http://www.pjbs.org

PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 9 (15): 2862-2868, 2006
ISSN 1028-8880

Effect of Gypsum on Reclamation of Boron Soils in Konya-Çumra Dedemoğlu Province

[1]Ahmet Melih Yılmaz, [1]Mehmet Şahin, [1]Bilal Acar and [2]Hatice Erik
[1]Department of Irrigation and Drainage Engineering, Faculty of Agriculture,
University of Selcuk, 42031 Konya, Turkey
[2]Department of Irrigation and Drainage Engineering, Faculty of Agriculture, University of Selcuk,
(Master of Science Admitted), 42031 Konya, Turkey

Abstract: The effects of gypsum on reclamation of boron soils were investigated in Konya-Çumra Dedemoğlu province under field conditions during 2003 summer season. The gypsum with 85% purity obtained from Mediterranean Fertilizer Industry was used in research with three replications. The gypsum doses were applied as 0 t ha^{-1} (control), 10 and 30 t ha^{-1}. Leaching water was taken from the artesian well that close to research plots. The irrigation water was applied as 30 cm increment which total of 180 cm. Initial and after every leaching, soil samples were taken from the 0-30, 30-60, 60-90 and 90-120 cm depths for analyzing. The results showed that after the leaching process, to be removed 30, 60 and 90% of B in soil profile, the applications of leaching water were determined as 0.37, 1.20 and 3.89 times of soil depths in control plots, respectively. In 10 t ha^{-1} gypsum applied plots, these were 0.41, 1.31 and 4.18 times of soil depths for removing 30, 60 and 90% of B, respectively. In examined the 30 t ha^{-1} gypsum applied plots, these were 0.39, 1.38 and 4.78 times of soil depths for removing 30, 60 and 90% of B, respectively. Equations and graphs that show the leaching water requirement of B in 1 m soil depth were obtained for each treatment.

Key words: Reclamation, boron soils, gypsum, leaching water requirement, equations

INTRODUCTION

In arid semi arid areas of the world, boron (B) toxicity results from high levels of B in soils and additions of B via the irrigation water. In saline soils, lack of drainage leads to excessive concentrations of B in the soils. Of all potential sources, irrigation water is the most important contributor to high levels of B within the soils. In general, B is present in high concentrations in association with saline water (Anapalı, 1991). The other sources of B in soils are plant and animal residuals. The most B salts are easily dissolved form in water so they are conveyed from the cultivated lands by irrigation water (Sonmez, 2003).

B toxicity is an important disorder that can limit plant growth on soils of arid and semi-arid environments throughout the world. B is one of an essential micro nutrient for higher plants, which grow slowly and will not complete their life cycles without it (Laila and Adel, 2002) but, the range between deficient and toxic B concentration is smaller than for any other nutrient element. B has important roles in carbohydrate and protein metabolism in crop body, differentiate of tissues, oxin and phenol metabolism, membrane permeability, pollen germination and pollen tube body (Marschner, 1995). B is dominated element in arid and semi arid regions and is carefully managed (Manyowa and Miller, 1991).

pH as a very strong effect in boron adsorption and increase of 0.5 units in pH resulted in a 22% increase in boron adsorption (Sartaj and Fernandes, 2005).

Some indicators of B in plants are pale colour in old leaves, moles with droughts in edge of leaves. The burning sensation starts in topical and edge of leaves and expands in central vessels of leaves. Leaves are seen like burned and are fallen before the ripening. In most plants, toxicity indicators are observed after 250-300 ppm B concentration in leaves of palm. Goldberg *et al.* (2003) studied about the effects of high boron application on growth of melon. They found that B treatments caused various deleterious effects on melon growth and development. Fresh and dry plant matter decreased significantly with increasing B concentrations; while B concentration of plant leaves, stems and fruits increased significantly with increasing B.

B is removed from soils by leaching with well quality irrigation water. In addition to this, applications of lime with leaching process and growing crops that are tolerant to B are also other improvement methods

Corresponding Author: Ahmet Melih Yılmaz, Department of Irrigation and Drainage Engineering, Faculty of Agriculture, University of Selcuk, 42031 Konya, Turkey

(Nable *et al.*, 1997). To remove the B from crop root zone depths, leaching water is applied to the soils by using basin or sprinkler irrigation methods. Surge basin irrigation was also accepted as efficient leaching technique (Sonmez, 2003).

B concentration of leaching water should be 0.75-2.0 ppm (Rowe and Abdel-Magid, 1995). Keren and Bingham (1985) reported that safe levels of B concentrations in irrigation water were 0.3 ppm for sensitive, 1-2 ppm for moderately tolerant and 2-4 ppm for tolerant crops.

In present study, effects of gypsum on reclamation of B and salt affected soils were researched in Konya-Çumra Dedemoğlu province under field conditions.

MATERIALS AND METHODS

The research was carried out in Konya-Çumra Dedemoğlu province where it is 40 km away with Southesthern part of Konya city during the 2003 summer season. It is almost 11 km far from Çumra. The average annual temperature of Konya is 11.5°C and averages of 23 and 0°C in July and January, respectively. The highest and lowest temperatures are 40 and -28.2°C (Anonymous, 1998).

The climate of Çumra represents Central Anatolia Region with hot and drought in summer; cold, rainy and snowy in winter. Poor vegetation is dominated. Evaporation is highest in July-September and total of 275-300 mm for only these three months. Total annual rainfall is almost 250-300 in research area and is mostly occurred in winter and spring months (Anonymous, 2004).

The first autumn freezing occurs in end of October while the spring final freezing in April. The relative humidity varies 40-41% in July-August and reaches almost 80-84% winter.

The research was designed randomized plot treatment with 3 replications. To represent the uniformity of study soils, plots were constructed in smaller sizes. The each plot size is 3.20×3.15 m (almost 10 m^2). The drain pipes were available in research area and after leaching; drainage water was removed by drain pipes and reached to the natural main drainage canal that was present in the edge of the research plots. Except the control plots, gypsum was weighted and applied by broadcasting into the plots with 10 and 30 t ha^{-1} doses. The gypsum with 85% purity obtained from Mediterranean Fertilizer Industry was used in research.

The estimated gypsum amount was calculated by using the Kovda (1967) equation by considering the research soil Exchangeable Sodium Percentage (ESP).

The amount of leaching water was calculated by using Reeve *et al.* (1955) equation and was applied as 30 cm increments with total of 180 cm during the research period. Leaching water was applied when the soil moisture level was reached to the field capacity.

During the research period, soil samples were taken from 0-30, 30-60, 60-90 and 90-120 cm depths before and after the leaching by using the soil auger. In these samples, soil texture, saturation percentage, bulk density, wilting point, pH, Electrical Conductivity (EC), soluble anion and cation in water, B, Cation Exchange Capacity (CEC) were determined by using the USDA Salt Laboratory Scale.

The ratio of leaching water to soil depth was dependent and residual B percentage according to the initial was assumed as independent variables. Regression and correlation analysis methods were applied to be obtained B leaching equations (Beyazgul, 1995).

RESULTS AND DISCUSSION

The physical and chemical properties were determined from the soil samples taken 0-30, 30-60, 60-90 and 90-120 cm depths before leaching and chemical material applications. The soil texture in upper part of soil profile was Clay-Loam (CL) and in lower part of clay (C). Bulk density and specific density were determined 1.29-1.54 and 2.58-2.81 g cm^{-3}, respectively. The volumetric percentages of Field Capacity (FC) and Permanent Wilting Point (PWP) were 32.70-37.88% and 21.60-24.90%, respectively and slightly decreased with an increased of soil depth. Total porosity varied 44.76-50.96% and saturation which of 65.13-80.80%. Porosity decreased in lower part of soil profile but saturation increased. The possible reason may be that clay was dominated in lower part.

The salt content of research soil was measured higher than limit value of the 4 mmhos cm^{-1} and varied 10.00-19.95 mmhos cm^{-1}. The ESP values were also higher than the limit value of 15% and varied 26.60-28.83%.

The B content of research soils were determined as in the range of between 7.58-8.14 ppm with pH of 7.60-8.20 so were classified as saline-sodic and B affected soils.

Leaching water used in research was obtained from the well operated by the electrical pumping unit that was very close to the research plots. The water samples taken from the well were analysed regularly during the study period and salt, Sodium Adsorption Ratio (SAR) and B contents of this leaching water varied as 743-825 micromhos/cm, 1.35-1.50 and 0.6-0.7 ppm, respectively. The water quality was classified as C_3S_1 and it may be possible to say that salt and sodium concentration are low. In addition, in examine the soluble anion and cation in water, Ca^{++} cation and Cl^{-} anion were dominant in leaching water.

Table 1: Effect of different leaching water doses on B concentrations in study soils

Treatments	Soil depth (cm)	B contents (ppm) Leaching water (cm) 0	30	60	90	120	150	180
Control (Jo)	0-30	7.87	4.51	3.25	2.51	1.96	1.41	1.22
	30-60	7.54	4.89	4.00	2.96	2.28	1.87	1.39
	60-90	7.69	5.71	4.93	3.43	2.84	2.12	1.42
	90-120	7.49	8.26	7.35	4.21	3.67	2.43	1.66
Gypsum (J_1) 10 t ha^{-1}	0-30	8.12	4.77	3.37	2.96	2.20	1.95	1.63
	30-60	8.06	5.12	4.21	3.21	2.71	2.09	1.65
	60-90	7.71	6.29	5.12	3.98	3.00	2.33	1.71
	90-120	7.67	8.09	7.77	4.71	3.54	2.53	1.73
Gypsum (J_2) 30 t ha^{-1}	0-30	8.45	4.92	3.32	3.09	2.39	2.01	1.82
	30-60	8.12	5.62	4.65	3.42	2.97	2.28	1.89
	60-90	7.87	7.01	5.39	4.26	3.34	2.51	1.96
	90-120	7.91	8.33	7.65	4.52	3.78	2.88	1.94

Table 2: Residual B percentages according to initial for different leaching water doses

Treatments	Soil depth (cm)	Leaching water (cm) 0	30	60	90	120	150	180
		Residual B percentages according to initial after leaching ($B/B_o \times 100$)*						
Control (Jo)	0-30	100.00	57.30	41.29	31.89	24.90	17.91	15.50
	30-60	100.00	64.85	53.05	39.26	30.24	24.80	18.44
	60-90	100.00	74.25	64.11	44.60	36.93	27.57	18.47
	90-120	100.00	110.28	98.13	56.21	49.00	32.44	22.16
Gypsum (J_1) 10 t ha^{-1}	0-30	100.00	58.74	41.50	36.45	27.09	24.01	20.07
	30-60	100.00	63.52	52.23	39.83	33.62	25.93	20.47
	60-90	100.00	81.58	66.41	51.62	38.91	30.22	22.18
	90-120	100.00	105.48	101.30	61.41	46.15	32.99	22.56
Gypsum (J_2) 30 t ha^{-1}	0-30	100.00	58.22	39.28	36.56	28.28	23.78	21.53
	30-60	100.00	69.21	57.27	42.12	36.58	28.08	23.28
	60-90	100.00	89.07	68.49	54.13	42.44	31.89	24.90
	90-120	100.00	105.31	96.71	57.14	47.79	36.41	24.53

* Bo: Initial B Content, B: B Contents after Leaching

The B contents measured in saturation extracts of soils after each leaching process are represented in Table 1.

It can be seen from the Table 1, high B concentrations were present in soils. In considering the degree of B tolerances of crops, B level was decreased 2.0-4.0 ppm that is only suitable for B tolerant crops (sugar beet, alfalfa, field been, onion, cabbage, lettuce, carrot etc.) as after few leaching process. After 150 and 180 cm leaching water application, B level was reduced to 1.0-2.0 ppm for moderately tolerant crops (sunflower, potato, olive, barley, mays etc.). Sugar beet and cereal are intensively growing crops in study region so B leaching may be considered efficient after leaching.

To determine effects of leaching water doses on B leaching, after the certain leaching process by using the ratio of B concentration after leaching to initial B content percentage (B/Bo × 100), the results were obtained and given in Table 2.

As shown in Table 2, after 30 cm leaching water application, 42.70, 41.26 and 41.78% of B were leached in control, 10 and 30 t ha^{-1} gypsum application, respectively in 0-30 cm soil depth. In 90 cm leaching water application, these were 68.11, 63.55 and 63.44% of B were leached in control, 10 and 30 t ha^{-1} gypsum application, respectively, in same soil depth.

Further leaching process, leaching efficiency of B decreased since, in application of 180 cm leaching water these were 84.50, 79.93 and 78.47% of B were leached in control, 10 and 30 t ha^{-1} gypsum application, respectively. The reason may be that there was great difference between initial soil and leaching water B concentrations and this reduced after each leaching. In examine the ratios mentioned above; gypsum resulted in lower leaching of B in accordance of control plots. The possible reason may be that adding to the gypsum increased the calcium concentration of soil and this calcium formed B components in soil ($Ca_2B_6O_{11}.5H_2O$) as reported by Ayyildiz (1983).

Application of leaching water led to leaching of B and also salts within the soil profile and so leaching efficiency of B decreased.

In Table 2, in general leaching efficiency in 30-60 cm was found lower than 0-30 cm soil depth. The reason of that leached of B from upper part of soil deposited in this layer. This is very common result that B deposits in lower part of soil since, B was leached from upper part and reached to the lower part. In this layer, after 30 cm leaching water application, B concentration increased by depositing of B from reaching the upper B and residual B percentages according to the initial B values decreased as 64.85, 63.52 and 9.21% of B were leached in control, 10 and 30 t ha^{-1} gypsum application, respectively. In 90 cm leaching water application, these were determined as 39.26, 39.83 and 42.12%, respectively. In examine the effects of gypsum on B leaching efficiency, increase of gypsum doses caused decrease of B leaching comparison to control plots. Application of leaching water led to leaching of B and also salts within the soil profile so leaching efficiency of B decreased like the above results.

In third layer of 60-90 cm soil depth, leaching of B decreased comparison to upper layers. In first 30 cm leaching water application, leaching of B was very low for all treatments. Due to B leaching from the upper to lower part, deposition of residual B increased in this layer and was determined as 74.25, 81.58 and 89.07% in control, 10 and 30 t ha^{-1} gypsum application, respectively. In further leaching process, in 90 cm leaching water application, B content decreased to the 44.60% (55.40% B was leached), 51.62% (48.38% B was leached) and 54.13% (45.87% B was leached) in control, 10 and 30 t ha^{-1} gypsum application, respectively.

In 180 cm leaching water application, these were found 22.16, 22.18 and 24.90% in control, 10 and 30 t ha^{-1} gypsum application, respectively. In initial doses, leaching efficiency was low and the reason is same that in lower part B was deposited from leached B of upper layers.

In last layer of 90-120 cm after first 30 cm water application, B concentration increased comparison to before leaching and residual B concentration was found 110.28, 105.48 and 105.31% in control, 10 and 30 t ha^{-1} gypsum application, respectively. The increase of B level was resulted from leaching of B from upper part to this layer. The leaching was efficient after each leaching process but it was lowest in such layer. Thus, in 180 cm leaching water application, residual B concentrations reduced as 22.16, 22.56 and 24.53% in control, 10 and 30 t ha^{-1} gypsum application, respectively. Leaching levels of B were highest in control plots and followed by 10 and 30 t ha^{-1} gypsum application plots.

In result, initial B levels were 7.49-7.87, 7.67-8.12 and 7.87-8.45 ppm in control and followed by 10 and 30 t ha^{-1} gypsum applied plots. After leaching, these were reduced as 1.22-1.66, 1.63-1.73 and 1.82-1.96 ppm in control, 10 and 30 t ha^{-1} gypsum application plots, respectively. This was almost the safe value of 1 ppm for many agricultural crops. These values were lower than 1-2 ppm that was suitable for main crops of in research region such as cereals. The aim of the research was to determine the effects of gypsum on B leaching. After the leaching process, B levels decreased in gypsum applied plots but leaching of B was lower comparison to control plots.

To determine the relationship between residual B concentrations in soil profile according to initial B content percentage (B/Bo × 100) and ratio of leaching water amount to soil depth (Dys/Dt), graph was formed and following mathematical equations were obtained;

For Control Plots;

$$D_{ys}/D_t = 5.75x\ e^{-0.03917\ B/Bo \times 100}\quad r = -0.84$$

For First Dose of Gypsum (10 t ha^{-1});

$$D_{ys}/D_t = 6.165x\ e^{-0.0387\ B/Bo \times 100}\quad r = -0.85$$

For Second Dose of Gypsum (30 t ha^{-1});

$$D_{ys}/D_t = 7.33x\ e^{-0.04147\ B/Bo \times 100}\quad r = -0.79$$

Correlation coefficients of equations were obtained as $r=-0.84$, $r=-0.85$ and $r=-0.79$ in control, 10 and 30 t ha^{-1} gypsum application plots, respectively. This values were almost equal to 1 (-1+1) and showed good relationships statistically. By using B leaching equations, B leaching curves were formed and were expressed in Fig. 1a-c. In these Fig. 1a-c as B level decreases in soil the effectiveness of unit leaching water also decreases. These curves were same the many researchers findings previously sited in the literatures.

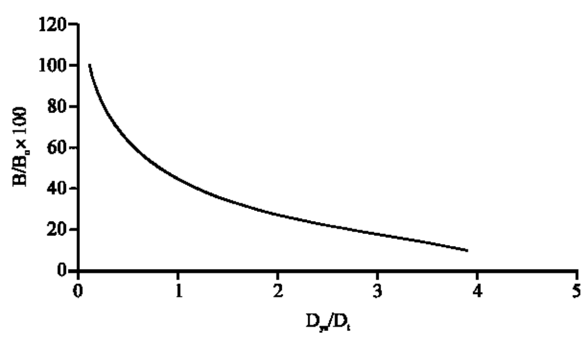

Fig. 1a: Relationship between residual B percentage in control plot and ratio of leaching water depth to soil depth

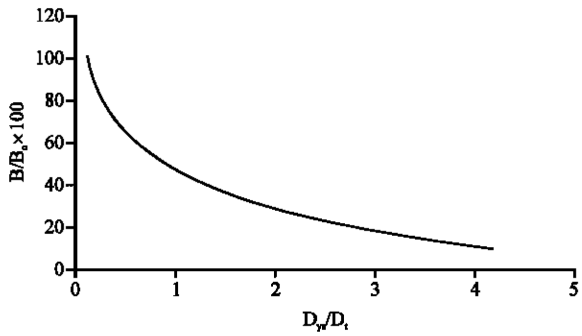

Fig. 1b: Relationship between residual B percentage in respect to initial in first dose of gypsum (10 t ha^{-1}) applied plot and ratio of leaching water depth to soil depth

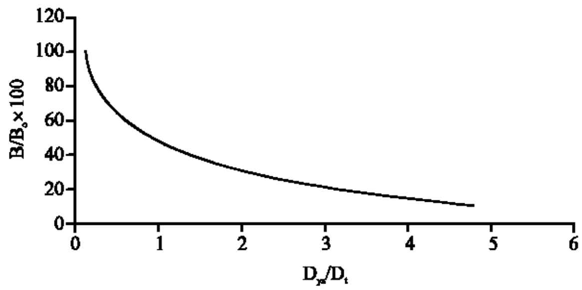

Fig. 1c: Relationship between residual B percentage in respect to initial in second dose of gypsum (30 t ha^{-1}) applied plot and ratio of leaching water depth to soil depth

According to the leaching equation and curves of B, in terms of the initial to be removed 30, 60 and 90% of B in soil profile, the applications of leaching water were determined as 0.37, 1.20 and 3.89 times of soil depths in control plots, respectively.

In 10 t ha^{-1} gypsum applied plots, these were 0.41, 1.31 and 4.18 times of soil depths for removing 30, 60 and 90% of B, respectively. In examined 30 t ha^{-1} gypsum applied plots, these were 0.39, 1.38 and 4.78 times of soil depths for removing 30, 60 and 90% of B, respectively. However, leaching water calculated from the leaching equation and curves of B was the net leaching water requirement and evaporation amount should be added to calculated value in practice.

By comparison to these three treatments, application water was higher in gypsum applied plots than only leaching water applied plots (control). The research soils were dominated calcium and sulphate so gypsum application resulted in increase of calcium since natural gypsum was present in research soils. Thus, water leached B and also calcium so leaching efficiency of B reduced. In addition, there was relationship between deposition of B and calcium, especially B formed as Ca Borate ($Ca_2B_6O_{11}.5H_2O$) precipitated had very high difficulty of leaching. The increment of Ca doses in gypsum applied plots led to low leaching of B. Thus, in present study the effect of gypsum application on B leaching was low and required more leaching water. The leaching efficiency was found as Control > first dose of gypsum (10 t ha^{-1}) > second dose of gypsum (30 t ha^{-1}). In these type of soils, as the gypsum increases, leaching water requirement also increases and leaching efficiency reduces. The main objective in reclamation of B soils was to remove maximum B in unit water. According to research, it can be not suggested of gypsum application for efficient leaching of B.

It may be concluded from the research that;

- In initial B contents of soils were 7.58-8.14 ppm and reduced by leaching and reached to the safe level for crops. By considering shallow rooted crops, examining the 0-30 cm soil depth, initial B content was very high and after 60 cm leaching water application, soil B content was available for only B tolerant crops (sugar beet, alfalfa, onion etc.). Increasing the leaching water doses resulted in decreases of B contents in soil profile. B contents in soil were reduced for the moderately tolerant crops such as barley, wheat, mays etc. after 120 cm leaching water application. The B contents were not found available even B sensitive crops in 180 cm leaching water application in control plots. In first dose of gypsum applied plot, B contents were reduced for tolerant crops after 60 cm and for moderately tolerant crops which of 150 cm leaching water applications. In second dose of gypsum applied plot, B contents were reduced for tolerant crops after 60 cm and for moderately tolerant crops which of 180 cm leaching water applications (Table 3).
- To determine present drainage and B toxicity problems in study region properly, detailed soil and land surveys are needed. The latest soil surveys in Konya closed basin was determined at the end of 1970 years and none surveys was conducted further.
- The results obtained from the leaching equations and curves in study soils can be used without field studies for similar characteristics of soils in this type of regions of the world. According to the many researches (Dorsan, 1988; Beyazgul, 1995; Yilmaz, 2001) surge basin irrigation has been suggested as more efficient method in leaching B from the soil profile.

Table 3: Relationship between residual B contents in first 30 cm soil depth and some crops

	Leaching water (cm)						
	0	30	60	90	120	150	180
Treatments	Boron contents (ppm)						
Control (0 t ha^{-1})	7.87	4.51	3.25	2.51	1.96	1.41	1.22
	-		Tolerant Crops (2-4 ppm) (Alfalfa, Onion, Lettuce etc.)		Moderately Tolerant Crops (1-2 ppm) (Barley, Wheat, Mays etc.)		
Gypsum (10 t ha^{-1})	8.12	4.77	3.37	2.96	2.20	1.95	1.63
	-		Tolerant Crops (2-4 ppm) (Alfalfa, Onion, Lettuce etc.)		Moderately Tolerant Crops, (1-2 ppm) (Barley, Wheat, Mays etc.)		
Gypsum (30 t ha^{-1})	8.45	4.92	3.32	3.09	2.39	2.01	1.82
	-		Tolerant Crops (2-4 ppm) (Alfalfa, Onion, Lettuce etc.)		Moderately Tolerant		

- Surface water resources are limited in study region so drainage water must be used in irrigation. Thus, most soils had salinity problems and should be improved. Surface water resources should be developed and if possible good quality water should be used in irrigation.
- To be succeeded good reclamation, farmers should be informed about irrigation water management. The organizations between agricultural sectors are prerequisites and farmer seminars should be organized by experienced persons.
- Reclamation works of saline-sodic and B affected soils should be sustainable so soils should be checked regularly. For this reason in improvement soils, physical and cultural practices are necessary. Soil organic matter contents should be increased for good crop growing and rotation system also is necessary to improve the soil fertility. In first years, B tolerant crops should be growth especially after reclamation.
- Before starting the detailed field studies, small size researches should be conducted to determine the most effective and economical reclamation methods in laboratory or field conditions.

REFERENCES

Anapalı, Ö., 1991. Iğdır Ovası tuzlu. sodyumlu ve borlu toprakların ıslahında kademeli jips uygulaması ile yıkama üzerine bir araştırma (An Investigation on gypsum application and leaching for improvement of Igdır plain saline-sodic and boron affected soils). Köy Hizmetleri Genel Müd. Köy Hizmetleri Erzurum Araştırma Enst. Müd. Genel Yayın No. 31. Erzurum.

Anonymous, 1998. Cumhuriyetin 75. Yilinda Konya. Konya Il Yilligi, Konya Valiligi, Konya.

Anonymous, 2004. Çiftçi El Kitabı (Guide Book of Farmers). Agricultural Chamber of Konya-Çumra.

Ayyildiz, M., 1983. Sulama Suyu Kalitesi ve Problemleri (Irrigation Water Quality and Its Problems). Ankara University, Agricultural Faculty Publications, No. 876. Student Notes. 224. Ankara.

Beyazgul, M., 1995. Salihli Ovası Tuzlu ve Alkali Toprakların Islahında Keçiborlu Kükürt İşletmesi Flotasyon Atıklarının Kullanma Olanakları (The Possibility Uses of Flotation Wastes Obtained from Keçiborlu Sulphur Factory for Improving Saline and Sodic Soils of Salihli Plain). Köy Hizmetleri Genel Müdürlüğü. Menemen Araştırma Enstitüsü Müdürlüğü Yayınları. Genel Yayın No. 207. Rapor Serisi: 135. Menemen. İzmir.

Dorsan, F., 1988. Gediz Havzasında Tuzlu, Tuzlu-Alkali Toprakların Kültürteknik Önlemlerle Islahı Üzerinde Bir Araştırma (An Investigation on Reclamation of Saline, Saline-Sodic Soils by Culturtechnique Methods in Gediz Basin). Aegean University, Graduate School of Natural and Applied Science, Ph.D Thesis, Izmir.

Goldberg, S., P.P. Shouse, S. Lesch, C. Grieve, J. Poss, H. Forster and D. Suarez, 2003. Effect of high boron application on boron content and growth of melon. Plant Soil J., 256: 403-411.

Keren, R. and F.T. Bingham, 1985. Boron in water, soils and plants. Adv. Soil Sci., 1: 230-276.

Kovda, V.A., 1967. International Source-Book on Irrigation and Drainage of Arid Lands in Relation to Salinity and Alkalinity. FAO/UNESCO.

Laila, E.A.N. and E.A.A. Adel, 2002. Effect of boron deficiency on some physiological and biochemical aspects during the developmental stages of wheat (*Triticum aestivum* L.) plant. J. Biol. Sci., 2: 470-476.

Manyowa, N.M. and T.E. Miller, 1991. The genetics of tolerance to high mineral concentrations in the tribe triticeae- a review and update. Euphytica, 57: 175-185.

Marschner, H., 1995. Mineral Nutrition of Higher Plants. 2nd Edn., Academic Pres. New York, pp: 379-396.

Nable, R.O., G.S. Banuelos and J.G. Paull, 1997. Boron Toxicity. Plant and Soil, 193: 181-198.

Reeve, R.C., A.F. Plsbury and L.V. Wilcox, 1955. Reclamation of saline and high boron soil in the Cachela Valley. Hilgardia, 24: 69-91.

Rowe, D.R. and I.M. Abdel-Magid, 1995. Handbook of Wastewater Reclamation and Reuse. CRC Press. Inc., pp: 550.

Sartaj, M. and L. Fernandes, 2005. Adsorption of boron from landfill leachate by peat and the effect of environmental factors. J. Environ. Eng. Sci., 4: 19-28.

Sonmez, B., 2003. Türkiye Çoraklık Kontrol Rehberi (Desertification Control Guide in Turkey). Tarım ve Köyişleri Bakanlığı Köy Hizmetleri Genel Müdürlüğü Toprak ve Gübre Araştırma Enstitüsü Müdürlüğü. Teknik Yayın No. 33. Ankara.

Yilmaz, A.M., 2001. Konya Ovası Tuzlu-Sodyumlu Toprakların Islahı Üzerine Bir Araştırma (A Research on Reclamation of Saline-Sodic Soils of Konya Plain). Selcuk University, Graduate School of Natural and Applied Science, Ph.D Thesis, Konya.