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Effect of Boron Soil Application on Nutrients Efficiency in Tobacco Leaf

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Abstract

The present study was based on the general hypothesis that boron may affect the accumulation and utilization of other nutrients in plant. For this purpose a field experiment was carried out to find out the influence of boron on the different nutrients content in FCV tobacco (*Nicotiana tabacum* L.) at TRS Khan Garhi, Mardan, during 2010-2011. Two varieties TM-2008 and Speight G-28 were tested and six levels of boron (0, 0.5, 1, 2, 3 and 5 kg·ha^{-1}) were applied in the form of boric acid, in randomized complete block design in split plot arrangement and replicated thrice. Results indicated that the yield of tobacco crop increased with 1 kg·B·ha^{-1} and then decreased sequence wise in both varieties. N and P concentrations were significantly affected by applied boron. Similarly, potassium was increased which is a good indication for a better quality of tobacco crop. Application of boron significantly increased the concentrations of boron nutrients ratios such as K/B; Cl/B and Mn/Fe were decreased while K/Cl and Zn/Cu ratios were increased at lower boron concentrations but decreased at higher concentrations of boron. The fertilizer use efficiency of both the cultivars showed similar trend; however, Speight G-28 was more efficient than TM-2008 in boron accumulation. The overall results revealed that the application of boron should be encouraged for balancing nutrients concentration, thus getting higher yield in the prevailing conditions.

Keywords

Boron, Nutrients Efficiency, Nitrogen, Phosphurus, Tobacco

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1. Introduction

Boron (B) is required for all plant growth. Adequate B nutrition is critical for high yields and quality of crops. Deficiencies of B result in many anatomical, biochemical and physiological changes in plants. It is a widespread agricultural problem in the world, which results in yield and quality loss of many crop species including tobacco [1]-[5]. B deficiency affects vegetative and reproductive growth of plants, resulting in inhibition of cell expansion and death of meristem cells [6], and affects the utilization of other plant nutrients [7]. Boron cannot be redistributed rapidly within most species of plants; even a small interruption of nutrient supply from the soil may depress the growth and yield loss can occur. The amount of yield losses directly depends upon the duration of deficiency and the plant growth stage at which it occurs [8]. Mahler [9] found that the role of boron is in the transmission of sugar across the membranes, differentiation and development of cell and also in auxin metabolism. It has been known that an optimal boron level for one crop species could be either toxic or inadequate for other crop species [10]. It is well defined that the chemistry of boron in soil and its role in plants are different from other elements, but its deficiency or toxicity can affect the solubility and availability of elements in soil [11] [12] and total uptake in plants body [13]-[16].

Tobacco (*Nicotiana tabacum* L.) belongs to the family Solanaccae, which is grown all over the world for the manufacturing of cigarettes, cigars and bids; in addition tobacco is used for hoqqa, snuffs and chewing [17]. Farmers obtain higher net return from tobacco as compared to other cash crops. In Pakistan, especially in Khyber Pakhtunkhwa, tobacco is the major cash crop for the farmers. The chemical composition of tobacco leaf plays a key role in the evaluation of tobacco quality. The absolute and relative amount of these constituents not only depends on crop varieties and maturity, soil, climatic condition and curing process, but also depends on the responsive mineral nutrition of tobacco crop, such as boron [18] [19]. Boron is one of the major deficient micronutrients after zinc in Pakistan [20], and B not only affects the yield but also affects the marketing value of tobacco leaf. It is apparent from the previous literature that boron may affect other micronutrients in soil and also in the plants. However, literary information on the subject of the effect of boron on the concentration, uptake and transportation of plant nutrients is insufficient. The changes in mineral nutrients composition induced by boron were observed by various researchers in different crops such as maize [21], sunflower [14], wheat [22] and radish [15], and this could be demonstrated in different cultivars of tobacco. For this purpose an experiment was carried out to test a general hypothesis that boron may affect the accumulation and utilization of other nutrients in plants and also to find out the suitable level of boron for getting higher yield and better quality of tobacco crop.

2. Materials and Methods

2.1. Experimental Layout and Sampling

A field experiment was conducted to study the influence of boron on the nutrients content of FCV tobacco (*Nicotiana tabacum* L.) in PTB, Tobacco Research Station, Khan Garrhi Mardan—Pakistan, during 2010-2011. The varieties TM-2008 and Speight-G 28 were grown. The experiment was laid out in randomized complete block design in split plot arrangement, where main plots consisted of 2 varieties and sub plots consisted of 6 levels of boron and replicated thrice. Seeds of tobacco were sown in the 1st week of December, 2010 and then in the 2nd week of March, 2011, healthy seedling was transplanted to the treated plots. The plot size was $6 \times 2.7\ m^2$, with 90 cm row to row distance and 60 cm plant to plant distance. The boron was applied at varying rates of 0, 0.5, 1, 2.0, 3.0 and 5.0 $kg \cdot ha^{-1}$ in the form of boric acid. A basal dose of N, P_2O_5 and K_2O at the rate of 70 $kg \cdot ha^{-1}$ each was applied in the form of compound fertilizer with 15:15:15. All fertilizers were applied at the time of transplantation. The tobacco plants were topped at 22nd leaf stage. A composite soil sample from 20 cm depth was collected before the conductance of experiment and analyzed for various physico-chemical properties of the soil by standard routine methods. Collection of representative leaf samples from each treatment plot was done after curing and then analyzed for the required qualitative and quantitative parameters. All the recommended and routine agronomic practices were carried out during growing season.

2.2. Plant Analysis

Representatives plant cured leaf samples were dried, ground by using Willy mill and ashed in a muffle furnace [23]. Boron concentration in the digest was determined by spectrophotometer using Azomathine-H method [24], while K by using flame photo meter and Zn, Cu, Fe, and Mn by atomic absorption spectrophotometer. Nitrogen was determined by [25].

2.3. Statistical Analysis

The collected data during the investigations of field and laboratory analysis was analyzed statistically, using ANOVA technique and the means comparison was done by LSD test of significance [26].

3. Results and Discussion

The physico-chemical properties of soil are presented in **Table 1**. The test soil was almost neutral in reaction, silt loam in texture, slightly calcareous, non-saline, low in organic matter, deficient in AB-DTPA extractable K, Fe, Zn and adequate in soluble Cl, Cu, Mn and dilute HCl extractable boron [27] [28].

3.1. Nitrogen

That data showed that applied boron significantly ($P < 0.05$) affected the nitrogen concentration in tobacco leaves (**Table 2**). The data showed that as the applied boron increased, the N concentration also increased but

Table 1. Physico-chemical properties of the test soil.

Parameter	Units	Values
Sand	%	21.13
Silt	%	66.45
Clay	%	12.42
Textural class	-	Silt loam
Lime ($CaCO_3$)	%	11.5
Organic matter	%	0.40
pH (1:5)	-	7.20
EC (1:5)	$dS \cdot m^{-1}$	0.15
Total N	%	0.08
AB-DTPA extractable P	$mg \cdot kg^{-1}$	5.75
AB-DTPA extractable K	$mg \cdot kg^{-1}$	74
Soluble Cl	$mg \cdot kg^{-1}$	28
AB-DTPA-extractable Cu	$mg \cdot kg^{-1}$	1.74
AB-DTPA-extractable Zn	$mg \cdot kg^{-1}$	0.51
AB-DTPA-extractable Fe	$mg \cdot kg^{-1}$	0.97
AB-DTPA-extractable Mn	$mg \cdot kg^{-1}$	11.17
Dilute HCl extractable B	$mg \cdot kg^{-1}$	0.65

Table 2. Boron effect on nitrogen concentration.

Varieties	B applied ($kg \cdot ha^{-1}$)						Mean
	0	0.5	1	2	3	5	
TM-2008	1.09ef	1.14de	1.12de	1.15de	1.20bcd	1.18cd	1.15
Speight G-28	1.17cde	1.28b	1.24bc	1.37a	1.01f	1.15de	1.21
Mean	1.13cd	1.21ab	1.18bc	1.26a	1.11d	1.17bcd	

LSD value ($P < 0.05$) for Boron = 0.066; LSD value ($P < 0.05$) for boron × varieties = 0.094; Means with different alphabets differ significantly.

goes downward at higher levels. The data ranged from 1.01% - 1.37% N in the leaves. Highest concentration of 1.37% N was observed for applied boron @ 2 kg·ha^{-1} in variety Speight G-28, while the lowest were 1.01 (for 3 kg·B·ha^{-1} in var. Speight G-28) and 1.09 (for TM-2008 at no boron level). Among the varieties, Speight G-28 accumulated more N as compared to TM-2008.

The relationship between N and B in this experiment clearly indicated that B can increase N content in tobacco leaves but higher levels of B can negatively affect it. Same results were observed in leaves of cotton [29]. Another study revealed that boron negatively affected different compounds of N [30], like decreased NO_3^- content, which is harmful for tobacco quality and health of smoker and on the other hand increased different N based enzymes which are beneficial for tobacco. Same trends were reported by [31] in rice and [32] in sugar beet grown in calcareous soil.

3.2. Phosphorus

The data for phosphorus content showed that B significantly affected P content in tobacco leaves (**Table 3**). The data ranged from 0.391% to 0.146% P. The highest (0.391%) was observed for Speight G-28 @ 3 kg·B·ha^{-1}, and the lowest was 0.146% recorded @ 0.5 kg·B·ha^{-1}, followed by 0.152% recorded at no boron level, for Speight G-28 and TM-2008, respectively. Furthermore, the level of 3 kg·ha^{-1} B was accumulated the highest P content in the tobacco leaves. As the applied B increased, the P content also increased but decreased with high level of 5 kg·B·ha^{-1}. Speight G-28 proved better in accumulating P in the case of P accumulation.

The data revealed that B has a positive effect on P concentration in tobacco leaves. This relationship was also found in cotton [29] and sugar beet [32]. In rice, although it was not very significant but showed an increasing trend [31]. Higher B concentration can affect the P concentration as reported by [33].

3.3. Potassium

The results regarding the potassium content showed non-significant differences among the tobacco treated plots and varietal response (**Table 4**). The data ranged from 1.01% - 1.38% in TM-2008 and 0.83% - 1.12% in Speight G-28. Maximum potassium concentration was observed in the treatment plots where high boron levels were applied and minimum concentration was recorded in control plots in both varieties. However, results showed increasing trends with increase in applied boron which indicated that boron has a positive effect on potassium concentration in tobacco leaf. This positive effect of boron on potassium in tobacco is a good indicator for good quality tobacco, because potassium enhances the smoking and ashing quality by increasing the burning quality of tobacco. These findings are in conformation with the early work of [19] [34].

Table 3. Boron effect on phosphorus concentration.

Varieties	B applied (kg·ha^{-1})						Mean
	0	0.5	1	2	3	5	
TM-2008	0.152f	0.362ab	0.204e	0.254cd	0.324b	0.214de	0.252
Speight G-28	0.250cd	0.146f	0.270c	0.198e	0.391a	0.227cde	0.247
Mean	0.201d	0.254b	0.238bc	0.226bcd	0.358a	0.220cd	

LSD value ($P < 0.05$) for Boron = 0.0320; LSD value ($P < 0.05$) for boron × varieties = 0.0453; Means with different alphabets differ significantly.

Table 4. Effect of applied boron on the potassium content of tobacco (%).

Varieties	B applied (kg·ha^{-1})						Mean
	0	0.5	1	2	3	5	
TM-2008	1.01	1.01	1.05	1.05	1.38	1.12	1.10
Speight G-28	0.83	0.94	1.11	1.07	1.11	1.12	1.03
Mean	0.92	0.98	1.08	1.06	1.25	1.12	

3.4. Nutrient Ratios in Tobacco Leaf

3.4.1. K/B Ratio

Results revealed that K/B ratio was linearly and significantly decreased in the tobacco leaves with increasing concentration of boron (**Figure 1**). This decrease is because of the significant increase in boron concentration and non-significant increase in potassium concentration of the leaves. These results are similar to the findings of Tariq *et al.* [19], who stated that as the boron concentration in tobacco leaf increases the K/B ratio considerably decreases. Similarly, decreasing trend for K/B ratio in other crops due to boron was also reported for cauliflower [35], radish [15] and tomato [36]. Moreover, results showed similar trends in both varieties of tobacco. Though the varietal differences in terms of K/B ratio is statistically non-significant.

3.4.2. Cl/B Ratio

It is clear from the results that as the boron concentration increases, the Cl/B ratio significantly decreases, which results a negative relationship in both tobacco varieties (**Figure 2**). This decreasing trend may be due to the competition of these two anions on the uptake sites. The decreasing trend in Cl/B ratio is a good indicator for tobacco because the Cl decreases the burning quality of tobacco and also affects the grade index. Similar results were observed for tobacco [19], hot pepper [37] and tomato crops [38].

3.4.3. K/Cl Ratio

The results showed that K/Cl ratio in tobacco leaves increases with increasing concentration of boron in tobacco (**Figure 3**). This decrease with increasing concentration of boron was due to the increase in K and decrease in Cl in the tobacco leaf. The same trend in both varieties was observed showing no concern with K/Cl ratio which confirms that boron is responsible for the changes in K/Cl ratio of tobacco. However, the increase in K/Cl ratio is a better sign for good quality of tobacco crop as stated earlier that K is needed for a better tobacco crop and lower concentration of Cl. The results of the present study are supported by the work of Hashmi *et al.* [39], who

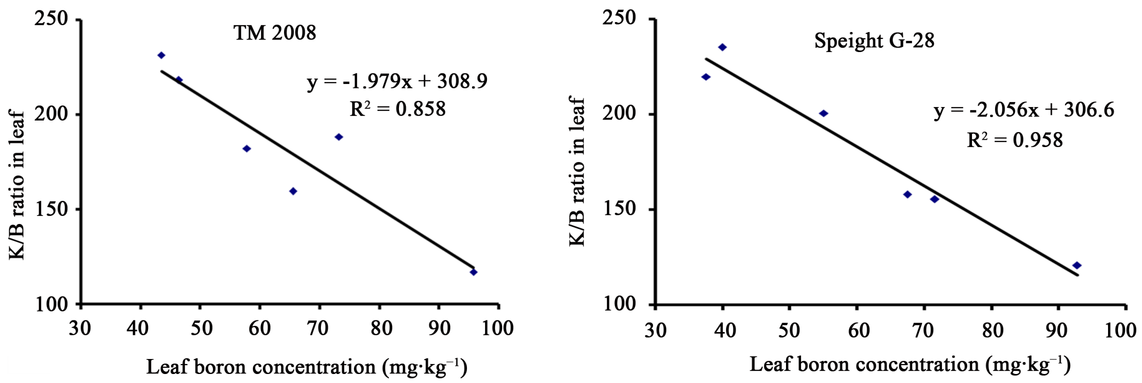

Figure 1. Relationship between boron concentration and K/B ratio of tobacco.

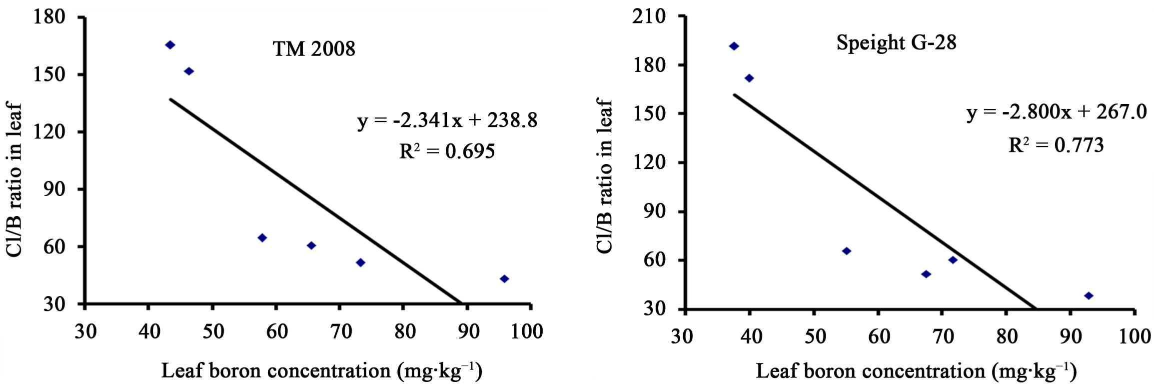

Figure 2. Relationship between boron concentration and Cl/B ratio of tobacco.

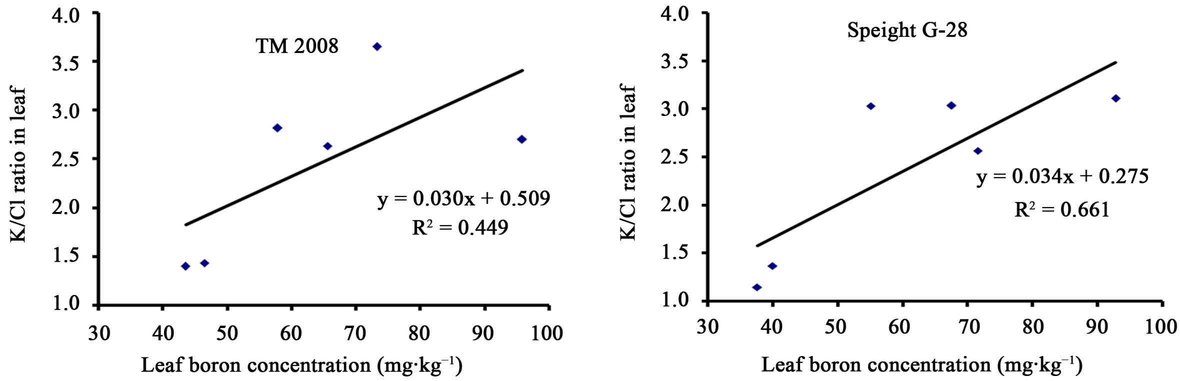

Figure 3. Relationship between boron concentration and K/Cl ratio of tobacco.

stated that increase in K content of tobacco leaves decreases the Cl content, which indicated that K is responsible for lowering the Cl content of tobacco leaves.

3.4.4. Zn/Cu Ratio

It is evident from the results that Zn/Cu ratio increases with increase in leaf boron concentration of tobacco (**Figure 4**). These results showed a close relationship of leaf boron with Zn/Cu ratio in tobacco and the same trend was occurred in both varieties. These results are supported by the early work of Leece [33], who reported that higher boron levels increased the Zn/Cu ratio in maize plant. Moreover, these findings are confirmed by Tariq and Mott [15], who stated that with increase in the concentration of boron in radish plant is proportional to increase in Zn/Cu ratio occurs.

3.4.5. Mn/Fe Ratio

It is evident from the results that Mn/Fe ratio decreases with increase in boron concentration of tobacco (**Figure 5**). These results indicated that Fe was increased and Mn was decreased with increase in boron content in leaf. Similar results were reported by Alvarez-Tinaut *et al.* [40], and Tariq and Mott [15]. They reported that Mn/Fe ratio in the plant decreases with increase in boron concentration. These results also suggested that antagonism of B-Mn can occur due to decrease in Mn/Fe ratio in plant.

3.5. Fertilizer Use Efficiency

Fertilizer use efficiency for the boron in the present study calculated according to the procedure developed by Crawswell [41] to calculate the most efficient level of boron fertilizer (**Figure 6**). Results clearly revealed that applied B @ 1 kg·ha^{-1} accumulated maximum boron, gave greater yield, and produced good quality tobacco as compared to other levels of boron fertilizers applied. Perhaps, loss of boron due to leaching, precipitation, erosion, and adsorption in soil were minimized. So it may be concluded that application of boron @ 1 kg·ha^{-1} is more effective, economical and viable than other levels of boron fertilizer applied. Furthermore, we agreed with the findings of Roberts [42] who stated that efficiency of the fertilizer can be optimized through best fertilizer management practices, which supplies nutrients at the right time, rate, and place. Therefore, the fertilizer use efficiency of 1 kg·B·ha^{-1} proved better than other levels of applied boron and should be applied before the deficiency occurs, because tobacco crop become unable to recover from the physiological or morphological changes which results from low-boron status of soil.

4. Conclusion

This study concluded that boron can affect the nutrient balance in tobacco. Furthermore, it can increase the yield and enhance the quality of the crop. B can increase N content in tobacco leaves but higher levels of B can negatively affect it. B increases different N-based enzymes which are beneficial for tobacco, and on the other hand it can affect different compounds of N, like decreased NO_3 content, which is harmful for tobacco quality and health of smoker. B has a positive effect on P concentration in tobacco leaves. Boron has a positive effect on potassium concentration in tobacco leaf. This positive effect of boron on potassium in tobacco is a good indicator

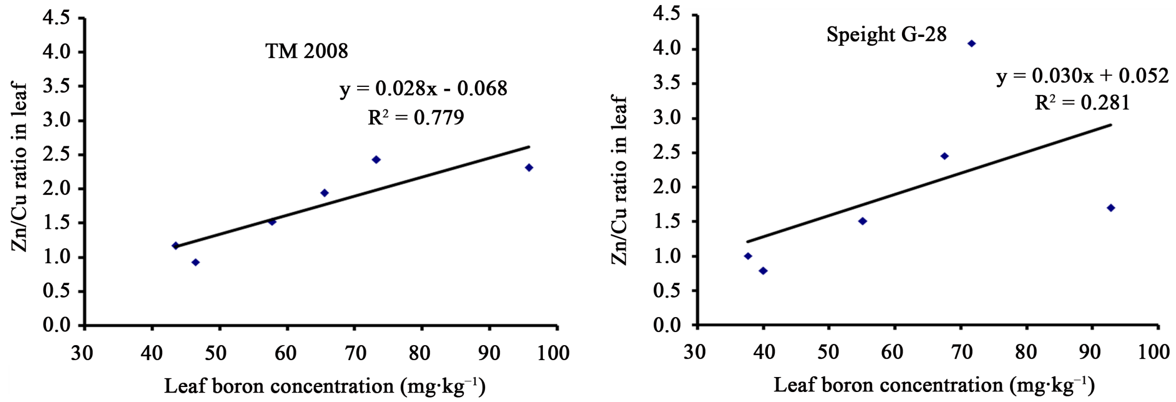

Figure 4. Relationship between boron concentration and Zn/Cu ratio of tobacco.

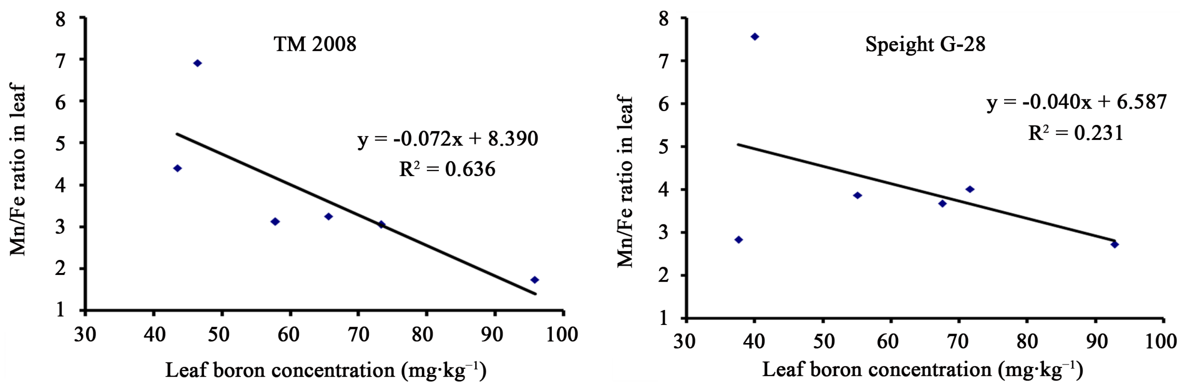

Figure 5. Relationship between boron concentration and Mn/Fe ratio of tobacco.

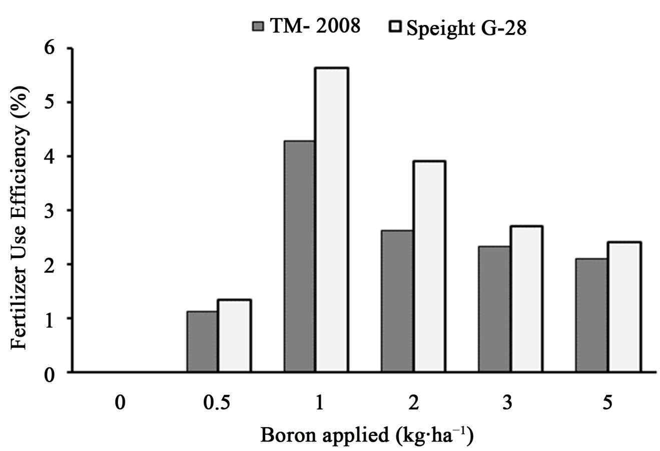

Figure 6. Effect of applied boron on the boron use efficiency in tobacco.

for good quality tobacco, because potassium enhances the smoking and ashing quality by increasing the burning quality of tobacco. Moreover, as boron concentration increases, K/B, Cl/B and Mn/Fe ratios considerably decrease. The decreasing trend in Cl/B ratio is a good indicator for tobacco, because the Cl decreases the burning quality of tobacco and affects the grade index, maybe due to the competition of these two anions on the uptake sites. The K/Cl and Zn/Cu ratios in tobacco leaves increase with increasing concentration of boron in tobacco. Boron is responsible for the changes in K/Cl and Zn/Cu ratios of tobacco, and shows a close relationship of leaf boron. Although there was no significant difference between these two varieties for all the discussed parameters, Speight G-28 proved to be more efficient than TM-2008. Results clearly revealed that applied B @ 1 $kg \cdot ha^{-1}$

accumulated maximum boron as compared to other levels of boron fertilizers applied. Perhaps, loss of boron due to leaching, precipitation, erosion, and adsorption in soil was minimized. So it may be concluded that application of boron @ 1 $kg \cdot ha^{-1}$ is more effective, economical and viable than other levels of boron fertilizer applied. The fertilizer use efficiency of 1 $kg \cdot B \cdot ha^{-1}$ proved better than other levels of applied boron and should be applied before the deficiency occurs.

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Abbreviation

AB-DTPA: Ammonium Bicarbonate Diethylene Triamine Pentaacetic Acid
B: Boron
$CaCO_3$: Calcium Carbonate
Cu: Copper
EC_e: Electrical Conductivity in Extract
Fe: Iron
K: Potassium
Mn: Manganese
N: Nitrogen
P: Phosphorus
Zn: Zinc