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Maize fodder quality characteristics and yield as affected by potassium application on calcareous sandy clay loam soil

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Abstract

A field experiment was conducted to evaluate the effect of K fertilizer on the quality and yield of maize fodder on a calcareous sandy clay loam soil under semiarid conditions of district Faisalabad, Pakistan. Six levels of K i.e.0, 25, 50, 75, 100 and 125 kg K_2O ha^{-1} along with 60 kg each of N and P_2O_5 ha^{-1} were applied. The system of layout was randomized complete block design (RCBD) with 3 replications. Crop was harvested after eight weeks of emergence. Fresh and dry fodder yield and quality parameters were determined. Potassium application significantly improved the yield and quality. Green fodder and dry matter yield increased by 31 and 21 %, respectively, over control whereas protein content improved by 32 % over control while other quality characteristics like crude fiber, acid detergent fiber contents (ADF) and neutral detergent fiber contents (NDF) remained non-significant as compared to control. Plant K concentration also increased with increasing K application. The K status of the soil was enhanced by 11 % due to K fertilizer application. So the potassium fertilizer should be applied along with nitrogen and phosphorus to the maize fodder to get the maximum yield of improved quality.

Keywords: Potassium, maize fodder yield, quality, calcareous soil

Introduction

Agriculture is an important factor controlling the GDP of Pakistan with a total share of 21 %. Livestock has the major contribution (52%) in this sector. Out of total cropped area of 23.51 mha only 2.35 mha is under fodder crops in Pakistan (Economic Survey of Pakistan, 2008). Green fodder is the most valuable and cheapest source of food for livestock. It is rich source of metabolizable energy, nutrient elements, carbohydrates, proteins and water. With quality nutritional fodder, milk production can be increased up to 100 % (Maurice *et al.,* 1985). It is reported that about 80-90 % of nutrients requirements of livestock are met from the fodder crops in irrigated areas (Younas and Yaqoob, 2005). The present fodder supply is 1/3 times less than the actual needs and the area under fodder crops has reduced during the past decade or so without any significant corresponding increase in per ha yield (Younas and Yaqoub, 2005). This reduction in area and yield is due to growing pressure of human population, shortage of irrigation water, less and erratic rainfalls, low priorities to fodder production and imbalance use of fertilizers (Rashid *et al*., 2007). The livestock feed pool in Pakistan was deficient by 21 % of total dry matter (DM), and by 33 % of crude protein requirements (Dost, 1997). Green fodders are not available in sufficient quantities especially in extreme hot months (June-July) and during cold seasons (December-January) thus the majority of the animals remained under fed (Younas and Yaqoub, 2005).

Low milk yield, less reproductive efficiency, delayed maturity and poor animal growth rate are major constraints due to imbalance nutrition. Under these circumstances, provision of balance nutrition can perk up the animal productivity up to 50 per cent with the existing gene pool (Economic Survey of Pakistan, 2008). Maize grown for green fodder is a short-duration crop and is ready for harvesting in about 8-10 weeks after sowing. No research in the recent past has been carried out to find out the profitability of maize as green fodder in Punjab inspite of the ever-increasing demands and its economic importance.

Potassium (K) is an essential major nutrient element for plants and animals together with nitrogen and phosphorus (Oborn *et al*., 2005). Soils of Pakistan are deficient in N and P but the status of K is variable (NFDC, 2003). The use of fertilizers has been mainly confined to the application of nitrogen and phosphorus, while ignoring potassium (K) which is being depleted under intensive cropping systems. The nutrient balance sheet for Pakistan shows an annual deficit of 265,000 tons K_2O (Bajwa,

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1994) with depletion of 8.8 mg K kg^{-1} annually (Malik *et al*., 1989). Another study showed that 28, 8 and 35 % soil series in Punjab, Sindh and NWFP, respectively, were deficient in available K (NFDC, 1994). Potassium deficiency typically occurs in coarse textured soils (Dobermann *et al*., 1998). Crop responses to K application are fairly good on sandy irrigated soils and even on clay soils (NFDC, 2003)). Potassium application also improves the quality of fodder (Rashid *et al*., 2007). Keeping in view the above facts and figures, this research was planned to assess the yield and quality attributes of maize fodder as influenced by K application in high pH, sandy clay loam and calcareous soil.

Materials and Methods

This trial was a continuum of a long term study in which six K rates (0, 25, 50, 75, 100 and 125 kg K_2O ha^{-1}) were applied to the potato crop in the previous season in six replications at farmer's field in the semiarid region of district Faisalabad, Pakistan. Representative composite soil samples were collected from 0-30 cm depth before planting and analyzed for EC_e (Rhoades, 1982), pH_s (Mclean, 1982), organic matter (Nelson and Sommers, 1982), total N (Tecator, 1981), particle size analysis (Gee and Bauder, 1986), P (Olson and Sommers, 1982), $CaCO_3$ and K as described by US Salinity Laboratory Staff (1954). In the present study six K rates (0, 25, 50, 75, 100 and 125 kg K_2O ha^{-1}) were applied to maize fodder before sowing. The nitrogen and phosphorus each was used @ 60 kg ha^{-1}. The sources of N, P and K were urea, DAP and K_2SO_4, respectively. All P, K and half of N were broadcast at the time of sowing while the remaining N was applied at first irrigation. The experiment was laid out using RCBD with three replications. The crop was sown by using 100 kg ha^{-1} seed during the second week of February. The crop was irrigated with canal water (EC of 0.37 dS m^{-1}, SAR of 4.41 (mmole $L^{-1})^{1/2}$ and RSC negligible). The potassium buildup status of the soil was assessed by analyzing the NH_4OAC extractable K in all the plots before sowing and after harvesting of the crop.

Data regarding the total green fodder yield was recorded by harvesting the whole plot. Percent dry matter was determined by using fresh and oven dry weight of plant samples. The plant samples were finally ground and passed through 0.5 mm sieve and preserved for analysis to determine potassium (K) concentration by flame photometer and nitrogen (N) by micro-kjeldahal apparatus as described by US Salinity Laboratory Staff (1954). Crude protein was calculated by multiplying the nitrogen content with a factor 6.25 (Jones, 1931). Crude fiber, acid detergent fiber (ADF) and neutral detergent fiber (NDF) contents were determined by following the AOAC (1995) methods. After harvesting, soil samples were collected from each treatment plot to determine K buildup. Analysis of variance (ANOVA) technique was used and Duncan's Multiple Range (DMR) test was applied to see the significance of differences among treatments means (Duncan, 1955).

Results and Discussion

The soil used was free from salinity/ sodicity and alkaline in reaction, calcareous in nature, deficient in organic matter and P, and medium in K. The texture was sandy clay loam (Table 1).

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

Soil Determinant	Unit	Value
EC_e	dS m^{-1}	1.20
pH_s	-	8.10
$CaCO_3$	%	7.53
Organic matter	%	0.56
Olsen P	mg kg^{-1}	6.63
Sand	%	56.00
Silt	%	20.00
Clay	%	24.00
Textural Class	-	Sandy clay loam

Green fodder yield and dry matter contents

The green fodder yield (Mg ha^{-1}) and dry matter contents (%) were improved significantly with K application (Table 2). Analysis of variance revealed that K showed a significant effect on the improvement of green fodder yield of maize crop. The green fodder yield reached to the plateau value of 56.77 Mg ha^{-1}, an increase of 31 % over control, with the treatment where 125 kg K ha^{-1} was applied. The treatments of 100 and 125 kg K ha^{-1} were statistically at par with each other ($p \leq 0.05$). Treatments where 50 and 75 kg ha^{-1} K was applied were also statistically similar to each other but significantly higher than control.

Table 2. Effect of K fertilizer on green fodder and dry matter yield of maize

K_2O rate (kg ha^{-1})	Green fodder yield (Mg ha^{-1})	Dry matter yield (%)
Control	38.99 d	19 f
25	44.63c	20 e
50	47.35 bc	21 d
75	49.92b	23 c
100	54.45a	23 b
125	56.77a	24 a
LSD at p = 0.05	3.1300	0.1945

These results are supported by the work of Laughlin *et al.* (1973) who obtained increased smooth brome grass yields of 6.3 to 11.5 tons ha^{-1} in Alaska (USA) with application of 112 kg K ha^{-1}. These results are also in agreement with the findings of Biswas and Benbi (1997) who reported positive response of K application to maize crop.

The effect of K on dry matter yield was positive (Table 2). The dry matter reached to the plateau value of 24 %, an increase of 21 % over control, with treatment where 125 kg K ha^{-1} was applied. Minimum dry matter 19 % was harvested from control plot which increased with the application of potassium @ 125 kg ha^{-1} to a maximum level of 24 %.

These results are supported by the work of Pholsen and Sornsungnoen (2004) who reported a 15 % increase in dry weight of sorghum fodder with 100 kg K_2O application over control plots. The results are also in line with the findings of Eichhorn (1983) and Malhi *et al*. (2004) who reported that the K application has significantly increased the dry matter yield of plants.

Potassium concentration (%) in plant

The data regarding the effect of potassium fertilizer on its concentration in plants are presented in Table 3. The analysis of variance revealed that K showed a significant effect on the improvement of K concentration in maize fodder. Maximum K concentration was observed in the treatment where 125 kg K_2O ha^{-1} was applied. The overall increase was 26 % over control. Treatments where 25 and 50 kg K_2O ha^{-1} was applied and the control plots were statistically similar to each other. Illite may be the inherent source of soil K, its presence greatly influences the K supplying ability of a soil (Sparks, 1987).

to different K fertilizer rates therefore, source of this K may be illite, one of the dominant clay minerals present in the soils of Pakistan (Mehdi, 1993).

The results are in accordance with Eichhorn (1982) who showed that plant K^+ concentrations in coastal bermuda grass increased from 10 to 21 g kg^{-1} as K rates increased from 0 to 555 kg ha^{-1} Corresponding values for plant uptake of K were 138 and 358 kg ha^{-1} at 0 and 555 kg ha^{-1} K.

Quality parameters of maize fodder

Crude protein contents

Analysis of variance depicted that the K showed a significant effect on the improvement of the crude protein contents (Table 3). The crude protein reached to the plateau value of 11.70 %, an increase of 31.32 % over control, with treatment where 100 kg K ha^{-1} was applied. The treatments with 100 and 125 kg ha^{-1} K_2O were statistically at par with each other. It appears from the present study that crude protein component of the fodder can be enhanced with concomitant decrease in protein supplementation reducing additional cost on supplementing rations. Increased as crude protein concentration at higher K fertilizer rates may be due to the phenomenon of dilution effect (Mislevy and Everett, 1981).

These results also support the work of Wichman (2001) who concluded that the K fertilizer had a diverse impact on crude protein. They found that K fertilizer tended to enhance protein content at Geyser, reduce protein content at Moore and had no effect on protein at Moccasin.

Table 3. Effects of K fertilizer on quality parameters of maize

K_2O rate (kg ha^{-1})	K concentration (%)	Crude protein contents (%)	Crude fiber content (%)	Acid detergent fiber (ADF) (%)	Neutral detergent fiber (NDF) (%)
Control	1.63 d	9.96 e	31.13	42.44	70.16
25	1.64 d	10.21 d	29.74	43.43	67.97
50	1.66 d	10.64 c	30.43	42.70	69.32
75	1.82 c	11.21 b	29.94	43.87	66.87
100	2.05 b	11.70 a	30.28	43.32	69.22
125	2.19 a	11.69 a	29.41	42.69	68.93
LSD at p = 0.05	0.0744	0.1277	NS	NS	NS

The K concentration in high yielding maize fodder is relatively large and removal is much higher where vegetative material is harvested on cut and carry basis, and this fact is prominent from the data depicted in table 3. It is clear from the data that K concentration is not comparable

Crude fiber content

Analysis of variance revealed that K showed a non-significant effect on the crude fiber (CF) contents of maize crop. All the treatments where K was applied were statistically at par with control. The respective means of crude fiber for 0, 25, 50, 75, 100 and 125 kg K ha^{-1} were 31, 20, 30, 20, 30 and 29 %, respectively (Table 3).

This non-significant response may be due to the fact that the stage of maturity at harvesting time was the most influential factor affecting CF of forage crops (Collar and Aksland, 2001). Crude fiber contents remained almost same across all the treatments varying about less than 1 %.

Acid detergent fiber contents (ADF) and neutral detergent fiber contents (NDF) of maize fodder

Analysis of variance revealed that the treatments had a non-significant effect on ADF and NDF in fodder quality parameters with respect to control.

The results are supported by the findings of Collar and Aksland, (2001) and Pholsen and Sornsungnoen (2004) who also reported non-significant effect of different K fertilizer rates on the quality parameters like ADF, and NDF, etc. of fodder crop.

K status in soil

Analysis of variance depicted that K status of the soil increased with application of K fertilizer (Table 4). At lower rate of K application the K status of the soil decreased than the original but at higher rates it increased significantly. The increase in available K level in the soil may be due to the reason that the applied K may become fixed on the negative charges on the soil by competing with that of NH_4 and is converted into slow release form.

Table 4. Effect of K fertilizer on K buildup status in the soil

K_2O rate (kg ha^{-1})	K before sowing (mg kg^{-1})	K after sowing (mg kg^{-1})
Control	66 f	62 e
25	74 e	73 d
50	78 d	82 c
75	82 c	84 c
100	85 b	94 b
125	117 a	119 a
LSD at p = 0.05	2.3408	5.8638

These results support the work of Swarup and Chhillar (1986) who reported that application of K did not affect the yield of wheat crop but enhanced its available status in soil and uptake by the crops. Contribution of the non-exchangeable K towards total potassium removal was about 93% in the absence of applied K which decreased to 87% with the use of K. Application of K resulted in lesser uptake from non-exchangeable form as compared to its application to crop.

These results are also in line with Collins (1978) who studied 48-h K fixation in the laboratory following K applications of 0 to 0.68 cmol K^+ kg^{-1}. He found that K fixation increased linearly with K application, averaging 0.24 cmol K^+ kg^{-1} at the highest application rate.

Conclusion

The maximum green fodder yield of 61.28 Mg ha^{-1} was obtained where K was applied @ 125 kg ha^{-1}. The K application improved the maize fodder quality traits including crude protein, dry matter, K concentration but crude fiber, acid detergent fiber (ADF) and neutral detergent fiber (NDF) contents (%) remained non significant. So the potassium fertilizer should be applied along with nitrogen and phosphorus to the maize fodder to get the maximum yield of improved quality.

References

AOAC. 1995. Official Methods of Analysis of AOAC International, (16th Ed.), P. Cunniff (ed.) AOAC International, Arlington, Virginia, USA.

Bajwa, M.I. 1994. Soil potassium status, potash fertilizer usage and recommendations in Pakistan. Potash Review No. 3/1994. Subject 1, 20th suite. International Potash Institute, Basel.

Biswas, C.R., and D.K. Benbi. 1997. Sustainable yield trends of irrigated maize and wheat in a long-term experiment on a loamy sand in semi-arid India. *Nutrient Cycling in Agro ecosystem* 46: 225-234.

Collar, C. and G. Aksland. 2001. Harvest stage effects on yield and quality of winter forage. p. 133-142. *In: 31st California Alfalfa Symposium.* 12-13 December,2001. University of California Cooperative Extension. University of California, Davis.

Collins, J.E. 1978. Potassium fixation in some loessial soils of Louisiana, M.S. thesis. Louisiana State University, Baton Rouge.

Dobermann, A., K.G. Cassman, C.P. Mamaril, and J.E. Sheehy. 1998. Management of phosphorus, potassium and sulfur in intensive irrigated lowland rice. *Field Crops Research* 56: 113-138.

Dost, M. 1997. End of assignment report on fodder component UNDP/FAO project Pakistan, 86/027. FAO/UNDP. Gilgit, Pakistan.

Duncan, D.B. 1955. Multiple Ranges and Multiple F test. *Biometrics* 11: 1-42.

Economic Survey of Pakistan. 2008. Ministry of Finance, Agriculture and Livestock, Federal Bureau of Statistics, Islamabad, Pakistan.

Eichhorn, M.M. Jr. 1982. Potash fertilization revives stands, boosts yields and nutritive value of coastal bermudagrass. *Better Crops with Plant Food* 66: 31-33.

Eichhorn, M.M., Jr. 1983. High yielding bermuda grass varieties require more nutrients. *Better Crops with Plant Food* 67: 30-31.

Gee, G.W. and J.W. Bauder. 1986. Particle size analysis. p 383–412. *In:* Methods of Soil Analysis, Part-I. Physical and mineralogical methods. Agronomy Monograph No. 9, (2nd Ed.), A. Klute, (ed.), SSSA, Madison, WI, USA.

Jones, D.B. 1931. Factors for converting percentages of nitrogen in foods and feeds into percentages of protein. USDA Circ. No. 183: 1-21.

Laughlin, W.M., P.F. Martin and O.R. Smith. 1973. Potassium rate and source influences on yield and composition of bromegrass forage. *Agronomy Journal* 65: 85-87.

Malhi, S.S., H. Loeppky, B. Coulman, K.S. Gill, P. Curry and T. Plews. 2004. Fertilizer nitrogen, phosphorus, potassium, and sulphur effects on forage yield and quality of timothy hay in the parkland region of Saskatchewan, Canada. *Journal of Plant Nutrition* 27: 1341 - 1360

Malik, D.M., R.A. Chaudhary and G. Hussain. 1989. Crop responses to potash application in the Punjab. p. 71-93. *In:* Proceeding of workshop on the role of potassium in improving fertilizer use efficiency. National Fertilizer Development Centre, Islamabad.

Maurice, E.H., F.B. Robert and S.M. Darrel. 1985. Forages. p. 413-421. *In:* The Science of Grassland Agriculture. (4th ed.) Iowa State Univ. Press (Ames), Iowa, USA.

McLean, E.O. 1982. Soil pH and lime requirement. p 199-224. *In:* A.L. Page, R.H. Miller, D.R. Keeney (eds.), Methods of soil analysis. Part2. Chemical and microbiological properties. *Agronomy Monograph No. 9, (2nd Ed.),* SSSA, Madison WI.

Mehdi, S.M. 1993. Potassium dynamics in soils of Pakistan. PhD. Thesis. Department of Soil Science, University of Agriculture, Faisalabad, Pakistan.

Mislevy, P., and P.H. Everett. 1981. Subtropical grass species response to different irrigation and harvest regimes. *Agronomy Journal* 73: 601-604.

Nelson, D.W. and L.E. Sommers. 1982. Total carbon, organic carbon and organic matter. p: 539-579. *In:* Methods of Soil Analysis, Part 2. Chemical and microbiological properties. *Agronomy Monograph No. 9, (2nd Ed.)* A.L. Page, R.H. Miller and D.R. Keeney (eds.), SSSA, Madison WI, USA.

NFDC. 1994. Sulphur status and crop response in Pakistan soils. *NDFC publication No.2/94*, NDFC, Islamabad.

NFDC. 2003. Fertilizers and their use in Pakistan. An extension guide. A. Nisar and M. Rashid, (eds.) NFDC, Islamabad, Pakistan.

Oborn, I., Y. Andrist-Rangel, M. Askekaard, C.A. Grant, C.A. Watson and A.C. Edwards. 2005. Critical aspects of K management in agricultural systems. *Soil Use and Management* 21: 102-112.

Olsen, S.R. and L.E. Sommers. 1982. Phosphorus. p. 403-430. *In:* Methods of soil analysis. Part 2. *Agronomy Monograph No. 9*. A.L. Page, R.H. Miller D.R. Keeney (Eds.). American Society of Agronomy. Madison, WI, USA.

Pholsen, S. and Sornsungnoen N. 2004. Effect of nitrogen and potassium rates and planting distances on growth, yields and fodder quality of forage sorghum (*Sorghum bicolor* L. Moench). *Pakistan Journal of Biological Sciences* 7: 1793-1800.

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. *Pakistan Journal of Agricultural Sciences* 44: 221-227.

Rhoades, J.D. 1982. Soluble salts. p 167-79. *In: Methods of soil analysis. Part2. Chemical and microbiological properties. Agronomy Monograph No. 9*, (2nd ed.). A.L. Page, R.H. Miller and D.R. Keeney (eds.) SSSA, Madison,WI, USA.

Sparks, D.L. 1987: Potassium dynamics in soil. *Advances in Soil Science* 6: 1-63.

Swarup, A. and R.K. Chhillar. 1986. Build up and depletion of soil phosphorus and potassium and their uptake by rice and wheat in a long-term field experiment. *Plant and Soil* 91: 161-170.

Tecator, A.B. 1981. Determination of Kjeldahl nitrogen content with Kjeltec autosystems I, II, III and IV. Tecator application note AN 30/81, Hoganas, Sweden.

U.S. Salinity Laboratory Staff. 1954. Diagnosis and improvement of saline and alkali soils. USDA HandBook No. 60. Washington, DC. 160p.

Wichman, D. 2001. Fertilizer use on dryland perennial forages. Mt. Ext. Fertilizer Facts No. 27.

Younas, M. and M. Yaqoob. 2005. Feed resources of livestock in the Punjab, Pakistan. Livestock Research for Rural Development. 17(2). *http://www.lrrd.org/lrrd 17/2/youn17018.htm* [Accessed on 04.11.2009]