Chapter 9
Multilocation Evaluation of Alternative Forage Crops Grown Under Salinity Conditions in the South of Morocco

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Abstract Salinity is a major problem affecting agricultural activity in many regions across the world. Therefore, practices such as biosaline agriculture and crop diversification by introducing alternative crops are key solutions to overcome this problem and enhance the productivity of salt-affected lands. This study aimed to evaluate the performance of several alternative forage crops, including cereals, pseudo-cereals, grasses, legumes, and fodder beet cultivated under saline conditions in five experimental sites in the south of Morocco. The obtained results indicated that not all crops performed very well on all sites. Crops with low tolerance to salinity, such as the cereals group, showed a significant reduction in dry biomass and yield due to increased salinity. In comparison, salt-tolerant crops such as blue panicum, sesbania, and fodder beet showed higher productivity under moderate and high salinity levels in comparison with low salinity. The findings of this study clearly indicated that the good adaptation and performance of most tested alternative crops under salinity conditions, especially the perennial crops such as blue panicum and sesbania are favored by farmers due to their low requirement in terms of agricultural inputs.

Keywords Biosaline agriculture · Blue panicum · Yield · Dry biomass · Irrigation

1 Introduction

Agriculture in marginal environments such as desert areas is facing several challenges, including desertification, salinity, drought, and heat, which limit crop growth and land productivity. Salinity affects several regions of the world and increasing

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significantly due to secondary salinization caused by excess irrigation, excessive use of agrochemical fertilizers, poor drainage, groundwater salinity, sea-level rise and intrusion, drought, and irregular rainfall. Eswar et al. (2021) reported that salinity mainly affects soils in North and Central Asia, Africa, and South America. It affects about 1060 Mha worldwide, and the salt-affected area is gradually increasing due to the influence of climate change. Consequently, soil salinity tends to increase with sea-level rise, intrusion, high temperature, low precipitation, and inadequate irrigation management.

Morocco is one of the countries suffering from salinity problems, specifically in the Southern region. Recent data published by Hssaisoune et al. (2020) indicate that all groundwater in the southern area is affected by salinity with a TDS (Total Dissolved solids) exceeding 2 g/l. While in terms of groundwater quality, 31% of groundwater in Morocco has low quality due to several factors (natural and/or anthropogenic) and processes (e.g., water–rock interactions, evaporation, and seawater intrusion).

Salinity affects plants in two ways: osmotic stress and ionic toxicity. The first way is caused by a high concentration of salt in the root zone, inhibiting plant water uptake by the root system. In contrast, ionic toxicity results from the accumulation of toxic ions such as sodium and chloride in the plant tissue, which affect all major plant processes, including photosynthesis, cellular metabolism, and plant nutrition (Bernstein 2019).

Biosaline agriculture is the cultivation and growth of crops under saline conditions using salt-tolerant crops and varieties and adapted cropping practices such as soil amendment, fertilization, and irrigation management to overcome adverse salinity effects on crop growth and development (Ayyam et al. 2019). In most cases, biosaline agriculture is introduced or adopted in salt-affected environments where farmers are used to cultivating traditional crops sensitive or moderately tolerant to salinity. Unfortunately, due to increased salinity, traditional crop productivity has declined, consequently reducing farmers' income. This was the case in Foum El Oued area in the south of Morocco, where all farms with a total area of more than 400 ha are affected by salinity. Groundwater EC (Electrical conductivity) in this region exceeds 4 dS/m, which is beyond the salt tolerance threshold of traditional crops such as forage corn, for example. Alternative crops have been introduced in the southern region to replace traditional forages and rehabilitate the abandoned salt-affected farms (Hirich et al. 2021).

According to Elouafi et al. (2020), traditional crops face many challenges caused by abiotic and biotic stresses (salinity, drought, pests, diseases, etc.). Toward these constraints, alternative crops could be introduced to replace common crops in a particular geographic area to the benefit of the farming communities. Furthermore, their niche markets and the high value could improve farmers' income.

Thus, the aim of this study was to evaluate the productivity of several alternative forage crops tested under field and salinity conditions in five locations in the south of Morocco, and analyzing their responses/adaptation to different agro-climatic conditions and salinity levels.

Fig. 1 Localization of multi-location experimental sites across south of Morocco

2 Materials and Methods

2.1 Experimental Sites

In this study, for the multi-location evaluation, five experimental sites were chosen which represent the different microclimates and agricultural production areas in the south of Morocco regarding soil type, salinity level, drought condition, and climate conditions. Trials were conducted from October 2020 to August 2021. The localization of the experimental sites is presented in Fig. 1.

2.2 Climatic Data

Figure 2 presents the annual average climate of each experimental site during the 2020/2021 cropping season. In terms of maximum and minimum average temperature, precipitation, and wind speed. The hottest site is Bir Anzarane followed by Es-Smara, and the coldest is Tarfaya. In terms of rainfall, most sites receive an amount

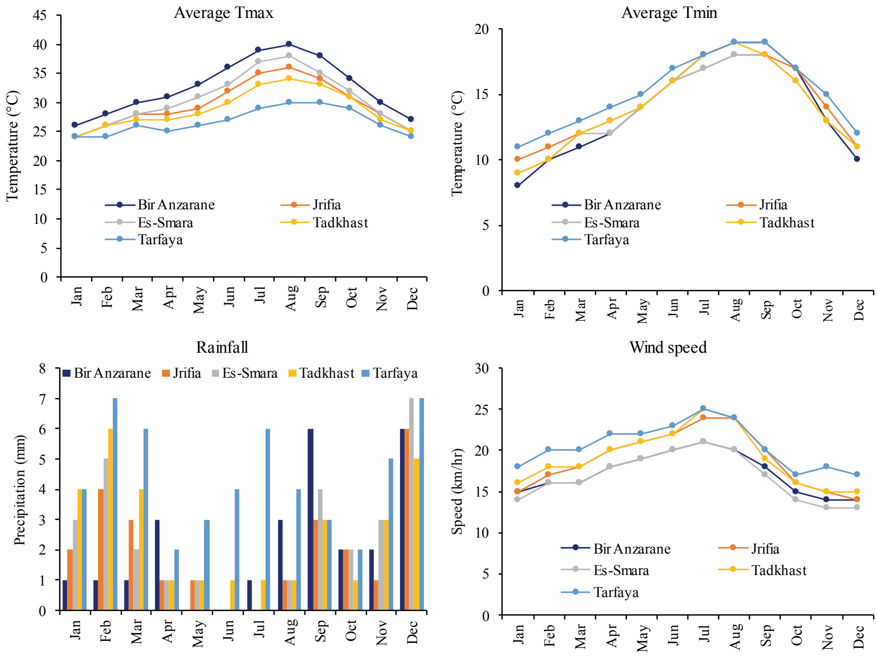

Fig. 2 Climatic data of the experimental sites in terms of maximal (Tmax) and minimal (Tmin) temperature, rainfall, and wind speed during the 2020/2021 cropping season. (*Source* https://power.larc.nasa.gov/data-access-viewer/)

of rain that does not exceed 50 mm. The driest area is Jrifia followed by Bir Anzarane and the wettest area is Tarfaya, which is closer to the Atlantic Ocean. The Tarfaya site has the highest wind speed during the year, while the Es-smara site has the lowest.

2.3 *Experimental Design and Agronomic Practices*

A Randomized Complete Block Design was adopted in each experimental site with four replications for each specie. The plot area was equal to 12.5 m^2 (2.5 × 5 m). Several alternative crop species were tested (Table 1).

Before sowing, the soil was plowed, and the seedbed was prepared. Irrigation was supplied using drip irrigation (25 cm between drippers and dripper discharge was equal to 2 L/hr), applying 3–4 irrigation per week with a half-hour for each irrigation. Standard agronomic practices such as weeding, pest and disease management, and harvest were conducted following farmers' practices. Crop was harvested at the grain filling stage.

Table 1 List of tested species and varieties

Category	Species	Variety
Cereals and Pseudo-cereals	Barley (*Hordeum vulgare)*	Najah, Amalou, Laanacer, Oussama and local variety
	Triticale (× *Triticosecale)*	Fouricale and local variety
	Oat (*Avena sativa)*	Rapidena and local variety
	Quinoa (*Chenopodium quinoa)*	Titicaca, Puno, ICBA Q1, ICBA Q3 and ICBA Q5
	Maize (*Zea mays)*	Torro plus and Dracma
	Pearl millet (*Pennisetum glaucum)*	IP19612, IP22269, IP12150, HHVBC Tall and MC94C2
	Sorghum (*Sorghum bicolor)*	ICSR 93034 and Tonka F1
Grasses and legumes	Alfalfa (*Medicago sativa)*	Local and Public variety
	Blue panicum (*Panicum antidotale)*	Public variety
	Sesbania (*Sesbania sesban)*	ILRI 15018, ILRI 15077, ILRI 17314 and ILRI 15037
	Atriplex (*Atriplex nummularia)*	Wild genotype
Fodder beet	*Beta vulgaris*	Monro, Jamon and Caribou

Several parameters were monitored, including agro-morphological parameters such as plant height, root length, number of tillers, root weight, plant weight, and fresh and dry biomass production.

2.4 Soil and Water Analysis

Table 2 shows the result of the soil physical and chemical analysis. The soil has a high percentage of sand and silt. According to the soil texture triangle, soils in Es-smara, Tadkhast, and Tarfaya are sandy loam, while the soil texture in Jrifia is sandy, and Bir Anzarane is loamy sand. Regarding salinity, all sites has a low salinity level except Es-Smara, which has a high level of salinity. Data indicate that both Tadkhast and Tarfaya are calcareous soils, while other sites present a low content of $CaCO_3$. Organic amendment content was moderate for Tarfaya soil and low for other sites. Regarding mineral content, all soils has high CaO, MgO, and K_2O, while P_2O_5 content was relatively low. The soil analysis indicates that soils of Tadkhast, Jrifia, and Bir Anzarane are non-saline and non-sodic, while Es-Smara soil is saline and sodic, and Tarfaya soil is saline and non-sodic.

The results of the water analysis is presented in Table 3 indicating that irrigation water in all sites is saline, with the highest EC recorded in Es-Smara. The most

Table 2 Soil physical and chemical properties in different multi-location sites of south of Morocco

Parameters	Bir Anzarane	Es-Smara	Jrifia	Tadkhast	Tarfaya
Clay (%)	4	12	2	10	6
Silt (%)	18	24	10	22	26
Sand (%)	78	64	88	68	68
pH	9.03	8.24	9.04	8.56	8.98
ECe (dS/m)	1.35	10.05	0.4	0.6	2.7
CEC (meq/100 g)	5.3	4.9	1.3	5.7	5.1
$CaCO_3$ (%)	4.2	7.6	12.3	26	38.3
Na_2O (ppm)	482	1565	73	86	717
ESP (%)	5.97	15.34	1.01	1.03	7.14
Organic matter (%)	0.13	0.5	0.08	1.01	1.49
Total Nitrogen (%)	0.01	0.03	0.01	0.06	0.09
C/N	7.54	9.66	4.64	9.76	9.6
P_2O_5 (ppm)	32	28	17	47	100
K_2O (ppm)	324	408	268	338	643
CaO (ppm	7032	7332	6694	7584	7577
MgO (ppm)	230	893	175	347	1104

CEC: Cation Exchange Capacity, ESP: Exchangeable Sodium Percentage

Table 3 Irrigation water quality

Parameters	Bir Anzarane	Es-Smara	Jrifia	Tadkhast	Tarfaya
pH	6.94	7.16	6.97	7.07	7.29
EC (dS/m)	6.64	12.40	6.20	3.85	8.67
TDS (g/l)	5.31	9.92	4.96	3.08	7.01
Na^+ (ppm)	962.88	1163.33	27.16	25.47	1306.30
K^+ (ppm)	17.47	32.64	27.16	25.47	49.19
Mg^{2+} (ppm)	89.90	242.15	51.52	64.32	173.03
Ca^{2+} (ppm)	348.00	421.70	279.19	167.04	283.46
Cl^- (ppm)	1725.43	2567.80	599.66	802.10	2655.46
$SO_4{}^{2-}$ (ppm)	512.52	855.09	2373.54	174.12	360.12
$HCO_3{}^-$ (ppm)	248.88	585.60	122.00	646.60	212.28

contributing elements to salinity increase are sodium and chloride in Bir Anzarane, Es-Smara, and Tarfaya sites, while increased salinity was due to more accumulation of sulfur in Jrifia and bicarbonates in Tadkhast site.

2.5 Statistical Analysis

Statistical analysis was carried out using R software. A one-way analysis of variance (ANOVA) was used to assess the effects of location on monitored parameters. The level of significance was set to $p < 0.05$. When the ANOVA gives a significant result for each analysis, statistically significant differences between means were identified using Tukey's pairwise comparisons test ($p \leq 0.05$).

3 Results

3.1 Agro-Morphological Parameters

Table 4 shows the obtained results regarding some agro-morphological parameters of tested alternative crops under demonstration site conditions. Plant height and root length data indicate that increased salinity has affected plant growth in all experimental sites, while average plant weight responded differently to salinity depending on crop species. For instance, there was no significant difference for oat, forage corn, quinoa, and pearl millet. However, barley and triticale plant weight declined with increased salinity. Conversely, highly salt-tolerant crops such as blue panicum, sesbania, and fodder beet showed a different trend where they accumulated more biomass under increased salinity levels.

3.2 Dry Biomass Yield

The dry biomass yield variation of cereals and quinoa is presented in Fig. 3. Statistical analysis showed a significant decrease in productivity for all tested species with an increase salinity level except for quinoa. Sorghum and pearl millet performed better under low salinity conditions, averaging 21 t/ha dry biomass. However, with medium saline irrigation water, the productivity of oat reached 19 t/ha dry biomass. This finding can be explained by the high number of tillers obtained in Bir Anzarane site compared to other sites. While triticale and barley showed the lowest decrease in productivity under high salinity conditions in Es-smara compared to Tadkhasst (low salinity), their productivity was up to 7.6 and 6.1 t/ha of dry biomass, respectively.

Figure 4 shows the dry biomass yield for the grass and legumes tested. The best performance was recorded for blue panicum under different salinity conditions. However, the crop recorded a dry biomass production of 21 t/ha/year under high irrigation water salinity levels (12.4 dS/m). Alfalfa production was decreased due to salinity. Conversely, sesbania, a very highly salt-tolerant crop, showed an increasing tendency with increased salinity to reach more than 22 t/ha of fresh biomass under Es-smara site.

Table 4 Agro-morphological parameters of different alternative crops in five different locations of south of Morocco

Species	Locality	Cereals and Pseudo-cereals							
		Plant height (cm)		Root length (cm)		Number of tillers		Plant weight (g)	
		Mean	*p* value	Mean	*p* value	Mean	*p* value	Mean	*p* value
Barley	Tadkhasst	68.67 ± 4.7 a	0.000***	12 ± 0.86	0.480	4.17 ± 0.6	0.176	13.39 ± 1.25 a	0.009**
	Bir Anzarane	63.83 ± 2.56 ab		11 ± 1.46		4.83 ± 0.95		13.98 ± 2.82 a	
	Jrifia	54.83 ± 2.65 b		11.5 ± 1.93		3.33 ± 0.33		10.1 ± 2.02 ab	
	Es-smara	34.28 ± 1.95 c		9.17 ± 0.75		6.33 ± 1.48		4.73 ± 0.7 b	
Oat	Tadkhasst	64.33 ± 5.36 ab	0.031*	13.67 ± 1.45	0.324	4 ± 0	0.059	17.72 ± 2.58	0.133
	Bir Anzarane	66 ± 1 ab		12 ± 1		5 ± 0.58		14.88 ± 2.58	
	Jrifia	76.67 ± 2.67 a		17.67 ± 5.61		2.33 ± 0.33		11.06 ± 1.17	
	Es-smara	58.67 ± 2.91 b		9 ± 2		3 ± 1		8.67 ± 3.31	
Triticale	Tadkhasst	88.5 ± 13.5 a	0.000***	17.5 ± 0.5 a	0.000***	4.5 ± 1.5	0.058	21.25 ± 4.8 a	0.000***
	Bir Anzarane	70.33 ± 3.84 ab		10.5 ± 0.67 b		3.83 ± 0.87		9.33 ± 0.81 b	
	Jrifia	65 ± 2 b		6 ± 0.63 c		1.5 ± 0.22		5.61 ± 0.91 b	
	Es-smara	49.14 ± 2.01 c		8.43 ± 0.3 b		4.5 ± 1.5		6.86 ± 0.66 b	
Forage corn	Tadkhasst	126 ± 9.87 ab	0.017*	25.33 ± 0.88	0.560	–	–	508 ± 146	0.110
	Bir Anzarane	166 ± 8 a		30 ± 1		–		434.2 ± 37.1	
	Jrifia	78.3 ± 17.2 b		26 ± 3.21		–		150.6 ± 53.4	
	Tarfaya	117 ± 14.7 ab		30.67 ± 1.76		–		344.3 ± 91	
	Es-smara	87 ± 5 b		27 ± 6		–		164.9 ± 36.7	

(continued)

Table 4 (continued)

Species	Locality	Cereals and Pseudo-cereals							
		Plant height (cm)		Root length (cm)		Number of tillers		Plant weight (g)	
		Mean	*p* value	Mean	*p* value	Mean	*p* value	Mean	*p* value
Pearl millet	Tadkhasst	111.75 ± 7.65 ab	0.037*	18.75 ± 2.14	0.252	5.75 ± 0.48	0.376	69.92 ± 9.3	0.080
	Jrifia	85.3 ± 10.9 b		26.33 ± 2.33		6 ± 0.58		252.1 ± 61.9	
	Tarfaya	134 ± 5 a		24 ± 7		7.5 ± 0.5		420.8 ± 61.6	
	Es-smara	93.75 ± 8.87 ab		22.25 ± 0.85		4.5 ± 1.5		206 ± 105	
Sorghum	Tadkhasst	105 ± 10.1 ab	0.007**	22 ± 2.08 b	0.001**	1.67 ± 0.67	0.250	236 ± 108 ab	0.032*
	Jrifia	83 ± 12 b		22.5 ± 2.5 b		2 ± 1		130.3 ± 47.1 ab	
	Tarfaya	142.3 ± 11.9 a		40.67 ± 2.4 a		2.33 ± 0.33		596 ± 167 a	
	Es-smara	85.75 ± 4.66 b		21 ± 1.96 b		1 ± 0		116.7 ± 22.2 b	
Quinoa	Tadkhasst	67.31 ± 4.48	0.002**	14.81 ± 1.13	0.479	–	–	9.46 ± 1.44	0.000***
	Es-smara	46.21 ± 4.1		15.93 ± 1.04		–		71.5 ± 12.2	
		Grasses and legumes							
		Plant height (cm)		Number of ramifications		Plant weight (g)		Fresh Biomass (t/ha/cut)	
		Mean	*p* value	Mean	*p* value	Mean	*p* value	Mean	*p* value
Alfalfa	Tadkhasst	59 ± 13.1	0.192	15.33 ± 2.33 b	0.017*	92.10 ± 40.9	0.363	5.2 ± 0.14	0.055
	Bir Anzarane	79.67 ± 5.17		37.33 ± 5.78 a		203.50 ± 59.8		4.01 ± 0.84	
	Es-smara	51.5 ± 0.5		44.5 ± 5.5 a		128.0 ± 59.1		2.11 ± 0.69	

(continued)

Table 4 (continued)

Species	Locality	Cereals and Pseudo-cereals							
		Plant height (cm)		Root length (cm)		Number of tillers		Plant weight (g)	
		Mean	*p* value	Mean	*p* value	Mean	*p* value	Mean	*p* value
Blue panicum	Tadkhasst	115.5 ± 6.71	0.253	33.5 ± 4.99	0.087	203.6 ± 33.9	0.186	7.22 ± 0.28	0.207
	Bir Anzarane	101 ± 9.02		22.67 ± 1.86		96.56 ± 9.95		4.32 ± 0.43	
	Jrifia	77 ± 4		25.5 ± 3.5		81 ± 13		5.77 ± 0.37	
	Tarfaya	111 ± 15.9		18 ± 2.08		150.3 ± 61.8		8.19 ± 1.34	
	Es-smara	101.8 ± 10.2		21.50 ± 3.4		98.3 ± 34		7.80 ± 1.71	
Sesbania	Tadkhasst	92.67 ± 9.33 b	0.014*	6.33 ± 0.33 b	0.029*	128.1 ± 34.6 b	0.023*	4.11 ± 1.89 b	0.013*
	Bir Anzarane	131 ± 8.89 a		12.67 ± 1.45 ab		257.8 ± 54.9 ab		7.83 ± 0.82 ab	
	Es-smara	81.67 ± 6.69 b		13.67 ± 2.19 a		340.6 ± 17.9 a		13.52 ± 1.63 a	
		Fodder beet							
		Root length (cm)		Plant weight (g)		Root weight (g)		Leaves weight (g)	
		Mean	*p* value	Mean	*p* value	Mean	*p* value	Mean	*p* value
Fodder beet	Tadkhasst	22.92 ± 1.26 ab	0.000***	1641 ± 292 ab	0.011*	1330 ± 251	0.066	311.3 ± 47.6 bc	0.000***
	Bir Anzarane	15.56 ± 1.06 c		1119 ± 128 b		953 ± 109		166.00 ± 26.9 c	
	Tarfaya	21.22 ± 2.42 bc		2267 ± 247 a		1683 ± 169		584.3 ± 93.7 a	
	Es-smara	30.5 ± 0.96 a		2317 ± 109 ab		1745 ± 114		572.3 ± 49.3 ab	

Values represent mean ± standard error. *, ** and *** indicate significance at $p < 0.05$, 0.01 and 0.001 respectively. a, b and c present Tuckey's test at $p = 0.05$

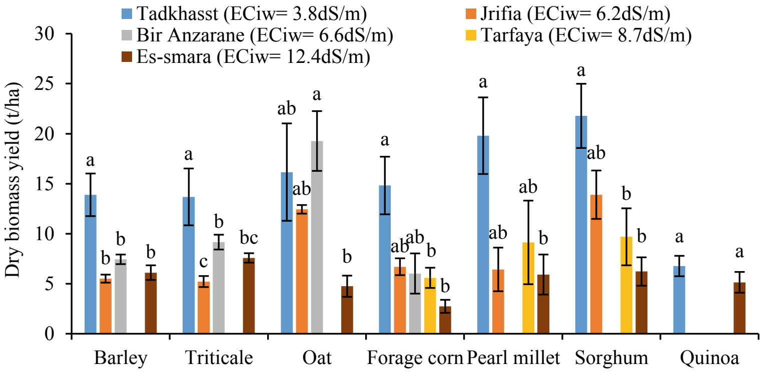

Fig. 3 Dry biomass production of evaluated alternative crops as affected by irrigation water salinity. Error bars indicate the standard error. Means sharing the same letters do not differ significantly at 5% level of significance

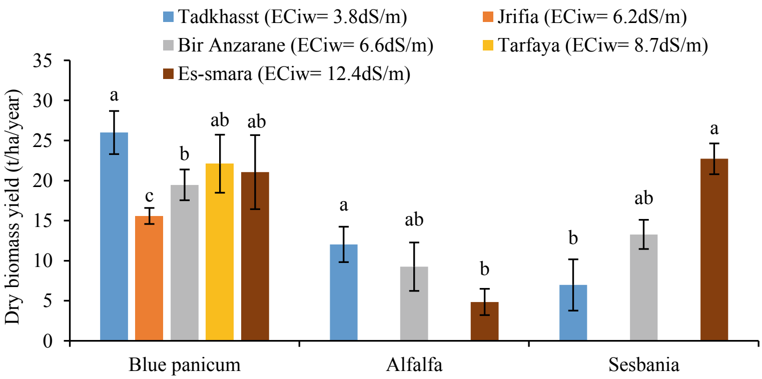

Fig. 4 Dry biomass production of blue panicum, alfalfa, and sesbania as affected by irrigation water salinity. Error bars indicate the standard error. Means sharing the same letters do not differ significantly at 5% level of significance

Fresh and dry biomass yields of fodder beet are presented in Fig. 5. Obtained results indicated that fodder beet yield increased relatively with increased salinity to reach its maximum in Tarfaya site with 140 t/ha of fresh biomass and declined slightly in Es-smara site (high salinity).

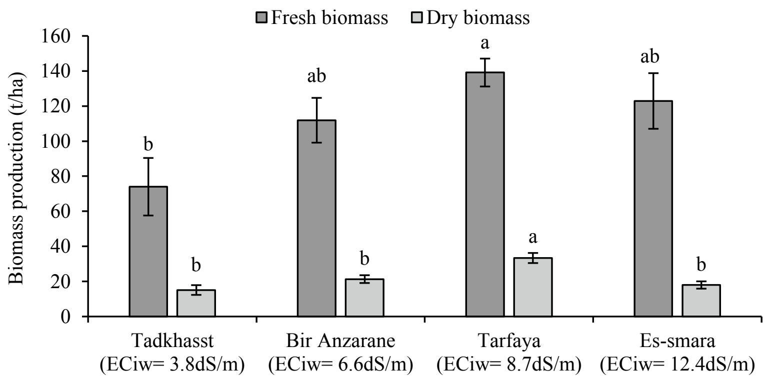

Fig. 5 Fresh and dry biomass production of fodder beet as affected by irrigation water salinity. Error bars indicate the standard error. Means sharing the same letters do not differ significantly at 5%

4 Discussion

Major cereal crops are becoming more vulnerable to climate change, and they are progressively failing to overcome salinity and water scarcity. Therefore, there is an urgent need to identify alternative solutions to sustain their productivity in marginal environments (Hirich et al. 2020). Crop diversity plays a major role in sustainable agriculture. Alternative crops are introduced to a new environment to replace traditional crops and help withstand biotic and abiotic threats to agricultural productivity (Elouafi et al. 2020).

The findings of this study indicated that tested alternative forage crops responded differently to site conditions in terms of soil, irrigation water salinity, and climate. However, we believe that several factors contributed to this difference. Still, the main influencing factor is the irrigation water salinity, as there is no significant difference in soil and climate. It was also evident that crops with low salinity tolerance, such as forage corn, sorghum, and pearl millet, were significantly affected by salinity and performed better under low salinity. On the other hand, salt-tolerant species such as barley, oat, triticale, blue panicum, sesbania, alfalfa, and fodder beet showed higher productivity under moderate and high salinity levels. The reduction in biomass production and other growth parameters for crops with low salinity tolerance can be explained by a decline in photosynthetic activity, as demonstrated by several studies conducted on maize (Omoto et al. 2012), sorghum (Netondo et al. 2004), and pearl millet (Radhouane 2009) where increased salinity has greatly reduced photosynthesis, stomatal conductance, transpiration, and chlorophyll content. Crops with low salinity tolerance generally use energy-demanding strategies such as osmotic adjustment, which requires the production and accumulation of osmolytes which are big molecules such as amino acids (proline, glycine-betaine), soluble sugars, and organic acids (Iqbal et al. 2020). On the other hand, crops resistant to salinity use other adaptation mechanisms such as salt exclusion or compartmentalization (Aslam et al. 2011). The photosynthetic activity of species with low tolerance to salinity is disturbed because of the accumulation of sodium in excessive amounts, which is highly toxic for growth due to its high interference with beneficial elements such as potassium (Iqbal et al. 2020).

To cope with salt stress, salt-tolerant crops or halophytic plants have evolved mainly two types of tolerance mechanisms based on limiting the entry of salt by the roots, or controlling its concentration and distribution (Hanin et al. 2016). Mishra and Tanna (2017) defined halophytes as salt-resistant or salt-tolerant plants that have a remarkable ability to complete their life cycle in saline conditions, and sometimes their yield increased under high salinity level by deploying mechanisms such as salt exclusion and compartmentalization. For instance, our results indicate that sesbania fresh biomass increased with the increasing salinity level which confirms the finding of (Hirich et al. 2021) who reported that sesbania biomass yield under high irrigation water salinity conditions (13–14 dS/m) is 1.3 higher compared to low salinity level (2–3 dS/m), while for blue panicum yields under both low and high salinity are more or less similar.

A previous study also showed that introduced alternative forage crops in the region of Foum El Oued, which is not far from the five sites, had a higher performance than traditional crops (Alfalfa and forage corn). For example, the fresh biomass yield of perennial species such as sesbania and blue panicum exceeded 100 t/ha, much higher than Alfalfa, where the maximum potential yield did not exceed 75 t/ha. Likewise, for an annual crop such as pearl millet which can be compared to forage corn, the fresh biomass yield was 44 and 36% higher under high and low salinity conditions, respectively (Hirich et al. 2021).

Blue panicum is highly tolerant to salinity conditions and could produce 10 t/ha of dry matter at 16 dS/m (Salehi 2020). Physiological Mechanisms for salinity tolerance in blue panicum include the accumulation of polyamines, abscisic acid, and the activities of anti-oxidative enzymes such as superoxide dismutase, peroxidase, and catalase (Ahmad et al. 2009).

Fodder beet shows good performance in a salt-affected arid land, and its productivity improved by 25% at 10 dS/m compared to 2 dS/m (Nadaf et al. 2000). Under salt stress, various physiological and biochemical mechanisms are involved in surviving fodder beet plants. According to (Yolcu et al. 2021), beet maintains leaf turgor by reducing stomatal conductance and transpiration and by accumulating compatible solutes such as proline and sucrose. Furthermore, fodder beet has a good capacity for salt-removing from soil up to 0.9 t/ha, by accumulating excessive amounts of sodium and chloride ions in leaves (Liu et al. 1997). In this context, fodder beet could be a good option for salt-affected soils.

Salt-tolerant grasses could be a judicious choice to replace traditional forages such as forage corn and alfalfa, especially in salt-affected lands where the biomass productivity of traditional forages is significantly affected (Qadir et al. 1996). Blue panicum is among other forage grasses that resist salinity stress and show great potential as feed for livestock. In a recent study conducted by (Farrag et al. 2021), it was demonstrated that blue panicum biomass yield only declined by 20% when it was subjected to saline irrigation with an EC value 9 dS/m (same salinity level as Tarfaya site), which indicates its high resistance to salinity.

5 Conclusions

In the light of the results obtained, it can be concluded that most of the evaluated alternative crops showed higher performance than traditional crops (forage corn and alfalfa) under low and high salinity conditions. Among the cereals crops, barley, triticale, and oat are the most recommended to cultivate under high salinity. In contrast, under low salinity, pearl millet and sorghum could produce a satisfactory level of biomass yield. Among other groups, a high potential has been revealed for blue panicum, sesbania, and fodder beet, especially under high salinity conditions where their fresh biomass yield can exceed 80, 50, and 100 t/ha, respectively. According to farmers, perennial crops such as blue panicum have great potential for upscaling as they are less demanding in terms of agricultural inputs (seeds, fertilizers, pesticides, etc.).

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