The International Journal of Biotechnology
2013 Vol.2, No.8, pp.141-153
ISSN(e): 2306-6148
ISSN(p): 2306-9864

INFLUENCE OF POTASSIUM AND BORON ON SOME TRAITS IN WHEAT (*TRITICUM AESTIVUM* CV. DARAB2)

Mahdi Zare[1] --- Masoud Zadehbagheri[2] --- Arash Azarpanah[3]

[1]*Department of Agriculture, Islamic Azad University, Abadeh branch, Abadeh, Iran*

[2]*College of Agriculture, Islamic Azad University, Shiraz branch, Shiraz, Iran*

[3]*Department of Agriculture, Islamic Azad University, Arsanjan branch, Arsanjan, Iran*

ABSTRACT

The boron element is unique among the essential elements in that a narrow range in concentration can mean the difference between plant deficiency and plant toxicity. Effect of potassium on boron toxicity reduction in wheat was evaluated at Agriculture Research Station located in Jahrom, Iran, during 2009. An experiment was conducted in a factorial experiment based on Completely Randomized Design (CRD) in three replications. The treatments were four levels of B (0, 20, 40 and 60 mg) and four levels of K (0, 25, 50 and 75 mg). The studied traits were number of spikes plant $^{-1}$, number of kernels spike^{-1}, 1000 seed weight, biological yield, harvest index and seed yield. The results demonstrated that all of traits except biological yield were increased when K element was applied. On the other hand, all of traits were decreased when B levels were increased. It seems to be that soils containing higher boron concentration were considered to probably cause B toxicity. $B_1 \times K_4$ and $B_4 \times K_1$ interaction effects had the highest and lowest seed yield (8.92 and 1.15 ton ha^{-1}, respectively), indicating that K promotes photosynthesis and transport assimilates of carbohydrates to the storages organs. In this research, 1000 seed weight had the highest correlation with seed yield.

Keywords: Boron, Potassium, Seed yield, Wheat

1. INTRODUCTION

Crops are often exposed to various types of stresses including deficiencies during their life time. Due to various roles of nutrients in plant cells, their deficiency may led to metabolic disorders. Micronutrient deficiency is widespread in many Asian countries due to the calcareous nature of soils, high pH, low organic matter, salt stress, continues drought, high bicarbonate content in irrigation water and imbalanced application of NPK fertilizers (Narimani *et al.*, 2010). A deficiency occurs when an essential element is not available in sufficient quantity to meet the needs of growing plant. Nutrient toxicity occurs when an element is in excess of plant needs and decreases plant growth or quality. Nutrient deficiency or toxicity symptoms often differ among species and varieties of plants (Torun *et al*., 2001).

Arquero *et al*. (2006) reported that soils containing more than 5 to 8 mg L^{-1} of hot water soluble B is considered to probably cause B toxicity. Moreover, poor drainage especially in saline soils may be responsible for the increased concentration of B in the soil solution (Malasha *et al*., 2008). According to a review reported by Marschner (1995), B is relatively immobile in plant tissues and its transportation is further hindered under water stress circumstances.

Potassium (K) is the most abundant cation in plants, and plays important roles in many physiological processes such as photosynthesis, assimilate transport and enzyme activation. Potassium is essential for high-yield crop production, and can be a limiting factor for such crops under certain environmental conditions, for example drought (Liebersbach *et al*., 2004) and salinity (Qi and Spalding, 2004). Therefore, elucidation of the mechanisms underlying responses and adaptation of plants to K deficiency is of key importance (Rengel and Damon, 2008).

Keeping in view the above concept, a greenhouse experiment was conducted to evaluate the effect of potassium and boron on wheat (*T. aestivum* cv. Darab2) to investigate appropriate concentration of these elements to improve seed yield.

2. MATERIALS AND METHODS

A greenhouse experiment was conducted at Agriculture Research Station of Jahrom, Fars, Iran, during 2009 growing season (located at 53°, 20´N & 28°, 38S) and 1100 m altitude to evaluate the effect of potassium and boron on wheat (*T. aestivum* cv. Darab2).

This experiment consisted of 16 treatments and 3 replications in a factorial experiment based on Completely Randomized Design (CRD) with combinations of four levels of B (0, 20, 40 and 60 mg) and four levels of K (0, 25, 50 and 75 mg). Pot culture was containing 5 kg loamy soil texture to prevent leaching of elements. Soils with nearly neutral PH, a high percentage of lime, and organic carbon and potassium were low.

At physiological maturity stage, 5 plants per pot were selected and number of spikes plant $^{-1}$, number of seeds spike $^{-1}$, 1000 seed weight, biological yield, harvest index and grain yield traits were calculated.

Harvest index was calculated using the following formula:

Harvest index (%) = (Grain yield / Biological Yield) × 100

Biological yield was determined after placing seedlings in an oven at 50 °C for 72 h.

Skewness, kurtosis, homogeneity of variance and normality of data were tested by Minitab (1998) statistical software. Analysis of variance of factorial experiment based on CRD and correlation analysis of traits were performed by SAS (2001) software. The phenotypic correlation between variable x and y (r_{xy}) was estimated following Kwon and Torrie (1964) using the formula:

$$r_{xy} = \frac{Cov_{xy}}{\sqrt{(Var_x . Var_y)}}$$

where, Cov_{xy} = covariance between variable x and y, Var_x = variance of x and Var_y = variance of y.

In addition, Excel software was used for charts adjustments as well. It should be pointed out for means comparison we applied Duncan's Multiple Range Test at $P < 0.05$ using SAS (2001) and MSTATC (1990) softwares.

3. RESULTS

3.1. Number of Spikes Plant^{-1}

The results indicated that potassium effect on number of spikes plant^{-1} was significant at $P < 0.01$ (Table 1). In present study, the maximum number of spikes plant^{-1} (10) belongs to both 50 and 75 mg potassium per kg soils (Figure 1). Values of 25 and 0 mg potassium per kg soil treatments had significantly different effect on this trait (9 and 5, respectively). It can be concluded that the effect of potassium on the tiller at the tillering stage, has increased the number of fertile tillers. Baque *et al.* (2006) reported that the maximum effective tillers were recorded in wheat plants received higher levels of potassium.

Kemler (1983) believe that insufficient application of potassium, especially in the early stages of wheat growth, reduce panicle and 1000 kernel weight. Results indicated that boron effect on number of spike plant $^{-1}$ was statistically significant at $P < 0.01$. Maximum and minimum number of spike plant^{-1} belongs to 20 and 60 mg boron per kg soils (10.9 and 6.12, respectively). Therefore, reducing the number of spikes with increasing boron levels was observed (Figure 2).

Results enumerated that interaction effect of boron and potassium on number of spike plant^{-1} was significant at $P < 0.01$ (Table 1). $B_2 \times K_3$ and $B_2 \times K_4$ interaction effects had the highest number of spike plant^{-1} (12.59 and 12.64, respectively) and $B_4 \times K_1$ had the lowest this trait (2.86). Therefore, number of spike plant^{-1} increased gradually by increasing boron and potassium concentration compared with the untreated plants. But, soils containing more than 40 mg boron per kg soil was considered to probably cause B toxicity.

3.2. Number of Kernels Spike^{-1}

Analysis of variance showed that potassium effect on number of kernels spike^{-1} was significant at $P < 0.01$ (Table 1). Consumptions of 50 and 75 mg of potassium per kg soil had maximum and also equal positive effect on number of kernels spike^{-1} (37.5 and 38, respectively) (Figure 3). Maximum number of kernels spike^{-1} was observed in treatment where 20 mg of boron per kg soil was applied (49.93). Data showed that minimum number of kernels spike^{-1} was observed in treatment where 60 mg of boron per kg soil was applied (22.43). So, it was not found to be useful as it declined the number of kernels spike^{-1} probably due to boron toxicity (Figure 4). Debnat *et al.* (2011) also reported similar results for boron application. The results also demonstrated that interaction effect of boron and potassium on number of kernels spike $^{-1}$ was significant at $P < 0.01$ (Table 1). The highest number of kernels spike $^{-1}$ was related to $B_2 \times K_3$ and $B_2 \times K_4$ interaction effects (52.94 and 53.43, respectively), indicating that consumptions of 50 and 75 mg of potassium per kg soil in the presence of 20 mg of boron per kg soil could bring about improvements in seed yield by increasing number of kernels spike $^{-1}$. $B_4 \times K_1$ had the lowest this trait (16.11) that it was probably due to potassium deficiency and boron toxicity.

3.3. 1000 Seed Weight

As shown in Table 1, effect of potassium on 1000 seed weight at was significant at $P < 0.01$. Analysis of variance showed that effect of boron on 1000 seed weight was significant at $P < 0.01$ (Table 1). Results indicated that application of boron was led to decrease in 1000 seed weight. Comparison means showed that application 0 mg kg^{-1} boron concentration in soil *has caused* wheat trend 1000 seed weight to *increase* and the lowest this trait at 60 mg kg^{-1} soil boron concentration was obtained (Figure 6). Result showed that interaction effect of potassium and boron on 1000 seed weight was significant at $P < 0.01$ (Table 1). In this study, application 75 mg kg^{-1} potassium and 0 mg kg^{-1} boron treatments in soil had the highest 1000 seed weight (Table 2).

3.4. Biological Yield

The results indicated that effect of potassium on biological yield was significant at $P < 0.01$ (Table 1). The highest biological yield was related to 75 mg kg^{-1} potassium treatment in soil. All treatments were significantly different (Figure 7). The results showed that effect of boron on biological yield was significant at $P < 0.01$ (Table 1). On the other hand, the maximum biological yield were belonged to application of 0 and 20 mg kg^{-1} boron treatments in soils and 60 mg kg^{-1} boron treatment had the minimum effect on this trait (Figure 8).

The results demonstrated that effect of potassium and boron on biological yield was significant at $P < 0.01$ (Table 1). In this study, comparison means showed that maximum biological yield was related to application of 75 and 0 mg kg^{-1} potassium and boron treatments in soil, respectively (Table 1).

3.5. Harvest Index

The results showed that potassium effect on harvest index was not significant (Table 1 and Figure 9), indicating approximately equal positive effects of potassium on seed and biological yield. The results showed that boron effect on harvest Index trait was significant at $P < 0.01$ (Table 1), indicating that seed and biological yield traits were differently reduced by increase boron levels (Figure 10).

Data presented in Table 1 displayed that interaction effect of potassium and boron on harvest index was significant at $P < 0.01$. In present study, comparison means showed that the highest harvest index was related to the $B_1 \times K_4$ treatment and the lowest harvest index was related to $B_4 \times K_1$ (Table 1).

3.6. Seed Yield

Results indicated that effect of potassium on seed yield was significant at $P < 0.01$ (Table 1). In this study, comparison means showed that application of 75 mg kg^{-1} potassium treatment in soil had the highest effect on seed yield (7 ton ha^{-1}) (Figure 11). This might be due to greater uptake of potassium by wheat from soil which might have increased the biomass due to increased water uptake and translocation of photosynthesis. The results indicated that effect of boron on seed yield was significant at $P < 0.01$ (Table 1). The maximum and minimum seed yield was belonged to 0 and 60 mg kg^{-1} boron concentration in soil, respectively (Figure 12).

Results presented in Table 1 showed that interaction effect of potassium and boron on seed yield was significant at $P < 0.01$. Comparison means showed that application of 75 mg kg^{-1} potassium and 0 mg kg^{-1} boron treatment in soil had the highest seed yield and application of 0 mg kg^{-1} potassium and 60 mg kg^{-1} boron treatment in soil had the lowest seed yield (Table 2) that it was probably due to potassium deficiency and boron toxicity.

4. DISCUSSION

Ali *et al.* (2009) have reported significant variations for number of spikes m^{-2} for application of boron. Singh *et al.* (1990) reported that high levels of applied B had an antagonistic effect on the uptake of nutrients in wheat plants. In flowers, low B reduces male fertility primarily by impairing microsporogenesis and pollen tube growth. Post-fertilization effects include impaired embryogenesis, resulting in seed abortion or the damaged embryos, and malformed fruits (Dell and Huang, 1997).

Previous studies illustrated that grain number was increased by potassium fertilizers (Baque *et al.*, 2006). Ahmad and Irshad (2011) also reported that application of B increased significantly number of kernels $spike^{-1}$ in wheat. As B application reduces spike sterility, this increase in grains may be due to reduced spike sterility.

In this study, 1000 seed weight tended to increase by increasing the concentration of potassium as compared with the untreated one (Figure 5). It should be mentioned that, about 90 percent of grain carbohydrates are usually obtained after pollination (Marschner, 1995). These results are in line with that of Baque *et al.* (2006) who also reported increase in number of grains $spike^{-1}$ of wheat for application of potassium. Potassium is the effective on grain filling period (Marschner, 1995). Inadequate potassium supply in the early stages of growth in contrast to the lack of loss after flowering stage is more striking. In addition, the positive response of wheat to potassium intake is mainly related to the beneficial effect of potassium on grain weight that will increase 1000 seed weight (Header and Bringer, 1981). Debnat *et al.* (2011) indicated no significant effect of boron application on 1000 seed weight. Potassium with help better absorption of nutrients will be need increase the availability of plant nutrient (Keerati *et al.*, 1991). The main role of potassium is the activation of many enzyme systems involved in the structure of organic substances and in the building up of compounds such as starch or protein and also involved in cell enlargement and in triggering the growth of young meristematic tissues (Arquero *et al.*, 2006).

Potassium is essential for high-yield crop production and can be a limiting factor for such crops under certain environmental conditions, for example drought and salinity (Liebersbach *et al*., 2004). The results were in agreement with Baque *et al.* (2006), who reported that higher levels of K improved the dry matter production in different plants parts.

Boron deficiency affects vegetative and reproductive stages of plant growth. In the vegetative stage, B deficiency leads to the inhibition of growth, the death of growing meristems and the inhibition of the development of vascular bundles (Godfray *et al*., 2010). During reproduction, B deficiency causes inhibition of or defects in flower, seed, and fruit development (Bartlett and Picarellin, 1973). Debnat *et al.* (2011) indicated that the straw yield of wheat was not influenced by the B treatments.

Considering the range between deficiency and toxicity of B is quite narrow, application of B can be extremely toxic to plant at concentrations only slightly above the optimum rate (Gupta, 2002). Scientists report that potassium is essential in biological yield and maintenance of osmotic potential and water uptake and had a positive impact on stomatal closure which increases tolerance to water stress (Epstein, 1972).

The improvement in vegetative growth may be attributed to the important role of potassium in nutrient and sugar translocation in plant and turgor pressure of plant cells. Also potassium active numerous enzyme systems involved in the formation of organic substances and in the buildup of compounds such as starch or protein. Potassium is involved in cell enlargement and in triggening the young tissues or be due to that potassium is involved in plant mersitematic growth (Chhokar *et al*., 2006).

Furthermore, potassium increases the amount of protein being made within the plant. However, it is more likely that the lower yields may be due to deficiency of B, because it is well known that cruciferous or root crops have high B demands (Godfray *et al*., 2010). B deficient condition the resulting concentration of other nutrient-elements may have changed their status in plants and resulted lower yields. These results were in line with the previous work of Karabal and Oktem (2003).

The beneficial effects of potassium on growth, yield and fruit quality may be attributed to their vital role in stimulating cell division and elongation as well as the biosynthesis and trans-located of organic foods in favor of enhancing growth and fruiting of trees (Nijjar, 1985). Pattanayak *et al.* (2008) reported that gradual increase in K rate steadily improved the harvest index or rice. Elongation of the stems, petioles and roots of plants in minus boron nutrient solutions is slow or may cease soon after the cotyledons have developed. The rate at which new nodes are formed is affected later. With the tendency for the terminal bud to abort or take on a fascinated appearance, similarly abnormal branches appear in the axils of the leaves (Nijjar, 1985).

Without an adequate amount of potassium, many parts of a plant begin to weaken. Plants are no longer able to handle stresses as sufficiently and are more susceptible to diseases. The coloring of the plant also changes dramatically. Many of the leaves start to turn yellow as the tissue begins to die and this loss of photosynthesis causes a plant's growth to become stunted (Nijjar, 1985).

Furthermore, potassium increases the amount of protein being made within the plant (Karabal and Oktem, 2003).

Appropriate potassium nutrition with the increase in leaf area, chlorophyll and absorption of other nutrients, will increase photosynthetic capacity and yield. Previous studies also emphasized that application micronutrients with high levels of potassium had positive impact and significant increase on wheat seed yield. Also, K promotes photosynthesis and transport assimilates of the carbohydrates to the storage organs. Potassium is involved in many aspects of the plant physiology. Moreover, foliar application of potassium nitrate increases yield and fruit quality (Qi and Spalding, 2004).

Dell and Huang (1997) found that sexual reproduction is often more affected by low B and significant grain yield reductions may occur without visual symptoms expressed during vegetative growth. The results was in agreement with the work of Vitosh *et al.* (1997), who found that boron is essential for the development and seed yield of corn, pea and sunflowers. They also pointed out that dicotyledons respond more quickly to boron than monocotyledons. Grain yield is a complex trait that results from contribution of several plant parameters. Biological yield followed by 1000 seed weight had the highest positive correlation coefficient with grain yield ($r = 0.972$ and $r = 0.930$, respectively) (Table 3). So, focus on utilization boron and potassium fertilizers and production of grain size and rich seeds wheat (*T. aestivum* cv. Darab2) that ultimately lead to 1000 grain weight can be useful. The seed yield was positively correlated with number of spikes plant $^{-1}$ ($r = 0.767$), number of kernels spike $^{-1}$ ($r = 0.674$) and harvest index ($r = 0.626$) (Table 3), indicating that direct selection to improve yield with these traits would be effective. Other authors have found that seed yield had positive and significant correlation with number of spikes m^{-2} (Alshreda, 2010), number of kernels spike $^{-1}$ (Alshreda, 2010; Debnat *et al.*, 2011), 1000 seed yield (Debnat *et al.*, 2011; Hellal *et al.*, 2012), straw yield (Hellal *et al.*, 2012), biological yield and harvest index (Alshreda, 2010).

It can be concluded that effects of potassium and boron on the traits in wheat was significant. Boron is essential for plant growth and development and adequate boron nutrition of cultivated plants can be of great economic importance. Concurrently management of application potassium in Jahrom region with high potential of wheat yield is inevitable. As a conclusion, optimum wheat growth response in farm soils can be gained by making sure plants are provided a reasonable supply of all essential elements. By soil testing for boron, deficiencies or toxicities can be identified and corrected before or after planting. A little boron goes a long way in preventing deficiencies or creating toxicities.

The results demonstrated that potassium, boron and potassium × boron effects on all studied traits, except potassium for harvest index, were statistically significant. It should be noted that application of 75 mg kg^{-1} potassium and 20 mg kg^{-1} boron treatments in soil increased the majority of traits. It could be recommended that using balanced fertilization of potassium and boron increase seed yield of wheat. 1000 seed weight is one of the seed yield components that had the highest positive correlation coefficient with grain yield. So, simultaneous selection regarding

1000 seed weight and seed yield is possible. Grain yield increase can be obtained if number of spikes plant $^{-1}$ and number of kernels spike $^{-1}$ are increased.

REFERENCES

Ahmad, R. and M. Irshad, 2011. Effect of boron application time on yield of wheat, rice and cotton crop in Pakistan. Soil Environ, 30(1): 50-57.

Ali, S., A. Shah, M. Arif, G. Miraj, I. Ali, M. Sajjad, Farhatollah, M. Yasir Khan and M. Moula Khan, 2009. Enhancement of wheat grain yield components through foliar application of zinc and boron. Sarhad J. Agric, 25(1): 15-19.

Alshreda, K., 2010. The effect of genotype × environment interaction on traits associated with drought tolerance in bread wheat (triticum aestivum l.) General Commission for Scientific Agric. Research (GCSAR). Available from http://www.gcsar.gov.sy/gcsarEN/spip.php?article352.

Arquero, O., D. Barranco and M. Benlloch, 2006. Potassium starvation increases stomatal conductance in olive trees. Hort. Sci, 41(2): 433-436.

Baque, M.A., M.A. Karim, A. Hamid and H. Tetsushi, 2006. Effects of fertilizer potassium on growth, yield and nutrient uptake of wheat (triticcum aestivum) under water stress conditions. South Pacific Studies, 27(1): 25-35.

Bartlett, R.J. and C.J. Picarellin, 1973. Availability of boron and phosphorous as affected by liming in acid potato soil. Soil Sci, 116(2): 77-83.

Chhokar, R.S., R.K. Sharma, D.S. Chauhan and A.D. Mongia, 2006. Evaluation of herbicides against phalaris minor in wheat in north-western indian plains. Eur. Weed Res, 46(1): 40–49.

Debnat, M.R., M. Jahiruddin, M.M. Rahman and M.A. Haque, 2011. Determining optimum rate of boron application for higher yield of wheat in old brahmaputra floodplain soil. J. Bangladesh Agric. Univ, 9(2): 205–210.

Dell, B. and L.B. Huang, 1997. Physiological response of plants to low boron. Plant Soil, 193(1-2): 103-120.

Epstein, E., 1972. Mineral nutrition of plants:Principles and perspectives.New york. USA: Wiley.

Godfray, C., J. Beddington, I. Crute, L. Haddad, D. Lawrence, J. Muir, J. Pretty, S. Robinson, S. Thomas and C. Toulmin, 2010. Food Security: The Challenge of Feeding 9 Billion People Science, 327(5967): 812–818.

Gupta, U.C., 2002. Boron and its role in crop production. Boca Ratow: CRC Press.

Header, H.E. and L. Bringer, 1981. Analysis of yield of winter wheat grown at increasing levels of potassium. J. Sci. Food Agric, 32(6): 547-551.

Hellal, F.A., R.M. Zeweny and A.A. Yassen, 2012. Evaluation of nitrogen and silicon application for enhancing yield production and nutrient uptake by wheat in clay soil. J. Appl. Sci. Res, 8(2): 686-692.

Karabal, E. and H.A. Oktem, 2003. Antioxidant responses of tolerant and sensitive barley cultivars toboron toxicity. Plant Sci, 164(6): 925- 933.

Keerati, K., P., R.W. Bell and J.F. Loneragan, 1991 Response of two peanut cultivers to boron, nitrogen and phosphate-calcium. Plant Soil, 138(1): 61-68.

Kemler, G., 1983. Modern aspects of wheat maturing. 2nd Edn., Switzerland: IPI. Bern.

Kwon, S.H. and J.H. Torrie, 1964. Heritability and interrelationship among traits of two soybean populations. Crop Sci, 4(2): 196-198.

Liebersbach, H., B. Steingrobe and N. Claassen, 2004. Roots regulate ion transport in the rhizosphere to counteract reduced mobility in dry soil. Plant Soil, 260(1-2): 79-88.

Malasha, N.M., F.A. Alia, M.A. Fatahallaa, E.A. Khatabb, M.K. Hatemb and S. Twaficb, 2008. Response of tomato to irrigation with saline water applied by different irrigation methods and water management strategies. Int. J. Plant Prod, 2(2): 101-116.

Marschner, H., 1995. Mineral nutrition of higher plants 2nd Edn., Germany: Academic press. Stuttgart.

Minitab, 1998. MINITAB 12. Minitab, State College, PA.

MSTATC, 1990. MSTATC a Microcomputer program for the design, management, and analysis of agronomic research experiments. Michigan State University, East Lansing, MI.

Narimani, H., M.M. Rahimi, A. Ahmadikhah and B. Vaezi, 2010. Study on the effects of foliar spray of micronutrient on yield and yield components of durum wheat. Archives of Appl. Sci, 2(6): 168-176.

Nijjar, G.S., 1985. Nutrition of fruit trees. New Delhi, India USHA Raji Kumar, Kalyani.

Pattanayak, S.K., S.K. Mukhi and K. Majumdar, 2008. Potassium unlocks the potential for hybrid rice. Better Crops, 92(2): 8-9.

Qi, Z. and E.P. Spalding, 2004. Protection of plasma membrane k+ transport by the salt overly sensitive1 na+-h+ antiporter during salinity stress. Plant Physiol, 136(1): 2547-2555

Rengel, Z. and P.M. Damon, 2008. Crops and genotypes differ in efficiency of potassium uptake and use. Physiologia Plantarum, 24(2): 105-110.

SAS, I., 2001. SAS user's guide. Version 8. SAS Institute Inc Cary, NC.

Singh, J.P., D.J. Dahiya and R.P. Norwal, 1990. Boron uptake and toxicity in wheat in relation to zinc supply. Fert. Res, 24: 105-110.

Torun, A., IGÃ. ltekin, M. Kalayci, A. Yilmaz, S. Eker and I. Cakmak, 2001. Effects of zinc fertilization on grain yield and shoot concentrations of zinc, boron, and phosphorus of 25 wheat cultivars grown on a zinc-deficient and boron-toxic soil. J. Plant Nutr, 24(11): 1817-1829.

Vitosh, M.L., D.D. Warneke and R.E. Lucas, 1997. Boron. Mishigan state university extention soil and manegemnt fertilizer. Available from htpp://www.Msue.msu.EDV.

Table-1. Analysis of variance for studied traits in wheat

SOV	df	Mean squares (MS) Number of spikes plant $^{-1}$	Number of kernels spike $^{-1}$	1000 seed weight (g)	Biological yield (ton ha^{-1})	Harvest index (%)	Grain yield (ton ha^{-1})
K	3	3211.85 **	29.91 **	16.72 **	149786.56 **	1.55 ns	33659.65 **
B	3	11502.69 **	193.89 **	37.37 **	811233.72 **	16.82 **	195036.6 **
B × K	9	206.71 **	3.89 **	6.96 **	21268.06 **	7.61 **	2517.92 **
E	32	0.025	1.004	2.009	0.334	1.46	1.027
CV%		1.35	7.52	2.26	4.52	2.45	8.11

K: Potassium, B: Boron, E: Error, CV: Coefficient of Variation.

ns, * and **: Not significant, significant at $P < 0.05$ and $P < 0.01$, respectively.

Table-2. Effects of Boron × Potassium interaction on studied traits in wheat

Treatment	Number of spikes plant $^{-1}$	Number of kernels spike $^{-1}$	1000 seed weight (g)	Biological yield (ton ha^{-1})	Harvest index	Grain yield (ton ha^{-1})
$B_1 \times K_1$	5.36 i	26.15 f	36.34 de	13.94 de	35.22 a	6.6 bcd
$B_1 \times K_2$	10.26 cd	32.13 e	39.09 bc	16.72 c	31.99 b	7.75 abc
$B_1 \times K_3$	9.06 e	35.58 d	41.42 ab	17.99 b	29.85 c	8.34 ab
$B_1 \times K_4$	9.08 e	35.60 d	42.58 a	19.94 a	29.54 c	8.92 a
$B_2 \times K_1$	7.43 h	43.72 c	33.72 f	12.25 f	32.20 b	5.2 de
$B_2 \times K_2$	10.96 b	49.62 b	36.27 de	14.80 d	32.65 b	6.68 bcd
$B_2 \times K_3$	12.59 a	52.94 a	38.43 cd	16.70 c	28.01 c	7.12 a-d
$B_2 \times K_4$	12.64 a	53.43 a	39.38 bc	18.42 b	29.68 c	7.92 abc
$B_3 \times K_1$	4.35 j	26.04 f	30.50 h	8.30 h	28.73 c	3.05 fg
$B_3 \times K_2$	9.21 e	32.44 e	34 ef	12.03 f	35.32 a	5.63 de
$B_3 \times K_3$	10.12 d	36.07 d	33.40 fg	14.84 d	29.09 c	6.34 cd
$B_3 \times K_4$	10.46 c	36.52 d	33.03 fgh	16.35 c	28.42 c	6.66 bcd
$B_4 \times K_1$	2.86 k	16.11 h	27.30 i	5.78 i	16.95 d	1.15 h
$B_4 \times K_2$	5.57 i	21.82 g	30.67 h	8.45 h	17.78 d	1.94 gh
$B_4 \times K_3$	8.23 f	25.40 f	31 gh	10.47 g	32.79 b	4.2 ef
$B_4 \times K_4$	7.81 g	26.45 f	33.01 fgh	13.29 e	27.85 c	4.5 ef

B: Boron, K: Potassium, Means in each column, followed by similar letter(s) are not significantly different at P < 0.05, using Duncan's Multiple Range Test.

Table-3. Correlation coefficients among studied traits in wheat

Trait	Number of spikes plant $^{-1}$	Number of kernels spike $^{-1}$	1000 seed weight (g)	Biological yield (ton ha^{-1})	Harvest index (%)
Number of kernels spike $^{-1}$	0.843 **				
1000 seed weight (g)	0.646 **	0.607 *			
Biological yield (ton ha^{-1})	0.801 **	0.680 **	0.918 **		
Harvest index (%)	0.439 ^{ns}	0.409 ^{ns}	0.464 ^{ns}	0.476 ^{ns}	
Grain yield (ton ha^{-1})	0.767 **	0.674 **	0.930 **	0.972 **	0.626 **

ns, * and **: Not significant, significant at $P < 0.05$ and $P < 0.01$, respectively.

Figure-1. Potassium effect on number of spike plant $^{-1}$

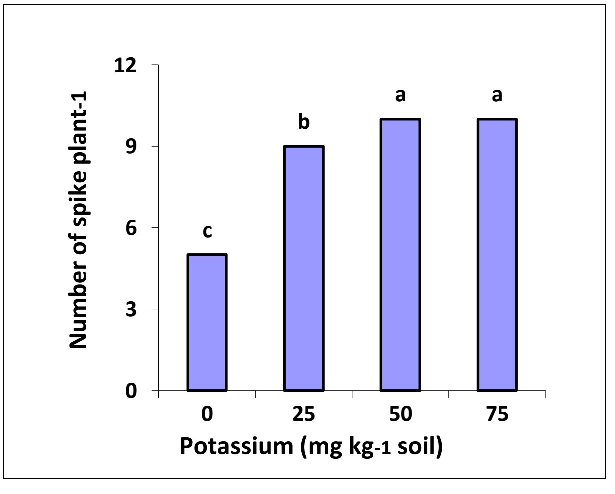

Figure-2. Boron effect on number of spike plant $^{-1}$

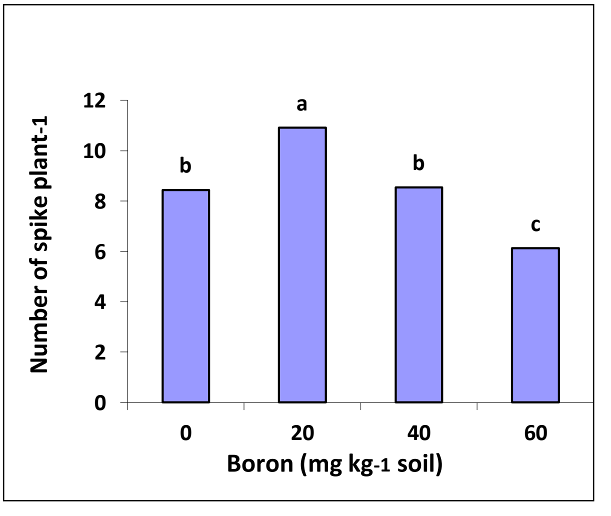

Figure-3. Effect of potassium on number of kernels spike $^{-1}$

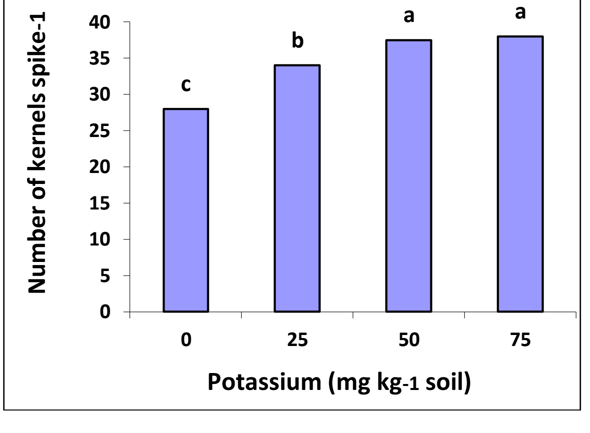

Figure-4. Effect of Boron on number of kernels spike $^{-1}$

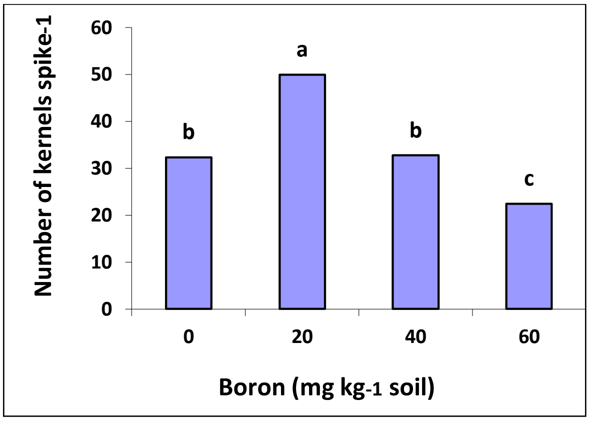

Figure-5. Effect of potassium on 1000 seed weight

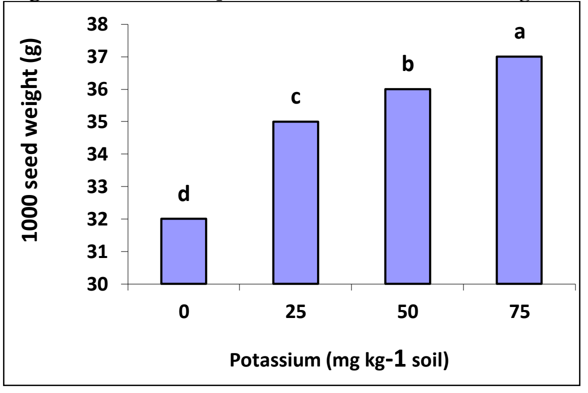

Figure-6. Effect of boron on 1000 seed weight

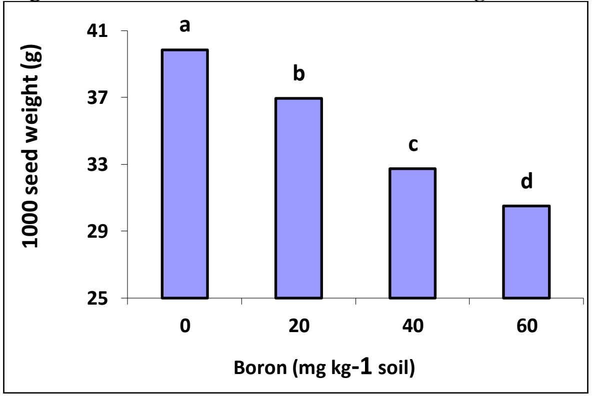

Figure-7. Effect of potassium on biological yield

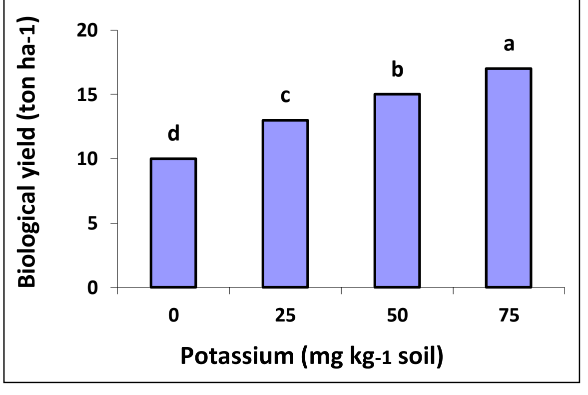

Figure-8. Effect of Boron on biological yield

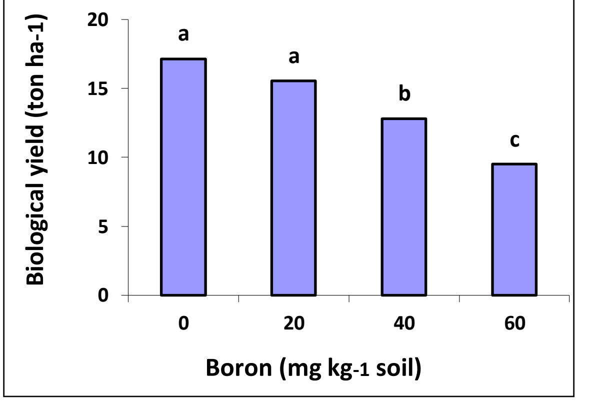

Figure-9. Effect of potassium on harvest index

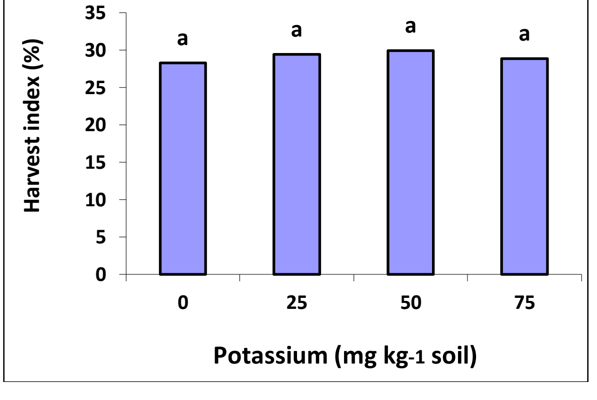

Figure-10. Effect of Boron on harvest index

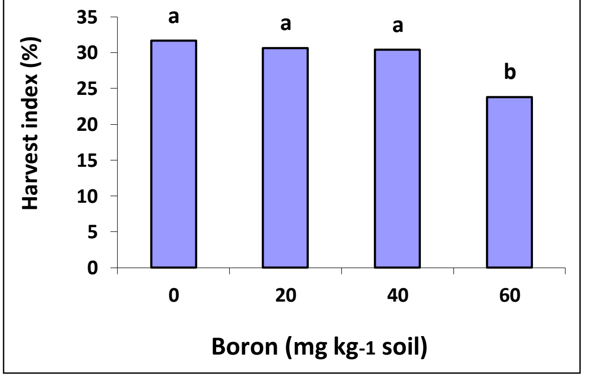

Figure-11. Effect of potassium on seed yield

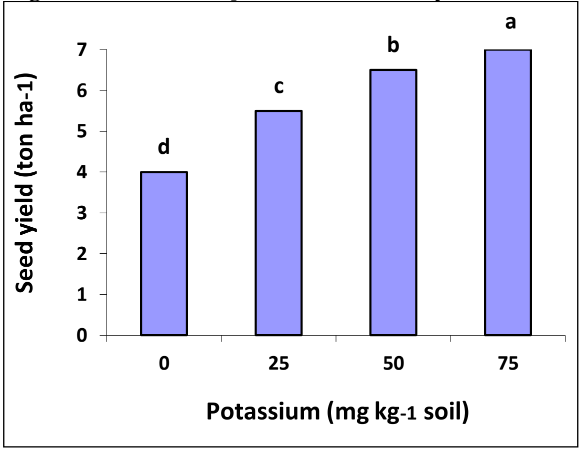

Figure-12. Effect of Boron on seed yield