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EVALUATION OF ADVANCED WHEAT GENOTYPES FOR ZINC EFFICIENCY AND YIELD

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ABSTRACT

Pakistani soils are alkaline, calcareous in nature and lacking in zinc. This study was carried out to categorize zinc-efficient wheat cultivars/genotypes that can be cultivated more efficiently on zinc-deficient soils. Growing such genotypes can minimize the cost of zinc fertilizer which is essential for elevated wheat productivity, enhanced wheat grain quality and ambiance protection. Three advance wheat genotypes (NIFA-V15, CT-03457 and CT-04192) were tested for Zn efficiency in field condition at NIFA Research Farm during 2011-12. The result revealed that combined application of Zn with N and P significantly increased yield and yield components of all tested wheat genotypes. Application of Zn alone and with N and P increased zinc uptake significantly ($\leq$ 0.05). Among the wheat genotypes, CT-04192 and NIFA-V15 produced the highest grain yield of 5.74 and 5.65 t ha^{-1}, respectively and also achieved the higher total Zn uptake (181.1, 175.5 g ha^{-1}) as compared to control. On the basis of the results obtained in this study it is assumed that these genotypes (CT-04192 and NIFA-V15) give higher yield along with best quality grain on Zn deficient soils. The use of Zn fertilizer had improved the N and P uptake, enhanced Zn content in soil and improved wheat production.

Keywords: NP fertilizer, nutrient uptake, wheat genotypes, yield, zinc

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the most important cereal food crop and cultivated on large extent to feed millions of people all over the world (Seleiman *et al*., 2010). Wheat provides food to 36% of world inhabitants (Abbas *et al***.,** 2011). Maximum (681.4 million tons) wheat is produced in Asia (Ali *et al*., 2013). Among all cereal crops wheat ranks first in Pakistan and is cultivated on vast area of about 8.66 million hectares with annual production of 23.50 million tons (Ali *et al*., 2013). It supplies 10.1% to agriculture and 2.2 % to Gross Domestic Production (Pakistan Economic Survey, 2013-14). It is extremely vulnerable to Zn deficiency; in such conditions it produces lower yield with a little levels of Zn concentration in seeds; which makes the foundation of Zn deficiency in human beings (Imtiaz *et al*., 2006). Wheat seed contains about 25-30 ppm Zn in dry

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weight, while for human health, the desired Zn concentration in wheat grain should be > 50 µg g^{-1} dry weight (Cakmak, 2008). With expanding cropping intensities in South Asia, nutrient management is a key issue being addressed by scientists for understanding any decline in wheat grain production. Zinc deficiency affected million hectares of cropland (Alloway, 2009). Extent of deficiency varies from one region to another and from one crop plant to another crop~~s~~ plant and within genotypes (Alloway, 2009).

Zn deficiency on the basis of their growth response wheat genotypes can be named as Zn efficient and Zn inefficient. Zinc efficiency is the capability of a crop plant~~s~~ to grow up and produce maximum yield in Zn-deficient situation. Nutritional disorders are not simply alleviated by soil application but possibly are ameliorated by growing currently accessible cultivars with desirable genetic traits. Because Zn deficiency is an extensive nutrition problem in several important crops, the agronomists and plant breeders are constantly probing for the cultivars that can be grown effectively on Zn-deficient soils on which it may be difficult to add their low Zn supplies. Keeping in view the significance of wheat crop in food security of the country and the key role of micronutrient especially Zinc in yield and quality improvement, the field experiments were carried out to categorize zinc-efficient wheat genotypes that can be grown more efficiently on low zinc soil. Growing such genotypes can condense cost of micronutrients fertilizer inputs of wheat crop and shield the environment.

MATERIALS AND METHODS

The experiment was conducted in Rabi Season during 2011-12 to screen out the advanced wheat genotypes for high yield and quality on Zn deficient soils.

Experimental site description

The experimental site was located at Nuclear Institute for Food and Agriculture (NIFA), Tarnab (longitude 71^{0}50, latitude 34^{0}01), Peshawar, Pakistan. The site is situated at the altitude of 400 m above sea level in the Peshawar valley of Khyber Pakhtunkhwa and has very cool winter and hot summer with annual rainfall of 337 and 303 mm during the experimental period of 2011-2012. The experimental site has been under cultivation since last 5 years. Sorghum as an exhaustive crop was grown at the experimental site to eliminate any of the leftover fertilizer applied to preceding crops. The composite soil samples were collected from 0-15 and 15-30 cm depth for analysis of various physical and chemical properties before the onset of the experiment. The texture of the experimental area was determined by the Bouyocous Hydrometer method (Bouyoucos, 1962). The proportion of sand in the soil profile ranged between 18 and 20%, silt between 40 and 48%, and clay between 32 and 40%, hence the texture of the selected site was clay loam. Total nitrogen, Olsen's P and soil organic matter were determined using methods of Page *et al*. (1982); Bremner and Mulvaney (1982) and Nelson and Sommers (1982), respectively. The quantity of total soil N was 0.041% in the 0-15 cm and in lower depth was 0.038%. The total P was 6.8 ppm in the 0-15 cm and 5 ppm in the lower depth i.e. 15-30 cm. Soil organic matter in the surface layer (0-15 cm) was 0.90% and 0.80% in the lower (15-30 cm) soil depth. The available Zn in 0-15 cm soil depth was 0.36 ugg^{-1} which was extracted with 0.005 M DTPA (Lindsay and Norvell,

1978) determined by Atomic absorption spectrophotometer. Electrical conductivity and pH of the experimental site was determined in soil-water suspension (1:5) (McLean, 1982). The soil was alkaline (pH 8.2) in reaction and it had no salinity problem (EC 0.8 dS m^{-1}).

Experimental design, treatments and sowing

Three advanced wheat genotypes (NIFA-V15, CT-03457 and CT-04192) were obtained from the Plant Breeding and Genetics Division of NIFA and were sown on November 11, 2011 at research farm of NIFA. Wheat genotypes were tested for their response to Zn under irrigated field conditions. The treatment details are: (1) Control (2) Zn @ 5 kg ha^{-1} (3) N and P @ 120-90 kg ha^{-1} (4) NP + Zn. The nitrogen, phosphorous and zinc fertilizer sources were Urea, Super Phosphate and Zinc Sulfate. Phosphorus, zinc, and $^1/_3$ of the nitrogen fertilizer were thoroughly mixed with soil before sowing the crop and remaining $^1/_3$ nitrogen fertilizer was applied with first irrigation and $^1/_3$ with third irrigation. All agronomic practices were similar for all treatment plots. Experimental design was two factor (factorial) randomized complete block design containing four zinc treatments with four wheat genotypes and three replicates. The crop was harvested at maturity and data were recorded on wheat yield and yield parameters. Grain and straw samples were analyzed for N, P and Zn.

Plant and grain samples

Nitrogen, phosphorous and zinc concentrations in straw and grain samples were analyzed. Nitrogen and P were calculated separately for total uptake by the following formula:

$$\text{Uptake of N/P/Zn (Kg ha}^{-1}\text{)} = \frac{\text{N\% / P\%/Zn\%} \times \text{dry matter (grain or straw) kg ha}^{-1}}{100}$$

Statistical analysis

The analysis of variance (ANOVA) for different characters was performed by using computer software MSTATC program and mean values were adjudged by DMRT.

RESULTS AND DISCUSSION

Grain yield

Zinc application showed significant (P<0.05) effect on grain yield (Table 1). Wheat grain yield was improved significantly by the application of Zn + NP over N and P alone and control. Data revealed that the highest grain yield (5.38 t ha^{-1}) was obtained with application of 5 kg Zn ha^{-1} + recommended NP which was significantly higher than the others treatments. The minimum grain yield (2.28 t ha^{-1}) was recorded in control plots. All this reflects that wheat grain yield was enhanced up to 19.5% over NP alone. This rise in grain yield due to Zn fertilization might be the fact that Zn plays a key role in biosynthesis of the Indole-3-Acetic Acid IAA (plant hormone) and starting of primodia for reproductive parts and a result of constructive outcome of zinc on the metabolic reactions within the crop plants (Singh *et al.,* 2012). Genotypes CT-04192 and NIFA-V15 produced (4.02 and 3.99 t ha^{-1}) significantly higher grain yield than CT-

03457 which produced minimum grain yield (3.50 t ha^{-1}) in fertilized plots. Similar results were recorded from controlled plots. Aycicek and Yildirim (2006) also reported identical trend in wheat seed production in different wheat genotypes. The genotypes NIFA-V15, CT-03457 and CT-04192 showed an overall increase in grain production with zinc application over NP and control plots.

Table 1. Influence of N, P and Zn fertilizer application on grain yield of wheat genotypes

Genotypes	**Grain yield (tons ha^{-1})**				**Mean**
	T1 (Control)	**T2 (Zn only)**	**T3 (NP)**	**T4 (NP+Zn)**	
NIFA-V15	2.34 f	3.17 d	4.80 b	5.65 a	3.99 AB
CT-03457	2.08 gh	3.04 e	4.12 c	4.76 b	3.50 C
CT-04192	2.43 f	3.12 d	4.60 bc	5.74 a	4.02 A
Mean	2.28 D	3.18 C	4.51 B	5.38 A	-

Means with same letter are statistically similar at ($P \leq 0.05$)

Straw yield

Response of NP + Zinc application on wheat straw remained significantly higher as compared to NP, Zn alone and control plots (no fertilizer). The pooled mean in Table 2 revealed that the maximum straw yield (4.54 and 4.46 t ha^{-1}) was recorded in CT-04192 and NIFA-V15 and the lowest straw yield (3.86 t ha^{-1}) was obtained in CT-03457.The maximum yield (5.70 t ha^{-1}) was produced in treatment where NP + Zn was applied while minimum (2.72 t ha^{-1}) was recorded in control. Shaheen *et al.* (2007) also reported similar results where straw yield was increased with the zinc application. Experimental results indicated that most excellent results were obtained with 5 kg Zn ha^{-1} when pooled with recommended NP fertilizer application. Similar achievement was observed by Hussain and Yasin (2004), they recorded 12% enhancement in wheat straw with the application of 5 kg Zn ha^{-1}, over control. Results are also in concurrence with Arshad *et al.* (2016) who obtained higher straw with inorganic fertilizers in combination with Zn application treatments than the plot received only inorganic fertilizers in diverse crops systems.

Table 2. Influences of N, P and Zn fertilizer application on straw yield of wheat genotypes

Genotypes	**Straw yield (tons ha^{-1})**				**Mean**
	T1 (Control)	**T2 (Zn only)**	**T3 (NP)**	**T4 (NP+Zn)**	
NIFA-V15	2.86 e	3.88 de	5.20 b	5.91 a	4.46 A
CT-03457	2.37 e	3.41 c	4.63 b	5.04 b	3.86 B
CT-04192	2.92 de	4.12 cd	4.95 b	6.16 a	4.54 A
Mean	2.72 D	3.80 C	4.93 B	5.70 A	-

Means with same letter are statistically similar at ($P \leq 0.05$)

1000-grain weight

Data revealed that 1000-grain mass was significantly ($P \leq 0.05$) higher in zinc treated plot, over the control (Table 3). Highest 1000-grain weight (45.08 g) was recorded in treatments, where Zn was applied along with recommended NP while minimum weight (22.71 g) was observed in control. The NP + Zn increased the

1000-grain weight by 16.8% than the recommended rate of NP alone. Khan *et al.* (2007) conducted field study on wheat using two zinc levels (5 and 10 kg ha^{-1}) and obtained higher enhancement in 1000-grain weight of wheat over control. The higher 1000-grain weight (36.26 and 33.71 g) was recorded in CT-04192 and NIFA-V15 while lower (28.74 g) was found in CT-03457. Practically, the Zn treatment optimistically influenced the seed set and grain weight which resulted in higher seed yield of the wheat crop. Other study reported by Mondal *et al*. (2005) showed that the low and the high 1000-grains mass among all varieties were found due to differential genetic behavior of wheat plants. The similar picture was also reported by Razvi *et al.* (2005) who harvested the increased 1000-grain weight by the application of Zn, over the rest of the treatments. The NP + Zn are the best combination for higher yield.

Table 3. Influence of N, P and Zn fertilizer application on 1000-grain weight of wheat genotypes

Genotypes	1000-grain weight (g)				Mean
	T1 (Control)	T2 (Zn only)	T3 (NP)	T4 (NP+Zn)	
NIFA-V15	23.08 g	28.63 f	37.13 de	46.00 ab	33.71 B
CT-03457	18.90 g	20.08 fg	33.98 e	42.00 bc	28.74 C
CT-04192	23.15 g	33.23 e	41.43 cd	47.25 a	36.26 A
Mean	21.71 D	27.31 C	37.51 B	45.08 A	-

Means with same letter are statistically similar at ($P \leq 0.05$)

Plant height

Tallest plants (Table 4) were recorded in CT-03457, followed by CT-04192 (99.59 cm) and NIFA-V15 (98.77 cm). All the treatments differed significantly in plant height due to Zn fertilization except NP application alone which was statistically at par with NP + Zn fertilization treatment. Khan *et al*. (2007) reported an increase in plant height of wheat significantly, over control.

Spike length

It is a vital yield contributing parameter and has a direct effect on the grain yield of wheat. It is evident from the data given in the Table 5 that Zn application with recommended NP had a significant effect on the spike length. The highest spike length (10.06 cm) was recorded NP + Zinc fertilization. The lowest spike length (8.03 cm) was observed in control. Spike length for all genotypes was significantly higher than that of CT-03457. This variation might be due to genetical difference among the genotypes. Zinc fertilization increased the spike length in CT-03457, NIFA-V15 and CT-04192 (8.87, 9.01 and 9.38 cm), respectively. Similar results were also reported by Razvi *et al.* (2005).

Total N uptake

Data revealed that the N uptake was significantly ($P \leq 0.05$) improved by the application of Zn, over the control (Table 6). The highest N uptake (177.66 kg ha^{-1}) was recorded with NP + Zn, while the lowest was observed in control. Genotype CT-04192 recorded maximum N uptake (113.94 kg ha^{-1}), followed by NIFA-V15 and CT-04192. Pederson *et al.* (2002) reported similarly, nitrogen concentration which was tremendously correlated with P and Zn concentrations in leaves, straw and grains. Nitrogen fertilizer also enhanced phosphorus and zinc concentrations in crops. The findings of Lehoczky *et al.* (2005) indicated that there is no correlation between zinc and NP fertilizer application. The NP fertilizer application showed no significant effect on the plant available Zn content of soils.

Table 4. Influence of N, P and Zn fertilizer application on plant height of wheat genotypes

Genotypes	**1000-grain weight (g)**				**Mean**
	T1 (Control)	**T2 (Zn only)**	**T3 (NP)**	**T4 (NP+Zn)**	
NIFA-V15	92.80 e	96.03 c	101.97 b	104.27 ab	98.77 B
CT-03457	93.50 de	103.87 ab	105.27 a	103.97 ab	101.65 A
CT-04192	93.53 de	95.40 cd	105.50 a	103.93 ab	99.59 B
Mean	93.28 C	98.43 B	104.24 A	104.06 A	-

Means with same letter are statistically similar at ($P \leq 0.05$)

Table 5. Influence of N, P and Zn fertilizer application on spike length of wheat genotypes

Genotypes	**Treatments (1000-grain weight g)**				**Mean**
	T1 (control)	**T2 (Zinc only)**	**T3 (NP)**	**T4 (NP+Zn)**	
V1 (NIFA-V15)	8.07 f	8.33 ef	9.47 bcd	10.18 a	9.01 B
V2 (CT-03457)	8.00 f	8.44 ef	9.06 cd	10.00 a	8.87 C
V3 (CT-04192)	8.02 f	9.69 abc	9.83 ab	9.99 a	9.38 A
Mean	8.03 D	8.82 C	9.30 B	10.06 A	-

Means with same letter are statistically similar at ($P \leq 0.05$)

Table 6. Influence of N, P and Zn fertilizer application on N uptake of wheat genotypes

Genotypes	**Nitrogen uptake (kg ha^{-1})**				**Mean**
	T1 (control)	**T2 (Zinc only)**	**T3 (NP)**	**T4 (NP+Zn)**	
NIFA-V15	38.44 f	64.56 e	137.27 bc	185.55 a	106.45 B
CT-03457	31.10 f	81.97 d	126.93 c	153.46 b	98.37 C
CT-04192	40.85 f	79.63 de	141.33 bc	193.97 a	113.94 A
Mean	36.79 D	75.38 C	135.18 B	177.66 A	-

Means with same letter are statistically similar at ($P \leq 0.05$)

Total P uptake

Data revealed that P uptake was significantly ($P \leq 0.05$) higher in NP with zinc application treatment, than in control (Table 7). The maximum P uptake (17.19 kg ha^{-1}) was obtained with the application of Zn along with recommended NP fertilizer. Genotype CT-04192 recorded significantly higher P uptake than other genotypes tested while minimum was recorded (9.76 kg ha^{-1}) in CT-03457. The results also correspond to the findings of Khan *et al. (*2008) and Khan and Imtiaz*,* (2013) where optimum NP fertilizer enhanced growth parameters and nutrient uptake in wheat crop.

Table 7. Influences of N, P and Zn fertilizer applications on P uptake of wheat genotypes

Genotypes	Phosphorus uptake (kg ha^{-1})				Mean
	T1 (Control)	T2 (Zn only)	T3 (NP)	T4 (NP+Zn)	
NIFA-V15	3.31 e	7.69 c	14.87 b	15.82 b	10.42 B
CT-03457	3.31 e	5.30 d	14.78 b	15.65 b	9.76 B
CT-04192	3.15 e	6.98 c	16.14 b	20.10 a	11.59 A
Mean	3.26 D	6.66 C	15.26 B	17.19 A	-

Means with same letter are statistically similar at ($P \leq 0.05$)

Total Zn uptake

The results regarding total Zn uptake presented in Table 8 showed the response of Zn in soil application on Zn uptake by wheat crop. The 5 kg Zn ha^{-1} application with recommended NP increased its uptake in all genotypes however maximum Zn uptake (181.1 g ha^{-1}) was noted in genotype CT-04192, followed by genotype NIFA-V15, (175.7 g ha^{-1}) while minimum Zn uptake (164.8 g ha^{-1}) was recorded in CT-03457. Palmgren *et al*. (2008) reported that the zinc application increases Zn content of wheat also they determined that increased expression of genes encoding Zn transporters can boost Zn uptake in plants. Similar enhanced response of Zn concentration by the application of zinc fertilizer was described by Ali *et al*. (2009). The escalating of Zn uptake was also obtained by Ali *et al*. (2013), who reported that the level of Zn content was increased by the application of 10.0 kg Zn ha^{-1}.

Table 8. Influence of N, P and Zn fertilizer application on Zn uptake of wheat genotypes

Genotypes	Zinc uptake (g ha^{-1})				Mean
	T1 (Control)	T2 (Zn only)	T3 (NP)	T4 (NP+Zn)	
NIFA-V15	58.4 f	130.3 e	169.3 cd	344.0 a	175.5 AB
CT-03457	63.8 f	178.6 c	140.5 de	276.3 b	164.8 B
CT-04192	75.4 f	151.3 cde	155.3 cde	337.4 a	181.1 A
Mean	65. 9 C	153.4 B	155.0 B	320.9 A	-

Means with same letter are statistically similar at ($P \leq 0.05$)

CONCLUSION

The results obtained from this study indicated that the Zn application in addition to N and P fertilizers is extremely required for quality production of wheat. Micronutrients are beneficial for crop growth as it helps to enhance NP uptake, keeps up micronutrients status in soil and enhance crop efficiency. The Zn content of tested genotypes represent the lower concentrations as compared to the standards of “Harvest Plus” (50-60 mg kg^{-1}) therefore, zinc fertilizer application of 5 kg ha^{-1} is indispensable for higher yield, quality and bio-available Zn in grains of wheat genotypes. Based upon the results it may be recommended that enhanced yield and quality of wheat irrespective of genotypes may be obtained with Zn application in addition to N and P fertilizers.

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