INFLUENCE OF BORON ON SORGHUM (*SORGHUM BICOLOR* L.) FORAGE YIELD UNDER DIFFERENT WATER SALINITY LEVELS

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Abstract

Sorghum is known for food and fodder in arid and semi-arid regions of the world. Boron as a micronutrient is reported to maximize forage yields as its role is related to plant growth under normal conditions. The present study investigated the effect of six concentrations of boron ((0 (control), 1, 2.5. 5, 7.5, 10 mg L^{-1}) on growth of multi-cut forage sorghum variety, Super Dan under three levels of irrigation water salinity viz. 1, 5 and 10 dS m^{-1} in pots containing sandy loam soil using Randomized Complete Design for a span of over four forage harvests in five-months during summer 2007-2008. The results indicated significant ($0.01<p<0.05$) effects of boron and salinity treatments and their interactions in respect of plant height and green matter (forage) weight. Both green forage (matter) and dry matter weights were significantly higher at boron concentration of 5 mg L^{-1} ($p<0.05$) under higher salinity levels of 5 dSm^{-1} (109.33 g and 37.18 g, respectively) and 10 dSm^{-1} (86.03 g and 29.95 g, respectively) in the first and subsequent harvests.

Keywords: *Sorghum; Salinity; Boron; Green matter; Dry matter*

1. Introduction

Sorghum (Sorghum bicolor L. Moench) is predominantly, grown in semiarid and subtropical regions because of its capacity to withstand to harsh weather conditions. In terms of tonnage, sorghum grain crop ranked as fifth largest in the world, it can survive very high temperatures and water-logged conditions, making it suitable to be grown in a tropical climate. Cultivated in a large part of the world, sorghum is mainly grown in semiarid or subtropical areas as a substitute source of starch or for forage to livestock as green or hay. Sorghum crop can be considered more salt tolerant in comparison with maize and maze being the important cereal crop placed as number one in productivity in the world among other crops (Maas, 1985). However, sorghum has also the potential to be utilized as an important crop in areas affected by the salinity (Ayers and Westcott, 1985; Igartua *et al.,* 1994). Among the world's arable lands, the saline soils cover about 5–10% (Szabolcs, 1994; Tanji, 1990), further it is important to note that areas affected by salinity is increasing steadily over the last few years infact this phenomenon is largely attributed to mismanaged irrigation (Ghassemi *et al.,* 1995; Iyengar and Reddy, 1994). It is pertinent that soil salinity greatly impact on the productivity of most crops that potentially reduce yields depending upon type of species and its extent (Francois and Maas, 1994; Munns *et al.* 2002). Micronutrient elements are required in relatively very small quantities for satisfactory plant growth and production, the deficiency of these micronutrients may cause great disturbance in the physiological and metabolic processes involved in the plant (Piri, 2012). Boron plays an important role in the plant growth as an essential micronutrient, it helps sugars and nutrients transfer from leaves to reproduction system that supports in the development of organs, increase in pollination as well as development of seed. The strengthening of cell wall, cell division, development of seed and sugar transport are related to boron (B) nutrition. However, boron requirements for optimum plant nutrition are relatively low in comparison with those of the primary nutrients contributing to the maximum forage yields (Ismail, 2003). In view of the above, the effect of various levels of boron on growth and development of multi-cut forage sorghum variety, Super Dan was investigated under different levels of salinity at the experimental site of the Directorate General of Agriculture and Livestock Research located at Rumais, Barka in the coastal Al-Batinah Governorate of Oman for a period of over five-months during summer season of 2007-2008.

2. Materials and methods

Study was conducted on the experimental site of the Directorate General of Agriculture and Livestock Research at Rumais, Barka in the coastal Al-Batinah Governorate of Oman. This study adopted factorial experiment in randomized complete design (RCD) with four replications and six levels of Boron concentrations (0 (control), 1, 2.5. 5, 7.5, 10 mg L^{-1}) under three levels of irrigation water salinity viz. Control (1 dS m^{-1}), 5 and 10 dS m^{-1} in pots of 70 cm diameter and 50-cm height containing sandy loam soil. The sorghum seeds of Super Dan variety were planted on 17th November 2007 in four pots containing sandy loam soil, per treatment under each salinity level and only five healthy plants were retained after germination. All the crop husbandry practices were followed according to recommendations of Ministry of Agriculture and Fisheries (Akhtar *et al.*, 2002). Plants grown in pots were fertilized with the recommended (standard) dose of 225 kg N ha^{-1}: 120 kg P_2O_5 ha^{-1}: 125 kg K_2O ha^{-1}. The recommended fertilization was basically in the form of urea, triple super phosphate and potassium sulphate. The entire quantities of potassium and phosphate fertilizers were applied before planting along with 1/2 nitrogen fertilizer and the remaining quantity of nitrogen was applied after one month from the date of planting. The pots of each treatment were frequently irrigated with 139 liters per pot water corresponding to levels of boron and salinity according the reference evapotranspiration (ET_o). The boron and salinity treatments were prepared in 100-liter plastic drums by diluting the saline water by control water and adding boric acid (H_3BO_4) as a source of Boron in different concentrations. The crop was harvested for forage on 19th February i.e. after 93 days coinciding about 50% blooming. Samples of soil were collected randomly at the beginning of the experiment while water samples were collected after two weeks for chemical analysis whose results are presented respectively in Tables 1 and 2. The observations on plant height (cm) and green forage weight were recorded at the time of the first harvest (cut) while only green forage weight was recorded in latter three harvests (cuts). One plant in each treatment was taken for green weight (g/plant) and dried in temperature of 70^{o}C for 72 hours to estimate dry matter weight via dry matter % (AOAC, 1984). The data on the above characters were subjected to statistical analysis following the methods proposed by Gomez and Gomez (1984) which makes use of MSTATC computer program.

Table 1. Composition of irrigation water samples used under six different six boron (concentrations) and three salinity treatments (levels)

Treatments	*Temp.* °c	*E.C.* $dS\ m^{-1}$	*TDS* ppm	*Boron* ppm	*Ca* ppm	*Mg* ppm	*Na* ppm	*K* ppm
S1B1	20.7	0.576	317	**0.42**	2.76	5.12	102	2.32
S1B2	20.6	0.546	300	**1.45**	2.28	3.80	102	2.07
S1B3	20.9	0.544	299	**2.85**	2.57	3.90	104	3.03
S1B4	21.0	0.556	306	**5.35**	3.73	4.36	104	2.21
S1B5	20.9	0.546	300	**7.75**	2.99	4.06	105	2.02
S1B6	21.3	0.548	301	**10.4**	3.61	4.39	104	2.00
S2B1	20.7	4.99	7797	**0.86**	91.5	217	575	8.65
S2B2	20.8	5.29	8266	**1.58**	103	225	610	10.5
S2B3	20.9	5.19	8109	**3.04**	92.0	213	585	10.4
S2B4	20.7	5.16	8063	**5.57**	94.0	214	590	11.0
S2B5	20.7	5.21	8141	**7.92**	93.0	216	595	10.0
S2B6	20.6	5.15	8047	**10.6**	96.0	213	590	11.0
S3B1	21.0	11.41	17030	**0.86**	212	493	1245	24.0
S3B2	20.9	10.86	16209	**1.65**	204	473	1205	23.0
S3B3	21.0	10.82	16149	**3.10**	209	479	1220	23.0
S3B4	21.0	11.13	16612	**5.59**	208	489	1235	23.0
S3B5	20.8	10.99	16403	**8.31**	214	494	1255	22.0
S3B6	20.7	10.60	15821	**11.1**	199	459	1175	22.0

Salinity treatments (levels): S1 (Control, 1dS m^{-1}), S1 (5 dS m^{-1}) and S3 (10 dS m^{-1})

Boron treatments (Concentrations): B1-0 mg L^{-1}; B2-1 mg L^{-1}; B3-2.5 mg L^{-1}; B4-5 mg/l; B4-7.5 mg L^{-1} and B6-10 mg L^{-1})

Table 2. Values for Boron Content (ppm) of the experimental soil after first forage harvest (cut) of sorghum

Treatments		Salinity levels			
		1 dS m^{-1}	5 dS m^{-1}	10 dS m^{-1}	Mean
Boron Concentrations	0 mg L^{-1}	1.28	1.42	1.75	1.48
	1 mg L^{-1}	1.74	1.69	2.66	2.03
	2.5 mg L^{-1}	2.46	2.96	4.03	3.15
	5 mg L^{-1}	4.70	4.10	4.83	4.54
	7.5 mg L^{-1}	4.09	20.69	20.81	15.20
	10 mg L^{-1}	10.47	23.52	19.58	17.86
	Mean	4.12	9.06	8.94	

3. Results and Discussion

Concentrations of higher amount of boron are often associated with saline soils of semi-arid and arid climates because in these areas crops are frequently exposed to stresses (Gupta *et al.*, 1985; Martinez-Balista *et al.*, 2008). Boron is one of the important micronutrients on which number of studies have been undertaken in the past to maximize yields not only in food (Piri, 2012; Contreras *et al.*, 2005; Rodríguez-Hernández *et al.*, 2013) but also in forage (Gupta, 1972; Ismail, 2003) crops. In the present study, boron was investigated for its effect on plant height, green and dry matter yields of sorghum under three levels of salinity viz. control (1 dSm^{-1}), 5 dS m^{-1} and 10 dS m^{-1} through its application in six different concentrations viz. 0 mg/l, 1 mg/l, 2.5 mg/l, 5 mg/l, 7.5 mg L^{-1} and 10 mg L^{-1}. The results of irrigation water chemistry is provided (Table 1) and the experimental soil after harvests of forage (Tables 2 and 3) indicated that only the concentrations of boron were increased under all the levels of salinity correspondingly in proportion to their concentrations of application while other elements including Ca^{+}, Mg^{+}, Na^{+} and K^{-} and TDS in irrigation water were not affected in their concentrations in different combinations of treatments in the experiment (Table 1). Similarly, temperature and electrical conductivity (EC) in irrigation water (Table 1) and electrical conductivity (EC) and pH in soil were unaffected (Tables 4 and 5) with either saline water level or boron content.

Table 3. Values for Boron Content (ppm) of the experimental soil after the last forage harvest (cut) of sorghum

Treatments		Salinity level 1 dS m^{-1}
Boron Concentrations	0 mg L^{-1}	1.27
	1 mg L^{-1}	1.92
	2.5 mg L^{-1}	4.10
	5 mg L^{-1}	11.64
	7.5 mg L^{-1}	15.57
	10 mg L^{-1}	19.58
	Mean	9.01

Table 4. Values for ECe of the experimental soil after first forage harvest (cut) of sorghum

Treatments		Salinity levels			
		1 dS m^{-1}	5 dS m^{-1}	10 dS m^{-1}	Mean
Boron Concentrations	0 mg L^{-1}	5.98	25.80	41.30	24.36
	1 mg L^{-1}	5.13	20.40	55.50	27.01
	2.5 mg L^{-1}	4.16	21.10	49.80	25.02
	5 mg L^{-1}	4.18	18.45	33.80	18.81
	7.5 mg L^{-1}	4.82	22.10	49.00	25.31
	10 mg L^{-1}	5.45	24.40	38.40	22.75
	Mean	4.95	22.04	44.63	

Table 5. Values for pH of the experimental soil after first forage harvest (cut) of sorghum

Treatments		Salinity levels			
		1 dS m^{-1}	5 dS m^{-1}	10 dS m^{-1}	Mean
Boron Concentrations	0 mg L^{-1}	7.50	7.50	7.50	7.50
	1 mg L^{-1}	7.90	7.40	7.40	7.57
	2.5 mg L^{-1}	7.90	7.30	7.70	7.63
	5 mg L^{-1}	7.70	7.60	7.80	7.70
	7.5 mg L^{-1}	7.60	7.70	7.40	7.57
	10 mg L^{-1}	7.50	7.60	7.10	7.40
	Mean	7.68	7.52	7.48	

In respect of concentrations of elements accumulated in the plant tissues of sorghum, accumulation of Boron and Barium was significantly different ($p<0.05$) between boron treatments whereas contents of other elements were not significantly different ($p>0.05$). The boron contents in the shoot tissues were found to increase significantly with the increased concentrations of Boron from 104 ppm at 0 mg /l to 591 ppm at 10 mg L^{-1} ($p<0.05$). This was also noticed by Goldberg *et al.* (2003) in barley. However, boron contents in the tissues of plants at 5 mg L^{-1} of boron concentration were nearly half the amount (320 ppm) to that at 10 mg L^{-1} (Table 6).

Table 6. Concentrations (ppm) of different elements in plant tissues (shoot) of sorghum in different Boron treatments over salinity levels

Treatments	B	Na	Mg	Ca	K	Ba	P	S	Mn	Cu	Zn	Ni	Cr
0 mg L^{-1}	104^a	1073	4013	4687	18667	201^b	1443	1463	66	12	15	7	2
1 mg L^{-1}	146^a	1057	4807	5180	21000	200^b	1587	1530	77	13	16	8	2
2.5 mg L^{-1}	136^a	797	3221	3758	12120	132^a	704	924	45	8	9	11	3
5 mg L^{-1}	320^b	1360	4840	5857	21033	184^b	1283	1587	68	13	13	6	2
7.5 mg L^{-1}	388^b	1257	4743	5003	18000	215^b	1412	1513	69	15	16	7	2
10 mg L^{-1}	591^c	1267	5350	5890	22100	202^b	1260	1677	68	14	16	5	2
F-test	**	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS
LSD (5%)	113.50	-	-	-	-	47.74	-	-	-	-	-	-	-

NS = Not significant; * = significant difference at $p<0.05$; ** = significant difference at $p<0.01$

Further, analyses of variance results obtained from the data indicated that both the effects of boron and salinity treatments and also the effects of their interactions were significant ($p<0.05$) and highly significant ($p<0.01$) in respect of plant height and green matter (forage) weight. However, in respect of dry matter weight the effect of boron was not significant ($p>0.05$) whereas that of salinity and interactions were significant ($p<0.05$) to highly significant ($p<0.01$) (Table 7).

Table 7. Error Mean Squares and F-values of plant height (cm), green and dry matter weight (g/plant) of sorghum in six boron concentrations under three levels of irrigation water salinity in the first forage harvest (cut) during the summer season 2007-2008

Source of Variance	d.f.	Plant height (cm)		Green matter (forage) weight (g/plant)		Dry matter weight (g/plant)	
		Mean Square	**F value**	**Mean Square**	**F value**	**Mean Square**	**F value**
Replication	3	14.99	2.89	6.24	0.76	1.895	0.71
Boron	5	15.56	3.00*	20.02	2.44*	6.288	2.37 NS
Salinity	2	105.01	20.26**	123.52	15.07**	38.79	14.62**
Boron x Salinity	10	12.38	2.39*	17.085	2.08*	5.371	2.02*
Error	51	5.18		8.194		2.654	
Total	71						

NS = Not significant; * = significant difference at p<0.05; ** = significant difference at p<0.01

In respect of plant height, among the salinity levels, it was the highest (139.82 cm) at 1 dSm^{-1} whereas it was the higher under boron concentrations between 1 mg L^{-1} and 5 mg L^{-1} (113.47 to 118.15 cm) (p<0.05). However, the plant height was highest at 5 mg L^{-1} concentration of boron under both 1 dSm^{-1} (144.46 cm) and 5 dSm^{-1} (129.35 cm) (Table 8).

Table 8. Mean plant height (cm) of sorghum in six boron concentrations under three levels of irrigation water salinity in the first forage harvest (cut) during the summer season 2007-2008

Treatments		Salinity levels			
		1 dS m^{-1}	**5 dS m^{-1}**	**10 dS m^{-1}**	**Mean**
Boron Concentrations	**0 mg L^{-1}**	140.23	119.29	44.69	**101.40**
	1 mg L^{-1}	142.73	103.23	108.49	**118.15**
	2.5 mg L^{-1}	143.38	99.70	108.70	**117.26**
	5 mg L^{-1}	144.46	129.35	66.61	**113.47**
	7.5 mg L^{-1}	140.35	89.14	4.17	**77.89**
	10 mg L^{-1}	127.76	92.29	67.23	**95.76**
	Mean	**139.82**	**105.50**	**66.65**	

In respect of green forage (matter) and dry matter weights, among the salinity levels, they were the highest (111.13 g and 37.79 g, respectively) both at 1 dSm^{-1} salinity level and at 5 mg L^{-1} concentration of boron (98.25 g and 33.65 g, respectively). Interestingly, both green forage (matter) and dry matter weights were significantly higher at boron concentration of 5 mg L^{-1} (p<0.05) under higher salinity levels of 5 dS m^{-1} (109.33 g and 37.18 g, respectively) and 10 dS m^{-1} (86.03 g and 29.95 g, respectively). (Tables 8 and 9) in the first harvest. This trend also was almost true in case of yield levels in the second, third and third harvests, although they were not significant (p>0.05) (Tables 10 and 11). Similar observations were made in sunflower by Asad *et al.* (2003) where boron was found to increase both vegetative and reproductive growth under high salinity levels. However, in the present study forage yields in response to boron concentrations exceeding 5 mg L^{-1} were inconsistent showing both increased or decreased yields (Tables 9 to 12). Wimmer *et al.* (2003) showed that salinity could interact with boron toxicity by a combined effect on boron and water uptake to produce a beneficial effect on performance of plants due to reduction of aquaporin functionality in NaCl-exposed plants which in turn induces the reduction of plant boron concentration (Martinez-Ballesta *et al.*, 2008).

Table 9. Means of green matter weight (g/plant) of sorghum in six boron concentrations under three levels of irrigation water salinity in the first forage harvest (cut) during the summer season 2007-2008

Treatments		Salinity levels			
		1 dS m^{-1}	**5 dS m^{-1}**	**10 dS m^{-1}**	**Mean**
Boron Concentrations	**0 mg L^{-1}**	100.90	74.84	18.03	**64.59**
	1 mg L^{-1}	97.35	85.43	82.49	**88.43**
	2.5 mg L^{-1}	110.42	61.55	55.08	**75.68**
	5 mg L^{-1}	99.40	109.33	86.03	**98.25**
	7.5 mg L^{-1}	135.57	47.15	0.00	**60.91**
	10 mg L^{-1}	123.11	117.72	30.88	**90.57**
	Mean	**111.13**	**82.67**	**45.42**	

Table 10. Means of dry matter weight (g/plant) of sorghum in six boron concentrations under three levels of irrigation water salinity at first forage harvest (cut) during the summer season, 2007-2008

Treatments		Salinity levels			
		1 dS m^{-1}	**5 dS m^{-1}**	**10 dS m^{-1}**	**Mean**
Boron Concentrations	**0 mg L^{-1}**	34.35	25.48	6.66	**22.16**
	1 mg L^{-1}	33.08	29.04	28.09	**30.07**
	2.5 mg L^{-1}	37.54	20.96	18.77	**25.76**
	5 mg L^{-1}	33.84	37.18	29.95	**33.65**
	7.5 mg L^{-1}	46.08	16.06	0.00	**20.72**
	10 mg L^{-1}	41.85	40.01	10.89	**30.92**
	Mean	**37.79**	**28.12**	**15.73**	

Table 11. Means of green and dry matter weight (g/plant) of sorghum in six boron concentrations over three salinity levels at second forage harvest (cut) during the summer season, 2007-2008

Boron Concentration	*Green matter (forage) weight (g/plant)*	*Dry matter weight (g/plant)*
0 mg L^{-1}	29.73 a	18.40
1 mg L^{-1}	35.23 a	20.76
2.5 mg L^{-1}	33.59 a	16.94
5 mg L^{-1}	33.26 ac	16.91
7.5 mg L^{-1}	47.40 bc	27.50
10 mg L^{-1}	40.34 b	21.31
F-test	**	NS

NS = Not Significant; * = significant difference at p<0.05; ** = significant difference at p<0.01

Table 12. Means of green and dry matter weight (g plant^{-1}) of sorghum in six boron concentrations over three salinity levels in the third and fourth harvests (cuts) during the summer season, 2007-2008

Boron Concentration	**Third Cut**		**Fourth Cut**	
	Green matter weight (g/plant)	**Dry matter weight (g/plant)**	**Green matter weight (g/plant)**	**Dry matter weight (g/plant)**
0 mg L^{-1}	58.29	31.10	56.37	18.41
1 mg L^{-1}	62.79	29.31	66.47	26.97
2.5 mg L^{-1}	52.51	30.71	63.46	20.02
5 mg L^{-1}	73.77	34.54	64.82	21.95
7.5 mg L^{-1}	70.68	36.89	67.36	25.58
10 mg L^{-1}	65.33	33.05	63.61	20.20
F-test	NS	NS	NS	NS

NS = No Significant at p<0.05

In view of the above results, it was concluded that boron application of 5 mg L^{-1} under higher salinity levels could significantly increase forage yields as observed in terms of green and dry matter weights with accumulation of half the boron contents in the tissues in comparison with highest boron level (10 mg L^{-1}).

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