



Proceeding Paper Effects of High Boron on the Nutrients Uptake of Aegilops Genotypes Differing in Their B Tolerance Level[†]

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- + Presented at the 2nd International Electronic Conference on Plant Sciences—10th Anniversary of Journal Plants, 1–15 December 2021; Available online: https://iecps2021.sciforum.net/.

Abstract: Boron (B) toxicity is a damaging abiotic stress condition that significantly affects wheat production, especially in the dry regions of the world. Other than having several detrimental effects on the metabolic and physiological activities of wheat plants, high B may hinder the uptake of elements from the soil, developing a nutrient imbalance in plants. Focusing on this issue, in this experiment, we used 19 Aegilops genotypes differing in their boron (B) toxicity tolerance level along with a B toxicity tolerant cultivar, Bolal, and estimated their root–shoot nutrient concentrations under B toxic growth condition. Furthermore, the association between their root–shoot nutrient concentrations and level of B toxicity tolerance was evaluated. The experimental genotypes were grown under three different B growth conditions in hydroponic system including 3.1 μ M B (Control); 1 mM B (toxic), and 10 mM B (highly toxic) treatment. The macro and micronutrient concentrations in the shoots and roots of the genotypes showed large variations and were observed to be differentially influenced by high B stress.

Keywords: abiotic stress; Aegilops; boron toxicity; nutrient content; stress tolerance; wild wheat

1. Introduction

Wheat wild relatives are considered an important source of tolerance to several abiotic stress conditions [1-3]. Their genetic diversity can be effectively utilized to develop breeding lines and modern wheat cultivars with greater stress tolerances. Despite their great potential, Aegilops species have not been completely explored for such tolerances and mechanisms involved in making them tolerant. Boron (B) toxicity is one of the crucial abiotic stress conditions that negatively affect the wheat productivity, especially in waterstressed areas of the world. Other than several symptoms, high B is known to impede the uptake and translocation of macro and micronutrients in plants [4]. Thus, we hypothesized that the plants showing less effect of B toxic growth conditions on nutrient uptake and translocation can be more tolerant to B toxicity. To test this hypothesis, an elemental analysis of root and shoot samples of 19 Aegilops genotypes (Figure 1) grown under different B concentrations in hydroponic system was undertaken. The goal of this experiment was to explore the effect of high B on the macro and micronutrient content in roots and shoots of experimental genotypes. The results may provide an answer to the question of whether the accumulation of different nutrients can be associated with the B toxicity tolerance of the Aegilops genotypes. Further, research can be conducted to see the effect of additional supply of those nutrients towards increasing the tolerance level of less tolerant genotypes.



Citation: Khan, M.K.; Pandey, A.; Hamurcu, M.; Ozbek, M.; Omay, M.R.; Gokmen, F.; Topal, A.; Gezgin, S. Effects of High Boron on the Nutrients Uptake of Aegilops Genotypes Differing in Their B Tolerance Level. *Biol. Life Sci. Forum* 2022, *11*, 75. https://doi.org/ 10.3390/IECPS2021-11996

Academic Editor: Adriano Sofo

Published: 30 November 2021

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Figure 1. Spike photographs of 19 Aegilops genotypes obtained from the AARI National Gene Bank, Izmir, Turkey, and Turkish Seed Gene Bank (TSGB), Ankara. (a) Ab1 (Aegilops biuncialis1: TGB 026218; 4x); (b) Ab2 (A. biuncialis2: TGB 026219; 4x); (c) Ab3 (A. biuncialis3: TGB 037313; 4x); (d) Ac1 (A. columnaris1: TGB 037373; 4x); (e) Ac2 (A. columnaris2: TGB 038488; 4x); (f) Ac3 (A. columnaris3: TGB 037489; 4x); (g) Ac4 (A. columnaris4: TGB 000107; 4x); (h) Ac5 (A. columnaris5: TR57295; 4x); (i) As1 (A. speltoides1: TGB 037791; 2x); (j) As2 (A. speltoides2: TR 62174; 2x); (k) Al1 (A. ligustica1: TGB 000803; 2x); (l) Al2 (A. ligustica2: TR 39488;2x); (m) At1 (A. triuncialis1: TGB 037311; 4x); (n) At2 (A. triuncialis2: TGB 037355; 4x); (o) At3 (A. triuncialis3: TGB 037376; 4x); (p) At4 (A. triuncialis4: TR 72224; 4x); (q) Au1 (A. umbellulata1: TGB 037353; 2x); (r) Au2 (A. umbellulata2: TGB 037356; 2x); and (s) Au3 (A. umbellulata1: TR 72200; 2x) [3].

2. Materials and Methods

The study comprised 19 Aegilops genotypes supplied by the Turkish Seed Gene Bank (TSGB), Ankara, and AARI National Gene Bank, Izmir, Turkey, as well as Turkish hexaploid cultivar Bolal 2973 which is well-known for its B toxicity tolerance [5]. The B tolerance level of these genotypes has already been identified in one of our previous studies [3].

2.1. B Treatment and Harvest

The genotypes were grown in a hydroponic system with conditions adjusted to 22 ± 10 °C, 16,000 Lx/day light intensity, 16/8 h light/dark photoperiod, and 45–55% humidity. Initially, germinated seeds were transferred to the hydroponic system, then following three days of growth plants were given different treatments. Three replicates of all the genotypes with five plants each were grown in three different B concentrations including 1/5th Hoagland solution containing 3.1 μ M B (Control), 1 mM B (toxic B), and 10 mM B (highly toxic B) for 7 days. After 7 days, root and shoot samples were harvested for conducting ICP-AES analysis.

2.2. ICP-AES Analysis

After washing with 0.1 N HCl and double distilled water, the harvested root–shoot samples were left in an oven at 70 °C for drying. This was followed by the crushing of the dried samples and dissolving 0.15–0.20 g of the ground sample in 2 mL of 35% H_2O_2 and 5 mL of 65% HNO₃. The mixture was processed in a closed microwave accelerating reaction system (CemMarsxpress, Matthews, NC, USA). Further, ICP-AES (Varian, Vista) was employed to identify the nutrient amount in the stock solution [6]. MS Excel 2010 was used to estimate the percentage changes in each of the studied macro and micronutrient under two different B treatments as compared to Control.

3. Results

The purpose of this experiment was to determine the variation in 19 Aegilops genotypes in terms of nutrient accumulation in roots and shoots under different B toxic growth environments. Moreover, it aimed to identify whether the accumulation of nutrients is associated with the tolerance level of experimental genotypes which were already identified by Khan et al. [3].

3.1. *Calcium* (*Ca*)

The percentage change in shoot Ca (SCa) accumulation in 10 mM B treatment ranged from -145% to 38% in comparison to the Control. While At3 and At4 showed a 145% and 71% decrease, respectively, in the SCa content in 10 mM B treatment, Ac4 and Bolal both showed the maximum upsurge of (38%) in SCa content in comparison to Control (Table 1).

Table 1. The percentage changes in the macro- and micronutrient content of 19 Aegilops genotypes and the B-tolerant check cultivar, Bolal 2973, in highly toxic B (10 mM B) treatment as compared to Control.

Code	Taxon	Ploidy	SCa	RCa	SP	RP	SNa	RNa	SMg	RMg	SMn	RMn	SCu	RCu	SFe	RFe
Ab1	Aegilops biuncialis	$4 \times$	-20	20	-28	31	45	50	-20	$^{-4}$	-5	-21	-167	2	-57	55
Ab2	Aegilops biuncialis	4 imes	-13	-37	4	100	58	58	-12	-95	$^{-1}$	-104	-124	-123	-81	-152
Ab3	Aegilops biuncialis	4 imes	-39	26	-17	48	27	78	-32	32	-24	33	-192	36	-104	60
Ac1	Aegilops columnaris	$4 \times$	-42	-251	-78	-300	53	-212	-49	-395	-103	-65	-80	-173	-71	-211
Ac2	Aegilops columnaris	4 imes	-11	-287	$^{-2}$	-313	4	-27	-7	-404	-55	-393	-78	-492	-115	-456
Ac3	Aegilops columnaris	4 imes	-29	-10	-62	-303	22	-204	-23	-76	-25	-156	-229	10	-79	-98
Ac4	Aegilops columnaris	4 imes	38	-17	50	-102	58	58	26	-100	40	-131	-68	-92	11	-97
Ac5	Aegilops columnaris	$4 \times$	-57	-74	-80	-195	30	-71	-49	-188	-75	7	-11	-37	-148	-210
As1	Aegilops speltoides	$2 \times$	5	-29	-30	-242	60	-158	0	-183	-48	-300	23	32	-26	-14
As2	Aegilops speltoides	$2 \times$	-69	-131	-170	-457	-47	-236	-117	-210	-213	-241	-52	-89	-211	-177
Al1	Aegilops ligustica	$2 \times$	-19	56	1	-17	41	13	-5	-25	-35	9	-19	44	19	27
Al2	Aegilops ligustica	$2 \times$	-45	-5	-120	-227	20	-130	-91	-156	-107	-152	-21	-116	-72	-156
At1	Aegilops triuncialis	$4 \times$	6	60	-55	16	50	48	-33	42	-37	41	30	38	-135	7
At2	Aegilops triuncialis	$4 \times$	26	37	24	1	61	53	8	17	-9	29	31	-18	-83	-31
At3	Aegilops triuncialis	$4 \times$	-145	-11	-181	-115	37	-19	-146	-54	-350	-165	-108	-44	-193	-9760
At4	Aegilops triuncialis	$4 \times$	-71	-72	-94	-137	26	-19	-50	-44	-81	-11	-62	-31	-83	-218
Au1	Aegilops umbellulata	$2 \times$	-30	-27	$^{-3}$	-27	48	31	-10	-54	-17	-9	-40	9	-51	-75
Au2	Aegilops umbellulata	$2 \times$	24	-87	35	-71	76	8	20	-109	-12	-10	37	-131	33	-186
Au3	Aegilops umbellulata	$2 \times$	18	19	-5	-100	71	37	11	-45	-4	52	29	23	-44	-35
Bolal	Triticum aestivum	6×	38	-36	-1	-76	51	-9	24	-91	5	25	16	-39	-6	21

In root Ca (RCa) accumulation, the percentage change in 10 mM B treatment ranged from –287% to 60%. A maximum reduction (287%) was observed in Ac2 followed by Ac1 (251%). However, the Aegilops accessions, At1 (60%) and Al1 (56%), revealed the highest increases in RCa content in highly toxic B treatment in comparison to Control.

3.2. Phosphorus (P)

The percentage change in shoot P (SP) accumulation in 10 mM B treatment ranged from -181% to 50% in comparison to Control. While At3 and As2 showed 181% and 170% decrement in the SP content in 10 mM B treatment, respectively, Ac4 and Au2 showed the maximum upsurge of 50% and 35%, respectively, in SP content in comparison to Control (Table 1).

In root P (RP) accumulation, the percentage change in 10 mM B treatment ranged from -457% to 100%. A maximum reduction (457%) was observed in As2 followed by Ac2

(313%). However, the Aegilops accession, Ab2 (100%) and Ab3 (48%), revealed the highest increases in RP content in highly toxic B treatment in comparison to Control.

3.3. Sodium (Na)

The percentage change in shoot Na (SNa) accumulation in 10 mM B treatment ranged from -47% to 76% in comparison to Control. While As2 showed a 47% decrement in the SNa content in 10 mM B treatment, Au2 and Au3 showed the maximum upsurge of 76% and 71%, respectively, in SNa content in comparison to Control (Table 1).

In root Na (RNa) accumulation, the percentage change in 10 mM B treatment ranged from -236% to 78%. A maximum reduction (236%) was observed in As2 followed by Ac1 (212%). However, the Aegilops accession, Ab3 (78%) and Ac4 (58%), revealed the highest increases in RNa content in highly toxic B treatment in comparison to Control.

3.4. Magnesium (Mg)

The percentage change in shoot Mg (SMg) accumulation in 10 mM B treatment ranged from -146% to 26% in comparison to Control. While At3 and As2 showed 146% and 117% decrement, respectively, in the SMg content in 10 mM B treatment, Ac4 and Bolal 2973 showed the maximum upsurge of 26% and 24%, respectively, in SMg content in comparison to Control (Table 1).

In root Mg (RMg) accumulation, the percentage change in 10 mM B treatment ranged from –404% to 42%. A maximum reduction (404%) was observed in Ac2 followed by Ac1 (395%). However, the Aegilops accession, At1 (42%) and Ab3 (32%), revealed the highest increases in SMg content in highly toxic B treatment in comparison to Control.

3.5. Manganese (Mn)

The percentage change in shoot Mn (SMn) accumulation in 10 mM B treatment ranged from -350% to 40% in comparison to Control. While At3 and As2 showed 350% and 213% decrement in the SMn content in 10 mM B treatment, respectively, Ac4 and Bolal 2973 showed the maximum upsurge of 40% and 5%, respectively, in SMn content in comparison to Control (Table 1).

In root Mn (RMn) accumulation, the percentage change in 10 mM B treatment ranged from -393% to 52%. A maximum reduction (393%) was observed in Ac2 followed by As1 (300%). However, the Aegilops accession, Au3 (52%) and At1 (41%), revealed the highest increases in RMn content in highly toxic B treatment in comparison to Control.

3.6. Copper (Cu)

The percentage change in shoot Cu (SCu) accumulation in 10 mM B treatment ranged from -229% to 37% in comparison to Control. While Ac3 and Ab3 showed 229% and 192% decrement in the SCu content in 10 mM B treatment, respectively, Au2 and At2 showed the maximum upsurge of 37% and 31%, respectively, in SCu content in comparison to Control (Table 1).

In root Cu (RCu) accumulation, the percentage change in 10 mM B treatment ranged from –492% to 44%. A maximum reduction (492%) was observed in Ac2 followed by Ac1 (173%). However, the Aegilops accession, Al1 (44%) and At1 (38%), revealed the highest increases in RCu content in highly toxic B treatment in comparison to Control.

4. Discussion

A large variability was observed in the root-shoot nutrient content of the studied Aegilops genotypes under B toxic stress condition. The two Aegilops genotypes, Ab2 and Ac4, that were found to be tolerant in our previous study [3] did not show maximum decrement in the uptake and translocation of any of the studied nutrients. In fact, among the two genotypes, Ac4 showed maximum concentration of several nutrients in shoots, including Ca, P, Mg, and Mn. However, no clear association has been found between the tolerance level of the genotypes and uptake or accumulation of any specific nutrient.

The large folds of increment and decrement in the nutrient uptake of different genotypes showed the greater influence of high B stress on the ion equilibrium of plants. The results were in accordance with the results of several previous studies where abiotic stress is known to be affecting nutrient content in roots and shoots [7,8].

5. Conclusions

From the results obtained, it can be concluded that B tolerance of Aegilops genotypes was not found to be associated with the enhanced or decreased accumulation of any specific nutrients in root and shoot samples. Moreover, B toxicity changes the ion balance of plants by influencing the elements uptake from the nutrient media.

Author Contributions: M.K.K. and A.P. conceived, wrote, and edited the manuscript. M.K.K., A.P., M.H., M.O. and M.R.O. performed the experiment and analysis. M.K.K. organized Figure 1, which shows the original photographs of spikes of all the studied Aegilops accessions. F.G., A.T. and S.G. made an intellectual contribution to the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: The authors acknowledge the TUBITAK 1001 (No. 119O455) project for the funding provided to conduct this research work.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The authors acknowledge TSGB, Ankara, and AARI National Gene Bank, Izmir, Turkey, for providing the Aegilops accessions used in this study.

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

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