OPEN ACCESS J. Arab. Crops Market. 02 (01) 2020. 01-07 DOI: 10.33687/jacm.002.01.3186

Check for updates

Available Online at EScience Press

Journal of Arable Crops and Marketing

ISSN: 2709-8109 (Online), 2709-8095 (Print)

https://esciencepress.net/journals/JACM

Boron fertilization improves quality and yield of maize (*Zea mays* L.)

[a]Rana Nauman Shabbir*, [a]Shabir Hussain, [a]Hakoomat Ali, [a]Ahsan Areeb, [a]Muhammad Irfan, [b]Zeeshan Ahmed, [a]Shakeel Ahmad, [a]Saadullah Manzoor

[a] Dept. of Agronomy, Faculty of Agricultural Sciences& Technology, Bahauddin Zakariya University, Multan, Pakistan.

[b] Dept. of Agronomy, University College of Agriculture & Environmental Sciences, The Islamia University of Bahawalpur, Pakistan.

**Corresponding Author Email: nauman.shabbir@bzu.edu.pk, Tel: +92-333-9503131*

ARTICLE INFO

Article history

Received: February 10, 2020

Revised: April 29, 2020

Accepted: May 28, 2020

Keywords

Boron

Maize

Oil contents

Protein contents

Starch contents

ABSTRACT

Boron deficiency drastically affects the yield and quality of many crops especially maize. The low availability of boron in soils is one of the major causes of poor quality and low yield of maize in Pakistan. A wirehouse experiment was carried out at Department of Crop Physiology, University of Agriculture, Faisalabad to optimize the dose of boron to increase quality and yield of maize. Two recommended local maize hybrids Monsanto-919 and Monsanto-5219 were evaluated in a randomized complete block design with factorial arrangements. The Boron was applied as borax @ 0, 0.3, 0.6, 0.9, 1.2 and 1.5 kg ha^{-1} at tasseling stage. Although both hybrids showed non-significant differences in yield attributes exogenous boron supply @ 0.6 kg boron ha^{-1} increased grain yield by 27% as compared to control treatment in both the hybrids. It increased grain oil, protein and starch contents by 10%, 12% and 16% respectively.

INTRODUCTION

Maize, commonly known as the king of grain crops, is grown extensively in Pakistan and occupies the third position after wheat and rice. Imbalanced application and improper management of plant essential elements have limited yield potential of crops in the country. Better plant nutrient management is necessary for achieving self-reliance in agriculture (Ahmad and Muhammad, 1998). Boron is one of the most commonly deficient micronutrients in agriculture, with reports of deficiencies in 132 crops and in 80 countries (Shorrocks, 1997). Boron deficiency results in the general stunting of the young plants due to shortening of the internodes; leaves of young plants fail to emerge, and death of growing point may occur (Follett *et al*., 1981). These deficiencies typically result from boron leaching (Welch, *et al*., 1991; Mortvedt and Woodruff, 1993; Marschner, 1995). Boron's widespread role within the plant includes cell wall synthesis, sugar transport, cell division, differentiation, membrane functioning, root elongation, and regulation of plant hormone levels (Pilbeam and Kirkby, 1983; Romheld and Marschner, 1991; Marschner, 1995). Many researchers have reported the significance of exogenous boron supply to different crops (Reinbott and Blevins, 1995; Hudson and Clarke, 1997; Ismail, 2003; Garcia *et al*., 2005). Increase in solution B concentration increased the concentration of B in the ear leaf and root and changed the concentrations of Nitrogen (N), Phosphorous (P), Manganese (Mn), Iron (Fe), Zinc (Zn), and Molybdenum (Mo) in the ear leaf and calcium (Ca), Magnesium (Mg), copper (Cu), Mn, Fe, Zn and Mo in the root (Mozafar, 1989; Adiloglu and Adiloglu, 2006). Soil-applied B rates of 2.8 kg ha^{-1} in a silt clay loam increased soybean yield by 11 % and 13%, respectively, in the first two years with no effect in the third year after application (Reinbott and Blevins, 1995).

Keeping in view the above-mentioned facts, the present study was carried out with the objective of evaluating the role of exogenous boron supply to maize hybrids.

MATERIAL AND METHODS

The present study was carried out at the wirehouse of Department of Crop Physiology University of Agriculture, Faisalabad. The Experiment was laid out in a randomized complete block design (RCBD) with factorial arrangements. Two local maize hybrids (Monsanto-919 and Monsanto-5219) were used as experimental crops. Five seeds of each hybrid were sown in plastic pots of 10 kg capacity, however; only two plants were grown till maturity.

Soil analysis: Before sowing, soil samples were taken from soil used to fill pots to determine initial soil fertility level. The available B in soil was determined by dilute HCl method (Kausar *et al*., 1990). Available S in soil was determined by Turbidimetric method (Verma, 1977). Available K in soil was determined with ammonium acetate solution (Richards, 1954). Available P in soil was determined by sodium bicarbonate method (Olsen and Sommers, 1982). Total Nitrogen in soil was determined by the Kjeldahl method. (Bremner and Mulvaney, 1982; Buresh *et al*., 1982). The soil analysis revealed 0.2 mg kg^{-1} available boron (B), 7.5 mg kg^{-1} available sulphur (S), 175 mg kg^{-1} potassium (K), 1 mg kg^{-1} phosphorous (P) and 0.21% available nitrogen (N) in the soil (Table 1). Borax was used as a source of boron and 1.5, 3.0, 4.5, 6.0 and 7.5 mg of borax, for application of boron @ 0, 0.3, 0.6, 0.9, 1.2 and 1.5 kg ha^{-1} respectively, was mixed separately in 10 kg of soil for each pot after taking soil samples for analysis. All other fertilization and cultural practices were standard and uniform. The plants were harvested at maturity to record various growth, quality and yield attributes by using standard procedures.

Table 1. Physico-chemical analysis of experimental soil.

Determination	Unit	Value obtained
pH		8.3
Organic matter	%	0.95
Available B	ppm	0.2
Available S	ppm	7.5
Available K	ppm	175
Total N	%	0.21
Available phosphorus	ppm	1

Quality variables: Total nitrogen in grain was determined by Gunning and Hibbard's method of sulphuric acid digestion and distillation by micro-Kjeldhals method (Jackson, 1962). Seed samples equal to one gram from each pot were taken randomly, ground and subjected to chemical analysis according to Kjeldahl's method to estimate nitrogen content (Jackson, 1962). Nitrogen (%) was then multiplied by a constant factor 6.25 for calculating protein (%) in the grain (Hiller *et al.,* 1948). For oil analysis, the representative samples from each pot were dried and ground. Oil contents in grains were determined by means of Soxhlet fat extraction method (Low, 1990). Grain starch contents were determined by treating the seed sample was with 80 % alcohol to remove sugars and then starch was extracted with perchloric acid. In hot acid, medium starch was hydrolyzed to glucose and dehydrated to hydro methyl furfural. This compound formed a green colour product with anthrone (Thimmaiah, 2004).

Statistical analysis: The data obtained from different variables were analyzed statistically using Fishers Analysis of Variance Technique and least significant difference test level was used to compare differences among the treatments means (Steel *et al.,* 1997).

RESULTS

Growth variables

The boron application significantly affected various growth attributes of both hybrids. The maximum leaf area (3164 cm^2) cm^2) was observed where boron was applied @ 0.6 kg ha^{-1} while minimum leaf area (2920 cm^2) in control treatment (no boron supply). Among hybrids, Monsanto-5219 attained significantly higher leaf area $plant^{-1}$ (3066) than Monsanto-919 (3029 cm^2) however, the interaction was non-significant among hybrids and boron levels (Table 4). The exogenous boron application significantly increased cob length in both the hybrids. The maximum cob length (17.68 cm) was recorded by the boron application @ 0.6 kg ha^{-1} while the control (0 kg boron ha^{-1}) gave minimum cob length (15.21 cm) which was statistically at par with boron applied @ 0.3 kg ha^{-1}. Among different hybrids, the maximum cob length (16.58 cm) was recorded in Monsanto-919 and minimum cob length of 16.43 cm was noted in Monsanto-5219 (Table 4).

Table 2. Analysis of variance (ANOVA) of two maize hybrids for various growth and yield variables.

Variables	Hybrids (1 d.f)	Boron levels (5 d.f)	B x H (5 d.f)	Error (22 d.f)
Leaf area (cm^2)	12469.4*	49864.8*	2338.4*	2181.5
Cob Diameter	1.02684 *	0.84988*	0.08 *	0.009
Cob length (cm)	0.30988 NS	6.18531*	1.08 NS	0.44
No. of grains cob^{-1}	126.94 NS	9194.33 *	431.41 NS	661.35
1000-grain weight (g)	419.57 NS	5148.08 *	92.62 NS	228.36
Grain yield (g $plant^{-1}$)	0.01174 NS	2.40011*	0.02447 NS	0.04
Harvest index (%)	0.9280 NS	56.3085*	4.3564 NS	5.3217
Grain oil content (%)	0.00694*	0.09614*	0.00393*	0.00103
Grain protein content (%)	0.64534*	1.23194*	0.13701*	0.02498
Grain starch content (%)	2.7280	82.0527*	8.7388	0.6605

NS= non-significant; Different letters within columns represent data significantly different at P < 0.05.

The maximum cob diameter (6.69 cm) was recorded where boron was applied @ 0.6 kg ha^{-1} which was at par with boron application @ 0.9 kg ha^{-1} however, control (0 kg Boron ha^{-1}) gave minimum cob diameter (5.95 cm) which was statistically at par with boron applied @ 0.3 kg boron ha^{-1}. Among hybrids, significantly higher cob diameter (6.32 cm) was recorded in Monsanto-919 while minimum cob diameter (5.9 cm) was observed in Monsanto-5219 (Table 4). Both hybrids recorded significantly higher cob diameter when they were supplied with 0.6 kg boron ha^{-1}. Minimum cob diameter (5.45cm) was recorded in Monsanto-5219 where boron was applied @ 1.2 kg ha^{-1}.

Yield attributes: The maximum number of grains cob^{-1} (527.16) was recorded in plants applied with boron @ 0.6 kg ha^{-1} (Table 3) however, it was at par with all other levels except control which gave the minimum number of grains cob^{-1} (432.23). Both hybrids showed non-significant differences for a number of grains cob^{-1}. Boron application significantly increased 1000-grain weight. The maximum 1000-grain weight (302.66 g) was recorded with boron application @ 0.6 kg ha^{-1}. While minimum 1000-grain weight (236.41 g) was recorded in control treatment (no boron application). The efficiency and effectiveness of different levels of boron application are ultimately determined by the level of grain yield ha^{-1}, which in turn is a function of the cumulative behaviour of all the yield components. Maximum grain yield per plant (175.4 g) was recorded where boron was applied @ 0.6 kg ha^{-1} while minimum grain yield (105.0 g) was recorded in hybrids with no boron application (Table 3).

Table 3. Influence of various boron levels on Leaf Area, cob diameter, and cob length of maize hybrids.

Treatments	Leaf Area m^2)	Cob Diameter cm)	Cob length cm)
Hybrids			
Monsanto-919	3029 b	6.32a	16.58
Monsanto-5219	3066 a	5.90b	16.43
Boron Levels			
Control	2920 d	5.95c	15.21 c
0.3 kg ha^{-1}	3006 c	6.01c	16.72 b
0.6 kg ha^{-1}	3164 a	6.69a	17.68 a
0.9 kg ha^{-1}	3130 a	6.52b	16.67 b
1.2 kg ha^{-1}	3069 b	5.78c	16.56 b
1.5 kg ha^{-1}	2995 c	5.67d	16.21 bc

Different letters within columns represent data significantly different at P < 0.05.

Quality variables: Analysis of variance ($P \leq 0.05$) showed that the exogenous boron supply significantly increased the quality variables of maize hybrids (Table 2). The grain oil contents were increased by 10% with boron application as compared with no boron application (control). The maximum grain oil contents (4.77 %) were recorded where boron was applied @ 0.6 kg ha^{-1}. statistically at par with 0.3 kg boron ha^{-1} while minimum grain oil contents (4.46 %) were observed in control treatment (Figure 1). Among hybrids, maximum grain oil contents (4.66%) were observed in Monsanto-919 which was significantly higher than grain oil contents of Monsanto-5219 (4.45%). The exogenous boron application increased grain protein contents by 12%. The maximum value (9.5%) for grain protein contents was recorded in boron application @ 0.6 kg ha^{-1}, while minimum grain protein contents (8.28 %) were recorded in control treatment. Hybrids also showed a significant effect with respect to grain protein contents. Among hybrids, maximum protein contents (8.84%) were observed in Monsanto-219, while minimum grain protein contents (8.57%) were recorded in Monsanto-919 (Figure 2). The interactive effect of hybrids and boron levels was also significant for this variable (Table 2). Both the hybrids gave significantly higher protein contents when they were supplied with @ 0.6 boron kg ha^{-1}. Minimum grain protein contents (8.26 %) were recorded in Monsanto-919 where no boron was applied (control).

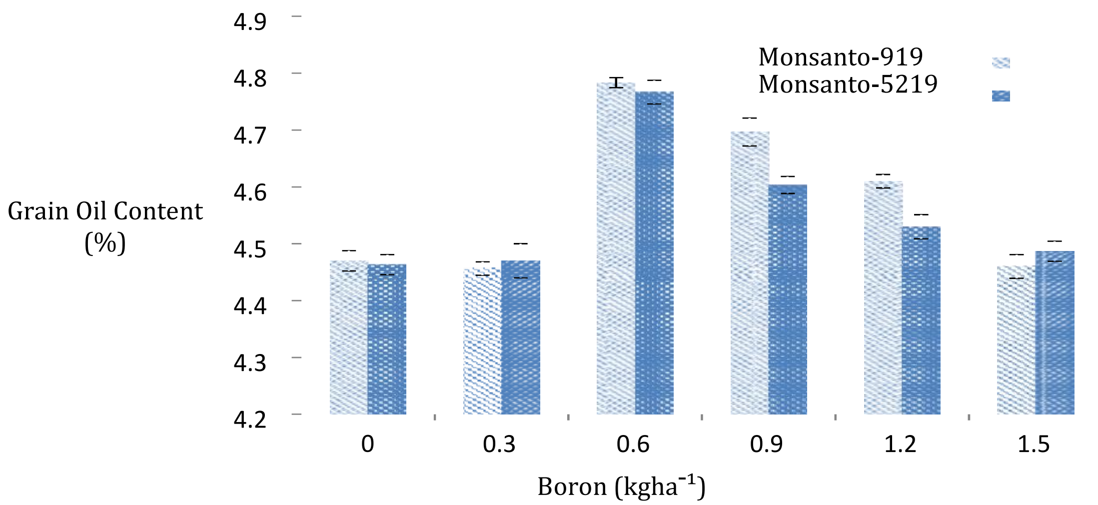

Figure 1. Grain oil content (%) as influenced by exogenous boron supply in two maize hybrids.

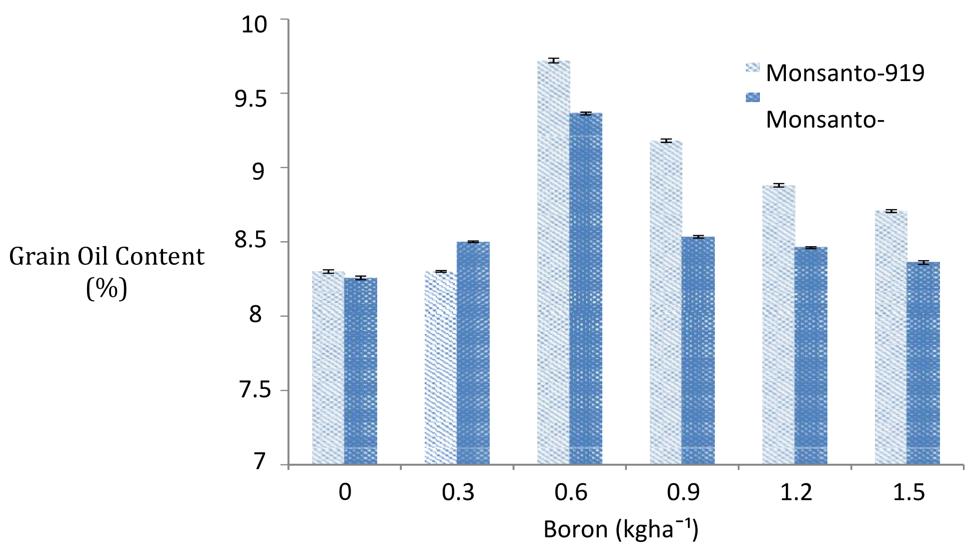

Figure 2. Grain protein content (%) as influenced by exogenous boron supply in two maize hybrids.

The significantly higher grain starch contents (71.45 %) were recorded where boron was applied @ 0.6 kg ha^{-1}, while minimum grain starch content (61.26 %) was observed where no boron was applied. However, hybrids did not show a significant effect of boron with respect to grain starch content. The interactive effect of hybrids and boron levels was also significant for this variable. Both the hybrids recorded significantly higher starch content when they were supplied with @ 0.6 kg boron ha^{-1}. Minimum grain starch contents (61.18 %) were recorded in Monsanto-919 with no Boron application (Figure 3).

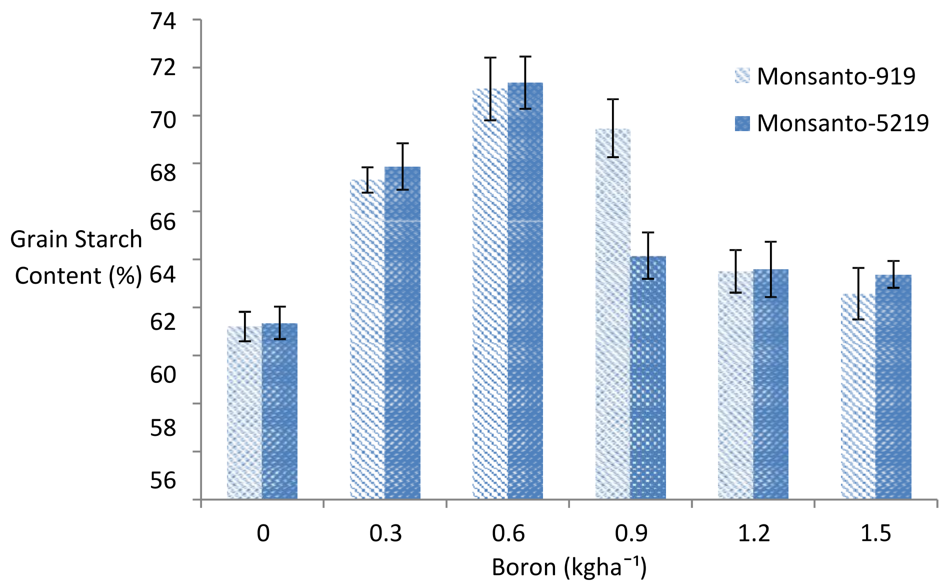

Figure 3. Grain starch content (%) as influenced by exogenous boron supply in two maize hybrids.

DISCUSSION

The increase in leaf area due to exogenous application of boron was probably due to the increase in chlorophyll contents of both the hybrids. These results support the findings of Sayed (1998) who reported that the application of boron increased the chlorophyll contents and relative water contents which increased the leaf area of maize plants. Parkash and Mehra (2006) reported that application of nitrogen (N) and boron (B) significantly increased the plant leaf area production in sunflower. The boron application has been reported to increase ear length and a number of grains spike^{-1} in wheat (Spasovski *et al*., 1987) which supports the results of this study that exogenous boron application increased cob length, diameter and number of grains cob^{-1} in maize hybrids. Many researchers have also reported the significant role of boron in increasing cob diameter of maize plants (Pasha *et al*., 2002; Parkash and Mehra, 2006). The increase in 1000-grain weight due to exogenous boron supply has also been reported by Mandal and Das (1988) while 1000-grain weight has also been reported to increase by the borax application in wheat (Mishra *et al*., 1989).

The boron application has been reported to increase grain yield up to 33% in wheat (Gunnes *et al*., 2003). Rahim *et al*., 2004 reported increased dry weight plant^{-1}, a number of grains cob^{-1} and grain weight cob^{-1} in maize plants which support the findings of the present study that boron application significantly increased various yield attributes of maize hybrids. The significant role of boron in improving the yield of crop plants has been reported by many researchers (Wrobel *et al*., 2006; Malhi *et al*., 2007; Misra and Patil, 2008; Tombo *et al*., 2008). The increase in biological yield is in agreement with Renukadevi *et al*. (2003) who reported increased biological yield in sunflower with boron application. The exogenous application of boron in soil has been reported to increase the harvest index and seed yield by 23% and 53%, respectively (Naik, 1991). The increase in grain oil content due to exogenous application of boron is in accordance with the findings of Oyinlola (2007) who reported high oil percentage content in sunflower due to boron supply. The increase in grain protein contents by exogenous boron supply support the findings of Bonilla *et al. (*1997) who reported very low levels of hydroxyproline-rich proteins in the cell walls of boron-deficient bean root nodules compared with those of boron-sufficient controls. The low levels of grain protein contents may be due to the inability of proteins to assemble and resulted in the secretion of proteins under boron deficient conditions as reported by Jackson (1991).

CONCLUSION

The exogenous application of boron significantly affected the growth, yield and quality attributes of both maize hybrids. The application of boron @ 0.6 kg ha^{-1} significantly increased leaf area, cob length and diameter, grain yield, 1000-grain weight and no. of grains cob^{-1}. It also significantly increased various quality attributes i.e. grain oil content, grain protein content and grain starch content. It was also observed that application higher doses of boron @1.2 and 1.5 kg ha^{-1} significantly reduced grain oil, protein and starch contents.

ACKNOWLEDGEMENT

The authors acknowledge the financial support provided by the Higher Education Commission (HEC) of Pakistan for the present study.

REFERENCES

Adiloglu, A. n. and S. Adiloglu. 2006. The effect of boron (B) application on the growth and nutrient contents of maize in zinc (Zn) deficient soils. Research Journal of Agriculture and Biological Sciences, 2: 1-4.

Ahmad, N., T. Muhammad and M. G. Chaudhry. 1998. Fertiliser, Plant Nutrient Management, and Self-reliance in Agriculture. The Pakistan Development Review. Pakistan Institute of Development Economics., Quaid-i-Azam University Campus, Islamabad, Pakistan, p. 217-233.

Bremner, J. M. and C. S. Mulvaney. 1982. Nitrogen-Total, Methods of Soil Analysis Part 2. Chemical and Microbiological Properties, Page, A.L., Miller, R.H., Keeney, D.R. ed. American Society of Agronomy, Soil Science Society of America, Madison, Wisconsin, p. 595-624.

Buresh, R. J., E. R. Austin and E. T. Craswell. 1982. Analytical methods in N-15 research. Fertilizer Research 3: 37-62.

Follett, R. H., L. S. Murphy and R. L. Donabue. 1981. Fertilizers and Soil. Prentice-Hall, Inc., Englewood Cliffs, New Jersey, USA, p. 557.

García-Hernández, E. R. and G. I. C. López. 2005. Structural cell wall proteins from five pollen species and their relationship with boron. Brazilian Journal of Plant Physiology, 17: 375-381.

Güneş, A., M. Alpaslan, A. Inal, M. S. Adak, F. Eraslan and N. Çiçek. 2004. Effects of boron fertilization on the yield and some yield components of bread and durum wheat. Turkish Journal of Agriculture and Forestry, 27: 329-335.

Hiller, A., J. Plazin and D. D. Vanslyuke. 1948. A study of conditions for determination of nitrogen and proteins. Journal of Biochemistry 176: 1401-1420.

Hudson, R. and J. Clarke. 1997. Dimilin and boron for insect control and yield increases in soybeans. Proceedings of the 5th Annual Southern Soybean Conference. Myrtle Beach, South Carolina, USA, p. 1-8.

Ismail, A. M. 2003. Response of maize and sorghum to excess boron and salinity. Biologia Plantarum, 47: 313-316.

Jackson, J. F. 1991. Borate control of energy-driven protein secretion from pollen and interaction of borate with auxin or herbicide--a possible role for boron in membrane events. Proceedings of the Plant Biochemistry and Physiology Symposium. The University of Missouri, Columbia, USA, p. 221-229.

Jackson, M. L. 1958. Soil chemical analysis. Prentice-Hall, Inc., Englewood Cliffs, New Jersey, USA.

Kausar, M. A., M. Tahir and A. Hamid. 1990. Comparison of three methods for the estimation of soil available boron for maize. Pakistan Journal of Scientific and Industrial Research, 33: 221-224.

Low, N. H. 1990. Food Analysis, Laboratory Manual. Department of Applied Microbiology and Food Science, University of Saskatchewan, Saskatchewan, Canada, p. 37-38.

Malhi, S. S., Y. Gan and J. P. Raney. 2007. Yield, seed quality, and sulfur uptake of Brassica oilseed crops in response to sulfur fertilization. Agronomy Journal, 99: 570-577.

Mandal, A. B. and A. D. Das. 1988. Response of wheat (*Triticum aestivum*) to boron application. Indian Journal of Agricultural Sciences, 58: 681-683.

Marschner, H. 1995. Mineral Nutrition of Higher Plants 2nd ed., Academic Press, San Diego, California, USA.

Martens, D. C., M. T. Carter and G. D. Jones. 1974. Response of Soybeans Following Six Annual Applications of

Various Levels of Boron, Copper, and Zinc. Agronomy Journal, 66: 82-84.

Mishra, S. S., I. M. L. Gulati, S. S. Nanda, L. M. Garnayk and S. N. Jana. 1989. Micronutrient studies in wheat. Orissa Journal of Agricultural Research 22: 94-96.

Misra, S. M. and B. D. Patil. 1987. Effect of boron on seed yield in Lucerne (*Medicago sativa* L.). Journal of Agronomy and Crop Science, 158: 34-37.

Misra, S. M. and B. D. Patil. 1987. Effect of Boron on Seed Yield in Lucerne (Medicago sativa L.). Journal of Agronomy and Crop Science, 158: 34-37.

Mozafar, A. 1989. Boron Effect on Mineral Nutrients of Maize. Agronomy Journal, 81: 285.

Naik, H. R. 1991. Influence of Boron on Seed Setting and Seed Production KBSH-2 Hybrid Sunflower Under Irrigated Conditions (Unpublished) M.Sc. Agric. thesis. University of Agricultural Sciences, GKVK.

Olsen, S. R. and L. E. Sommers. 1982. Phosphorous, In: Page, A. L., (eds.), Methods of Soil Analysis. American Society of Agronomy, Soil Science Society of America, Madison, Wisconsin, USA, p. 403-430.

Oyinlola, E. Y. 2007. Effect of Boron Fertilizer on Yield and Oil Content of Three Sunflower Cultivars in the Nigerian Savanna. Journal of Agronomy, 6: 421-426.

Parkash, Y. R. and P. M. Mehra. 2006. Growth and yield of sunflower as influenced by nitrogen and boron nutrition. CAB Abstract, CABI Publishing, UK.

Pasha, B. U., A. Ali, M. Saleem and B. H. Niazi. 2002. Role of boron for potassium/sodium ratio in sunflower under saline conditions. Helia, NARC, Islamabad, Pakistan, p. pp. 69-78.

Pilbeam, D. J. and E. A. Kirkby. 1983. The physiological role of boron in plants. Journal of Plant Nutrition, 6: 563-582.

Rahim, M., H. Ali and T. Mahmood. 2004. Impact of nitrogen and boron application on growth and yield of maize (*Zea mays* L.) crop. Journal of Research in Science, 15: 153-157.

Reinbott, T. M. and D. G. Blevins. 1995. Response of soybean to foliar-applied boron and magnesium and soil-applied boron1. Journal of Plant Nutrition, 18: 179-200.

Renukadevi, A., P. Savithri and K. Andi. 2003. Sources, levels and methods of boron application on the dry matter production, yield attributes and yield of sunflower (Helianthus annuus) crop. Crop Research Hisar - The Pherobase, 25: 436-440.

Richard, L. A. 1954. Diagnosis and improvement of saline and alkali soils. USDA Hand Book. No. 60. US Govt. Press, Washington, DC, USA, p. 160.

Römheld, V. and H. Marschner. 1991. The function of micronutrients in plants, In: Mortvelt, J. J., (eds.), Micronutrients in Agriculture, 2nd ed. SSSA Book Series, Wisconsin, Madison, USA, p. 297-328.

Sayed, S. A. 1998. Impacts of boron application on maize plants growing under flooded and unflooded conditions. Biologia Plantarum, 41: 101-109.

Shorrocks, V. M. 1997. The occurrence and correction of boron deficiency, In: *al.*, B. D. *e.*, (eds.), Developments in plant and soil sciences: Boron in soils and plants. Kluwer Academic Publishers, Dordrecht, Netherlands, p. 121-148.

Spasovski, K., M. Jekic and T. Avramovski. 1987. Effect of NPK fertilizer and foliar application of trace elements on some morphological properties of wheat cv. Benzostaya Agrohemija, 2: 119-126.

Steel, R. G. D., J. H. Torrie and D. A. Dicky. 1986. Principles and procedures of statistics: a biometrical approach 3rd ed., McGraw Hill, Inc. Book Co., New York, USA.

Thimmaiah, S. R. 2004. Standard methods of biochemical analysis. Kalyani Publishers, Ludhiana, India.

Togay, Y., N. Togay, F. Cig, M. Erman and A. E. Celen. 2008. The effect of sulphur applications on nutrient composition, yield and some yield components of barley (*Hordeum vulgare* L.). African Journal of Biotechnology, 7: 3255-3260.

Verma, B. C., K. Swaminathan and K. C. Sud. 1977. An improved turbidimetric procedure for the determination of sulphate in plants and soils. Talanta, 24: 49-50.

Welch, R. M., W. H. Allaway, W. A. House and J. Kubota. 1991. Geographic distribution of trace element problems, In: Mortvelt, J. J., (eds.), Micronutrients in Agriculture. Book Series 4, Wisconsin, Madison, USA, p. 31-57.

Wrobel, S., B. Hrynczuk and K. Nowak. 2006. Fertilization with boron as a security factor of the nutrient availability under drought conditions. Polish Journal of Environmental Studies, 15: 554-558.