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EFFECT OF HIGH LEVELS OF BORON ON THE YIELD, BORON CONTENT, BORON UPTAKE AND ANATOMICAL STRUCTURE OF SOME WHEAT CULTIVARS

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ABSTRACT: **Four wheat cultivars (*Triticum aestivum*) *i.e.*, Sakha 8, Sakha 69, Sakha 93 and Sids 1 were treated with high levels of boron to detect the tolerant and sensitive cultivars. Sakha 69 was relatively tolerant to boron and Sids 1 was relatively sensitive to boron. The tolerant (Sakha 69) and sensitive (Sids 1) cultivars were treated with nutrient solution in a sand culture with different boron levels as boric acid (0, 0.5, 1, 2, 4, 8 and 16 mg B L^{-1}). Increasing level of boron up to 1 mg/L increased straw and grain yields of two cultivars. The greatest yields was recorded at 0.5 mg B/L. High levels of boron above 1 mg/L caused a gradual decrease in straw, grain and weight of 100 grains for sensitive and resistant wheat cultivars. Application of boron was more effective in its B-uptake by straw and grains and in Sids 1 than in Sakha 69. Tissue examination revealed that the total area of conductive tissue in the stem was greater than the ground tissue which was lower in Sakha 69 (boron–resistant) as compared with Sids 1 (boron–sensitive). However the opposite trend was observed in the roots tissues. This might be the reason for higher ability of Sakha 69 to transport boron to the stem and withstand the unfavourable effect of high boron levels on root growth. Sids 1 accumulated more B than Sakha 69 in the root and consequently less B transported to stems.**

INTRODUCTION

The need of expanding agricultural land in Egypt had lead to the use of saline well waters in irrigation. This saline water usually contains high levels of boron which may result in deterioration of the soil for the long continued use. Under this condition, toxicity effects may occasionally arise by excessive use of irrigation water rich in boron.

Kausar *et al.* (1988) found 21% increase in yield of wheat with application of 4 kg B/ha. Also, Holloway and Alston (1992) mentioned that high soil-B level was the cause of the decrease in straw yield in bread wheat. Al-Yousif *et al.* (1994) found that increasing the boron concentration in the plant media resulted in a significant increase in boron content. Bellaloui and Brown (1998) found that differences in sensitivity to boron deficiency and excess amongst wheat cultivars and species were a consequence of either reduced boron uptake.

Moreover, selecting or breeding cultivars with tolerance to boron toxicity is probably the most promising approach to handling the problem of boron toxicity. Investigations dealing with the effect of boron on the internal structure of the plant needs more studies. Lal and Paliwal (1993) reported that toxic concentration of boron may affect adversely the cell elongation resulting into slower growth rate and may be the important reason for the plant to be dwarf. Cakmak and Römheld (1997) stated that boron plays an essential role in the structure and function of cell walls and cellular membranes. Hu and Brown (1994) suggested that B plays a critical role in the cell wall structure of higher plants. Matoh *et al.* (1992) reported that 98 % of boron in tobacco cells is located in cell walls. Hu and Brown (1996) demonstrated that the boron requirement of a plant is correlated with the pectin content of the cell wall. Pilbean and Kirkbik (1983)concluded that the continuous supply of B is not essential for cell growth, but is necessary for the keeping of meristemic activity.

Boron deficiency is associated with a disruption of normal cell division (Kouchi and Kumazawa, 1976). Bala*tos *et al.* (1994) found that cell walls varied in thickness and were missing in places, causing cell breakage in B-deficient nodules.

The current work was conducted to obtain information about the effect of high levels of boron on the yield, boron content and boron uptake by some wheat cultivars. Also, the anatomy of the main stem and root of wheat plants were studied.

MATERIALS AND METHODS

A germination experiment was carried out firstly to differentiate between different cultivars of wheat on their tolerance to boron. The wheat cultivars were Sakha 8, Sakha 69, Sakha 93 and Sids 1. They were germinated in pure sand culture treated with high levels of boron for 11 days. The adverse effect of high boron levels showed that Sakha 69 was the most tolerant while Sids 1 was the most sensitive to high levels of boron.

The other experiment was conducted to study the effect of added boron at different concentrations on the yield, boron content and boron uptake by the previous two wheat cultivars.

The anatomical structure of wheat plants was also considered in this experiment. Plastic pots having the dimension of 18 cm in diameter and 20 cm in depth were prepared and filled with 5 kg of washed dried sand per pot. Each pot had a hole at the bottom to facilitate drainage. Twenty grains of wheat (Sakha 69 and Sids 1) were sown in each pot and thinned to four plants after germination. The pots were flushed with nutrient solution of Arnon (1938) for 14 days. Thereafter, the nutrient solution was continued applied accompanied with different concentrations of boron applied as boric acid. The treatments of B consisted of seven levels as boric acid (0, 0.5, 1, 2, 4, 8 and 16 mg B L^{-1}). The plants were supplied with nutrient solution. Irrigation with solution was done so as to allow the excess to drain from the pot. All treatments were replicated six times in a completely randomized factorial design.

At elongation stage (80 days-old), 3 replicates were used for taking plants to study some tissue aspects. They were fixed in formalin acetic alcohol (FAA) solution for at least 48 hours. The procedure of paraffin method (Johansen, 1940) was used. Sections of 14 µm thickness were stained using safranin and light green. The area of both total cross sections and thickness of various tissues (ground and conductive tissues) were then determined by means of stage micrometer.

The remaining three replicates were harvested at maturity stage. The yield of grains and straw were determined for each treatment and then analyzed for boron.

The dry tissue is ignited to a white or gray ash in a muffle furnace at 500°C for 8 hours. The ash was dissolved by 1 N HCl and boron was determined by curcumin method as described by Dible *et al.* (1954).

RESULTS AND DISCUSSION

1- Grain and straw yields:

Effect of the different treatments of boron on the straw and grain yields of wheat cultivars is given in Table (1). Data indicate that application of boron in the cultural media had a marked effect on the straw and grain yields of Sakha 69 and Sids1. Increasing level of boron up to 1 mg/L in the nutrient solution consistently increased straw and grain yields of both two cultivars over that of control. The greatest yield was recorded at 0.5 mg/L. The relative increases for straw and grain were 27% and 8% for Sakha 69 and 34% and 6% for Sids 1, respectively. Similar trends were found for weight of 100 grains, where the corresponding values were 26 and 12% for Sakha 69 and Sids 1, respectively. These results resemble those obtained by Da Silva (1983) who reported that boron application at 0.65 kg/ha increased wheat yields. Kausar *et al.* (1988) found 21% increase in yield of wheat with application of 4 kg B/ha. Further increase of boron level beyond the level of 1 mg/L was followed by a gradual decrease of straw, grain and weight of 100 grains for both sensitive and resistant wheat cultivars. At the highest rate of boron (16 mg B/L), these parameters for Sakha 69 and Sids 1 were decreased by 18 and 22% for straw; 49 and 53 for grain and 19 and 21% for weight of 100 grains, respectively. This means that the highest decrease of these parameters was recorded for Sids 1, while the lowest one was recorded for Sakha 69. This reflects the differences between the two cultivars to boron tolerance. The harmful effect of high B levels was more obvious on Sids 1 than Sakha 69. These results are in agreement with those observed by Chauhan and Power (1978) who concluded that the yield of wheat grain declined by 13, 20 and 32% at the 4.0, 6.0 and 8.0 ppm B in irrigation water, respectively. Holloway and Alston (1992) found that high soil – B levels had been found to decrease straw yield in some earlier studies in bread wheat.

2. Content and uptake of boron by straw and grain yields:

Data in Table (1) showed that the addition of different levels of boron in the cultural media caused a marked effect on the content of boron in wheat cultivars (sensitive and resistant to boron). It is clear that the addition of boron tended to increase the content of boron by the tested wheat cultivars. The relative increases were 19, 86, 203, 310, 450 and 699% in grains of Sakha 69 when boron treatments were 0.5, 1, 2, 4, 8 and 16 mg/L, respectively. The corresponding values for Sids 1 were 40, 62, 125, 312, 453 and 445% in the same order. The relative increases were 10, 55, 131, 292, 514 and 616% in straw of Sakha 69 when treatments were 0.50, 1.00 2.00, 4.00, 8.00 and 16.00 mg B/L. The corresponding values for Sids 1 were 29, 107, 201, 309, 430 and 609% in the same order. This might be attributed to increasing boron levels in the cultural media. These results are in accordance with those obtained by Jin *et al.* (1988) who mentioned that boron concentration in plants was significantly increased as a result of boron application. Al-Yousif *et al.* (1994) found that increasing the boron concentration in the plant media resulted in a significant increase in boron content. Kastori *et al.* (1995) reported that the content of boron in all analyzed plant parts increased with the increase of boron levels in nutrient solution.

Data also revealed that the application of boron was more effective in its content in straw than in grains and in Sids 1 than in Sakha 69. Such effect being dependent on the sensitivity of Sids 1 to boron concentration rather than Sakha 69 and also to harmful effect of boron on wheat growth.

Regarding boron uptake by wheat cultivars, Table 1 indicates a significant positive correlation between boron in the plant medium and its uptake by plants.

Table (1): Effect of different levels of boron on the yield, boron content and boron uptake by grain and straw yields of two wheat cultivars.

Boron level (mg/L)	Yield & 100-grain weight			Boron content (mg/kg)		Boron uptake (µg / pot)	
	Grain (g/pot)	Straw (g/pot)	100 grain weight (g)	Grain	Straw	Grain	Straw
Sakha 69 cv.							
0.00	4.59	17.57	2.24	6.60	10.12	30.00	178.00
0.50	4.95	22.26	2.82	7.87	11.09	39.00	247.00
1.00	4.65	17.99	2.37	12.26	15.71	57.00	283.00
2.00	3.69	16.78	2.07	20.03	23.33	74.00	391.00
4.00	3.53	15.84	2.04	27.03	39.70	95.00	629.00
8.00	3.12	15.62	2.03	36.29	62.10	113.00	970.00
16.00	2.33	14.23	1.82	52.73	72.44	123.00	1031.00
Mean	3.84	17.18	2.20	23.26	33.50	76.00	533.00
$L.S.D_{0.05}$	0.28	2.72	0.19	2.44	2.15	12.28	98.03
Sids 1 cv.							
0.00	3.26	16.59	1.80	8.97	12.14	29.00	201.00
0.50	3.45	22.21	2.02	12.56	15.61	43.00	347.00
1.00	3.29	17.01	1.85	14.57	25.17	48.00	428.00
2.00	2.34	15.50	1.56	20.14	36.60	47.00	567.00
4.00	2.24	14.31	1.47	36.99	49.71	83.00	711.00
8.00	2.04	14.11	1.44	49.56	64.37	101.00	908.00
16.00	1.53	12.90	1.43	48.87	86.05	75.00	1110.00
Mean	2.59	16.09	1.65	27.38	41.38	61.00	610.00
$L.S.D_{0.05}$	0.19	1.36	0.13	2.52	1.75	7.80	70.89

However, application of boron in the media had a marked stimulatory effect on boron uptake by wheat cultivars. In general, the highest values of boron were obtained at the highest level of boron. These results reflect the effect of boron on the grains and straw yields of wheat due to increasing boron level which are relatively more absorbed by plants. These results agree with those obtained by Keren *et al.* (1985) who suggested that boron plant uptake is proportional to B concentration in the soil solution. Nable *et al.* (1990) showed that the rate of boron uptake is linearly related to the external boron concentration. In this connection, Wilders and Neales (1971) concluded that there are two components of boron uptake : a passive diffusion of $B(OH)_3$ and an active transport for $B(OH)^-_4$ ion. They based their conclusion of active uptake on the following:(1) the observation that internal boron concentrations were greater than the external boron concentrations as a result of the transport of the $B(OH)^-_4$ ion, (2) the uptake was inhibited by anoxia and DNP.

Data also reveal that application of boron was more effective in boron uptake by straw and grains in Sids 1 than in Sakha 69. This is mainly due to the different abilities of the two cultivars to accumulate boron. In this connection, Bellaloui and Brown (1998) found that differences in sensitivity to boron deficiency and excess amongst cultivars and species were a consequence of either reduced boron uptake as in wheat.

3. Anatomical structure of wheat cultivars as affected by boron levels:

3.1. Stems:

The effect of different levels of boron on the total stem area and different tissues of wheat cultivars is shown in Table (2) and Plates (1) and (2). The response to different levels of boron was reflected on the internal structure of the stem which was placed on record as different tissue areas. The total stem area of Sakha 69 and Sids 1 increased with increasing boron levels up to 1 mg/L. Further increase was accompanied by a decrease in the total stem area. This could be attributed to the adverse effect of high levels of boron on plant growth. In this concern, Lal and Paliwal (1993) demonstrated that toxic concentration of boron may affect adversely the cell elongation resulting into slower growth rate.

Table (2): Effect of different levels of boron on anatomical structure of wheat varieties (stems).

Boron level (mg/L)	Total area (μ^2)	Whole diameter (μ)	Ground tissue (μ^2)	Conductive tissue (μ^2)			Vascular bundle number
				Phloem	Xylem	Total	
Sakha 69 cv.							
0.00	5870474	2735	686	40	80	120	52
0.50	6442107	2865	889	43	96	139	58
1.00	5985016	2761	718	42	83	125	54
2.00	5208275	2576	684	39	76	115	51
4.00	5117683	2553	670	38	73	111	47
8.00	4107096	2287	643	37	72	109	47
16.00	3454929	2098	640	36	70	106	45
Mean	5169369	2554	704	39	79	118	51
Sids 1 cv.							
0.00	5065503	2540	748	38	67	105	50
0.50	7657977	2685	763	47	85	132	54
1.00	5569181	2664	748	39	83	122	51
2.00	3819806	2206	712	36	66	102	50
4.00	3556452	2129	657	36	66	102	47
8.00	3492083	2109	546	34	64	98	43
16.00	1977450	1587	416	27	49	76	33
Mean	4448350	2274	656	37	69	105	47

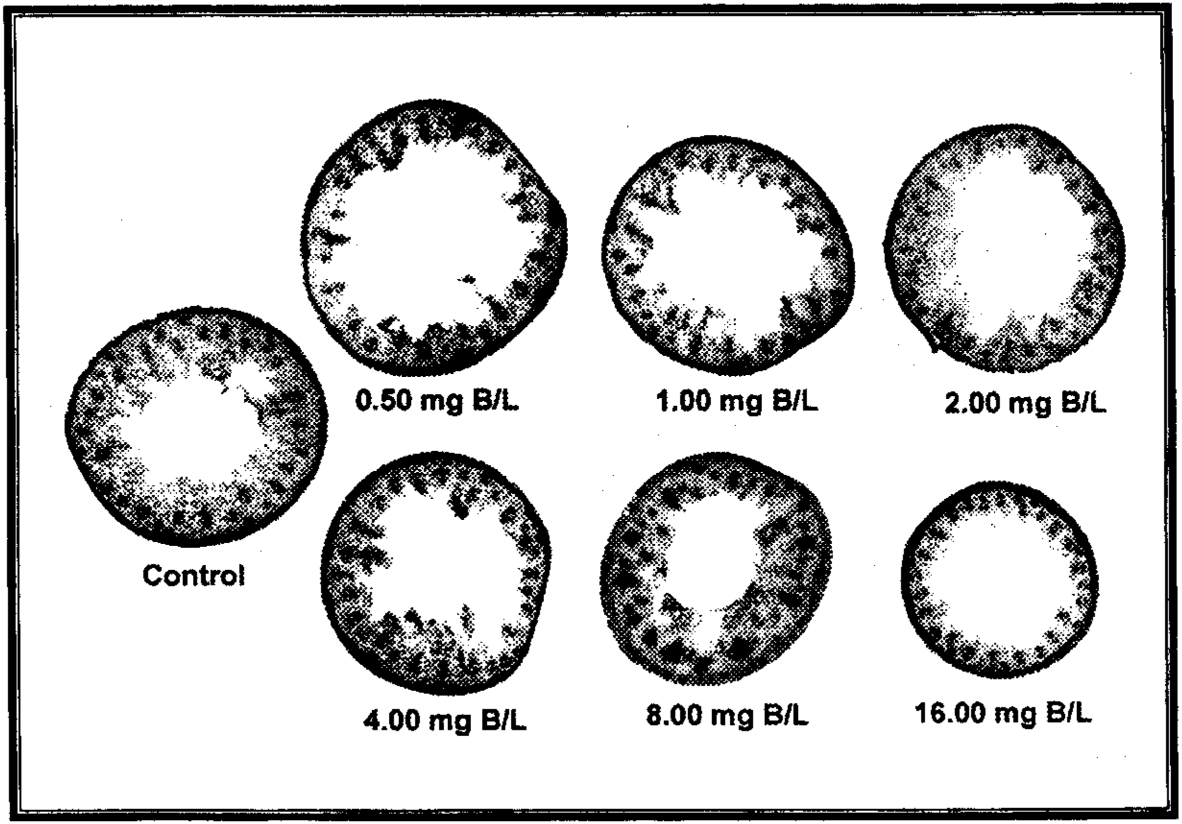

Plate (1): Effect of different treatments of boron on cross section of Sakha 69 stem.

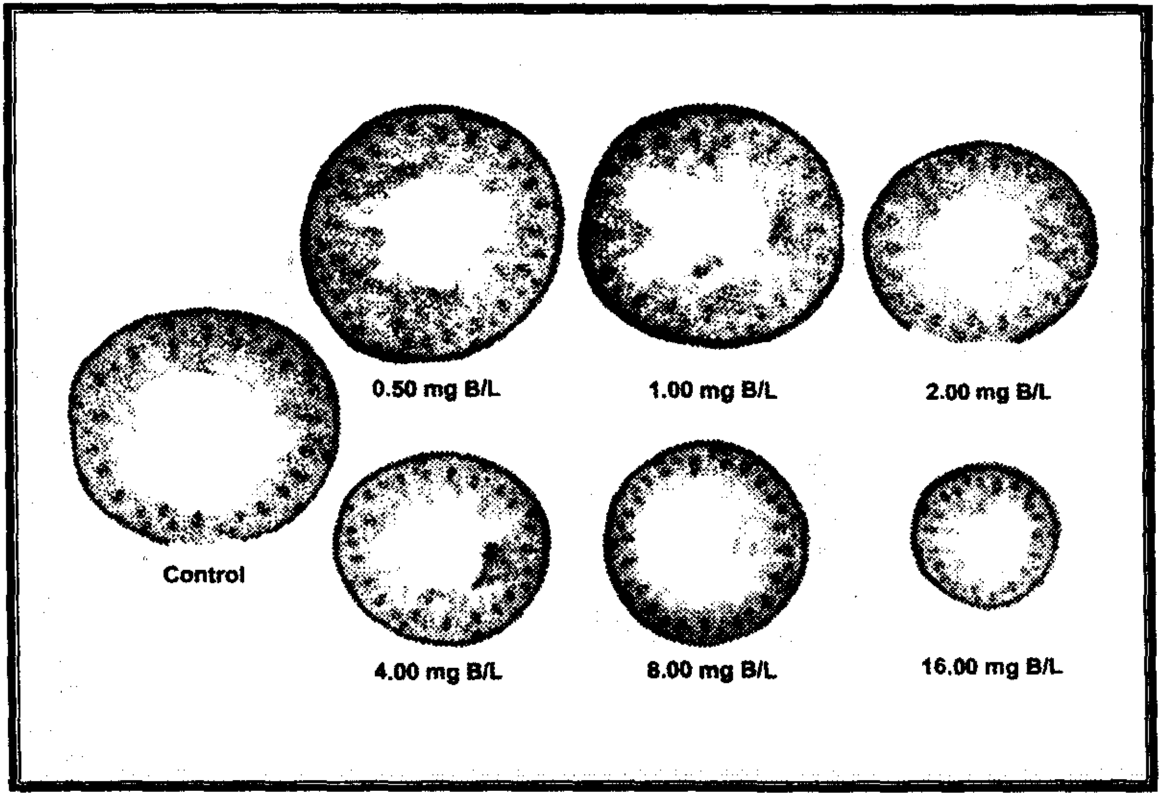

Plate (2): Effect of different treatments of boron on cross section of Sids 1 stem.

Also, there was an increase in the total area of ground tissue and whole diameter with increasing boron levels up to 1 mg/L, but at higher levels, they decreased. Similar trend was also observed for the total area of conductive tissue and vascular bundle number of Sakha 69 and Sids 1 (including the phloem and xylem). Comparing the two cultivars, the total area, whole diameter, conductive tissue and vascular bundle number of Sakha 69 stem (relative resistant to boron) were higher than of Sids 1 (relative sensitive to boron) at all levels of boron. However, an opposite trend was observed for ground tissue, where it increased in Sids 1 than in Sakha 69.

3.2. Roots:

Table (3) and Plates (3) and (4) show the effect of different levels of boron on the total root area and different tissue of the wheat plants. The total root area of Sakha 69 and Sids1 increased with increasing boron levels up to 1 mg/L. The maximum increase was observed at 0.5 mg B L^{-1}. Further increase was accompanied by a gradual decrease in the total root area, it was lower than of control. This could be attributed to the adverse effect of high levels of boron on the plant growth and cell division or inhibition of meristematic activity. The toxic concentration of boron may affect adversely the cell elongation resulting into slower growth rate (Lal and Paliwal, 1993). There was an increase in the total area of ground tissue and whole diameter with increasing boron levels up to 1 mg/L, but at higher levels, they were lower than that of control. The total area of conductive tissue (including the phloem and xylem) and vascular bundle number of Sakha 69 and Sids 1 (including the phloem and xylem) took similar trends to that obtained for the ground tissue. It increased with increasing levels of boron up to 1 mg/L and then decreased. Comparing the two cultivars, regarding the total area, whole diameter, ground tissue and vascular bundle number, Sakha 69 (relatively resistant to boron) showed higher values than Sids 1 (relative sensitive to boron) at all levels of boron. However, an opposite trend was observed for conductive tissue, where it increased in Sids 1 than in Sakha 69.

From the above mentioned results, it is obvious that the boron treatments considerably increased the total area of conductive tissue in the stem of Sakha 69 (boron – resistant) than Sids 1 (boron – sensitive). However, an opposite

Table (3) : Effect of different levels of boron on anatomical structure of wheat varieties (roots).

Boron level (mg/L)	Total area (μ^2)	Whole diameter (μ)	Ground tissue (μ^2)			Conductive tissue (μ^2)			Vascular bundle number	Vascular bundle diameter (μ)
			Cortex	Pith	Total	Phloem	Xylem	Total		
Sakha 69 cv.										
0.00	746470	975	269	340	609	23	35	58	17	438
0.50	954952	1103	302	348	650	25	45	70	18	496
1.00	756840	982	271	348	619	24	40	64	18	456
2.00	707717	950	262	339	601	22	31	53	16	421
4.00	691709	939	262	334	596	19	30	49	16	402
8.00	597038	872	247	294	541	19	30	49	14	335
16.00	493522	793	245	220	465	19	29	48	11	321
Mean	706893	945	265	318	583	22	34	56	16	410
Sids 1 cv.										
0.00	714441	963	272	315	587	29	51	80	15	396
0.50	887609	1063	301	329	630	37	66	103	17	408
1.00	745781	975	275	316	591	36	54	90	17	408
2.00	657652	954	264	305	569	26	36	62	15	363
4.00	635850	915	244	272	516	26	36	62	15	362
8.00	560642	900	238	269	507	24	36	60	14	360
16.00	428665	845	226	260	486	18	31	49	13	315
Mean	661520	945	260	295	555	28	44	72	15	373

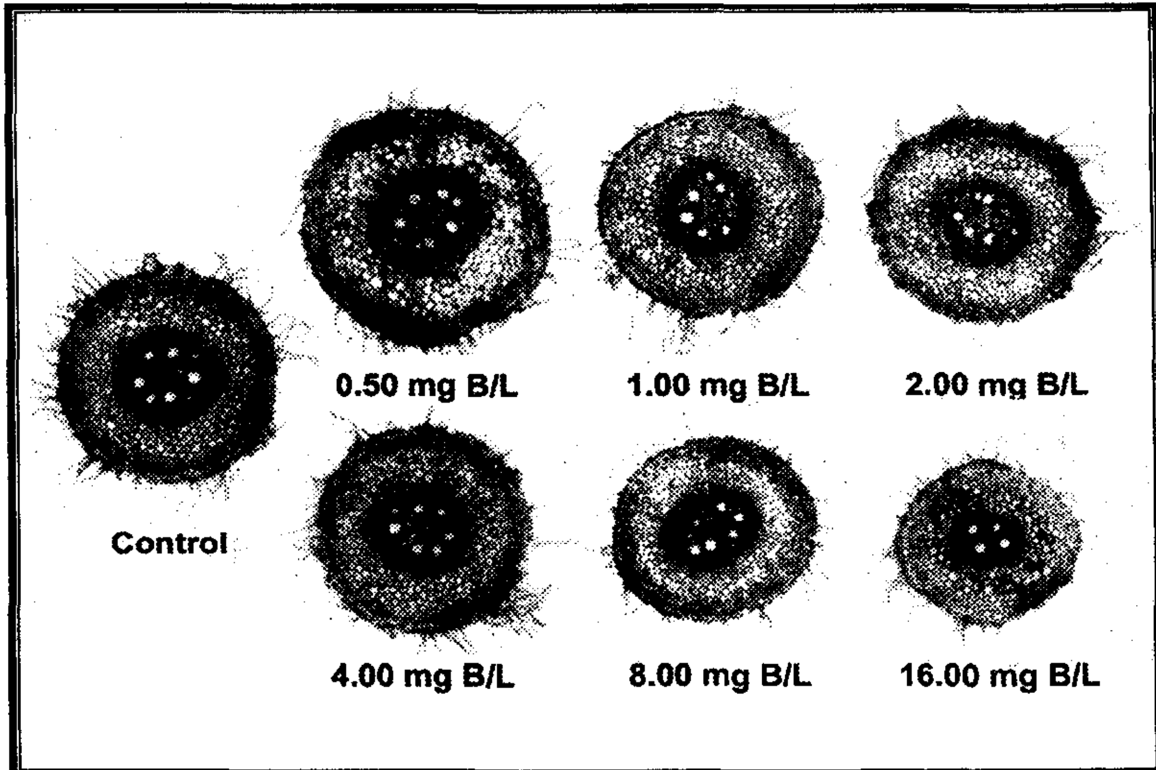

Plate (3): Effect of different treatments of boron on cross section of Sakha 69 root.

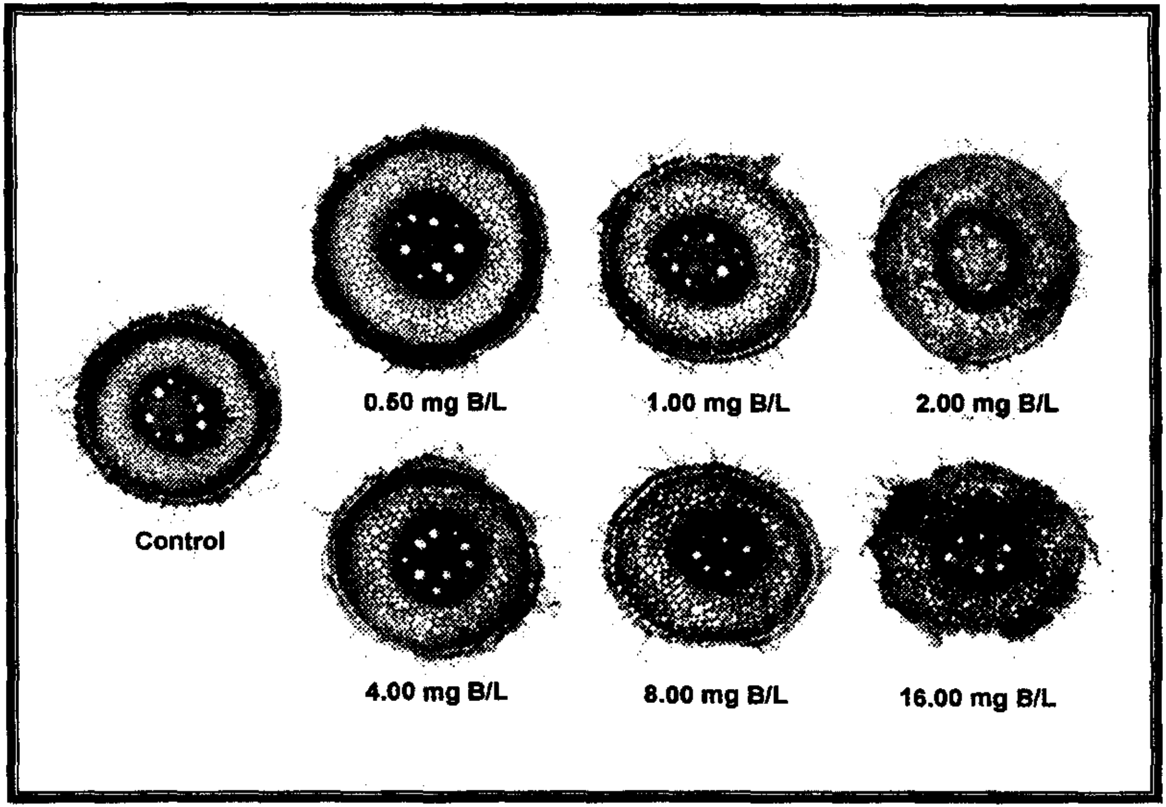

Plate (4): Effect of different treatments of boron on cross section of Sids 1 root.

trend was recorded for the area of conductive tissue in the root, where it increased in Sids 1 than Sakha 69. This variation might be responsible for high ability of Sakha 69 to transport boron to the stem to withstand the unfavourable effect of high boron levels on root growth In this concern, Nable *et al.* (1997) concluded that genotypes classified as susceptible produce shorter root axes and less lateral roots than tolerant genotypes in media with higher boron concentration.

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تأثير التركيزات المرتفعة من البورون على المحصول ، محتوى وامتصاص البورون وعلى التركيب التشريحي لبعض أصناف القمح

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** معهد بحوث الأراضى والمياه والبيئة – مركز البحوث الزراعية

اختيرت أربعة أصناف من القمح هي سخا٨ ، سخا ٦٩ ، سخا ٩٣ ، سدس ١ حيث تم التفرقة بينها من حيث درجة تحملها للبورون لمعرفة الصنف المقاوم والصنف الحساس للبورون ، وقد أوضح التأثير السلبي للتركيزات المرتفعة من البورون على تلك الأصناف ان الصنف سخا ٦٩ مقاوم للبورون بينما الصنف سدس ١ حساس للبورون.

في التجربة الاخرى : عومل الصنف المقاوم (سخا ٦٩) والصنف الحساس (سدس ١) بتركيزات مختلفة من البورون هي (صفر , ٠,٥ , ١ , ٢ , ٤ , ٨ , ١٦ ملليجم بورون/لتر في صورة حمض بوريك). وقد أوضحت النتائج المتحصل عليها أن زيادة مستوى البورون حتى تركيز ١ ملليجم/لتر أدى إلى زيادة محصول القش والحبوب وكان أعلى محصول عند ٠,٥ ملليجم بورون/لتر. المستويات العالية من البورون كانت مصحوبة بنقص تدريجي في القش والحبوب ووزن ١٠٠ حبة للصنفين الحساس والمتحمل . كما أوضح الفحص التشريحي للأنسجة أن المساحة الكلية للنسيج الموصل في الساق ازدادت بينما المساحة الكلية للنسيج البارنشيمى المحيط قلت في الصنف سخا ٦٩ (مقاوم للبورون) بالمقارنة بالصنف سدس ١ (حساس للبورون) , وقد حدث العكس بالنسبة للمجموع الجذري.

هذا الاختلاف يرجع أساسا إلى قدرة الصنف سخا ٦٩ على نقل البورون إلى الساق لكي يقل التأثير الضار على نمو المجموع الجذري ، بينما في الصنف سدس ١ حدث تراكم للبورون الممتص في المجموع الجذري وقل انتقاله إلى السيقان.