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Optimizing Zinc Nutrition for Maize (Zea mays L.) Yield in two Contrasting Soil Series of Sindh

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ABSTRACT

A pot study was carried out to determine the effects of different levels of zinc on growth and fodder yield of maize grown in Pacca and Sultanpur soil series. The research was conducted in a wire house at the department of soil science, Sindh Agriculture University Tando jam. The research was laid out in two factors, completely randomized design arrangement having three replications. Factor A consisted of soil series (02), i.e. S_1: Pacca soil series and S_2: Sultanpur soil series and factor B were assigned with various levels of zinc. The recommended doses of N, P and K were applied at 170 kg N ha^{-1}, 85 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1} in combination with different levels of zinc sulphate at 0.0, 2.5, 5.0, 7.5 and 10.0 kg $ZnSO_4$ ha^{-1} at the time of sowing in all treatments in Pacca and Sultanpur soil series. The soil under study of both soil series were silt loam in texture in Pacca soil series, sandy loam in Sultanpur soil series, non-saline, alkaline in nature, poor in organic matter, moderately calcareous in both soil series. Moreover, both soil series are low in total nitrogen and available phosphorus, while Pacca soil series was medium in potassium and Sultanpur soil series was adequate in potassium. The response of zinc sulphate on maize growth revealed that Sultanpur soil series was more prominent in zinc content of soil and leaf samples of maize as compared to Pacca soil series. The experimental results showed that higher seed germination (%) at the level of 7.5 kg $ZnSO_4$ ha^{-1} and application of 10.0 kg $ZnSO_4$ ha^{-1} has resulted in higher plant height, thicker stem girth, maximum number of green leaves, less number of dry leaves and maximum green fodder yield. Furthermore, it indicated higher zinc content in plant and soil. Sultanpur series remained more efficient than Pacca soil series in almost all recorded parameters. It was obvious from study that 10.0 kg $ZnSO_4$ ha^{-1} may be considered for getting maximum fodder yield of maize.

Keywords: Zinc, Pacca, Sultanpur, Yield, Soil series

1. INTRODUCTION

Maize (Zea mays L.) ranks third in importance after rice and wheat in Pakistan among cereal crops. In since it is a staple crop for the majority of people living in rural areas, it is a leading crop in the cultivation system. Maize is planted twice a year for both grain and fodder because of its short growing season (Harris et al., 2007). One of the most important cereal and fodder crops in the world is maize. Although it is really a tropical plant, it is currently grown widely and successfully in temperate, tropical, and sub-tropical climates worldwide (Tahir et al., 2009).

An exhaustive cereal crop is maize. It is a crop with several uses, including human food, animal feed, particularly for livestock and poultry and raw industrial materials (Khaliq et al., 2004). Because the overall amount of carotene in green maize leaves and stalks is higher than in grain, green maize feed is high in vitamin A. Despite having a low protein level, animals consume maize feed because it is tasty and succulent (Ali et al., 2004). It can be safely fed to livestock at any stage of crop growth because of its high production potential, rapid growth, greater adaptability, superior fodder quality, succulency, palatability, and lack of toxicants (Mahdi et al., 2011).

Proteins, enzymes, and all living things require zinc (Andreini et al., 2006; Broadley et al., 2007). The use of ATPase and RNAase as markers of zinc deficiency is not supported by the activation of these enzymes by other micronutrient shortages and stressors (Pandey et al., 2002). According to Barak and Helmke (1993), zinc is the sole metal that is involved in all six kinds of enzymes, including oxido-reductases, transferases, ydrolases, lyases, isomerases, and ligases. Deficiency of zinc in plants prevents chlorophyll synthesis, stress tolerance and growth. growth (Kawachi et al., 2009; Lee et al., 2010). According to Naik and Das (2008), zinc insufficiency is the most prevalent micronutrient problem across all crops.

Pakistani soils are typically calcareous and respond alkaline. Cereals grown on these soils typically have low levels of available micronutrients, especially zinc (Maqsood et al., 2009; Rashid and Ryan, 2008). The lack of micronutrients (Zn, Mn, Fe, and Cu) in arid and semi-arid soils is known to be one of the main determinants limiting yield and to significantly disrupt plant quality and yield (Yassen et al., 2010). Many different types of soils, such as sandy soils, high pH calcareous soils, and soils with high phosphorus levels, are susceptible to zinc deficiency (Hacisalihoglu and Kochian, 2003).

The parent material, atmospheric depositions, human activity, and the addition of fertilizers, sewage sludge, industrial waste products, and farmyard manures all have a major impact on the amount of zinc present in various soils. The zinc shortage present situation in agricultural soils is the result of numerous details. Lower amount of total zinc concentration, high calcite content, high pH, high amount of available phosphorus, and high concentrations of salts and bicarbonates are the principal soil variables that contribute to zinc deficiencies in main food crops like rice. This is known as "hidden" (or "latent") deficiency, and it can occur on slightly zinc-deficient soils, reducing yields and affecting quality without causing overt symptoms (Alloway, 2003; 2009).

Objective of this is (i) to measure the effects of zinc on the growth, fodder yield and zinc content of maize. (ii) To assess the effects of soil series on the growth, fodder yield and zinc content of maize.

2. MATERIALS AND METHODS

A pot experiment was carried out to examine the effects of different zinc levels on the growth and fodder yield of maize crops grown in Sultanpur and Pacca soil series. A pot experiment was conducted under natural conditions. The details of experiments are as under:

2.1. Site of research work

The experiment was carried out in the wire-house at the soil science department, Sindh Agricultural University Tando jam.

2.2. Experimental design and treatments detail

The trial was carried out in three replicated two factors, complete randomized design. The experiment was involve growing maize (*cv.* Akber) under two factors: Factor A= Soil series (02), i-e.S_1: Pacca soil series and S_2: Sultanpur soil series, factor B= Zinc Sulphate doses (05), i-e. T_1= 0.0 kg $ZnSO_4$ ha^{-1} (Control), T_2= 2.5 kg $ZnSO_4$ ha^{-1}, T_3= 5.0 kg $ZnSO_4$ ha^{-1}, T_4= 7.5 kg $ZnSO_4$ ha^{-1} and T_5= 10.0 kg $ZnSO_4$ ha^{-1} under recommended doses of NPK (170 kg N-85 kg P_2O_5- 60 kg K_2O ha^{-1})**.**

2.3. Fertilizer application

2.3.1. Zinc

Zinc in the form of Zinc Sulphate (33% Zn) was used. At sowing time total dose of Zin sulphate was applied

2.3.2. NPK Fertilizers

NPK fertilizers were applied at the dose of 170 N kg ha^{-1}, P_2O_5 at 85 kg ha^{-1} and K_2O at 60 kg ha^{-1}. Nitrogen applied as Urea at the prescribed rates in three splits, 1/3 at sowing, and 1/3 after 4 weeks and the rest at after 8 weeks. Phosphorus and Potassium were applied as Di- ammonium phosphate (DAP) and Sulphate of Potash (SOP), respectively at the time of sowing.

2.3.3. Soil sampling, processing and analysis

Fertile soil was collected from two different places. Pacca soil series was taken from southern eastern corner of Horticulture Garden and Sultanpur soil series was collected from Northwest of Hyderabad-Mirpurkhas Road near dispensary area from 20 cm depth as suggested by Ryan et al. (2001). It was correctly processed and examined for electrical conductivity (dSm^{-1}), texture, Soil pH, organic matter (%) and nitrogen by using factor (OM% /20=N%), available phosphorus (mg kg^{-1}), exchangeable potassium (mg kg^{-1}) and AB- DTPA- extractable zinc (Rayan *et al.,* 2001).

2.3.4. Soil preparation for pot experiment

Soil used in pot experiments was collected from two different places as mentioned above, Pacca soil series was taken from southern eastern corner of Horticulture Garden and Sultanpur series was collected from Northwest of Hyderabad-Mirpurkhas Road near dispensary area. Soil was air dried and ground passed through 4mm garden sieve. The air-dried soil was placed in pots (10 kg soil pot^{-1}).

2.3.5. Seed sowing process

Seed of maize (cv. Akber) were soaked for 12 hours, and seed sowing was done by marking 2 cm deep hole with the pencil in each pot. 6 seeds in each pot were sown. 3 seedlings were maintained in each pot in such a way that every plant was for away from each other at equal distance.

2.3.6. Irrigation

Normal irrigation water was applied to the pots. As requirement of the crop.

2.3.7. Soil analysis

Composite soil samples were taken before sowing and after harvesting. The soil samples were air dried at a room temperature and ground passed through a 2mm sieve. Prepared soil samples were collected and tagged in plastic bags for the analysis of physio-chemical properties.

Harvesting: Crop was harvested after ten weeks by cutting at soil level with sharp sickle. The plant data related to the following agronomic traits were recorded.

2.3.8. Agronomical observations

Nine plants per treatment (three plants from each replication) were selected. The selected plants were tagged and numbered and following observations were recorded.

2.3.9. Seed germination (%)

The seed germination (%) was recorded at 2, 4 and 6 days after sowing.

2.3.10. Plant height

Plant height (cm) was recorded from each treatment at the time of harvesting.

2.3.11. Stem girth

Stem girth (cm) was recorded from every treatment at harvesting time.

2.3.12. Number of green and dry leaves

Numbers of leave (green and dry) plant-1 were noted from every treatment at harvesting time.

2.3.13. Green fodder yield

The green fodder yield (g pot-1) pant-1 was noted from every treatment at harvesting time.

2.3.14. Plant analysis

At the time of maturity, the leaves of the plants taken in the paper bags and air dried for 48 hours at 68 0C. Plants materials (leaves) were milled in Wiley mill and analyzed for Zinc by wet oxidation followed by the analysis of the digests on atomic absorption spectrophotometer.

2.3.15. Statistical Analysis

Collected data was exposed to statistical analysis using statistics Ver 8.1. The analysis was done by co-factors analysis. The treatments were separated at alpha 0.05.

3. RESULTS

A pot trial was carried out during period of 2012-2013, to assay the effect of on the growth profile of maize crops grown in Pacca and Sultanpur soil.The results of this study are presented as under:

3.1. Physicochemical properties of soil before sowing

Soil was analyzed to determine some physic-chemical characters before sowing of crop is given in table 1. Experimental results showed that soil was silt loam in texture in Pacca soil series (S_1) and sandy loam in Sultanpur soil series (S_2), non-saline (S_1= 1.44, S_2= 0.58 dSm^{-1}), alkaline in reaction (S_1= 7.41, S_2= 7.21), medium in organic matter (S_1= 0.97, S_2= 0.97%), moderately calcareous (S_1= 14.0, S_2= 13.8%), low in total nitrogen (S_1= 0.048, S_2= 0.044%), and low in available phosphorus (S_1= 3.91 S_2= 2.62 mg kg^{-1}), Pacca soil series was medium in potassium (90 mg kg^{-1}) and Sultanpur soil series was adequate in potassium (135 mg kg^{-1}), soil was low in zinc (0.5 mg kg^{-1}) of Pacca soil series and zinc (1.1 mg kg^{-1}) was medium in Sultanpur soil series, respectively.

Table 1. Physicochemical properties of soil before sowing

S.No.	Physico-chemical properties	Pacca soil series	Sultanpur soil series
	Particle size Sand% Silt% Clay%	 12.5 76 11.5	 78 2.5 19.5
1	Texture class	Silt loam	Sandy loam
2	Electrical conductivity (dSm^{-1})	1.44	0.58
3	pH (1:5 soil water extract)	7.41	7.21
4	Calcium carbonate (%)	14	13.8
5	Organic matter (%)	0.97	0.97
6	Total nitrogen (%)	0.048	0.044
7	AB-DTPA extractable phosphorus ($mg\ kg^{-1}$)	3.91	2.62
8	AB-DTPA extractable potassium K^{+} ($mg\ kg^{-1}$)	90	135
9	AB-DTPA extractable Zinc ($mg\ kg^{-1}$)	0.5	1.1

3.2. Agronomical observation of seed germination

The mean results of seed germination percentage (%) of maize fodder grown in Pacca and Sultanpur soil series affected by several levels of Zinc sulphate (Figure 1). The statistical analysis of variance for seed germination (%) of maize grown soil series of Pacca and Sultanpur under application of zinc sulphate treatments were not significantly different ($P < 0.05$). The observed coefficient of variance was 19.18 which showed that experiment was homogeneous. The results of seed germination (%) of maize showed the superiority in Sultanpur soil series which recorded 75.913% seed germination followed by Pacca soil series 68.233 %. The seed germination (%) recorded at 0.0, 2.5. 5.0, 7.5 and 10.0 kg $ZnSO_4$ ha^{-1} remained 58.200, 67.183, 74.917, 80.500 and 79.567%, respectively.

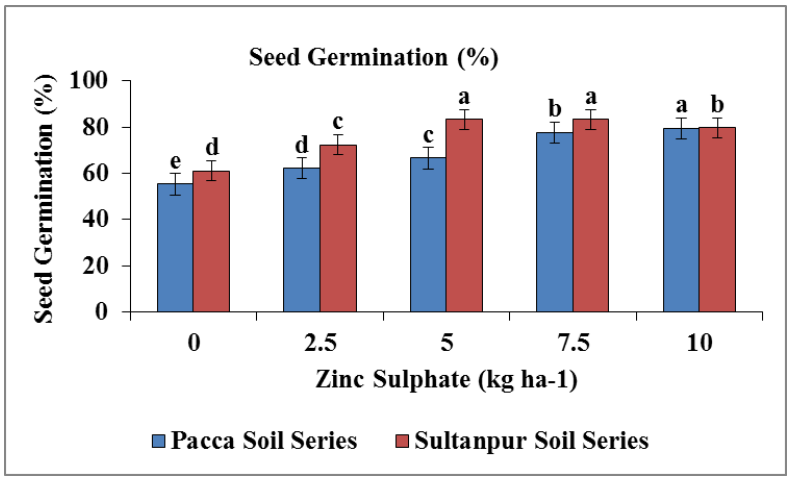

Figure 1. Effect of zinc sulphate on seed germination (%) of maize fodder grown in Pacca and Sultanpur soil series

3.3. Plant height (cm)

The mean results of plant height of maize fodder grown in Pacca and Sultanpur soil series affected by various levels of Zinc sulphate (Figure 2). The statistical analysis of variance for plant height of maize grown in soil series of Pacca and Sultanpur under application of zinc sulphate treatments were significantly different ($P < 0.05$). It was observed from results that soil series differences for plant height was higher (77.467 cm) recorded in Sultanpur soil series and lower plant height (73.680 cm) was noted in Pacca soil series. In case of zinc sulphate levels showed the superiority of 10.0 kg $ZnSO_4$ ha^{-1} which recorded taller plants (97.983 cm) followed by 7.5 kg $ZnSO_4$ ha^{-1} which recorded (86.600 cm). The drawf plants (52.417 cm) were observed in control pots which received no fertilizer. The overall results showed that in both soil series maize fodder responded to zinc nutrient and plant height increased linearly with the increment in zinc sulphate level.

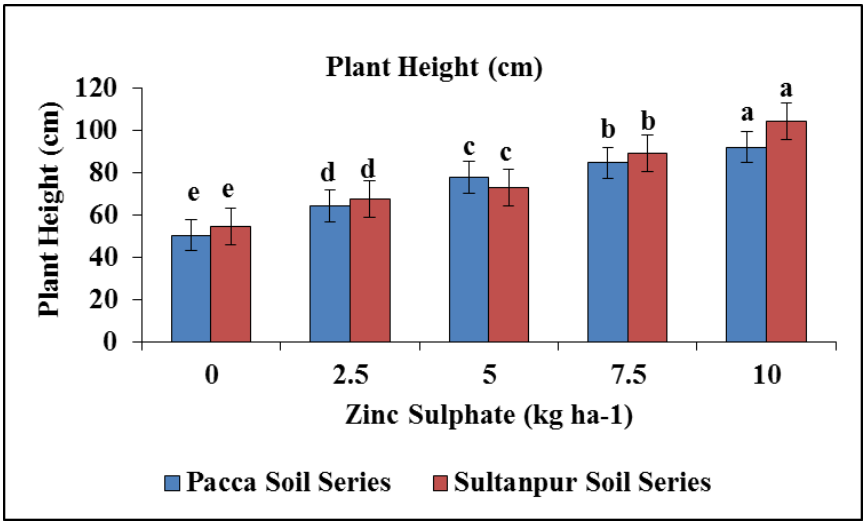

Figure 2. Effect of zinc sulphate on plant height (cm) of maize fodder grown in Pacca and Sultanpur soil series

3.4. Stem girth (cm)

The mean results of stem girth of maize fodder grown in Pacca and Sultanpur soil series affected by various levels of Zinc sulphate are given in the figure 3. The statistical variance of analysis for stem girth of maize grown in soil series of Pacca and Sultanpur under application of zinc sulphate treatments were significantly different ($P < 0.05$). It was found that soil series differences for recording the stem girth was more (4.320 cm) in Sultanpur soil series and lower stem girth (4.253 cm) was noted in Pacca soil series. In case of zinc sulphate doses 10.0 kg $ZnSO_4$ ha^{-1} resulted thicker stem girth (6.100 cm) fallowed by 7.5 kg $ZnSO_4$ ha^{-1} which recorded (5.366 cm) stem girth against (2.183 cm) thinner stem girth of maize plant which observed in control treatments. From the results it is clear that in both soil series maize fodder responded to zinc sulphate fertilization and the stem girth increased with increase in zinc sulphate doses.

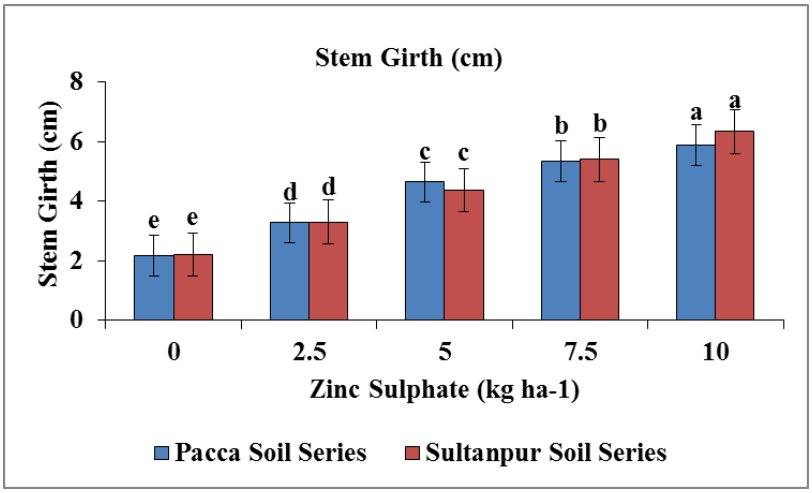

Figure 3. Effect of zinc sulphate on stem girth (cm) of maize fodder grown in Pacca and Sultanpur soil series

3.5. Number of green leaves plant-1

The mean results of numbers of green leave $plant^{-1}$ of maize fodder grown in Pacca and Sultanpur soil series affected by various levels of zinc sulphate (Figure 4). The statistical analysis of variance for numbers of green leave $plant^{-1}$ of maize fodder grown in the soil series of Pacca and Sultanpur under application of zinc sulphate treatments were significantly different ($P < 0.05$). It was observed that soil series differences for numbers of green leaves $plant^{-1}$ (8.720) were higher in Sultanpur soil series and lower number of green leaves (7.060) was recorded in Pacca soil series. More number of green leaves (10.633) at 10.0 kg $ZnSO_4$ ha^{-1} of zinc sulphate dose fallowed by 7.5 kg $ZnSO_4$ ha^{-1} which recorded (8.583) green leaves whereas a smaller number of green leaves (5.083) was noted in control treatment where no zinc sulphate was added.

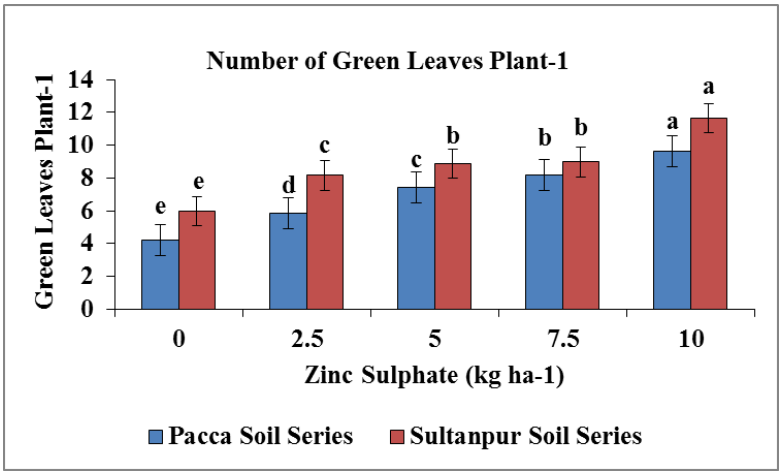

Figure 4. Effect of zinc sulphate on number of green leave plant-1 of maize fodder grown in Pacca and Sultanpur soil series

3.6. Numbers of dry leave plant^{-1}

The mean results of numbers of dry leaves plant-1 of maize fodder grown in Pacca and Sultanpur soil series affected by various levels of zinc sulphate (Figure 5). statistical analysis of variance for numbers of dry leave plant^{-1} of maize fodder grown in the soil series of Pacca and Sultanpur under application of zinc sulphate treatments were significantly different ($P < 0.05$) in series. Maximum number of dry leaves (3.620) was noted in Pacca soil series and minimum number of dry leaves (3.213) was recorded in Sultanpur soil series. As for as zinc sulphate doses are concerned, less number of dry leaves (2.583) was recorded at 10.0 kg $ZnSO_4$ ha^{-1} fallowed by 7.5 kg $ZnSO_4$ ha^{-1} which noted (2.983) dry leaves plant^{-1} whereas more dry leave (4.350) was found in control treatment.

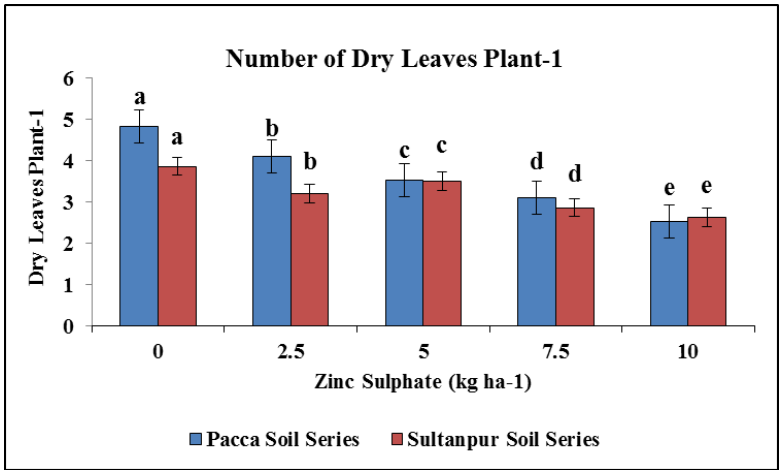

Figure 5. Effect of zinc on number of dry leaves plant-1 of maize fodder grown in Pacca and Sultanpur soil series

3.7. Fresh biomass (g pot^{-1})

The mean result of the green fodder yield (g pot-1) of maize fodder grown in Pacca and Sultanpur soil series affected by various levels of Zinc sulphate (Figure 6). The statistical analysis of variance for green fodder yields (g pot^{-1}) of maize fodder grown Sultanpur and Pacca soil series under application of zinc sulphate treatments were significantly different ($P < 0.05$) in series mean. It was found that soil series difference for green fodder was higher (180.91 g pot^{-1}) was recorded in Sultanpur soil series and minimum green fodder yield (156.67 g pot^{-1}) was noted in Pacca soil series. In case of zinc sulphate doses the maximum green fodder yield (202.38 g pot^{-1}) was noted at 10.0 kg $ZnSO_4$ ha^{-1} fallowed by 7.5 kg $ZnSO_4$ ha^{-1} which yielded (182.03 g pot^{-1}) and lowest value for green fodder yield (123.00 g pot^{-1}) was recorded in control pots. From the results it is clear that in both soil series maize fodder responded to zinc sulphate fertilization and the green fodder yield increased with increase in zinc sulphate doses.

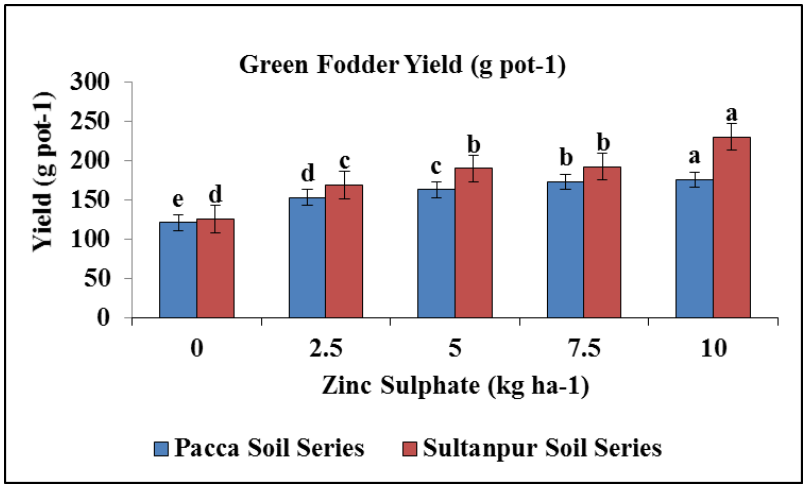

Figure 6. Effect of zinc sulphate on green fodder yield (g pot^{-1}) of maize fodder grown in Pacca and Sultanpur soil series

3.8. Zinc contents of soil (mg kg $^{-1}$)

The mean results of zinc the contents of soil (mg kg^{-1}) of maize fodder grown in Pacca and Sultanpur soil series affected by various levels of the Zinc sulphate (Figure 7). The statistical analysis of variance for zinc contents of the soil (mg kg^{-1}) of maize fodder grown in the soil series of Pacca and Sultanpur under application of zinc sulphate treatments were significantly different (P <0.05) of soil series mean. It was found that soil series difference for zinc content in soil was higher (1.18 mg kg^{-1}) recorded in Sultanpur soil series and minimum zinc content of soil (0.70 mg kg^{-1}) was noted in Pacca soil series. As for as zinc sulphate doses are concerned, the higher zinc content (1.31 mg kg^{-1}) was noted at 10.0 $ZnSO_4$ kg ha^{-1} fallowed by 7.5 $ZnSO_4$ kg ha^{-1} which recorded zinc content (0.99 mg kg^{-1}) wherea s minimum zinc content (0.72 mg kg^{-1}) was found in control treatment. Overall in treatments significant difference between both soils series for zinc content was noticed in this trail.

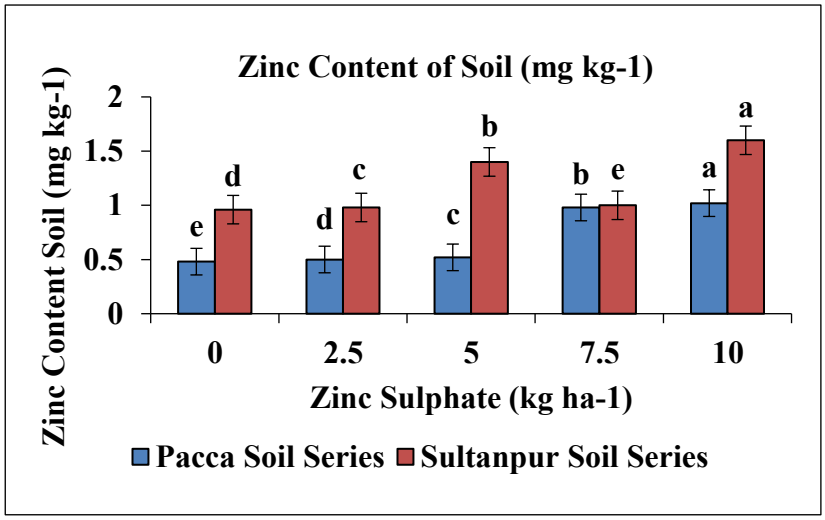

Figure 7. Effect of zinc sulphate on zinc contents of the soil (mg kg-1) of maize fodder grown in Pacca and Sultanpur soil series

3.9. Zinc content of maize leaves

The mean results of zinc content of leaves (mg kg^{-1}) of maize fodder grown in Pacca and Sultanpur soil series affected by various levels of the Zinc sulphate (Figure 8). The statistical analysis of variance for zinc content in plant (mg kg^{-1}) of maize fodder grown in the soil series of Pacca and Sultanpur under application of zinc sulphate treatments were significantly different (P <0.05). It was found that soil series difference for zinc content in leaves (mg kg^{-1}) was higher (57.0 mg kg^{-1}) was observed in Sultanpur soil series and minimum zinc content (35.1 mg kg^{-1}) of leaves was recorded in Pacca soil series. In case of various zinc sulphate levels are concerned, the higher zinc content (58.75 mg kg^{-1}) of leaves was noticed at 5.0 $ZnSO_4$ kg ha^{-1} fallowed by 10.0 $ZnSO_4$ kg ha^{-1} which

recorded zinc content (53.75 mg kg^{-1}) of leaves whereas low zinc contents (36.25 mg kg^{-1}) of leaves were found in control pots.

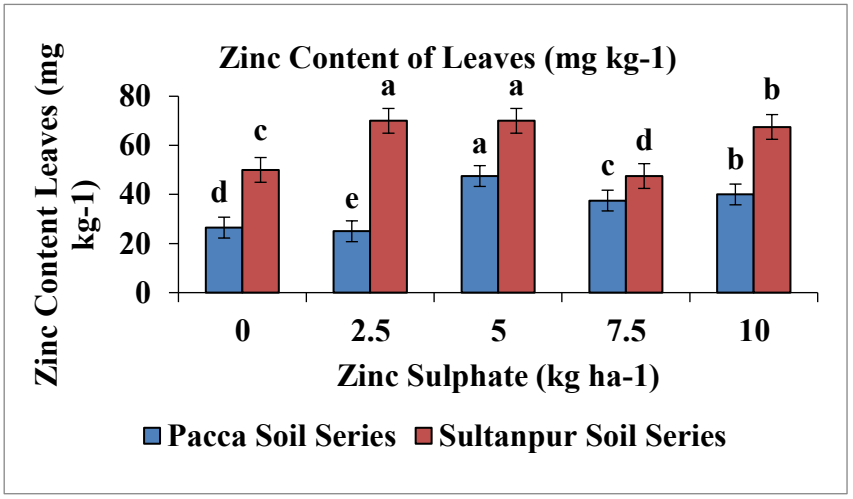

Figure 8. Effect of zinc sulphate on zinc content of maize leaves (mg kg-1) of maize fodder grown in Pacca and Sultanpur soil series

3.10. Pearson correlation analysis and regression correlation analysis with fodder green yield between other traits of maize

The regression and correlation analysis for both Pacca and Sultanpur soil series reveals that plant height and number of green leaves showing the maximum R^2 values, proving they are the most significant factors for green fodder yield in both series shown in (Figure 9) For Pacca soil, the relationship between plant height and yield shows an R^2 value above 0.90, underscoring its essential character. Similarly, Sultanpur soil exhibits high R^2 values above 0.92 for number of green leaves, underlining its significance. The zinc content in soil and stem girth also contributes positively, with adequate to strong correlations in both soils. However, the number of dry leaves constantly displays a negative correlation, suggesting that lower dry leaves are associated with higher yields. Overall, the analysis highlights the vital performance for growth-related characteristics, with Sultanpur soils revealing slightly higher R^2 values, reflecting greater yield potential.

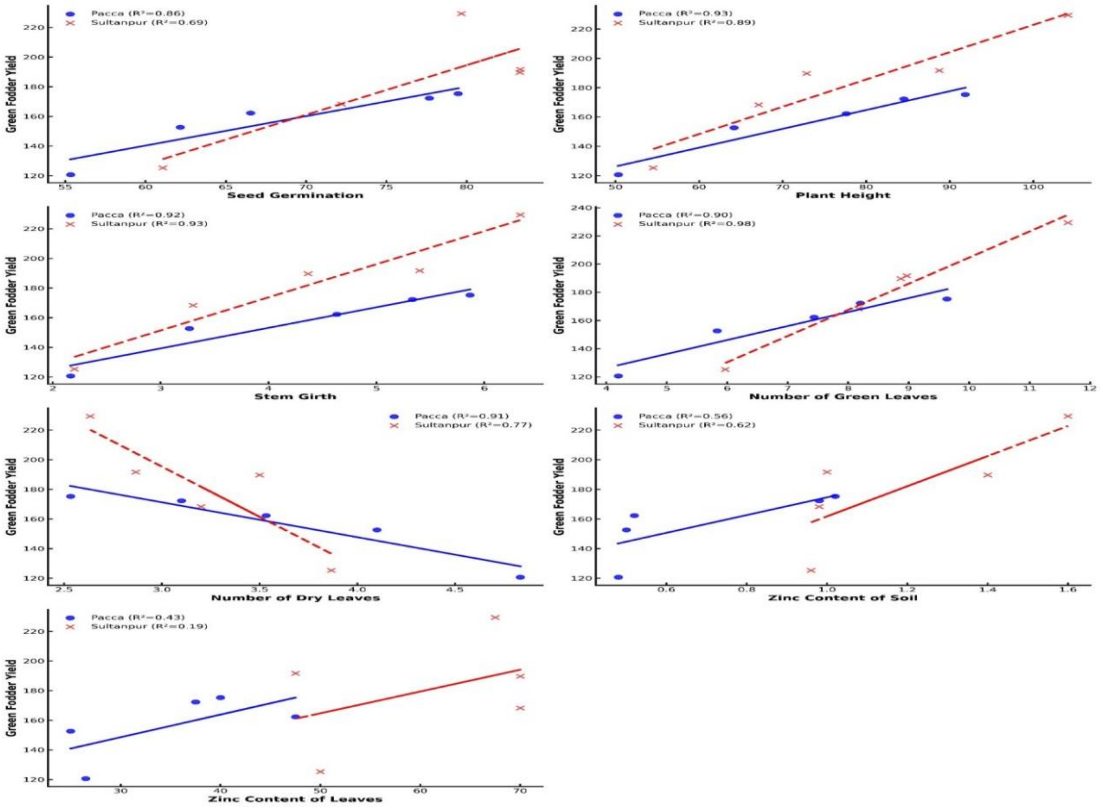

Figure 9. Relationships of maize fodder yield with biomass and zinc nutrition.

Moreover, the Pearson correlation analysis for both Pacca and Sultanpur soil series reveals significant relationships between green fodder yield and key parameters. In both soil series, plant height and number of green leaves show the strongest positive correlations with green fodder yield show in (Figure 10 and 11). For example, in Sultanpur soil, plant height exhibits a strong correlation ($R^2 = 0.92$*), and number of green leaves shows an equally high correlation ($R^2 = 0.91$*), indicating their critical role in enhancing yield. Similarly, in Pacca soil, zinc content in soil and zinc content in leaves have moderate yet significant positive correlations ($R^2 = 0.78$* and $R^2 = 0.76$*, respectively), emphasizing the importance of zinc availability for optimal growth. Conversely, number of dry leaves demonstrates a consistent negative correlation in both series (e.g., $R^2 = -0.65$* in Sultanpur soil), indicating that minimizing dry foliage is crucial for yield improvement. Overall, Sultanpur soil tends to show slightly stronger correlations for key parameters, reflecting its higher potential for supporting maize fodder yield under optimal management conditions.

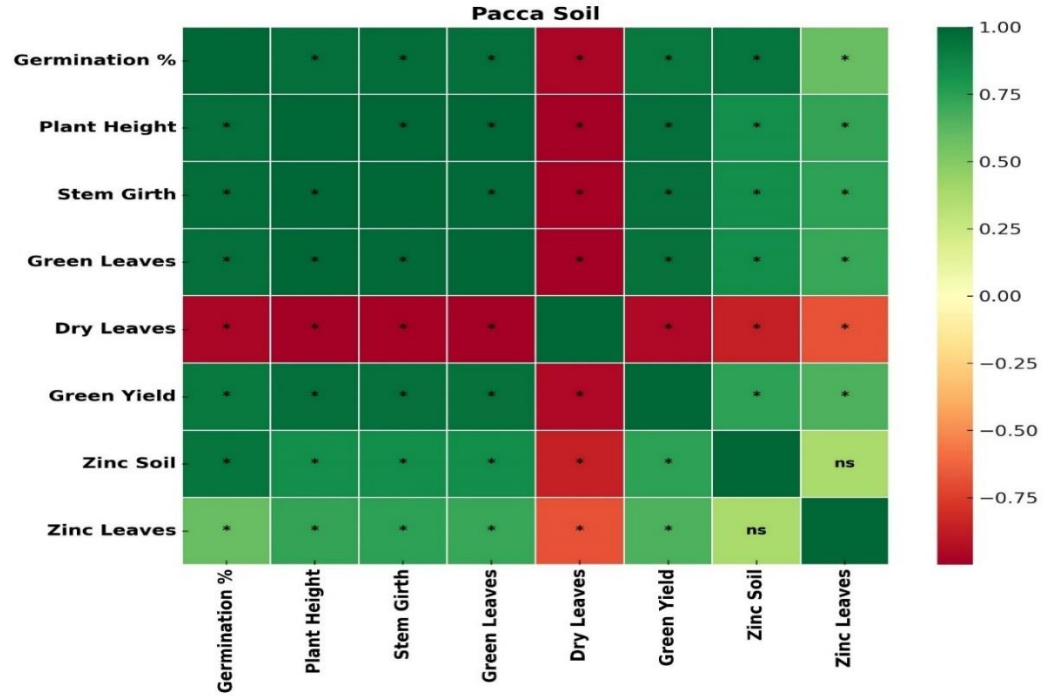

Figure 10. Relationships maize biomass and yield traits with each other at Pacca soil

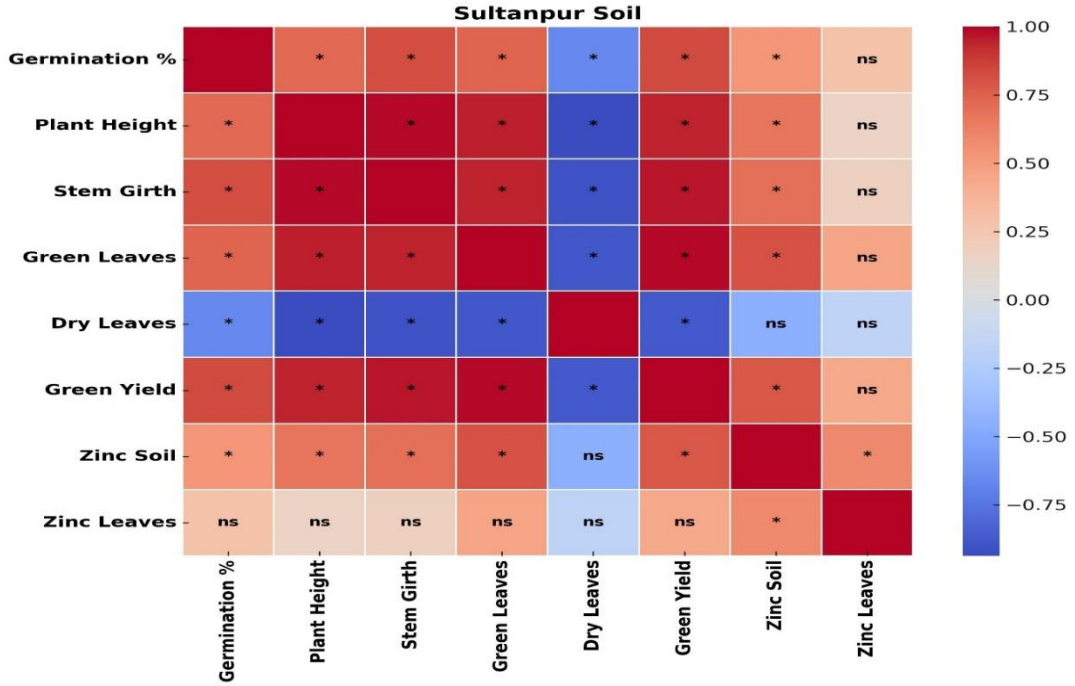

Figure 11. Relationships maize biomass and yield traits with each other at Pacca soil

4. DISCUSSION

the objectives of this research were to determine the effect of the different zinc levels on the growth and fodder yield of the maize crop grown in sultanpur and pacca series of soil and the findings of the experiment exposed that the applications of zinc sulphate have significant effect on the growth and fodder yield of maize crop grown in Sultanpur series of soil as compare to Pacca soil series. The analysis of physico-chemical properties of both soil series (Pacca soil series (S_1) and Sultanpur soil series (S_2) before sowing of crop (Table 1) showed that zinc was deficient in experimental sites of both soil series which might be due to high pH and calcareous nature of soil (Philips and Rao, 2005). The results are also agreement with findings of Rashid and Rafique (1996) who reported that zinc deficiency is wide spread in Pakistan. Furthermore the soil was silt loam in texture in Pacca soil series (S_1) and sandy loam in Sultanpur soil series (S_2), non-saline (S_1= 1.44, S_2= 0.58 dSm^{-1}), alkaline in reaction (S_1= 7.41, S_2= 7.21), medium in organic matter (S_1= 0.97, S_2= 0.97%), moderately calcareous (S_1= 14.0, S_2= 13.8%), low in total nitrogen (S_1= 0.048, S_2= 0.044%), low in available phosphorus (S_1= 3.91 S_2= 2.62 mg kg^{-1}), Pacca soil series was medium in potassium (90 mg kg^{-1}), Sultanpur soil series was adequate in potassium (135 mg kg^{-1}), soil was low in zinc (0.5 mg kg^{-1}) of Pacca soil series and zinc (1.1mg kg^{-1}) was medium in Sultanpur soil series, respectively. Similar results of physicochemical properties also have been observed by Deho (1997); Leghari (1997); Junejo (2000); Pathan (2001); Bhutto (2001); Soomro *et al.* (2011); Keram *et al*. (2012) and Khan *et al*. (2012).

Analysis of soil after harvest of crop showed that zinc content of soil (Table 8) increased significantly in Sultanpur soil series (1.18 mg kg^{-1}) fallowed by Pacca soil series (0.70 mg kg^{-1}). These results are in close in line with the outcomes of Dahar (2002) and Tariq *et al*. (2002). Dahar (2002) reported that 40%samples were deficient in zinc and 53.33% were marginal but 6.66 % samples were adequate in zinc content at different soil layers in different series of soil around Tando jam. The zinc concentration of maize fodder leaves (Table 9) was increased with 5.0 kg $ZnSO_4$ ha^{-1} followed by 10.0 $ZnSO_4$ kg ha^{-1}. These findings are conforming to the results of Tariq *et al*. (2002); Borges *et al.* (2009); Nehru *et al.* (2012) and Sheraz *et al.* (2012).

The data regarding to plants parameters as affected by zinc sulphate levels showed that seed germination (80.500 %) was increased through 7.5 $ZnSO_4$ kg ha^{-1}, whereas application of 10.0 $ZnSO_4$ kg ha^{-1} generally produce taller plants (97.983 cm), thicker stems (6.100 cm), maximum numbers of green leave (10.633) $plant^{-1}$, less numbers of dry leave (2.583) $plant^{-1}$ and maximum green fodder yields (202.38) g pot^{-1}. It is marked from the results that the effect of Zinc sulphate applications on seed germination (%) (Table 2), plant height cm (Table 3), stem girth cm (Table 4), numbers of green leave $plant^{-1}$ (Table 5), numbers of dry leave $plant^{-1}$ (Table 6), and green fodder yields g pot^{-1} (Table 7) were greater in Sultanpur soil series as compare to Pacca soil series. Overall results (Table 2-7) showed that both soil series responded well to zinc sulphate fertilizer on growth and yield parameters increased linearly with the increment in zinc sulphate levels. The results are conforming to the results of Faisul-ur-Rasool *et al* (2011); Sheraz *et al.*(2012); Nehru *et al.*(2012) and Keram *et al*.(2012).

5. CONCLUSION

A pot trial was carried out in the wire-house at soil science department, Sindh, agricultural university, Tando jam during 2012-2013, under normal conditions to evaluate effects of various zinc levels on the growth and fodder yields of maize (Zea mays L.) crop grown in the soil series of Pacca and Sultanpur. The key findings of this study are summarized and concluded in the following paragraphs: The pots were designed as two factors completely randomized design with five treatments and three replications. Factor A= Soil series (02), i-e.S1: Pacca soil series and S2: Sultanpur soil series, factor B= Zinc doses (05), i-e. T1= 0.0 kg ha^{-1} ZnSO4 (Control), T2= 2.5 kg ha^{-1} ZnSO4, T3= 5.0 kg^{ha-1} ZnSO4, T4= 7.5 kg ha^{-1} ZnSO4, T5= 10.0 kg ha^{-1} ZnSO4 under recommended doses of NPK (170 kg N-85 kg P2O5- 60 kg K2O ha^{-1}). The nitrogen (170 kg ha^{-1}) fertilizer were applied in the form of urea (46% N) in three equal doses, phosphorus (85 kg ha^{-1}) in the form of Di ammonium phosphorus (18% N, and 46%P2O5) and K^+ (60 kg ha^{-1}) in Sulphate of Potash (60% K2O) were applied at the sowing time. Zinc in the form of Zinc Sulphate (33% Zn) fertilizer and total dose applied at the time of sowing. The observations recorded were plant height (cm), seed germination %, number of dry leaves plant-1, stem girth (cm), number of dry leaves $plant^{-1}$ and green fodder yield (g pot-1). The soil was silt loam in texture in Pacca soil series, sandy loam in Sultanpur soil series, non-saline, alkaline in nature, poor in organic matter and moderately calcareous in both soil series. Moreover, both soil series are low in total nitrogen, low in available phosphorus, while Pacca soil series was medium in potassium and Sultanpur soil series was adequate in potassium. Zinc Sulphate application had significant effect on zinc content in soil and leaf samples of maize grown in Pacca and Sultanpur soil series. The maximum zinc content was recorded with the application of 10.0 kg ZnSO4 ha^{-1} in T5 in both soil series. The response of zinc sulphate on maize growth revealed that Sultanpur soil series more prominent on zinc content in soil and leaf samples of maize as compare to Pacca soil series. It is obvious from this study that incorporation of zinc @ 10.0 kg ZnSO4 ha-1 to maize pots had taller plants, thicker stems, maximum numbers of green leave, less dry leaves and maximum green fodder yield. Sultanpur soil series remained more efficient then Pacca soil series in just about all growth and yield parameters. In case of zinc sulphate fertilizer use efficiency among both soil

series was observed. The overall performance of maize growth in both soil series supplied with zinc sulphate was better as compare to the control.

6. REFERENCES

Ali, Z., Hassan, M. Z., Khan, S., & Bashir, M. (2004). Cost benefits analysis of wheat, barley, oat and mustard crops for fodder production. *Sarhad Journal of Agriculture, 20*(4), 669–671.

Alloway, B. J. (2004). *Zinc in soils and crop nutrition*. IZA Publications. International Zinc Association.

Alloway, B. J. (2009). Soil factors associated with zinc deficiency in crops and humans. *Environmental Geochemistry and Health, 31*, 537–548.

Andreini, C., Banci, L., Bertini, I., & Rosato, A. (2006). Zinc through the three domains of life. *Journal of Proteome Research, 5*(11), 3173–3178.

Barak, P., & Helmke, P. A. (1993). The chemistry of zinc. In A. D. Robson (Ed.), *Zinc in soils and plants* (pp. 90–106). Kluwer Academic Publishers.

Borges, I. D., Renzo, G. V., Luiz, J., Andrade, D., & Rezende, P. (2009). Micronutrients accumulate at different maize development stages. *J. Agrotec, 33*(4), 1413–7054.

Broadley, M. R., White, P. J., Hammond, J. P., Zelko, I., & Lux, A. (2007). Zinc in plants. *Journal of Animal and Plant Sciences, 173*, 677–702.

Dahar, G. J. (2002). *Soil fertility research: Distribution of micronutrients at various depths in different soil series around Tandojam*. SAU Publishers.

Faisul-ur-Rasool, M. S. S., Hasan, B., Bhat, R. A., Aziz, M. A., Singh, L., Aalum, I., & Bashir, S. (2011). Effect of nitrogen, zinc and seed rate on growth dynamics and yield of fodder maize (Zea mays L.) under temperate conditions. *Journal of Plant Archives, 11*(2), 965–971.

Hacisalihoglu, G., & Kochian, L. V. (2003). Mechanisms of Zn efficiency in crop plants. *Journal of Environmental Science, 159*, 341–350.

Kawachi, M., Kobae, Y., Mori, H., Tomioka, R., Lee, Y., & Maeshima, M. (2009). A mutant strain of Arabidopsis thaliana that lacks vacuolar membrane zinc transporter MTP1 revealed the latent tolerance to excessive zinc. *Journal of Plant Cell Physiology, 50*, 1156–1170.

Keram, K. S., Sharma, B. L., & Sawarkar, S. D. (2012). Impact of Zn application on yield, quality, nutrients uptake and soil fertility in a medium deep black soil (vertisol). *International Journal of Science, Environment and Technology, 1*, 563–571.

Khaliq, T., Mahmood, T., & Masood, A. (2004). Effectiveness of farmyard manure, poultry manure and nitrogen for corn (Zea mays) productivity. *Journal of Agriculture and Biology, 2*, 260–263.

Khan, M. U., Quasim, M., & Jamil, M. (2012). Response of rice to zinc fertilizer in calcareous soils of D. I. Khan. *Asian Journal of Plant Science, 1*, 1–2.

Lee, S., Kim, S. A., Lee, J., Guerinot, M. L., & Ghosh, R. K. (2010). Zinc deficiency inducible encodes a plasma membrane-localized zinc transporter in rice. *Journal of Molecular Cells, 29*, 551–558.

Maqsood, M. A., Ullah, R., Kanwal, S., Aziz, T., & Ashraf, M. (2009). Evaluation of Zn distribution among grain and straw of twelve indigenous wheats (Triticum aestivum L.) genotypes. *Pakistan Journal of Botany, 41*(1), 225–231.

Naik, S. K., & Das, D. K. (2008). Relative performance of chelated zinc and zinc sulphate for lowland rice (Oryza sativa L.). *Nutrition Cycle in Agroecosystems, 81*, 219–227.

Nehru, J., Vishwa, K., & Vidyalaya. (2012). Impact of Zn application on yield, quality, nutrients uptake and soil fertility in a medium deep black soil (vertisol). *International Journal of Science, Environment and Technology, 1*(5), 563–571.

Pandey, N., Pathak, G. C., Singh, A. K., & Sharma, C. P. (2002). Enzymatic changes in response to Zn nutrition. *Journal of Plant Physiology, 159*, 1151–1153.

Rashid, A., & Ryan, J. (2008). Micronutrient contents to crop production in the Near East: Significance and management strategies. In B. J. Alloway (Ed.), *Micronutrient deficiencies in global crop production* (p. 149). Springer Science + Business Media.

Sheraz, M. S., Hasan, B., & Singh, L. (2012). Influence of seed rate, nitrogen and zinc on fodder maize (Zea mays) in temperate conditions of western Himalayas. *Indian Journal of Agronomy, 57*, 85–88.

Tahir, M., Javed, M. R., Tanveer, A., Nadeem, M. A., Wasaya, A., Bukhari, S. A., & Rehman, J. U. (2009). Effect of different herbicides on weeds, growth and yield of spring planted maize (Zea mays L.). *Pakistan Journal of Life and Social Sciences, 7*, 168–174.

Tariq, M., Khan, A., & Perveen, S. (2002). Response of maize to applied soil zinc. *Asian Journal of Plant Science, 1*(4), 476–477.

Yassen, A., Abou, El-Nour, & Shedeed, S. (2010). Response of wheat to foliar spray with urea and micronutrients. *Journal of American Science, 6*(9), 14–22.