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Contribution of Micronutrient Fertilization in Wheat Production and its Economic Repercussions

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Abstract. Wheat response to the application of Zn, Fe and B in rice-wheat cropping pattern at ten locations in the fields in the Punjab, Pakistan was studied. The highest mean wheat grain yield (4707 kg/ha) was recorded with application of Zn:B @ 5:1 kg/ha, followed by 4678 kg/ha with Zn:Fe @ 5:10 kg/ha. The three micronutrients increased the grain yield from 1.8 to 11.8% over control, highest being recorded with the application of Zn:B @ 5:1 kg/ha. Combined application of all the three micronutrients reduced the grain yield by 1% compared to the highest yield attained by the combine application of Zn and B. However, the application of Zn @ 5 kg/ha proved to be the most economical micronutrient application with VCR of 4.80. None of the three nutrients increased the wheat grain yield in Gujrat, whereas Zn significantly increased the grain yield over control in Mandi Bahauddin. Straw to grain ratio of wheat was significantly decreased by the application of micronutrients over control mainly due to increase in grain weight.

Keywords: micronutrients, wheat, fertilizer, zinc, iron, boron

Introduction

Wheat (*Triticum aestivum*) is an important rabi (winter) crop of Pakistan and is the most extensively cultivated crop in both the irrigated and the rainfed areas of the country. In Pakistan, during the year 2006-07, wheat was grown on an area of 8.58 million hectares with a total production of 23.30 million tones and average yield of 2716 kg/ha (GOP, 2008). To maintain the yield on a sustainable basis, proper amount of nutrients have to be added to each crop. Continuous cropping and contrasting edaphic requirement of crops have shown evidence of soil nutrient depletion and imbalances, low nutrient use efficiency, decline in organic matter and stagnant yield (Gupta *et al*., 2003). To get optimum yield, a balance dose of macronutrients as well as micronutrients are required. The soils of Pakistan, across much of the 22 m/ha cultivated area, have been formed from calcareous alluvium and loess, and are low in most of the essential plant nutrients. Loss of organic matter, whether by erosion or high temperature, in agro ecosystem adds to impoverishment of soil resources of several nutrient elements (Hadda and Arora, 2006).

Deficiency of various micronutrients is related to soil type, crop and to various cultivars. Introduction of new high yielding hybrids or cultivars, demanding a higher level of soil fertility, has further accentuated the incidence of micronutrient deficiencies.

The widespread deficiencies of Fe and Zn on the world scale are estimated to be 30-50% of the cultivated area (Cakmak, 2002). Soil and plant analyses show that >50% of the cultivated soils of the country are unable to provide sufficient Zn and B to meet the need of many crops (Khattak, 1995). The information obtained from 329 soil samples collected from various depths during the period of seven months revealed widespread deficiency of Zn and B followed by Fe (Zia *et al*., 2004). The widespread Zn and B deficiencies and micronutrient disorders have been reported for different field crops in all the four provinces of the country. More than 60% of soil in Punjab, 21% in NWFP, 6-94% in Sindh and 90% in Baluchistan, are reported to be Zn deficient; Fe and B deficiency has been reported by Aziz *et al*. (2004) in citrus, deciduous fruits, groundnut and many other crops, who also found that make-up dose of nutrients improved the crop quality and increased resistance in plants against biotic and abiotic stresses. Chaudhry *et al*. (2001) reported that 5 kg/ha Zn appeared to be the optimum dose for wheat crop. Rashid (2006) reported that wheat responded to B. Pervaiz *et al*. (2003) found that straw grain ratio (SGR) decreased with the subsequent increase in Zn application. The present study was, therefore, under taken to identify the wheat response to micronutrients and their economic contribution towards wheat production.

Materials and Methods

Ten experiments were conducted in fields of two districts, *viz.* Mandi Bahauddin and Gujrat, in the Punjab province of

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Pakistan under irrigated condition for three years during 2004-5 to 2006-07. The samples were collected from experimental sites at the depth of 0-15 and 15-30 cm before sowing the wheat crop. Soil samples were analyzed for texture, EC_e, pH, soil organic matter, extractable phosphorus (P) and potash (K) by the methods described by Ryan *et al*. (2001) and Page *et al.* (1982). The micronutrients (Zn and Fe) were analysed using atomic absorption spectrophotometer (Ryan *et al*., 2001) while boron (B) was analyzed by 0.05 M HCl extraction method (Rashid *et al*., 1994) using spectrophotometer.

A basal dose of NPK @ 80:114:120 kg/ha were applied to all plots in the form of urea, triple supper phosphate (TSP) and sulphate of potash (SOP), respectively. Full amount of PK and half of N were applied at sowing while remaining half amount of N was applied at the first irrigation. All the micronutrients Zn:Fe:B @ 5:10:1 kg/ha were applied at the sowing alone and in different combinations as zinc sulphate ($ZnSO_4.7H_2O$), Iron sulphate ($FeSO_4.7H_2O$) and boric acid (HBO_3), respectively. Three wheat varieties *viz*., Inqulab-91, AS 2000 and NIAB were grown in randomized complete block design (RCBD). Net plot size was 252.9 m^2 for all the treatments. The agronomic efficiency for micronutrients (Zn, Fe and B) was computed according to Craswell (1987), as follows:

Agronomic efficiency (AE) = grain yield (fertilized plot) - grain yield (control plot)/micronutrient fertilizer rate.

Yield and fertilizer rates were in kg/ha.

The economic analysis of crop response to micronutrients was calculated through gross profit and value cost ratio (VCR) as described by Ahmed and Rashid (2003). The price of wheat grain was Rs. 23.75/kg and that of the fertilizers, Zn, Fe and B, was Rs. 340, 249 and 910/kg, respectively. The statistical analysis of the data was carried out by applying Analysis of Variance technique (Steel and Torrie, 1980) using MSTAT package.

Results and Discussion

Original soil characteristics. The physicochemical properties of soil of the fields, prior to sowing of crop, are described in Table 1. Mean soil pH value was 7.42 in the range of 6.7-7.7 with the variation of 0.27. The electrical conductivity (EC) was 0.28 in the range of 0.1-0.4 dS/m with the variation of 0.23 at all the experimental sites in the category of normal soils i.e. free from salinity and sodicity. The organic matter in all the experimental sites ranged from 0.40-0.80% with the average values of 0.60%, whereas bicarbonate extractable soil phosphorus ranged from 3-6 mg/kg with the mean value of 4.37 mg/kg indicating that soil organic matter and bicarbonate extractable phosphorus were low. Boron in the soil ranged from 0.10-0.86 mg/kg with the mean value of 0.31 mg/kg and Zn ranged from 0.54-2.69 with the average value of 1.58 mg/kg. It indicates that the soils are low to medium range making B and Zn fertilization probable. Similarly, iron ranged from 0.96-2.67 mg/kg with the mean value of 1.97 mg/kg indicating low range of Fe.

Table 1. Physicochemical properties of experimental sites

Soil properties	Units	Mean	Range	Standard deviation
pH	-	7.42	6.7-7.7	0.27
EC	dS/m	0.28	0.1-0.40	0.23
Organic matter	%	0.60	0.40-0.80	0.12
Available phosphorous (P)	mg/kg	4.37	3.0-6.0	0.71
Available potassium (K)	mg/kg	116	110-130	12.16
Zinc (Zn)	mg/kg	1.58	0.54-2.69	1.53
Iron (Fe)	mg/kg	1.97	0.96-2.67	1.43
Boron (B)	mg/kg	0.31	0.10-0.86	0.73

Wheat response to micronutrients. Wheat responded significantly ($P<0.05$) to individual micronutrient application across all the experimental sites. The pooled data revealed that increase in grain yield with the application of individual nutrient compared to control was 1.78% for B, 4.35% for Fe and 8.12% for Zn (Table 2). This increase in wheat grain yield with application of micronutrients was due to the improvement in grain weight. It is evident from Table 5 that straw to grain ratio decreased with the application of micronutrients as compared to control. The data also indicated that wheat was consistently responsive to Zn followed by Fe and B application. The combined application of three micronutrients reduced the grain yield by 1% compared to the highest yield of 4707 kg/ha attained with combined application of Zn (5 kg/ha) and B (1 kg/ha). It might be due to the antagonistic effect of Zn and Fe or of Fe with P (Imtiaz *et al*., 2003; Alam and Shereen, 2002). It is a well established fact that different nutrients may interact with each other by affecting the availability of each other from soil and their status in the plants through the process of growth and absorption. Interaction of nutrients in crop plants occurs when the supply of one nutrient affects the absorption and utilization of the other nutrient (Fageria *et al*., 1997). This type of interaction is most common when one nutrient is in excess concentration in the growth medium. Similarly, Imtiaz *et al*. (2003) found that as the Zn concentration in the substrate increased, the concentration of Fe in the plants decreased. In another study, Alam and Shereen (2002) indicated that chlorophyll content generally increased at low level of Zn and P, while at higher Zn and P level, it decreased as compared to the control.

Table 2. Impact of micronutrients on wheat yield and economic performance

Nutrients (kg/ha)			Yield	Increase	Net return	VCR	GNR
Zn	Fe	B	(kg/ha)	in yield (%)	(Rs.)		
0	0	0	4211[d]	-	-	-	-
0	0	1	4286[cd]	1.78	879	1.97	75
0	10	0	4394[bc]	4.35	1856	1.75	18.3
5	0	0	4553[ab]	8.12	6423	4.79	68.4
0	10	1	4663[a]	10.73	7343	3.16	41.10
5	0	1	4707[a]	11.78	9178	4.53	82.70
5	10	0	4678[a]	11.09	6901	2.65	31.13
5	10	1	4636[a]	10.09	5004	1.98	26.56

VCR = value: cost ratio; GNR = grain: nutrient ratio; means followed by different letters are significantly different at 5% level of probability.

Varietal response to micronutrients. The response of three wheat genotypes *viz*. Inqlab-91, AS-2000, NIAB to micronutrients (B, Fe and Zn) fertilization were studied through ten field experiments located in two irrigated districts *viz*. Mandi Bahauddin and Gujrat (Table 3). These wheat varieties responded significantly to micronutrients when applied singly as well as in various combinations. Data also indicated that yield potential of NIAB variety was greater than the other two varieties. Yield variations in various varieties with the application of micronutrients might be due to the difference in their yield potential (Kausar and Hamid, 1998) or micronutrient accumulative behaviour. Application of Zn alone to all the three varieties produced higher yield as compared to the yield obtained by the application of Fe and B alone. It revealed that application of Zn alone produced about 3 and 6% more yield compared to the yield obtained with the application of Fe and B alone, respectively. It also indicated that all the wheat varieties were more responsive to Zn followed by Fe and B. The integrated use of these micronutrients revealed that combined application of Zn and B gave the highest yield compared to all other combinations. Combined application of all the three nutrients impaired the yield by about 1.5% in all the varieties compared to the highest yield obtained by Zn and B. The results are in line with those of Chaudhary *et al*. (2007) who reported that response of Inqlab 91 to Fe and B was higher than Chakwal 97, and in case of Zn, Chakwal 97 performed better than Inqlab 91 by increasing the wheat grain yield under water stressed condition. Graham *et al*. (1987) reported that Zn reduced the toxic effects of excessive B in crop plants.

Site specific response to micronutrients. The results of ten experiments, conducted on wheat in irrigated area of two districts *viz*. Mandi Bahauddin and Gujrat during 2004-05 to 2006-07, revealed a site specific response to B, Fe and Zn, when applied either singly or in combination (Table 4). The wheat grain yield of control in Gujrat district was about 7% higher than the control yield in Mandi Bahauddin. It might be due to the variation in original soil status of nutrients (Table 1). Individual application of all the three micronutrients did not significantly increase the wheat grain yield compared to control yield in Gujrat district; whereas, response to all the micronutrients applied individually was statistically significant in Mandi Bahauddin. It means that Mandi Bahauddin area is more responsive to micronutrients than Gujrat district.

Table 3. Response of wheat varieties to micronutrients and economic performance

Nutrients (kg/ha)			Inqlab 91				AS 2000				Niab			
Zn	Fe	B	Yield (kg/ha)	Net return	VCR	GNR	Yield (kg/ha)	Net return	VCR	GNR	Yield (kg/ha)	Net return	VCR	GNR
0	0	0	4139[c]	-	-	-	2967[c]	-	-	-	5385[c]	-	-	-
0	0	1	4213[c]	0	0.05	74	3022[bc]	404	1.44	55	5481[bc]	1378	2.52	96
0	10	0	4320[bc]	99	1.04	18.1	3096[abc]	574	1.23	12.9	5624[abc]	3186	2.28	23.9
5	0	0	4472[ab]	4499	3.65	66.60	3215[abc]	4190	3.47	49.6	5830[ab]	8869	6.23	89.0
0	10	1	4584[ab]	5467	2.61	40.45	3299[ab]	4499	2.32	30.18	5964[a]	10359	4.05	52.64
5	0	1	4627[a]	7278	3.80	81.33	3316[a]	5667	3.19	58.16	6038[a]	12907	5.96	108.83
5	10	0	4598[ab]	5001	2.19	30.6	3296[a]	3624	1.87	21.93	5998[a]	10369	3.48	40.87
5	10	1	4557[ab]	3128	1.61	26.13	3266[ab]	2001	1.40	18.69	5943[ab]	8163	2.62	35.06

VCR = value: cost ratio; GNR = grain: nutrient ratio; means followed by different letters are significantly different at 5% level of probability.

Table 4. Districtwise wheat response to micronutrients and economics

Nutrients (kg/ha)			Gujrat				Mandi Bahauddin			
Zn	Fe	B	Yield (kg/ha)	Net return	VCR	GNR	Yield (kg/ha)	Net return	VCR	GNR
0	0	0	4342[c]	-	-	-	4071[e]	-	-	-
0	0	1	4419[c]	927	2.02	77	4144[cd]	832	1.92	73
0	10	0	4531[bc]	1999	1.80	18.9	4248[bcd]	1714	1.69	17.2
5	0	0	4695[abc]	6684	4.93	70.6	4402[abcd]	6161	4.62	66.2
0	10	1	4808[ab]	7676	3.26	42.36	4509[abc]	7011	3.07	39.82
5	0	1	4853[a]	9534	4.66	85.17	4552[a]	8822	4.39	80.16
5	10	0	4824[ab]	7258	2.73	32.13	4523[abc]	6545	2.56	30.13
5	10	1	4780[ab]	5313	2.04	27.38	4483[abc]	4695	1.92	25.75

VCR = value: cost ratio; GNR = grain: nutrient ratio; means followed by different letters are significantly different at 5% level of probability.

The highest increase of 10% in grain yield of wheat over control was observed with the application of Zn alone followed by 4% with Fe alone in both the districts.

The capacity of soil to supply plant-available nutrients can vary greatly among fields and seasons leading to insufficient plant use across large areas (Dobermann *et al.*, 2004; Dobermann and White, 1999). Combined application of Zn and B gave the highest yield in both the districts. Combined application of the entire three micronutrients decreased wheat grain yield by 1.5% compared to the highest yield in both the districts. It might be due to antagonistic effect of Fe with Zn or Zn with P (Imtiaz *et al.*, 2003; Alam and Shereen, 2002). High level of several minerals (Ca, P, N, Mn, Cu and Zn) in soil contributes to Fe chlorosis presumably because they are involved in interaction with Fe nutrition, although Fe deficiency *per se* may inhibit absorption of some other elements (Madero *et al.*, 1993).

Agronomic performance of micronutrients for wheat. The agronomic efficiency of micronutrients varied considerably when applied singly or in combination (Table 2). The overall data revealed that agronomic efficiency of B (75) was at the highest followed by Zn (68.4) when applied singly. It might be due to low requirement of wheat for B as compared to that for Zn and Fe. The GNR increased with the combined application of Zn and B by about 10% and 21% compared to individual application of B and Zn, respectively. It may be explained by the fact that application of higher rate of Zn *viz*. 5 kg/ha reduced GNR compared to low dose of B (1 kg/ha). The GNR was reduced by the combined application of three micronutrients. While comparing different varieties, B efficiency was higher in NIAB followed by Inqlab 91 and AS 2000. The site specific agronomic performance was almost the same in both the districts.

Economic importance of micronutrients for wheat. The net return is the value of increased yield as a result of applied fertilizer after providing the cost of fertilizer whereas the value cost ratio (VCR) is the rate of return from the money spent on fertilizer. The value 2 of VCR means a 100% return from the money spent on fertilizer. Variable tested with VCR value below 2 is not recommended for farmers because in this case net profit decreases (Ahmed and Rashid, 2003). The net return and VCR values were affected by micronutrients when applied singly as well as in combination (Table 2). The pooled data revealed that among the individual application of micronutrients, Zn application gave the highest net return of Rs. 2841 with the VCR value of 4.79. The application of Fe and B may not be recommended to farmers as the VCR by Fe and B application was lower than 2. The integrated use of micronutrients revealed that application of any two micronutrients gave the net return ranging from Rs. 3045 to Rs. 4058 with VCR value above 2. Combined application of three micronutrients may reduce the net profit which may be due to the reduction of efficiency of micronutrients. In case of various genotypes, application of each nutrient performed better whether applied singly or in combination as the VCR in most of the treatments was above 2 (Table 3). Based on site specific response to micronutrients, application of Zn and B is recommended in Gujrat district; whereas application of Zn is recommended in Mandi Bahauddin district.

Straw to grain ratio. Straw to grain ratio (SGR) of wheat crop was significantly decreased by the application of micronutrients (Table 5 and 6). The maximum decrease in SGR was observed in the treatment where only Zn was applied that was about 24% lower than the control. There was a decrease in SGR in all the varieties with the application of individual micronutrient as compared to combined application of these micronutrients. Application of Fe alone impaired the SGR of Inqlab 91 and NIAB to about 30% and 27% followed by 24% and 19% with Zn application, respectively, whereas, the trend was reciprocal in AS-2000 variety, in which Zn performed better to increase the grain yield. The combined application of

Table 5. Impact of micronutrients on straw: grain ratio of wheat (districtwise)

Nutrients (kg/ha)			Mandi Bahauddin		Gujrat		Over all	
Zn	Fe	B	SGR	Decrease (%)	SGR	Decrease (%)	SGR	Decrease (%)
0	0	0	2.114	-	1.75	-	1.950	-
0	0	1	1.766	16.46	1.63	6.76	1.704	12.61
0	10	0	1.490	29.52	1.37	21.49	1.437	26.30
0	10	1	1.682	20.43	1.58	9.46	1.637	16.05
5	0	0	1.478	30.09	1.47	16.04	1.472	24.51
5	10	0	1.548	26.77	1.52	12.72	1.537	21.17
5	0	1	1.756	16.93	1.62	7.44	1.693	13.18
5	10	1	1.868	11.64	1.71	1.89	1.799	7.74

SGR = straw: grain ratio.

Table 6. Effect of micronutrients on straw: grain ratio of three wheat varieties

Nutrients (kg/ha)			Inqlab91		AS2000		NIAB		Over all	
Zn	Fe	B	SGR	Decrease (%)	SGR	Decrease (%)	SGR	Decrease (%)	SGR	Decrease (%)
0	0	0	2.033	-	2.02	-	1.807	-	1.950	-
0	0	1	1.770	12.94	1.843	8.76	1.677	7.19	1.704	12.61
0	10	0	1.420	30.15	1.780	11.88	1.320	26.95	1.437	26.30
0	10	1	1.704	16.18	1.580	21.78	1.703	5.76	1.637	16.05
5	0	0	1.540	24.25	1.200	40.59	1.467	18.18	1.472	24.51
5	10	0	1.636	19.28	1.270	37.12	1.607	11.06	1.537	21.17
5	0	1	1.784	12.25	1.493	26.09	1.810	0.66	1.693	13.18
5	10	1	1.904	6.35	1.533	24.11	1.943	0.08	1.799	7.74

SGR = straw: grain ratio.

all the three nutrients did not significantly increase the grain weight of Inqlab 91 and NIAB compared to the yield obtained by the application of other micronutrients. The higher response of AS 2000 to Zn might be due to micronutrient accumulative behaviour of this cultivar. Pervaiz *et al*. (2003) found that SGR decreased with the increase in Zn application. Non-significant effect of integrated application of micronutrients over control might be due to antagonistic effect that reduced the grain weight of wheat. Imtiaz *et al*. (2003) reported that Zn application has adverse effect on Fe concentration and Fe uptake by plants. They also reported that Zn has also antagonistic effect on the uptake of Mn and Cu in plants.

Conclusion

This study showed that differences in grain yield between individual micronutrient application and control was significantly higher with Zn followed by Fe and B. Application of Zn alone to the three varieties produced higher yield compared to the yields obtained by Fe and B. None of the three micronutrients augmented the wheat grain yield in Gujrat district whereas Zn performed significantly better in Mandi Bahauddin District. Agronomic efficiency of B was the highest followed by Zn and Fe when applied singly. The economic performance revealed that Zn gave the highest net return (Rs. 2841) with the VCR value of 4.79. The application of Fe and B may not be recommended to the farmers as the VCR is < 2. SGR of wheat decreased by the application of micronutrients, mainly due to the increase in grain weight.

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