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Wheat yield enhancement through balanced nutritional management

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Abstract

In order to get maximum wheat production by integrating chemical and organic fertilizers along with micronutrients under the agri-environment of Dera Ismail Khan, Pakistan, a two years research project was carried out. Randomized complete block (RCB) design in split-plot arrangements with 4 replications was used for two consecutive years. Main-plot consisted of NPK and organic fertilizers (farmyard manure, compost, soil conditioner) while microelements viz. zinc, copper and boron were maintained alone and in all possible combinations in sub-plots. Data revealed that using NPK (100% Recommended Fertilizer Dose-RFD) significantly influenced wheat yield parameters. This treatment gave highest tillers' count (268.56 and 228.06 m^{-2}), grains' count (56.50 and 57.25 $spike^{-1}$) economic yield (4.40 and 5.29 t ha^{-1}), respectively for two years. Data further showed that application of boron @ 2 kg ha^{-1} significantly produced highest tillers (246.69 and 202.87 m^{-2}), number of grains (53.56 and 55.25 $spike^{-1}$) and grain yield (3.90 and 4.38 t ha^{-1}) during both experimental years. It was also noted that the two factors (NPK, organic fertilizers and micronutrients) non-significantly interacted with each other in almost all yield and yield contributing parameters; however, NPK (full RFD) in combination with B @ 2 kg ha^{-1} remained the best treatment combination for higher wheat productivity. Moreover, highest net return with maximum BCR (2.17and 2.57) was also achieved by the combined application of these two treatments during both the years.

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IntroductionWheat is an important plant based staple food crop of Pakistan. Wheat yield is very much low in the country as compared to advanced countries of the world such as USA, China, India, France and Russia (Khan *et al.*, 2000). This yield gap greatly affects the need of food in the country and it might be due to the non-availability and high priced inputs, especially fertilizers which are being used in improper environments at inadequate rates without supplementation of micro-elements. It is obvious that judicious use of all the resources available including balanced nutritional management may sustain the self-sufficiency in wheat. The use of various organic sources such as farmyard manure, compost and soil conditioner etc. enhance plant growth, improve soil properties with increased yield whereas the availability of synthetic fertilizers is also improved. The under-ground bio-activities as well as water/nutrient holding capacity of soil might be improved with the addition of organic fertilizers into the soil. Khan *et al.* (2007) observed that application of organic manures in combination with inorganic fertilizers improves soil fertility as well as increased productivity. It was supported by Duan *et al.* (2004) who reported that using organic and chemical fertilizers is useful for maintaining soil fertility with enhanced crop productivity.It is obvious that organic manures are key component for improving soil health as well as better crop yields (Weil and Magd off, 2004) while Defra *et al.* (2002) had an idea that organic sources are beneficial for healthy agro-environment. Delate and Camberdella (2004) revealed that production of organic grains had lashing many changed decisions concerning with organic farming whereas Burnett and Rutherglen (2008) showed that wheat may be commonly grown in organic farming systems. It is also a fact that chemical fertilizers consume huge quantity of energy as well as money; however, Prabu *et al.* (2003) demonstrated that farming under organic culture supplemented with or without chemical fertilizers seems to be possible solution under such circumstances. Combined application of chemical and organic fertilizers not only provides essential nutrients but also positively correlated to increase crop productivity with lesser environmental pressures (Hammad *et al.*, 2011). The major and basic problem of Pakistani soils is nutrients (macro and micro) deficiency. Moreover, calcareous nature along with higher pH values, lower fertility, prolonged drought, improper irrigation and imbalanced fertilizers application are possible reasons for micro-elements deficiency (Ahmadikhah *et al.,* 2010). Stone and Savin (2000) observed that micronutrients contents of leaf, straw and grain increased with the application of mineral fertilizers and soil conditioner. Moreover, efficacy of micronutrients is also improved by adding organic fertilizers in rice-wheat cropping system. Keeping that in view, this research was carried out under the agri-environment of Dera Ismail Khan.

Materials and methods

Experimental layout

The present research trial was designed in randomized complete block under split-plot arrangements with four replications for two consecutive years. Size of a sub-plot was maintained as 1.8 × 5 (9 m^2) containing 6 rows each of 5 m length and 30 cm apart. Gomal-8, an approved genotype of wheat, was sown @ 100 kg ha^{-1} on 1st week of November during both the cropping years.

Treatments detail

Main-plot consisted NPK (100% Recommended Fertilizer Dose-RFD) @ 150:120:90 kg ha^{-1} and NPK (50% RFD) @ 75:60:45 kg ha^{-1}along with FYM (10 t ha^{-1}), compost (500 kg ha^{-1}) and soil-conditioner (11 kg ha^{-1}). The sub-plot was comprised of three micronutrients viz. zinc, copper and boron at 10, 8 and 2 kg ha^{-1}, respectively along with all possible combinations and control treatments.

Nutrients application

Sources of NPK were ures, di-ammonium phosphate and potassium sulphate while micronutrients used were zinc sulphate, copper sulphate and borax. Half dose of nitrogen along with full doses of P, K, organic fertilizers and micronutrients were admixed into the soil at the time of sowing while next half dose of nitrogen was used at first irrigation.

Edaphic properties

An average temperature range from 26C° and 11C°and relative humidity of 79% (November) and 60% (April) was observed during the study period. Textural class of site area was silty clay having less than 1% organic matter during both the years. Soil pH was noted as 7.6 and 8.2 while nitrogen (0.042 and 0.032 %), phosphorus (16.85 and 7.00 ppm) and potash (400 and 285 ppm) contents were also recorded for two years.

Data recording and analysis

Data on different parameters including tillers' count(m^{-2}), grains' count (spike^{-1}), thousand seed weight (g), economic and biomass yield (t ha^{-1}), benefit cost ratio were recorded during two cropping seasons and were subjected to analysis of variance (Steel *et al.,* 1997) with subsequent means comparison through Tukey's HSD test. New computer software "Statistix" was used to analyze research data.

Results and discussion

Tillers (m^{-2})

Tillering is an important process in plant growth helps to cover production deficit caused by lower planting density and germination.

It is closely synchronized with number of leaves growing on main shoot whereas tillers' density depends on cultivar and growing environments (Reddy, 2004). Data on tillers' count (Table 1) showed significant variations by the application of chemical (NPK), organic and micronutrient fertilizers during both experimental years. Significantly maximum tillering (268.56 and 228.06 m^{-2}) was recorded by using NPK (100% RFD) followed by NPK (50% RFD) along with farmyard manure which gave 238.72 and 178.28 tillers m^{-2}.

Table 1. Effect of NPK, organic fertilizers and micronutrients on tiller count (m^{-2}), grains (spike^{-1}) and thousand seed weight (g) in wheat.

NPK & Organic Fertilizers	Tillers (m^{-2})		Grains (spike^{-1})		TSW (g)	
	Year 1st	Year 2nd	Year 1st	Year 2nd	Year 1st	Year 2nd
NPK (full RFD)	268.56 a	228.06 a	56.50 a	57.25 a	47.23 a	47.36 a
NPK (half) + FYM	238.72 b	178.28 b	52.34 b	53.40 b	44.57 ab	44.71 ab
NPK (half) + Compost	210.31 c	155.09 c	48.09 c	47.65 c	42.29 b	42.31 b
NPK (half) + Soil Cond.	219.12 c	164.25 bc	50.50 bc	50.50 bc	43.27 ab	43.32 b
$LSD_{0.05}$	18.35	20.83	2.60	3.53	4.12	3.67
Micronutrients						
Zinc (Zn)	237.38 ab	186.12 abc	52.43 ab	53.12 a	44.64	45.04
Copper (Cu)	228.62 ab	173.06 bc	50.93 ab	50.87 ab	43.67	43.67
Boron (B)	246.69 a	202.87 a	53.56 a	55.25 a	45.56	45.81
Zn + Cu	232.62 ab	176.00 abc	52.06 ab	51.56 ab	44.27	44.19
Zn + B	240.94 a	193.56 ab	53.06 a	53.87 a	45.09	45.40
Cu + B	235.19 ab	178.81 abc	51.87 ab	52.50 ab	44.39	44.23
Zn + Cu + B	234.06 ab	179.63 abc	52.18 ab	52.31 ab	44.41	44.52
Control (no micronutrient)	217.94 b	161.31 c	48.75 b	48.12 b	42.67	42.53
$LSD_{0.05}$	20.00	27.19	3.68	4.69	NS	NS

Any two means in their respective group sharing common letter(s) are non-significant at 5%

NS – Non-significant.

The lowest tillers' count (210.31 and 155.09 m^{-2}) was obtained by applying NPK (50% RFD) along with compost during both the years, respectively. It is obvious that tillers development might be improved when plants are supplied complete and quick nourishment. Cheema *et al.* (2003) revealed that number of tillers increased with higher rates of NPK whereas Khan *et al.* (2007) observed that green manure and zinc in addition to NPK (at recommended levels) produced maximum tillers. Our results further showed that micronutrients significantly effected tillers' density during both the cropping years. Highest tillers' count (246.69 and 202.87 m^{-2}) was achieved with application of boron. It was statistically similar with treatments received Zn+B (240.94 and 193.56 m^{-2}) and zinc (237.38 and 186.12 m^{-2}) during two successive years.

The plots where no micronutrient was applied throughout growing period gave minimum tillers (217.94 and 161.31 m^{-2}). Our findings are in line with Uddin *et al.* (2008) who obtained maximum but significant tillers by adding boron. Likewise, increased tillers' density by adding boron into the soil was observed by Holloway and Alston (2010).

Two years data analysis also depicted that chemical, organic and micronutrient fertilizers were non-significantly interacted with each other.

Table 2. Effect of NPK, organic fertilizers and micronutrients on economic yield (t ha^{-1}) and biomass (t ha^{-1}) in wheat.

NPK & Organic Fertilizers	Economic yield (t ha^{-1})		Biomass (t ha^{-1})	
	Year 1st	Year 2nd	Year 1st	Year 2nd
NPK (full RFD)	4.40 a	5.29 a	14.50 a	14.66 a
NPK (half) + FYM	3.66 b	3.98 b	12.21 b	11.40 b
NPK (half) + Compost	3.30 b	3.53 c	11.19 c	10.36 b
NPK (half) + Soil Cond.	3.47 b	3.74 bc	11.61 bc	10.70 b
$LSD_{0.05}$	0.44	0.35	0.72	1.09
Micronutrients				
Zinc (Zn)	3.81 a	4.23 ab	12.60 a	11.92 a
Copper (Cu)	3.57 ab	3.99 bc	12.08 ab	11.56 ab
Boron (B)	3.90 a	4.38 a	12.91 a	12.29 a
Zn + Cu	3.73 a	4.10 ab	12.34 ab	11.77 ab
Zn + B	3.87 a	4.30 a	12.86 a	12.08 a
Cu + B	3.73 a	4.13 ab	12.23 ab	11.77 ab
Zn + Cu + B	3.79 a	4.15 ab	12.50 ab	11.81 ab
Control (no micronutrient)	3.27 b	3.80 c	11.51 b	11.04 b
$LSD_{0.05}$	0.39	0.29	0.99	0.87

Any two means in their respective group sharing common letter(s) are non-significant at 5%.

Grains (spike^{-1})

Grain setting and filling is an important process which contributes in yield of a particular crop. It is highly affected with environmental conditions. Results pertaining to grains' count (Table 1) portrayed significant variations with the application of chemical, organic and micronutrient fertilizers during the two years experiments. Application of NPK (100% RFD) produced significantly maximum grains (56.50 and 57.25 $spike^{-1}$) followed by using NPK (50% RFD) along with farmyard manure (52.34 and 53.40 $spike^{-1}$) and soil-conditioner (50.50 $spike^{-1}$), respectively during the two years of experimentation. The use of NPK (50% RFD) along with compost resulted in lowest grains' count (48.09 and 47.65 $spike^{-1}$) for two consecutive years. Grain setting in spike is a critical growth point wheat plant which greatly influences yield while any stress at this stage greatly reduces the yield. Increased number of grains by applying NPK (100% RFD) might be due to provision of all nutritional requirements to plants. It was also observed during the study that plants efficiently utilized rich organic sources along with NPK (50% RFD) but at later reproductive stage, a little shortage of nutrients was faced by the plants which resulted in less number of grains in a spike.

Table 3. Effect of NPK, organic fertilizers and micronutrients on economic analysis (BCR) in wheat.

Micronutrients	NPK & Organic Fertilizers							
	NPK (full RFD)		NPK (half) + FYM		NPK (half) + Compost		NPK (half) + Soil Cond.	
	Net Income (Rs.)	BCR	Net Income (Rs.)	BCR	Net Income (Rs.)	BCR	Net Income (Rs.)	BCR
Year 1st								
Zinc (Zn)	53928/-	1.87	37892/-	1.69	34708/-	1.64	39775/-	1.77
Copper (Cu)	48552/-	1.82	44036/-	1.84	24468/-	1.47	36959/-	1.76
Boron (B)	63023/-	2.17	51339/-	2.09	43035/-	1.92	50662/-	2.16
Zn + Cu	45128/-	1.64	30372/-	1.48	24116/-	1.38	25343/-	1.42
Zn + B	51663/-	1.79	38955/-	1.67	33211/-	1.57	36998/-	1.67
Cu + B	51407/-	1.82	41259/-	1.74	23995/-	1.43	39558/-	1.76
Zn + Cu + B	40815/-	1.55	25291/-	1.38	22619/-	1.34	27430/-	1.43
Control (no micronutrient)	48648/-	1.96	39268/-	1.90	30708/-	1.71	39871/-	2.00
Year 2nd								
Zinc (Zn)	77941/-	2.20	43185/-	1.75	36538/-	1.64	45299/-	1.83
Copper (Cu)	68234/-	2.10	51226/-	1.93	31529/-	1.57	41595/-	1.80
Boron (B)	89671/-	2.57	59352/-	2.19	46963/-	1.95	58856/-	2.26
Zn + Cu	63921/-	1.87	37778/-	1.57	27477/-	1.41	29713/-	1.47
Zn + B	77789/-	2.14	46687/-	1.76	37169/-	1.61	42015/-	1.73
Cu + B	69126/-	2.05	48464/-	1.82	30333/-	1.52	44575/-	1.80
Zn + Cu + B	59593/-	1.77	30840/-	1.44	26803/-	1.38	32954/-	1.49
Control (no micronutrient)	76512/-	2.43	46454/-	2.00	36936/-	1.80	47785/-	2.11

These findings are in agreement with Hammad *et al.* (2011) who obtained more number of grains by using NPK (100% RFD). Data further revealed significant results by adding micronutrients into the soil. Among various treatments, highest number of grains (53.56 and 55.25 spike^{-1}) was recorded in treatments where boron was added. It was statistically in line when Zn+B (53.06 and 53.87) and zinc alone (52.43 and 53.12 grains spike^{-1}) was applied during both the years. Among different trace elements, boron is an important micronutrient which affects fruit setting and qualitative improvement in plants. Highest grains' count in plots received boron might be due to provision of complete nourishment required for better seed setting. The lowest grains' count (48.75 and 48.12 spike^{-1}) was, however, observed in control treatments where no micronutrient was used during two successive years. These findings are in agreement with Uddin *et al.* (2008) who also recorded maximum grains in a spike by using boron. As far as the interaction is concerned, the two factors non-significantly interacted with each other.

Thousand seed weight (g)

Being genetic character of any particular crop plant, seed index seldom varies or influenced by biotic and abiotic factors. Results on thousand seed index (Table 1) swayed significant variations by the application of chemical and organic fertilizers. The plots received NPK (100% RFD) had maximum seed index (47.23 and 47.36 g) which was, however, statistically similar with NPK (50% RFD) along with farmyard manure (44.57 and 44.71 g) during both the years. Minimum seed weight (42.29 and 42.31 g) was noted in treatments received NPK (100% RFD) along with compost during both the years. The findings are also supported by Hussain *et al.* (2002) who observed significant variations in seed weight with high fertilizer rates. The two years experimentation further revealed that thousand seed index was non-significantly influenced by micronutrients, alone and in combination whereas the interaction of chemical, organic and micronutrient fertilizers was also found non-significant.

Economic yield (t ha^{-1})

Yield is the most integrative aspect of a particular genotype (Araus *et al.,* 2001).Data presented in Table 2 portrayed that the use of chemical, organic and micronutrient fertilizers significantly influenced economic yield of wheat for two successive years. The plots received NPK (100% RFD) produced highest yield (4.40 and 5.29 t ha^{-1}) which was followed by application of NPK (50% RFD) along with farmyard manure (3.66 and 3.98 t ha^{-1}) and soil-conditioner (3.47 and 3.74 t ha^{-1}) during two cropping years. Minimum produce (3.30 and 3.53 t ha^{-1}) was, however, obtained by using NPK (50% RFD) along with compost during both the years. In case of micronutrients, use of boron produced highest yield (3.90 and 4.38 t ha^{-1}) and it was statistically similar with Zn+B (3.87 and 4.30 t ha^{-1}) and zinc alone (3.81 and 4.23 t ha^{-1}) during the two consecutive years. The control treatment where no micronutrient was added into the soil gave lowest economic yield (3.27 and 3.80 t ha^{-1}). It is obvious that NPK (at recommended levels) is an instant source of nourishment for plants and it plays important role in improving crop productivity. Growth and development of a plant is boosted when different micro-elements are added into the soil along with NPK. Application of boron is basically responsible for development of inflorescence and grain setting. Results also depicted that almost all yield contributing parameters gave enhanced findings with the combined use of NPK (full RFD) and boron during both years. Hussain *et al.* (2002) obtained highest grain yield in various cultivars of wheat with higher NPK doses while Hammad *et al.* (2011) also recorded increased production with the application of NPK (at recommended levels). Chaudry *et al.* (2007) further supported our findings by observing significant increase in yield by using boron along with NPK while Uddin *et al.* (2008) also obtained 50% more yield by applying boron. As far as the interaction is concerned, non-significant findings were observed during both years of experimentation.

Biomass (t ha^{-1})

Application of NPK, organic fertilizers and micronutrient (Table 2) significantly influenced the biomass production for two cropping years. The use of NPK (100% RFD) produced maximum and significant biomass (14.50 and 14.66 t ha^{-1}) followed by NPK (50% RFD) along with farmyard manure (12.21 and 11.40 t ha^{-1}) during two successive years. Application of NPK (100% RFD) provided complete nourishment to plants which enhanced their growth and resulted in taller plants and that might be the cause of highest biomass production. Minimum biomass (11.19 and 10.36 t ha^{-1}) was produced by NPK (50% RFD) in combination with compost during the two experimental years. These findings are in line with Hammad *et al.* (2011) who recorded highest biomass yield with NPK (at recommended levels). On the other hand, various micronutrient treatments showed significant results. Application of boron produced highest biomass (12.91 and 12.29 t ha^{-1}) during two years of experimentation. It was statistically alike with Zn+B (12.86 and 12.08 t ha^{-1}) and zinc alone (12.60 and 11.92 t ha^{-1}). Increase in biomass production by the application of boron might be due to more tillers' count as well as long statured plants. The lowest biological yield (11.51 and 11.04 t ha^{-1}) was obtained in control treatment where no micronutrient was used. Khan *et al.* (2009) also reported that micronutrients application increased biomass yield in wheat. It was also observed during the two years study that chemical, organic and micronutrient fertilizers non-significantly interacted with each other.

Benefit cost ratio (BCR)

Economic analysis provides basic reflection in determining treatments for getting maximum benefit. Moreover, it is also used to assess the production efficacy of any particular crop (Hammad *et al.,* 2011). Benefit cost ratio for two years experiments (Table 3) showed that application of chemical (NPK), organic fertilizers and micronutrients had better economic returns. Maximum net-income (Rs. 63,023/- and

89,671/-) was achieved with NPK (100% RFD) combined with boron. It was followed by the same NPK treatment when combined with zinc (Rs. 53,928/- and 77,941/-) during both years. These findings are in line by Nadim *et al.* (2013) who obtained maximum net benefit by using NPK (at recommended levels) along with soil application of boron. Further, the lowest net benefit (Rs. 22,619/- and 26,803/-) was recorded by the combined application of NPK (50% RFD) along with compost, zinc, copper and boron for two consecutive years. Lowest net return under this treatment might be due to the combination of high priced inputs.

Comparing the ratio of expenditures and income for various treatments, highest benefit cost ratio (2.17 and 2.57) was achieved by the combined application of NPK (100% RFD) and boron during both the experimental years. Lower cost of additional micronutrient used alone in said treatment having highest grain yield resulted in maximum BCR. The lowest BCR (1.34 and 1.38) was recorded by using NPK (50% RFD) along with compost and all the three micronutrients for two consecutive years.

Conclusion

Wheat productivity was enhanced with the application of NPK in combination with organic sources and micronutrients. Organic fertilizers improved plant growth status but a little deficiency was faced by the plants in latter growth period. However, using NPK (at recommended levels) recorded highest grain yield. Significant role play by different micronutrients was also observed during the study period. Among various treatment combinations, application of NPK (full RFD) along with boron was shown as the best combination recorded highest results.

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