Research Article

Integration of Organic, Synthetic Fertilizers and Micronutrients for Higher Growth and Yield of Wheat

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Abstract | An experiment to investigate the effect of organic, synthetic fertilizers and micronutrients on growth and yield of wheat was conducted at the Agricultural Research Institute, Dera Ismail Khan, Pakistan. The trial was laid out in a randomized complete block design (RCBD) using split-plot arrangements with four replications. Main plot consisted of NPK and organic fertilizers while micronutrients viz. Zn, Cu and B (alone and in combinations) were assigned to sub-plots. The results revealed significant variations in plant growth and yield attributes with recommended doses of NPK fertilizers. This treatment (NPK at recommended levels) resulted in higher leaf area index (0.33 and 0.27 [49 days after sowing-DAS] and 2.03 and 2.77 [98-DAS]), crop growth rate (40.42 and 40.96 g m^{-2} day^{-1}), relative growth rate (88.94 and 84.14 mg g^{-1} day^{-1}), net assimilation rate (3.58 and 3.89 mg m^{-2} day^{-1}) and grain yield (4.40 and 5.29 t ha^{-1}) during the years of experimentation. Similar trend was also noted by the application of micronutrients (alone and in combination with NPK). Addition of boron @ 2 kg ha^{-1} enhanced almost all growth parameters. The use of NPK and organic fertilizers had, however, non-significant interaction with micronutrients during both the experimental years. It was concluded that application of NPK (recommended dose) along with boron was the best combination for obtaining higher yields of wheat.

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Introduction

Wheat yield is low in Pakistan as compared to other wheat producing countries of the world including China, USA, Russia, Australia and France (Khan et al., 2000). Among many biotic and abiotic factors, the high cost of inputs (mainly fertilizers) along with no or sub-optimum application of micronutrients is the key factor responsible for low wheat yield in the country. Research work conducted on nutrients management in wheat revealed that the use of balanced nutrients (by incorporating farmyard manure, compost, humic acid etc. with the synthetic fertilizers) is the main tool for successful crop production (Khan et al., 2007). Such a supplementation of organic fertilizers expands bio-activities beneath the soil surface with increased water and nutrient holding capacity which resulted in less soil crust and moisture/nutrient losses (Defra, 2002; Weil and Magdoff, 2004). Haque et al. (2002) also stated that integrated plant nutrients management has great potential for yield stabilization whereas combined application of organic and chemical sources is useful practice in increasing fertility, quality and yield of crop (Duan et al., 2004). Rehm and Sims (2006) reported that application of NPK along with micronutrients plays an important role in yield enhancement especially when the soils are deficient in organic matter, nitrogen, phosphorus and micronutrients. Such deficiency of trace elements affects the quality and quantity of different plant products (Ahmadikhah et al., 2010). Stone and Savin (2000) reported that use of mineral fertilizers enhances micronutrients contents in leaf, straw and grain while in accordance, organic fertilizers improves the supply of zinc, copper and boron. This research was, therefore, aimed at improving wheat growth and yields through the combined application of organic, chemical and micronutrient fertilizers under the agro-ecology of the area.

Materials and Methods

The experiment was laid out in a randomized complete block design with split-plot arrangements having four replications. Six rows, each of 5 m long and 30 cm apart were kept in a sub-plot of 1.8m×5m. Wheat variety "Gomal-8" was sown @ 100 kg seed ha^{-1} in last week of October for two consecutive years (2009-2011). The experimental area is located at an elevation range of 120 to 200 meters above sea level with arid to semi-arid climate and moderate spells (10-15 mm month^{-1}) during monsoon season. The average maximum and minimum temperatures during the crop season were 26°C and 11°C with relative humidity of 79% (in October) and 60% (in April). Physico-chemical properties of the experimental site are given in Table 1.

Table 1: *Physico-chemical characteristics of experimental site*

Symbol	Unit	Values	
		2009-10	2010-11
Textural Class	-	Silty clay	Silty clay
pH (1:5)	1-14	7.6	8.2
EC (1:2.5)	dS m^{-1}	0.26	0.41
Organic Matter	%	0.68	0.87
N	%	0.042	0.032
P	Ppm	16.85	7.00
K	Ppm	400	285

Source: *Soil Chemistry Lab., Agricultural Research Institute, Dera Ismail Khan, Pakistan*

The experimental treatment consisted of main plot where NPK and organic fertilizers viz. NPK @ 150-120-90 kg ha^{-1}, NPK @ 75-60-45 + FYM @ 10000 kg ha^{-1}, NPK @ 75-60-45 + compost @ 500 kg ha^{-1}, NPK @ 75-60-45 + soil conditioner @ 11 kg ha^{-1} were applied. While micronutrients, alone and in combinations, viz. Zn @ 10 kg ha^{-1}, Cu @ 8 kg ha^{-1}, B @ 2 kg ha^{-1}, Zn+Cu @ 10+8 kg ha^{-1}, Zn+B @ 10+2 kg ha^{-1}, Cu+B @ 8+2 kg ha^{-1}, Zn+Cu+B @ 10+8+2 kg ha^{-1} and control [no micronutrient] were assigned to sub-plots. Half dose of N along with full doses of all other fertilizers including micronutrients were applied at sowing while remaining half N was top dressed with first irrigation. The sources of fertilizers were Urea, DAP, SOP, Compost (46% organic matter, 2.5% N, 1% each P and K, 6% silica) and Soil conditioner (50% w/w humic acid) whereas trace elements were used in sulphate form ($ZnSO_4$, $CuSO_4$) and borax ($Na_2B_4O_7$). Data on various physiological parameters were recorded as per procedure as follows during both the cropping seasons:

Crop growth rate (g m^{-2} day^{-1})

Dry weight of plants (m^{-2}) in each sub-plot was recorded at 49 and 98 DAS and then crop growth rate was calculated by using the formula:

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

W_1 = Dry weight (49 DAS), W_2 = Dry weight (98 DAS), T_1 & T_2 = Time interval in days

Relative growth rate (mg g^{-1} day^{-1})

Relative growth rate was calculated by using the following formula:

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

Net assimilation rate (mg m^{-2} day^{-1})

Net assimilation rate was calculated by using the following formula:

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

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_1 and T_2 are time interval while grain yield (t ha^{-1}) was recorded at maturity.

Table 2: *Leaf area index at 49 days after sowing of wheat as affected by NPK, organic fertilizers and micronutrients during 2009-10 and 2010-11*

2009-10									
NPK and Organic Fertilizers	**Micronutrients**								
	Zinc (Zn)	**Copper (Cu)**	**Boron (B)**	**Zn + Cu**	**Zn + B**	**Cu + B**	**Zn+Cu+B**	**Control**	**Means**
NPK (full dose)	0.35 ^{NS}	0.30	0.38	0.33	0.37	0.32	0.33	0.30	0.33 a
NPK (half) + FYM	0.26	0.27	0.29	0.26	0.27	0.27	0.26	0.21	0.26 ab
NPK (half) + Compost	0.22	0.16	0.22	0.21	0.23	0.19	0.22	0.16	0.20 b
NPK (half) + Soil Cond.	0.24	0.21	0.26	0.21	0.25	0.25	0.23	0.20	0.23 b
Means	**0.27 ab**	**0.23 ab**	**0.29 a**	**0.25 ab**	**0.27 ab**	**0.26 ab**	**0.26 ab**	**0.22 b**	
$LSD_{0.05}$ NS = non-significant	NPK + Organic fertilizers = 0.07; Micronutrients = 0.06 Any two means in their respective group sharing no common letter(s) are significant (P<0.05)								
2010-11									
NPK (full dose)	0.28 ^{NS}	0.26	0.30	0.27	0.28	0.27	0.27	0.26	0.27 a
NPK (half) + FYM	0.23	0.25	0.26	0.25	0.25	0.25	0.23	0.18	0.24 ab
NPK (half) + Compost	0.19	0.16	0.21	0.19	0.21	0.17	0.19	0.16	0.19 b
NPK (half) + Soil Cond.	0.22	0.19	0.25	0.19	0.23	0.22	0.22	0.18	0.21 b
Means	**0.23 ab**	**0.22 ab**	**0.25 a**	**0.22 ab**	**0.24 ab**	**0.23 ab**	**0.23 ab**	**0.19 b**	
$LSD_{0.05}$ NS = non-significant	NPK + Organic fertilizers = 0.05; Micronutrients = 0.05 Any two means in their respective group sharing no common letter(s) are significant (P<0.05)								

Leaf area index at 49 and 98 days after sowing

Leaf area index was measured at 49 and 98 days after sowing (DAS) by using the following formula:

$$\text{Leaf area index (LAI)} = \frac{\text{Total leaf area } (m^{-2})}{10000}$$

Statistical analysis

The data were recorded and analyzed using analysis of variance technique (Steel et al., 1997) with subsequent comparison of the individual treatment means through Tukey HSD Test (Black, 2011). The analysis was performed using "Statistix 8.1" computer software program.

Results and Discussion

Leaf area index at 49 days after sowing

The data presented in Table 2 revealed that use of NPK and organic fertilizers significantly improved leaf area index at 49 DAS during the year 2009-10. The maximum LAI (0.33 and 0.27) was recorded by the application NPK (full dose) during both the cropping seasons while the use of FYM along with NPK (half dose) had statistically at par LAI (0.26 and 0.24). The minimum LAI (0.20 and 0.19) was obtained by the application of compost along with NPK (half dose). The use of micronutrients in all possible combinations had significant effect on LAI during the first cropping season while it was non-significantly affected during the next cropping season. Maximum LAI of 0.29 during 2009-10 and 0.25 during 2010-11 was recorded by the application of boron. This was statistically at par with other treatments viz. Zn+B and Zn, respectively during the two planting seasons. Sole as well as combined application of these two elements improved plant growth with better translocation of food towards the apical portion of leaves at earlier stage which subsequently improved leaf area index. Manal et al. (2010) reported that the use of boron helps plants in chlorophyll formation with increased photosynthetic activities. Minimum LAI (0.22 and 0.19) was recorded in control where no micronutrients were applied during the two successive years. As far as the interaction of NPK, organic fertilizers and micronutrients application is concerned, there were non-significant differences among treatment means.

Leaf area index at 98 days after sowing

As shown in Table 3, the use of NPK, organic fertilizers and micronutrients significantly affected leaf area index (98 DAS). There was a linear increase in leaf area index from one growth phase to another. Significantly maximum leaf area index (2.03 and 2.77) was recorded in NPK (full dose) treatment during both the experimental years. It was followed with LAI of 1.70 and 2.03 recorded in FYM along with NPK (half dose) treatment during the two cropping seasons. The

Table 3: *Leaf area index at 98 days after sowing of wheat as affected by NPK, organic fertilizers and micronutrients during 2009-10 and 2010-11*

NPK and Organic Fertilizers	Micronutrients								
2009-10									
	Zinc (Zn)	Copper (Cu)	Boron (B)	Zn + Cu	Zn + B	Cu + B	Zn+Cu+B	Control	Means
NPK (full dose)	2.07 NS	1.95	2.20	2.04	2.09	1.97	1.99	1.91	2.03 a
NPK (half) + FYM	1.70	1.74	1.87	1.73	1.84	1.79	1.66	1.31	1.70 b
NPK (half) + Compost	1.44	1.08	1.50	1.44	1.51	1.27	1.46	1.03	1.34 c
NPK (half) + Soil Cond.	1.59	1.39	1.73	1.35	1.65	1.62	1.56	1.31	1.52 bc
Means	**1.70 ab**	**1.54 bc**	**1.82 a**	**1.64 ab**	**1.76 ab**	**1.66 ab**	**1.67 ab**	**1.39 c**	
$LSD_{0.05}$	NPK+Organic fertilizers=0.23			Micronutrients=0.23					
NS = non-significant	Any two means in their respective group sharing no common letter(s) are significant (P<0.05)								
2010-11									
NPK (full dose)	3.37 ab	2.46 c-f	3.50 a	2.63 bcd	2.83 abc	2.46 c-f	2.49 cde	2.40 c-g	2.77 a
NPK (half) + FYM	1.93 d-k	2.12 c-j	2.40 c-g	1.94 d-k	2.29 c-h	2.20 c-i	1.87 d-k	1.47 ijk	2.03 b
NPK (half) + Compost	1.65 g-k	1.23 k	1.69 e-k	1.59 h-k	1.71 e-k	1.24 k	1.68 f-k	1.18 k	1.49 c
NPK (half) + Soil Cond.	1.74 e-k	1.53 h-k	1.97 d-k	1.53 h-k	1.86 d-k	1.84 d-k	1.71 e-k	1.34 jk	1.69 bc
Means	**2.17 ab**	**1.83 cd**	**2.39 a**	**1.82 bc**	**2.17 ab**	**1.93 bc**	**1.94 bc**	**1.60 d**	
$LSD_{0.05}$	NPK+Organic fertilizers=0.40			Micronutrients=0.31		NPK + Organic x Micronutrients = 0.80			
NS = non-significant	Any two means in their respective group sharing no common letter(s) are significant (P<0.05)								

plants receiving sufficient amount of NPK (full dose) produced higher leaf area, which in turn boosted the photosynthetic activity and increased dry matter accumulation. These findings are supported by Warraich et al. (2002) who reported that leaf area index was significantly increased with increasing NPK levels. Application of micronutrients, alone and in combinations, significantly affected leaf area index (98 DAS) during both the years of experimentation. Maximum LAI (1.82 and 2.39) was recorded in boron treatment while the use of zinc + boron had LAI of 1.76 and 2.17 and zinc alone (1.70 and 2.17) during both the years. Tahir et al. (2009) noted that boron application increases cell division, meristematic tissues and leaves expansion with more leaf area. LAI was minimum (1.39 and 1.60) in control where no micronutrients was added. The data further revealed that there was non-signification interaction between NPK, organic fertilizers and micronutrients during 2009-10 while significant interaction was noted during the succeeding year. Maximum leaf area index (2.20 and 3.50) was recorded in NPK (full dose) + boron treatment which was statistically at par with NPK (full dose) + zinc producing LAI of 2.09 and 3.37. The minimum leaf area index (1.03 and 1.18) was recorded in compost along with NPK (half dose) treatment during the two cropping seasons.

Crop growth rate (g m^{-2} day^{-1})

Crop growth rate plays an important role in crop production and it is highly manipulated by the crop variety, temperature, radiation and supply of nutrients. The data given in Table 4 revealed that crop growth rate was significantly affected by the application of NPK alone and in combination with organic fertilizers and micronutrients. Significantly higher crop growth rate (40.42 and 40.96) was produced with NPK (full dose) followed by 33.72 and 31.64 g m^{-2} day^{-1} recorded in FYM and NPK (half dose) treatment during both the experimental years. Using compost along with NPK (half dose) had CGR of 28.74 and 23.79 g m^{-2} day^{-1}. Among different micronutrients and their combinations, the maximum crop growth rate (37.07 and 36.30) was recorded in boron treatment during both the experimental years. It was statistically at par with zinc + boron (35.77 and 33.68) and zinc alone (35.19 and 32.50) while combined application of zinc + copper + boron (33.92 and 30.76) and copper + boron (33.82 and 30.50) had lower crop growth rate. Minimum crop growth rate (28.57 and 25.18) was recorded in control during both the cropping seasons. Previously, Tahir et al. (2009) reported that application of boron along with NPK causes leaf expansion and increased photosynthetic activities which improves plant growth while Reddy (2004)

Table 4: *Crop growth rate (g m^{-2} day^{-1}) of wheat as affected by NPK, organic fertilizers and micronutrients during 2009-10 and 2010-11*

NPK and Organic Fertilizers	Micronutrients								
	Zinc (Zn)	Copper (Cu)	Boron (B)	Zn + Cu	Zn + B	Cu + B	Zn+Cu+B	Control	Means
2009-10									
NPK (full dose)	42.76 ^{NS}	36.09	47.30	40.77	44.07	37.38	39.27	35.73	40.42 a
NPK (half) + FYM	34.06	34.36	35.42	34.12	35.32	35.21	33.70	27.59	33.72 b
NPK (half) + Compost	30.89	24.65	31.38	30.75	31.57	26.15	31.15	23.43	28.74 c
NPK (half) + Soil Cond.	31.74	29.71	34.19	29.63	33.45	33.09	31.57	27.55	31.36 bc
Means	**35.19 ab**	**31.20 bc**	**37.07 a**	**32.95 abc**	**35.77 ab**	**33.82 abc**	**33.92 abc**	**28.57 c**	
$LSD_{0.05}$	NPK+Organic fertilizers=2.98			Micronutrients=5.62					
NS = non-significant	Any two means in their respective group sharing no common letter(s) are significant (P<0.05)								
2010-11									
NPK (full dose)	43.47 ^{NS}	36.60	52.13	38.62	45.89	37.63	38.45	34.94	40. 96 a
NPK (half) + FYM	31.51	32.80	34.19	31.75	34.06	34.03	30.83	23.94	31.64 b
NPK (half) + Compost	25.08	20.10	26.11	25.03	27.08	21.59	25.41	19.97	23.79 c
NPK (half) + Soil Cond.	27.52	24.92	32.77	24.10	30.11	29.77	27.33	21.90	27.30 bc
Means	**32.50 ab**	**28.60 bc**	**36.30 a**	**29.87 bc**	**33.68 ab**	**30.76 abc**	**30.50 abc**	**25.18 c**	
$LSD_{0.05}$	NPK+Organic fertilizers=4.88			Micronutrients=6.37					
NS = non-significant	Any two means in their respective group sharing no common letter(s) are significant (P<0.05)								

Table 5: *Relative growth rate (mg g^{-1} day^{-1}) of wheat as affected by NPK, organic fertilizers and micronutrients during 2009-10 and 2010-11*

NPK and Organic Fertilizers	Micronutrients								
	Zinc(Zn)	Copper(Cu)	Boron(B)	Zn + Cu	Zn + B	Cu + B	Zn+Cu+B	Control	Means
2009-10									
NPK (full dose)	89.16 ^{NS}	88.46	90.02	88.98	90.00	88.53	88.55	87.79	88.94 a
NPK (half) + FYM	85.23	86.55	87.79	85.25	87.50	86.59	84.71	81.59	85.65 ab
NPK (half) + Compost	82.48	79.30	83.15	82.35	83.33	80.42	83.15	78.98	81.64 b
NPK (half) + Soil Cond.	83.63	82.08	85.96	81.66	84.52	84.50	83.58	80.77	83.34 b
Means	**85.34 ^{NS}**	**84.10**	**86.73**	**84.56**	**86.12**	**85.01**	**85.00**	**82.28**	
$LSD_{0.05}$	NPK+Organic fertilizers=4.63								
NS = non-significant	Any two means in their respective group sharing no common letter(s) are significant (P<0.05)								
2010-11									
NPK (full dose)	86.04 ^{NS}	81.43	87.30	83.81	86.09	83.24	83.80	81.41	84.14 a
NPK (half) + FYM	78.67	80.52	81.20	79.77	81.08	80.67	78.28	73.89	79.26 ab
NPK (half) + Compost	74.35	73.10	75.01	74.29	75.51	73.64	74.60	70.92	73.93 b
NPK (half) + Soil Cond.	77.81	74.21	80.48	74.12	78.23	78.19	77.67	73.84	76.82 b
Means	**79.23 ^{NS}**	**77.31**	**81.00**	**78.00**	**80.21**	**78.94**	**78.59**	**75.01**	
$LSD_{0.05}$	NPK+Organic fertilizers=7.24								
NS = non-significant	Any two means in their respective group sharing no common letter(s) are significant (P<0.05)								

stated that due to sufficient availability of nutrients at the time when plants were requiring nutritional supplement influenced the size and efficiency of leaf canopy and the crop converted solar energy into economic growth. The interaction between synthetic, organic fertilizers and micronutrients was non-significant statistically during the two successive planting seasons.

Relative growth rate (mg g^{-1} day^{-1})

Relative growth rate is based on the initial plant

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Table 6: *Net assimilation rate (mg m^{-2} day^{-1}) of wheat as affected by NPK, organic fertilizers and micronutrients during 2009-10 and 2010-11*

NPK and Organic Fertilizers	**Micronutrients**								
	Zinc (Zn)	**Copper (Cu)**	**Boron (B)**	**Zn + Cu**	**Zn + B**	**Cu + B**	**Zn+Cu+B**	**Control**	**Means**
2009-10									
NPK (full dose)	3.72 NS	3.39	3.83	3.70	3.77	3.44	3.45	3.32	3.58 a
NPK (half) + FYM	2.61	2.73	3.25	2.69	3.11	2.75	2.60	1.73	2.68 ab
NPK (half) + Compost	2.04	1.54	2.22	1.86	2.29	1.64	2.05	1.48	1.89 b
NPK (half) + Soil Cond.	2.35	1.80	2.71	1.76	2.54	2.52	2.34	1.66	2.21 ab
Means	**2.69 NS**	**2.36**	**3.00**	**2.50**	**2.92**	**2.58**	**2.61**	**2.05**	
$LSD_{0.05}$	NPK + Organic fertilizers = 1.42								
NS = non-significant	Any two means in their respective group sharing no common letter(s) are significant (P<0.05)								
2010-11									
NPK (full dose)	4.19 NS	3.39	4.95	3.80	4.38	3.55	3.62	3.22	3.89 a
NPK (half) + FYM	2.85	2.95	3.12	2.88	3.08	3.04	2.80	2.07	2.85 ab
NPK (half) + Compost	2.44	1.60	2.51	2.44	2.58	1.78	2.47	1.35	2.14 b
NPK (half) + Soil Cond.	2.70	2.41	2.90	2.16	2.78	2.72	2.59	2.06	2.54 b
Means	**3.09 NS**	**2.58**	**3.37**	**2.82**	**3.16**	**2.77**	**2.87**	**2.18**	
$LSD_{0.05}$	NPK + Organic fertilizers = 1.44								
NS = non-significant	Any two means in their respective group sharing no common letter(s) are significant (P<0.05)								

weight in time interval. The data given in Table 5 showed that application of NPK and organic fertilizers had significant effect on relative growth rate. Among different treatments, the use of NPK (full dose) had maximum relative growth rate (88.94 and 84.14) while it was statistically at par (85.65 and 79.26) when NPK (half dose) along with FYM was applied. The application of compost along with NPK (half dose) had the lowest relative growth rate (81.64 and 73.93). High RGR with the application of full-recommended doses of NPK was due to availability of sufficient amount of nutrients during plant growth stages. Warraich et al. (2002) reported better plant growth with increased NPK application. On the other hand, application of micronutrients, alone and in combinations had no significant effect on RGR. Shukla and Warsi (2000) in their study also reported that application of micronutrients had no significant effect on relative growth rate and dry matter accumulation in wheat. The minimum relative growth rate (82.28 and 75.01) was recorded in control. The data further revealed non-significant interaction of NPK, organic fertilizers and micronutrients during both the years of experimentation.

Net assimilation rate (mg m^{-2} day^{-1})

Net assimilation rate corresponds to the efficiency of photosynthesis in overall sense and in connection with relative growth rate (Reddy, 2004). It is affected by different factors like temperature, CO_2, water, leaf age, minerals, chlorophyll and genotype. The data given in Table 6 indicated almost similar trend as noted for relative growth rate during both the cropping seasons. The use of NPK and organic fertilizers significantly improved net assimilation rate. The maximum NAR (3.58 and 3.89) was recorded in NPK (full dose) treatment which was statistically at par with NPK (half dose) along with FYM (2.68 and 2.85) and soil conditioner (2.21 and 2.54) during both the experimental years. The lowest net assimilation rate was, however, recorded in NPK (half dose) along with compost with NAR of 1.89 and 2.14 mg m^{-2} day^{-1}. Higher net assimilation rate with the application of NPK (full dose) was due to increased leaves expansion, more leaf area and crop growth rate. The use of different micronutrients had non-significant effect on net assimilation rate. The lowest net assimilation rate (2.05 and 2.18) was recorded in control where no micronutrient was applied. The interaction of NPK, organic fertilizers and micronutrients was also non-significant statistically.

Grain yield (t ha^{-1})

Organic matter accumulation by green plants depends on photosynthesis and conversion of light energy into chemical energy which represents crop productivity

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Table 7: *Grain yield (t ha^{-1}) of wheat as affected by NPK, organic fertilizers and micronutrients during 2009-10 and 2010-11*

NPK and Organic Fertilizers	Micronutrients								
	Zinc (Zn)	Copper (Cu)	Boron (B)	Zn + Cu	Zn + B	Cu + B	Zn+Cu+B	Control	Means
2009-10									
NPK (full dose)	4.52 NS	4.21	4.57	4.52	4.57	4.46	4.49	3.87	4.40 a
NPK (half) + FYM	3.62	3.76	3.84	3.67	3.80	3.79	3.61	3.23	3.66 b
NPK (half) + Compost	3.48	2.98	3.50	3.41	3.56	3.10	3.49	2.88	3.30 b
NPK (half) + Soil Cond.	3.56	3.35	3.68	3.34	3.59	3.59	3.56	3.12	3.47 b
Means	**3.81 a**	**3.57 ab**	**3.90 a**	**3.73 a**	**3.87 a**	**3.73 a**	**3.79 a**	**3.27 b**	
$LSD_{0.05}$	NPK+Organic fertilizers=0.44			Micronutrients=0.39					
NS = non-significant	Any two means in their respective group sharing no common letter(s) are significant (P<0.05)								
2010-11									
NPK (full dose)	5.47 NS	5.00	5.62	5.27	5.60	5.18	5.24	4.98	5.29 a
NPK (half) + FYM	3.87	4.08	4.19	4.00	4.14	4.11	3.87	3.56	3.98 b
NPK (half) + Compost	3.60	6.31	3.70	3.59	3.76	3.40	3.70	3.18	3.53 c
NPK (half) + Soil Cond.	3.82	3.58	4.04	3.56	3.83	3.83	3.82	3.48	3.74 bc
Means	**4.23 ab**	**3.99 bc**	**4.38 a**	**4.10 ab**	**4.30 a**	**4.13 ab**	**4.15 ab**	**3.80 c**	
$LSD_{0.05}$	NPK+Organic fertilizers=0.35			Micronutrients=0.29					
NS = non-significant	Any two means in their respective group sharing no common letter(s) are significant (P<0.05)								

(Reddy, 2004). The data given in Table 7 showed significant variations in grain yield by the applicatio of NPK, organic fertilizers and micronutrients during the years 2009-10 and 2010-11. Maximum grain yield (4.40 and 5.29) was obtained by the application of NPK (full dose). It was followed by FYM (3.66 and 3.98) treatment and soil conditioner (3.47 and 3.74) along with NPK (half dose) during both the experimental years. The use of compost along with NPK (half dose) produced the lowest grain yield (3.30 and 3.53) during two cropping seasons. The data further revealed that the use of boron produced maximum grain yield (3.90 and 4.38) during the year 2009-10 and 2010-11. It was statistically at par with grain yield recorded in zinc + boron (3.87 and 4.30) and zinc (3.81 and 4.23) alone treatments during both the years. The minimum grain yield (3.27 and 3.80) was recorded in control. The use recommended NPK fertilizer was an instant source of plant food which played an important role in enhancing crop productivity. The growth and development of crop plant was further improved by supplementing micronutrients along with the application of NPK. Basically boron application helps plants in spikelet appearance and grain setting. In the present study, almost all the parameters showed better results with the application of NPK (full dose) and boron during both the cropping seasons. Hammad et al. (2011) reported the highest economic yield with the application of recommended NPK fertilizers. The results are further supported by Chaudry et al. (2007) who recorded significant increase in grain yield with the application of boron along with basal dose of NPK while Uddin et al. (2008) also obtained 50% more yield with the application of boron. The interaction of NPK, organic fertilizers and micronutrients was, however, non-significant statistically during two years of experimentation.

Conclusion

The use of different organic fertilizers resulted in improved growth status of wheat. However, higher leaf area index (49 and 98 DAS), crop growth rate, relative growth rate, net assimilation rate and ultimately the yield were recorded with the application of NPK (at recommended levels). Similarly, micronutrients application (alone and in combination) also played a significant role in improving crop growth. Addition of boron with NPK (at recommended levels) was the best combination producing higher results.

Author's Contribution

Research work presented in this paper, is part of Ph.D. dissertation of the corresponding author. Dr. Mohammad Safdar Baloch was the research supervisor for two consecutive years. Dr. Ejaz Ahmad Khan contributed during writing up and correction of manuscript. Dr. Abdul Aziz Khakwani and Dr. Kashif Waseem helped in data analysis and results compilation.

References

- Ahmadikhah, A., H. Narimani, M.M. Rahimi and B. Vaezi, 2010. Study on the effects of foliar spray of micronutrient on yield and yield components of durum wheat. Archives of Applied Science and Research 2 (6): 168-176.
- Black, K., 2011. Business statistics: for contemporary decision making. 7th Ed. John Wiley & Sons. Pp. 424.
- Chaudry, E.H., V. Timmer, A.S. Javed and M.T. Siddique, 2007. Wheat response to micronutrients in rainfed areas of Punjab. Soil and Environment 26 (1): 97-101.
- Defra. 2002. Action plan to develop organic food and farming in England. Available at:http://www.defra.gov.uk/foodfarm/growing/organic/policy/actionplan/pdf/actionplan-2year.pdf (Accessed on 08-09-2015)
- Duan, Z., H. Xiao, Z. Dong, X. Li and G. Wang, 2004. Combined effect of NPK fertilizers and water on spring wheat yield in an arid desert region. Communication in Soil Science and Plant Analysis 35 (1-2): 161-175. http://dx.doi.org/10.1081/CSS-120027641
- Hammad, H.M., A. Ahmad, K.Q. Laghari, F. Abbas, W. Nasim, W. Farhad and A.H. Malik, 2011. Organic farming in wheat crop under arid condition of Pakistan. Pakistan Journal of Agricultural Sciences 48 (2): 97-101.
- Haque, M.Q., M.H. Rahman, R. Begum and M.F. Islam, 2002. Integrated use of inorganic and organic fertilizers in wheat-rice cropping pattern for sustained crop production. Symposium No. 13, Paper No. 354, 17th World Congress of Soil Science, August 14-21, Thailand.
- Khan, M.A., I. Hussain and M.S. Baloch, 2000. Wheat yield potential – current status and future strategies. Pakistan Journal of Biological Sciences 3 (1): 82-86. http://dx.doi.org/10.3923/pjbs.2000.82.86
- Khan, M.U., M. Qasim and I.U. Khan, 2007. Effect of integrated nutrient management on crop yields in rice-wheat cropping system. Sarhad Journal of Agriculture 23 (4): 1019-1026.
- 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 conditions. Journal of American Sciences 6 (8): 398-404.
- 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. Micro-nutrients and production of hard red spring wheat. Minnesota Crop News, University of Minnesota.
- Shukla, S.K. and A.S. Warsi, 2000. Effect of sulphur and micronutrients on the growth, nutrient content and yield of wheat. Indian Journal of Agriculture Research 34 (3): 203-205.
- Steel, R.G.D., J.H. Torrie and D.A. Deekey, 1997. Principles and procedures of statistics: a biometrical approach, 3rd ed., McGraw Book Co. Inc., New York.
- Stone, J.P. and R. Savin, 2000. Grain quality and its physiological determinants in wheat ecology and physiology of wheat determinants. Viva Books Private Limited, India. Pp. 85-96.
- Tahir, M., A. Tanveer, T.H. Shah, N. Fiaz and A. Wasaya, 2009. Yield response of wheat to boron application at different stages. Pakistan Journal of Life and Social Sciences 7 (1): 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. Journal of Subtropical Agriculture Research and Development 6 (2): 483-486.
- Warraich, E.A., N. Ahmad, Shahzad, M.A. Basra and I. Afzal, 2002. Effect of nitrogen on source-sink relationship in wheat. International Journal of Agriculture and Biology 4 (2): 300-302.
- Weil, R.R. and F. Magdoff, 2004. Significance of soil organic matter to soil quality and health. In: Magdoff, F. and R.R. Weil (eds.), Soil Organic Matter in Sustainable Agric. CRC Press, Boca Raton, FL, USA, pp. 1-43. http://dx.doi.org/10.1201/9780203496374.ch1