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Severity and Spatial Distribution of Boron Toxicity in Barley Cultivated Areas of Central Anatolia and Transitional Zones

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Abstract: The aim of this study was to determine the severity and spatial distribution of boron toxicity symptoms on barley cultivated areas in Central Anatolia and Transitional Zones (CATZs). Boron concentrations of plants sampled from barley cultivated areas of the CATZs region at 189 sites during springs 1996 and 1997 were determined. Boron toxicity symptoms were observed mainly in small areas near Konya-Çumra, Ankara-Gölbaşı, Yenikent and Yozgat-Yerköy and between the provinces of Konya and Aksaray. While boron toxicity symptoms were not observed in 79% of samples, 15% and 6% of samples showed light and medium-severe toxicity symptoms, respectively. As boron toxicity scores increased, boron concentrations of the plant samples increased ($r = 0.728$, $P < 0.01$). However, the linear relation between boron toxicity score and boron concentrations of soil was not convincing ($r = 0.367$). Combining all sites and boron toxicity scores, a map was constructed to demonstrate extra boron covering areas. Plants samples were free from boron symptoms in spite of the fact that their boron concentrations were up to 44.4 ppm. It was concluded that boron toxicity is not a common problem in CATZs, but it could be a problem in some localities of the region. The low frequency of boron problems may be attributed to common cultivation of boron tolerant barley cultivars, which have been improved under CATZ conditions over the last decade.

Key Words: *Hordeum vulgare*, boron, boron toxicity and distribution.

Arpa Yetiştirilen Orta Anadolu ve Geçit Bölgelerinde Bor Toksisitesi Şiddeti ve Yaygınlığı

Özet: Bu çalışmanın amacı, arpa (*Hordeum vulgare* L.) yetiştirilen Orta Anadolu ve Geçit Bölgelerinde (OAGB), bor toksisite şiddetinin ve alansal yaygınlığının belirlenmesidir. 1996 ve 1997 yılı ilkbaharında yürütülen bu çalışmada, OAGB'lerinde arpa yetiştirilen 189 durakta bor semptomları (0-9) ıskalasına göre gözlemlenmiş ve zarar görülen alanlardan bor analizi için bitki ve toprak örnekleri alınmıştır. Bor zararı belirtilerine esas olarak Konya-Çumra, Ankara-Gölbaşı ve Yozgat-Yerköy, Aksaray-Konya illeri arasındaki bazı lokal alanlarda rastlanmıştır. Yapılan gözlemlerin % 79'unda Bor zararına hiç rastlanmamış iken % 15'sinde hafif, % 6'sında ise orta ve şiddetli zarar görülmüştür. Zarar skoru arttıkça bitki bor kapsamı artmıştır ($r = 0.728$, $P < 0.01$). Bununla birlikte zarar skoru ile topraktaki bor kapsamı arasındaki ilişki düşük bulunmuştur ($r = 0.367$). Duraklar ve belirlenen skor değerleri işlenerek bor bakımından alanlar haritalanmıştır. Örneklerde, 44.4 ppm'e kadar olan bitki bor düzeylerine rağmen yapraklarda bor zararlarına rastlanılmamıştır. Elde edilen sonuçlara göre, bor zararı yaygınlık arz etmemekte, çok sınırlı ve lokal alanlarda bulunmaktadır. Bor zararının yaygın olmamasının önemli bir nedeni OAGB koşullarında geçmişten beri ıslah edilen bor toksisitesine toleranslı arpa çeşitlerinin yaygın olarak yetiştirilmesine bağlanabilir.

Anahtar Sözcükler: Arpa, bor, bor toksisitesi ve dağılımı.

Introduction

Barley (*Hordeum vulgare* L.) is one of the most important and widely grown cereal crops in Central Anatolia and Transitional Zones (CATZs) regions. It is also an indicator cereal species for boron toxicity (Krantz and Melsted, 1964). Boron toxicity and deficiency result in losses in grain yield. Each toxicity score (1 to 5 scale) decreased barley grain yield by 330 kg ha^{-1} in a toxicity study conducted under CATZs conditions (Avcı et al., 1998). Critical concentrations were 5 ppm in soil and 10 ppm in wheat (Mortvedt, 1972; Mengel and Kirkby, 1987).

B toxicity and Zn deficiency were reported to be the most important micro nutrient problems in CATZs (Sillanpaa, 1982). In contrast to these survey results, Kacar and Fox (1967) indicated that 25% of Turkish soil

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showed B deficiency based on analysis of 20 samples. B deficiency was also found in vineyard soils in Konya (Bayraklı and Er, 1998). The latest research showed that the hot water extractable B concentration in CATZ soils was 0.62 ppm on average and ranged from 0.01 to 11.00 ppm. B deficiency is very common in many areas of Central Anatolia (Eyüpoğlu et al., 2002; Gezgin et al., 2002).

Barley genotypes may show different responses to B toxicity. Alkan et al. (1995) indicated that the Hamidiye and Bülbül 89 barley varieties were susceptible to B toxicity while Yesevi, Tokak, Obruk and Anadolu varieties were tolerant. They also pointed out that the use of B tolerant varieties was an important strategy for solving the B toxicity problems in barley growing areas.

A rapid and reliable methodology is required for screening B toxicity and distribution. Kalaycı et al. (1996) reported that durum wheat was more susceptible to B toxicity than bread wheat and concluded that symptom scoring was more reliable than top and root B contents for toxicity studies. Sillanpaa (1982) reported that B toxicity was a problem in the Central Anatolian Plateau based on the analysis of soil samples. The objective of this study was to determine their toxicity problems and B distribution at a regional level by a survey study.

Materials and Methods

An intensive survey was conducted during spring 1996 and 1997 in order to screen B problematic barley fields. Barley plants were between booting and heading stages during the surveys. Plants were observed and scored at 189 sites. The range of scores used for severity of B damage in this study was from 0 to 9. When no necrotic spots were observed on the leaves and stems the plant was scored with 0. When necrotic spots covered 1 to 10% of plant canopy, it was scored with 1. A score of 2 was given when 11 to 20% of the plants were covered with spots. The same range was applied to the subsequent scores. If more than 90% of the whole plant was covered with necrotic spots, it was given a score of 9. In the case of toxicity symptoms on plant, soil samples were taken in addition to plant samples.

Konya, Ankara, Afyon, Eskişehir, Kütahya, Uşak, Karaman, Aksaray, Kırşehir, Yozgat and Kırıkkale provinces, which have climatic properties of CATZs, were selected as survey areas. The average rainfall and barley yields of these provinces are given in Table 1. Site intervals ranged from 8 to 15 km. depending on the presence of barley fields on the route. Symptom scoring was performed at 189 check sites. Eighty-eight plant and 20 soil samples from 0-20 cm soil depth were taken in toxic fields. The B concentrations in plant and soil samples were measured using the hot water extractable method described by Berger and Troug (1944). Twenty grams of air-dried soil, 40 ml of 0.01 M $CaCl_2$ and about 0.5 g of activated charcoal were boiled for 5 min in a quartz flask and filtered immediately; then 2 ml of the extract, 4 ml of buffer solution and 4 ml of azomethine reagent were mixed. This mixture was allowed to develop color for 1 hour. The intensity of the color was measured spectrophotometrically at 420 nm and compared to standards varying from 0 to 2 ppm.

Table 1. The acreages, yields and annual precipitations of provinces in CATZs covered by a survey (Summary of Agricultural Statistics, 1996).

Provinces	Acreage (ha)	Yield (t ha^{-1})	Annual rainfall (mm)
Konya	454,172	2.0	336
Ankara	189,072	2.1	376
Afyon	163,542	2.5	432
Eskişehir	113,019	2.2	381
Karaman	100,735	2.3	343
Aksaray	93,175	2.4	439
Yozgat	68,850	2.5	555
Kütahya	65,950	2.3	573
Uşak	63,800	3.0	553
Kırşehir	63,467	2.1	377
Kırıkkale	31,072	2.6	364

The sites were marked on a road map according to the car's kilometer gauge recordings. This map was later digitalized using the Surfer, Version 6.01 program and a final map was produced after entering the symptom scores. Regression and correlations performed using the statistical software Minitab, Release 13.0.

Results

Considerable variation in terms of the B scores was determined in this study. The B scores observed for the 2 seasons were mapped in Figure 1. Detailed observations along various routes were as follows:

1) Ankara - Eskişehir route: B toxic fields with scores of 1 to 3 were observed 50 km along the Ankara Eskişehir road. The field with score of 3 was irrigated with underground water, and so excess B most probably originated from this underground water. Generally, the plant development stage was between booting and heading along this route, while it was between heading and seed filling along the remaining part.

2) Eskişehir - Uşak – Afyon – Konya route: Apart from one site, which had a score 1, no B toxic fields were seen along this route.

3) Konya – Aksaray route: Many fields were B toxic along this route. Seven out of 9 check sites showed 3 to 8 B toxicities on barley plants.

4) Aksaray – Kırşehir route: Four B toxic fields were observed with scores of 2 to 3 at 15 check sites. In addition to these, Malya State Farm, where large scale certified seed of the barley cultivar Bülbül-89 has been multiplied, was also checked. At this farm, B toxicity scores of 2 and 3 were determined on leaves of cv. Bülbül-89; however, this cultivar outyielded the B tolerant cultivar Tokak 157/37 based on average yield in the state farm over the 6 years.

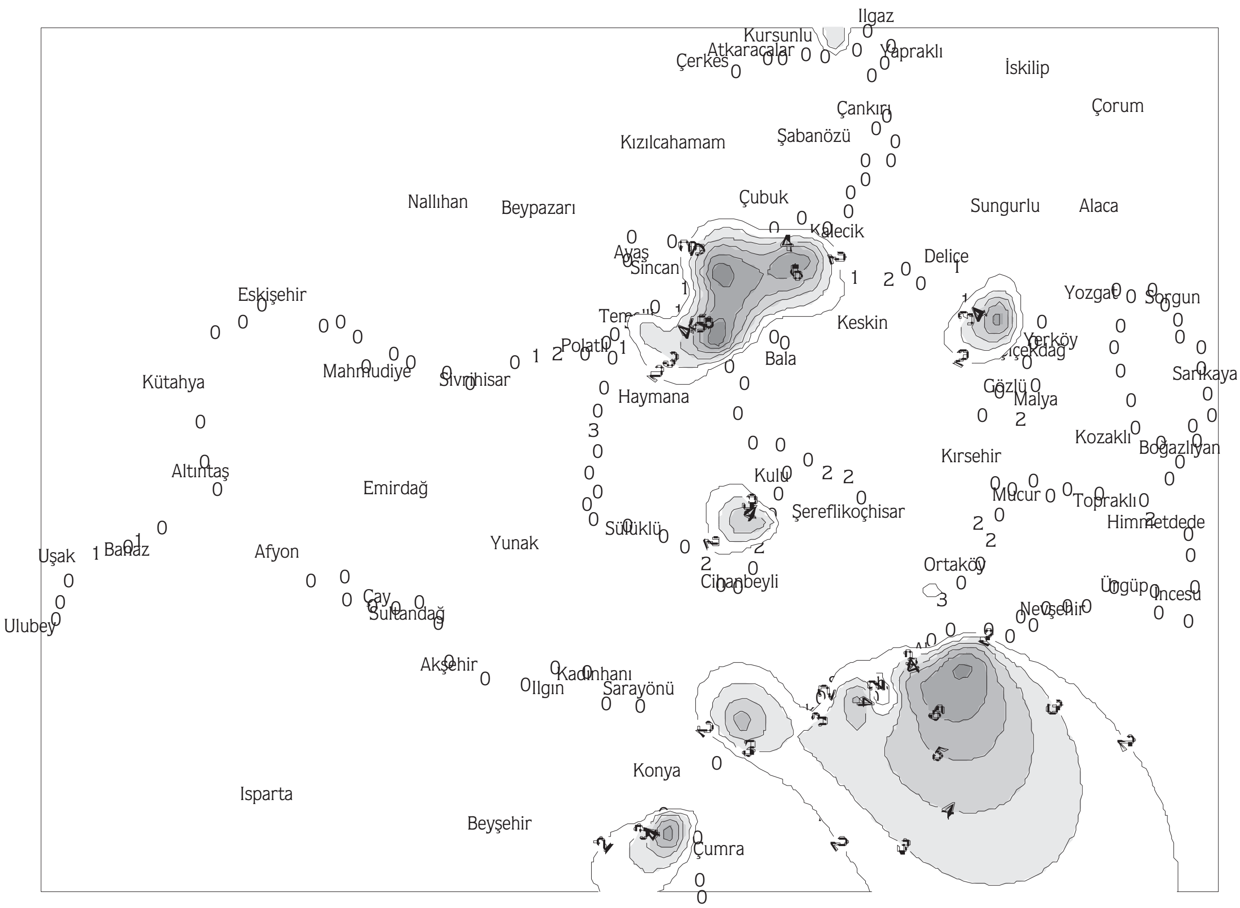

Figure 1. Severity and distribution of boron toxicity in Central Anatolia and Transitional Zones
The numbers show the severity of toxicity (0 = no symptoms, 9 = full range of symptoms).

5) Yozgat - Yerköy - Ankara route: At 6 check sites, plants with 1 to 3 B toxicity symptoms were observed. The high B toxicity symptoms were recorded in a small part of a field.

6) Ankara Bala – Ankara Ayaş route: High B toxicities with 7-8 scores were found near Mogan Lake in Gölbaşı, in a field near stream beds in the town of Yenikent , and in a field at Atatürk Forest Farm (AOÇ), on the way to Etimesgut (Ankara).

7) Ankara – Çankırı route: No toxic fields were observed at 24 sites except for at 2 with scores of 1 and 4 near Belören-Ilgaz (Çankırı province).

8) Ankara Polatlı – Konya Cihanbeyli – Ankara routes: 28 sites were observed and toxicity scores from 1 to 6 were recorded at 4 sites. A field was found with scores of 6 from the town of Kulu to the crossroads of Konya and Adana provinces.

9) Yozgat – Nevşehir – Kırşehir route: 43 fields were checked and there was only one toxic field, with a score of 2.

Overall analysis of the data indicated that there were no symptoms (zero score) on barley plants in 79% of surveyed sites. Light and medium-severe B toxicity levels were found at 15% and 6% of all checked sites, respectively (Figure 2).

The B concentrations in 88 plant samples collected during survey were correlated with B symptom scores of the plants. Significant and positive correlations ($r = 0.728$, $P < 0.01$) between these properties were determined. The linear regression equation (*Plant-B cons = 11.8 B-score + 21.9*) was also found between plant-B and B toxicity symptoms (Figure 3). Mean B scores and plant-B concentrations showed parallel increases. The mean plant-B concentration was 36.9 ppm and ranged from 4.4 to 224 ppm (Table 2). The critical plant-B concentration was about 44.4 ppm. There were no any symptoms on the plants screened when B concentration was below this level. The simple correlation coefficient between B scores and soil-B concentrations in soil samples collected from high B toxic fields was lower than the correlation between B-scores and plant-B concentrations ($r = 0.367$, $P < 0.10$). Mean soil-B concentration was 4.3 ppm and ranged from 0.41 to 12.9 ppm (Table 2).

Discussion

The high and significant correlation coefficient between symptom scores and plant-B concentrations implied that the toxicity symptoms on barley plants originated from excess plant-B concentrations. Although 10 ppm plant-B is the critical concentration for wheat plants (Mortvedt, 1972), B concentration reached 44.4 ppm in barley plants without any visible symptoms on leaves in this study. This clearly indicates the importance of the tolerance of barley varieties grown in the CATZs region (Alkan et al., 1995). On the other hand, critical B concentration values showed great variation, such as 10 to 130 ppm in plant dry matter for wheat and barley (Ross et al., 1997). The high and significant correlation

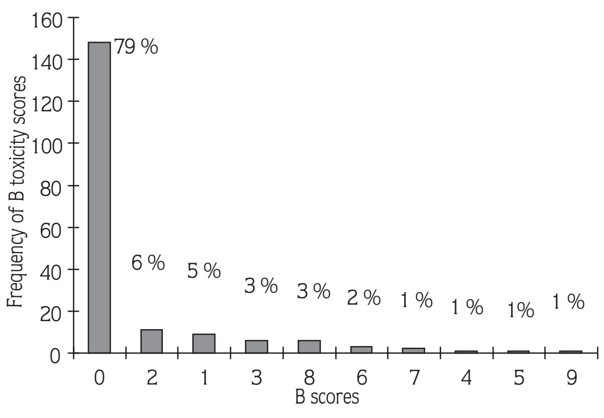

Figure 2. Frequency of B toxicity scores of 189 fields in the CATZs region.

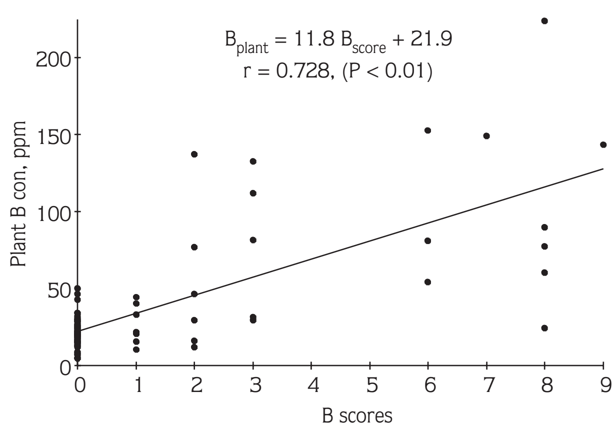

Figure 3. The linear relationship between plant-B and B symptom scores.

Table 2. Plant and soil boron concentrations of survey samples collected from the CATZs region.

Plant Boron Concentrations (PBC), ppm								Soil Boron Conc. (SPC), ppm	
Tour No.	PBC	Tour No.	PBC	Tour No.	PBC	Tour No.	PBC	Tour No.	SPC
1	9.00	23	21.40	45	143.60	67	24.20	2	5.70
2	29.40	24	32.90	46	33.90	68	15.90	3	3.10
3	10.40	25	21.50	47	25.30	69	12.50	26	1.90
4	15.60	26	15.60	48	14.50	70	26.60	45	4.70
5	4.40	27	26.30	49	24.90	71	18.30	50	2.40
6	46.60	28	16.30	50	81.00	72	32.20	51	2.80
7	40.10	29	16.60	51	31.50	73	15.60	52	3.00
8	8.30	30	42.60	52	132.50	74	4.50	54	10.60
9	4.80	31	22.10	53	36.70	75	11.80	57	2.50
10	13.50	32	20.00	54	149.10	76	11.80	61	1.10
11	19.70	33	19.40	55	18.70	77	37.20	68	0.41
12	29.40	34	28.40	56	54.30	78	224.10	73	6.00
13	15.60	35	21.40	57	152.90	79	44.40	76	2.00
14	15.20	36	18.00	58	90.00	80	20.50	78	0.80
15	46.70	37	31.10	59	22.10	81	12.80	79	0.90
16	36.80	38	22.10	60	20.80	82	15.10	83	8.50
17	19.40	39	19.00	61	112.10	83	29.30	84	4.00
18	23.50	40	33.90	62	49.80	84	21.50	86	3.50
19	25.90	41	17.00	63	23.20	85	81.40	87	9.20
20	20.00	42	20.00	64	137.40	86	7.20	88	12.90
21	18.70	43	29.80	65	76.80	87	77.30		
22	28.40	44	29.40	66	6.90	88	60.40		

coefficient between B symptom scores and plant-B concentrations showed that symptom scoring is a reliable method in toxicity studies as was reported previously by Kalaycı et al. (1996). The low and non-significant correlation coefficient between B symptom scores and soil-B concentrations suggests that the results of only soil-B concentrations data may be misleading when making a decision on B toxicity.

Although 5 ppm soil-B (hot water extractable) is considered the critical level by many researchers, this quantity did not reflect the responses of many plant species cultivated under arid and semi-arid conditions. On the other hand, the plant available part was more important than total B in the soil, and so the form of B in the soil greatly affected the plant availability (Ross et al., 1997). Generally, the total B in the soil inadequately expresses the plant available part. From this point of view and as concluded by Kalaycı et al. (1996), the results of symptom scoring highly reflect the reality rather than those of plant-B and soil-B concentration analyses. Thus, this study can be considered important to illustrate an accurate depiction of the B toxicity situation in the region.

In terms of plant-B status, some barley varieties had high concentrations in their dry matter and showed high B toxicity scores, although they were able to maintain higher grain yields than a B tolerant cultivar. This situation was called specific tolerance (Cartwright et al. 1998). A similar case was observed with cv. Bülbül 89, which has been cultivated in Malya State Farm (Avcı et al., 1998). In spite of this, this variety showed very good adaptation at the farm and its surroundings due to its high and stable grain yield.

Conclusions

Based on the analysis of plants and soil collected from the CATZs region, it can be concluded that B toxicity was not a serious problem. However, there was a limited, partial and local problem mainly concentrated in the regions in the provinces of Konya and Aksaray.

The common cultivated variety was B-tolerant Tokak 157/37 during the survey and so, the plant samples were belong to this cultivar in the majority of cases. In spite of the high plant-B concentration (44.4 ppm) in the samples, no visible B toxicity symptoms were observed on barley plant leaves. This showed the apparent importance of plant B tolerance in crop production. Similar studies based on symptom scoring can provide more accurate results than the analysis of plant and soil B concentrations in the laboratory, not backed by field observations.

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References

Akar, T., M. Avcı, F. Düşünceli, H. Tosun, A.N. Ozan, S. Albustan, K. Yalvaç, İ. Sayım, D. Özen and H. Sipahi. 1998. Orta Anadolu ve geçit bölgelerinde arpa (*Hordeum vulgare*, L.) tarımının sorunları ve çözüm yolları. Orta Anadoluda Hububat tarımının sorunları ve çözüm yolları sempozyumu, Konya.

Alkan, A., M. Kalaycı, A.Yılmaz, H. Ekiz, B. Tosun, S.Eker and İ. Çakmak. 1995. Değişik Arpa Genotiplerinde Bor Toksisitesinin Araştırılması. Arpa Malt Simpozyumu (III), Konya.

Avcı, M., T. Akar, N. Zencirci, H. Tosun and M. Kalaycı. 1998. Breeding for boron tolerance and its impact on yield components of barley varieties. Journal of Field Crops Central Research Institute, Vol: 7, No: 2, 1998

Bayraklı, F. and F. Er, 1995. Boron concentration of vineyards and soils in Hadim Aladağ part of Konya. M. Şefik Yeşilsoy Symposium on Arid Region Soils, 174-178. İzmir

Berger, K.C. and H. Troug. 1944. Boron tests and determination for soils and plants. Soil Science. 57: 25 - 36.

Cartwright, B., A.J. Rathjen, D.H.B. Sparrow, J.G. Paull and B.A. Zarcinas. 1985. Boron tolerance in Australian varieties of wheat and barley. In: Genetic Aspects of Plant Nutrition, 16-20 June 1985 Madison, USA (eds. W.H. Gabelman, B.C. Loughman) Dordrecht, Netherlands, Martinus Nijhoff (1987) 139-151.

Eyüpoğlu F., N. Kurucu, İ. Güçdemir and S. Talas. 2002. Boron status of Central Anatolian soils in: International Conference On Sustainable Land Use and Management, 2002, Çanakkale Turkey. http://www.toprak.org.tr/bildiri_can.htm.

Gezgin, S., N. Dursun, M. Hamurcu, M. Harmankaya, M. Önder, B. Sade, A. Topal, N. Çiftçi, B. Acar and M. Babaoğlu. 2002. Boron Content of Cultivated Soils in Central-Southern Anatolia and Its Relationship with Soil Properties and Irrigation Water Quality. In: Boron in Plant and Animal Nutrition, 1st ed. (Ed: H. E. Goldbah). Kluwer Academic Pub., New York, pp: 391- 400.

Kacar, B. and R.L. Fox. 1967. Boron status of some Turkish soils. University of Ankara Yearbook of the Faculty of Agriculture 1966: 99-111.

Kalaycı, M., A. Alkan, I. Çakmak, O. Bayramoğlu, A. Yılmaz, M. Aydın, V. Özbek, H. Ekiz and F. Özberisoy., 1996. Studies on differential response of wheat cultivars to boron toxicity. in: Wheat: Prospects for Global Improvement, (Eds. H.J. Braun et al.), 189-195. Kluwer Academic Publishers.

Kranz, B.A. and Melsted, S.W. 1964. Nutrient deficiencies in corn, sorghums and small grains. In: Hunger Signs in Crops. 3rd edition Sprague, H.B., ed. David McKey, New York, 25.

Mengel, K. and Kirkby E.A. 1987. Principals of Plant Nutrition. 4th edition, International Potash Institute, Bern, Switzerland, 1987.

Mortvedt, J.J. 1972. Micronutrients in Agriculture. Soil Science Society of America, Book Series, No: 4, Madison, WI, USA.

Ross, O., N. Gary, S. Banuelos and J.G. Paull. 1997. Boron toxicity. Plant and Soil 193: 181–198.

SIS, 1996. Statistical Year Book of Turkey. State Institute of Statistics Publications, Ankara.

Sillanpaa, M., 1990. Micronutrient assessment at the country level: an International study. FAO Soils Bulletin No: 63. Rome.