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Response of Cape Gooseberry (*Physalis peruviana* L.) Plant at Early Growth Stage to Mutual Effects of Boron and Potassium

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Abstract: As regards the interaction between boron (B) and potassium (K), there is a limited knowledge, and the nature of this complex interaction is still clearly unknown. The main objective of the present study was to assess the mutual effects of B and K on plant growth, membrane permeability and mineral nutrition of Cape gooseberry (*Physalis peruviana* L.) in greenhouse natural light conditions. For this purpose, four levels of B (0, 5, 10, and 20 mg kg^{-1}) and three levels of K (0, 200, and 400 mg kg^{-1}) were treated to soil. However, whether K supply to the soil or not, plants withered within a few days at the highest B level caused by B toxicity. Supplied K to the soil had a significant positive effect on plant growth, indicating that K addition partially alleviated the reduction of shoot dry weight caused by B toxicity. Moreover, inhibitory effect of K on excess B appeared in shoot more than in roots. B and K applications increased significantly B and K contents in shoot of Cape gooseberry plants as well as B uptake. Also, the contents of K, phosphorus (P), iron (Fe), sodium (Na), and B in shoot of Cape gooseberry increased with supplied B in the absence of K, but calcium (Ca) and magnesium (Mg) contents decreased. The contents of P, Ca, and Mg decreased with supplied K in the absence of B, but Na content enhanced. It was concluded that there might be an accumulative effect due to plant growth reduction caused by B toxicity in Cape gooseberry plant and also synergism related to plant absorption of B and K.

Keywords: Boron toxicity, potassium, *Physalis peruviana* L., growth, membrane permeability, mineral nutrition

Bor ve Potasyumun Karşılıklı Etkilerine Altınçilek (*Physalis Peruviana* L.) Bitkisinin Erken Gelişme Dönemindeki Tepkisi

Öz: Bor (B) ve potasyumun (K) arasındaki etkileşim hakkındaki bilgilerimiz sınırlıdır ve bu karmaşık etkileşiminin doğası hala açıkça bilinmemektedir. Bu çalışmanın amacı, altınçilek (*Physalis peruviana* L.) bitkisinin gelişimi, membran geçirgenliği ve mineral beslenmesi üzerine B ve K'un karşılıklı etkilerini doğal ışık altında ve sera koşullarında araştırmaktır. Bu amaçla toprağa, dört düzeyde bor (0, 5, 10 ve 20 mg kg^{-1}) ve üç düzeyde potasyum (0, 200 ve 400 mg kg^{-1}) uygulanmıştır. Ancak, toprağa K uygulansın ya da uygulanmasın en yüksek B düzeyinde bitkiler birkaç gün içinde ölmüştür. Uygulanan K bitki gelişimi üzerine olumlu etki göstermiş ve B toksisitesinin neden olduğu gövde kuru ağırlık azalması K uygulaması tarafından kısmen hafifletilmiştir. B ve K uygulamaları altın çileğin gövdesindeki B ve K içeriği yanında B alımını da önemli miktarda artırmıştır. Bununla birlikte, toprakta aşırı B'a karşı K'un önleyici etkisinin kökten daha çok bitki gövdesinde olduğu görülmüştür. Potasyum uygulanmadığında, altın çileğin gövdesindeki K, fosfor (P,) demir (Fe), sodyum (Na) ve B içerikleri uygulanan B ile artmış, kalsiyum (Ca) ve magnezyum (Mg) içerikleri ise azalmıştır. Bor uygulanmadığında, P, Ca ve Mg içerikleri uygulanan K ile azalmış ancak Na içeriği ise artmıştır. Altınçilek bitkisinin gelişiminde meydan gelen azalma B toksisitesinin neden olduğu akümülasyon etkisinden olabileceği ve ayrıca bitkinin B ve K absorbsiyonu ile ilgili olarak ise sinerjistik bir ilişkinin olabileceği sonucuna varılmıştır.

Anahtar Kelimeler: Bor toksisitesi, potasyum, *Physalis peruviana* L., gelişme, membran geçirgenliği, mineral beslenme

1. Introduction

Boron influences metabolic events and cellular functions in the development and growth of plants as an essential micronutrient which the range of insufficient and toxic levels is narrow (El-Hamdaoui et al. 2003). Hence, excess B caused by reducing crop productivity of many plants is the most widespread nutritional problem in agricultural areas where with high pH in arid and semi-arid regions. Main sources of excess B concentrations in arable lands is irrigation with B-laden waters, wastes from surface mining, fly ash, soil formed on marine sediment (Nable et al. 1997), and poor drainage, especially in saline soils (Grieve and Poss 2000). Toxic levels of B in plants cause degradation of membrane integrity and structure, increases in membrane permeability (Karabal et al. 2003), and negative effects in many enzyme activity (Shkolnik 1974). Boron toxicity symptoms occur as dark brown spots and necrotic lesions in the form of chlorotic tips and borders on the oldest leaves and it cause reducing in plant vigour and development (Nable et al. 1997). It has been known that either toxic or insufficient B level varies from species to species and based on genetic variation (Blevins and Lukaszewski 1998). However, the mechanism of toxicity is still not clearly understood why B is toxic to plants or how tolerant plants avoid toxicity (Reid et al. 2004).

Potassium as an essential macronutrient is the most plentiful inorganic cation in plants and plant tissue concentrations of K can vary within a wide range. The roots mainly absorbed the form of K^+ ion and K exists as a free or absorptive bound cation in plants that it can be displaced quite easily (Mengel and Kirkby 2001). Although K does not form components in the plant system as a major inorganic osmolyte, it has vital role in many physiological processes (Marschner 2012). It plays a key role in photosynthesis, protein synthesis, and oxidative metabolism as an activator of numerous enzymes, and serves as one of the most components in translocation of photosynthates into sink organs, maintenance of turgescence, and transport of water and nutrients in plant system. K also provides electrical charge balance during vectorial ion transfer across cellular membranes and influences phloem transport. In addition, K^+ reduce excess uptake of ions such as Na and Fe in saline and flooded soils (Marschner 2012).

The roles of K and B overlap in the maintenance of conducting tissues and both of these serve in acting as a buffer (Mengel and Kirkby 2001). In addition, alkaline cations (K, Ca, Mg and Na) were affected B (Mozafar 1989), and the interaction of B with alkaline cations, especially Ca and Na, has been investigated in numerous studies by researchers. As regards the mutual effects of B and K, however, there is limited knowledge and the nature of this complex interaction is still clearly unknown. Although an optimal level of B increases K permeability in the cell membrane (Schon et al. 1990), the relationship between K and excess B investigated in a few studies. It was reported that excess B treatment increased B and K contents in some plant including radish (Tariq and Mott 2006a, 2006b), maize and sorghum (Ismail 2003). Besides, Cikili et al. (2013) in cucumber and Samet et al. (2013, 2015) in bean and pepper notified that the shoot and root growth were strongly depressed by excess B, but K supply decreased partially the inhibitory effect of B toxicity.

Cape gooseberry (*Physalis peruviana* L.) belongs to the family of *Solanaceae*, which is a vegetable of annuals and perennials and are grown for their fruits and for decoration. Cape gooseberry which is known as ground-cherry or Cape gooseberry is a new vegetable crop for Turkey agriculture. It has significant as an alternative for vegetable crop diversification in Turkey. Therefore, the main objective of the present study was to assess the mutual effects of boron and potassium on growth, membrane permeability and mineral nutrition of Cape gooseberry plants at early growth stage.

2. Material and Methods

The seeds of Cape gooseberry (*Physalis peruviana* L., Colombian ecotype) plants were obtained from Ege University, Menemen Research, Application and Production Farm. Cape gooseberry plants were used for a pot culture experiment which was carried out in a greenhouse under natural light conditions. The seeds were germinated in a seedling viol filled with peat. Three week-old seedlings were transplanted at a rate of one plant per pot filled with 2 kg of air-dried soil.

Some characteristics of the soil used in the experiment were as follows: texture loam (sand:clay; 35.8:21.7, by dry weight), lime ($CaCO_3$) 17.29 g kg^{-1}, organic carbon 6.25 g kg^{-1} (Walkley-Black), pH (1:2.5 soil/water) 7.34, saturation extract of 0.51 dS m^{-1} electrical conductivity (EC), and total nitrogen (Kjeldahl) 0.86 g kg^{-1}. The concentrations of ammonium acetate (CH_3COONH_4)-extractable K, Ca, Mg, and Na were as follows (mg kg^{-1}): 100, 2151, 124, and 64. The concentration of sodium bicarbonate ($NaHCO_3$)-available P was 12.43 mg kg^{-1} and hot water extractable-B was 1.64 mg kg^{-1}. Diethylene triamine pentaacetic acid (DTPA)-extractable Fe, manganese (Mn), zinc (Zn) and copper (Cu) were as follows (mg kg^{-1}): 24.28, 65.27, 2.09 and 1.17. The soil characteristics were determined according to methods detailed in Page et al. (1982).

Three levels of K (0, 200, and 400 mg kg^{-1}) as K_2SO_4 and four levels of B (0, 5, 10, and 20 mg kg^{-1}) as H_3BO_3 were applied in soil and replicated three times in a completely randomized factorial design. A basal dose of nitrogen (N) and P were added at 150 and 75 mg kg^{-1} as ammonium nitrate (NH_4NO_3) and ammonium dihydrogen phosphate ($NH_4H_2PO_4$), respectively. All the supplementary were included in soil by spraying the solutions and mixed thoroughly with soil before transplantation of seedlings. The pots were watered daily to 70% of water holding capacity with tap water.

Plants were harvested properly at six weeks after transplantation and separated into shoots and roots for fresh and dry matter production. Fresh weight of the shoots was measured and washed with running tap water and then rinsed with de-ionized water three times. Similarly, the roots carefully taken out cleaned and washed. All shoots and roots were dried at 70 °C and dry weights (DW) were quickly measured. The shoots samples were grinded to powder for nutrient ions analysis. The samples were digested by using dry-ash method for extractions. These nutrient ions were determined by ICP-OES (Perkin-Elmer Optima 2100 DV; Waltham, MA). The total uptakes in the shoots were calculated using the following formulation:

$$Total\ K\ or\ B\ uptake = DW_{shoot} \times [K\ or\ B]_{shoot}$$

Membrane permeability (MP) measurements with fresh matter were done before harvest. Membrane permeability (EC%) for the shoot disc samples was measured by the electrical conductivity method as described by Yan et al. (1996).

Plants withered within a few days at the level of 20 mg B kg^{-1}, and for this reason assessments and statistical tests were made for three levels of B and K. The experimental design was a completely randomized factorial design with three replicates and obtained data were analyzed by ANOVA. The levels of significance are represented by * at $p<0.05$, ** at $p<0.01$, and *ns:* non-significant. The significant differences among the treatment means were compared Duncan's multiple-range test at α: 0.05. The statistical tests were performed by using MINITAB package program (Minitab Corp., State College, PA).

3. Results and Discussion

3.1. Plant growth and biomass

The combined effect of B and K on dry weight (DW) of shoots and roots of Cape gooseberry plant were shown in Table 1. The shoot and root DW were dramatically decreased with increasing of B. When K untreated to the soil, reduction of shoot DW for 5 and 10 mg kg^{-1} B supply to the soil were 25.7% and 58.2%, respectively. However, supplied K to the soil had a significant positive effect on the shoot growth, indicating that K addition improved the reduction of shoot DW caused by the toxic effect of B. For example, when 200 and 400 mg kg^{-1} K supply to the soil at the highest level of B, increments of the shoot DW according to the control were found 20.7% and 56.3%, respectively (Table 1). Similarly, supplied K enhanced root growth of B-treated Cape gooseberry plants, but this increase was not statistically significant. Eventually, potassium that plays the vital roles in many physiological processes might partially attenuate the detrimental effect of B on the growth. The reduction of plant growth due to inhibitory effect of B toxicity was well reported for pepper (Samet et al. 2015, Yermiyahu et al. 2008), tomato (Gunes et al. 1999), cucumber (Cikili et al. 2013), and bean (Gunes et al. 2009) plants. Potassium amelioration on shoot and root growth of plants under B-toxic conditions was also documented previously for bean and pepper (Samet et al. 2013, 2015), and cucumber (Cikili et al. 2013).

Table 1. The mutual effects of boron and potassium on dry weights of shoot and root, and membrane permeability in shoot of Cape gooseberry plants

Treatment		*Shoot DW*		*Root DW*		*MP*
Potassium	*Boron*	*(g pot^{-1})*	*Change, %*	*(g pot^{-1})*	*Change, %*	*(EC %)*
0	0	4.16 a	100.0	1.40	100.0	34.1 abc
	5	3.09 bc	74.3	0.96	68.6	38.7 ab
	10	1.74 d	41.8	0.45	32.1	42.4 a
200	0	4.15 a	100.0	1.16	100.0	37.9 ab
	5	3.83 a	92.3	1.14	98.3	30.8 bc
	10	2.10 d	50.6	0.51	44.0	24.5 c
400	0	3.56 ab	100.0	1.40	100.0	41.8 ab
	5	3.01 bc	84.6	1.18	84.3	37.4 ab
	10	2.72 c	76.4	0.55	39.3	30.7 bc
F-test significance		**		ns		*
0		3.00	100.0	0.94	100.0	38.4 a
200		3.36	112.0	0.93	98.9	31.1 b
400		3.10	103.3	1.04	110.6	36.6 ab
F-test significance		ns		ns		*
	0	3.96 a	100.0	1.32 a	100.0	37.9
	5	3.31 b	83.6	1.09 b	82.6	35.6
	10	2.19 c	55.3	0.50 c	37.8	32.5
F-test significance		**		**		ns

Means in columns followed by different letters, where available according to F-test significance, are significantly different according to the Duncan's multiple range test at $p < 0.05$.

3.2. Membrane permeability

The combined effect of B and K were significant on membrane permeability (MP) of excised leaves of Cape gooseberry plant (Table 1). Membrane permeability was increased by B toxicity, but K supply remarkable recovered MP. Excess B in soil resulted in increases in membrane permeability of leaves Cape gooseberry plants. For example, in untreated-K conditions, MP increased by 13.5% and 24.3% for increasing levels of B in comparison with the control, respectively. However, with the application of 200 mg kg^{-1} of K, the MP declined by 18.7% and 35.4% for these B levels, respectively. This effect of K on the MP decrease might be derived from a guarding effect in the absorption and translocation of B and/or a protective role of membrane damage in oxidative metabolism. Sotiropoulos et al. (2002) suggested that B toxicity caused volume increment of inter-cellular spaces, volume reduction of mesophyll cells, and cell damage in kiwifruit. Moreover, excess B-mediated membrane damage was also previously reported for tomato (Eraslan et al. 2007, Gunes et al. 1999) and barley (Karabal et al. 2003).

3.3. Boron toxicity symptoms

The initial symptoms of B toxicity appeared as dark brown spots and necrotic lesions in the form of tip chlorotic border of oldest leaves in 5 mg kg^{-1} B level in K-untreated plant. In 10 mg kg^{-1} B level, it intensified severity of leaf injury induced by B toxicity. After transplanting three week-old Cape gooseberry seedlings to the pots, plants withered within a few days at the level of 20 mg B kg^{-1}, whether K supply or not. However, it was seen that the severity of leaf symptoms of B toxicity was less noticeable in the B-treated plants, when supplied of 200 mg kg^{-1} K in the soil. Similar observations relating to B toxicity were reported in the previous studies for some plants, such as bean (Gunes et al. 2009), tomato (Gunes et al. 1999), lemon (Rajaie et al. 2009) and apple in limed and acidic soils (Paparnakis et al. 2013).

3.4. Contents and uptakes of B and K

The mutual effects of K and B applications on the K and B contents in shoot of Cape gooseberry plants and their uptakes were shown on Table 2. Both of B and K supply increased significantly the shoot B content of Cape gooseberry plants from 53.1 to 328.3 µg g^{-1} dry weight (Table 2). High B accumulation in plant shoot caused by excess B was also reported previously for pepper (Yermiyahu et al. 2008), tomato and pepper (Eraslan et al. 2007), wheat (Turan et al. 2009) and barley (Karabal et al. 2003). Moreover, these results agreed with our previous findings in pepper (Samet et al. 2015), and in cucumber (Cikili et al. 2013).

The B uptakes in shoot remarkable enhanced depending on both of B and K supply to soil and ranged from 0.192 to 0.888 mg plant^{-1} dry weight (Table 2). However, in untreated-B conditions, the B uptakes in shoot were observed insignificant reduction with increasing of K supply. As reported by Carr et al. (2011), there was a liner relation between B application and uptake. Also, Tariq and Mott (2006a) in radish, and Kaur et al. (2006) in B-sensitive genotypes of *Brassica rapa* revealed that the shoot B uptake and the B concentration enhanced with increasing of B levels. The shoot K contents significantly accrued with increasing both of B and K supply to soil and varied from 37.32 to 87.04 mg g^{-1} dry weight (Table 2).

Table 2. The changes in contents and uptakes of B and K in shoot of Cape gooseberry plants as affected by supply of boron and potassium

Treatment		*B content*	*B uptake*	*K content*	*K uptake*
Potassium	*Boron*	*(µg g^{-1})*	*(mg plant^{-1})*	*(mg g^{-1})*	*(mg plant^{-1})*
0	0	60.1 g	0.250 c	37.32 e	155.2
	5	170.2 e	0.529 b	44.00 e	135.7
	10	287.7 c	0.501 b	55.08 d	95.9
200	0	53.1 g	0.221 c	69.92 c	290.3
	5	153.8 f	0.590 b	71.21 c	272.5
	10	307.4 b	0.647 b	81.48 b	171.4
400	0	53.9 g	0.192 c	77.76 b	276.9
	5	211.4 d	0.635 b	87.04 a	261.1
	10	328.3 a	0.888 a	79.61 b	217.7
F-test significance		**	**	**	ns
0		172.7 b	0.426 b	45.47 b	128.9 b
200		171.4 b	0.486 b	74.21 a	244.7 a
400		197.9 a	0.572 a	73.47 a	251.9 a
F-test significance		**	**	**	**
	0	55.7 c	0.221 c	61.67 b	240.8 a
	5	178.5 b	0.584 b	67.43 a	223.7 a
	10	307.8 a	0.679 a	72.06 a	161.7 b
F-test significance		**	**	**	**

Means in columns followed by different letters, where available according to F-test significance, are significantly different according to the Duncan's multiple range test at p < 0.05.

It might be expounded the increases in shoot K content of Cape gooseberry plants as increasing nutrient absorption caused by the deleterious effect of excess B on membrane damage. Similar results noticed for bean (Samet et al. 2013) and cucumber (Cikili et al. 2013). Besides, the increases in K contents with excess B treatments were reported in some plants including tomato (Eraslan et al. 2007) maize and sorghum (Ismail 2003) and radish (Tariq and Mott 2006a). Also, B and K concentration in apple leaves showed a positive correlation with added B in limed and acidic soils reported by Paparnakis et al. (2013).

An interaction of B and K was no significant effect on shoot K uptake of Cape gooseberry plants (Table 2). While, in comparison with the control, an increment of K uptake was found expectedly with increasing of K levels, the reduction of K uptake in shoot was observed by B treatments. Irrespective of K application, however, the shoot K uptake was significantly decreased from 240.8 to 161.7 mg plant^{-1} by increasing of B to soil. Tanaka (1967) reported that the K uptake and content of radish seedlings enhanced increasing of K levels in growth medium, but decreased the B uptake and content.

3.5. Mineral constituents of plant

Whether K supply or not, the shoot N content was increased linearly with supplied B levels and range from 44.33 to 58.40 mg g^{-1} dry weight (Table 3). But, an interaction of B and K was no significant effect on shoot N content. Regardless of K application, the N content in shoot notably increased with increasing of B levels. As reported by Lopez-Lefebre et al. (2002), there was a positive effect of B on N uptake and metabolism. It was notified an increment of the N content with excess B level for pepper and tomato (Eraslan et al. 2007), and bunch onion (Inal and Tarakcioglu 2001). Otherwise, excess B had no significant effect on the N concentration in kiwifruit as explained by Sotiropoulos et al. (2002). Irrespective of B treatments, the shoot N content remarkably decreased with 400 mg kg^{-1} K supply to the soil.Çelik et al. (2010) reported that increasing of K levels decreased the N concentrations in both leaves and roots of maize.

The shoot P content range from 1.88 to 3.63 mg g^{-1} dry weight, and it considerably increased with supplied B, but significantly diminished with supplied K (Table 3). This is in agreement with the results of Samet et al. (2013) in bean, and Lopez-Lefebre et al. (2002) explained that P uptake in tobacco was encouraged by B application. Moreover, Patel and Golakiya (1986) reported that it might be a positive effect of B on P uptake of groundnut due to the effect of B on plasmalemma permeability and thus increasing P absorption. Also, the addition of increasing levels of K decreased the P, Mg, and Ca concentrations in both leaves and roots of maize reported by Çelik et al. (2010).

Applied B, in the absence of K, was significantly decreased the Ca content in shoot from 10.93 to 8.75 mg g^{-1} dry weight (Table 3). In the presence of K, however, insignificant enhancements in the shoot Ca content were found with applied B, and varied from 7.55 to 8.84 mg g^{-1} dry weight. It is well known that toxic effects of B may be alleviated or reduced by supplied Ca in growth medium. For example, Turan et al. (2009) notified that Ca concentrations in shoot, root and cell wall of wheat plant decreased with increasing of B applications. Also, Eraslan et al. (2007) for tomato, and Lopez-Lefebre et al. (2002) for tobacco declared similar findings. In untreated-B conditions, the shoot Ca content was significantly decreased by K applications. Mengel and Kirkby (2001) elucidated that K, Ca, and Mg compete with each other in the growth media and the addition of any one of them will reduce the uptake rate of the other two. In addition to this, in the presence of B, the reductions in the shoot Ca content was insignificant with applied K. Furthermore, increasing of K in growth medium was decreased the Ca uptake and content of radish seedlings reported by Tanaka (1967).

The changes in the shoot Mg content of Cape gooseberry plants have been similar in the shoot Ca content, and the shoot Mg content varied from 3.08 to 6.30 mg g^{-1} dry weight (Table 3). The Mg content in shoot significantly decreased in both supplied B and K. Similar findings were notified for pepper (Samet et al. 2015), cucumber (Cikili et al. 2013) with B and K applications, and for tobacco with B treatments (Lopez-Lefebre et al. 2002). In addition, a strong antagonism between K and Mg and also Ca reported with excess K applications (Marschner 2012, Garcia et al. 1999). In untreated-K conditions, the significant reduction in the shoot Mg content observed with increasing of B levels whereas the Mg content in shoot was enhanced with applied B in the presence of K. This might be derived from as a result the antagonistic effect of between B and Mg. Both of excess B and also increasing added K to the soil had no significant effect on Mg accumulation in bean reported by Samet et al. (2013). Çolpan et al. (2013) reported that total P, Ca, and Mg contents of the tomato leaf enhanced increasing of K doses.

Table 3. The changes in contents of N, P, Ca, and Mg in the shoot of Cape gooseberry plants as affected by supply of boron and potassium

Treatment		*N*	*P*	*Ca*	*Mg*
Potassium	*Boron*	*(mg g^{-1})*	*(mg g^{-1})*	*(mg g^{-1})*	*(mg g^{-1})*
0	0	48.39	2.44 de	10.93 a	6.30 a
	5	51.48	2.49 de	8.75 bc	5.88 a
	10	58.40	3.63 a	9.94 ab	5.26 b
200	0	48.31	1.99 fg	8.30 c	3.42 cd
	5	53.13	2.77 cd	7.55 c	3.73 c
	10	56.51	3.25 b	8.84 bc	3.93 c
400	0	44.33	1.88 g	7.59 c	3.08 d
	5	46.12	2.31 ef	8.58 bc	3.71 c
	10	54.92	3.06 bc	8.75 bc	3.86 c
F-test significance		ns	*	*	**
0		52.76 a	2.85 a	9.88 a	5.81 a
200		52.65 a	2.67 a	8.23 b	3.69 b
400		48.45 b	2.41 b	8.31 b	3.55 b
F-test significance		**	**	**	**
	0	47.01 c	2.11 c	8.94 ab	4.27
	5	50.25 b	2.52 b	8.29 b	4.44
	10	56.61 a	3.31 a	9.18 a	4.35
F-test significance		**	*	**	ns

Means in columns followed by different letters, where available according to F-test significance, are significantly different according to the Duncan's multiple range test at $p < 0.05$.

The shoot Fe content that ranged from 103.9 to 332.7 µg g^{-1} dry weight enhanced significantly with increasing of supplied B in all K levels (Table 4). This might be an accumulation effect caused by reduction of plant growth resulting from excess B. Similar results was declared in agreement with the findings in bean and pepper (Samet et al. 2013, 2015), cucumber (Cikili et al. 2013), lemon seedlings (Rajaie et al. 2009), tobacco (Lopez-Lefebre et al. 2002) and kiwifruit (Sotiropoulos et al. 1999). Also, at K treatments with B together, the changes in the Fe content showed an indecisive trend. The Fe content decreased with increasing of supplied K at the level of 5 mg B kg^{-1}, but enhanced at the level of 10 mg B kg^{-1}. Marschner (2012) reported that K^+ reduce excess uptake of ions as an example of Fe in flooded and saline soils. Moreover, Çelik et al. (2010) suggested that increasing of K decreased the Fe concentrations in both leaves and roots of maize.

The interaction effect of B and K were insignificant on the Mn and Cu contents in shoot of Cape gooseberry that Mn and Cu contents in shoot varied from 55.1 to 100.3 µg g^{-1} dry weight and from 11.5 to 20.2 µg g^{-1} dry weight, respectively (Table 4). The shoot Mn and Cu contents, however, tended to increase with supplied B while it tended to decline with supplied K. Irrespective to K supply, the Mn and Cu contents in shoot significantly enhanced with increasing of supplied B. Lopez-Lefebre et al. (2002) revealed that Mn concentration increased and Cu concentration decreased in tobacco leaves with B application. Contrarily, Mn concentration in radish was decreased by toxic levels of B supply notified by Tariq and Mott (2006a). Regardless of B application, the Mn and Cu contents in shoot notably decreased with increasing of K application. These might be resulting from an antagonistic relationship between K and other cations. Potassium interacts with almost all of the secondary nutrient and the micro nutrient suggested by Pervez et al. (2006). It was also reported reducing in the Mn content for cucumber (Cikili et al. 2013), and increment in Cu content for cucumber (Cikili et al. 2013), bean and pepper (Samet et al. 2013, 2015) with in both increasing K and B supply.

The Zn content in shoot of Cape gooseberry were notably influenced by supplied B whereas the effect of supplied K were not significant on the shoot Zn content as well as the interaction effect of B and K supply (Table 4). The Zn content in shoot of Cape gooseberry plants ranged from 38.3 to 55.2 µg g^{-1} dry weights in both supplied B and K. Regardless of supplied K, the Zn content in shoot was substantially increased by B treatments. It was declared in previous studies an increment of the Zn content with supplied B in some plants including lemon seedling (Rajaie et al. 2009), tomato (Gunes et al. 1999), and kiwifruit (Sotiropoulos et al. 1999). Other than this, it was observed an indefinite tendency in the shoot Zn content with K treatments. Similar findings were explained in pepper (Samet et al. 2015) and cucumber (Cikili et al. 2013) with both supplied B and K.

Table 4. The changes in content of some micro nutrient elements in the shoot of Cape gooseberry plants as affected by supply of boron and potassium

Treatment		*Fe*	*Mn*	*Zn*	*Cu*	*Na*
Potassium	*Boron*	*(µg g^{-1})*	*(µg g^{-1})*	*(µg g^{-1})*	*(µg g^{-1})*	*(µg g^{-1})*
0	0	103.9 e	73.1	38.3	14.2	173 c
	5	199.5 c	72.5	43.5	16.2	200 bc
	10	261.1 b	99.8	52.7	20.2	267 ab
200	0	125.0 e	56.2	41.3	14.4	293 a
	5	176.3 cd	62.9	42.9	13.7	247 abc
	10	327.7 a	91.5	54.9	18.3	293 a
400	0	113.9 e	55.1	40.3	11.5	220 abc
	5	139.0 de	57.7	40.4	11.9	256 ab
	10	332.7 a	89.1	55.2	16.6	200 bc
F-test significance		**	ns	ns	ns	*
0		188.9	81.9 a	44.8	16.9 a	213 b
200		209.7	70.2 b	46.4	15.5 b	278 a
400		195.2	67.3 b	45.3	13.3 c	225 b
F-test significance		ns	**	ns	**	*
	0	114.3 c	61.5 b	40.0 b	13.4 b	229
	5	171.6 b	64.3 b	42.3 b	14.0 b	234
	10	307.2 a	93.6 a	54.2 a	18.4 a	253
F-test significance		**	**	**	**	ns

Means in columns followed by different letters, where available according to F-test significance, are significantly different according to the Duncan's multiple range test at $p < 0.05$.

The Na content in shoot of Cape gooseberry plants varied from 173.3 to 293.3 µg g^{-1} dry weight (Table 4), and the variations in shoot Na content did not follow a definite trend with only supplied K. Besides, it was found that the Na content in shoot considerably increased with only supplied B. Similar findings in our previous study was found for pepper (Samet et al. 2015), cucumber (Cikili et al. 2013), and El-Kholi (1961) observed that an antagonism was between Na and K with levels of excess B. This might be expounded as increasing of Na absorption by virtue of the deleterious effect of B on plasmalemma permeability. In addition, it was stated the increment in Na content with applied B in maize and sorghum (Ismail 2003) and barley (Singh and Singh 1984). On the contrary these results, the reductions in the Na content with B application notified by Tariq and Mott (2006b) in radish in nutrient solution.

4. Conclusion

The results of the present study indicated the importance of nutritional status of K in plant for increasing tolerance to B toxicity, and have shown that reduction of dry weight in shoot and root are good indicator for B toxicity. We have demonstrated that supplied K alleviated partially the deleterious effect of excess B on plant growth and membrane permeability as well as imbalance in mineral nutrition. Inhibitory effect of K on excess B was appeared in shoot more than in roots. We concluded that there might be an accumulative effect due to plant growth reduction caused by B toxicity in Cape gooseberry plant and also synergism related to plant absorption of B and K.

The contents of K, N, P, Fe, Na, and B in shoot of Cape gooseberry, in the absence of K, considerably increased with supplied B, but the contents of Ca and Mg decreased. Besides, the contents of P, Ca, and Mg significantly decreased in the absence of B with supplied K, but Na content enhanced. Eventually, K addition to the growing media can be beneficial in plant growth reduction and mineral imbalances sourced from B toxicity. Further investigations are needed to clarify the mutual effects of B and K on plant physiological and mineral metabolism, and characteristics depending on concentration and plant species.

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