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Soil Applied Zinc Ensures High Production and Net Returns of Divergent Wheat Cultivars

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Abstract: Zinc (Zn) scarcity in soil is an important obstacle in achieving maximum wheat grain yield in calcareous soils. This can be overcome through Zn application appropriate either in the soil or foliage. A field study was conducted at Agronomic Research Area, Bahauddin Zakariya University, Multan (Pakistan) during Rabi 2010-11 to evaluate the role of soil applied Zn fertilizer on the growth and yield of divergent wheat cultivars. Wheat cultivars viz. Bakhar-2002, Shafaq-2006, Saher-2006, Faisalabad-2008 and Lasani-2008 were grown with Zn applications at the rate of 0, 4, 8 and 12 kg ha^{-1}. Soil applied Zn at all levels significantly improved the maximum yield related traits of all wheat cultivars as compared with control. Though all the Zn levels excelled compared with control; however, the plots receiving Zn at 8 and12 kg ha^{-1} observed higher wheat output along with higher grain Zn contents. Wheat cultivars, Lasani-2008 and Saher-2006 out yielded all other wheat cultivars under study due to significant expansion in yield related traits. Moreover economic analysis disclosed that Lasani-2008 sown with 8 kg ha^{-1} of Zn observed the highest net income and benefit: cost ratio compared with all other zinc levels. In order to get higher production and net returns, wheat cultivar Lasani-2008 should be grown with 8 kg ha^{-1} of Zn under arid conditions of Multan, Pakistan.

Keywords: Benefit cost ratio, micronutrient, soil fertilization, *Triticum aestivum* L., Zinc.

1. Introduction

In Pakistan wheat is cultivated on an area of 8.66 million hectares with an average yield of 2.69 t ha^{-1} (USDA, 2012). This average yield is tremendously lower than the yields realized in other countries of the world. Out of various factors responsible for its low yield, planting geometry, cultivars, weeds and inputs like irrigation and fertilizers have an effective role in increasing the yield of crops (Bakht *et al*., 2007; Hussain *et al*., 2014; Nagarathna *et al*., 2007).

Optimum plant nourishment is one of the most imperative factors in improving the quality and quantity of plants produce. Among all the plant nutrients, zinc (Zn) is one of the essential micronutrients vital for optimum crop growth (Sommer and Lipman, 1996; Shaheen *et al*., 2007; Rana and Kashif, 2014) and is required in small concentrations to permit numerous key plant physiological pathways to function normally (Alloway, 2002; Mousavi *et al*., 2011; Yosefi *et al*., 2011). It plays an important role in maintaining the integrity of biological membranes, the resistance to contagion by certain pathogens (Alloway, 2008) and the pollination by impact on pollen tube formation (Marschner, 1995; Outten and O'Halloran, 2001; Pandey *et al*., 2006). It is also required in the carbonic enzyme which presents in all photosynthetic tissues and for chlorophyll biosynthesis (Graham *et al*., 2000; Ali *et al*., 2008; Xi-Wen *et al*., 2011). Zinc deficient soils decreased the activity of these enzymes, in consequential carbohydrate accumulated in plants leaves (Marschner and Cakmak, 1989; Taheri *et al*., 2011), metabolism of plant hormones such as auxin (IAA) and tryptophan decreases, which ultimately stops leaf growth.

However, higher concentrations of Zn cause toxicity in plants. With phytotoxicity intensifying, reduced growth and yields (Broadley *et al*., 2007), primarily due to the alteration in various physiological processes such as photosynthesis and photosynthetic electron transport, transpiration, biosynthesis of chlorophyll and cell membrane integrity (Millan-Lopez *et al*., 2005; Jayakumar and Jaleel, 2009; Hussain *et al*., 2010). In addition, large amount of Zn reduces the uptake of phosphorus and iron (Vitosh *et al*., 1994; Prasd *et al*., 1999).

In view of the aforementioned discussion, this field study was designed to appraise the optimum level of soil applied Zn fertilizer in promoting the productivity and net returns of divergent wheat cultivars.

2. Material and Methods

This study was conducted at Agronomic Research Area, Bahauddin Zakariya University, Multan, during the Rabi season 2012-2013. Five wheat cultivars viz. Bhakar-2002, Shafaq-2006, Saher-2006, Faisalabad-2008 and Lasani-2008 were grown under four levels of soil applied Zn viz. 0, 4, 8 and 12 kg ha^{-1}. The experiment was laid out in randomize complete block design (RCBD) with split plot arrangement by keeping Zn levels in main plots and wheat cultivars in sub plots. The experiment was replicated thrice with net plot size of 5 m × 1.8 m. A composite sample to a depth of 30 cm was obtained from the experimental area prior to sowing of crop and analyzed for its properties as described by Homer and Pratt (1961) (Table 1).

The seedbed was prepared by cultivating the field twice by tractor mounted cultivator followed by planking at suitable moisture contents. The sowing was done by hand drill keeping the seed rate of 125 kg ha^{-1} on November 11, 2010 on well prepared seedbed by keeping row to row distance of 20 cm. Nitrogen (N) and phosphorus (P) fertilizers were applied at the rate of 200 and 150 kg ha^{-1}, respectively by using urea and triple super-phosphate as a fertilizer source. Whole P and half of N were applied at the time of sowing and remaining N was applied with 1st irrigation. Soil moisture was kept at satisfactory levels to put off water deficit and wilting. Weeds were restricted by hand weeding as required. All other agronomic practices were kept constant to keep the crop free from insect and diseases. At maturity, crop was harvested on April 14, 2013.

Table 1: Mechanical and chemical soil characteristics at the experimental sites during the growing season

Soil analysis	Unit	Value
Sand	%	23.1
Silt	%	59.1
Clay	%	17.1
Organic matter	%	0.63
Saturation	%	39.0
Soil Texture	-	Silty clay loam
Total Nitrogen	%	0.05
Available Phosphorus	mg kg^{-1}	5.50
Available Potassium	mg kg^{-1}dS	300
EC	m^{-1}	3.09
pH	-	7.90
Zinc	mg kg^{-1}	0.36
$CaCO_3$	%	9.00

Table 2: Effect of soil applied Zn on plant height and yield components of different wheat cultivars

Treatments	Plant height (cm)	Productive tiller m^{-2}	Spikelet $spike^{-1}$	Grains $spike^{-1}$	1000-grain weight (g)
Zn_1V_1	94.47 hi	242.2 d-g	13.93 j	38.66 i	42.26 hi
Zn_1V_2	94.19 i	244.9 d-g	14.15 ij	40.28 hi	43.07 f-i
Zn_1V_3	97.62 fg	248.5 c-e	14.29 hi	40.85 h	41.98 hi
Zn_1V_4	95.27 hi	247.0 c-f	14.14 ij	39.84 hi	42.67 g-i
Zn_1V_5	96.33 g-i	257.1 a-c	14.49 gh	43.69 fg	41.23 i
Zn_2V_1	96.78 f-h	1.675 h	14.59 d-g	42.80 g	43.83 e-h
Zn_2V_2	96.15 g-i	234.3 g	14.54 e-h	42.70 g	43.91 e-h
Zn_2V_3	99.87 de	238.5 e-g	14.83 b-e	44.54 e-g	43.23 f-i
Zn_2V_4	98.61 ef	236.0 fg	14.53 f-h	43.05 fg	45.30 b-f
Zn_2V_5	100.90 b-e	243.5 d-g	14.93 bc	46.42 c-e	42.88 g-i
Zn_3V_1	100.10 de	242.4 d-g	14.86 b-d	43.67 fg	45.77 b-e
Zn_3V_2	100.00 de	248.1 c-e	14.79 c-f	44.74 d-g	45.85 b-e
Zn_3V_3	101.10 b-d	250.7 cd	14.91 bc	45.99 de	44.01 e-h
Zn_3V_4	100.80 c-e	248.0 c-e	14.88 b-d	44.89 d-f	47.06 a-c
Zn_3V_5	103.20 ab	261.4 ab	15.12 b	48.75 b	44.96 c-g
Zn_4V_1	100.50 c-e	246.3 c-f	14.86 b-d	46.57 cd	48.90 a
Zn_4V_2	101.50 b-d	247.0 c-f	14.89 b-d	47.99 bc	47.52 ab
Zn_4V_3	102.70 a-c	251.8 b-d	14.95 bc	49.80 b	44.61 d-g
Zn_4V_4	100.40 c-e	250.6 cd	14.82 b-f	48.23 bc	48.86 a
Zn_4V_5	104.40 a	265.8 a	15.49 a	52.87 a	46.39 b-d
LSD at 5%	2.10	9.65	0.26	1.79	1.98

Here Zn_1, Zn_2, Zn_3 and Zn_4 represents 0, 4, 8 and12 kg ha^{-1} of Zn; and V_1, V_2, V_3, V_4 and V_5 represents Bhakar-2002, Shafaq-2006, Saher-2006, Faisalabad-2008 and Lasani-2008, respectively
Means not sharing the same letter within a column differ significantly from each other at 5% of probability level

A unit area of 1 m^2 was selected at random from two different sites from each plot and total number of productive tillers were counted and averaged. Twenty random selected tillers were used to record plant height, spike length, number of spikelets per spike and number of grains per spike. Three random selected samples of 1000 grains were counted and weighed on an electrical balance and averaged to record 1000-grain weight. At maturity each plot was harvested manually, sun dried for a week, tied into bundles and weighed for getting biological yield. After recording biological yield, the bundles were threshed manually and the grains were weighed to record grain yield. The yields (biological and grain) from the harvested areas were converted into kg ha^{-1} by unitary method. Harvest index (HI) was taken as ratio of grain yield to biological yield expressed in percentage. Zinc contents in grains were measured by digesting the known weight of a sample in a ternary acid mixture and reading the element on Pye Unicum Sp-2900 Atomic Absorption Spectrophotometer (Philippines) (Yashida *et al*., 1976).

All the collected data were analyzed statistically using the Fisher's analysis of variance technique and Duncan's multiple range test (DMR) at 5% probability level was used to compare significance of treatment means (Steel *et al.*, 1997). For economic analysis, total expenses incurred on wheat production from sowing to harvesting were computed. The expenses included the price of land rent, seedbed preparation, seed sowing, fertilizers, irrigations and plant protection measures. Further, gross income was estimated by considering the current prices of the wheat grains and straw. Net income was figured by subtracting expenses from gross income while benefit: cost ratio (BCR) was computed by dividing gross income with total expenses incurred (Shah *et al*., 2006).

3. Results

Interactive effect of wheat cultivars and soil applied Zn levels had significant on entire yield related traits, so only the results regarding interaction between wheat cultivars and Zn levels are presented below.

Soil applied Zn significantly improved the plant height and number of productive tillers of all wheat cultivars compared with control (Table 2).

Table 3: Effect of soil applied Zn on grain and biological yield, harvest index and grain zinc contents of different wheat cultivars

Treatment	Biological yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest Index (%)	Grain zinc contents (ppm)
Zn_1V_1	9100 j	4059 k	44.62 h	16.05 i
Zn_1V_2	9078 j	4191 ij	46.18 bcdef	16.04 i
Zn_1V_3	9219 ij	4205 ij	45.63 cdefgh	18.72 h
Zn_1V_4	9117 j	4132 jk	45.32 efgh	15.68 i
Zn_1V_5	9303 hi	4286 hi	46.09 bcdefg	16.03 i
Zn_2V_1	9396 gh	4372 gh	46.53 abcde	20.46 fg
Zn_2V_2	9368 ghi	4404 efg	47.03 ab	19.76 g
Zn_2V_3	9505 g	4464 defg	46.97 ab	23.03 b
Zn_2V_4	9362 ghi	4391 fgh	46.91 abc	19.98 g
Zn_2V_5	9663 f	4593 bc	47.54 a	21.03 ef
Zn_3V_1	9699 f	4484 cdefg	46.23 bcdef	21.52 de
Zn_3V_2	9745 ef	4513 cde	46.32 abcdef	21.60 de
Zn_3V_3	9974 cd	4681 ab	46.93 abc	24.68 a
Zn_3V_4	9736 ef	4545 cd	46.68 abcd	21.91 cde
Zn_3V_5	10040 c	4759 a	47.40 ab	21.92 cde
Zn_4V_1	9875 de	4451 defg	45.08 fgh	22.38 bcd
Zn_4V_2	9966 cd	4522 cd	45.38 defgh	22.39 bcd
Zn_4V_3	10310 b	4591 bc	44.54 h	25.16 a
Zn_4V_4	9967 cd	4500 cdef	45.15 fgh	22.70 bc
Zn_4V_5	10550 a	4725 a	44.82 gh	22.81 bc
LSD@ 5%	145.2	100.6	1.127	0.8228

Here Zn_1, Zn_2, Zn_3 and Zn_4 represents 0, 4, 8 and12 kg ha^{-1} of Zn; and V_1, V_2, V_3, V_4 and V_5 represents Bhakar 2002, Shafaq 2006, Saher 2006, Faisalabad 2008 and Lasani 2008, respectively

Means not sharing the same letter within a column differ significantly from each other at 5% of probability level

Table 4: Effect of soil applied Zn on net income and benefit: cost ratio (BCR) of different wheat cultivars

Treatments	Total expenses (US$ ha^{-1})	Gross income (US$ ha^{-1})	Net income (US$ ha^{-1})	BCR
Zn_1V_1	861.09	1473.62	612.53	1.71
Zn_1V_2	861.09	1498.42	637.33	1.74
Zn_1V_3	861.09	1511.47	650.38	1.76
Zn_1V_4	861.09	1489.45	628.36	1.73
Zn_1V_5	861.09	1533.78	672.69	1.78
Zn_2V_1	867.00	1557.75	690.75	1.80
Zn_2V_2	867.00	1562.11	695.11	1.80
Zn_2V_3	867.00	1584.07	717.07	1.83
Zn_2V_4	867.00	1559.07	692.07	1.80
Zn_2V_5	867.00	1621.36	754.36	1.87
Zn_3V_1	871.55	1602.18	730.64	1.84
Zn_3V_2	871.55	1611.33	739.78	1.85
Zn_3V_3	871.55	1661.58	790.04	1.91
Zn_3V_4	871.55	1617.07	745.53	1.86
Zn_3V_5	871.55	1726.98	855.43	1.98
Zn_4V_1	876.09	1608.38	732.29	1.84
Zn_4V_2	876.09	1629.20	753.11	1.86
Zn_4V_3	876.09	1668.02	791.93	1.90
Zn_4V_4	876.09	1624.87	748.78	1.85
Zn_4V_5	876.09	1712.27	836.18	1.95

Note: 1 US$ = 110 Pakistan Rs.
Here Zn_1, Zn_2, Zn_3 and Zn_4 represents 0, 4, 8 and12 kg ha^{-1} of Zn; and V_1, V_2, V_3, V_4 and V_5 represents Bhakar 2002, Shafaq 2006, Saher 2006, Faisalabad 2008 and Lasani 2008, respectively

Maximum plant height and number of productive tillers were noted in wheat cultivar Lasani-2008 sown under 8 and 12 kg ha^{-1} of Zn but it was at par with Sehar-2006 sown under 12 kg ha^{-1} of Zn only for plant height. While minimum plant height and number of productive tillers were observed in Bakhar 2002 and Shafaq-2006 under control (Table 2). Likewise, all levels of soil applied Zn improved the number of spikelets per spike and number of grains per spike of all wheat cultivars compared with control (Table 2).

Maximum number of spikelets per spike and number of grains per spike were noted in wheat cultivar Lasani 2008 sown under 12 kg ha^{-1} of Zn while minimum number of spikelets per spike and number of grains per spike were observed in Bakhar-2002, Shafaq-2006 and Faisalabad grown without Zn application (Table 2). However with respect to 1000-grain weight, Sehar-2006 under 12 kg ha^{-1} and Faisalabad 2008 under 8 and 12 kg ha^{-1} of Zn application recorded higher 1000-grain weight while all the cultivars under control recorded the minimum 1000-grain weight (Table 2).

Zinc application at all levels, 8 and 12 kg ha^{-1} were the best, improved the grain and biological yield of all tested wheat cultivars than control (Table 3). Wheat cultivar Lasani 2006 with 12 kg ha^{-1} of Zn observed the higher biological yield while all the tested cultivars observed minimum biological yield under control conditions (Table 3). Wheat cultivar Lasani 2006 with 8 and 12 kg ha^{-1} of Zn and Sehar 2006 with 8 kg ha^{-1} of Zn observed the higher grain yield while all the tested cultivars observed minimum grain yield under control conditions (Table 3). However all the tested cultivars observed higher harvest index under 4 and 8 kg ha^{-1} of Zn application compared with control and higher level of Zn application (Table 3). Moreover, Sehar 2006 under 8 and 12 kg ha^{-1} of Zn application observed higher grain Zn contents but all the tested cultivars noted minimum Zn grain contents under control (Table 3).

All Zn levels substantially improved the gross and net income, and benefit: cost ratio (BCR) of all tested wheat cultivars compared with control i.e. without Zn application (Table 4). Nonetheless wheat cultivar Lasani-2006 observed maximum net income tied with accelerated BCR sown under 8 and 12 kg ha^{-1} of Zn application whereas all the cultivars recorded lesser net income and BCR when sown without Zn application (Table 4).

4. Discussion

Balanced use of fertilizer is one of the most important factor in enhancing the quality and quantity of crops product. The importance of trace elements in maintaining optimum plant physiology is becoming eminent. Among all of these elements, Zn is famous to have an effective character either as a metal component of enzymes or as a structural, functional or regulatory co-factor of numerous enzymes (Grotz and Guerinot, 2006). Plant height is one of the main vegetative growth parameter of wheat plant which represents the genetic variation and fertilizer effect. The increase in plant height might be due to the involvement of Zn in different physiological process like enzyme activation (Yassen *et al*., 2010), stomatal regulation (Oosterhuits and Weir, 2010) and chlorophyll formation (Habib, 2009) etc., which ultimately increase the plant height (Yaseen *et al*., 2011).

Results of this field study disclosed that increasing rate of Zn application improved the yield and related traits of all wheat cultivars under study (Tables 2, 3). Abbas *et al*. (2009) also observed the improved wheat growth and yield with the application of zinc fertilizer.

Significant expansion in yield related traits like number of productive tillers, spikelets per spike, grains per spike and 1000-grain weight was the cause of accelerated yield of tested wheat cultivars with Zn application (Table 2). It might be due to the involvement of Zn in physiological processes like enzyme activation and chlorophyll formation (Bailey *et al*., 2002; Hansch and Mendel, 2009) and genetic variation among different wheat cultivars (Sattar *et al*., 2010). Similar results were reported by Rahimi *et al*. (2012) who observed that application of zinc fertilizer improved the number of tillers of wheat

Divergent wheat cultivars behaved differently due to their different genetic makeup; and Lasani 2006 out yielded other cultivars under 8 and 12 kg ha^{-1} of Zn application. It might be due to its better genetic makeup and contribution of Zn in enzyme activation (Yassen *et al*., 2010), chlorophyll biosynthesis (Cakmak, 2008), pollen tube formation and pollen viability (Pandey *et al*., 2006), starch utilization (Habib, 2009), ensuing in greater seed set. Many researchers has reported the same findings in wheat (Narimani *et al.,* 2010; Abbas *et al*., 2011; Nadim *et al*., 2012). Micronutrients including Zn application plays a vital role in a variety of physiological and biochemical processes (Reeves and Baker, 2000; Doncheva *et al*., 2001; Stoyanova and Doncheva, 2002; Di Baccio *et al*., 2005; Broadley *et al*., 2007), culminating in more dry matter and grain yield production in cereals (Khan *et al*., 2010; Hussain *et al*., 2012; Sharma *et al*., 2014).

Progressive increase in Zn grain contents might be due to higher soil Zn contents due to external soil Zn application compared with control. Moreover different Zn grain contents in divergent wheat cultivars under control and varying levels of Zn application indicated the relative acquisition efficiencies of these genotypes from a Zn deficient and fertilized soil. Efficient genotypes such as Bhakar 2002 and Lasani-2008 accumulated more Zn contents in grains (Maqsood *et al*., 2009).

Economic feasibility in monetary terms seemed the reliable tool in determining the commercial adoption of any new innovation at farmer's head (Khan *et al.*, 2012). Findings of this study disclosed the economic feasibility of Zn application over control with higher economic returns and BCR of all tested wheat cultivars (Table 4). The supremacy in terms of higher BCR is the direct result of improvement of yield and related traits with Zn application at the rate of 8 kg ha^{-1} and 12 kg ha^{-1}.

5. Conclusion

The negative effect of Zn deficiency in calcareous soil causes in reduction of wheat crop yield. So, horizontal approaches like in present study, soil applied Zn can be used which significantly improved the production and net returns of all wheat cultivars compared with control. However, to get high production and net returns, wheat cultivar Lasani 2008 should be grown with 8 kg ha^{-1} of Zn under arid conditions of Multan, Pakistan.

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Competing Interests

Authors declare that they have no competing interests.

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