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EFFECT OF MICRONUTRIENTS ON GROWTH AND YIELD OF WHEAT

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Physiology and yield attributes of wheat variety Gomal-8 were evaluated using different levels of Zn, Cu, Fe, Mn and B alone and in different combinations. The results revealed that application of boron @ 2 kg ha^{-1} produced higher leaf area index (0.33 and 3.49) and leaf area duration (2.30 and 48.90) at 49 and 98 days after sowing. The same treatment also enhanced crop growth rate (33.40 g m^{-2} day^{-1}), number of grains (46.50 $spike^{-1}$) and grain yield (3.67 t ha^{-1}) of wheat. However, the use of copper @ 8 kg ha^{-1} produced the maximum number of tillers (249 m^{-2}) and statistically at par grain yield (3.62 t ha^{-1}) similar to that of boron application. Higher net assimilation rate (3.19 mg m^{-2} day^{-1}) was recorded when copper was applied @ 6 kg ha^{-1}. Among different micronutrients, zinc application produced minimum number of grains (37.75 $spike^{-1}$) while the use of iron did not improve plant growth. The study showed that boron application improved the wheat grains and yield while the use of copper and manganese had also positive effect on wheat productivity.
Keywords: wheat, *Triticum aestivum*, micronutrients, growth, yield, LAI, CGR, NAR

INTRODUCTION

In Pakistan, wheat requirement is increasing every year due to population expansion and stagnant yield per unit area. Khan *et al*. (2000) reported wheat yield in Pakistan as two and half times low as compared to advanced wheat producing countries of the world while bridging up this gap is a challenging scenario for scientists and farmers. Seed quality, salinity, water logging, improper and inadequate use of fertilizers, poor irrigation management, high input prices, low farmers' education and no use of micronutrients and organic manures are limiting factors towards the higher wheat yield (Khan *et al*., 1999). It is perceived that micronutrients play a pivotal role in the yield improvement (Rehm and Sims, 2006). Ziaeian and Malakouti (2001) reported that total uptake of Zn, Cu, Fe and Mn, in grain and flag leaves was significantly increased. These micronutrients help in chlorophyll formation, nucleic acid, protein synthesis and play an active role in several enzymatic activities of photosynthesis as well as respiration (Reddy, 2004). Research on the use of micronutrients in increasing wheat production is limited in Pakistan, although most soils of the country are facing their wide spread deficiencies (Nisar and Rashid, 2003). According to an estimate, wheat crop removes 34-50 g copper, 232-1219 g iron, 140-330 g manganese and 66-209 g zinc for producing 2 t ha^{-1} grains (NFDC, 1998). The plant analytical data showed that Cu, Fe, Mn and Zn contents of leaf, straw and grain of wheat increased with the application of various levels of Hal-Tonic and mineral fertilizers (Khan *et al.,* 2006). In spite of adequate application of NPK fertilizer, normal growth of high yielding varieties could not be obtained due to little or no application of micronutrients. High fertilizer responsive varieties express their full yield potential when trace elements are applied along with NPK fertilizers (Nataraja *et al.,* 2006). Chaudry *et al.* (2007) stated that micronutrients (Zn, Fe, B) significantly increased the wheat yield over control when applied single or in combination with each other while Mandal *et al.* (2007) observed significant positive interaction between fertilizer treatments and physiological stages of wheat growth. Considering the aforementioned facts, it was felt necessary to study the factors responsible for fertilizer efficiency improvement in wheat under the agro-ecology of the area.

MATERIALS AND METHODS

The present research was conducted at the Agricultural Research Institute, Dera Ismail Khan during 2009-10. The experiment was laid out in a randomized complete block design with four replications. Three different doses of zinc, copper, iron, manganese and boron were applied alone and in combination in the form of $ZnSO_4$, $CuSO_4$, $FeSO_4$, $MnSO_4$ and Borax. Basel fertilizer dose of NPK @ 150-120-90 kg ha^{-1} in the form of Urea, Di-Ammonium Phosphate and Potassium Sulphate, respectively was applied in all treatments. Half dose of nitrogen and full dose of P_2O_5 and K_2O were applied at the time of sowing while remaining nitrogen was applied with first irrigation. Sowing was done by man driven hand drill with plant to plant and row to row distance of 10 and 30 cm, respectively. The net plot size was 1.8 × 5 m^2. A recommended seed rate of 100 kg ha^{-1} of wheat variety Gomal-8 was used. Geographical coordinates of the experimental site was 31° North, 70° East having clay-loam soil with pH 7.65 and organic matter < 1%. Soil fertility status showed 0.081% nitrogen, 18 ppm phosphorus and 400 ppm exchangeable potassium. The weather condition of the experimental site is given in Table 1. All cultural practices were followed according to standard recommendations for the locality. The detail of treatments is given as under:

T_1 = Zn @ 5 kg ha^{-1} T_2 = Zn @ 10 kg ha^{-1}
T_3 = Zn @ 15 kg ha^{-1} T_4 = Cu @ 6 kg ha^{-1}
T_5 = Cu @ 8 kg ha^{-1} T_6 = Cu @ 10 kg ha^{-1}
T_7 = Fe @ 8 kg ha^{-1} T_8 = Fe @ 12 kg ha^{-1}
T_9 = Fe @ 16 kg ha^{-1} T_{10} = Mn @ 8 kg ha^{-1}
T_{11} = Mn @ 12 kg ha^{-1} T_{12} = Mn @ 16 kg ha^{-1}
T_{13} = B @ 1 kg ha^{-1} T_{14} = B @ 2 kg ha^{-1}
T_{15} = B @ 3 kg ha^{-1}
T_{16} = Zn + Cu + Fe + Mn + B @ 5 + 6 + 8 + 8 +1 kg ha^{-1}
T_{17} = Zn + Cu + Fe + Mn + B @ 10 + 8 +12+12+2 kg ha^{-1}
T_{18} = Zn + Cu + Fe + Mn + B @ 15+10+16+16+3 kg ha^{-1}

Data on following physiological parameters were recorded as per procedure given below:

***Leaf area index (49 and 98 days after sowing)*:** Leaf area index (m^{-2}) was measured at 49 and 98 days after sowing by using the following formula:

$$\text{Leaf area index (LAI)} = \frac{\text{total leaf area}}{\text{ground area}}$$

***Leaf area duration (49 and 98 days after sowing)*:** Leaf area duration was calculated by integrating leaf area index over crop growth period. It is expressed in days and calculated as under:

Leaf area duration (LAD) = LAI x M

Where M is the number of weeks in the crop growth period

***Crop growth rate (g m^{-2} day^{-1})*:** Dry weight of plants (m^{-2}) in each sub-plot was recorded at 49 and 98 days after sowing and then crop growth rate was calculated by using the formula:

$$\text{Crop growth rate (CGR)} = \frac{W_2 - W_1}{T_2 - T_1}$$

Where W_1 = Dry weight (49 DAS), W_2 = Dry weight (98 DAS), T_1 and T_2 are the time interval in days.

***Relative growth rate (mg g^{-1} day^{-1})*:** Relative growth rate was calculated by using the following formula:

$$\text{Relative growth rate (RGR)} = \frac{\text{Ln}(W_2) - \text{Ln}(W_1)}{T_2 - T_1}$$

Where Ln is Natural Log

***Net assimilation rate (mg m^{-2} day^{-1})*:** Net assimilation rate was calculated by using the following formula:

$$\text{Net assimilation rate} = \frac{(W_2 - W_1)(\text{Ln}(LA_2) - \text{Ln}(LA_1))}{(T_2 - T_1)(LA_2 - LA_1)}$$

Where W_1 and W_2 are dry weight (49 and 98 DAS), LA_1 and LA_2 are the leaf area (49 and 98 DAS), T_2 and T_1 are time interval, Ln is the natural log.

While agronomic data on number of tillers (m^{-2}), number of grains ($spike^{-1}$), 1000-grain weight (g) and grain yield (t ha^{-1}) were recorded at maturity. The data thus obtained were analyzed statistically using analysis of variance techniques (Steel and Torrie, 1984) and means were separated by Duncan's new multiple range test (Gomez and Gomez, 1976) in MSTAT computer software program.

RESULTS AND DISCUSSION

***Leaf area index (LAI) at 49 and 98 days after sowing*:** The ratio of total leaf area to ground cover is termed as LAI. It is typically increases to maximum after the crop emergence (Reddy, 2004). The data presented in Table 2 revealed non-significant results. The maximum LAI (3.49) was recorded by the application of boron @ 2 kg ha^{-1} which was statistically at par (3.46 and 3.37) with combined application of micronutrients in T_{18} and T_{17}, respectively and sole application of Zn and Mn in T_3 and T_{12} with LAI value of 3.21 each after 98 days after sowing. In general, the application of boron had boosted up the tissue formation with better plant growth which increases its concentration in leaves and results in higher leaf area index. Likewise, when boron is used in combination with zinc, copper, iron and

Table 1. Metrological parameters during the year 2009-10

Month	Temperature (^{0}C)		Relative Humidity		Rainfall (mm)
	Max.	Min.	0800 Hrs.	1400 Hrs.	
October	33	16	82	57	13
November	25	10	80	55	-
December	22	5	81	63	-
January	16	5	88	76	9.2
February	22	8	76	58	1.1
March	30	15	63	63	22
April	37	19	74	45	-

Table 2. Leaf area index and leaf area duration (49 and 98 days after sowing) of wheat as affected by different micronutrients

Treatments	Leaf area index		Leaf area duration	
	49 DAS*	**98 DAS**	**49 DAS**	**98 DAS**
T_1 - Zn @ 5 kg ha^{-1}	0.23 ^{NS}	2.76 c-f	1.58 ^{NS}	38.65 c-f
T_2 - Zn @ 10 kg ha^{-1}	0.22	2.50 ef	1.54	35.04 ef
T_3 - Zn @ 15 kg ha^{-1}	0.30	3.21 abc	2.09	44.94 abc
T_4 - Cu @ 6 kg ha^{-1}	0.20	2.38 ef	1.41	33.39 ef
T_5 - Cu @ 8 kg ha^{-1}	0.29	2.92 b-e	2.02	40.92 b-e
T_6 - Cu @ 10 kg ha^{-1}	0.21	2.69 c-f	1.49	37.64 c-f
T_7 - Fe @ 8 kg ha^{-1}	0.21	2.61 def	1.49	36.52 def
T_8 - Fe @ 12 kg ha^{-1}	0.23	2.31 f	1.62	32.39 f
T_9 - Fe @ 16 kg ha^{-1}	0.25	2.46 ef	1.77	34.39 ef
T_{10} - Mn @ 8 kg ha^{-1}	0.25	2.48 ef	1.73	34.78 ef
T_{11} - Mn @ 12 kg ha^{-1}	0.23	2.74 c-f	1.61	38.32 c-f
T_{12} - Mn @ 16 kg ha^{-1}	0.26	3.21 abc	1.82	44.99 abc
T_{13} - B @ 1 kg ha^{-1}	0.22	2.73 c-f	1.55	38.18 c-f
T_{14} - B @ 2 kg ha^{-1}	0.33	3.49 a	2.30	48.90 a
T_{15} - B @ 3 kg ha^{-1}	0.25	3.06 a-d	1.76	42.90 a-d
T_{16} - Zn+Cu+Fe+Mn+B	0.25	3.20 abc	1.73	44.76 abc
T_{17} - Zn+Cu+Fe+Mn+B	0.29	3.37 ab	2.01	47.25 ab
T_{18} - Zn+Cu+Fe+Mn+B	0.24	3.46 a	1.73	48.48 a
$LSD_{0.05}$	**-**	**0.46**	**-**	**6.48**

* DAS = days after sowing; any two means in the column sharing no common letter(s) are significant (P<0.05); NS=non-significant

manganese, it helped plants in chlorophyll formation and increased the photosynthetic activities (Ziaeian and and Malakouti, 2001; Card *et al*., 2005; Manal *et al.,* 2010). It was further observed that sole effects of boron (T_{15}) and combined effect of all the five micronutrients (T_{16}) at different levels remained statistically similar. The application of iron @ 12 and copper @ 6 kg ha^{-1} produced the minimum leaf area index of 2.31 and 2.38, respectively.

***Leaf area duration (LAD) at 49 and 98 days after sowing*:** Leaf area duration is directly associated with leaf area index. Data given in Table 2 revealed that micronutrients had non-significant effect on leaf area duration 49 DAS. The micronutrients had, however, showed significant effect on LAD 98 DAS. The maximum LAD (48.90) was noted with boron application @ 2 kg ha^{-1} and it was statistically similar to T_{18} and T_{17} with LAD of 48.48 and 47.25, respectively. These results were also statistically at par with T_{12}, T_3, T_{16} and T_{15} which in turn showed LAD of 44.99, 44.94, 44.76 and 42.90, respectively. The minimum LAD (34.39, 33.39 and 32.39) was recorded in T_9, T_4 and T_8.

***Crop growth rate (g m^{-2} day^{-1})*:** Crop growth rate, the dry matter production per unit time is affected by various factors including temperature, solar radiation and age of cultivar. The data in Table 3 revealed that use of micronutrients, alone and in combination had significantly affected the crop growth rate. Micronutrients application enhanced the plant growth through increased plant photosynthesis and other physiological activities. Among various treatments, application of boron @ 2 kg ha^{-1} accelerated crop growth rate (33.40 g m^{-2} day^{-1}). It was followed by the combined application of micronutrients in T_{16} and sole application of zinc and copper in T_2 and T_4 with CGR of 28.08, 27.44 and 27.34 g m^{-2} day^{-1}, respectively. The results in T_{16}, T_2 and T_4 were also statistically similar. The use of boron helped the plants to better utilize the available nutrients with increased leaf area, high photosynthesis and dry matter accumulation which enhanced crop growth rate. These results corroborate the findings of Asad and Rafique (2002) who reported that boron fertilization increased the dry matter production of wheat. Statistically similar results were recorded by the combined application of micronutrients in T_{17}, sole application of boron in T_{13}, T_{15} and iron in T_8 which produced crop growth rate of 26.55, 26.39, 25.56 and 25.09 g m^{-2} day^{-1}, respectively. In general, the use of medium doses of boron or zinc and/or iron produced the higher crop growth rate whereas the application of lower rates of copper, manganese and combination of all micronutrients had the higher crop growth rate. The minimum crop growth rate (19.69, 18.35 and 16.67 g m^{-2} day^{-1}) was recorded in T_{12}, T_{11} and T_7.

***Relative growth rate (mg g^{-1} day^{-1})*:** Relative growth rate (RGR) expresses the dry weight increase in time interval in relation to the initial weight. Since crop growth rate is an absolute measure of growth, similar values could be expected for different initial weights (Reddy, 2004). The data presented in Table 3 revealed that application of different micronutrients had significant effect on the relative growth rate of wheat cv. Gomal-8. As far as the doses of micronutrients are concerned, significantly maximum RGR (89.60) was produced by the application of boron @ 3 kg ha^{-}

Table 3. Crop growth rate, relative growth rate and net assimilation rate of wheat as affected by different micronutrients

Treatments	CGR ($g\ m^{-2}\ day^{-1}$)	RGR ($mg\ g^{-1}\ day^{-1}$)	NAR ($mg\ m^{-2}\ day^{-1}$)
T_1 - Zn @ 5 kg ha^{-1}	24.29 def	85.01 a-e	2.39 def
T_2 - Zn @ 10 kg ha^{-1}	27.44 bc	88.45 abc	2.92 ab
T_3 - Zn @ 15 kg ha^{-1}	20.42 ghi	75.80 i	1.66 i
T_4 - Cu @ 6 kg ha^{-1}	27.34 bc	88.73 ab	3.19 a
T_5 - Cu @ 8 kg ha^{-1}	21.90 fgh	77.49 hi	1.91 ghi
T_6 - Cu @ 10 kg ha^{-1}	22.72 efg	84.10 b-f	2.31 ef
T_7 - Fe @ 8 kg ha^{-1}	16.67 j	79.68 f-i	1.75 i
T_8 - Fe @ 12 kg ha^{-1}	25.09 cde	87.38 abc	2.75 bc
T_9 - Fe @ 16 kg ha^{-1}	20.02 hi	78.25 ghi	2.10 fgh
T_{10} - Mn @ 8 kg ha^{-1}	20.11 hi	78.35 ghi	2.11 fgh
T_{11} - Mn @ 12 kg ha^{-1}	18.35 ij	82.10 d-h	1.83 hi
T_{12} - Mn @ 16 kg ha^{-1}	19.69 hi	80.57 e-i	1.72 i
T_{13} - B @ 1 kg ha^{-1}	26.39 bcd	86.70 a-d	2.64 bcd
T_{14} - B @ 2 kg ha^{-1}	33.40 a	83.36 c-g	2.53 cde
T_{15} - B @ 3 kg ha^{-1}	25.56 bcd	89.60 a	2.31 ef
T_{16} - Zn+Cu+Fe+Mn+B	28.08 b	81.05 e-i	2.49 cde
T_{17} - Zn+Cu+Fe+Mn+B	26.55 bcd	79.84 e-i	2.16 fg
T_{18} - Zn+Cu+Fe+Mn+B	21.79 fgh	80.83 e-i	1.83 hi
$LSD_{0.05}$	**2.33**	**4.52**	**0.28**

Any two means in the column sharing no common letter(s) are significant (P<0.05)

^{1} which was statistically at par (88.73, 88.45 and 87.38 mg g^{-1} day^{-1}) with the sole application of Cu (6 kg ha^{-1}), Zn (10 kg ha^{-1}) and Fe (12 kg ha^{-1}), respectively. The reason might be the high concentrations of boron and zinc in the leaves increased plant food accumulation which resulted in more relative growth rate (Card *et al.*, 2005; Nataraja *et al.*, 2006). Kumar *et al.* (2009) also showed that increased level of copper application enhanced the Cu concentrations in leaves and dry matter production. As compared to its sole application, the combined form application of boron showed the better relative growth rate. The sole application of copper and zinc in T5 and T3 produced the minimum relative growth rate (77.49 and 75.80 mg g^{-1} day^{-1}, respectively).

***Net assimilation rate (mg m^{-2} day^{-1})*:** The plant capacity to increase dry weight in terms of area of its assimilatory surface expresses the net assimilation rate. It represents the photosynthetic efficiency in the overall sense and in connection with LAR and RGR (Reddy, 2004). The data given in Table 3 revealed that different micronutrients had significant effect on net assimilation rate. Among various treatments, the use of copper (6 kg ha^{-1}) produced the significantly maximum net assimilation rate (3.19) which was statistically at par with the application of zinc in T_2 (2.92 mg m^{-2} day^{-1}). In general, high concentrations of Cu in the leaves and more relative growth rate resulted in increased photosynthetic rate and chlorophyll formation. Shukla and Warsi (2000) also obtained the highest net assimilation rate with the application of Zn along with NPK. The results recorded in the sole application of iron and boron in T_8, T_{13}, T_{14} and combination T_{16} showed statistically similar net assimilation rate of 2.75, 2.64, 2.53 and 2.49 mg m^{-2} day^{-1}, respectively. The minimum net assimilation rate of 1.75, 1.72 and 1.66 mg m^{-2} day^{-1} was produced by statistically at par treatment including the sole application of iron (8 kg ha^{-1}), manganese (16 kg ha^{-1}) and zinc (15 kg ha^{-1}), respectively.

***Number of tillers (m^{-2})*:** Tillering capacity of a plant depends on the genotype and environment. The data pertaining to number of tillers revealed that micronutrients either alone or in combination had significant effect on number of tillers (Table 4). Among various treatments, the application of copper @ 8 kg ha^{-1} (T_5) produced the maximum number of tillers (249.0). It was followed by sole application of Mn (8 kg ha^{-1}), Cu (6 kg ha^{-1}), Zn (10 kg ha^{-1}) and Mn (16 kg ha^{-1}) having statistically similar number of tillers (229.8, 226.5, 220.8 and 218.5 m^{-2}), respectively. Kumar *et al.* (2009) obtained increased number of tillers with the application of Cu while Manal *et al.* (2010) recorded higher number of tillers with the application of Mn. Though statistically non-significant, the use of micronutrients in T_{17} and sole application of boron and iron @ 2 and 12 kg ha^{-1} produced comparatively higher number of tillers (216.3, 212.0 and 210.8 m^{-2}). The minimum and statistically similar number of tillers was recorded in T_{16}, T_{11}, T_6, T_7 and T_{18}.

Table 4. Number of tillers, number of grains, 1000-grain weight and grain yield of wheat as affected by different micronutrients

Treatments	Tillers (m^{-2})	Grains ($spike^{-1}$)	1000-grain weight (g)	Grain yield (t ha^{-1})
T_1 - Zn @ 5 kg ha^{-1}	206.0 d-g	44.25 abc	40.54 hi	3.15 cde
T_2 - Zn @ 10 kg ha^{-1}	220.8 bcd	37.75 g	43.22 bcd	3.15 cde
T_3 - Zn @ 15 kg ha^{-1}	195.5 fg	45.75 a	41.56 fgh	3.20 bcd
T_4 - Cu @ 6 kg ha^{-1}	226.5 bc	41.00 c-g	41.68 e-h	3.38 b
T_5 - Cu @ 8 kg ha^{-1}	249.0 a	39.75 efg	41.56 fgh	3.62 a
T_6 - Cu @ 10 kg ha^{-1}	190.0 g	43.00 a-e	44.02 ab	3.05 def
T_7 - Fe @ 8 kg ha^{-1}	190.0 g	42.00 b-f	42.24 d-g	2.86 f
T_8 - Fe @ 12 kg ha^{-1}	210.8 c-f	40.25 d-g	44.02 ab	3.24 bcd
T_9 - Fe @ 16 kg ha^{-1}	201.8 efg	44.25 abc	42.66 b-g	3.26 bcd
T_{10} - Mn @ 8 kg ha^{-1}	229.8 b	43.00 a-e	41.31 gh	3.60 a
T_{11} - Mn @ 12 kg ha^{-1}	190.3 g	44.25 abc	43.00 b-e	3.06 def
T_{12} - Mn @ 16 kg ha^{-1}	218.5 bcd	39.25 fg	42.80 b-f	3.14 cde
T_{13} - B @ 1 kg ha^{-1}	195.5 fg	45.25 ab	41.39 gh	3.15 cde
T_{14} - B @ 2 kg ha^{-1}	212.0 cde	46.50 a	42.58 cg	3.67 a
T_{15} - B @ 3 kg ha^{-1}	201.0 efg	43.25 a-e	43.06 bcd	3.19 bcd
T_{16} - Zn+Cu+Fe+Mn+B	194.0 g	46.00 a	43.65 abc	3.30 bc
T_{17} - Zn+Cu+Fe+Mn+B	216.3 b-e	43.50 a-d	39.67 i	3.29 bc
T_{18} - Zn+Cu+Fe+Mn+B	190.0 g	41.00 c-g	44.64 a	2.96 ef
$LSD_{0.05}$	**14.36**	**3.13**	**1.19**	**0.18**

Any two means in their respective group sharing no common letter(s) are significant (P<0.05)

***Number of grains (spike^{-1})*:** One of the basic yield components of wheat is the number of grains spike^{-1} which is affected by various factors including balanced nutrition. As shown in Table 4, micronutrients application along with basal dose of NPK substantially improved the number of grains spike^{-1} in wheat cv. Gomal-8. Maximum number of grains (46.50) was produced by boron application @ 2 kg ha^{-1} which was statistically at par with T_{16}, T_3 and T_{13} with 46.00, 45.75 and 45.25 grains spike^{-1}. Since boron is responsible for the translocation of food materials in plants therefore it played vital role in grain setting as well as higher number of grains in wheat. Present results are in line with Uddin *et al.* (2008) who obtained higher number of grains by the application of boron @ 2 kg ha^{-1} while Tahir *et al.* (2009) recorded significant increase in number of grains with the foliar application of boron. The use of zinc, iron and manganese @ 5, 16 and 12 kg ha^{-1} produced numerically similar results (44.25 grains spike^{-1}) whereas the combination of medium doses of micronutrients and sole application of boron @ 3 kg and copper @ 10 kg ha^{-1} produced statistically same number of grains spike^{-1} (43.50, 43.25 and 43.00). Minimum number of grains (39.75, 39.25 and 37.75) was recorded in T_5, T_{12} and T_2, respectively.

***1000-grain weight (g)*:** The data presented in Table 4 revealed that micronutrients application had significant effect on the grain weight. Maximum grain weight (44.64g) was recorded in T_{18}, which was statistically at par (44.02g) with grain weight obtained in T_6 and T_8 respectively. This might be due to enhanced accumulation of assimilates in the grains, which resulted in heavier grains of wheat. Present results are supported by Soleimani (2006) who recorded significantly increased seeds weight by integrating Zn, Fe, Mn and Cu. It was also observed that combined use of lower doses of micronutrients in T_{16} and sole application of zinc, boron and manganese @ 10, 3 and 12 kg ha^{-1} produced statistically similar 1000-grain weight of 43.65, 43.22, 43.06 and 43.00g. In general, the use of medium doses of zinc, iron and manganese produced higher seed weight whereas the application of higher rates of copper, boron and combination of all micronutrients had higher seed weight. The minimum grain weight (40.54 and 39.67g) was, however, recorded in T_1 and T_{17}, respectively.

***Grain yield (t ha^{-1})*:** Crop productivity is the rate at which a crop accumulates organic matter due to the rate of photosynthesis and conversion of light energy into chemical energy by green plants (Reddy, 2004). The grain yield depends on three components viz. number of spikes, kernels spike^{-1} and kernels weight. The data given in Table 4 indicated that micronutrient and their doses had significant effect on grain yield. Among various treatments, application of boron @ 2 kg ha^{-1} (T_{14}) produced maximum grain yield (3.67 t ha^{-1}) while the use of copper and manganese both @ 8 kg ha^{-1} (T_5 and T_{10}) was statistically at par with boron producing grain yield of 3.62 and 3.60 t ha^{-1}, respectively. The use of boron produced the highest grain yield due to maximum number of grains spike^{-1} while increased number of tillers in Cu and Mn application resulted in higher grain yield. The present results are supported by Chaudry *et al.* (2007) who stated that boron application along with basal dose of NPK significantly increased the wheat yield. Uddin *et al.* (2008) also obtained 50% yield increase by the application of boron @ 2 kg ha^{-1}. Kumar *et al.* (2009) recorded 69% yield increase over control with the application of Cu. Grain yield (3.38 t ha^{-1}) obtained with the application of copper @ 6 kg ha^{-1} alone and in combination of lower as well as medium doses of micronutrients in T_{16} and T_{17} was statistically at par (3.30 and 3.29 t ha^{-1}). Minimum and statistically similar grain yield (2.96 and 2.86) was recorded in T_{18} and T_7, respectively. These two treatments also produced lowest number of tillers per unit area.

CONCLUSION

In the present research, the use of micronutrients significantly affected wheat yield. Among micronutrients, the application of boron @ 2 kg ha^{-1} and copper @ 8 kg ha^{-1} had significantly positive effect on most of yield contributing parameters of wheat cv. Gomal-8. The use of boron @ 2 kg ha^{-1} recorded more grains $spike^{-1}$, higher grain weight and increased grain yield.

REFERENCES

Asad, A. and R. Rafique. 2002. Identification of micronutrient deficiency of wheat in the Peshawar valley. Commun. Soil Sci. Plant Anal. 33: 349-364.

Card, S., J. Cathcart and J. Huang. 2005. The micronutrient and trace element status of crops grown on the Alberta Soil Quality Benchmark Sites. AESA Soil Quality Monitoring Program, Alberta Agri. Food & Rural Dev., Cons. & Dev. Branch, pp.20.

Chaudry, E.H., V. Timmer, A.S. Javed and M.T. Siddique. 2007. Wheat response to micronutrients in rainfed areas of Punjab. Soil & Environ. 26:97-101.

Gomez, K.A. and A.A. Gomez. 1976. Statistical procedure for agricultural research with emphasis on rice, 2nd Ed. IRRI, Los Banos, Philippine.

Khan, Z.A., M.A. Khan and M.S. Baloch. 1999. Effect of different manures on the yield of wheat. Scientific Khyber 12:41-46.

Khan, M.A., I. Hussain and M.S. Baloch. 2000. Wheat yield potential – current status and future strategies. Pak J. Bio. Sci. 3:82-86.

Khan, H., Z.U. Hassan and A.A. Maitlo. 2006. Yield and micronutrients content of bread wheat (*Triticum aestivum* L.) under a multi-nutrient fertilizer Hal-Tonic. Intl. J. Agric. Biol. 8: 366-370.

Kumar, R., N.K. Mehrotra, B.D. Nautiyal, P. Kumar and P.K. Singh. 2009. Effect of copper on growth, yield and concentration of Fe, Mn, Zn and Cu in wheat plants (*Triticum aestivum* L.). J. Environ. Biol. 30:485-488.

Manal, F.M., A.T. Thalooth and R.K.M. Khalifa. 2010. Effect of foliar spraying with uniconazole and micronutrients on yield and nutrients uptake of wheat plants grown under saline condition. J. Amer. Sci. 6:398-404.

Mandal, A., A.K. Patra, D. Singh, A. Swarup and R.E. Masto. 2007. Effect of long-term application of manure and fertilizer on biological and biochemical activities in soil during crop development stages. Bioresour. Technol. 98:3585-3592.

Nataraja, T.H., A.S. Halepyati, B.T. Pujari and B.K. Desai. 2006. Influence of phosphorus levels and micronutrients on the physiological parameters of wheat. Karnataka J. Agri. Sci. 19:685-687.

NFDC. 1998. Micronutrients in Agriculture: Pakistan Perspective. NFDC Publication No. 4/98, Islamabad.

Nisar, A. and M. Rashid. 2003. Fertilizers and Their Use in Pakistan, 3rd Ed. Ext. Bull. NFDC, Islamabad.

Reddy, S.R. 2004. Principles of Crop Production - Growth Regulators and Growth Analysis, 2nd Ed. Kalyani Publishers, Ludhiana, India.

Rehm, G. and A. Sims. 2006. Micronutrients and production of hard red spring wheat. Minnesota Crop News, Univ. Minnesota.

Shukla, S.K. and A.S. Warsi. 2000. Effect of sulphur and micronutrients on growth, nutrient content and yield of wheat (*Triticum aestivum* L.). Indian J. Agri. Res. 34:203-205.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics: A biological approach, 2nd Ed. McGraw Hill Book Co. Inc. New York, USA.

Suleimani, R. 2006. The effects of integrated application of micronutrient on wheat in low organic carbon conditions of alkaline soils of Western Iran. Proc. 18th World Congress of Soil Sci., July 9-15, Philadelphia, USA.

Tahir, M., A. Tanveer, T.H. Shah, N. Fiaz and A. Wasaya. 2009. Yield response of wheat (*Triticum aestivum* L.) to boron application at different growth stages. Pak. J. Life Soc. Sci. 7:39-42.

Uddin, M.N., M.S. Islam and A.B.M.S. Islam. 2008. Effect of boron on wheat at different boron application methods. J. Subtrop. Agric. Res. Dev. 6:483-486.

Ziaeian, A.H. and M.J. Malakouti. 2001. Effects of Fe, Mn, Zn and Cu fertilization on the yield and grain quality of wheat in the calcareous soils of Iran. Food Security and Sustainability of Agro-Ecosystems, pp.840-841.