were linked to the barrel of irrigation water.
Each treatment (5.0 m x 3.6 m) was represented by 12 irrigation lines, distant by 0.3 m. A drip irrigation system, with a distance of 0.25 m between drippers and a discharge rate of 4 L.hr^{-1}, was installed. The well water (≈2 dS m^{-1}) was used for irrigation during the establishment phase of each season (Table 1). Crop was irrigated twice weekly. After emergence, the crop was fertilized with ammonium sulfate, di-ammonium phosphate and potassium sulfate, as side dressing. The dose used was 100 kg N ha^{-1}, 90 kg P_2O_5 ha^{-1} and 90 kg K_2O ha^{-1}. For the 2017 season, an extra 30 kg N ha^{-1} was provided on August 21st, after the second cut.

Soil moisture using neutron probe

Based on the 2016 results, only the genotype Tall was tested for water consumption in 2017. For this, the neutron probe was calibrated in April 2017, against the soil moisture of the experimental site. Readings of count ratio were taken, in duplicates, at four soil depths down to 0.6 m, at three soil moisture levels. These gave the linear relationship (2) between the volumetric soil moisture and the count ratio:

$$\textit{Volumetric Soil Moisture } (\theta_v) = 13.33 \times \textit{Count Ratio} + 4.55 \qquad (2)$$
$$(r^2 = 0.933)$$

Volumetric soil moisture was converted into mass soil moisture (θ_m) using the bulk density of each soil layer.

At sowing of millet crop, two access tubes were introduced in the soils of each treatment, to 0.6 m in depth. Neutron probe readings were taken before, and 24 hours after each irrigation, at four soil depths (0.15, 0.30, 0.45, 0.60 m), between July 21 and September 14, 2017. The difference in the soil moisture before and after the irrigation corresponded to the consumed water.

Plant sampling and analysis

Before each cut in 2016 (Table 1), plant heights and leaf numbers were determined on five tagged plants per treatment. Biomass production was obtained by removing five plants during the 2016 season and three replicates (four plants per replicate) per treatment in 2017. Fresh weights were recorded, then plant subsamples were dried (65 ˚C) in order to obtain the dry weights. After each cut, some well water (Table 1) was provided to leach salts before restarting the irrigation with saline water.

Potassium and sodium concentrations in leaves were analyzed for the second cut in 2017 (21st August). For this, ground leaf samples (<1 mm) were digested in the presence of concentrated sulfuric acid and hydrogen peroxide (30% v/v) at a temperature of 200 ˚C (Estefan et al., 2013). Potassium and sodium contents were read at a flame photometer.

To quantify the nitrogen used by the plant, ^{15}N-labelled fertilizer was added to the genotype Tall in microplots (2 to 3 replicates per treatment). Each microplot comprised 12 plants, distributed in three rows. Ammonium sulfate enriched by ^{15}N (*ca* 2% atom excess) was solubilized in well water then applied manually to all labeled plants. Only the middle-protected plants were considered for analysis, after drying (65 ˚C) and grinding (< 1 mm). Plant samples were analyzed for Kjeldhal nitrogen and for ^{15}N atom excess (a.e.) by mass spectroscopy (Isotope Bioscience Laboratory, Gent University, Belgium). Similarly, the ^{15}N a.e. of the applied fertilizer was measured. Nitrogen derived from fertilizers (Ndff %) was calculated as the ratio between ^{15}N a.e. in plant and that in applied fertilizer (Zapata, 1990). Nitrogen fertilizer yields were calculated from nitrogen yield and Ndff (%).

Data analysis

Effect of treatments (genotype and salinity) was tested using the ANOVA analysis (Jandel Scientific, SigmaStat 3.5). Means were compared with the LSD test. Trendlines were established for consumed water *versus* soil depth and for the dry matter production against the saline water. The correlation coefficients (r) were checked for level of significance.

RESULTS AND DISCUSSION

Consumed water

Grown in arid regions such as West Texas (Machicek, 2018), pearl millet was promoted as a drought-tolerant crop (Choudhary et al., 2015). In this study, the irrigation water was smaller than the evapotranspiration (ET0). The ratio between irrigation water and the evapotranspiration (Irrigation/ET0) was 0.58 for 73% of the 2016 season (Table 1) and ranged between 0.56 and 0.70 during the 2017 season. Applied water was at best 70% of the evapotranspiration, even during the full vegetative development. But, the applied crop coefficient was close to that implemented for full irrigation in South-East Tunisia (Nagaz et al., 2009).

Using the neutron probe technique, the amounts of water consumed during the application of saline water, from July 21st to September 14th 2017, represented from 51% (12 dS m^{-1}) to 63% (2 dS m^{-1}) of applied water. Plants in the control consumed 9% more water than those in the 4 dS m^{-1} treatment. In addition to the quantitative aspect, relationships between consumed water and salinity were evaluated for three soil depths. The depth 0.45-0.6 m was excluded as 96% of consumed water originated in the upper 0.45 m of the soil. Quadratic trendlines were obtained, with close absolute values of the coefficients a and b for 0-0.15 m and 0.15-0.30 m (Figure 1). Yet, these coefficients presented opposite signs suggesting a greater consumption in 0-0.15 m in the treatment 4 dS.m^{-1}, to the contrary of the control (2 dS.m^{-1}). This layered water consumption was also demonstrated with the ANOVA test for the second cut (Jul 21-Aug 21), when the treatment 4 dS.m^{-1} gave a significantly larger consumption in the 0-0.15 m (25.8 mm), as compared to the 0.15-0.30 m layer (11.4 mm). This pattern was inversed in the control (2 dS.m^{-1}) with a significantly smaller consumption in the upper soil (10.5 mm), and a higher value in the 0.15-0.30 m (35.5 mm).

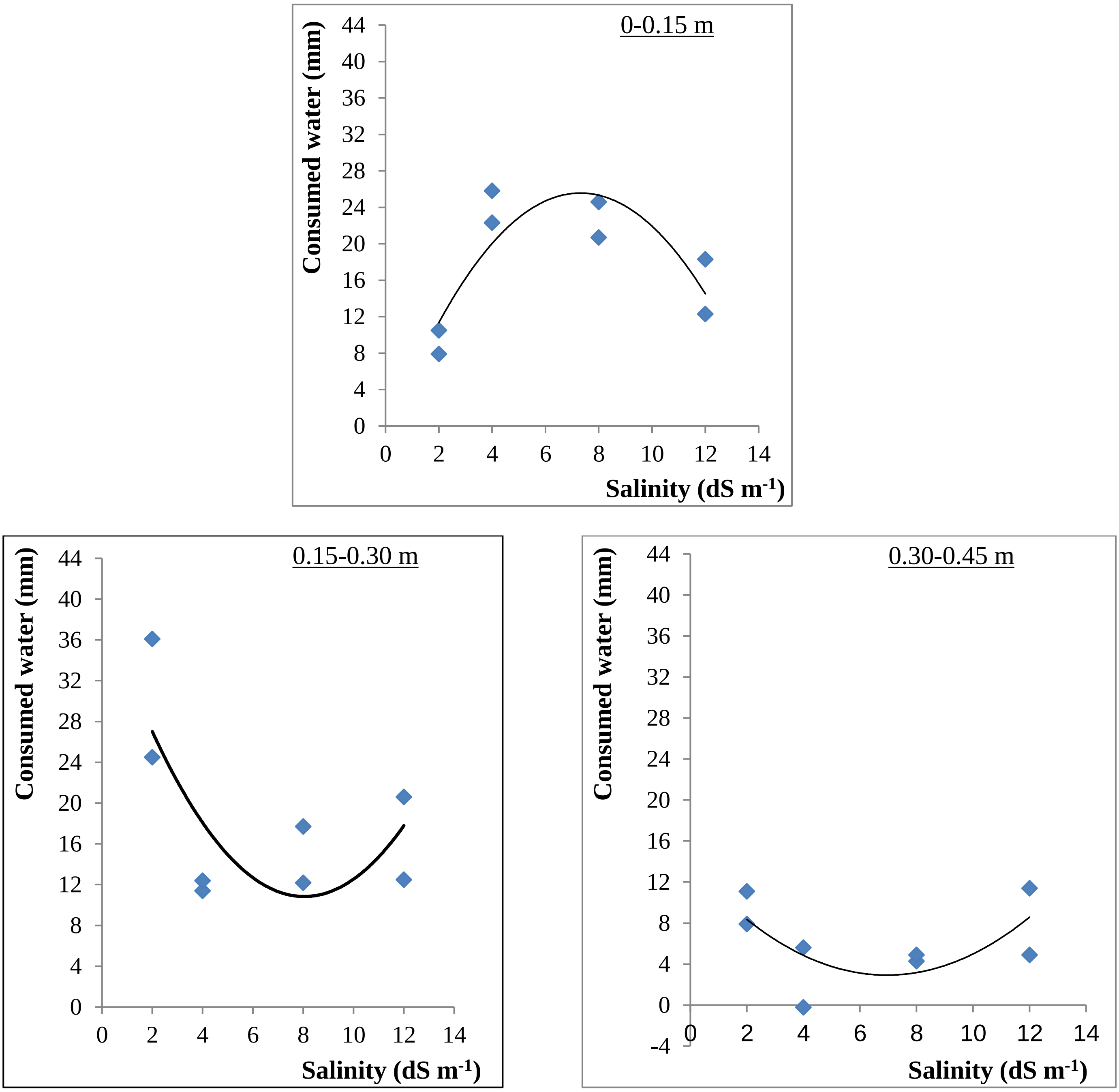

Figure 1. Effects of four salinities of irrigation water on the water consumption of millet (genotype Tall) from July 21 to August 21 (2nd cut) and August 21 to September 14 (3rd cut) 2017, in three soil depths. Each point is the mean of two replicates.

0-0.15 m $y = -0.5038x^2 + 7.3694x - 1.381$ ($r^2 = 0.710$)
0.15-0.30 m $y = 0.4433x^2 - 7.1281x + 39.492$ ($r^2 = 0.510$)
0.30-0.45 m $y = 0.2218x^2 - 3.0823x + 13.631$ ($r^2 = 0.417$)

These results suggest an effect of the saline water on the root distribution in the soil, with the formation of shallower roots as the level of salinity increases. In fact, in southern Italy hydroponic tomato, grown between 2.2 and 15 dS.m^{-1}, had shallower and smaller roots in the most severe treatment (Lovelli et al., 2012). *Arabidopsis* roots exposed to a band of sodium chloride grew away from salts (Munns and Gilliham, 2015), while Jerusalem artichoke tested in soils reaching 2.8 g of salt kg^{-1}, produced more horizontal roots and grew preferably in the upper soil, in order to avoid salinity stress (Yang et al., 2016).

Physiological responses to saline water

In addition to the potential distinction between roots distribution, aspects related to the physiology of the aboveground were studied. These concerned plant height, number of leaves, foliar concentrations of monovalent cations and nitrogen uptake. As expected by the name of the genotype, taller plants were found in the genotype Tall, as compared to IP13 (Table 2). On July 28, the highest plants were in the treatment 4 dS m^{-1} for the genotype Tall and in the control for IP13 (Table 2). Thus, saline conditions had a stronger impact on IP13 than on Tall. Heights of plants belonging to the genotype Tall plants heights decreased significantly between 2 and 4 dS m^{-1} on one side, and 12 dS m^{-1} on the other (data not shown) in September 2017.

Table 2. Effects of the salinity of the irrigation water (2, 4, 8 and 12 dS m^{-1}) on the height of two genotypes of millet (IP13; Tall) and the number of leaves, as determined on July 7th and July 28th 2016.

		Salinity (dS.m^{-1})	**Plant height (m)**		**Number leaves plant^{-1}**	
			July 7	**July 28**	**July 7**	**July 28**
Genotype	**IP13**	2	0.71	$1.18^{\gamma\gamma}$	10.0^{ab}	8.4
		4	1.25	0.85^{γ}	11.4^{a}	7.0
		8	1.06	0.87^{γ}	9.0^{b}	6.6
		12	1.13	0.87^{γ}	9.4^{ab}	6.2
		Mean	**1.04***	**0.94***	**9.9***	**7.0***
	Tall	2	0.87	1.28^{B}	10.8	9.4
		4	1.17	1.66^{A}	10.4	9.0
		8	1.72	1.24^{B}	12.0	8.0
		12	1.50	1.30^{B}	11.6	8.0
		Mean	**1.31****	**1.35****	**11.2****	**8.6****
	Between genotypes		Significant differences			
	Within each genotype			Significant differences	Differences within IP13 only	

Salinity stress reduced leaf transpiration and net photosynthetic rates of maize and sorghum genotypes irrigated with saline water at 8 dS m^{-1} (Niu et al., 2012). The ability of plants to maintain normal rates of transpiration under saline conditions is an important indicator of salt tolerance, particularly because transpiration is related to rates of CO$_2$ uptake (Negrão et al., 2017). This was tested through enumerating leaves per plant on two dates. A genotypic difference was found with Tall plants presenting more leaves than IP13 on both dates (Table 2). Within the genotype IP13, the number of leaves decreased between the treatment 4 dS m^{-1} and 8 dS m^{-1} on July 7th (Table 2), suggesting a greater sensitivity to saline conditions.

Saline conditions lead to the accumulation of sodium in cells cytosol, causing ionic imbalance and toxicity of transpiring plans (Hanin et al., 2016). The impact of saline conditions on the uptake and accumulation of monovalent cations was studied in leaves of plants receiving a full cycle of saline water in 2017. Potassium contents were not different between genotypes, with 42.9 mg kg^{-1} dry weight in IP13 and 42.2 mg kg^{-1} dry weight in Tall. Within the genotype IP13, a salinity effect was observed, as the level of potassium was significantly higher in the treatment 4 dS m^{-1} (46.9 mg kg^{-1}) as compared to the other treatments (Figure 2). To the contrary, the genotype Tall maintained constant levels of potassium, regardless of the salinity of the irrigation water. The maintenance of potassium homeostasis is essential for a number of physiological activities, while the level of cytosolic potassium is considered an attribute of the adaptability to a range of conditions (Hanin et al., 2016).

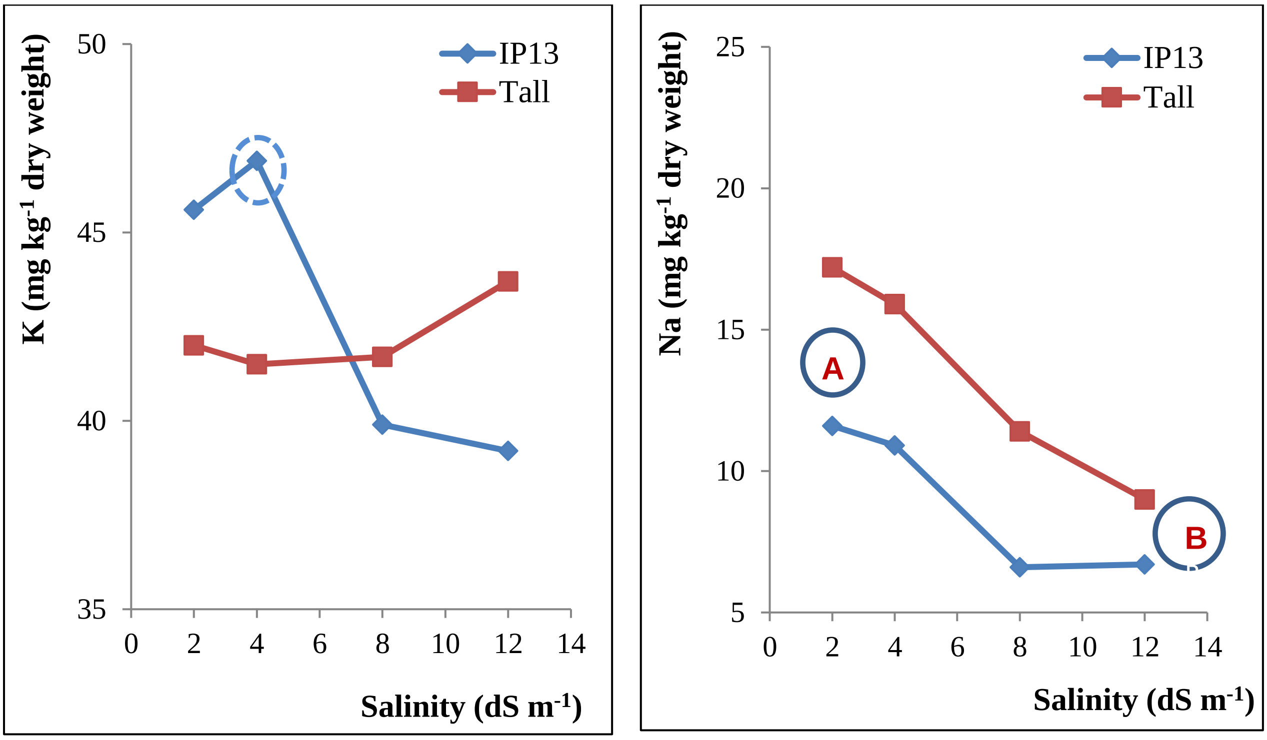

Figure 2. Potassium and sodium concentrations in leaves of the genotypes IP13 and Tall harvested on August 21st 2017 receiving four levels of saline water. In IP13 the potassium content was significantly higher in the treatment 4 dS m^{-1} symbolized by a dashed circle, while the sodium was higher in the control (2 dS m^{-1}) as compared to 12 dS m^{-1}.

[Sodium$_{\text{Tall}}$] > [Sodium$_{\text{IP13}}$].

The dissimilarity between genotypes was further demonstrated with higher sodium in the leaves of the genotype Tall (13.4 mg kg^{-1}), as compared to IP13 (8.9 mg kg^{-1}). In fact, leaves of a salt-tolerant ecotype of millet were able to store large amounts of salt in leaves (Radhouane, 2013). When both genotypes were taken together, the salinity reduced the uptake of sodium, with higher value in the control (14.4 mg.kg^{-1}) than in the treatment 12 dS.m^{-1} (7.9 mg.kg^{-1}). As the salinity increased, the accumulation of sodium in leaves decreased (Figure 2), with smaller concentrations in IP13.

Another physiological aspect related to plant nutrition, was the nitrogen uptake under saline conditions. Because of its dual purpose, grain and forage crop, and higher tolerance to salinity, the labeled N fertilizers were applied to the genotype Tall only. The ^{15}N enrichment of the aboveground plant parts indicated that 40 to 50% of plant nitrogen originated from fertilizers (Table 3), during the first cuts in 2016 and in 2017. This relatively high value could be due to the sandy nature of the soil, with a small level of organic nitrogen and low residual N fertilizers. The difference between the two 2016 cuts is expectable as nitrogen was added once, after emergence as side dressing. Nitrogen yield and nitrogen fertilizer uptake were higher in the treatment receiving 4 dS.m^{-1} because of the higher dry matter production.

Table 3. Nitrogen content (g kg^{-1} dry matter), nitrogen derived from fertilizers (Ndff), nitrogen yield and nitrogen fertilizer yield of pearl millet, genotype Tall, labeled with ^{15}N fertilizer, as affected by the saline water during the 2016 and 2017 seasons.

Time		**Salinity (dS.m^{-1})**	**N (g.kg^{-1})**	**Ndff (%)**	**N yield (g.m^{-2})**	**N fertilizer uptake (g.m^{-2})**
2016	May 10 - July 7	2	23.4	44.5	10.9	4.8
		4	17.9	47.5	20.1	9.5
		8	16.5	45.3	17.7	8.0
		12	18.9	39.6	16.7	8.8
		Mean	**19.2^{A}**	**46.1^{A}**	**17.4^{A}**	**8.3^{A}**
	July 8 - July 27	2	20.1	31.1	6.3	2.0
		4	13.2	30.8	9.5	2.9
		8	14.5	28.9	3.0	0.9
		12	16.2	32.2	2.7	0.9
		Mean	**16.0^{B}**	**30.7^{B}**	**5.6^{B}**	**1.7^{B}**
Salinity effect			**2>12≡4≡8**	**No effect**	**4>8≡12≡2**	
			Significant time effect			
2017	July 21 - Sept 14	2	13.7	40.9	8.7	3.6
		4	17.4	43.2	14.6	6.3
		8	15.9	43.1	12.1	5.1
		12	16.1	45.2	10.8	4.9
		Mean	**15.8**	**43.1**	**11.5**	**5.0**
			No significant differences			

Nitrogen uptake was not different between treatments. This could be linked to the addition of the labeled N fertilizer during the early growth phases, before the application of saline water (Table 1). The uptake of nitrogen takes place in the first growth stages, as shown in corn that accumulated 63% of its nitrogen requirement by flowering, the R1 stage (Website 1). This disagrees with published results where under salt stress, the increase in chloride uptake was accompanied by a decrease in shoots nitrate (Yadav et al., 2011). Further, sorghum labeled with ^{15}N urea and receiving continuously saline water (7 dS m^{-1}) derived less N from fertilizers, as compared to less saline treatments (Al Ain et al., 2017).

Biomass production

The tolerance to salinity was assessed through the aerial biomass production. By July 21st (first cut) the crop had received 58% of irrigation water as well water (2 dS.m^{-1}), and 42% as saline treatments (Table 1). Then the control treatment produced significantly higher fresh weight than the remaining treatments (Table 4). By the second cut, the genotype Tall produced more fresh weight, while the treatment 4 dS.m^{-1} gave the best results (Table 4). On September 14, the treatment 4 dS.m^{-1} was superior to 8 and 12 dS.m^{-1}, while the treatment 4 dS.m^{-1} and the control (2 dS.m^{-1}) were not significantly different.

Table 4. Fresh weights (g m^{-2}) of two millet genotypes (Tall, IP13) receiving four levels of saline water (2, 4, 8, 12 dS m^{-1}) during the 2016 (two cuts) and 2017 (three cuts) seasons.

		Fresh weight (g.m^{-2})					
		2016		**2017**			
		May 10-July 7	**July 8-July 28**	**May 27-July 21**	**July 22-Aug 21**	**Aug 22-Sept 14**	***July 22-Sept 14***
Salinity (dS.m^{-1})	**2**	**3158^{A}**	**1846^{A}**	**8279^{A}**	**1840^{B}**	**2652^{AB}**	***4492^{B}***
	4	**3297^{A}**	**1512^{AB}**	**4487^{B}**	**3166^{A}**	**3206^{A}**	***6372^{A}***
	8	**2161^{B}**	**801^{B}**	**4140^{B}**	**2031^{B}**	**2181^{AB}**	***4212^{B}***
	12	**1729^{B}**	**784^{B}**	**4053^{B}**	**2021^{B}**	**1846^{B}**	***3867^{B}***
Genotype	**Tall**	**3085****	**1708****	**5655**	**2657****	**2292**	***4492***
	IP13	**2089***	**755***	**4274**	**1872***	**2650**	***4522***
	Within one column, different symbols refer to a significant difference between genotypes and letters between salinity.						

On July 21st, dry matter production was not different between the salinity treatments, nor between genotypes (Table 5). This could be related to the fact that 58% of the irrigation water, applied till then, was the non-saline well water (Table 1). To the contrary, on August 21st the treatment 4 $dS.m^{-1}$ gave the highest dry matter production (Table 5). When the second and third cuts were summed together, the 4 $dS.m^{-1}$ provided the highest yield. In addition, the genotype Tall was superior to the genotype IP13, especially when saline water was applied (Table 5), that is between July 30th and September 14th.

Table 5. Effects of the levels of salinity on the dry matter production ($g\ m^{-2}$) of two genotypes of pearl millet, as determined for two cuts in 2016 and three cuts in 2017.

		Dry matter production ($g.m^{-2}$)					
	Salinity ($dS.m^{-1}$)	**2016**		**2017**			
		May 10-July 7	**July 8-July 28**	**May 27-July 21**	**July 22-Aug 21**	**Aug 22-Sept 14**	***July 22-Sept 14***
	2	365^{B}	388^{AB}	1004	345^{B}	396^{AB}	*716^{B}*
	4	755^{A}	487^{A}	761	633^{A}	483^{A}	*1117^{A}*
	8	366^{B}	223^{B}	762	419^{B}	392^{AB}	*811^{AB}*
	12	448^{B}	200^{B}	688	393^{B}	321^{B}	*714^{B}*
Genotype	**Tall**	**605^{**}**	**532^{**}**	**857**	**531^{**}**	**401**	***932*****
	IP13	**389^{*}**	**200^{*}**	**751**	**364^{*}**	**395**	***759****
Interaction		In 4: Tall> IP13	In Tall: 4>2≡8≡12	No significant interaction			
		Within one column, genotype followed by the same symbol, and salinity followed by the same letter, are not significantly different					

Similarly, to the fresh weights, the dry weights showed differences (Table 5). On September 14, there was a significant difference between the treatments 4 $dS.m^{-1}$ and 12 $dS.m^{-1}$. The genotype Tall was more tolerant to salinity than IP13, as it produced larger dry matter on August 21. When the second and third cuts were pooled, the production of the genotype Tall was higher than that of IP13, whereas plants receiving mildly saline waters (4 and 8 $dS.m^{-1}$) produced more than the non-saline control or the highest salinity. The genotype IP13 was more productive in the control, but as the salinity increased the dry matter decreased. The better performance of the genotype Tall meets the result found in an on-farm evaluation of 10 genotypes in Kazakhstan, in soils having a salinity of 6-8 $dS.m^{-1}$ (Toderich et al., 2018).

For the dry matter content, there was a genotype effect with higher content in Tall (18.2%) as compared to IP13 (15.3%) on September 14**,** 2017. Within the genotype IP13, the treatment 8 dS.m^{-1} (17.3%) had higher dry matter than the treatments 2 dS.m^{-1} (13.9%) and 4 dS.m^{-1} (13.8%). Salt stress caused a reduced water uptake in proso millet (*Panicum miliaceum*) exposed to short spells of saline conditions in Sicily on sandy volcanic soils (Caruso et al., 2018).

The agronomic water use efficiencies (AgWUE) were compared for the second cut in both seasons. These were selected because of similar amounts of saline irrigation water, (90 mm in 2016; 82 mm in 2017) and cumulative growing degree days (Table 1). The highest AgWUE was in the genotype Tall (4 dS.m^{-1}) with 10.4 kg.m^{-3} for the second cut in 2017 against 8.8 kg.m^{-3} in 2016. The best values for the genotype IP13 (4 dS m^{-1}) were for the second (5.6 kg.m^{-3}) and third (6 kg.m^{-3}) cuts in 2017. Average values for corn, 1.05 kg.m^{-3}, and for foxtail millet, 1.43 kg.m^{-3}, (Nielsen et al. 2006), were smaller than the WUE obtained in this study. The highest value (10.4 kg.m^{-3}) was close to the WUE (11 kg DM ha^{-1} mm^{-1}) obtained for a hybrid variety grown for 35 days in West Texas (Machicek, 2018).

The relationships between the dry weight and the salinity of the irrigation water gave quadratic equations (Figure 3). The coefficients of regression were significant at the 5% level for the genotype Tall and 10% for IP13. The maximum x value for each genotype, calculated using the corresponding equation, was equal to 5.6 dS.m^{-1} for IP13 and 7.1 dS.m^{-1} for Tall. In other words, the genotype IP13 peaked at a salinity value below that for Tall.

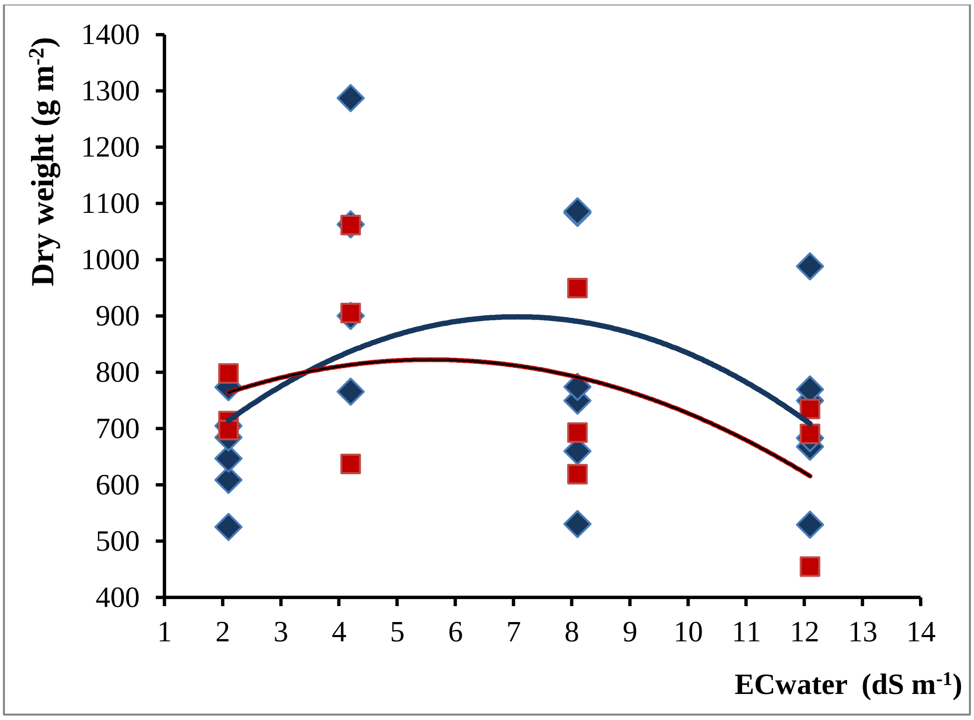

Figure 3. Relationships between the cumulative dry matter of pearl millet, produced from 21 July till 14 September 2017 (sum of cuts on August 21 and September 14) and the salinity of irrigation water for the genotypes Tall (in blue) and IP13 (in red).

Tall : $y = -7.49x^2 + 105.82x + 525.06$ **R = 0.405** (p <0.05)**

IP13 : $y = -4.85x^2 + 54.07x + 671.86$ **R = 0.497* (p <0.10)**

CONCLUSIONS

Consumed water ranged between 51 and 63% of applied water and originated mostly (96% of it) in the upper 0.45 m. As salinity increased, water consumption became shallower suggesting a different root distribution in the treatments receiving saline water, as compared to the control (2 $dS.m^{-1}$). Of the two genotypes, IP13 was more sensitive to saline conditions than Tall, as it excluded even the potassium in order to reduce the build-up of ions inside the cells. In addition, the impact of saline conditions on the uptake of N was evaluated in the genotype Tall. The ^{15}N labeled fertilizer showed that 40 to 50% of plant N originated from the fertilizers, regardless of the treatment. There seems to be no effect of saline conditions on the N nutrition and uptake.

Both genotypes were fast growers, producing three forage cuts over 92 days between end of May and mid-September 2017. In terms of fresh weight production, the treatment 4 $dS.m^{-1}$ was the closest to the control, while no differences were found between 4 and 8 $dS.m^{-1}$ in three cuts out of five in 2016 and 2017. The genotype Tall produced higher dry matter than IP13, especially under saline conditions. The best water use efficiency was in the treatment 4 $dS\ m^{-1}$, with 10.4 $kg.m^{-3}$ for Tall and 8.8 $kg.m^{-3}$ for IP13. The genotype Tall could be used in as a salinity-resistant crop that can also be used for phytoremediation, allowing the absorption of salts and sodium accumulated in the soil of coastal areas.

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