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GROWTH, YIELD AND QUALITY OF MAIZE (*Zea mays* L.) FODDER AS AFFECTED BY NITROGEN-ZINC INTERACTION IN ARID CLIMATE

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Quality fodder can be produced through balanced use of fertilizers. A field trial was conducted to work out the best combination of nitrogen and zinc for enhancing growth, yield and quality of maize fodder. Seven treatments viz. T1 = Control; T2 = N @ 50 kg ha^{-1} + Zn @ 5 kg ha^{-1}; T3 = N @ 50 kg ha^{-1} + Zn @ 10 kg ha^{-1}; T4 = N @ 100 kg ha^{-1} + Zn @ 5 kg ha^{-1}; T5 = N @ 100 kg ha^{-1} + Zn @ 10 kg ha^{-1}; T6 = N @ 150 kg ha^{-1} + Zn @ 5 kg ha^{-1} and T7 = N @ 150 kg ha^{-1} + Zn @ 10 kg ha^{-1}were used to test the crop. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Recommended dose of phosphorus (P) and potassium (K) fertilizer (60 and 75 kg ha^{-1}) was applied as basal dose to all treatments. The sources of N, P, K and Zn were urea, single super phosphate (SSP), sulphate of potash (SOP) and zinc sulphate ($ZnSO_4$), respectively. The maize variety Pak Afgooi was used as a test crop. Results showed a significant increase in plant height, stem circumference and biological yield with increased level of nitrogen and zinc fertilizers. Maximum improvement in plant height (160%), biological yield (72%), leaf area (116%), dry matter (80%) and relative water contents (17%) was observed in T7 (N @ 150 kg ha^{-1} + Zn @ 10 kg ha^{-1}). However, these results were non-significant with T6 (N @ 150 kg ha^{-1} + Zn @ 5 kg ha^{-1}) where the improvement in these parameters was 152, 69, 103, 79 and 18%, respectively. The T7 also significantly improved crude protein, ash contents, and nitrogen and zinc uptake as compared to control. It may be concluded that treatment combination N @ 150 kg ha^{-1} and Zn 5 kg ha^{-1} (T6) may be recommended for getting enhanced yield of improved quality maize fodder.
Keywords: Maize, fodder, nitrogen, zinc, yield, quality, *Zea mays*

INTRODUCTION

Fodder shortage is one of the limiting factors for agriculture development. The fodder supply reported by Younas and Yaqoob (2005) is one third of actual requirements while area under fodder has decreased during last decade without any significant corresponding increase in per hectare fodder production in Pakistan. Maize is the cheapest and valuable source of animal feed and is a rich source of nutrients, metabolizable energy, proteins, carbohydrates and water. In irrigated areas, 80-90% of livestock nutrient requirements are met by fodder crops (Younas and Yaqoob, 2005). The fodder in Pakistan is produced about 52-54% less than actually required for the animals (Bhatti, 1988), though it is a vital part of human diet being a part of various enzymes and animal feed (Maiti and Ebeling, 1998). Rashid *et al.* (2007) reported that due to shortage of irrigation water, increased human population, low priorities to fodder production and imbalance use of fertilizers, the area is reduced. The major threats of imbalance nutrition are less reproductive efficiency, low milk yield, delayed maturity and weaker animal growth rate. Maize is a short duration green fodder crop. It has an edge over other cultivated fodder crops due to high production potential, wider adaptability, quick growing nature, succulence, palatability, excellent fodder quality and free from toxicants and can safely be fed to animals at any stage of crop growth.

Nitrogen acts as a promoter for plant growth, making one to four percent of plants dry matter (Anonymous, 2000). It is an integral part of cell membrane, chlorophyll, amino acids, nucleic acids, enzymes and proteins (Seilsepour and Rashidi, 2011), and its deficiency reduces plant growth and yield (Haque *et al*., 2001; Shah *et al*., 2003; Maqsood *et al*., 2014), while its application improves crop production (Ahmad, 2000). There is a linear relationship between nitrogen fertilizer rates and days to tasseling (Gungula *et al*., 2003). It also improves dry matter in maize (Abbas *et al.,* 2003). Hence, optimum application of nitrogen is necessary to improve maize quality (Li *et al*., 2010). Nitrogen is the major essential nutrient required by the plants and its availability remains under quest due to a number of factors.

Approximately 50 percent of cereal cultivated areas of the world are deficient in soil zinc available for plants (Cakmak, 2002). Zinc acts as a structural as well as functional part of around 2,800 proteins, required for their biosynthesis and detoxifies oxygen free radicals that are highly toxic in nature (Cakmak, 2000; Broadley *et al*., 2007). Its deficiency is documented worldwide in soils under cultivation (Alloway, 2004; Hotz and Brown, 2004), affecting both crop production as well as human nutrition (Hotz and Brown, 2004; Welch and Graham, 2004). Its application enhances activities of enzymes especially antioxidant (Cakmak, 2000). The uptake of micronutrients is influenced by their interaction with macronutrients (Aulakh and Malhi, 2005). Integrated use of nitrogen and zinc improves biomass yield, nitrogen and zinc contents as well as their uptake in maize (Obrador *et al.,* 2003; Adiloglu and Saglam, 2005). Zinc concentration in plant body may decrease due to higher rates of nitrogen and vice versa (Adiloglu and Saglam, 2005). Therefore, present study has been conducted to work out balanced dose of nitrogen and zinc for maize fodder in arid climate.

MATERIALS AND METHODS

The experiment was conducted on research area of Department of Soil Science, University College of Agriculture & Environmental Sciences, Islamia University of Bahawalpur, to study the effectiveness of combined use of nitrogen and zinc for maize fodder. Representative composite soil samples were collected from 0-30 cm soil depth before planting and analyzed for ECe by EC meter using soil extract, pHs by pH meter using soil saturated paste, total N by Kjeldahl method, organic matter by following the method of Moodie *et al*. (1959), soil textural class by saturation method, P by following Olsen's method (Watanabe and Olsen, 1965), K by flame photometer and Zn by Atomic Absorption Spectrophotometer as described by Ryan *et al*. (2001). The soil used for experiment was sandy loam in texture, alkaline in reaction, deficient in organic matter, phosphorus and zinc contents while medium in K contents (Table 1).

The crop was sown in August, 2012. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The treatments used in the experiment were T1 = Control; T2 = N @ 50 kg ha^{-1} + Zn @ 5 kg ha^{-1}; T3 = N @ 50 kg ha^{-1} + Zn @ 10 kg ha^{-1}; T4 = N @ 100 kg ha^{-1} + Zn @ 5 kg ha^{-1}; T5 = N @ 100 kg ha^{-1} + Zn @ 10 kg ha^{-1}; T6 = N @ 150 kg ha^{-1} + Zn @ 5 kg ha^{-1} and T7 = N @ 150 kg ha^{-1} + Zn @ 10 kg ha^{-1}. Recommended dose of P and K @ 60 kg ha^{-1} and 75 kg ha^{-1}, respectively, was applied as basal dose. The seed @ 120 kg ha^{-1} was used for fodder purpose. The sources of N, P, K and Zn were urea, SSP, SOP and $ZnSO_4$, respectively. All P, K, Zn and half of N was applied at the time of sowing, while remaining N was applied with second irrigation. The crop was irrigated with good quality canal water meeting the irrigation criteria (Ayers and Westcot, 1985) as and when required by the crop according to weather conditions.

Data regarding plant height from the base (soil surface) to the upper tip of tassel of the plant and stem circumference from the base, middle and upper part of the plant stem was recorded and averaged from each plot by taking ten consecutive plants. Biological yield was recorded by harvesting and weighing the whole plot. Leaf area was calculated according to the method of Saxena and Singh (1965) while relative water contents were determined as described by Dhopte and Manuel (2002) by using the formula:

Where W is fresh weight, DW is dry weight and TW turgid weight of the sample.

Nitrogen agronomic efficiency (NAE) was determined with the following equation as devised by Dilallessa (2006)

Where, Yf and Yo are the yields of fertilized and unfertilized plots, respectively, and Nr the rate of fertilizer N application. The plant samples were ground and passed through a sieve of 0.5 mm mesh size. These samples were digested and used for chemical analysis; nitrogen by micro-Kjeldahl apparatus, phosphorus by spectrophotometer, potassium by flame photometer and zinc by Atomic Absorption Spectrophotometer as described by Ryan *et al*. (2001). Crude protein was calculated by multiplying nitrogen contents with 6.25 as described by Vlachos and Arvanitoyannis (2008). Nitrogen and Zn uptake was calculated through the method of Reddy and Bhanumurthy (2010) by multiplying the nitrogen contents (%) of maize

Table 1. Physical and chemical characteristics of the experimental field (0-30 cm depth)

Soil determinant	Unit	Pre-sowing analysis		Post-harvest analysis	
		15-0 cm	30-16cm	15-0cm	30-16cm
Textural class		Sandy loam	Sandy loam	Sandy loam	Sandy loam
Saturation percentage	%	29	28	30	28
pH_s		7.8	7.8	7.9	7.8
EC_e	dS m^{-1}	1.7	1.4	1.7	1.5
Organic matter	%	0.47	0.34	0.52	0.41
Total nitrogen	%	0.024	0.017	0.026	0.021
Available phosphorus	ppm	3.5	3.1	3.7	3.2
Extractable potassium	ppm	70	62	69	64
Zinc	ppm	0.72	0.63	0.79	0.7

fodder with total dry matter. Fodder quality parameters including acid detergent fibers (ADF), neutral detergent fibers (NDF), and ash contents were determined by AOAC (1995) methods. Post-harvest soil samples were collected and analyzed for different physical and chemical characteristics by following the method from Ryan *et al*. (2001). The data was analyzed statistically using Fisher's analysis of variance techniques (Nadeem *et al.,* 2009) and the treatment means were compared by LSD test at 5 % probability level (Steel *et al*., 1997).

RESULTS

Growth and yield components: Plant height, stem circumference and biological yield were significantly improved with nitrogen and zinc combinations (Table 2). The results revealed that nitrogen and zinc application significantly improved the plant height of maize fodder. Maximum plant height (226 cm) was observed with the treatment T7 where nitrogen was applied @ 150 kg ha^{-1} along with zinc @ 10 kg ha^{-1}. These results were non-significant withT6 but significantly different from all other treatments. The effect of combined application of nitrogen and zinc fertilizer on stem circumference of maize fodder showed positive results (Table 2). The maximum stem circumference (7.31 cm) with an increase of 47% over the control was exhibited with the treatment T7. All the other treatment combinations also showed significantly better results than the control.

Data indicated that biological yield of maize fodder was significantly improved by the combined application of nitrogen and zinc (Table 2). The treatment T7 resulted in the maximum biological yield (62.62 tons ha^{-1}) with an increase of 72% over the control and it was at par with the treatment T6, where low level of zinc (5 kg ha^{-1}) was applied with same N i.e. 150 kg ha^{-1} N.

Physiological parameters of maize fodder: Leaf area was significantly increased as nitrogen and zinc levels were increased (Table 3). Maximum increase in leaf area (116%) over the control was observed in T7 and it was at par with T6. All other treatment combinations also gave significantly better results as compared to control as well as the treatments where only nitrogen was applied. The results also showed that dry matter was increased with increase in nitrogen and zinc level. The highest dry matter (26.42 %) was recorded in T7 and it was non-significant with T4, T5 and T6 but significantly different from other treatments.

Relative water contents were also significantly influenced as a result of combined application of nitrogen and zinc. The highest relative water contents (84.46%) with an increase of 18% over the control were found in T6, where N @ 150 kg ha^{-1} was applied in combination with Zn @ 5 kg ha^{-1}. Nitrogen use efficiency was significantly affected by nitrogen and zinc application in fodder maize. The highest NUE was found in T3 (N @ 50 kg ha^{-1} + Zn @ 10 kg ha^{-1}) and lowest was observed in T6 (N @ 150 kg ha^{-1} + Zn @ 5 kg ha^{-1}). The results showed that nitrogen agronomic efficiency was higher at lower levels of nitrogen along with Zn application and it decreased as nitrogen level increased.

Table 2. Effect of nitrogen and zinc application on plant height, stem circumference and biological yield of maize fodder

Treatment	Plant height (cm)	Stem circumference (cm)	Biological yield (kg ha^{-1})
T1	87.03 d	4.98 f	36162.4 d
T2	141.87 c	5.57 e	47870.2 c
T3	164.43 bc	5.64 e	49091.3 c
T4	172.97 b	6.24 d	56559.6 b
T5	183.50 b	6.44 c	56967.0 b
T6	219.30 a	6.97 b	61010.0 a
T7	226.17 a	7.31 a	62620.0 a
SEM	9.66	0.06	1187.6

T1 = Control; T2 = N @ 50 kg ha^{-1} + Zn @ 5 kg ha^{-1}; T3 = N @ 50 kg ha^{-1} + Zn @ 10 kg ha^{-1}; T4 = N @ 100 kg ha^{-1} + Zn @ 5 kg ha^{-1}; T5 = N @ 100 kg ha^{-1} + Zn @ 10 kg ha^{-1}; T6 = N @ 150 kg ha^{-1} + Zn @ 5 kg ha^{-1} and T7 = N @ 150 kg ha^{-1} + Zn @ 10 kg ha^{-1}

Table 3. Effect of nitrogen and zinc application on physiological parameters of maize fodder

Treatments	Leaf area (cm^2)	Dry matter (%)	Relative water contents (%)	Nitrogen agronomic efficiency
T1	140.50 d	14.67 c	71.80 c	
T2	189.92 c	19.38 b	79.17 b	214.14 b
T3	194.69 c	19.65 b	80.87 ab	258.59 a
T4	225.13 b	23.24 ab	83.18 ab	204.04 bc
T5	228.71 b	23.67 ab	83.10 ab	208.08 b
T6	284.71 a	26.29 a	84.46 a	165.65 d
T7	302.86 a	26.42 a	84.37 a	176.43 cd
SEM	9.09	0.72	4.99	9.16

T1 = Control; T2 = N @ 50 kg ha^{-1} + Zn @ 5 kg ha^{-1}; T3 = N @ 50 kg ha^{-1} + Zn @ 10 kg ha^{-1}; T4 = N @ 100 kg ha^{-1} + Zn @ 5 kg ha^{-1}; T5 = N @ 100 kg ha^{-1} + Zn @ 10 kg ha^{-1}; T6 = N @ 150 kg ha^{-1} + Zn @ 5 kg ha^{-1} and T7 = N @ 150 kg ha^{-1} + Zn @ 10 kg ha^{-1}

Biochemical attributes of maize fodder: The data regarding crude protein as a result of nitrogen and zinc application on maize fodder depicted statistically significant results (Table 4). The maximum crude protein (9.45%), an increase of 50% over the control was recorded in the treatment comprising 150 kg ha^{-1} N and 10 kg ha^{-1} Zn. The other treatments also showed significantly better results as compared to control in improving the crude protein contents in maize fodder. Results revealed that ADF and NDF contents of maize fodder were not significantly influenced by the application of nitrogen and zinc (Table 4). Data showed that the ash contents were significantly influenced as a result of combined application of nitrogen and zinc. The highest ash contents (9.77%) were found in T7 which was non-significant with T6. All other treatments also showed significantly better results as compared to control in improving the ash contents in maize fodder (Table 4).

Table 4. Effect of nitrogen and zinc application on biochemical attributes of maize fodder

Treatments	Crude protein (%)	ADF (%)	NDF (%)	Ash contents (%)
T1	6.31 g	42.81 a	66.37 a	7.23 e
T2	7.50 f	43.00 a	66.07 a	8.13 d
T3	7.74 e	42.17 a	67.26 a	8.30 cd
T4	8.21 d	42.61 a	67.66 a	8.83 c
T5	8.46 c	41.97 a	65.87 a	8.90 bc
T6	9.19 b	42.45 a	66.25 a	9.57 ab
T7	9.45 a	42.81 a	66.64 a	9.77 a
SEM	0.07	0.48	0.69	0.22

T1 = Control; T2 = N @ 50 kg ha^{-1} + Zn @ 5 kg ha^{-1}; T3 = N @ 50 kg ha^{-1} + Zn @ 10 kg ha^{-1}; T4 = N @ 100 kg ha^{-1} + Zn @ 5 kg ha^{-1}; T5 = N @ 100 kg ha^{-1} + Zn @ 10 kg ha^{-1}; T6 = N @ 150 kg ha^{-1} + Zn @ 5 kg ha^{-1} and T7 = N @ 150 kg ha^{-1} + Zn @ 10 kg ha^{-1}; ADF = Acid detergent fibers; NDF = Neutral detergent fibers

Nitrogen and zinc uptake by maize fodder: Data showed that increasing level of nitrogen in combination with zinc doses increased N and Zn uptake by maize fodder over the control (Table 5). The maximum N (27.02 kg ha^{-1}) and Zn (67.39 g ha^{-1}) uptake was calculated with the treatment comprising 150 kg ha^{-1} N along with 10 kg ha^{-1} Zn which was statistically significant over the control. However, the results of T7 were non-significant with T6 in case of nitrogen uptake.

Table 5. Effect of nitrogen and zinc application on N and Zn uptake by maize fodder plant

Treatments	N uptake by plant (kg ha^{-1})	Zn uptake by plant (g ha^{-1})
T1	6.40 e	11.17 g
T2	12.46 d	23.21 f
T3	13.79 d	28.20 e
T4	18.15 c	38.78 d
T5	20.76 b	47.54 c
T6	25.08 a	57.79 b
T7	27.02 a	67.39 a
SEM	0.68	1.51

T1 = Control; T2 = N @ 50 kg ha^{-1} + Zn @ 5 kg ha^{-1}; T3 = N @ 50 kg ha^{-1} + Zn @ 10 kg ha^{-1}; T4 = N @ 100 kg ha^{-1} + Zn @ 5 kg ha^{-1}; T5 = N @ 100 kg ha^{-1} + Zn @ 10 kg ha^{-1}; T6 = N @ 150 kg ha^{-1} + Zn @ 5 kg ha^{-1} and T7 = N @ 150 kg ha^{-1} + Zn @ 10 kg ha^{-1}

DISCUSSION

The results of the present study showed that vegetative growth was significantly improved as a result of nitrogen and zinc application to maize fodder. The increase in vegetative growth might be due to positive interaction of nitrogen and zinc elements within the plant body by promoting photosynthesis and activity of several enzymes that endorsed vegetative growth. These results are in line with Uchino *et al*. (2013) and Afzal *et al.* (2012), who concluded that increasing level of nitrogen improved all growth attributes. The obtained results were in corroboration with those of Sarwar (2011), Behera *et al*. (2008) and Tahir *et al.* (2009), who revealed that higher application rates of zinc performed significantly better than lower rates for vegetative growth of maize under same level of nitrogen.

The statistical analysis of data revealed that the biological yield and yield contributing parameters were increased with increasing levels of nitrogen as well as zinc. This may be due to effectiveness of nitrogen and zinc in the promotion of photosynthesis that resulted in rapid growth and produced large amount of succulent and green foliage, which in turn may have generated higher yield. These results are in accordance with that of Hammad *et al.* (2011) who observed that nitrogen application rate responded linear and highly significant to biological yield of maize fodder. These results are in line with those of Bakht *et al*. (2007) and Khan *et al*. (2012) who reported that the application of nitrogen at higher rates was useful in increasing biological yield. The results are also supported by those of Asif *et al.* (2013) who reported positive effect of combined use of nitrogen and zinc on yield and yield contributing parameters. The increase in DM may be attributed to positive interaction between N and Zn supply to maize fodder, as greater biomass yield produces more dry matter. These results coincided with the findings of most of the researchers (Aslam *et al.*, 2011; Carpici, 2010), who reported that increasing rates of nitrogen and zinc fertilizers increased dry matter of the crop.

The leaf area of the crop was increased with increase in nitrogen and zinc levels. It may be due to synergistic effect of N and Zn which are integral part of chlorophyll that affect photosynthesis and produce rapid, succulent and green foliage. The improvement in leaf area (35-115%) over the control was recorded. These results were in line with the findings of those observed by Aslam *et al.* (2011) and Asif *et al*. (2013), who concluded the increment in leaf area as nitrogen and zinc fertilizer rate was increased. In our study, relative water contents of maize fodder were significantly affected by the combined use of nitrogen and zinc. The increase in RWC may be due to synergistic effect of nitrogen and zinc which can strengthen and support plant roots during the vegetative growth stage enabling plants to uptake more water and nutrients. These results are supported by those of Vazin (2012) who observed an increase in RWC over the control. The results showed that nitrogen agronomic efficiency was higher at lower levels of nitrogen and it decreased as nitrogen levels increased. Similar findings were reported by Dilallessa (2006), who found that the NAE was lower at higher levels of nitrogen and vice versa.

In the present study, crude protein (CP) contents of maize fodder were influenced by the effect of nitrogen and zinc application. Influence of nitrogen on crude protein contents was significant. Thus, it showed an increasing trend of crude protein contents with nitrogen application. Application of zinc also improved CP contents. It is well documented that zinc exerts a major influence on nitrogen metabolism due to which nitrogen uptake and protein contents were improved (Cakmak, 2002; Alloway, 2004). This may be attributed to positive effect of N and Zn on maize fodder. Their combined application also exhibited a highly significant effect to improve CP contents in maize fodder. It was reported by various researchers that protein contents were improved by nitrogen and zinc application (Asif *et al*., 2013).

In the present study, it was observed that ADF and NDF contents were not significantly influenced by the application of nitrogen and zinc on maize fodder. The ADF and NDF are structural component of plants and are composed of cellulose, hemicellulose, and lignin which have imperative task in forage digestibility. Decrease in ADF and NDF contents indicated fodder quality improvement. The data of the present study depicted that the decrease in ADF and NDF contents of maize fodder was statistically non-significant. This might be attributed due to fertility status of the experimental soil. It was reported in previous study that increasing levels of nitrogen increased ADF contents in forage crop (Islam *et al*., 2008).

In the present research work, the ash contents were increased with nitrogen and zinc application. The increase in fertilizer supply increased ash contents. The minimal ash contents were found in the control which indicated that nitrogen and zinc application had a positive effect on ash contents of maize fodder. The improvement in ash contents may be due to synergistic effect of nitrogen and zinc supply. Islam *et al.* (2010) examined that ash contents were improved with nitrogen supply.

In our study, the nitrogen and zinc uptake was increased in maize fodder. The increase in N and Zn uptake might be due to synergistic interaction of nitrogen and zinc. These results are in accordance with the findings of Keram *et al.* (2012), Morshedi and Farahbakhsh (2010) and Ashoka and Desai (2008), who revealed the positive interaction between nitrogen and zinc. These results are in line with those of Mahdi *et al.* (2012 who found significantly higher N and Zn contents and their uptake as a result of Zn application.

The maximum growth and yield of maize fodder was obtained by applying 150 kg ha^{-1} N along with Zn @ 10 kg ha^{-1} which was non-significant with T6 i.e. application of nitrogen @ 150 kg ha^{-1} along with zinc @ 5 kg ha^{-1}. The application of nitrogen and zinc improved the growth, yield and biochemical attributes of maize fodder. Similarly, N and Zn uptake by maize fodder was significantly increased with increased levels of nitrogen and zinc. It may be concluded that zinc fertilizer should be applied along with NPK to obtain better yield and quality of maize fodder in arid climate.

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REFERENCES

A.O.A.C. 1995. Official Methods of Analysis of AOAC International. 16th ed. P. Cunnif (Ed.) AOAC International, Arlington, Virginia, USA.

Abbas, M., M.Z. Rizwan., A.M. Maqsood and M. Rafiq. 2003. Maize response to split application of Nitrogen. J. Agri. Biol. 5:19-21.

Adiloglu, S. and M.T. Saglam. 2005. The effect of increasing nitrogen doses on the zinc content of maize plant in the soils of different properties. Pak. J. Biol. Sci. 8:905-909.

Afzal, M., A. Ahmad and A. H. Ahmad. 2013. Effect of nitrogen on growth and yield of sorghum forage (*Sorghum bicolor* L. Moench CV.) under three cuttings system. Cercetari Agronomice Moldova. 45:57-64.

Ahmad, N. 2000. Fertilizer scenario in Pakistan: Policies and development. p. 15-21. In: Proc. Conf. Agri. Fertilizer Use, Planning and Development Division, Govt. of Pakistan, Islamabad, Pakistan.

Alloway, B. 2004. Zinc in soils and crop nutrition. Areas of the world with zinc deficiency problems. (Available online at *http://www.zinc-crops.org/Crops/Alloway-all.php*).

Anonymous. 2000. Fertilizers and their use. FAO, International Industry Association, Rome.

Asif, M., M.F. Saleem, S.A. Anjum, M.A. Wahid and M.A. Bilal. 2013. Effect of nitrogen and zinc sulphate on growth and yield of maize (*Zea mays* L.). J. Agric. Res. 51:455-464.

Ashoska, M.P. and B.K. Desai. 2008. Effect of micronutrients with or without organic manures on yield of baby corn-chickpea sequence. Kar. J. Agric. Sci. 21:485-487.

Aslam, M, A. Iqbal, M.S.I. Zamir, M. Mubeen, M. Amin. 2011. Effect of different nitrogen levels and seed rates on yield and quality of maize fodder. Crop Environ. 2:47-51.

Aulakh, M.S. and S.S. Malhi. 2005. Interactions of nitrogen with other nutrients and water: Effect on crop yield and quality, nutrient use efficiency, carbon sequestration and environmental pollution. Adv. Agron. 86:341-409.

Ayers, R.S. and D.W. Westcot. 1985. Water quality for agriculture. FAO Irrigation Drainage Paper 29 (Rev.1). FAO, Rome, Italy.

Bakht, J., M. F. Siddique, M. Shafi, H. Akbar, M. Tariq, N. Khan, M. Zubair and M. Yousef. 2007. Effect of planting methods and nitrogen levels on the yield and yield components of maize. Sarhad J. Agri. 23:253-259.

Behera, S. K., D. Singh, B. S. Dwivedi, S. Singh, K. Kumar and D. S. Rana. 2008. Distribution of fractions of zinc and their contribution towards availability and plant uptake of zinc under long term maize (*Zea mays* L.)-wheat (*Triticum aestivum* L.) cropping on an Inceptisol. Aust. J. Soil Res. 46:83-89.

Bhatti, B.M. 1988. National perspective of fodder crops in Pakistan. NARC, Islamabad, Pakistan.

Broadley, M.R., P.J. White, J.P. Hammond, I. Zelko and A. Lux. 2007. Zinc in plants. New Phytol. 173:677-702.

Cakmak, I. 2000. Role of zinc in protecting plant cells from reactive oxygen species. New Phytol. 146:185-205.

Cakmak, I. 2002. Plant nutrition research: Priorities to meet human needs for food in sustainable ways. Plant Soil 247:3-24.

Carpici, E.B., N. Celik and G. Bayram. 2010. Yield and quality of forage maize as influenced by plant density and nitrogen rate. Turkish J. Field Crops 15(2):128-132.

Dhopte, A.M. and L.M. Manuel. 2002. Principle and Techniques for Plant Scientists, 1st Ed. Updesh Purohit for Agrobios, Odhpur, India; pp. 373. ISBN: 81-7754-116.

Dilallessa, T.D. 2006. Effect of tillage system, residue management and nitrogen fertilization on maize production in Western Ethiopia. Ph. D. Thesis, Univ. Free State, Bloemfontein, South Africa.

Gungula, D.T., J.G. Kling and A.O. Togun. 2003. CERES Maize predictions of maize phenology under nitrogen stressed conditions in Nigeria. Agron. J. 95:892-899.

Hammad, H.M., A. Ahmad, A. Wajid and J. Akhter. 2011. Maize response to time and rate of nitrogen application. Pak. J. Bot. 43:1935-1942.

Haque, M.M., A. Hamid and N.I. Bhuiyan. 2001. Nutrient uptake and productivity as affected by nitrogen and potassium application levels in maize/sweet potato intercropping system. Korean J. Crop Sci. 46:1-5.

Hotz, C. and K.H. Brown. 2004. Assessment of the risk of zinc deficiency in populations and options for its control. Food Nutr. Bull. 25:94-204.

Islam, M.R., S.M.E. Rahman, K.M.S. Islam and R. Chowdhury. 2008. Effect of the application of dried slurry on yield and chemical composition of maize fodder (*Zea mays* L.). Bang. J. Anim. Sci. 37: 52-57.

Keram, K.S., B.L. Sharma and S.D. Sawarkar. 2012. Impact of Zn application on yield, quality, nutrients uptake and soil fertility in a medium deep black soil (vertisol). Int. J. Sci. Environ. Tech. 1:563-571.

Khan, N., N.W. Khan, S.A. Khan, M.A. Khan and K.B. Marwat. 2012. Combined effect of nitrogen fertilizers and herbicides upon maize production in Peshawar. J. Anim. Plant Sci. 22:12-17.

Li, H., L. Li, T. Wegenastb, C.F. Longinb, X. Xua, A.E. Melchingerb and S. Chena. 2010. Effect of N supply on stalk quality in maize hybrids. Field Crop Res. 118:208-214.

Mahdi, S.S., B. Hasan, L. Singh and A.M. Ganie. 2012. Quality of fodder maize (*Zea mays* L.) and soil health influenced by nitrogen, seed rate and zinc in Kashmir Valley. Ind. J. Soil Conser. 40:147-151.

Maiti, R.K. and P.W. Ebeling. 1998. Maize Science. Oxford and IBH publishing Co. New Dehli, Calcutta. 323p.

Maqsood, M., M.A. Shehzad, Y. Ramzan and A. Sattar. 2014. Effect of nitrogen nutrition on growth, yield and radiation use efficiency of different wheat (*Triticum aestivum* L.) cultivars. Pak. J. Agri. Sci. 51:451-458.

Moodie, C.D., H.W. Smith and R.A. McCreery. 1959. Laboratory Manual for Soil Fertility. p. 1-75. Department of Agronomy, State College of Washington Pullman, Washington, USA.

Morshedi, A. and H. Farahbakhsh. 2010. Effects of potassium and zinc on grain protein contents and yield of two wheat genotypes under soil and water salinity and alkalinity stresses. Plant Ecophysiol. 2:67-72.

Nadeem, M.A., Z. Iqbal, M. Ayub, K. Mubeen and M. Ibrahim. 2009. Effect of nitrogen application on forage yield and quality of maize sown alone and in mixture with legumes. Pak. J. life Soc. Sci. 7:161-167.

Obrador, A., J. Novillo and J.M. Alvarez. 2003. Mobility and availability to plants of two zinc sources applied to a calcareous soil. Soil Sci. Soc. Am. J. 67:564-572.

Rashid, M., A.M. Ranjha and A. Rehim. 2007. Model based P fertilization to improve yield and quality of sorghum (*Sorghum bicolor* L.) fodder on an ustochrept soil. Pak. J. Agri. Sci. 44:221-227.

Reddy, D.M. and V.B. Bhanumurthy. 2010. Fodder, grain yield, nitrogen uptake and crude protein of forage maize as influenced by different nitrogen management practices. Ind. J. Bio. Sci. Manage. 1:69-71.

Ryan, J., G. Estefan and A. Rashid. 2001. Soil and Plant Analysis: Lab. Manual. Int. Center Agri. Res. in Dry Areas (ICARDA), Aleppo, Syria.

Sarwar, M. 2011. Effect of zinc fertilization in integration with organic and mineral nitrogen sources on maize production under rainfed conditions. Ph. D. Thesis. Pir Mehr Ali Shah Arid Agric. Univ., Rawalpindi, Pakistan.

Saxena, M.C. and Y. Singh. 1965. A note on leaf area estimation of intact maize leaves. Ind. J. Agron. 10:437-439.

Seilsepour, M. and M. Rashidi. 2011. Effect of different application rates of nitrogen on yield and quality of cotton (*Gossypium hirsutum* L.). Am. Euras. J. Agric. Environ. Sci. 10:366-370.

Shah, Z., S.H. Shah, M.B. Peoples, G.D. Schwenke and D.F. Herriedge. 2003. Crop residue and fertilizer N effects on nitrogen fixation and yields of legume-cereal rotations and soil organic fertility. Field Crops Res. 83:1-11.

Steel, R.G.D., J.H. Torrie and D.A. Dicky. 1997. Principles and Procedures of Statistics- A Biometrical Approach. p. 204-227. 3rd ed. McGraw Hill Book Int. Co., Singapore.

Tahir, M., N. Fiaz, M.A. Nadeem, F. Khalid and M. Ali. 2009. Effect of different chelated zinc sources on the growth and yield of maize (*Zea mays* L.). Soil Environ. 28:179-183.

Uchino, H., T. Watanabe, K. Ramu, K.L. Sahrawat, S. Marimuthu, S.P. Wani and O. Ito. 2013. Effects of nitrogen application on sweet sorghum (*Sorghum bicolor* (L.) Moench) in the semi-arid tropical zone of India. J. Agri. Res. Q. 47:65-73.

Vazin, F. 2012. Effect of zinc sulfate on quantitative and qualitative characteristics of corn (*Zea mays*) in drought stress. Cercetari Agronomice Moldova. 3:15-24.

Vlachos, A. and I.S. Arvanitoyannis. 2008. A review of rice authenticity/adulteration methods and results. Crit. Rev. Food Sci. Nutr. 48:553-598.

Watanabe, F.S. and S.R. Olsen. 1965. Test of an ascorbic acid method for determining phosphorus in water and $NaHCO_3$extracts. Soil Sci. Soc. Am. Proc. 29:677-678.

Welch, R.M. and R.D. Graham. 2004. Breeding for micronutrients in staple food crops from a human nutrition perspective. J. Exp. Bot. 55:353-364.

Younas, M. and M. Yaqoob. 2005. Feed resources of livestock in the Punjab, Pakistan. Livestock Research for Rural Development, Vol. 17, Art. #18. Available online at http://www.lrrd.org/lrrd17/2/youn17018.htm.