INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
15–623/201x/00–0–000–000
DOI: 10.17957/IJAB/15.0089
http://www.fspublishers.org

Full Length Article

Herbage Production, Nutritional Composition and Quality of Teosinte under Fe Fertilization

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Abstract

Animal husbandry is integral part of subsistence farming for small holder farmers but non availability of good quality fodder for feeding to the livestock is major hurdle for dairy industry in South Asia. Micronutrients such as Fe deficiency in soil affect yield and quality of forage crops severely. This study was conducted for two consecutive years (2012 and 2013) to examine the effect of foliar spray of $FeSO_4$ on the development, herbage yield, nutritive composition and quality of teosinte grown in Fe deficient alkaline field. The experiment was conducted in Randomized Block Design with set of seven treatments *viz.* two foliar sprays of 0.5, 1.0 and 2.0% $FeSO_4$ at 30, 37 DAS and three foliar sprays of 0.5, 1.0 and 2.0% $FeSO_4$ at 30, 37 and 44 DAS. An additional treatment with recommended dose of fertilizer along with foliar spray of deionized water was kept as control. The results of this study revealed an increase of 29.6 to 32.6% in green herbage yield (GHY) and 53.3 to 60.8% in dry matter yield (DMY) with 1.0 and 2.0% foliar sprays of $FeSO_4$ at 30, 37 and 44 DAS over control. Fe foliar spray enhanced nitrogen (N), phosphorus (P), potash (K) and iron (Fe) content of herbage, however Mn content decreased due to antagonism. Increased herbage quality and estimated digestibility parameters like crude protein (CP), total digestible nutrients (TDN), digestible dry matter (DDM), digestible crude protein (DCP), dry matter intake (DMI), relative feed value (RFV), relative forage quality (RFQ), net energy for lactation (NE_L), digestible feed energy (DFE) and reduction in fibers were recorded with three 1.0% foliar sprays of Fe. Gross return, net field benefit (NFB), benefit cost ratio of teosinte crop improved with foliar Fe application. Maximum rate of returns (400%) were recorded with three 1.0% $FeSO_4$ at 30, 37 and 44 DAS. Thus, we conclude that three foliar sprays of 1.0% $FeSO_4$ enhanced the teosinte growth, yield and quality which will certainly improve livestock production.

Keywords: Digestibility parameters; Fe foliar sprays; Herbage yield; Nutritive composition; Quality parameters; teosinte

Introduction

Dairy farming is most important component of economic and social life of the rural masses in developing countries of the world. However, non availability of good quality fodder for feeding to the livestock is major constraints in profitable dairy farming (Dhindsa *et al.*, 2014). Among different summer non-legume forages, livestock farmers prefer teosinte (*Euchlaena mexicana* Schräd) as feed for animals due to its vigorous growth, high yield and toleration to moderate drought and temporary flooding. In comparison to other fodders grown in summer season (pearl millet, sorghum and maize), teosinte stays green for longer period of time ensuring extended availability of green herbage for livestock during fodder scarcity period (ICAR, 2011). For better growth and high fodder yield, teosinte requires heavy amount of nutrients (ICAR, 2011). Soil fertility can affect potential yield, quality and growth rate of forage crops (Nayyar *et al.*, 2001; Singh, 2009; Tripathi *et al.*, 2009). Forage crops are generally grown in marginal soils in South Asian countries leading to low yield and quality of fodder for the livestock (Nayyar *et al.*, 2001; Tripathi *et al.*, 2009; Kumar *et al.*, 2013). Mineral imbalances in soils and forages are responsible for low production and reproductive impairment of the dairy animals (Romheld and Marschner, 1991; Tripathi *et al.*, 2009; Singh, 2012; Singh *et al.*, 2014).

Micronutrient deficiency in soils is one of the yield limiting factors for many crop species (Nayyar *et al.*, 2001; Tripathi *et al.*, 2009; Kumar *et al.*, 2013; Rana *et al.*, 2013; Ryan *et al.*, 2013). In Indo Gangetic Plains (IGP), intensive

To cite this paper: Kumar, B., S.S. Dhaliwal, S.T. Singh, J.S. Lamba and H. Ram, 201x. Herbage production, nutritional composition and quality of teosinte under Fe fertilization. *Int. J. Agric. Biol.*, 00: 000-000

cultivation, mono cropping, use of high analysis fertilizers devoid of micronutrients and no or meager addition of organic manures to the soil resulted in micro nutrient deficiencies and organic matter depletion in the soils (Nayyar *et al.*, 2001; Cakmak, 2002; Ryan *et al.*, 2013). Soil constraints like alkalinity (pH>7.0), calcareousness, excess of carbonate and bicarbonate ions, ionic imbalances and soil pollution further aggravated deficiency of iron in the soil (Nayyar *et al.*, 2001; Mirzapour and Khoshgoftarmaneh, 2013; Ryan *et al.*, 2013). Iron is essential for chlorophyll and protein formation, photosynthesis, electron transfer, oxidation and reduction of nitrates and other enzymatic activities in plants (Singh *et al.*, 2011; El-Fouly *et al.*, 2011; Ali *et al.*, 2014). In animals, iron is an essential component of hemoglobin and plays important role in many biochemical reactions including anti-oxidant defense, protein metabolism and in the electron transport system. Micronutrient deficiencies can cause severe reduction in production of forages and increase the health disorder in livestock (Romheld and Marschner, 1991). For example, ruminants fed on poor quality fodder and roughages for extended periods of time are prone to Fe deficiency which impairs health and milk production of animal (Tripathi *et al.*, 2009; Singh, 2012). Further, due to low level of iron in food products, approximately 2 billion people suffer from Fe deficiency worldwide (Ryan *et al.*, 2013). Although, the total Fe content of soil is much higher than the plant requirement but its bioavailability is limited particularly in alkaline calcareous soil causing significant reduction in yield and quality of fodder crops (Cakmak, 2002; Singh *et al.*, 2011; Ali *et al.*, 2014). For example, approximately 12% Indian soils are deficient in iron which is limiting micronutrient next only to zinc and forages grown on such soil are of poor quality and often yield less (Nayyar *et al.*, 2001; Singh, 2009; Tripathi *et al.*, 2009). Although, micronutrients are required in small quantities but their deficiencies are now being recognized as a critical yield limiting factor in forage crops (Nayyar *et al.*, 2001; Rana *et al.*, 2013; Ryan *et al.*, 2013). Iron uptake and transport in plants can be enhanced through leaf as soil fertilizer application for iron is problematic (Cakmak, 2002; Ryan *et al.*, 2013). Further, foliar feeding is relatively new economical alternate approach of feeding nutrients to the plant by applying liquid fertilizer directly to their leaves (Cakmak, 2002; Ali *et al.*, 2014). There is urgent need to devise the methods to correct the micronutrient deficiency in fodder crops as it will help to improve not only crop yields but also livestock production. Very limited work has been carried out on micro nutrient Fe nutrition of teosinte, which key fodder crop grown as is feed for livestock. Since, coarse textured and marginal soils of this region are prone to Fe deficiency (Nayyar *et al.*, 2001; Chhibba *et al.*, 2007; Tripathi *et al.*, 2009) because of being alkaline, teosinte fodder raised on them may suffer short supply of this nutrient causing poor yield and quality of herbage for livestock. The present investigation was, therefore, undertaken to assess the effects of foliar application of Fe on growth, herbage yield, quality, estimated intake, digestibility parameters and returns of teosinte under field conditions.

Materials and Methods

Experiment Location

Field experiment was conducted for two consecutive years during summer seasons of 2012 and 2013 in Punjab, India at the Fodder Farm of Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana (30°56′ N, 75°52′ E, 247 m above sea level) from July to September. The climate of this area is characterized as sub-tropical and semi-arid with hot and dry summer from April to June, hot and humid from July to September and cold winters from November to January. The average annual rainfall is about 705 mm, most of which is received during the monsoon period from July to September. A few showers are also received during winter season in the months of December and January. Major soils of the region are Inceptisols, Entisols, Aridisols, Alfisols and their associations.

Treatment Detail and Crop Raising Practices

The field experiments during the 2012 and 2013 were conducted with a set of seven treatments (Table 1) in Randomized Block Design at same experimental site. The experimental field was ploughed using tractor drawn disc harrow followed by tiller and leveled. Teosinte, *cv.* TL 1 was sown on July 6 and July 7 during the year 2012 and 2013, respectively using seed rate at 40 kg ha^{-1} with spacing of 30 cm × 10 cm in plot size of 12 m^2. The recommended dose of fertilizers (RDF) 100 kg N and 30 kg P_2O_5 ha^{-1} were applied through urea (46.0% N) and single super phosphate (16.0% P_2O_5) of which full dose of P and half N were applied at sowing time and remaining half N at 30 days after sowing. Immediately after sowing of the crop, herbicide atrazine 50 WP @ 1.0 kg ha^{-1} was sprayed in each experimental plot for controlling the weeds. Total of six and five irrigations were provided to the crop in growing season during the year 2012 and 2013, respectively. Commercial grade of ferrous sulfate ($FeSO_4.7H_2O$) having Fe content of 20.5% was used for foliar spray in the study. Applications of foliar sprays on crop at different stages as per treatments were done with manually operated knapsack sprayer pump having 16 L capacity with ensured complete coverage of plant surface. Spray drifts of different treatments were avoided by taking suitable measures. The crop was harvested manually using sickle at the age of 75 days for green fodder purposes.

Soil and Climate Characteristics

Different soil parameters pertaining to know the fertility status of soil were estimated in laboratory using standard methodologies (Table 2). Soil texture was determined using method as described by Day (1965). Soil pH and EC were determined by method given by Jackson (1973) and Richard (1954), respectively. Rapid titration method (wet digestion method) was used for organic carbon determination (Walkley and Black, 1964). Available N, P and K were determined by the standard methods of Subbiah and Asija (1956), Olsen *et al.* (1954) and Merwin and Peech (1950), respectively. DTPA-extractable micronutrients (Zn, Cu, Fe and Mn) content in soil were measured on atomic absorption spectrophotometer (Varian AAS FS 240) from 1:2 soil-extractant ratio using DTPA-TEA buffer (0.005 M DTPA + 0.001 M $CaCl_2$ + 0.1 M TEA, pH 7.3) with method described by Lindsay and Norvell (1978). The soils of the area are developed above the flood plains sediments and are classified as Fluvisol (FL) according to World Reference Base for Soil Resources (WRB). The surface (0 -15 cm) soil of the field was loamy sand (*Typic Ustochrept*) in texture having pH 8.6 (alkaline) and EC 0.21 dSm^{-1}, low in Walkley and Black carbon, low in available nitrogen, available P and medium in available K. The $CaCO_3$ content in the soil was estimated by the Puri's Rapid Titration method devised by Puri *et al.* (1930). Soil of experimental site was deficient in status of available Fe (Table 2). The climatic data recorded at meteorological observatory of Punjab Agricultural University, Ludhiana, Punjab, India and is presented in Table 3. Total amount of rainfall received during the crop seasons were 379.0 and 400.8 mm during the year 2012 and 2013, respectively. Maximum and minimum air temperatures recorded were 36.9°C and 22.5°C and 35.4°C and 22.6°C in the July and September months during the year 2012 and 2013, respectively. Mean relative air humidity ranged from 67 to 80% and 73 to 79% during the crop growing seasons of 2012 and 2013, respectively.

Observations and Measurements

Before harvesting the crop, various growth parameters such as plant height, tillers $plant^{-1}$, leaves $plant^{-1}$, stem girth and leaf stem ratio was measured. The height of ten randomly selected plants from each experimental plot was measured from the base of the plant to the base of the fully opened youngest leaf on stem with meter ruler. Tillers and leaves from ten randomly selected plants in each experimental plot was counted and averaged. Stem girth was measured using Vernier caliper to measure the circumference of teosinte plant stems about 15 cm above ground level from ten selected plants and averaged. Leaf stem ratio (LSR) is the ratio between fresh leaf weights per plant to its green stem weight and was measured by taking five plants from each experimental plot. Fresh green herbage yield (GHY) was measured by weighing the harvested fresh green plants on plot basis and then converted to ha^{-1} yield (Mg ha^{-1}). For percent dry matter estimation, 1,000 g sample of green fodder from harvested plots was collected, chopped, sun dried and kept in oven for 24 h at 60°C for obtaining constant weight and then reweighed using electronic balance. Then, percent dry matter from each treatment was multiplied with green herbage yield to obtain dry matter yield (DMY) and converted to Mg ha^{-1}. Cost of cultivation for raising teosinte fodder crop under different Fe treatments along with cost of different variable inputs during crop growing season is given in Table 4. Net returns were recorded after calculating the gross return by taking then market selling rate of US $ 14.2 Mg^{-1} of green fodder and then subtracting the total cost of cultivation as per individual treatment expenditure from it.

Forage Nutrient Composition and Quality Estimation

Fresh fodder samples collected from each plots at harvest were washed sequentially with tap water, acidulated water containing 0.01 N HCl, distilled water and deionized water. Samples were then air-dried followed by oven drying at 60°C to a constant weight. The dried samples were ground in Wiley mill with stainless steel blades to pass through 40 mesh sieve and then used for quality and nutrient composition estimation. N% content in fodder was estimated by AOAC (2000). Crude protein (CP) content was worked out by the formula CP = %N × 6.25 and expressed in percentage. Crude protein yield (CPY) was worked out by multiplying the crude protein percentage with dry matter yield and then dividing it by 100. For estimation of Fe, Zn, Cu and Mn content in fodder, 0.5 gram of grounded teosinte sample was digested using diacid mixture (HNO_3: $HClO_4$ in ratio 4:1) as per method given by Page *et al.* (1982) and their content in the digests after proper dilution were determined with Varian Model of atomic absorption spectrophotometer (Varian AAS FS 240). Percent phosphorus (P) and potassium (K) in teosinte fodder were estimated by the methods described by Jackson (1973). Acid detergent fiber (ADF) and neutral detergent fiber (NDF) were determined using the procedure outlined by Van Soest *et al.* (1991). Digestible crude protein (DCP%), total digestible nutrients (TDN), digestible dry matter (DDM), dry matter intake (DMI), Relative forage quality (RVF), relative forage quality (RFQ), net energy for lactation (NE_L) and Digestible feed energy (DFE) were estimated according to the following equations adapted from Gill *et al.* (2013) and Lithourgidis *et al.* (2006) from the measured variables:

Total digestible nutrients (TDN) = 87.84- (0.7 × ADF)
Dry matter digestibility (DDM) = 88.9 - (0.779 × % ADF, dry matter basis)
Digestible crude protein (DCP) = (0.929 × CP) - 3.77
Dry matter intake (DMI) = 120/NDF
Relative feed value (RFV) = (DDM × DMI)/1.29
Relative feed quality (RFQ) = (TDN × DMI) / 1.23
Net energy for lactation (NE_L) = 1.5 - (ADF × 0.0267)
Digestible feed energy (DFE) = 4.4 × (TDN/100)

Table 1: $FeSO_4$ foliar spray (FS) treatment structure

S. No.	Treatment detail
T_1	Recommended dose of fertilizers (RDF) (spray of deionized water)
T_2	RDF + two FS of 0.5% $FeSO_4$ at 30 and 37 days after sowing (DAS)
T_3	RDF + three FS of 0.5% $FeSO_4$ at 30, 37 and 44 DAS
T_4	RDF + two FS of 1.0% $FeSO_4$ at 30 and 37 DAS
T_5	RDF + three FS of 1.0% $FeSO_4$ at 30, 37 and 44 DAS
T_6	RDF + two FS of 2.0% $FeSO_4$ at 30 and 37 DAS
T_7	RDF + three FS 2% $FeSO_4$ at 30, 37 and 44 DAS

Table 2: Important characteristics of experimental soil

Texture	pH (1:2)	EC (1:2) dS m^{-1}	OC (%)	$CaCO_3$ (%)	Available			DTPA extractable			
					N	P	K	Fe	Zn	Mn	Cu
					kg ha^{-1}			mg kg^{-1}			
Sandy loam	8.6	0.21	0.22	3.45	252.7	11.6	143.9	1.71	0.70	4.02	0.4

Table 3: Weather data at the experimental site during the two growing seasons

Month	Temperature (°C)						Relative humidity (%)			Total rainfall (mm)		
	2012		2013		30 year average		2012	2013	30 year average	2012	2013	30 year average
	Max	Min	Max	Min	Max	Min						
July	35.7	27.9	35.0	27.7	34.4	25.8	67.0	71.0	71.0	76.9	111.2	232.1
August	33.7	26.6	33.0	26.4	33.4	25.2	80.0	79.0	78.0	160.4	252.1	179.7
September	32.8	23.9	33.8	24.1	33.7	22.1	76.0	73.5	70.0	141.7	37.5	101.8
Total	-	-	-	-	-	-	-	-	-	379.0	400.2	513.6

Statistical Analysis

The data were analyzed using analysis of variance (ANOVA) by using IRRISTAT version 92 (IRRI, 1992). The data presented is comparison of treatment means and was made by least significant difference (LSD) at p = 0.05. Correlation coefficient (r) was calculated among different variable and correlation matrix was prepared to find out the relationship among variables to herbage yield and other traits. Gross returns, net field benefits, net returns, benefit cost ratio, dominance and marginal analysis (CIMMYT, 1988) were used to determine the profitability of different foliar $FeSO_4$ treatments. The non-significant treatment differences were denoted as NS.

Results

Growth Parameters

Foliar application of $FeSO_4$ affected the growth parameters of teosinte significantly (Table 5). Maximum plant height, tillers plant^{-1}, number of leaves plant^{-1}, stem girth and leaf stem ratio (LSR) of teosinte was recorded with three foliar application of 2.0% ferrous sulfate and was recorded at par with three 0.5 and 1.0% foliar application of $FeSO_4$ (Table 5). Mean data showed that, three foliar applications of 0.5, 1.0 and 2.0% of $FeSO_4$ caused 15.4, 18.5 and 22.3% increase in plant height respectively over control. Mean tillers plant^{-1} was improved by 20.8% and 22.9% with three foliar sprays of 1.0 and 2.0% $FeSO_4$ respectively at 30, 37 and 44 days after sowing over control. Number of leaves plant^{-1} was increased by 8.4% to 16.0% with the increase in concentration of the ferrous sulfate from 0.5 to 2.0%, respectively over control. Foliar sprays of 1.0% $FeSO_4$ recorded statistically similar number of leaves plant^{-1} (12.2%) as three foliar sprays of 2.0% $FeSO_4$ (Table 5). Highest leaf stem ratio (LSR) and stem girth of teosinte was recorded with three foliar sprays of 2.0% $FeSO_4$ and both the traits were found on par with three foliar sprays of 1.0% $FeSO_4$, but were significantly better than other foliar Fe treatments and control (Table 5). There was increment of 28.2 and 30.6% in LSR and 15.1 and 18.3% in stem girth of plant with the three foliar sprays of 1.0 and 2.0% ferrous sulfate, respectively over control.

Herbage Yield

Significant (p=0.05) improvement in green herbage yield (GHY) was recorded with the three foliar spray of 0.5, 1.0 and 2.0% of ferrous sulfate at 30, 37 and 44 days after sowing on the crop (Table 5). Maximum mean green herbage yield (55.0 Mg ha^{-1}) of teosinte was recorded with three foliar application of 2.0% $FeSO_4$ and was found at par with three foliar sprays of 0.5 and 1.0% $FeSO_4$ (51.4 and 53.8 Mg ha^{-1}), but were significantly better than control. The increase in green herbage yield was 23.9, 29.6 and 32.6% with three foliar sprays of 0.5, 1.0 and 2.0% $FeSO_4$, respectively over control. Similarly, there was significant increase in dry matter yield (DMY) with increase in concentration and frequency of Fe on crop. Maximum DMY was recorded in three foliar sprays of 2.0% $FeSO_4$ and was found at par with three foliar sprays of 1.0% $FeSO_4$. There was gain of 53.3 and 60.8% in DMY with three foliar sprays of 1.0 and 2.0% $FeSO_4$, respectively over control.

Table 4: Treatment wise cost of cultivation (USD ha^{-1}) for raising teosinte as fodder (assuming own land)

Input factors cost/price unit	Treatments						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
Tractor hours cost (field preparation, sowing and ridge making) @ 5.0 h^{-1}	62.5	62.5	62.5	62.5	62.5	62.5	62.5
Seed cost @ 0.83 kg^{-1}	33.3	33.3	33.3	33.3	33.3	33.3	33.3
Seed treatment (Bavistin) cost @ 8.3 kg^{-1}	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Fertilizer cost (Urea @ 0.09 and single super phosphate @ 0.07 kg^{-1})	21.8	21.8	21.8	21.8	21.8	21.8	21.8
Herbicide cost (Atrazine) @ 6.0 kg^{-1}	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Irrigation cost @ 0.5 $irrigation^{-1}$	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Human labour cost @ 0.52 h^{-1}	247.3	247.3	247.3	247.3	247.3	247.3	247.3
Transportation and marketing cost	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Foliar Fe spray ($FeSO_4$ @ 1.3 kg^{-1}) including labour cost	0.0	20.0	30.0	23.0	35.0	30.0	42.0
Total variable cost	414.2	434.2	444.2	437.2	449.2	444.2	456.2
Half yearly interest on variable cost @ 9%	18.7	19.6	20.0	19.7	20.3	20.0	20.6
Total cost of cultivation including treatment cost (rounded off)	433.0	454.0	464.0	457.0	470.0	464.0	477.0

USD=United States Dollar (1US $= INR 60/-)
T_1 = Recommended dose of fertilizers (RDF) (spray of deionized water); T_2 = RDF + two FS of 0.5% $FeSO_4$ at 30 and 37 days after sowing (DAS); T_3 = RDF + three FS of 0.5% $FeSO_4$ at 30, 37 and 44 DAS; T_4 = RDF + two FS of 1.0% $FeSO_4$ at 30 and 37 DAS; T_5 = RDF + three FS of 1.0% $FeSO_4$ at 30, 37 and 44 DAS; T_6 = RDF + two FS of 2.0% $FeSO_4$ at 30 and 37 DAS; T_7 = RDF + three FS of 2% $FeSO_4$ at 30, 37 and 44 DAS

Table 5: Effect of foliar application of $FeSO_4$ on the growth and yield parameters of teosinte fodder (pooled data of two years)

Treatments	Plant height (cm)	Tillers per plant	Leaves per plant	Stem girth (cm)	LSR	GHY (Mg ha^{-1})	DMY (Mg ha^{-1})	CPY (Mg ha^{-1})
T_1	178.3c	4.8b	13.1c	1.86c	0.480d	41.5c	7.2d	0.54d
T_2	187.7bc	5.0b	13.6bc	1.97bc	0.538c	46.5b	8.5c	0.65c
T_3	205.7ab	5.4a	14.2b	2.05b	0.584b	51.4ab	9.9b	0.81b
T_4	191.8b	5.2b	13.9b	2.00b	0.553bc	48.5b	9.8b	0.79b
T_5	211.2a	5.8a	14.7a	2.14a	0.615a	53.8a	11.1a	1.00a
T_6	195.3b	5.2b	14.1b	2.04b	0.577b	49.2b	10.2b	0.85b
T_7	218.1a	5.9a	15.2a	2.20a	0.627a	55.0a	11.6a	1.07a
LSD (p=0.05)	12.8	0.5	0.7	0.11	0.037	3.7	0.8	0.08

LSR= leaf stem ratio; GHY = Green herbage yield; DMY= Dry matter yield; CPY= Crude protein yield
T_1= RDF (control) spray of deionized water; T_2 = RDF + two foliar sprays (FS) of 0.5% $FeSO_4$ at 30 and 37 DAS; T_3 = RDF + three FS of 0.5% $FeSO_4$ at 30, 37 and 44 DAS; T_4 = RDF + two FS of 1.0% $FeSO_4$ at 30 and 37 DAS; T_5 = RDF + three FS of 1.0% $FeSO_4$ at 30, 37 and 44 DAS; T_6 = RDF + two FS of 2.0% $FeSO_4$ at 30 and 37 DAS; T_7 = RDF + three FS of 2.0% $FeSO_4$ at 30, 37 and 44 DAS
Means sharing the same letter in a column do not differ significantly at p= 0.05; NS= Non significant

Herbage Quality and Nutrient Composition

Foliar sprays of $FeSO_4$ on crop increased crude protein content and crude protein yield significantly (p=0.05) over control (Tables 5, 7). Three foliar sprays of 2.0% ferrous sulfate on crop recorded highest mean crude protein content and crude protein yield and both the traits were found at par with three foliar sprays of 1.0% ferrous sulfate. Increase in crude protein content up to 21.2 and 24.1% was recorded with three foliar sprays of 1.0 and 2.0% $FeSO_4$ over control. Similar trend was also observed in crude protein yield of teosinte. Mean CPY registered an increase of 85.2 and 98.1% with three foliar sprays of 1.0 and 2.0% ferrous sulfate, respectively over control.

Three foliar application of 0.5, 1.0 and 2.0% $FeSO_4$ increased N, P and K percent in fodder significantly (p=0.05) over control, however foliar sprays of 1.0 and 2.0% recorded statistically similar values for these nutrients (Table 6). In this study, teosinte crop receiving higher concentration (1.0 and 2.0% vs 0.5%) and frequency (3 vs 2) of foliar $FeSO_4$ were significantly superior for N, P and K content of herbage (Table 6). Mean increase in N, P and K content of herbage with three foliar sprays of 1.0% $FeSO_4$ was 21.1, 27.8 and 83.1%, respectively over control. The corresponding figures with foliar sprays of 2.0% $FeSO_4$ were 23.7, 31.1 and 94.9%, respectively over control.

In regards to micronutrient content of fodder, consistent improvement in Fe content occurred with two and three foliar sprays of $FeSO_4$ (Table 6) over control. Fe content of herbage at harvest increased significantly with three foliar sprays of 0.5, 1.0 and 2.0% ferrous sulfate over control but later levels (1.0% and 2.0%) were found at par with each other. Mean Fe content in herbage increased from 99.7 mg kg^{-1} in control to 121.0 and 124.2 mg kg^{-1} with three 1.0 and 2.0% foliar sprays of $FeSO_4$. Copper (Cu) and manganese (Mn) content of fodder decreased moderately with the increase in frequency and rate of foliar iron sulfate. Mean Cu and Mn content in fodder decreased significantly (p=0.05) with three 2.0% foliar sprays of $FeSO_4$, whereas non-significant differences were recorded with three 1.0% foliar sprays as compared to control. Zinc (Zn) content of fodder decreased however, it was not influenced significantly with foliar Fe application (Table 6).

Table 6: Macro (N, P and K) and micro nutrient (Zn, Fe, Cu, and Mn) contents of teosinte fodder as influenced by foliar Fe application (pooled data of two years)

Treatments	N	P	K	Zn	Fe	Cu	Mn
		%			mg kg^{-1}		
T_1	1.18c	0.61d	0.59e	32.0	99.7c	6.2a	27.8a
T_2	1.23c	0.68c	0.66de	31.8	106.7b	6.1a	26.9a
T_3	1.32b	0.72bc	0.71d	31.6	110.1b	5.7ab	26.3a
T_4	1.27bc	0.70bc	0.86c	31.4	108.0b	5.8ab	26.6a
T_5	1.43a	0.78a	1.08a	31.3	121.0a	5.6ab	26.3a
T_6	1.33b	0.73b	0.95b	31.3	112.2b	5.4ab	24.3b
T_7	1.46a	0.80a	1.15a	30.8	124.2a	5.2b	22.6c
LSD (p=0.05)	0.06	0.04	0.08	NS	6.20	0.6	1.6

T_1= RDF (control) spray of deionized water; T_2 = RDF + two foliar sprays (FS) of 0.5% $FeSO_4$ at 30 and 37 DAS; T_3 = RDF + three FS of 0.5% $FeSO_4$ at 30, 37 and 44 DAS; T_4 = RDF + two FS of 1.0% $FeSO_4$ at 30 and 37 DAS; T_5 = RDF + three FS of 1.0% $FeSO_4$ at 30, 37 and 44 DAS; T_6 = RDF + two FS of 2.0% $FeSO_4$ at 30 and 37 DAS; T_7 = RDF + three FS of 2.0% $FeSO_4$ at 30, 37 and 44 DAS

Means sharing the same letter in a column do not differ significantly at p= 0.05; NS= Non significant

Table 7: Effect of foliar application of $FeSO_4$ on the fibers, estimated digestibility parameters and quality of teosinte fodder at harvest (pooled data of two years)

Treatments	NDF	ADF	CP	TDN	DDM	DCP	DMI	RFV	RFQ	NE_L	DFE
					%						M Cal kg^{-1}
T_1	71.0a	35.9a	7.38c	62.7c	60.9c	2.9c	1.69c	79.9e	86.2d	0.246b	2.76b
T_2	70.7a	35.6a	7.70c	62.9bc	61.2cb	3.2c	1.70c	80.5de	86.8d	0.249b	2.77b
T_3	68.5bc	35.3ab	8.22b	63.1b	61.4b	3.7bc	1.75b	83.4b	89.9b	0.254b	2.78b
T_4	70.1a	35.5ab	7.99bc	63.0bc	61.2cb	3.5bc	1.71c	81.3d	87.6cd	0.251b	2.77b
T_5	67.8c	34.8b	8.98a	63.5a	61.8a	4.4a	1.77a	84.9a	91.7a	0.259ab	2.79ab
T_6	69.3b	35.3ab	8.31b	63.1b	61.4b	3.9b	1.73b	82.4c	88.5c	0.254b	2.78b
T_7	67.1c	34.7b	9.16a	63.7a	62.0a	4.5a	1.78a	85.9a	92.4a	0.263a	2.81a
LSD (p=0.05)	0.9	0.7	0.51	0.3	0.4	0.5	0.02	1.0	1.0	0.008	0.02

NDF = Neutral detergent fiber; ADF = Acid detergent fiber; CP = Crude protein; TDN = Total digestible nutrients; DDM = Digestible dry matter; DCP = Digestible crude protein; DMI = Dry matter intake; RFV = Relative feed value; RFQ = Relative forage quality; NE_L= Net lactation for energy; DFE = Digestible feed energy

T_1= RDF (control) spray of deionized water; T_2 = RDF + two foliar sprays (FS) of 0.5% $FeSO_4$ at 30 and 37 DAS; T_3 = RDF + three FS of 0.5% $FeSO_4$ at 30, 37 and 44 DAS; T_4 = RDF + two FS of 1.0% $FeSO_4$ at 30 and 37 DAS; T_5 = RDF + three FS of 1.0% $FeSO_4$ at 30, 37 and 44 DAS; T_6 = RDF + two FS of 2.0% $FeSO_4$ at 30 and 37 DAS; T_7 = RDF + three FS of 2.0% $FeSO_4$ at 30, 37 and 44 DAS

Means sharing the same letter in a column do not differ significantly at p= 0.05

Fibers, Estimated Intake and Digestibility Parameters

Fibers (measured by NDF or ADF) are a strong predictor of forage quality, since it is the poorly digested portion of the cell wall. Neutral detergent and acid detergent fibers (NDF and ADF) decreased with the foliar application of ferrous sulfate on the crop (Table 7). Three foliar sprays of 1.0 and 2.0% $FeSO_4$ recorded 4.7 and 5.8% decrease in NDF than control and both levels were found at par with each other. Similar to NDF, acid detergent fiber (ADF) of herbage decreased significantly by 3.5% with three foliar sprays of 1.0 and 2.0% ferrous sulfate over control.

High forage yield is very important for the producers but for the livestock enterprises, it is also important to produce high quality forages. In our study, we found that high forage yield and good quality teosinte characteristics for animal nutrition could be obtained with the three foliar sprays of 1.0% $FeSO_4$ at 30, 37 and 44 days old crop. Total digestible nutrients (TDN), digestible dry matter (DDM), digestible crude protein (DCP) and dry matter intake (DMI) of fodder increased with the foliar application of ferrous sulfate (Table 7). Maximum and significant (p=0.05) increase in the TDN, DDM, DCP and DMI was recorded with three foliar sprays of 2.0% ferrous sulfate and all the parameters were statistically similar to three foliar sprays of 1.0% $FeSO_4$. Foliar sprays of 1.0% ferrous sulfate recorded 1.3, 1.4, 51.7 and 4.7% increase in mean values of TDN, DDM, DCP and DMI over control (Table 7). Superiority in DMI with foliar spray of ferrous sulfate is a reflection of their lower NDF values compared to control which is confirmed in our study.

Relative feed value (RFV) is an accurate indicator for quality over protein content alone which provides an indication of digestibility and how much forage an animal can eat. Significant (p=0.05) increase in RFV was observed with the foliar application of ferrous sulfate on the teosinte fodder (Table 7). Three foliar sprays of 1.0 and 2.0% ferrous sulfate recorded mean increase of 6.3 and 7.5% in RFV and both treatments were found at par with each other but were significantly superior to all other treatments. Relative forage quality (RFQ) is calculated by estimating the digestibility of the forage dry matter and how much animal can eat based on its filling capacity. Increase in RFQ of teosinte with foliar sprays of ferrous sulfate was recorded in this study.

Three foliar sprays of 1.0 and 2.0% $FeSO_4$ recorded mean RFQ of 91.7 and 92.4% and were found at par with each other but significantly superior to all other treatments. In this study, higher RFV and RFQ values in foliar Fe applied treatments over control agrees with the other quality characteristics (ADF, NDF, DDM, DMI and TDN). Significant improvement in net energy for lactation (NE_L) of teosinte herbage under foliar Fe sprays was recorded (Table 7). In response to three foliar sprays of 2.0% ferrous sulfate, teosinte fodder recorded maximum mean NE_L (0.263 Mcal kg^{-1}) and was at par with three foliar sprays of 1.0% $FeSO_4$ (0.259 Mcal kg^{-1}). Significantly superior ($p=0.05$) digestible feed energy (DFE) of fodder was recorded with three foliar sprays of 1.0 (2.79 M Cal kg^{-1}) and 2.0% (2.81 M Cal kg^{-1}) ferrous sulfate over control (2.76 M Cal kg^{-1}).

Economic and Marginal Analysis

Gross returns, treatment cost that vary, total cost, net field benefits, net return and benefit cost ratios are shown in Table 8. Gross income was highest in treatment where three foliar sprays of 2.0% $FeSO_4$ were applied and closely followed by three foliar sprays of 1.0% $FeSO_4$ at 30, 37 and 44 days after sowing of crop (Table 8). Foliar sprays of Fe at various rates recorded higher net field benefits (NFB), net return and benefit cost ratio than control (Table 8). Highest NFB, net returns and benefit cost ratio was recorded in three foliar sprays of 2.0% $FeSO_4$ closely followed by three foliar sprays of 1.0% $FeSO_4$ at 30, 37 and 44 DAS over control.

As rate of return in relation to investment is not depicted in net field benefits, final recommendation for the production technology to the growers cannot be specified only on its basis. Dominance analysis is used to eliminate the less optimal and to identify the most optimal treatment for the farmers. For dominance analysis, first foliar Fe spray treatments were arranged in ascending order according to increasing order of variable cost (Table 9). Treatment that had net benefits less than or equal to those of treatments with lower variable cost was dominated (D). In this study, foliar sprays of 2.0% $FeSO_4$ at 30 and 37 DAS treatment (T_6) was dominated due to its lower net field benefits as compared to preceding treatment (Table 9).

As real differences were found in herbage yield of teosinte among different treatments, therefore, marginal analysis was performed among un-dominated treatments (Table 9). Marginal analysis aid the grower to get the maximum benefit from the inputs by using the limited resources. Maximum marginal rate of return (400%) was obtained by three foliar sprays of 1.0% $FeSO_4$ at 30, 37 and 44 days after sowing of teosinte crop (Table 9).

Correlation Studies

Simple correlation analysis (Table 10) indicated that plant height was significantly and positively ($p<0.01$) correlated with tillers $plant^{-1}$, leaves $plant^{-1}$, stem girth, LSR, N, P, K, Fe, CP, RFV, RFQ, GHY, DMY and CPY but significantly and negatively correlated with Cu and Mn content of plant. Similarly, tillers $plant^{-1}$ showed significant and positive ($p<0.01$) correlations with different growth parameters (leaves $plant^{-1}$, stem girth, LSR), nutrients (N, P, K, Fe) quality traits (CP, RVF, RFQ) and fodder yield (GHY, DMY and CPY) but significantly and negatively ($p<0.05$) correlated with Mn content of fodder. In regards to leaves $plant^{-1}$, stem girth and LSR, also recorded significant and positive correlation with different growth traits and yield of teosinte fodder. N, P and K% of herbage indicated significant and positive correlation between growth, quality and yield of teosinte (Table 10). Iron content of herbage showed significant and positive correlations ($p<0.1$) with different growth parameters such as plant height (0.744), tillers $plant^{-1}$ (0.618), leaves $plant^{-1}$ (0.659), stem girth (0.638) and leaf stem ratio (0.761). The quality parameters such as CP, RFV and RFQ were significantly and positively correlated with Fe content of herbage (Table 10). Fe content in foliar fertilized plants increased linearly with applied dosages. Significant and positive correlations ($p<0.01$) were indicated between Fe content and green herbage yield (0.714), dry matter yield (0.754) and crude protein yield (0.813) of teosinte. There was significant negative correlation between Fe-Cu ($P<0.1$, $r=-0.515$) and Fe-Mn ($p<0.1$, $r=-0.502$) content of plant.

Discussion

The results obtained in this investigation indicated that foliar sprays of Fe had the dominant effect on the growth, herbage yield, better nutrition and quality of teosinte. Increase in different growth parameters such as plant height, leaves $plant^{-1}$ and tillers $plant^{-1}$ with Fe addition can be attributed to the fact that Fe has a structural and physiological role in different processes like chlorophyll formation, thylakoid synthesis, chloroplast development, energy transfer and photosynthesis, so having a essential role in enhancing plant growth and development (Cakmak, 2002; Singh, 2011; Ali *et al.*, 2014). Apart from it, Fe application on plant helps more water and nutrients absorption and promotes nucleic acids, IAA, cell division and cell elongation in plant which in turn perked up plant growth parameters such as stem girth and leaf stem ratio (El-Fouly *et al.*, 2011).

Fe addition to the crop through foliar sprays enhanced the green herbage (GHY) and dry matter yield (DMY) which was mainly due to increase in growth parameters such as plant height, tillers $plant^{-1}$, leaves $plant^{-1}$, leaf stem ratio and stem girth (Table 5). This is confirmed in our study as foliar Fe application recorded positive and significant correlation with growth and yield parameters of teosinte (Table 10). Due to direct absorption and higher response through foliar sprays (Chhibba *et al.*, 2007; Singh *et al.*, 2011; Ryan *et al.*, 2013), Fe through foliar sprays of $FeSO_4$ activates various enzymatic reactions and improves photosynthesis in the plant leading to higher herbage yield

Table 8: Effect of foliar Fe spray on net returns, net field benefits and benefit cost ratio of teosinte fodder (pooled data of two years)

Treatments	GHY (Mg ha^{-1})	Gross returns	Cost that vary	Total cost	Net field benefits	Net returns	Benefit cost ratio
					(USD ha^{-1})		
T_1	41.5	589	0	433	589	156	1.36
T_2	46.5	660	20	454	640	206	1.45
T_3	51.4	730	30	464	700	266	1.57
T_4	48.5	689	23	457	666	232	1.51
T_5	53.8	764	35	470	729	294	1.63
T_6	49.2	699	30	464	669	235	1.51
T_7	55.0	781	42	477	739	304	1.64

Teosinte fodder selling rate USD 14.2 Mg^{-1}

Table 9: Effect of Fe foliar sprays on dominance and marginal analysis of teosinte

Treatment	Total treatment variable cost	Marginal cost that vary	Net field benefits	Marginal net benefits	Marginal rate of return
		(USD ha^{-1})			(%)
T_1	433	-	589	-	-
T_2	454	20	640	51	255.0
T_4	457	23	666	77	334.7
T_3	464	30	700	111	370.0
T_6	464	30	669 D	-	-
T_5	470	35	729	140	400.0
T_7	477	42	739	150	357.1

USD=United States Dollar (1US $= INR 60/-)

D = Dominated

T_1= RDF (control) spray of deionized water; T_2 = RDF + two foliar sprays (FS) of 0.5% $FeSO_4$ at 30 and 37 DAS; T_3 = RDF + three FS of 0.5% $FeSO_4$ at 30, 37 and 44 DAS; T_4 = RDF + two FS of 1.0% $FeSO_4$ at 30 and 37 DAS; T_5 = RDF + three FS of 1.0% $FeSO_4$ at 30, 37 and 44 DAS; T_6 = RDF + two FS of 2.0% $FeSO_4$ at 30 and 37 DAS; T_7 = RDF + three FS of 2.0% $FeSO_4$ at 30, 37 and 44 DAS

Table 10: Correlation coefficient studies among growth, nutrients, quality and yield of fodder teosinte (pooled data of two years)

Traits	Plant height	Tillers per plant	Leaves per plant	Stem girth	LSR	N (%)	P (%)	K (%)	Fe (mg kg^{-1})	Cu (mg kg^{-1})	Mn (mg kg^{-1})	CP (%)	RFV (%)	RFQ (%)	GHY (Mg ha^{-1})	DMY (Mg ha^{-1})
Tillers per plant	0.500**															
Leaves per plant	0.717**	0.602**														
Stem girth	0.532**	0.601**	0.762**													
LSR	0.739**	0.528**	0.668**	0.674**												
N (%)	0.771**	0.660**	0.780**	0.747**	0.821**											
P (%)	0.732**	0.603**	0.700**	0.719**	0.705**	0.738**										
K (%)	0.653**	0.701**	0.708**	0.764**	0.722**	0.814**	0.780**									
Fe (mg kg^{-1})	0.744**	0.618**	0.659**	0.638**	0.761**	0.828**	0.689**	0.719**								
Cu (mg kg^{-1})	-0.355**	-0.253	-0.321*	-0.306*	-0.420**	-0.494**	-0.270	-0.395**	-0.515**							
Mn (mg kg^{-1})	-0.308**	-0.345*	-0.233	-0.202	-0.323*	-0.424**	-0.243	-0.420**	-0.502**	0.486**						
CP (%)	0.776**	0.614**	0.750**	0.719**	0.801**	0.901**	0.775**	0.790**	0.785**	-0.521**	-0.342**					
RFV (%)	0.753**	0.620**	0.689**	0.699**	0.751**	0.793**	0.706**	0.701**	0.789**	-0.507**	-0.488**	0.813**				
RFQ (%)	0.774**	0.622**	0.696**	0.700**	0.750**	0.797**	0.712**	0.707**	0.786**	-0.430**	-0.423**	0.810**	0.982**			
GHY (Mg ha^{-1})	0.693**	0.692**	0.668**	0.639**	0.719**	0.708**	0.685**	0.689**	0.714**	-0.351*	-0.460**	0.662**	0.771**	0.778**		
DMY (Mg ha^{-1})	0.699**	0.750**	0.751**	0.678**	0.769**	0.819**	0.695**	0.822**	0.754**	-0.474**	-0.526**	0.877**	0.778**	0.773**	0.916**	
CPY (Mg ha^{-1})	0.769**	0.797**	0.797**	0.742**	0.821**	0.901**	0.758**	0.867**	0.813**	-0.521**	-0.486**	0.908**	0.842**	0.838**	0.867**	0.967**

**Correlation is significant at the 0.01 level; *Correlation is significant at the 0.05 level

LSR = Leaf stem ratio; N = Nitrogen; P =Phosphorus; K = Potassium; Fe =Iron; Cu = Copper; Mn = Manganese; CP = Crude protein; RFV = Relative feed value; RFQ = Relative forage quality; GHY = Green herbage yield; DMY = Dry matter yield; CPY = Crude protein yield

in our study. Improved chlorophyll content and photosynthesis might had resulted in generation of more food reserves in plants and thus increase in green herbage and dry matter yield (Table 5). Fe increases carbohydrate synthesis and improves the assimilate partitioning from source to the sink in the plant which led to the increase in teosinte herbage yield (Jin *et al.*, 2008; Singh *et al.*, 2011; Ali *et al.*, 2014). Nadim *et al.* (2012) confirmed that foliar application of iron significantly increased the plant height, number of tillers and yield over control in wheat crop. Rana *et al.* (2013) and Kumar *et al.* (2013) also reported significant increase in growth, yield and quality with foliar Fe and Zn sprays at different crop growth stages in sorghum and maize fodder crops over control.

High forage yield along with proper nutrition is important for the livestock farmers for better growth and development of cattle. Crude protein content of forage is a vital criterion for quality evaluation (Lithourgidis *et al.*, 2006; Kumar *et al.*, 2014), while for livestock producers crude protein yield (CPY) is an important for determining the supplemental protein feed for the reduction of expenditure on feed costs (Gill *et al.,* 2013). Higher the crude protein yield of fodder less will be the expenditure on concentrate feeding to the livestock. Similar to GHY and DMY, Fe sprays on crop also improved N, P, K, crude protein content and crude protein yield (CPY) of teosinte (Table 6). This is evident as Fe sprays on crop recorded positive and significant correlation among different macro nutrients (N, P and K), crude protein content and crude protein yield of teosinte (Table 10). Improvement in crude protein content and crude protein yield with foliar Fe sprays on teosinte indicates better nutrition and ultimately improvement in the health and milk status of the livestock. Fe participates in content of nitrate reductase enzyme in leaf which is responsible for protein formation in plants (Jin *et al.*, 2006). Proper Fe availability through foliar fertilization at different stages of crop might had activated nitrate reductase enzyme in leaf resulting more protein content as well as crude protein yield in our study (Table 5 and 7). Involvement of Fe in chlorophyll development and photosynthesis in leaves of plant (Cakmak, 2002; Jin *et al.*, 2008; El-Fouly *et al.*, 2011; Ali *et al.*, 2014), caused better growth and development of crop, which ultimately improved N, P, K, crude protein content and crude protein yield of teosinte fodder. The increase in crude protein yield was attributed to the increase in dry matter yield and crude protein content with foliar sprays of Fe over control (Tables 5 and 7). Increase in crude protein yield up to 75% in sorghum fodder was also reported by Rana *et al.* (2013) with two foliar spray of 0.5% $FeSO_4$ at 35 and 45 DAS over control. Similar results were also espoused by Sajad *et al.* (2014) with the foliar application of zinc at different growth stages of maize fodder.

Our results showed that Fe content in herbage improved linearly and significantly with foliar Fe fertilization (Table 6), whereas negative correlation was recorded between Fe-Cu and Fe-Mn content in herbage (Table 10) possibly due to antagonism and competition of same transport sites (Ghasemi-Fasaei and Ronaghi, 2008). Jin *et al.* (2006) and Ali *et al.* (2014) recorded significant increase in the growth and Fe content of red clover herbage and mungbean grain with foliar Fe fertilization. Plant tissue Fe concentration required for normal plant growth ranges from 100 to 200 ppm (Calhoun and Holmberg, 1991) but higher Fe levels from 250 to 500 ppm in the green forages may be toxic and could produce Cu depletion in animals (Phillippo *et al.,* 1987). In our study, we recorded positive influence on the Fe content of fodder at harvest with foliar $FeSO_4$ sprays and resulted in Fe rates more than 100 mg kg^{-1} which is essentially required for normal and healthy functioning of the plant. Due to proper Fe rates in plant, higher green herbage yield, dry matter yield and other quality parameters of teosinte were recorded in our study (Tables 5, 6 and 7). Since three foliar application of ferrous sulfate at 1.0% improved plant Fe content and had no negative affect either on fodder Mn or Cu concentration; therefore is considered as an appropriate dose of foliar Fe application for teosinte fodder. This is in agreement with findings of Moosavi and Ronaghi (2010) as they concluded that foliar spray of 1.0 % $FeSO_4$ was the most appropriate Fe treatment for dry bean in iron deficient soils.

The NDF values are important in ration formulation for the livestock because they reflect the amount of forage the animal can consume. The ADF values are important because they relate to the ability of an animal to digest the forage. As NDF and ADF percentage decreases, herbage intake and digestibility will generally increase. Considerable reduction in NDF and ADF values of teosinte herbage with foliar Fe fertilization in our study indicates more intake and digestibility of fodder by the cattle (Table 7) leading to improved livestock health and productivity. Sajad *et al.* (2014) recorded higher TDN values in maize fodder where 100 kg N + 10 kg Zn ha^{-1} was applied to the crop.

For livestock enterprises, high forage yield along with high quality production food for animals is the prime motto. Reduction in fibers (NDF and ADF) and improvement in estimated digestibility parameters such as TDN, DDM, DCP and DMI (Table 7) with foliar sprays of $FeSO_4$ reflects that under Fe deficient soils, foliar Fe fertilization could be one of the most important criteria for enhancing the yield and quality of teosinte fodder. Rana *et al.* (2013) recorded higher *in vitro* dry matter digestibility (IVDMD) and digestible dry matter (DDM) in sorghum fodder with the foliar sprays of iron over the control.

Relative feed value (RFV) and Relative forage quality (RFQ) is good indicator for the forage digestibility and quality estimation in addition to crude protein content. Fe application on crop showed positive and significant correlation with RVF and RFQ ensuring improved quality of herbage (Table 10). Similar to our study, Sajad *et al.* (2014) recorded maximum fodder maize RFV (79.3%) in treatment combination of 100 kg N ha^{-1} + 10 kg Zn ha^{-1} than control (78.1%) indicating enhancement of fodder quality with micro nutrient application. Enhancement in net energy for lactation (NE_L) and digestible feed energy (DFE) of tesointe fodder might be due to improvement in nutritional composition and other quality parameters such as CP, TDN, DMI, DDM, RFV and RFQ in our study (Table 7). These results are in accordance with Albayrak and Turk (2011) and Sajad *et al.* (2014) who reported enhanced NE_L values in crested wheatgrass and maize fodder with higher application rates of N and Zn fertilizers.

Gross returns, net field benefits, net returns and benefit cost ratio under foliar Fe fertilized treatments improved due to higher herbage yield (Table 5). Khalid *et al.* (2013) also recorded maximum marginal rate of return by 7518% with foliar spray of chelated Zn (120 g Zn ha^{-1}) on maize crop 15 days after planting. The present investigation confirmed that teosinte well performed and produced higher growth, herbage yield and quality through improved CP, RFV and RFQ by better conversion of assimilates in plants under Fe fertilization treatments. This is confirmed in correlation study among different traits (growth, yield, quality and macro nutrients), which showed significant and positive association with each other (Table 10). Mirzapour and Khoshgoftarmaneh (2013) also reported significant and positive correlation between leaf Fe^{+2} concentration and yield of pomegranate under foliar Fe fertilization in calcareous soils.

In conclusion, $FeSO_4$ as foliar spray improved plant growth, herbage yield (GHY and DMY) and quality of teosinte. Three foliar spray of 1.0% $FeSO_4$ at 30, 37 and 44 DAS was most suitable to achieve better fodder yield, quality and returns from teosinte. Nutritional composition (N, P, K and Fe) and estimated parameters for forage quality such RFV, RFQ, NE_L and DFE also got improved with the three 1.0% $FeSO_4$ foliar sprays. Further, dominance and marginal analysis confirmed maximum marginal rate of returns (400%) with three foliar sprays of 1.0% $FeSO_4$. Based on these findings, we conclude that repeated foliar spray of 1.0% $FeSO_4$ thrice at 30, 37 and 44 days after sowing should be used along with recommended dose of fertilizers for sustainable production of this important fodder crop raised in Fe deficient alkaline soils. The increased Fe content, quality, herbage yield and returns in teosinte will further strengthen the livestock industry in South Asian and other tropical countries of the world.

Acknowledgements

The authors thank Head, Department of Animal Genetics and Breeding, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab, India for providing necessary inputs to conduct this research trial.

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(Received 15 June 2015; Accepted 20 August 2015)