Growth And Photosynthetic Pigments Of Fodder Beet Plants As Affected By Water Regime And Boron Foliar Fertilization

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ABSTRACT: Pot experiment was conducted in the greenhouse of the National Research Centre, Dokki- Cairo, Egypt during the winter season of 2006/2007 to evaluate the effect of available water depletion before irrigation (AWDBI) and boron foliar spray on growth and photosynthetic pigments of fodder beet plants c.v. Red Forshenger. The experiment contained 3 levels of AWDBI in combination with 2 boric acid treatments in addition to the control treatment *i.e*. 9 treatments in 6 replicates arranged in split plot design. Negative relationship was found between leaf area, and fresh and dry weights of fodder beet plants and AWDBI. The whole fresh weight/plant showed the same response while the dry weight of whole plant with the two drought treatments showed approximately the same values. Top, root and whole plant fresh or dry-weight gave their higher values when plants received 75 ppm boric acid which exceeded than those received 150 ppm boric acid or sprayed by fresh water. However, leaf area and shoot/root ratio increased as the boric acid concentration increased up to 150 ppm. Plant height and number of leaves/plant did not significantly affect by boron spraying. Top/root ratio increased with boron application under different AWDBI. The highest percentages of Chl a, Chl b, carotenoids and total chlorophyll were obtained by spraying 75 ppm boric acid compared to spraying with 150 ppm or control plants. This was true for Chl a / Chl b and total chlorophyll / carotenoids ratio. Positive relations were found among the concentration of N, K, Ca and Zn and drought treatments. Phosphorus, Mg and Na concentrations did not affect. Either Fe or Cu concentration decreased by both drought treatments, however, the concentration of Mn decreased with the 50 days period AWDBI and tended to increase to be more than the control treatment. Increasing the period of available water depletion before irrigation induced positive effect on N and Ca uptake, while, K, Mg, Na, Fe, Mn and Cu uptake showed opposite trend. In the same time the dose 75 ppm boric acid increased both concentration and uptake of macro and micro-nutrients by the plant tops; however the higher dose (150 ppm) led to a reverse effect.

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1. INTRODUCTION

The increasing demand for animal proteins of the growing population in Egypt is handicapped through the shortage of the carbohydrate components in animal feeds. On the other hand, the horizontal expansion of new reclaimed areas requires the cultivation of crops offering a source for satisfying income to the farmers. Fodder beet can easily fulfill both aims through its high content of carbohydrate which reached about 72% DM and production in some new regions ranged between 25-30 tons/feddan.

Boron plays an important role in carbohydrate metabolism and transportation (Belvins and Lukaszewski, 1998 and Marschner, (1995); but the increase of boron led to toxicity as found by Kato *et al.* (2008). Lewis (1980) assumed that boron controls the metabolic reactions of carbohydrate transport. Boron was also reported to control different reactions in carbohydrate metabolism such as α-amylase, Glucose 6-phosphate dehydrogenase, ß-amylase and reduction of UDPG-synthesis (Goldbach, 1997). The specific B role in carbohydrate metabolism reported to be species dependent (Brown and Hu, 1998). Boron is now known to be mobile in the phloem of all species that utilize polyols (complex sugars) as primary photosynthetic metabolites. In these species a polyol-B-polyol complex is formed in the photosynthetic tissues and is transported in the phloem to currently active sink regions such as vegetative or reproductive meristems. In species that do not produce significant quantities of polyols, B once delivered to the leaf in the transpiration stream cannot reenter the phloem, resulting in essentially complete phloem immobility. Thus, B may cause accumulation of sugars and starch or reduction of sucrose (Agarwala and Chatterjee, 1996).

For many crops, B fertilization is required. Shaaban *et al*. (2004) found that boron foliar application with 25 ppm boron or 25 ppm boron + 50 ppm zinc in the spray solution has significantly increased both fresh and dry weight of cotton plants grown under high calcium carbonate level in the soil. Ziaeyan and Rajaie (2009) stated that Zn and B fertilization significantly increased plant biological yield, grain yield, thousand grain weight, number of grains per stalk, grain protein content and the concentration of B and Zn in corn tissues grown under high $CaCO_3$ conditions. Climate, particularly high light intensity and low temperature are factors that need to be considered in relation to the occurrence of B deficiency (Shorrocks, 1997). Boron application could help plants to ameliorate water stress of beats as reported by Ahmed, *et al.*, 2009. One of the main problems in the new cultivated areas is the lake of water which affected the growth of different crops grown in these areas. Clover *et al.* (1999); Mohammedian *et al.* (2005) and Hoffmann (2010) found that water deficit has affected reversely the growth and yield of fodder beet. However, the sensitivity of beet to water deficit has been poorly studied. Little is known about physiological traits which can be used to assess the effects of drought. Understanding the physiological responses to water stress and the traits associated with it is therefore strongly desirable to develop mechanistic forecasting systems for fodder beet growth**.** Furthermore, water stress reduces the growth and yield to such an extent that it is likely to depend on stress duration and phenological stages.

The current work was designed to investigate the effect of foliar spray of boron on growth traits, photosynthetic pigments and mineral status of fodder beet plants grown under depletion of different percentage of available soil water before irrigation.

2. MATERIALS AND METHEODS

Pot experiment was conducted in the greenhouse of the National Research Centre at Dokki-Cairo, Egypt during the winter season of 2006/2007 to evaluate the effect of available soil moisture stress and boron foliar spray on growth and photosynthetic pigments of fodder beet plants c.v. Red Forshenger. The experiment included 3 levels of water depletion before irrigation in combination with 2 boric acid treatments in addition to control treatment *i.e*. 9 treatments in 6 replicates arranged in split plot design. Metallic tin pots 35 cm in diameter and 50 cm in depth were used. Every pot contained 30 kg of air dried clay loam soil. The inner surface of the pots was coated with three layers of bitumen to prevent direct contact between the soil and metal. In this system, 2 kg of gravel, (particles about 2-3 cm in diameter) were used to cover the bottom of the pot. Irrigation water was poured through a vertical tube (2.5 cm in diameter), so the movement of water was from the base upward.

Seeds of fodder beet (*Beta vulgaris L.* cv. Red Forshenger) were sown in Dec., 15. The plants were thinned twice: the 1st 20 days after sowing and the 2nd two weeks later to leave three plants/pot. Calcium super phosphate (15.5 % P_2O_5) and potassium sulfate (48.5 % K_2O) in the rate of 2.29 and 1.14 g/pot were added before sowing. Ammonium sulfate (20.5 % N) in the rate of 6.86 g/pot was added in two equal portions: the 1st two weeks from sowing and the 2nd two weeks latter. The water regime treatments started 21 days after sowing. Boron treatments in the form of boric acid (17% B) were twice sprayed: the 1st at 21 days after sowing and the 2nd two weeks later. Control plants sprayed with the same amount of fresh water.

Samples from every treatment were taken, cleaned, dried at 70ºC and then ground in a stainless steal mill. The dry matter was digested and the macro and micro-nutrients were determined according to the methods described by Chapman and Pratt (1978). Chlorophyll a, b and carotenoids were determined according to the method of Nush (1980).

The data collected were statistically analyzed as described by Snedecor and Cochran (1990).

3. RESULTS AND DISCUSSION

3.1. Growth

A negative relationship was found between area of leaves, fresh and dry weights of fodder beet plants and AWDBI. The whole fresh weight/plant showed the same response while the dry weight of whole plant with the two drought treatments showed approximately the same values (Table 1). Under drought conditions, beet leaves wilt in response to water deficiency, tend to lie flat on the soil and thus, increase the effective area exposed to the direct sun radiation. As a consequence of the reduction in transpiration rates of such leaves, leaf temperature increases and may result in leaf scorching and death (Clover *et a*l., 1999).

Abdallah and Yassen (2008) showed that extension of irrigation to 21 and 28 days reduced the foliage fresh weight/plant, although foliage dry weight and root diameter were not significantly affected by irrigation augmentation, but the root length/plant was seriously affected and showed a clear reduction. Drought induced reduction in different growth traits through its effect on the physical and chemical properties and/or physiological processes inside the plant tissues. The effect of reduced soil water level included an increase in the solution concentration of non absorbed nutrients and that of exchangeable cations which tend to reduce the concentration of absorbed anions like phosphate (Pariher and Tiwari, 2003).

The decrement in nutrients in top and root at drought treatments might be due to reducing the solubility of mineral in the soil. The films are thin and path length of movement increase; hence movement of cations to root is reduced. High tension exerts a physiological effect on the root, elongation, turgidity and number of root hairs decreased with increasing tension (Abdallah and Yassen, 2008). Monti *et al*. (2006) observed a lower photosynthetic capacity than the potential even when the favorable water conditions were restored. They concluded that this was somewhat related to the reduction of the root apparatus caused by water stress. Plant vegetative growth was inhibited with reduced water availability.

Leaf water potential, relative water content and canopy transpiration were reduced with increasing soil water stress. Leaf photosynthesis rate was reduced when stomatal resistance exceeded 3.5 $s.cm^{-1}$ (Ismail *et al*., 1994).

Table 1: Growth of fodder beet plants as affected by water regime

AWDBI %	**Plant Height (cm)**	**No of leaves**	**Leaf area (cm^2/ Plant)**	**Root (cm)**		**Fresh weight(g/plant)**			**Dry weight(g/plant)**			**Top/root**
				L	**D**	**Top**	**Root**	**Whole**	**Top**	**Root**	**Whole**	
25	44.43	9.57	2011	12.70	2.61	78.4	97.8	176.2	12.38	19.75	32.13	0.627
50	41.23	9.13	1449	11.77	2.53	77.3	77.8	155.1	8.88	10.67	19.55	1.010
100	35.23	9.40	1344	12.03	2.94	70.1	71.0	141.1	8.75	13.65	22.40	0.640
$LSD_{5\%}$	N.S	N.S	567	N.S	0.43	1.1	17.14	32.6	3.32	5.97	6.54	------

L= length, D= diameter, AWDBI= available water depletion before irrigation

Data recorded in Table 2 indicated that top, root and whole plant fresh or dry-weight gave its higher values when plants received 75 ppm boric acid and even more than that received 150 ppm boric acid or that sprayed with fresh water. However, area of leaves and top to root ratio increased as the boric acid concentration increased up to 150 ppm. Plant height and number of leaves/plant did not significantly affected by boron spraying.

Table 2: Growth of fodder beet plants as affected by boron spray

Boric acid ppm	**Plant Height (cm)**	**No of leaves**	**Leaf area (cm^2/ Plant)**	**Root (cm)**		**Fresh weight(g/plant)**			**Dry weight(g/plant)**			**Top/root**
				L	**D**	**Top**	**Root**	**Whole**	**Top**	**Root**	**Whole**	
0	40.67	10.13	1173	11.67	2.53	75.0	90. 7	165.7	8.56	14.04	22.60	0.610
75	42.00	8.47	1746	12.70	2.63	84.3	90.0	174.3	12.59	20.02	32.20	0.629
150	34.23	9.50	1885	12.10	2.91	66.6	65.9	132.5	9.17	10.01	2121	0.916
$LSD_{5\%}$	N.S	N.S	638	0.70	N.S	12.28	15.6	41.3	N.S	8.33	8.13	------

L= length, D= diameter

Previously, Crisp *et al*. (1976) noticed that lettuce plants (*Lactuca sativa* L.) grown in a boron deficient nutrient medium developed tip burn. Their leaves showed no overall increased auxin activity compared with those of control plants until they were 66 days old, when boron deficient plants showed a relative increase in the activity of one auxin. Karabal *et al.* (2003) mentioned that compared with controls (no boric acid treatment) boron toxicity resulted in a reduction in root weights and did not cause any significant change in protein contents. Boric acid treatment did not cause significant (P>0.05) changes in proline and H_2O_2 contents of both tissues and cultivars. Wang *et al.* (2006) reported that boron deficiency inhibits growth of the plant apex, which consequently results in a relatively weak apical dominance, and a subsequent sprouting of lateral buds. Boron application to the shoot apex inhibited lateral bud growth and stimulated lateral root formation, presumably by stimulated polar IAA transport. Lopez-Gómez *et al.* (2007) stated that the presence of B produced a decrease in the lipid peroxidation values, suggesting that B additions afforded some protection to the membranes. This means that boron application improved the oxidative defense against stress. Kocábek, *et al.* (2009) found that seedlings grown with 5 mM boric acid were short, stunted and pale. However, at concentrations between 1 and 3 mM, hypocotyls elongation was stimulated in all *Arabidopsis* ecotypes tested relative to plants grown at 0.1 mM H_3BO_3. Cervilla, *et al.* (2009) mentioned that 2 mM B supply inhibited root growth and increased the root B concentration in both tomato cultivars. Kassem *et al.* (2009) observed positive effects on growth of cotton plants when sprayed by 85 and 170 ppm boric acid, but the positive response with 170 ppm treatment was less than the 85 ppm treatment.

It is clear from data presented in Table 3 that plant height, number of green leaves fresh weight of leaves, root diameter and length and dry matter of leaves as well as root dry weight did not show any significant response to the interactive effects of depletion of available soil moisture before irrigation and boron spraying. However, leaf area, fresh and whole plant fresh and dry weight were significantly responded to this interaction. Pant *et al.* (1998) reported that water stress treatments, regardless of B levels and genotypes. Boron X irrigation interactions indicated the possibility of the influence of water stress on the severity of wheat sterility in South and South-east Asia.

Ben-Gal and Shani (2003) revealed that water application levels were 30, 60, 100, 130 and 160% of potential evapotranspiration. Boron levels in irrigation water were 0.02, 0.37, and 0.74 $M.m^{-3}$. B and drought stresses did not result in a larger effect but rather, one or the other stress causing factor was found to be dominant in plant response. Both irrigation water quantity and boron concentration influenced water use of the plants in the same manner as they influenced the yield.

Top / root ratio increased with boron application under different AWDBI. Abdollahian-Noghabi (1999) declared that due to limited shoot growth in severe drought stress, the ratio of shoot to root dry weight was severely reduced. Under drought stress, on sugar beet as well as fodder beet plants, the ratio of storage root to leaf dry matter of sugar beet decreased indicating a different partitioning of the assimilates (Hoffmann, 2010).

Table 3: Growth of fodder beet as affected by boron foliar spray and water regime

AWDBI %	**Boric acid ppm**	**Plant height (cm)**	**No of leaves**	**Leaf area cm^2/ plant**	**Root (cm)**		**Fresh weight(g/plant):**			**Dry weight(g/plant)**			**Top/ root ratio**
					L	**D**	**Top**	**Root**	**Whole**	**Top**	**Root**	**Whole**	
25	**0**	45.0	10.7	1445	14.0	2.43	92..0	129.0	221.7	11.83	21.50	33.33	0.553
	75	45.0	8.7	2008	12.7	2.53	94.0	119.7	213.7	16.77	27.95	44.72	0.600
	150	34.3	9.3	2579	11.3	2.87	49.3	44.7	94.0	8.55	9.79	18.34	0.873
50	**0**	39.7	8.7	1080	9.3	2.00	77.3	76.7	122.4	6.78	9.01	15.79	0.753
	75	44.3	7.7	1650	12.7	2.30	77.0	66.0	143.0	9.85	13.91	23.46	0.735
	150	39.7	11.0	1618	13.3	3.30	77.7	90.8	168.0	10.02	9.08	15.10	1.764
100	**0**	37.3	11.0	995	11.7	3.17	55.7	66.3	143.6	7.08	11.61	18.69	0.610
	75	39.7	9.0	1580	12.7	3.07	82.0	84.3	166.2	10.24	18.19	28.42	0.563
	150	28.7	8.2	1457	11.7	2.57	72.7	62.3	95.0	8.93	11.15	20.18	0.801
$LSD_{5\%}$		N.S	N.S	1192	N.S	N.S	N.S	44.2	74.7	N.S	N.S	15.08	-----

L= length, D= diameter, AWDBI= available water depletion before irrigation

Photosynthetic pigments

It was observed from data in table 4 that there was no response of Chl a, carotenoids and total chlorophyll concentrations in leaves of fodder beet plants as the increase in depletion of available water before irrigation. The opposite was true for the concentration of Chl b by both drought treatments. Furthermore, Chl a/ Chl b ratio decreased as the AWDBI was increased, but total chlorophyll / carotenoids ratio was increased by 50% depletion of AWDBI and tended to decrease by the irrigation after depletion of 100% of available water. Ardic *et al.* (2009) reported that chlorophyll florescent increased in the drought resistant variety, but decreased in the drought sensitive cowpea variety by boron treatment.

Table 4: Photosynthetic pigments $mg.g^{-1}$) in leaves of fodder beet as affected by water regime

AWDBI %	Chl a	Chl b	Carot	T.Chl	Chl a/ Chl b	T.Chl/Carot.
25	3.410	1.478	0.885	4.888	2.307	5.523
75	3.285	1.613	0.843	4.898	2.037	5.810
100	3.372	1.905	1.181	5.277	1.770	4.468
$LSD_{5\%}$	N.S	0.15	N.S	N.S	-----	-----

AWDBI: available water depletion before irrigation

Data recorded in table 5 indicated that the highest percentages of Chl a, Chl b, Carotenoids and total chlorophyll values obtained by spraying of 75 ppm boric acid compared to the 150 ppm treatment or control. This was also true for Chl a/Chl b and total chloropyhll / carotenoids ratios. Zhao and Oosterhuis (2000) found that the values of Chl a, Chl b and total chlorophyll of boron deficient plants during the early growth of cotton considerably decreased leaf photosynthetic rate and carbohydrate transport from leaves to fruits, and depressed plant growth and dry matter accumulation. Mouhtaridou *et al.* (2004) noticed that SPAD units of leaves characterizing chlorophyll contents declined as B concentration of the culture medium increased from 0.1 to 6.0 mM.

Table 5: Photosynthetic pigments (mg.g^{-1})in leaves of fodder beet as affected by boron spray

Boric acid (ppm)	Chl a	Chl b	Carot	T.Chl	Chl a/ Chl b	T.Chl / Caro
0	3.158	1.646	0.962	4.804	1.918	4.992
75	4.308	1.961	1.157	6.269	2.197	5.418
150	2.601	1.389	0.790	3.990	1.873	5.051
$LSD_{5\%}$	N.S	0.49	N.S	0.471	-----	------

Boron deficiency during the early growth of cotton increased leaf chlorophyll content, decreased leaf stomatal conductance and net photosynthetic rate, and reduced non-structural carbohydrate export from the leaf to the fruit (Zhao and Oosterhuis, 2003). Mazhar *et al.* (2006) found that chlorophyll and carotenoids content increased as B concentration increased up to 20 ppm as compared to the untreated *Taxodium destincum L*. plants.

The interaction between water regime and boron fertilization appeared to not affect both chlorophyll a and crotenoids (Table 6). However, the concentration of 100 ppm at the first water regime (25 AWDBI) appeared to negatively affect the concentration of carotenoids followed by the concentration 75 ppm with the two other AWDBI treatments. This means that boron toxicity appeared with less concentration as water is more deficient. Plants exposed to B toxicity found to exhibit increases of malondialdehyde (MDA) and hydrogen peroxide (H_2O_2) content, resulting in oxidative stress and membrane peroxidation (Ardic *et al.* 2009, Cervilla *et al*., 2007, 2009).

Mineral composition

A positive relation was found between the concentration of N, K, Ca and Zn concentration and drought treatments. Phosphorus, Mg and Na concentrations did not significantly affect. Either Fe or Cu concentration decreased by both drought treatments, however, the concentration of Mn decreased with the treatment 50 AWDBI (Table 7).This may be due to nutrient accumulation as the metabolism was depressed with water deficit.

Table 6: Photosynthetic pigments (mg.g^{-1}) in leaves of fodder beet as affected by boron spray and water regime

AWDBI %	Boric acid (ppm)	Chl a	Chl b	Carot	T.Chl	Chl a /Chl b	T.Chl /Carot
25	0	3.295	1.630	0.860	4.925	2.021	5.727
	75	4.071	1.710	1.351	5.781	2.381	4.281
	150	2.860	1.095	0.444	3.955	2.612	8.908
50	0	2.917	1.600	0.810	4.517	1.823	5.577
	75	4.619	1.858	0.872	6.477	2.486	7.428
	150	2.319	1.381	0.848	3.700	1.679	4.363
100	0	3.261	1.707	1.217	4.968	1.910	4.082
	75	4.233	2.316	1.249	6.549	1.828	5.243
	150	2.623	1.691	1.078	4.314	1.551	3.955
$LSD_{5\%}$		N.S	0.84	N.S	0.763	----	----

AWDBI = available water depletion before irrigation

Table 7: Effect of drought on mineral concentration of macro and micro-nutrients in fodder beet tops

AWDBI %	Macronutrients (%)						Micronutrients (ppm)			
	N	P	K	Mg	Ca	Na	Fe	Mn	Zn	Cu
25	3.91	0.31	3.18	0.87	0.39	4.08	665	85.5	54.6	7.18
50	4.55	0.29	3.83	0.83	0.74	4.10	644	65.7	90.9	5.98
100	4.99	0.30	3.90	0.80	0.60	3.98	576	92.8	95.7	6.25

Data in Table (8) showed that increasing the depletion of available water percentage before irrigation induced positive effect on N and Ca uptake, while, K, Mg, Na, Fe, Mn and Cu uptake showed the opposite trend. Mazhar *et al*. (2006) found that N, P, K, B, Cu, Ca, Fe, Zn and Mn increased significantly in shoots by water level decreased from 40 to 100% of water holding capacity.

Table 8: Effect of drought on macro and micro-nutrients uptake by tops of fodder beet plants

AWDBI %	Macronutrients (mg/plant)						Micronutrients (mg/plant)			
	N	P	K	Mg	Ca	Na	Fe	Mn	Zn	Cu
25	484.0 a	38.3a	393.6b	107.7b	48.2a	505.1b	8.23b	1.07c	0.675a	0.088b
50	404.0 a	25.7a	340.1a	73.7a	65.7b	364.0a	5.71a	0.58a	0.807a	0.053a
100	436.6 b	26.2a	341.2a	70.0a	52.5a	348.0a	5.04a	0.81b	0.837a	0.054a
$LSD_{5\%}$	41.8	NS	40.1	11.4	11.2	48.3	1.43	0.12	NS	0.02

A marked increase was detected in N and Na concentration by increasing the concentration of boron in the sprayed solution (Table 9). Meanwhile, P, Fe and Mn showed the highest response by spraying 75 ppm. On the contrary, B treatment lowered the concentration of K, Zn and Cu ppm. Zude *et al.* (1997) found that boron foliar application increases the concentrations of Ca, K and Mg in the leaves of apple. Shaaban *et al.* (2004) found that boron foliar application led to significant increases in both concentrations and uptake of calcium, potassium, iron, manganese, zinc and copper in cotton shoots especially plants grown under high calcium carbonate levels in the soil. They found also that a special nutrient balance between boron and other nutrients in the shoot tissues led to a good plant growth. Hanafy-Ahmed *et al.* (2008) reported that boron foliar application increased uptake and concentration of nutrients in wheat leaves.

Table 9: Effect of boron foliar spray on macro and micro-nutrients concentration in fodder beet tops

Boric acid	Macronutrients (%)						Micronutrients (ppm)			
	N	P	K	Mg	Ca	Na	Fe	Mn	Zn	Cu
0	4.21	0.26	3.75	0.82	0.36	3.85	595	63.8	92.5	6.63
75	4.39	0.39	3.68	0.85	0.93	3.94	718	103.6	72.5	6.70
150	4.85	0.26	3.48	0.83	0.43	4.38	573	81.1	76.2	6.08

Increasing the concentration of B in the foliar sprayed solution increased the uptake of all determined nutrients (Table 10). However, the uptake declined by increasing the boron dose to 150 ppm. Mouhtaridou, *et al*. (2004) noticed that by increasing B concentration of the culture medium from 0.1 to 6.0 mM, contents of B, P, Ca, and Mg in explants increased, whereas, K, Fe, Mn, and Zn contents decreased. Adiloglu and Adiloglu (2006) emphasized that nitrogen, P and K concentrations in maize leaves increased with B application.

Table 10: Effect of boron spray on macro and micro-nutrients uptake by the tops of fodder beet plants

Boric acid (ppm)	Macronutrients (mg/plant)						Micronutrients (mg/plant)			
	N	P	K	Mg	Ca	Na	Fe	Mn	Zn	Cu
0	360.3a	22.2a	321.0a	70.2a	30.8a	329.5a	5.09a	0.55a	0.79a	0.057a
75	552.7c	49.1b	463.3b	107.0b	117 b	496.0b	9.04b	1.30b	0.91a	0.084a
150	444.7b	23.8a	319.1a	76.1a	39.4a	401.5a	5.25a	0.75a	0.70a	0.055a
$LSD_{5\%}$	33.2	7.12	47.3	10.0	16.8	43.1	2.35	0.39	NS	NS

Obermeyer *et al.* (1996) suggested that boron stimulates ATP hydrolysis, H^+ transport activity and control membrane voltage charging. A recent study stated that at least three B-binding membrane glycoproteins were detected in the B-deficient plant tissues indicating that B and certain membrane glycoproteins are involved in membrane processes associated with nutrient uptake and cell growth (Redondo-Nieto *et al*. 2007). Limited research work has been done on the interactive effects of B and water deficit. Pant *et al*. (1998) and Mazhar *et al.* (2006) concluded that B application can be used to reduce the harmful effect of water stress up to 40 % of water holding capacity. Smith, *et al.* (2010) observed the increase of boron in the shoot tissues while water stress increased in broccoli plant. Nevertheless, Apostol and Zwiazek (2004) stated that in the plants treated with B for 10 and 6 weeks, stomatal conductance was reduced with a concomitant reduction in a steady-state root water flow; meanwhile, tissue concentrations of essential elements including K, P, Ca, Mg, and S were not altered by B-treatments.

Conclusions:

From the present work it could be concluded that:

1- A negative relationship appeared between leaf area, and fresh and dry weights of fodder beet plants and AWDBI.
2- Top, root and whole plant fresh or dry-weight gave their higher values when plants received 75 ppm boric acid, while leaf area and top/root ratio increased as the boric acid concentration increased up to 150 ppm. Moreover, plant height and number of leaves/plant did not affect.
3- The highest percentages of Chl.a, Chl.b, carotenoids and total chlorophyll were obtained by spraying 75 ppm boric acid
4- A positive relation was found between the concentration of N, K, Ca, Zn and drought treatments. However, P, Mg and Na concentrations did not affected. Either Fe or Cu concentrations decreased by drought treatments, however, the concentration of Mn decreased with the 50 days AWDBI.
5- Increasing AWDBI induced positive effect on N and Ca uptake, while, K, Mg, Na, Fe, Mn and Cu uptake showed the opposite trend.
6- A reasonable dose of boric acid (75 ppm) could increase both concentration and uptake of macro and micro-nutrients by the plant tops, however the higher dose (150 ppm) led to a reverse effect.

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