Soil Environ. 35(2): 181-186, 2016
www.se.org.pk
Online ISSN: 2075-1141
Print ISSN: 2074-9546

Influence of boron fertilization on growth and yield of wheat crop under salt stress environment

Muhammad Zafar-ul-Hye[1], Kashif Munir[1], Maqshoof Ahmad[2] and Muhmmad Imran[1*]
[1]Department of Soil Science, Bahauddin Zakariya University, Multan
[2]Department of Soil Science, University College of Agriculture and Environmental Sciences, The Islamia University of Bahawalpur

Abstract

Nutrient management in sodic condition is much more important for economical production of wheat. A field experiment on salt affected soil was performed to evaluate the response of wheat (cv. Sehar) to soil boron (B) application. Boron was applied at 0, 0.5, 1.0, 1.5 and 2.0 kg ha^{-1}. There was antagonistic influence of B application on various plant growth parameters of wheat under salt affected conditions and minimum yields were observed at 2 kg ha^{-1}. The pre-sowing soil analysis indicated that soil had optimum B level for growth of wheat crop. Addition of B increased phyto-available B concentration in soil as confirmed in post-harvest soil analysis. With the incremental of B, plant accumulated greater B concentrations. However, B concentration in plant tissues was not upto toxic limits generally accepted for wheat crop. Therefore, B mediated reduced the plant growth and grain yield under salt conditions might be related to interactions among N, P and K. Based on findings, it is concluded that B application is not required for sodic soils.

Keywords: Boron application, growth parameters, wheat crop

Introduction

Wheat crop is of vital importance in cereals and is the staple food crop for Pakistani people. It contributes 10.3% to the value added in agriculture and 2.2% to GDP. In Pakistan, 9.40 million hectares area was under wheat crop cultivation in 2013-14. Its total production was 25.29 million tons by an average yield of 2797 kg ha^{-1} (GOP, 2014).

Boron is also vital mineral among micronutrients compulsory for plants growth (Brown *et al*., 2002). It is involved in many physiological processes in plants like RNA and carbohydrates metabolism (Herrera-Rodriguez *et al*., 2010; Siddiky *et al*., 2007) and development of cell wall. It has also a vital function in pollen tube growth and its germination, seed development, plasma membrane stimulation, floret fertility and anther development (Wang *et al*., 2003; Oosterhuis, 2001).

Boron insufficiency is also the main reason in reduction of plant height, plant total dry matter, number of reproductive parts during fruiting stage and leaf photosynthetic rate (Zhao and Oosterhuis, 2003). Its insufficiency also harms grain setting in wheat crop plants, resulted in improved open spikelet numbers as well as decreased grains per spike.

Boron soil application increased K concentration (Tariq and Mott, 2006). This was expected due to mutual synergistic interaction between B and K (Hosseini *et al.*, 2007). Widespread insufficiency of B is found in soil having calcareous in nature that ultimately influences various Pakistani horticultural and agronomic crops (Rashid *et al*., 2011). This type of B insufficiency may be because of its fixation with $CaCO_3$ (Chen *et al*., 2009). Hence, Pakistani soils are normally calcareous as well as alkaline/saline in nature that are insufficient in micronutrient particularly B (Rashid and Ryan, 2004).

Soil sodicity is major crop limiting problem in arid zone agriculture. Almost 40,000 hectares Pakistani cultivated land is lost every year due to salinity. It is estimated that about 33% of irrigated land is influenced by saline soil condition and this cause an alarming situation to farming community (Ahmad et al., 2006; Ashraf et al., 2008). High concentration of soluble salts in the soil moisture of root zone results in the reduction of petiole epinasty, loss of turgor, plant growth, early senescence and leaf abscission (Ashraf and Harris, 2004; Noreen and Ashraf, 2008).

Soil salinity/sodicity is the major environmental strain in arid to semi-arid areas of Pakistan which ultimately reduced the crop yield of many crops. Salinity of soil is one of the major concern during the last decade because of its increasing area throughout the globe (Wicke *et al*., 2011). Apart from this, agricultural production of crops is largely affected by salinity problems around the globe (Wicke *et al*., 2011). Alkaline calcareous soils respond differently to B fertilization and soil B bioavailability decreased as increase in soil pH above 7 (Wang *et al*., 2001).

*Email: mimran106@yahoo.com

Very little information has been investigated about the B requirement is sodic soils in Pakistan. So, this trial was aimed to check B requirement for wheat growth and yield grown under sodic soil conditions as well as its effect on N, P and K concentration. This study also aimed to check bioavailable B in soil after crop harvest under salt affected conditions.

Materials and Methods

A field study was conducted on salt affected soil to observe the effect of boron on wheat crop in the experimental area of Bahauddin Zakariya University, Multan. Before sowing, randomized soil samples were collected from the field. These were air dried, passed through a 2 mm sieve and analyzed in laboratory to determine physical and chemical characteristics of the soil (Table 1). The experiment was laid out in Randomized Complete Block Design with five treatments. Every treatment was replicated thrice. Wheat cultivar *Sehar* was sown in rows (rows were 20 cm apart) of 6 × 4 m^2 plots. Experiment comprised of the following B treatment: control, 0.5, 1.0, 1.5 and 2.0 kg B ha^{-1} as boric acid.

grinding machine and stored in clean dry plastic containers for chemical analysis. Dried plant material was digested in diacid mixture (20 ml concentrated HNO_3 and 10 ml of 72 % $HClO_4$) (Richards *et al.,* 1954). For B determination, plant samples were dry ashed in porcelain crucible. Boron was analyzed on a colorimeter using Azomethine-H (Bingham, 1982). Soil was also sampled for hot water extractable post-harvest B status. Vanadate-molybdate method was used for the determination of Phosphorus concentration in plant digested samples with UV-visible spectrophotometer (Shimadzu UV-1201; Chapman and Pratt, 1961). Nitrogen contents in plant tissues were determined by Kjeldahl method (Nelson and Sommers, 1973). Flame photometer was used for potassium (K) determination (Chapman and Parker, 1961).

Least significant difference (LSD) test was applied to separate significantly different treatment means (Steel *et al*., 1997). Standard deviations reported where required. Computer based softwares; *Statistix 9*® and MS Excel, were used for statistical analysis. The computer package Excel Graphics was used for the preparation of graphs.

Table 1. Pre-sowing soil analysis

Parameter	Unit	Value	Method
Sand	%	19	Bouyoucos hydrometer method
Silt	%	61	(Moodie *et al*., 1959).
Clay	%	20	
Textural Class	Silt loam		USDA
EC_e	dS m^{-1}	2.3	Saturated soil paste extract
pH_s	-	8.2	Saturated soil paste
Organic matter	%	0.78	Walky and Black (1934).
Calcium carbonate	%	7.44	(Moodie *et al.*, 1959).
Available Boron	mg kg^{-1}	0.48	(Bingham, 1982)
Sodium adsorption ratio	$(mmol_c\ L^{-1})^{1/2}$	42.5	Saturated soil paste extract
Exchangable sodium percentage	%	18	Saturated soil paste extract

Uniform rates (in kg ha^{-1}) of 110 N, 90 P and 60 K were applied to all plots respectively as urea, triple super phosphate, sulphate of potash. Full dose of P, K, B and half dose of N were applied at the time of sowing and remaining half of the N was applied in two split doses. Canal water was applied throughout the growing period when required. Standard agronomic practices were followed for crop husbandry.

At maturity, plant height, tillers per unit area, grains per spike, grain weight, straw yield and grain yield were measured. Samples from each plot were harvested manual threshed to separate grain and straw. Grain and straw samples were then dried in oven at 70° C. The oven dried plant samples were ground to powdered form with electric

Results

Plant growth and grain yield

There was significant effect of B application on plant height, tillers per unit area, grain per spike and grain weight (Table 2). Maximum growth and values of above parameter was observed in control treatment. Boron application @ 1.5 kg ha^{-1} or higher rate significantly reduced plant height, tillers per unit area, grain per spike and grain weight with respect to control.

Significant differences on straw yield were observed (Table 2). Maximum straw yield (8.23 t ha^{-1}) was obtained at control and it decreased with incremental rate of B application. As compared to control, decrease in straw yield was 4%, 6%, 9% and 10% respectively at 0.5, 1.0, 1.5 and 2.0 kg B ha^{-1}. However, there were non-significant differences in grain yields achieved at control, 0.5, 1.0 and 1.5 kg B ha^{-1}. Nevertheless, a significant reduction (13% than control) in grain yield was observed at 2.0 kg B ha^{-1}.

Nitrogen concentration in plant tissues (%)

The data revealed that there were non-significant effect of boron application on nitrogen concentration in grains and straw is concerned. However maximum nitrogen concentration in grains (1.78 %) was found where no boron was applied and minimum nitrogen concentration in grains (1.68 %) was found where boron was applied at 2.0 kg B ha^{-1}. The treatments 0.5, 1, 1.5 and 2 kg B ha^{-1} decreased 2.32%, 2.71%, 4.21% and 5.50% nitrogen concentration in grains as compared to the control respectively (Table 3). However, maximum nitrogen concentration in straw (0.692%) was found where B was applied at 1.0 kg ha^{-1} and minimum nitrogen concentration in straw (0.61 %) was found where boron was applied at 1.5 kg ha^{-1}. Boron application at 1.5 kg B ha^{-1} decreased 0.114% as compared to control. The treatments 0.5, 1 and 2 kg B ha^{-1} increased the nitrogen concentration by 5.81, 12.98, and 0.98% in straw as compared to the control respectively (Table 3).

Table 2: Growth and yield parameters of wheat crop under different boron levels

B rate (kg B ha^{-1})	Plant height (cm)	No. of tillers m^{-2}	Grains spike^{-1}	Grain weight (mg grain^{-1})	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})
Control	96 A	379 A	53 A	46 A	4.51 A	8.23 A
0.5	95 AB	375 AB	52 AB	45 A	4.63 A	7.96 AB
1	95 AB	373 ABC	51 B	44 AB	4.50 A	7.71 BC
1.5	94 BC	371 BC	51 BC	43 B	4.40 A	7.45 CD
2	92 C	369 C	49 C	41 C	3.90 B	7.37 D
LSD <0.05	**2.25**	**6.13**	**1.70**	**2.12**	**0.33**	**0.28**

Means not sharing the same letter within a column differ significantly from each other at 5% level of probability

Table 3: Boron and nitrogen concentration in wheat grain and straw under different boron levels

B rate (kg B ha^{-1})	Biological Yield (t ha^{-1})	Boron Concentration in grains (mg kg^{-1})	Boron Concentration in straw (mg kg^{-1})	Nitrogen Concentration in grains (%)	Nitrogen Concentration in Straw (%)
Control	12.74 A	1.00 C	1.16 D	1.78 A	0.61 A
0.5	12.60 AB	1.02 B	1.17 CD	1.74 A	0.65 A
1	12.21 BC	1.02 B	1.18 C	1.73 A	0.69 A
1.5	11.85 C	1.04 A	1.20 B	1.71 A	0.61 A
2	11.27 D	1.05 A	1.23 A	1.68 A	0.62 A
LSD <0.05	**0.47**	**0.02**	**0.02**	**0.15 $^{n.s.}$**	**0.17 $^{n.s.}$**

ns = Non Significant, Means not sharing the same letter within a column differ significantly from each other at 5% level of probability

Significance effect of B application was observed on wheat biological yield. Control and 0.5 kg B ha^{-1} produced non-significant differences with respect to each other and significantly differed from treatments 1, 1.5 and 2 kg B ha^{-1}. There was a gradual decrease in biological yield from all treatments. In the treatments where 0.5, 1, 1.5, and 2 kg B ha^{-1} were applied, biological yield was decreased by 1.10%, 4.11%, 6.99% and 11.54% as compared to the control respectively.

Boron concentration in plant tissues and in soil

Significant effect of B application was observed on straw and grain B concentrations. Boron concentration in plant tissues progressively increased with the incremental rates of B (Table 3).

There were significant differences in plant available B in soil after crop harvest. Maximum phytoavailable boron in soil after crop harvest (0.53 mg kg^{-1}) was at 2 kg B ha^{-1} and minimum phytoavailable B in soil after crop harvest (0.47 mg kg^{-1}) was at control (Table 4).

Phosphorous concentration in plant tissues (%)

The data revealed that there were non-significant differences as far as effect of boron application on phosphorus concentration in grains and straw is concerned. However, maximum phosphorus concentration in grains (0.458 %) was found where boron was applied at 2 kg ha^{-1} and minimum phosphorus concentration in grains (0.43 %) was found where boron was applied at 1 kg ha^{-1}. The treatments 1 and 1.5 kg B ha^{-1} decreased 4.195% and 0.987% as compared to control whereas treatments 0.5 and 2 kg B ha^{-1} increased 0.58% and 2.83% respectively, as compared to control (Table 4). However, maximum phosphorus concentration in straw (0.027%) was found in control (Table 4). The treatments 0.5, 1, 1.5 and 2 kg B ha^{-1} decreased P concentration in straw by 3.7%, 15.93%, 11.11% and 11.11% as compared to control respectively (Table 4).

Table 4: Phosphorous, potassium concentration in wheat grain and straw and available soil boron after harvest in soil under different boron levels

B rate (kg B ha^{-1})	Phosphorous Concentration in grains (%)	Phosphorous Concentration in straw (%)	Potassium Concentration in grains (%)	Potassium Concentration in straw (%)	Available soil Boron after crop harvest (mg kg^{-1})
Control	0.446 A	0.027 A	0.98 B	1.45 C	0.47 C
0.5	0.448 A	0.026 A	1.33 AB	2.44 AB	0.47 C
1	0.427 A	0.023 A	1.99 A	2.25 AB	0.49 BC
1.5	0.441 A	0.024 A	0.98 B	2.30 B	0.51 AB
2	0.458 A	0.024 A	1.27 AB	2.17 A	0.53 A
LSD <0.05	**0.05** $^{n.s}$	**5.14** $^{n.s}$	**0.77** $^{n.s}$	**0.19**	**0.03**

n.s. = Non Significant, Means not sharing the same letter within a column differ significantly from each other at 5% level of probability

Potassium concentration in plant tissues (%)

The data showed that there were non-significant differences on potassium concentration in grains is concerned. However maximum Potassium concentration in grains (1.99%) was obtained where B was applied @ 1.00 kg ha^{-1} and minimum Potassium concentration in grains (0.98%) was found where boron was applied @ 1.5 kg ha^{-1}. The application of 0.5, 1 and 2 kg B ha^{-1} increased potassium concentration by 35.61%, 103%, and 29.2% respectively, whereas, 1.5 kg B ha^{-1} decreased potassium concentration in grains by 0.23% as compared to the control (Table 4). There were significant differences as far as effect of boron application on potassium concentration in straw is concerned. Maximum K concentration in straw (2.44%) was found where B was applied @ 0.5 kg B ha^{-1} and minimum K concentration in straw (1.45%) was found where no boron was applied (Table 4). The treatments 0.5, 1 and 2 kg B ha^{-1} produced non-significant differences with respect to each other and differed significantly with control and 1.5 kg B ha^{-1}. The 0.5, 1, 1.5 and 2 kg B ha^{-1} increased potassium concentration in straw by 68.82%, 55.31%, 58.93% and 49.96% respectively as compared to the control.

Discussion

Boron is essential element for plant growth. However, there is a narrow range between B sufficiency and toxicity. Moreover, high concentration of Na^+ in sodic soil interacts with different plant nutrients and affects their availability from the soil, uptake by roots and utilization in plants. Membrane permeability significantly increases in the presence of salts and increased levels of B (Alpaslan and Gunes, 2001). Additional B fertilization as well as salinity/sodicity caused reduction in crop yield and activity by various mechanisms in the plants. Reduction in osmotic potential in the soil solution in plants was observed due to salinity problems that ultimately reduce water uptake and possibly caused ion toxicity in plant tissue (Shannon and Grieve, 1999). High osmotic stresses in plants were observed in saline/sodic soils and high concentration of potentially toxic ions (Na^+ and Cl^-) which effect reduction in plant growth (Martinez & Lauchli, 1993). Osmotic adjustment is facilitated by ion absorption and it may cause nutritional imbalance and ion toxicity (Aslam *et al*., 1996; Lutts *et al*., 1996). Balance use of fertilizers could reduce salt induced nutritional imbalance and growth inhibition in plants (Aslam *et al.,* 1996).

As concentration of B fertilization increased, growth and yield attributes of wheat decreased (Table 2 and 3). The reason behind these phenomena might be due to less net leaf photosynthates accumulation or production of some toxic substances which lead to suppression of growth. Similar findings were reported by Zhao and Oosterhuis (2003) who reported that plant height in cotton decreased due to net leaf photosynthates accumulation. Edelstein *et al.* (2005) also reported that combined effects of B application and salinity reduced the growth of plant. Supanjani (2006) also supported that combined effects of salinity and B application produced toxic substances that lead to suppression of growth *i.e.*, growth and yield parameters in hot pepper. Sotiropolou (2006) reported that plant growth in pears reduced by the combined effects of salinity and B application.

Soluble B concentrations in basal leaf parts significantly improved as a result of combination of salt and high B doses as paralleled with high sole B fertilization. Boron toxicity interacted with salinity and it effect B partitioning as well as water uptake within the plant. Smith et al. (2010) demonstrate in their experiment that plants head yield and shoot biomass were significantly reduced by B. Grieve and Poss (2000) also reported the same findings that combined effect of salinity and B significantly reduced the yield components. Yield of wheat was also decreased as B fertilization rates are increased (Table 3). Miwa and his co-workers (2007) stated that yield outputs were reduced in many crops due to the toxic effects of B. By applying B, its concentration in grains and straw increased (Table 3.). The results are in line with those of Wrobel (2009) who reported under salt affected conditions that there was statistically significant improvement in grain and straw B concentration. Boron toxicity is frequently confused with the problems of salinity/sodicity (Gupta, 1993) and usually found at toxic level in these types of soils (Hutchison & Viets, 1969; Ilin & Anikina, 1974).

The application of B had no significant effect on N and P concentration in grains under salt affected soil (Table 3 and 4). Similar findings were given by Farshad, 2011; Ghattak *et al*., 2006 who reported that B neither antagonistically nor synergistically affected the N and P concentration in wheat grains under salt affected conditions. Boron has also synergetic effect on K concentration in wheat grains and straw (Table 4). Boron had synergistic effect on K concentration in wheat grains and straw under salt affected conditions (Mehmood *et al*., 2009). After crop harvest, B concentration increase as its rate increase (Table 4). These results are in agreement with those of Khan *et al*. (2006) who observed in a field experiment that the B concentration in soil after crop harvest was significantly increased. This was due to more accumulation of B in soil which retained even after the harvesting of crops under salt affected conditions.

Conclusion

Excess of B was found to decrease yield and nutrient attributes of wheat in sodic soils. Therefore, it is recommended that B is not required for sodic soil.

References

Ahmad, M.S.A., Q. Ali, R. Bashir, F. Javed and A.K. Alvi. 2006. Time course changes in ionic composition and total soluble carbohydrates in two barley cultivars at seedling stage under salt stress. *Pakistan Journal of Botany* 38: 1457–1466.

Alpaslan, M. and A. Gunes. 2001. Interactive effects of boron and salinity stress on the growth, membrane permeability and mineral composition of tomato and cucumber plants. *Plant and Soil* 236: 123-128.

Ashraf, M. and P.J.C. Harris. 2004. Potential biochemical indicators of salinity tolerance in plants. *Plant Science* 166: 3–16.

Ashraf, M., H.R. Athar, P.J.C. Harris and T.R. Kwon. 2008. Some prospective strategies for improving crop salt tolerance. *Advances in Agronomy* 97: 45–110.

Aslam, M., T.J. Flowers, R.H. Qurashi and A.R. Yeo. 1996. Interaction of phosphorus and salinity on the growth and yield of rice (*Oryza sativa* L.). *Journal of Agronomy and Crop Science* 176: 249-258.

Bingham, F.T. 1982. Methods of Soil Analysis. Boron p.431-448. In: Page A. L: (ed.). Part II; Chemical and Microbiological Properties. *American Society of Agronomy* Madison, WI, USA.

Brown, P.H., N. Bellaloui, M.A. Wimmer, E.S. Bassil, J. Ruiz, H. Hu, H. Pfeffer, F. Dannel and V. Romheld. 2002. Boron in plant biology. *Plant Biology* 4: 205–223.

Chapman, D.H. and F. Parker. 1961. Determination of NPK. In: Methods of Analysis for Soils, Plants and Water, pp. 150–179. Berkeley, CA: University of California, Agriculture Division.

Chapman, D.H. and P.F. Pratt. 1961. Methods of analysis for soils, plants and waters. Univ. of California, Division of Agri. Sci., Riverside, USA.

Chen, W.T., S.B. Ho and D.Y. Lee. 2009. Effect of pH on boron adsorption-desorption hysteresis of soils. *Soil Science* 174: 330–338.

Edelstein, M., M. Ben-Hur, R. Cohen, Y. Burger and I. Ravina. 2005. Boron and salinity effects on grafted and non-grafted melon plants. *Plant and Soil* 269: 273–284.

Farshad, A. 2011. The effect of boron and zinc application on concentration and uptake of nitrogen, phosphorous and potassium in corn grain, Department of Soil Science, Science and research branch, Islamic Azad University, Fars, Iran 4 (7): 0974 – 6846.

Ghatak, R., P.K. Jana., G. Sounda., R.K. Ghosh and P. Bandyopadhyay. 2006. Effect of boron on yield, concentration and uptake of N, P and K by wheat grown in farmer's field on red and laterite soils of Purulia, West Bengal. *Indian Agriculture* 50: 15-77.

GOP. 2014. Agricultural Statistic of Pakistan. Minestry of Food, Agriculture and Livestock, Islamabad, Pakistan.

Grieve, C. N. and J.A. Poss. 2000. Wheat response to interactive effects of boron and salinity. *Journal of Plant Nutrition* 23: 1217 – 1226.

Gupta, U.C. 1993. Boron and its role in crop protection. CRC Pres. p. 208-224.

Herrera-Rodriguez, M.B., A. Gonzalez-Fontes, J. Rexach, J.J. Camacho-Cristobal, J.M. Maldonado and M.T. Navarro-Gochicao. 2010. Role of boron in vascular plants and response mechanism to boron stresses. *Plant Stress* 4: 115-122.

Hosseini, S.M., M. Maftoun, N. Karimian, A. Ronaghi and Y. Emam. 2007. Effect of zinc× boron interaction on plant growth and tissue nutrient concentration of corn. *Journal of plant nutrition* 30: 773-781.

Hutchinson, G.L. and F.G. Viets. 1969. Detoxification of boron in plants with Triisopropanolamine. *Soil Science* 108: 217-221.

Ilin V.B. and A.P Anikina. 1974. Soil amelioration: Boron Stalinization of soils. *Society of Soil Science* 6: 68-74.

Khan, R., A. H. Gurmani, A.R. Gurmani, and M.S. Zia. 2006. Effect of boron application on rice yield under wheat rice system. *International Journal of Agriculture and Biology* 8: 805-808.

Lutts, S., J.M. Kinet and J. Bouharmont. 1996. NaCl induced senescence in leaves of rice (*Oryza sativa* L.) cultivars differing in salinity resistance. *Annals of Botany* 78: 389-398.

Martinez, V. and A. Lauchli. 1993. Effects of Ca^{2+} on salt-stress response of barley roots as observed by In vivo (31) P nuclear magnetic resonance and In vitro analysis. *Planta* 190: 519-524.

Mehmood, E., K. Rizwana, A. Muhammad and S.S. Muhammad. 2009. Is Boron Required to Improve Rice Growth and Yield in Saline Environment? Institute of Soil & Environmental Sciences, University of Agriculture, Faisalabad, Pakistan. *Pakistan Journal of Botany* 41(3): 1339-1350.

Miwa, K., J. Takano, H. Omori, M. Seki, K. Shinozaki and T. Fujiwara. 2007. Plants tolerant of high boron levels. *Science* 318(5855): 1417.

Moodie, C.D., H.W. Smith and R.A. Mcreery. 1959. Laboratory manual for soil fertility. State college of Washington, Mimeograph, Pullman Washington, D. C. USA pp.31-39.

Nelson, D.W., and L.E. Sommers. 1973. Determination of total nitrogen in plant material. *Agronomy Journal* 65: 109-112.

Noreen, S. and M. Ashraf. 2008. Alleviation of adverse effects of salt stress on sunflower (*Helianthus annuus* L.) by exogenous application of salicylic acid: growth and photosynthesis. *Pakistan journal of Botany* 40: 1657-1663.

Oosterhuis, D.M. 2001. Physiology and nutrition of high yielding cotton in the USA. In. Informacoes Agronomicas N-Setembro. pp. 18-24.

Rashid, A. and J. Ryan. 2004. Micronutrient constraint to crop production in soils with mediterranen type characteristics: A review. *Journal of Plant Nutrition* 27: 959-975.

Rashid, A., E. Rafique, A.U. Bhatti, J. Ryan, N. Bughio and S.K. Yau. 2011. Boron deficiency in rainfed wheat in Pakistan: Incidence, spatial variability and management strategies. *Journal of Plant Nutrition* 34: 600–613.

Richards, L.A. 1954. Diagnosis and improvement of saline and alkali soils. USDA Agric Handbook 60, Washington DC.

Shannon, M.C. and C.M. Grieve. 1999. Tolerance of vegetable crops to salinity. *Scientia Horticulturae* 78: 5–38.

Siddiky, M.A., N. K. Halder, K.U. Ahammad, K. Anam and M. Rafiuddin. 2007. Response of brinjal to zinc and boron fertilization. *International Journal of Sustainable Agriculture and Technology* 3(3): 40-45.

Smith, T.E., S.R. Grattan, C.M. Grieve, J.A. Poss and D.L. Suarez. 2010. Salinity's influence on boron toxicity in broccoli: II. Impacts on boron uptake, uptake mechanisms and tissue ion relations. *Agriculture and Water Management* 97: 783-791.

Sotiropoulos, T.E., Fotopoulos, S. Dimassi K.N., Tsirakoglou, V and Therios, I. N. 2006. Response of the pear rootstock to boron and salinity in vitro. *Biology and Plant* 50: 779-781.

Steel, R.G.D., J. H. Torrie and D.A. Dicky. 1997. Principles and Procedures of Statistics. A Biometrical Approach 3rd Ed. McGraw Hill Book International Co., Singapore p. 204-227.

Supanjani, K.D.L. 2006. Hot pepper response to interactive effects of salinity and boron. *Plant Soil Environment* 52: 227-233

Tariq, M. and C.J.B. Mott. 2006. Effect of applied boron on the accumulation of cations and their ratios to boron in radish (*Raphanus sativus* L.). *Soil and Environment* 25: 40-47.

Walky, A. and I.A. Black. 1934. An examination of the Degtiareff method for determining soil organic matter and proposed modification of the chromic acid titration method. *Soil Science* 63: 29-38.

Wang, G., A. Dobermann, C. Witt, Q. Sun and R. Fu. 2001. Performance of site-specific nutrient management for irrigated rice in southeast china. *Agronomy Journal* 93: 869–878.

Wang, Q., L.U. Longdou, W.U. Xiaoqin, L.I. Yiqin and L.I.N Jinxing. 2003. Boron influences pollen germination and pollen tube growth in Picea meyeri. *Tree Physiology* 23: 345–351.

Wicke, B., E. Smeets, V. Dornburg, B. Vashev, T. Gaiser, W. Turkenburg and A. Faaij. 2011. The global technical and economic potential of bioenergy from salt-affected soils. *Energy Environment and Science* 2011: 2669–2681.

Wrobel, S. 2009. Response of spring wheat to foliar fertilization with boron under reduced boron availability. *Journal of Elementology* 14: 395 – 404.

Zhao, D. and D.M. Oosterhuis. 2003. Cotton growth and physiological responses to boron deficiency. *Journal of Plant Nutrition* 26(4): 855-867.