RESPONSE OF SORGHUM (*Sorghum bicolor* L.) FODDER TO PHOSPHORUS FERTILIZER ON TORRIPSAMMENT SOIL.

M. Rashid and M. Iqbal

Livestock Production Research Institute Bahadur Nagar Farm, Okara
Corresponding author e-mail: mruaf@yahoo.com

ABSTRACT

Sorghum is an important fodder for animals in Pakistan. Phosphorus is a quality nutrient for fodders. The use of P for sorghum is negligible. Thus a field study was conducted to evaluate the effect of model based P fertilization to improve yield and quality of sorghum fodder on Torripsamment soil (Loamy sand, calcareous). Adsorption isotherm was constructed by equilibrating 2.5 g soil with 25 ml of 0.01 M $CaCl_2$ solution containing 0, 20, 40, 60, 80, 100, 200,300,400 and 500 µg P mL^{-1} as KH_2PO_4 and shaking for 24 hour at 20 ^{0}C. P fertilizer doses were computed by using empirically derived Freundlich equation to adjust soil solution P levels of 0.05, 0.1, 0.15, 0.20, 0.25, 0.30, 0.35, 0.40, and 0.50 mg P L^{-1}. It was observed that different P fertilizer doses were required to adjust different soil solution P levels. Adsorption of P increased with P application rate but marginal adsorption decreased significantly. Yield and quality of sorghum fodder were improved with P application. Yield increased upto T_6 where P was applied @ 25 kg ha^{-1} but quality traits (P concentration, dry matter, crude protein, crude fiber and ash contents (%) improved with the highest rate of P use i.e. 43 kg ha^{-1}. P application showed non-significant affect on NDF and ADF contents (%). External and internal P requirements of sorghum fodder to obtain 95 % relative yield were 0.22 mg L^{-1} and 0.20 % respectively.

Key word: - P fertilization, derived Freundlich equation, sorghum yield and quality.

INTRODUCTION

Mineral fertilizers play a vital role towards improving crop yields but one of the main constraints in achieving proven crop potential is imbalanced use of nutrients, particularly low use of P as compared to N. The optimum rate of P application is important in improving yields of most crops (Cisar *et al*., 1992). A better P supply increases mineral P concentration in plants (Halliday and Trenkel, 1992). Soils of Pakistan are alkaline (pH > 7.0) and mostly calcareous (CaCO3 > 3.0%) in nature. When P fertilizer is added, part of it goes to soil solution and is taken up by plants or precipitates, while rest goes to exchange sites and is adsorbed (Wandruszka, 2006). Olsen method is widely used as a test for available P in alkaline, calcareous soils (Memon, 1996) but P sorption isotherm technique has been suggested by many investigators (Fox and Kamprath, 1970 and Holford, 1997) to determine the amount of P, required to bring its concentration in soil solution to the level optimum for maximum plant growth. It is more accurate than conventional soil P test (Klages *et al*., 1988) as it takes into account the soil Physico - chemical properties. This technique is based on the assumption that a certain soil solution P concentration is required to supply adequate P to plants. Values of 0.2 and 0.3 mg L^{-1} in soil solution are considered adequate for most plants to attain near maximum growth (Beckwith, 1965; Borrero *et al*., 1988; Pena and Torrent, 1990; Chaudhry *et al*., 2003).

Soil solution P levels can be determined by different equations, which show P adsorption relationships (Huang, 1998; Zamuner and Culot, 1999). The Langmuir and the Freundlich equations described the adsorption phenomena satisfactorily (Boschetti *et al*., 1998). Gregory *et al*. (2005) stated that the Freundlich isotherm is a heterogonous binding model and is widely applicable in measuring the heterogeneity of soils. Freundlich equation describes well the P adsorption over a limited range of P concentration (Barrow, 1978; Bhal and Toor, 2002; Delgado *et al*., 2002; Mahmut, 2003; Hussain *et al*., 2006).

In Pakistan farmers are using only nitrogen fertilizers for fodder crops while the use of P fertilizer is negligible. These crops are often grown on marginal lands. Hence the production is low and quality is poor to meet the animal's nutritional requirement (Khan *et al*., 2003). Fodders are the most valuable and cheapest source of food for livestock having rich source of metabolizable energy, nutrient elements, carbohydrates and protein. With quality nutritional fodder, milk production can be increased up to 100 % (Maurice *et al*., 1985).

The importance of P in the diet of animals is that its highest requirements are during lactation, early growth and for reproduction. High producing cows need much more P than cows producing at average or low levels. P deficiencies occur in animals when forages containing 0.10-0.12 % P are fed (Black *et al*., 1949) and (Pinchak *et al*., 1989). The animals require fodders containing 0.35-0.40 % P and if the weight of the animal is

100,200,300 and 400 kg, they correspondingly need 8.1, 13.2, 14.0 and 14.4 g P daily (Iqbal *et al*. 2004).

Forage sorghum (*Sorghum bicolor L.*) is the best modern and high yielding grass especially for hay and silage. (Dogget, 1988, Skerman and Riveros, 1999). Sorghum is cultivated on 0.577 million hectares and with total production of 7.447 million tones in the Punjab province of Pakistan (Punjab development statistics, 2003). Sorghum has a significant role in livestock production, particularly in the tropical zone where feed stuffs could not meet animal requirements due to many factors such as poor soil fertility, drought and others (Pholsen and Suksri 2007). Keeping in view the present study was conducted to see the effect of P fertilization on the yield and quality of sorghum fodder.

MATERIALS AND METHODS

Loamy sand (Torripsamment soil) was selected. The soil samples were collected from 0-30 cm depth. The soil was alkaline in reaction (pH 8.3), non-saline (ECe 1.32 dSm^{-1}), calcareous ($CaCO_3$ 6.0 %) and low in organic matter (0.4 %), available P (4.9 ppm) and K (57 ppm).

P adsorption isotherms and application of Freundlich equation to compute P doses

Phosphorus adsorption capacity of the soil was determined by shaking 2.5g soil with 25ml 0.01M $CaCl_2$ containing P concentrations 0, 20, 40, 60, 80, 100, 200,300,400 and 500 µg P ml^{-1} prepared from KH_2PO_4 for 24 hours at $20^{o}C$.The soil solutions were filtered through Whatman No.41 filter paper and P concentration was measured using Ascorbic Acid Method (Murphy and Riley, 1962) and adsorption isotherms were constructed according to the methods described by Rowell (1994). The amount of P adsorbed was calculated from the difference of P added and P remained in solution after P equilibrium was established. The adsorption data was fitted to the empirically derived Freundlich equations (Pant and Reddy 2001) as under to compute P fertilizer doses. $X/m = K_f (EPC)^{1/n}$

Linear form of the equation = Log X/m = Log K_f + 1/n (Log EPC): X/m = Amount of P adsorbed per unit of soil (ug g^{-1}) **EPC** = Equilibrium P concentration in soil solution (ug ml^{-1}) K_f is proportionality constant for Freundlich equation (mg P kg^{-1}) 1/n is empirical constant expressed in L kg^{-1}.P doses were computed (table-I) by putting the adsorption data into the linear form of the derived Freundlich equation to attain soil solution P levels of 0.05, 0.10, 0.15, 0.20, 0.25, 0.30, 0.35, 0.40 and 0.50 mg L^{-1}.

Field experiment: The field experiment was conducted on loamy sand soil. There were ten treatments and three replications layedout in Randomized Complete Block Design (RCBD). Whole P (calculated) table 1 and

recommended K (60 kg ha^{-1}) were applied at the time of sowing. Nitrogen @ 60 kg ha^{-1} was applied in two splits i.e. half at sowing and half with first irrigation. The crop was sown during Kharif -2009 having plot size of 200 m^2. The crop was harvested at head initiation stage, fodder yield and dry matter contents (%) data were recorded. Plant samples were analyzed for P concentration, crude protein, crude fiber, ash content, ADF& NDF (%) (AOAC, 1995). Data thus generated were statistically analyzed according to Steel *et al.,* (1997). The comparisons among the treatment means were made by using Duncan's Multiple Range Test at 5 % probability level (Duncan, 1955).

Table 1: - P fertilizer doses computed by Freundlich equations

Treatments	Soil solution P levels	Loamy sand	
		P	P_2O_5
	mg L^{-1}	← kg ha^{-1} ⟶	
T_1	0.00	0	0
T_2	0.05	9	22
T_3	0.10	15	34
T_4	0.15	19	45
T_5	0.20	24	54
T_6	0.25	25	57
T_7	0.30	27	63
T_8	0.35	31	70
T_9	0.40	35	79
T_{10}	0.50	43	99

RESULTS AND DISCUSSION

Green fodder yield (Mg ha^{-1}) of sorghum as affected by P fertilizer: P fertilizers are seldom applied to sorghum fodder in Pakistan while it is considered an exhaustive crop and removes large amounts of NPK. In the present study 10 rates of P fertilizer to adjust soil solution P levels of 0, 0.05, 0.10, 0.15, 0.20, 0.25, 0.30, 0.35, 0.40, and 0.50 mg L^{-1} were applied to sorghum fodder on Torripsamment soil testing low in available P. There was a significant increase in green fodder yield with each increment of P (Table II). This increase was upto T_6. The maximum fodder yield of 32.16 $Mgha^{-1}$ was obtained with T_6 where P was applied @ 25 kg ha^{-1} (against soil solution P level of 0.25 mg L^{-1}). There was progressive increase in fodder yield upto this rate of P application. At the highest P application rate the fodder yield was static and no further increase in yield was observed. The optimum P rate for maximum fodder yield was 25 kg ha^{-1} against soil solution P level of 0.25 mg L^{-1}. Most of the scientists considered 0.2 mg P L^{-1} adequate for general crops. Thus sorghum fodder is better feeder of P. Similarly, Fox (1981) stated that the most crops require P less than 0.2 mg P L^{-1} in solution. Rehman *et al*. (2004) found that the standard solution P concentration of

0.20 mg P L^{-1} provides adequate P for wheat if it is continuously maintained in the soil. The results are also in line with those of Anees and Hassan (1996) and Gill *et al*. (1995) who emphasized adequate P fertilization to sorghum fodder on the basis of soil tests to get better yields. Kanwar (1985) concluded that P response to sorghum varied across soil

Types and followed the order Alfisols > Entisols > Vertisols.

Dry matter yield: There was progressive increase in dry matter content with increase in P application rate. This increase was upto the highest rate of P used (Table II). The maximum DM content of sorghum fodder was 13.89 % with T_{10} where P was applied @ 43 kg P ha^{-1} (against soil solution P level of 0.50 mg L^{-1}). The soil under study was P deficient, so P application improved the soil P status from deficient to optimum level, which caused improvement in DM content. The increase in DM content confirmed the necessity of P application in P deficient soils for obtaining better yields (Ahmad, *et al*., 1999). These results are in line with those of Das *et al*. (1996) who observed that dry matter yield of sorghum increased with the application of P at all the stages of crop growth and boot leaf stage; response was observed up to 80 kg P_2O_5 ha^{-1}. Akmal and Asim (2002) also obtained similar results regarding dry matter yield of sorghum.

Table II: - Effect of P on green fodder yield (Mg ha^{-1}), P concentration (%) and dry matter contents (%) of sorghum fodder

Treatments	Soil solution P levels mg L^{-1}	Fodder yield Mg ha^{-1}	Dry matter ← % →	P concentration %
T_1	0.00	12.33 D	9.15 E	0.102 I
T_2	0.05	21.47 C	10.22 D	0.114 H
T_3	0.10	22.35 C	10.37 D	0.156 G
T_4	0.15	27.25 B	10.84 CD	0.167 F
T_5	0.20	29.31 AB	11.16 C	0.179 E
T_6	0.25	32.16 A	11.31 C	0.186 D
T_7	0.30	31.97 A	12.91 B	0.187 D
T_8	0.35	31.64 A	13.04 B	0.195 C
T_9	0.40	31.64 A	13.67 AB	0.204 B
T_{10}	0.50	31.53 A	13.89 A	0.214 A

Means sharing the same letters are statistically significant at 5 % level of Probability

P Concentration in sorghum fodder: The data regarding the effect of P fertilizer on P concentration in sorghum fodder are presented in tables II. P concentration (%) in sorghum fodder increased significantly with increasing P application rate (more P in soil solution) with the highest rate. Maximum P concentration (0.21 %) in sorghum fodder was observed with T_{10} where P was

applied @ 43 kg ha^{-1} (against soil solution P level of 0.50 mg L^{-1}). Sorghum is a C4 plant and has extensive deep root system, which can explore larger volume of soil for P extraction, so the absorption of P increased. Similar results were found by Buah *et al*. (2000), Alvarez *et al*. (2000), Ahmad *et al*. (2003), Munir *et al*. (2004) and Rehman *et al*. (2004). The P concentration in plants is necessary, as the animals require it. P deficiencies occur in animals when forages containing 0.10-0.12 % P are fed (Black *et al,* 1949) and (Pinchak *et al*., 1989).

Quality of sorghum fodder: Quality fodder is needed for better performance of animals. The parameters used to describe forage quality are crude protein, crude fiber, ash, ADF and NDF contents (%) (Soest, 1985). Addition of P fertilizer is necessary as it improves both quality and quantity of the green fodder (Dhillon *et al*., 1998). P application to soil regulates Mg uptake, which prevent tetany (a disease) in animals (Lock *et al*., 2000).

The effect of P on crude protein content in sorghum fodder is presented in table III. The crude protein, crude fiber and ash contents in sorghum fodder increased with increase in P application rate. The maximum crude protein, crude fiber and ash contents were 9.25, 30.12 and 13.45 % respectively, in sorghum fodder with T_{10} where P was applied @ 43 kg P ha^{-1} against soil solution P level of 0.50 mg L^{-1}. This indicated better utilization of N with increasing P inputs. The increase in crude protein content was due to the fact that P is an important structural component of DNA and RNA. The Phosphate group in nucleic acids bridges the RNA or DNA. DNA is the carrier of genetic information and RNAs function in protein synthesis (Mengel and Kirkby, 2001). Similarly, Chaudhary and Karwasra. (1984) reported that crude protein content in sorghum fodder was increased with P application.

The increase in crude fiber contents was due to more dry matter accumulation with P application (Chand *et al*., 1992). Similarly, Ayub *et al*. (2002) reported that crude fiber content increased with P application along with N. Increase in ash % is due to increase in mineral matter (Soest, 1985). ADF and NDF are composed of cellulose plus lignin and cellulose plus hemi cellulose plus lignin, respectively and are the structural carbohydrates in plants, which play an important role in the digestibility of forage. The decrease in ADF and NDF (cell wall components) is an indication in improvement of the quality of fodders. On the other hand high values of both the parameters indicate poor digestibility due to more lignification (Soest, 1985). P application showed non-significant effect on ADF and NDF contents in fodder. However, there was slight decrease in the quantity of these parameters and increase in soluble carbohydrates in fodder by P fertilization, which showed quality improvement (Reid and Jung 1965). The results of this study are also in agreement with those of

Karwasra *et al*. (1984) and Chand *et al*. (1992) who reported that ADF and NDF contents of sorghum fodder did not change significantly with P application. Pholsen and Sukseri (2007) reported that P and K fertilizers application had no effect on ADF and NDF contents in forage sorghum.

Table III: - Effect of P fertilization on the quality of sorghum fodder

Treatments	Soil solution P levels	Crude protein	Crude fiber	ash	NDF	ADF
	mg L^{-1}		$\longleftarrow$	%	$\longrightarrow$	
T_1	0.00	5.56 ^{G}	27.27 ^{G}	10.21 ^{G}	61.24NS	35.65NS
T_2	0.05	6.41 ^{F}	27.51 ^{FG}	11.06 ^{F}	61.23	35.59
T_3	0.10	6.63 ^{EF}	27.70 ^{EF}	11.91 ^{E}	61.20	35.50
T_4	0.15	6.88 ^{DE}	28.04 ^{E}	12.12 ^{E}	61.20	35.43
T_5	0.20	6.99 ^{DE}	28.48 ^{D}	12.50 ^{D}	61.19	35.43
T_6	0.25	7.14 ^{D}	28.92 ^{C}	12.66 ^{D}	61.15	35.37
T_7	0.30	7.29 ^{D}	29.27 ^{BC}	12.78 ^{CD}	61.12	35.37
T_8	0.35	7.76 ^{C}	29.58 ^{B}	13.09 ^{BC}	61.11	35.31
T_9	0.40	8.19 ^{B}	29.61 ^{B}	13.33^{AB}	61.10	35.26
T_{10}	0.50	9.25 ^{A}	30.12 ^{A}	13.45 ^{A}	61.09	35.24

Means sharing the same letters are statistically significant at 5 % level of Probability.

P requirements of sorghum fodder: The soil solution P level and P concentration in sorghum fodder at head initiation stage were plotted against 95 % relative yield of sorghum fodder for the determination of P requirement by the Boundary Line Technique (Webb, 1972) as shown in the Fig 1 and 2

Maximum soil solution P level of 0.22 mg L^{-1} was required for 95 % relative yield on this soil. Hassan *et al*. (1994) calculated P fertilizer requirement using adsorption isotherms as 83, 51,50 and 8 mg P kg^{-1} for the Missa, Gujranwala, Abbotabad and Risalpur soil series to adjust soil solution P level of 0.2 mg P L^{-1} and soil solution P requirement of corn for near maximum (95 %) biomass production was 0.3 mg PL^{-1}. Internal P requirement in sorghum fodder to obtain 95 % relative yield was 0.20 %. Rehman *et al*. (1992) and Chaudhry *et al*. (2003) reported that the critical phosphorus concentration ranged from 0.22 to 0.26 % for 40-60 cm tall maize plants. Similarly, Rehman *et al*. (2007) stated that internal P requirement in sorghum fodder harvested from Typic Camborthid soil was 0.326 %.
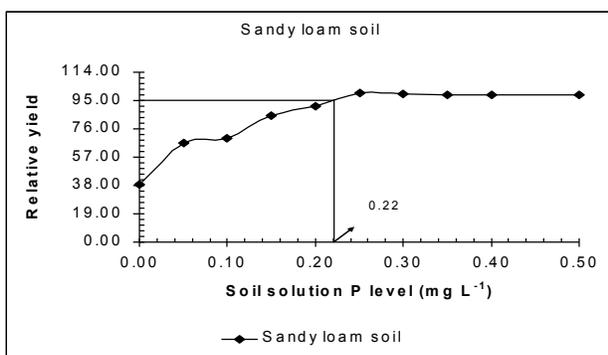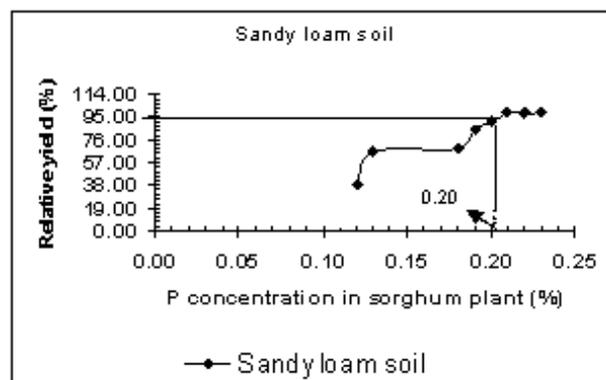

Fig 2:- Internal P requirement of sorghum fodder

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Fig 1:- External P requirement of sorghum fodder

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