environmental sciences proceedings

MDPI

Proceeding Paper

Will Roots Play a Decisive Role in Forage Sorghum Production under Salt Stress? †

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† Presented at the 2nd International Laayoune Forum on Biosaline Agriculture, 14–16 June 2022; Available online: https://lafoba2.sciforum.net/.

Abstract: Root developmental plasticity might provide breeders with the opportunity to generate crops with more resistant root system designs to abiotic pressures such as salt stress. The potential influence of diverse root designs in a panel of sorghum varieties' production and performance under salt stress was investigated in this study. Dry weight yield had a significant positive correlation with three root parameters: main root length, main root angle, and lateral root length. These root features have varying positive correlations with other salt tolerance indices. Interestingly, all root properties have a negative correlation with the electrolyte leakage. Except for the lateral root length, the negative correlations were significant in all other root features. This pattern holds true for other salt performance indices studied, such as total soluble sugar content, chlorophyll content, growth, and leaf area. Furthermore, there is an inter-variety variation in the contribution level of lateral root and main root length towards the total root length and this was found to influence yield and performance. These findings give a hint on the root architectural features that play a positive role in sorghum salt tolerance and improved forage yield.

Keywords: forage; root; salinity; sorghum; yield

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Citation: Amombo, E.; Ashilenje, D.S.; Lazaar, K.; Hirich, A.; Kouisni, L.; Devkota, K.P.; Oukarroum, A.; Cherki, G.; El Gharous, M.; Nilahyane, A. Will Roots Play a Decisive Role in Forage Sorghum Production under Salt Stress? *Environ. Sci. Proc.* **2022**, *16*, 61. https://doi.org/10.3390/environsciproc2022016061

Academic Editor: Redouane Choukr-Allah

Published: 20 June 2022

1. Introduction

Recently, there is increasing interest in forage sorghum grown in desert areas. Some of the advantages cultivating this crop include high water use efficiency than other forage crops, higher heat and drought tolerance, versatility, and potentially high-quality nutrients for cows, sheep, and camels [1]. Compared to many forages, sorghum can produce more biomass and good feed quality if crop management practices are well optimized. In marginal and desertic areas, sorghum production is constrained by various abiotic stresses especially salt stress. Therefore, improved crop management and new varieties with increased tolerance to salinity can significantly increase their yields. However, the sorghum genera are very diverse genetically, phenotypically, and geographically and relatively few recognized species have been evaluated for potential forage selection.

Root growth and developmental flexibility may allow breeders to create crops with more resistant root system designs to abiotic stresses such as salt stress. However, this area remains underexplored in crop production systems. Thus, in this paper, we investigate the possible impact of diverse root characteristics on sorghum yield and performance under salt stress.

2. Materials and Methods

In this study, thirteen local sorghum varieties were used. The plants were cultivated in Laayoune, Morocco, under medium saline conditions (EC of 7884.5 S/cm) during the spring season of 2021 as part of an ongoing salt-tolerant forage germplasm phenotyping and genotyping project. Sampling for relative water content (RWC), chlorophyll content Chl), electrolyte leakage (EL), and total soluble carbohydrate (TSC) content was carried out during harvest. For root sampling, plants were removed, and roots scraped carefully to minimize damage at the soft dough stage when sorghum is apparently at the silage harvest maturity stage. The root data were processed for correlation analysis with other tested physiological parameters on SPSS (v.16, SPSS Inc., Chicago, IL, USA).

3. Results

Implications of Root Traits on Sorghum Performance and Dry Yield

Significant difference among varieties was observed for all root traits that were tested in sorghum (Table 1).

Table 1. Means of tested root parameters.

VARIETY	MRL [1]	MRV	MRA	LRN	LRL
1	61.56	11.82	12.74	77	74.74
2	73.91	26.70	13.63	112	144.37
3	114.30	24.09	23.40	248	355.34
4	57.27	13.42	4.24	95	92.37
5	72.37	15.38	17.21	193	134.32
6	133.20	9.731	6.00	104	161.33
7	48.05	26.49	1.79	63	70.68
8	95.16	23.84	10.94	124	177.64
9	60.85	12.67	7.84	108	158.32
10	60.46	18.18	10.60	142	140.86
11	29.36	5.80	18.43	77	112.93
12	18.84	21.28	123.00	129	289.18
13	121.10	31.15	33.99	247	301.49

[1] MRL—main root length; LRL—lateral root length; MRV—main root vector; MRA—main root angle; LRN—lateral root number.

To further analyze the possible interaction of various root features with yield and performance, a correlation analysis was carried out. Dry weight yield had a significant positive correlation with three root parameters: MRL (0.523), main root angle (MRA; 0.516), and lateral root length (LRL; 0.531). Among the performance indices, the lateral root number (LRN) was positively correlated with the RWC (0.568) while the correlations with Chl, leaf area, and height were insignificant despite being positive. All the tested root traits correlated negatively with EL. The negative correlations were significant except for LRL. However, for the non-root parameters, all the negative correlations were insignificant. Overall, the highest root–root correlations were observed between LRL and MRA, while the root–non-root parameters were LRN vs. RWC, LRL vs. RWC, height vs. dry yield, and LRL vs. dry yield. Among the non-root–non-root parameters, the highest positive correlation was between leaf length (LL) and leaf width (LW) as well as TSC and LW (Table 2).

Table 2. Pearson correlation coefficients of tested parameters.

	RWC	Height	EL	Chl	LL	LW	TSC	MRL	LRL	MRV	MRA	LRN	DW
RWC [1]	1												
Height	0.184	1											
EL	−0.049	−0.118	1										
Chl	0.083	0.400 *	−0.126	1									
LL	0.430 **	0.520 **	−0.056	0.360 *	1								
LW	0.388 *	0.387 *	−0.092	0.142	0.724 **	1							
TSC	0.186	0.255	−0.096	0.16	0.571 **	0.662 *	1						
MRL	0.016	0.063	−0.465 **	0.107	0.073	0.091	0.053	1					
LRL	0.439 *	0.042	−0.224	0.105	0.014	0.012	0.144	0.843 **	1				
MRV	0.071	0.102	−0.443 **	0.05	0.079	0.13	0.044	0.943 **	0.843 **	1			
MRA	0.101	0.036	−0.358 *	0.087	0.157	0.207	0.103	0.901 **	0.775 **	0.794 **	1		
LRN	0.568 **	0.023	−0.343 *	0.091	0.03	0.034	0.12	0.954 **	0.920 **	0.900 **	0.909 **	1	
DW	0.282	0.834 **	−0.532 *	0.301	0.654 **	0.417 *	0.389	0.523 **	0.531 **	0.239	0.516 **	0.351 *	1

[1] RWC—relative water content; EL—electrolyte leakage; Chl—chlorophyll content; LL—leaf length; LW—leaf width; TSC—total soluble carbohydrate; MRL—main root length; LRL—lateral root length; MRV—main root vector; MRA—main root angle; LRN—lateral root number; DW—dry weight. * Significant at 0.05. ** Significant at 0.01.

4. Discussion

The above-ground phenotypic traits measured in this study may be utilized as credible predictors of salt tolerance and forage yield. In terms of the physiological consequence of cellular water deficiency, the RWC, for example, is one of the most relevant markers of plant water status [2]. As a result, it can predict sorghum water status in terms of cellular hydration while accounting for the effects of both leaf water potential and osmotic adjustment. The preservation of considerably greater RWC in some sorghum varieties can be attributed to the resistance to salt-induced physiological drought, which is consistent with our earlier findings that high RWC was related to salt resistance [3]. Chlorophyll (a and b) functions as an intermediate in the transition of absorbed solar energy and its action in photosynthesis and organic compound production [4]. As a result, it can be utilized as a plant health indicator under stressful conditions. The ability of sorghum varieties to maintain relatively higher total Chl contents reflects their ability to maintain higher photosynthetic efficiency, organic compound accumulation, and growth under salt stress, as evidenced by relatively higher digestible sugar contents, leaf area, and plant height in most of the varieties. This is also evidenced by a strong positive correlation between Chl, height, RWC, and soluble carbohydrate contents. The EL reflects the stability index of cellular membranes. Here, we observe a negative correlation between RWC, Chl, height, and leaf area with EL, indicating that salinity could not only damage membranes but also limit growth and photosynthetic capacity. Additionally, a negative correlation with all root parameters indicates that EL can be a reliable phenotypic marker for salt sensitivity in large sorghum varieties.

Soluble carbohydrates not only serve as vital nutritive molecules, but they can also serve as significant osmolytes in plants, helping to promote osmotic adjustment [5]. A substantial correlation between soluble carbohydrates and RWC suggests that high soluble carbohydrate levels in sorghum had a favorable effect in water absorption and retention, which may boost photosynthesis and plant development. Roots play a vital role in plant response to stress and production. However, partly due to the difficulties in viewing them throughout the plant's life cycle, they have received less attention than other organs. In this case, we see structural variety in traits such as MRL, LRN, MRV, and MRA in a sorghum population and various correlations with salt performance indices. This demonstrates the presence of a significant amount of flexibility in sorghum root system architecture (RSA) during salt stress. The positive connection between LRN and RWC suggests that the design in sorghum varieties with the greatest LRN and the shortest MRL may be related to sorghum salt tolerance. As a result, they might be used to simulate sorghum with more efficient roots to improve tolerance and yield.

5. Conclusions

In this study, we see structural variety in root traits such as MRL, LRN, MRV, and MRA. This demonstrates the presence of a significant level of flexibility in sorghum RSA during salt stress. The positive connection between LRN and RWC suggests that the design in varieties with the greatest LRN and the shortest MRL may be related to sorghum salt tolerance and yield. As a result, they might be a target for developing and modeling sorghum with more efficient roots to improve tolerance and yield.

Author Contributions: Conceptualization, E.A., A.N., A.H. and A.O.; methodology, E.A., A.N. and K.P.D.; data collection, E.A., D.S.A., K.L. and A.N.; writing, editing, and reviewing, E.A., A.N., A.H., L.K., A.O., G.C. and M.E.G.; project administration, A.N.; funding acquisition, A.N. All authors have read and agreed to the published version of the manuscript.

Funding: This research is funded by OCP Phosboucraa Foundation, grant number FPB_SPA005_2020.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Acknowledgments: The authors acknowledge the OCP Phosboucraa Foundation for funding this project. Appreciation is extended to farmers for providing their farmlands to conduct the research trials and all field assistants.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Ramos, J.C.P.; Júnior, V.R.R.; Monção, F.P.; da Costa Parrela, R.A.; Caxito, A.M.; Cordeiro, M.W.S.; da Hora, F.F.; de Assis Pires, D.A. Effect of replacing forage sorghum silage with biomass sorghum silage in diets for F_1 Holstein × Zebu lactating cows. *Trop. Anim. Health Prod.* **2021**, *53*, 99. [CrossRef] [PubMed]
2. Sapes, G.; Sala, A. Relative water content consistently predicts drought mortality risk in seedling populations with different morphology, physiology and times to death. *Plant Cell Environ.* **2021**, *10*, 3322–3335. [CrossRef] [PubMed]
3. Amombo, E.; Li, X.; Wang, G.Y.; Fan, S.G.; Zhang, Y.K.; Fu, J.M. Screening of diverse tall fescue population for salinity tolerance based on SSR marker-physiological trait association. *Euphytica* **2018**, *214*, 220. [CrossRef]
4. Yang, Z.; Li, J.L.; Liu, L.N.; Xie, Q.; Sui, N. Photosynthetic regulation under salt stress and salt-tolerance mechanism of sweet sorghum. *Front. Plant Sci.* **2020**, *10*, 1722. [CrossRef] [PubMed]
5. Turner, N.C. Turgor maintenance by osmotic adjustment: 40 years of progress. *J. Exp. Bot.* **2018**, *69*, 3223–3233. [CrossRef] [PubMed]