Sains Malaysiana 47(6)(2018): 1269–1276
http://dx.doi.org/10.17576/jsm-2018-4706-23

Agronomic Biofortification of Fodder Sorghum with Zinc under Different Levels of Nitrogen

(Biofortifikasi Agronomi Sorgum Foder dengan Zink pada Tahap Nitrogen Berbeza)

WAQAS AHMAD*, MUHAMMAD TAHIR, RIAZ AHMAD & RASHID AHMAD

ABSTRACT

Zinc (Zn) deficient soil prevails throughout the world and it has become the bottleneck in achieving production potential and quality of crops. The negligible use of micronutrients along with irregular use of macronutrients is practised for fodder production in Pakistan. Varying levels of zinc (0, 5, 10 and 15 kg ha^{-1}) and nitrogen (0, 60, 120 and 180 kg ha^{-1}) were evaluated for their effect on yield, quality and zinc uptake on fodder sorghum (variety Hegari) in a field experiment for two consecutive years (2014 and 2015). Data were analysed by using Fishers' analysis of variance (at $p<0.05$*) and response surface methodology (RSM). Correlation between different parameters was also studied. Application of zinc and nitrogen improved the plant height, leaf area plant^{-1}, green fodder yield, dry matter yield, crude protein percentage and zinc content of plant but decreased the neutral detergent fiber, acid detergent fiber and ash percentage. Values for different parameters recorded at second and third levels of zinc and nitrogen were remained at par with each other. Application of 10 kg ha^{-1} zinc and 120 kg ha^{-1} nitrogen showed an average increase of 7.3 and 18.6% in green fodder yield while 12.1 and 15.8% in dry matter yield, respectively. Similarly 6.1 and 7.5% increase in crude protein was noted over control. Correlation between NDF and ADF was negative with rest of the studied parameters. In conclusion, Zn_2 and N_2 gave the best results in term of yield and quality of fodder sorghum.*

Keywords: Agronomic biofortification; fodder; nitrogen; sorghum; zinc

ABSTRAK

Tanah yang kekurangan zink (Zn) berlaku di seluruh dunia dan ia menjadi halangan bagi mencapai potensi pengeluaran dan kualiti tanaman. Penggunaan mikronutrien yang tidak dapat dielakkan bersama penggunaan makronutrien yang tidak teratur diamalkan untuk pengeluaran foder di Pakistan. Tahap zink (0, 5, 10 dan 15 kg ha^{-1}) dan nitrogen (0, 60, 120 dan 180 kg ha^{-1}) telah dinilai untuk kesannya terhadap hasil, kualiti dan pengambilan zink pada sorgum foder (pelbagai Hegari) dalam uji kaji bidang selama dua tahun berturut-turut (2014 dan 2015). Data dianalisis menggunakan analisis Fisher's pelbagai (pada $p<0.05$*) dan kaedah gerak balas permukaan (RSM). Korelasi antara parameter yang berbeza juga dikaji. Penggunaan zink dan nitrogen meningkatkan ketinggian tumbuhan, tumbuhan daun tanaman^{-1}, hasil foder hijau, hasil bahan kering, peratusan protein mentah dan kandungan zink tumbuhan tetapi menurunkan serat detergen neutral, serat pencuci asid dan peratusan abu. Nilai untuk parameter yang berbeza yang dicatatkan pada tahap kedua dan ketiga zink dan nitrogen kekal setanding dengan satu sama lain. Penggunaan 10 kg ha^{-1} zink dan 120 kg ha^{-1} nitrogen menunjukkan peningkatan purata sebanyak 7.3 dan 18.6% dalam hasil foder hijau manakala 12.1 dan 15.8% dalam hasil bahan kering. Begitu juga 6.1 dan 7.5% peningkatan dalam protein mentah telah diperhatikan melalui kawalan. Korelasi antara NDF dan ADF negatif dengan sisa parameter yang dikaji. Sebagai kesimpulan, Zn_2 dan N_2 memberikan hasil terbaik dalam bentuk hasil dan kualiti sorgum foder.*

Kata kunci: Biofortifikasi agronomik; foder; nitrogen; sorgum; zink

INTRODUCTION

Livestock contribution in agriculture is 55.1% (GOP 2016) and it is a big source of money earning in arid and semiarid parts of country (Reddy & Soussan 2004). There is 33% difference between fodder demand and supply and situation becomes worse if shortage is expressed in term of quality (Anonymous 2011). Sorghum is the most important summer fodder (Fulkerson et al. 2008). It is very sensitive to zinc deficiency which affects its growth and development by affecting the auxin production and rate of photosynthesis (Alloway 2008). Zinc is also essential for many enzymes required for nitrogen metabolism, energy transfer, better growth and yield of plants and protein synthesis (Cakmak 2002; Hafeez et al. 2013). Nitrogen increased the number of nodes and internodes thus growth of sorghum improved due to more number of leaves per plant (Amin & El-Murtada 2011). Increasing levels of nitrogen increased the dry matter yield of sorghum (Azam et al. 2010). Nitrogen application not only improved the yield but also quality of produce in pearl millet (Ayub et al. 2009). Zinc deficiency affects the dairy animals. In female animals zinc deficiency affects the secretion of follicle stimulating hormone, luteinizing hormone and in males it reduces spermatogenesis (Hosnedlova et al. 2007). Its deficiency affects the process of keratinisation (Yatoo et al. 2013). In Pakistan, irregular nitrogen use for fodder production and wide spread zinc deficiency affects the fodder quality. Agronomic biofortification involves the practice of using zinc fertilizers to enhance the zinc concentration in different plant parts (Alloway 2008) and is one of the possible options to produce quality fodders with improved zinc concentration.

Materials and Methods

SITE DESCRIPTION AND SOIL ANALYSIS

The experiment was conducted at Agronomic Research Area, University of Agriculture, Faisalabad, Pakistan (73.09° east longitude; 31.25° north latitude; altitude 183 m). Fodder sorghum (variety Hegari) was sown in the field on 23rd May in 2014 and 2015. Soil analysis and data regarding the climatic condition are presented in Table 1 and Figure 1, respectively.

EXPERIMENTAL DESIGN

Four different zinc levels viz. Zn_0=0 (control), Zn_1=5, Zn_2=10 and Zn_3=15 kg ha^{-1} in combination with four levels of nitrogen viz. N_0=0 (control), N_1=60, N_2=120 and N_3=180 kg ha^{-1} were studied on fodder sorghum (variety Hegari). Experiment was laid out in RCBD with split plot arrangement having three replications keeping zinc in main plots and nitrogen in sub-plots. Crop was sown with the help of hand drill keeping 30 cm distance between the rows. Net plot size of main plot was 7.2 × 7.2 m while net plot size of sub-plots was 7.2 × 1.8 m. Nitrogen (in the form of urea) was applied according to the treatments, half at the time of sowing and half four weeks after sowing. Zinc (in the form of zinc sulphate 33%) was applied according to the treatments at the time of sowing. Phosphors and potassium were applied at the rate 60 and 40 kg ha^{-1} at the time of sowing, respectively. Four irrigations were applied during full crop season by connecting each sub-plot with water channel, first 20 days after sowing and then after 15 days interval. Weeding was done twice with the help of kasula (a hand tool), first 15 days and second 30 days after sowing. Crop was harvested at 50% heading stage.

COLLECTION OF DATA

Plant height and leaf area $plant^{-1}$ were recorded by taking average value of ten randomly selected plants from each sub plot with the help of measuring tape and leaf area meter (model LI 3000), respectively. Green fodder and dry matter yield were calculated by using the fresh and dry weight of sub-plots. Nitrogen percentage was determined by using Kjeldahl apparatus then multiplied with factor 6.25 to calculate crude protein percentage (AOAC 1990). Ash % was determined by using furnace, desiccator and oven (AOAC 1990). Total zinc in plant was determined by using the atomic absorption spectrometer (Thermo series) following Soltanpour (1985) after wet digestion of the samples. Similarly NDF and ADF were determined according to the methods of van Soest et al. (1991).

TABLE 1. Physico-chemical analysis of soil

Characteristics	Sand %	Silt %	Clay %	Soil texture class	pH	EC (dSm^{-1})	Organic matter (%)	Total nitrogen (%)	Available P (ppm)	Available K (ppm)	Zinc (ppm)
2014	28	49	21	silt-loam	7.6	1.60	0.81	0.047	10.4	68	0.41
2015	27	50	21	silt-loam	7.7	1.63	0.80	0.045	10.9	74	0.45

Source: Agricultural Metrology Cell, University of Agriculture, Faisalabad

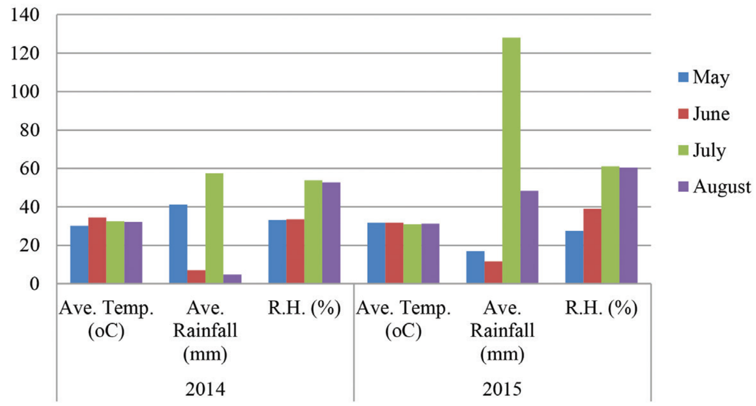

FIGURE 1. Climatic conditions during the experimental period in 2014 & 2015

STATISTICAL ANALYSES

Data collected for all the studied parameters were subjected to statistical analyses using Fishers' analysis of variance technique using computer software Statistic 8.1 (McGraw-Hill 2008) and difference among the treatment means were compared by using the least significant difference (LSD) test at 5% probability level by doing two way analysis (Steel et al. 1997). Correlation was computed following Kwon and Torrie (1964). Response surface methodology (Box et al. 2005) was applied to develop the response surfaces of green fodder yield, dry matter yield and crude protein percentage. General polynomial quadratic equation for two variables $Y=\beta_0+\beta_1x+\beta_2y+\beta_3x^2+\beta_4xy+\beta_5y^2$ was used to calculate the values for these parameters, where Y=response variable; x=zinc (kg ha^{-1}); y=nitrogen (kg ha^{-1}) in this experiment. To calculate the actual values of green fodder yield (t ha^{-1}), the following quadratic polynomial equations were used;

$$GFY\ (t\ ha^{-1})_{2014} = 64.62+0.519x+0.141y-0.003x^2-3.3\times10^{-5}xy-0.0003y^2$$

$$GFY\ (t\ ha^{-1})_{2015} = 68.93+0.673x+0.141y-0.009x^2-3.4\times10^{-5}xy-0.0003y^2$$

Quadratic equations for calculation of real values of dry matter yield (t ha^{-1}) according to which response surface diagrams were created as follows;

$$DMY\ (t\ ha^{-1})_{2014} = 21.69+0.359x+0.034y-0.015x^2-0.001xy-9.69\times10^{-5}y^2$$

$$DMY\ (t\ ha^{-1})_{2015} = 22.97+0.358x+0.037y-0.001x^2-3.4\times10^{-5}xy-0.0001y^2$$

Crude protein percentage values were calculated by using following quadratic polynomial equations;

$$CP\ (\%)_{2014} = 3.45+0.037x+0.002y-0.0019x^2-2.73\times10^{-5}xy-1.74y^2$$

$$CP\ (\%)_{2015} = 3.52+0.037x+0.002y-0.0018x^2-2.67\times10^{-5}xy-2.43y^2$$

RESULTS AND DISCUSSION

Increasing doses of zinc improved the plant height and leaf area per plant but did not affect the NDF, ADF and ash percentage. Similarly, increasing levels of nitrogen improved plant height and leaf area but NDF, ADF and ash percentage decreased (Table 2). Maximum values of plant height and leaf area were recorded at Zn_3 but remained statistically at par with Zn_2. Application of Zn_2 increased the plant height 3.9 and 4.1% while leaf area 3.9 and 3.7% during first and second years, respectively, as compared to control. Plant height and leaf area also increased with increasing doses of nitrogen giving maximum at N_3 but remained statistically at par with the N_2. Nitrogen application at the rate of 120 kg ha^{-1} improved the plant height 6.4 and 6.3% while leaf area 20.6 and 22.8% during 2014 and 2015, respectively, with respect to N_0. NDF, ADF and ash percentage decreased with increasing levels of nitrogen. Minimum values of these parameters were recorded at N_3 but remained at par with N_2. Use of N_2 decreased NDF 9.7 and 9.3%, ADF 10.1 and 6.9% and ash 7.9 and 8.0% during first and second years, respectively, as compared to control (N_0). The interaction between zinc and nitrogen was non-significant. The application of zinc also improved the leaf area per plant which might be due to the fact that zinc has role in proper functioning of photosynthetic enzymes (Fageria 2002). Our results confirm the investigation of Mehdi et al. (2012) who suggested that application of 10 kg ha^{-1} zinc in maize fodder increases plant height and leaf area. Nitrogen is the most limiting nutrient for crop production which accelerates cell division and cell elongation (Bhoya et al. 2014; Singh & Sumeriya 2012), this fact clears that use of nitrogen improved plant height of sorghum. Leaf area also increased with increasing nitrogen application which developed thicker canopy of sorghum and helped in improving green fodder yield. Chao et al. (2001) and Rana et al. (2014) also reported that nitrogen application makes the crop canopy denser. Values of NDF, ADF and ash percentage decreased with increasing dose of nitrogen which improved the fodder quality as these three factors are negative indicator of fodder quality. Similar results regarding the quality parameters due to applied nitrogen were found by different researchers (Amin & El–Murtada 2011; Ayub et al. 2007; Verma et al. 2005). Green herbage yield is the ultimate focus of a crop grown for fodder purpose. Green fodder yield depends on yield components. In fodder sorghum these are plant height, stem diameter, number of leaves per plant and leaf area per plant (Ayub et al. 2009). Figures 2 and 3 present the response surface diagrams for green forage yield (t ha^{-1}) during 2014 and 2015 in response to applied zinc and nitrogen. It is clear from Figures 2 and 3 that both zinc and nitrogen affected the green forage yield (t ha^{-1}) linearly. Effect of nitrogen was more pronounced as there is sharp increase in GFY with nitrogen application as compared to zinc. Application of nitrogen at the rate of 120 kg ha^{-1} improved the green fodder yield 19.1 and 17.9% during first and second years, respectively. Parallel increase in green forage yield was recorded with increasing nitrogen doses up to 120 kg ha^{-1} (Ayub et al. 2007; Shukla et al. 2003). Application of zinc (Zn_2) improved the green fodder yield up to 7.15% (2014) and 7.41% (2015) as compare to Zn_0. Verma et al. (2005) performed an experiment and reported an increase of 8% increase in GFY at 5 kg ha^{-1} of applied zinc. Response surface curves for dry matter yield (t ha^{-1}) during 2014 and 2015 in response to applied zinc and nitrogen showed that zinc and nitrogen affected the dry matter yield linearly up to Zn_2 and N_2 and the increase remained almost constant from Zn_2 to Zn_3 and N_2 to N_3 (Figures 4 & 5). The contribution of zinc and nitrogen to dry matter yield was almost equal. Zn_2 increased DMY 12.5 and 11.7% while N_2 increased DMY 15.4 and 15.8% during 2014 and 2015,

TABLE 2. Effect of different levels of zinc and nitrogen on agronomic and quality related attributes of fodder sorghum during 2014 and 2015

Zinc application rates (kg ha^{-1})	Plant height (cm)		Leaf area plant^{-1} (cm^2)		Neutral detergent fiber (%)		Acid detergent fiber (%)		Ash (%)	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Zn_0 (0)	265.29^c	271.96^c	1440^b	1456^b	55.22	53.54	32.94	32.12	8.00	7.90
Zn_1 (5)	268.63^{bc}	275.96^{bc}	1480^{ab}	1491^{ab}	54.00	52.32	32.26	31.01	8.03	8.03
Zn_2 (10)	275.75^{ab}	283.08^{ab}	1496^a	1505^a	53.39	51.54	31.72	30.39	8.05	8.05
Zn_3 (15)	279.83^a	287.01^a	1516^a	1523^a	52.99	51.15	31.64	30.13	8.07	8.22
LSD at P 0.05	10.17	9.42	43.00	45.00	NS	NS	NS	NS	NS	NS
Nitrogen application rates (kg ha^{-1})										
N_0 (0)	260.50^c	267.67^c	1300^d	1317^c	57.33^a	55.33^a	34.35^a	32.87^a	8.31^a	8.33^a
N_1 (60)	267.38^{bc}	274.54^{bc}	1422^c	1435^b	54.79^{ab}	52.96^{ab}	32.61^{ab}	31.13^{ab}	8.14^{ab}	8.15^{ab}
N_2 (120)	277.08^{ab}	284.25^{ab}	1568^b	1577^a	52.28^b	50.61^b	31.19^b	30.72^{ab}	7.95^{bc}	7.96^{bc}
N_3 (180)	284.54^a	291.71^a	1643^a	1646^a	51.20^b	49.64^b	30.41^b	28.93^b	7.75^c	7.78^c
LSD at P 0.05	12.19	11.25	65.00	86.00	3.77	3.70	2.25	2.33	0.22	0.20
Year Mean	272.38^b	279.54^a	1483	1493	53.90	52.13	32.14	30.91	8.04	8.06
LSD at P 0.05	2.80		NS		NS		NS		NS	
The interaction between zinc and nitrogen is non-significant										

Means within the column and for each treatment represented by same letter are not different according to the *p* ≤0.05 level of significance; NS = Non-significant

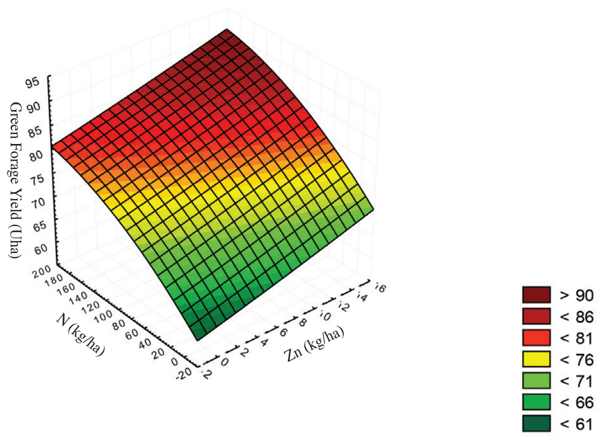

FIGURE 2. Green forage yield response (t ha^{-1}) to applied zinc (kg ha^{-1}) and nitrogen (kg ha^{-1}) during 2014

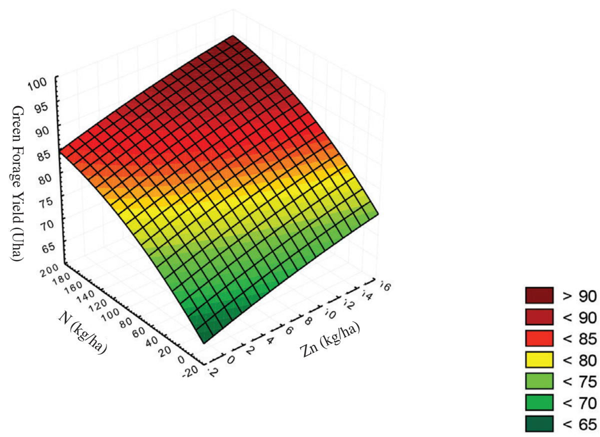

FIGURE 3. Green forage yield response (t ha^{-1}) to applied zinc (kg ha^{-1}) and nitrogen (kg ha^{-1}) during 2015

respectively. Nitrogen makes the plant succulent by absorbing more amount of water and increase the fresh weight but the effectiveness of zinc for increasing the dry biomass is clear from the results that zinc helped to increase dry biomass parallel with nitrogen. This is due the fact that zinc affects nitrogen uptake and its metabolism (Fageria 2002). Similar results were concluded by Castagnara et al. (2012) that dry biomass of oat increases linearly in response to applied zinc doses. It is clear from Figures 6 and 7 that both zinc and nitrogen affected the crude protein percentage. The response of crude protein from the applied zinc is curvilinear, that shows a little decrease in the values of CP% at Zn_3. Effect of nitrogen on crude protein percentage is linear. Application of Zn_2 increased crude protein percentage 6.3 and 5.9% while N_2 improved CP% at 7.6 and 7.4% in 2014 and 2015, respectively, as compared to control. Nitrogen is a part of amino acids which are building blocks of protein. A fodder securing more crude protein percentage consider best in quality and more nutritious than other. Our results confirm the findings of Sharifi and Taghizadeh (2009) that zinc increased nitrogen uptake and nitrogen content due to synergistic effect which affect the protein formation. Zinc and nitrogen enhanced the percentage of crude protein which resulted in improvement in forage quality. Table 3 presents the effect of zinc and nitrogen on zinc content of plant and zinc uptake from the soil. The effect of zinc and nitrogen and interaction between zinc and nitrogen was found significant on plant zinc content. During 2014, statistically maximum zinc content were recorded at

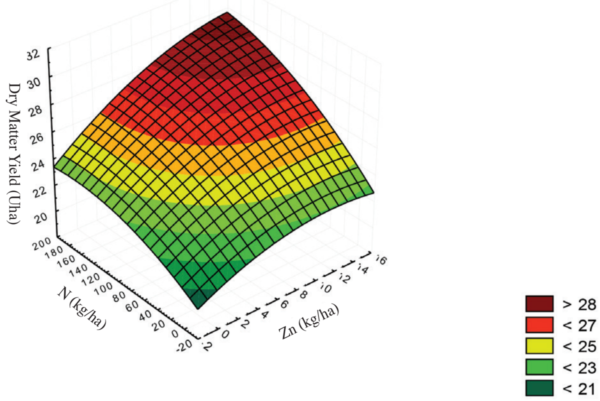

FIGURE 4. Dry matter yield response (t ha^{-1}) to applied zinc (kg ha^{-1}) and nitrogen (kg ha^{-1}) during 2014

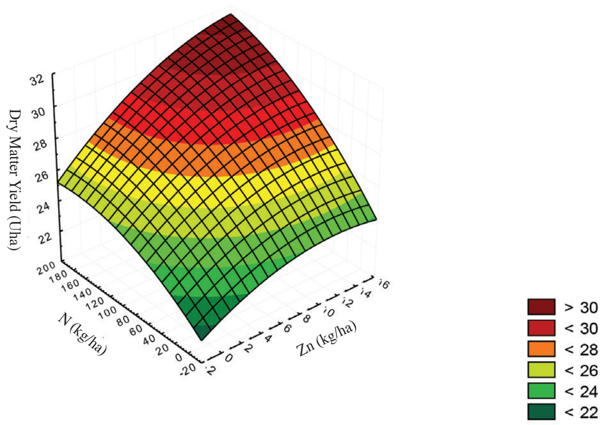

FIGURE 5. Dry matter yield response (t ha^{-1}) to applied zinc (kg ha^{-1}) and nitrogen (kg ha^{-1}) during 2015

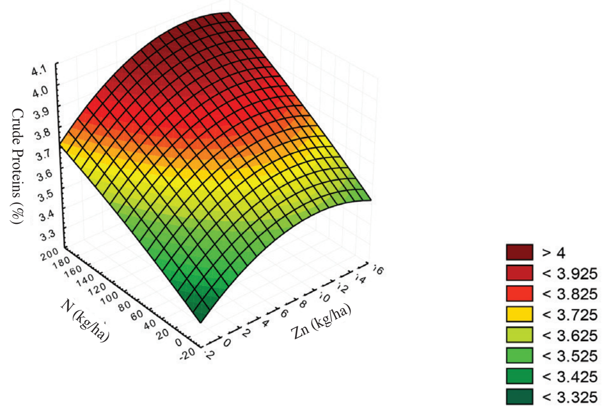

FIGURE 6. Crude protein response (%) to applied zinc (kg ha^{-1}) and nitrogen (kg ha^{-1}) during 2014

Zn_3N_3, it remained at par with zinc content recorded at Zn_2N_3 and Zn_3N_2. Similar trend was recorded during 2015. The interactive effect between zinc and nitrogen for zinc uptake was found significant during 2014. Maximum zinc uptake was recorded at Zn_3N_3 it remained at par with

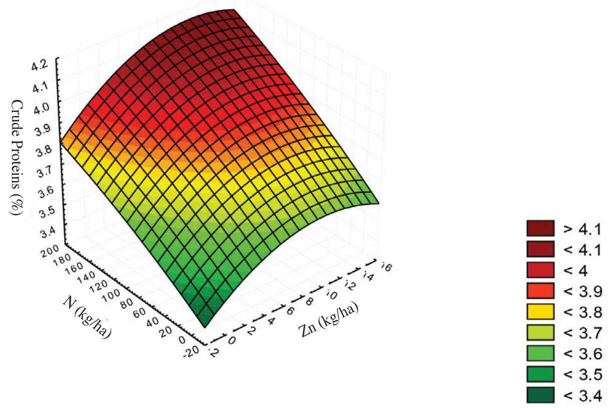

FIGURE 7. Crude protein response (%) to applied zinc (kg ha^{-1}) and nitrogen (kg ha^{-1}) during 2015

values of zinc uptake recorded at Zn_3N_2, Zn_2N_3 and Zn_2N_2. During 2015, the interactive effect was non-significant. Maximum zinc uptake was recorded at Zn_3 and N_3 which remained at par with value of zinc uptake recorded at Zn_2 and N_2. Increase of plant zinc content was one of the objectives in this experiment. Total zinc content of the sorghum plant increased with the increasing level of applied zinc. This is because of increased availability of zinc for plants from soil. Application of zinc to soil improved the zinc content, zinc uptake in sorghum (Ashoka et al. 2008) and in all cultivars of maize (Chaab et al. 2011). Zinc deficiency in fodders is the root cause of zinc deficiency in animals feeding on such fodders. Increasing levels of nitrogen and zinc improved the total zinc uptake by the sorghum to develop the zinc biofortified sorghum fodders. Dilution effect caused by the rapid vegetative growth due to excessive nitrogen application without adding zinc to the soil was controlled by the application of zinc (Hafeez et al. 2013). Increase in the values of different parameters in 2015 might be due to the reason that more rain fall in the month of July was recorded during second year of experiment. Statistically significant increase in plant height, green fodder yield and crude protein percentage was found in during 2015 than 2014. Table 4 presents the coefficient of correlation during both years of experiment. Correlation between leaf area and total zinc content of plant was non-significant during both years of experiment. The correlation between ash, total zinc content of plant and zinc uptake was non-significant during 2014 but was highly significant during 2015. NDF and ADF showed negative correlation with rest of the parameters under study but positively correlated with each other during both year of experiment. NDF and ADF are negative indicators of fodder quality so there is negative correlation between NDF, ADF and other parameters of sorghum. These results are in accordance with those reported by Ayub et al. (2002) that nitrogen improved the yield and quality fodder sorghum by increasing crude protein percentage and by decreasing NDF, ADF and ash percentage.

TABLE 3. Effect of different levels of zinc and nitrogen on zinc content of plant and zinc uptake of fodder sorghum during 2014 and 2015

Nitrogen application rates (kg ha^{-1})	Zn content (mg kg^{-1}) Zinc application rates (kg ha^{-1}) Zn$_0$ (0)	Zn$_1$ (5)	Zn$_2$ (10)	Zn$_3$ (15)	Mean	Zinc uptake (kg ha^{-1}) Zinc application rates (kg ha^{-1}) Zn$_0$ (0)	Zn$_1$ (5)	Zn$_2$ (10)	Zn$_3$ (15)	Mean
2014										
N_0 (0)	22.85^{g}	26.39^{f}	29.64^{e}	31.47^{de}	27.59^{C}	0.51^{h}	0.60^{f-h}	0.69^{ef}	0.75^{de}	0.64^{C}
N_1 (60)	22.39^{g}	26.12^{f}	31.89^{d}	33.91^{c}	28.58^{B}	0.52^{gh}	0.65^{e-g}	0.83^{cd}	0.90^{bc}	0.73^{B}
N_2 (120)	22.37^{g}	25.55^{f}	35.04^{bc}	36.21^{ab}	29.86^{A}	0.53^{gh}	0.67^{ef}	0.99^{ab}	1.03^{a}	0.81^{A}
N_3 (180)	22.04^{g}	25.02^{f}	36.49^{ab}	37.85^{a}	30.28^{A}	0.54^{gh}	0.69^{ef}	1.03^{ab}	1.09^{a}	0.84^{A}
Mean	22.41^{D}	25.77^{C}	33.19^{B}	34.93^{A}		0.53^{C}	0.65^{B}	0.88^{A}	0.94^{A}	
LSD at P 0.05	Zn=1.32 N=0.855 Zn×N=1.98					Zn=0.09 N=0.06 Zn×N=0.13				
Year Mean	29.08					0.75^{B}				
2015										
N_0 (0)	23.56^{gh}	27.13^{f}	30.37^{e}	32.53^{d}	28.40^{B}	0.56	0.66	0.75	0.82	0.70^{C}
N_1 (60)	23.10^{h}	26.86^{f}	32.12^{d}	34.14^{cd}	29.05^{B}	0.57	0.71	0.88	0.95	0.78^{B}
N_2 (120)	23.02^{h}	26.20^{f}	35.22^{bc}	36.66^{ab}	30.28^{A}	0.58	0.74	1.05	1.10	0.87^{A}
N_3 (180)	22.47^{h}	25.44^{fg}	36.17^{ab}	37.79^{a}	30.47^{A}	0.59	0.75	1.09	1.15	0.89^{A}
Mean	23.04^{D}	26.41^{C}	33.47^{B}	35.28^{A}		0.58^{C}	0.71^{B}	0.94^{A}	1.01^{A}	
LSD at P 0.05	Zn=1.36 N=0.88 Zn×N=2.03					Zn=0.12 N=0.08 Zn×N=NS				
Year mean	29.55					0.81^{A}				
LSD at P 0.05	NS					0.05				

Means within the columns and rows (two ways analysis) for both treatments represented by same letter are not different according to the *p ≤0.05* level of significance; NS = Non-significant

TABLE 4. Coefficient of correlation among agronomic and quality parameters of fodder sorghum during 2014 (lower diagonal) and 2015 (upper diagonal) at different levels of zinc and nitrogen

	PH	LA	GFY	DMY	CP	NDF	ADF	Ash	T Zn	Zn Uptake
PH	1.00	0.900**	0.944**	0.920**	0.928**	-0.944**	-0.920**	0.928**	0.668**	0.810**
LA	0.900**	1.00	0.961**	0.878**	0.930**	-0.980**	-0.909**	0.895**	0.336	0.549*
GFY	0.945**	0.954**	1.00	0.955**	0.952**	-0.990**	-0.935**	0.969**	0.550*	0.731**
DMY	0.905**	0.846**	0.937**	1.00	0.947**	-0.943**	-0.918**	0.958**	0.675**	0.838**
CP	0.927**	0.917**	0.935**	0.938**	1.00	-0.968**	-0.974**	0.915**	0.557*	0.732**
NDF	-0.934**	-0.986**	-0.981**	-0.910**	-0.956**	1.00	0.944**	-0.956**	-0.499*	-0.689**
ADF	-0.931**	-0.984**	-0.977**	-0.906**	-0.961**	0.998**	1.00	-0.921**	-0.546*	-0.712**
Ash	0.884**	0.991**	0.928**	0.813**	0.902**	-0.966**	-0.968**	1.00	0.634**	0.791**
T Zn	0.677**	0.355	0.579*	0.729**	0.599*	-0.481	-0.479	0.307	1.00	0.966**
Zn Uptake	0.798**	0.538*	0.730**	0.860**	0.743**	-0.649**	-0.647**	0.495	0.975**	1.00

where *=Significant and **=Highly significant at p≤0.05 and p≤0.01, respectively
PH=Plant height (cm), LA=Leaf area (cm^2), GFY=Green forage yield (t ha^{-1}), DMY=Dry matter yield (t ha^{-1}), CP=Crude Protein (%), NDF=Neutral detergent fiber (%), ADF=Acid detergent fiber (%), Ash (%), T Zn=Total zinc content of plant (mg kg^{-1}), Zinc uptake (kg ha^{-1})

Conclusion

The application of zinc and nitrogen at rate of 10 and 120 kg ha^{-1}, respectively, increased the green fodder yield and quality of fodder sorghum by increasing crude protein percentage. Zinc content of plant also increased with the application of zinc (Zn_2) and produced zinc fortified fodder sorghum.

References

Alloway, B.J. 2008. *Zinc in Soils and Crop Nutrition*. Brussels, Belgium: International Zinc Association.

Amin, M. & El-Murtada, H. 2011. Effect of different nitrogen sources on growth, yield and quality of fodder maize (*Zea mays* L.). *Journal of Saudi Society of Agricultural Sciences* 10: 17-23.

Anonymous. 2011. Pakistan Agriculture Research Council. Government of Pakistan. Available on line at http://www.parc.gov.pk/NARC/Fodder/Pages/intro.html.

AOAC. 1990. *Officials Methods of Analysis*. Washington D.C., USA. Association of Official Analytical Chemists.

Ashoka, P., Mudalagiriyappa, M., Pujari, B.T., Hugar, P.S. & Desai, B.K. 2008. Effect of micronutrients with or without organic manures on yield of baby corn (*Zea mays* L.) chickpea (*Cicer artietinum* L.) sequence. *Karnataka Journal of Agricultural Sciences* 21(4): 485-487.

Ayub, M., Nadeem, M.A., Tahir, M., Ibrahim, M. & Aslam, M.N. 2009. Effect of nitrogen application and harvesting intervals on forage yield and quality of pearl millet (*Pennisetum americanum* L.). *Pakistan Journal of Life and Social Sciences* 7: 185-189.

Ayub, M., Nadeem, M.A., Tanveer, A., Tahir, M. & Khan, R.M.A. 2007. Interactive effect of different nitrogen levels and seeding rates on fodder yield and quality of pearl millet. *Pakistan Journal of Agricultural Sciences* 44(4): 592-596.

Ayub, M., Nadeem, M.A., Tanveer, A. & Husnain, A. 2002. Effect of different levels of nitrogen and harvesting times on growth, yield and quality of sorghum fodder. *Asian Journal of Plant Sciences* 4: 304-307.

Azam, M., Waraich, E.A, Pervaiz, A. & Nawaz, F. 2010. Response of a newly developed fodder sorghum (*Sorghum bicolor* L. Monech) variety (F-9917) to NPK application. *Pakistan Journal of Life and Social Sciences* 8: 117-120.

Bhoya, M., Chaudhari, P.P., Raval, C.H. & Bhatt, P.K. 2014. Effect of nitrogen and zinc on growth and yield of fodder sorghum (*Sorghum bicolor* L.) Moench varieties. *International Journal of Agricultural Sciences* 10(1): 294-297.

Box, G.E.P., Hunter, W.G. & Hunter, J.S. 2005. *An Introduction to Design, Data Analysis, and Model Building. Statistics for Experimenters*. 2nd ed. New York: John Wiley & Sons.

Cakmak, I. 2002. Plant nutrition research priorities to meet human needs for food in ustainable ways. *Plant Science* 247: 3-24.

Castagnara, D.D., Krutzmann, A., Steiner, T.Z.F., Castro, A.M.C., Neres, M.A. & Oliveira, P.S.R. 2012. Effect of boron and zinc fertilization on white oats grown in soil with average content of these nutrients. *Revista Brasileira de Zootecnia* 41: 1598-1607.

Chaab, A., Savaghebi, Gh. R. & Motesharezadeh, B. 2011. Differences in the zinc efficiency among and within maize cultivars in a calcareous soil. *Asian Journal of Agricultural Sciences* 3(1): 26-31.

Chao, N.K., Kang, Y.K. & Boo, C.H. 2001. Effect of split nitrogen application on agronomic characteristics, forage yield and composition of Japanese millet. *Journal of Animal Science and Technology* 43(2): 253-253.

Fageria, N.K. 2002. Influence of micronutrients on dry matter yield and interaction with other nutrients in annual crops. *Pesquisa Agropecuária Brasileira* 37: 1765-1772.

Fulkerson, W.J., Horadagoda, A., Neal, J.S., Barchia, I. & Nandra, K.S. 2008. Nutritive value of forage species grown in the warm temperate climate of Australia for dairy cows. *Livestock Science* 114: 75-83.

GOP. 2016. Economic Survey of Pakistan 2015-2016. Islamabad: Ministry of Finance, Finance Division. Economic Advisor's Wing. pp. 24-42.

Hafeez, B., Khanif, Y.M. & Saleem, M. 2013. Role of zinc in plant nutrition- A review. *American Journal of Experimental Agriculture* 3(2): 374-391.

Hosnedlova, B., Travnicek, J. & Soch, M. 2007. Current view of significance of zinc for ruminants: A review. *Agricultura Tropica et Subtropica* 40(2): 57-64.

Kwon, S.H. & Torrie, J.H. 1964. Heritability and interrelation among traits of two soybean populations. *Crop Sciences* 4: 196-198.

McGraw-Hill, C. 2008. *Statistix 8.1*. Analytical Software, Tallahassee, USA.

Mehdi, S.S., Husain, B. & Singh, L. 2012. Influence of seed rate, nitrogen and zinc on fodder maize (*Zea mays* L.) in temperate conditions of western Himalayas. *Indian Journal of Agronomy* 57(1): 85-88.

Rana, A.S., Ahmad, A.H., Saleem, N., Nawaz, A., Hussian, T. & Saad, M. 2014. Differential response of sorghum cultivars for fodder yield and quality. *Journal of Global Innovative in Agricultural and Social Sciences* 2(1): 6-10.

Reddy, V.R. & Soussan, J. 2004. Assessing the impacts of watershed development programmes: A sustainable rural livelihoods framework. *Indian Journal of Agricultural and Economics* 59(3): 331-343.

Sharifi, R.S. & Taghizadeh, R. 2009. Response of maize (*Zea mays* L.) cultivars to different levels of nitrogen fertilizer *Journals of Food, Agriculture and Environment* 7(3-4): 518-521.

Shukla, V.K., Agarwal, S.B. & Thakur, G.S. 2003. Response of seed rate and nitrogen levels on forage yield of sorghum under rainfed condition in Madhya Pradesh. *Jawaharlal Nehru Krishi Vishwa Vidyalaya Research Journal* 37: 83-84.

Singh, P.H. & Sumeriya, K. 2012. Effect of nitrogen on yield, economics and quality of fodder sorghum genotypes. *Annals of Plant and Soil Research* 14: 133-135.

Soltanpour, P.N. 1985. Use of AB-DTPA soil test to evaluate elemental availability and toxicity. *Communications in Soil Science and Plant Analysis* 16: 323-338.

Steel, R.G.D., Torrie, J.H. & Dickey, D.A. 1997. *Principles and Procedures of Statistics: A Biometrical Approach*. 3rd ed. New York: McGraw Hill Book Co., Inc. pp. 400-428.

van Soest, P.J., Robertson, J.B. & Lewis, B.A. 1991. Methods for dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. *Journal of Dairy Science* 74: 3583-3597.

Verma, S.S., Singh, N., Joshi, Y.P. & Deorari, V. 2005. Effect of nitrogen and zinc on growth characters, herbage yield, nutrient uptake and quality of fodder sorghum (*Sorghum bicolor* L). *Indian Journal of Agronomy* 50: 167-169.

Yatoo, M.I., Saxena, A., Deepa, P.M., Habeab, B.P., Devi, S., Jatav, R.S. & Dimri, U. 2013. Role of trace elements in animals: A review. *Veterinary World* 6: 963-967.

Department of Agronomy
University of Agriculture
Faisalabad-38040
Pakistan

*Corresponding author; email: waqasahmad.uaf@gmail.com

Received: 13 August 2017
Accepted: 22 January 2018