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Nutrient management in fodder sorghum + cowpea – chickpea cropping system for higher system productivity and nutrient use

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Abstract

A field experiment was conducted during 2010-12 at Central Research Farm, IGFRI, Jhansi to study the influence of FYM, phosphorus and sulphur application in fodder sorghum + cowpea – chickpea cropping system in clay loam soil of Bundelkhand of central India. Pooled data of two years study revealed that system productivity in terms of chickpea equivalent yield was 3.04, 3.12 and 2.98 t ha^{-1} with the application of 5 t FYM ha^{-1}, 60 kg P_2O_5 ha^{-1} and 20 kg S ha^{-1}, respectively and significantly higher over their respective controls but application of 30 kg P_2O_5 ha^{-1} recorded at par chickpea equivalent yield (2.99 t ha^{-1}). Similarly, agronomic nutrient use efficiency was 8.8, 9.4 and 5.4 kg chickpea equivalent yield per kg N applied, physiological nutrient use efficiency was 11.76, 146.75 and 87.04 kg chickpea equivalent yield per kg nutrient uptake and apparent nutrient recovery was 70.24, 6.42 and 6.17 percent with the application of 5 t FYM ha^{-1}, 30 kg P_2O_5 ha^{-1} and 20 kg S ha^{-1}, respectively. Application of FYM, P, S also increased N, P, K and S uptake of cropping system significantly. Two years application of FYM, phosphorus and sulphur also improved soil organic carbon, available N, P and S status under semi-arid condition.

Keywords: Chickpea equivalent yield, FYM, Nutrient uptake, Nutrient use efficiency, Soil fertility

Introduction

Currently, India is facing a challenge of producing adequate food from shrinking natural resource base for the ever-increasing population. Moreover, the declining soil fertility and mismanagement of plant nutrients have made this task more difficult (NAAS, 2012). Increasing demand of livestock products and deficit of forages has created a renewed interest of farmers to produce more biomass from different production systems (IGFRI, 2013; Kantwa *et al*., 2014). In developed countries, for example, over application of inorganic and organic fertilizers has led to contamination of soil and water resources. Whereas, in developing countries, harsh climatic conditions, population pressure, land constraints, and the decline of traditional soil management practices have often reduced soil fertility. Therefore, integrated approach recognizes that soils contain definite reserve of most of the plant nutrients essential for plant growth and judicious management of this reserve, will have a major impact on plant growth, soil fertility and agricultural sustainability.

Organic sources of nutrients ensure their regulated supply by releasing them slowly resulting in increased crop yield and nutrient use efficiency (Sharma, 2002), long term sustainability of soil fertility by improving level of soil organic carbon, availability of nutrients and soil microbial properties (Melero *et al*., 2007). Phosphorus and sulphur are major nutrient elements for cereal-legume cropping system (Jiang *et al*., 2006; Palsaniya and Ahlawat, 2009). Phosphorus plays important role in many of the physiological processes such as the utilization of sugar and starch, photosynthesis, energy storage and transfer. Legumes (cowpea and chickpea) generally have higher phosphorus requirement because the process of symbiotic nitrogen fixation consumes a lot of energy (Schulze *et al*., 2006). Similarly with the intensification of agriculture and usages of high analysis and sulphur free fertilizers, the crop productivity often reduced (Palsaniya and Ahlawat, 2009; Choudhary *et al*., 2016). Sulphur is an integral component of S containing amino acids and ferredoxin, an iron-sulphur protein occurring in the chloroplasts. Ferredoxin has a significant role in nitrogen dioxide and sulphate reduction and assimilation of N by root nodule and free living N-fixing soil bacteria (Scherer, 2008; Scherer *et al*., 2008). The production and productivity of fodder sorghum + cowpea – chickpea, a prominent fodder - food cropping system in central India is low due to imbalanced and inadequate use of nutrients. The information on integrated use of organics, P and S particularly in fodder – food cropping systems is meagre; therefore, the present investigation was carried out to find out best dose of phosphorus and sulphur in conjunction with FYM for obtaining higher yield and economic return from fodder sorghum + cowpea – chickpea cropping system besides sustaining soil fertility.

Materials and Methods

Experimental site and designing: A field experiment was conducted at Central Research Farm, IGFRI Jhansi (25°27' N latitude and 78°35' E longitude, and 271 m above mean sea level) during 2010 to 2012. The soil at study site had pH (1:2 soil: water) 6.90, electrical conductivity (1:2 soil: water) 0.13 dS per m, organic carbon 7.2 g kg^{-1}, bulk density 1.25 Mg m^{-3} and clay loam texture. Initial available nitrogen, phosphorus, potassium and sulphur content of experimental site were 227.5, 23.9, 159.7 and 31.7 kg ha^{-1}, respectively. Treatments comprising of two levels of organic manure (no FYM and 5 t FYM ha^{-1}), three levels of phosphorus (0, 30 and 60 kg P_2O_5 ha^{-1}) and two levels of sulphur (0 and 20 kg S ha^{-1}) were tested in randomized block design (RBD) with three replications in fodder sorghum + cowpea - chickpea cropping system. Phosphorus and sulphur were applied through DAP and elemental sulphur, respectively. Fodder sorghum (*cv*. PC-6) and cowpea (*cv*. BL-1) were sown in intercropping system with 1:1 ratio during first fortnight of July and chickpea (*cv*. Awarodhi) was sown during fourth week of November to first week of December. Crops were sown at 30 cm row to row spacing under seasonal rainfed condition. During *Kharif* season no irrigation was applied, however, during *Rabi* two irrigations at critical crop growth stage (branching and podding stage) were applied. Except nutrient, as per treatment, crops were grown with recommended package of practices (Prasad, 2014).

Observations and statistical analysis: Observations on various parameters were recorded as per standard procedures. For system productivity, chickpea grain equivalent yield (CEY) was worked out by converting the fodder yield of sorghum + cowpea and chickpea straw yield on the basis of marketable price rate of each component and chickpea grain and expressed in kg ha^{-1}. The equivalent yield was calculated as under;

$$CEY = \frac{Yield\ of\ fodder\ sorghum\ (t^{-1}) \times Price\ of\ fodder\ (₹\ t^{-1})}{Price\ of\ chickpea\ (₹\ t^{-1})}$$

Various nutrient use efficiencies viz., agronomic nutrient use efficiency, ANUE (kg yield kg^{-1} nutrient applied), physiological nutrient use efficiency, PNUE (kg grain kg^{-1} nutrient uptake) and apparent nutrient recovery, ANR (%) were worked out on the basis of system productivity (chickpea equivalent yield) as per formula given by Duncan and Baligar (1990):

Table 1. Influence of nutrient management in sorghum + cowpea - chickpea cropping system on yield and nutrient use efficiencies (pooled data of 2 years)

Nutrient management	System productivity (CEY, t ha^{-1})	ANUE, kg CEY kg^{-1} nutrient applied	PNUE, kg CEY kg^{-1} nutrient uptake	ANR (%)
Organic manure				
No FYM	2.66	-	-	-
5 t FYM ha^{-1}	3.04	8.8	11.8	70.2
SEm$\pm$	0.04	-	-	-
CD ($P \leq 0.05$)	0.11	-	-	-
Phosphorus levels				
No P_2O_5	2.43	-	-	-
30 kg P_2O_5 ha^{-1}	2.99	9.4	146.7	6.4
60 kg P_2O_5 ha^{-1}	3.12	5.8	109.0	5.3
SEm$\pm$	0.05	-	-	-
CD ($P \leq 0.05$)	0.14	-	-	-
Sulphur levels				
No S	2741	-	-	-
20 kg S ha^{-1}	2956	5.4	87.0	6.2
SEm$\pm$	0.04	-	-	-
CD ($P \leq 0.05$)	0.11	-	-	-

Note: Average N supplied with the application of 5 t FYM ha^{-1} was 23 kg N ha^{-1} season^{-1} (27 kg N ha^{-1} season^{-1} during 2010-11 and 19 kg N ha^{-1} during 2011-12)

Selling rates: Chickpea grain ₹ 21000 & 28000 t^{-1}, chickpea stover ₹ 1000 &1500 t^{-1} and green fodder ₹ 750 & 1000 t^{-1} for the year 2010-11 and 2011-12, respectively

Agronomic nutrient use efficiency (ANUE in kg CEY kg^{-1} nutrient applied) $= \frac{Y_t - Y_c}{N_8}$

Apparent nutrient recovery (ANR in kg nutrient uptake kg^{-1} nutrient applied) $= \frac{U_n - U_c}{N_8}$

Physiological nutrient use efficiency (PNUE in kg dry matter kg^{-1} nutrient uptake) $= \frac{Y_t - Y_c}{U_n - U_c}$

Where,

Y_t is the CEY in fertilized plot (kg ha^{-1})

Y_c is the CEY from controlled plots (kg ha^{-1})

N_a is the amount of nutrient applied (kg ha^{-1})

U_t is nutrient uptake in fertilized treatment (kg ha^{-1})

U_c is nutrient uptake in unfertilized treatment (kg ha^{-1})

Nutrient use efficiency of FYM was worked out on the basis of N content that was 5.4 and 3.8 kg N t^{-1} FYM, respectively during the year 2010-11 to 2011-12. The chemical composition of applied FYM during the year 2010-11 to 2011-12 was 0.54 and 0.38% N, 0.31 and 0.23% P_2O_5 and, 0.49 and 0.57% K_2O, respectively. To know soil nutrient status, the soil samples (0-15 cm) were collected and analysed for organic carbon, available N, P, K and S adopting standard analytical methods (Singh *et al.,* 1999). Data obtained from all observations were statistically analyzed in randomized block design using the technique of analysis of variance (ANOVA). The differences between the treatment means were tested as to their statistical significance with appropriate critical difference (CD) value at 5% level of probability using software SAS.

Results and Discussion

System productivity: Pooled data showed that application of FYM, phosphorus and sulphur significantly increased the productivity of fodder sorghum + cowpea – chickpea cropping system (Table 1). Application of 5 t FYM ha^{-1} in each season recorded 3.04 t ha^{-1} CEY of the system which was 14.3% higher over no FYM application. Kumar *et al.* (2005) also reported that application of FYM either to *Kharif* crop or *Kharif* and *Rabi* crop both increased the system productivity by 7.7%. Similarly, Gawai and Pawar (2006) also reported the significant increase in forage production due to residual effect of FYM in integrated nutrient management of sorghum – chickpea cropping sequence under irrigated conditions. Pooled data of 2 years field study revealed that although application of 60 kg P_2O_5 ha^{-1} recorded highest CEY (3.12 t ha^{-1}) but application of 30 kg P_2O_5 ha^{-1} produced significantly higher (23.3%) system productivity in terms of chickpea grain equivalent yield over control and at par yield with application of 60 kg P_2O_5 ha^{-1} . The dose of P application observed in this study was less than the amount reported by other workers. Siag (1995) reported linear increase in grain yield with P application up to 60 kg P_2O_5 ha^{-1} while Patel and Kotecha (2008) reported 12.4% increase in dry matter yield of forage sorghum with 80 kg P ha^{-1} over control. Chickpea supplied with 20 kg S ha^{-1} produced 2.96 t ha^{-1} chickpea grain equivalent yield which was significantly higher (7.8%) over control (no sulphur application). The increase in yield might be due to involvement of S in synthesis of sulphur containing amino acids, carbohydrates metabolism, protein synthesis, energy transformation and chlorophyll synthesis. Such trends of system productivity are attributed to the effect of treatments on the yield of individual component crops of the system. Similar findings were also reported by Palsaniya and Ahlawat (2009) and Srinivasarao *et al.* (2010).

Nutrient use efficiency: Adequate supply of nutrients through suitable source play an important role in physiological and developmental processes of plant life and the favourable effect of these important nutrients have accelerated the growth processes of the crop. Average agronomic nutrient use efficiency (ANUE) and physiological nutrient use efficiency (PNUE) of 5 t FYM ha^{-1} application was 8.81 and 70.24 kg chickpea equivalent grain yield kg^{-1} N applied and uptake, respectively through FYM (Table 1). The apparent nutrient recovery (ANR) for FYM application was 70.24%. Higher availability of nutrients due to increased microbial activity with FYM application probably led to improvement in biomass and grain yield, which consequently led to higher ANUE, PNUE and ANR. Over the successive phosphorus levels, application of 30 kg ha^{-1} recorded higher ANUE, PNUE and ANR compared to its higher doses (Table 1). The agronomic nutrient use efficiency was 9.41 and 5.77 kg chickpea equivalent grain kg^{-1} P_2O_5 applied at phosphorus levels of 30 and 60 kg ha^{-1}, respectively. The respective values for PNUE were 146.75 and 108.98 kg chickpea equivalent grain per kg P_2O_5 uptake. The apparent nutrient recovery (ANR) for 30 and 60 kg P_2O_5 ha^{-1} application was 6.42 and 5.29%, respectively. The declining rate of yield increase with successive higher level of applied phosphorus was responsible for lower ANUE under higher levels of P_2O_5 application. Similarly, decline in PNUE at successive levels might be ascribed to greater increase in phosphorus uptake of applied at 60 kg P_2O_5 ha^{-1}. Despite the higher phosphorus value recorded at higher level of P_2O_5, utilization of applied

Table 2. Nutrient uptake by fodder sorghum + cowpea – chickpea cropping system as influenced by nutrient management (pooled data of 2 years)

Nutrient management	Nitrogen uptake (kg ha^{-1})			Phosphorus uptake (kg ha^{-1})		
	Sorghum + cowpea	Chickpea	System	Sorghum + cowpea	Chickpea	System
Organic manure						
No FYM	183.4	39.6	223.0	13.4	3.8	17.2
5 t FYM ha^{-1}	206.8	48.5	255.3	14.7	4.7	19.4
SEm$\pm$	2.9	1.1	3.0	0.2	0.1	0.2
CD ($P \leq 0.05$)	8.5	3.1	8.9	0.7	0.3	0.7
Phosphorus levels						
No P_2O_5	166.6	35.0	201.6	11.7	3.2	14.9
30 kg P_2O_5 ha^{-1}	201.9	46.9	248.8	14.4	4.3	18.7
60 kg P_2O_5 ha^{-1}	216.8	50.2	267.0	16.1	5.1	21.2
SEm$\pm$	3.6	1.3	3.7	0.3	0.1	0.3
CD ($P \leq 0.05$)	10.4	3.8	10.9	0.8	0.4	0.9
Sulphur levels						
No S	185.9	41.9	227.8	13.4	4.0	17.4
20 kg S ha^{-1}	204.3	46.2	250.5	14.8	4.4	19.2
SEm$\pm$	2.9	1.1	3.0	0.2	0.1	0.2
CD ($P \leq 0.05$)	8.5	3.1	8.9	0.7	0.3	0.7

Nutrient management	Potassium uptake (kg ha^{-1})			Sulphur uptake (kg ha^{-1})		
	Sorghum + cowpea	Chickpea	System	Sorghum + cowpea	Chickpea	System
Organic manure						
No FYM	170.9	32.7	203.6	8.6	7.4	16.0
5 t FYM ha^{-1}	185.0	38.7	223.8	9.4	9.2	18.6
SEm$\pm$	2.6	0.9	2.7	0.1	0.2	0.2
CD ($P \leq 0.05$)	7.8	2.7	8.0	0.4	0.6	0.7
Phosphorus levels						
No P_2O_5	155.4	30.1	185.5	7.7	6.8	14.6
30 kg P_2O_5 ha^{-1}	183.2	37.6	220.7	9.3	8.8	18.1
60 kg P_2O_5 ha^{-1}	195.3	39.5	234.9	10.1	9.2	19.3
SEm$\pm$	3.2	1.1	3.3	0.2	0.2	0.3
CD ($P \leq 0.05$)	9.5	3.3	9.8	0.5	0.7	0.9
Sulphur levels						
No S	170.6	34.0	204.6	8.4	7.7	16.1
20 kg S ha^{-1}	185.4	37.4	222.8	9.7	8.8	18.6
SEm$\pm$	2.6	0.9	2.7	0.1	0.2	0.2
CD ($P \leq 0.05$)	7.8	2.7	8.0	0.4	0.6	0.7

phosphorus was poor at higher P_2O_5 level. The ANUE and PNUE with the application of sulphur were 5.37 and 87.04 kg chickpea equivalent grain kg^{-1} S applied and uptake, respectively. The positive response on fodder yields to sulphur fertilization were also reported by Hazra and Tripathi (1998). They reported that the response of green fodder yield kg kg^{-1} S at optimum level of S application was 87 and 85 with sorghum and cowpea, respectively. The apparent nutrient recovery (ANR) for 20 kg S ha^{-1} application was 6.17%.

Nutrient uptake: The N, P, K and S uptake by sorghum + cowpea – chickpea also recorded the similar trend to that of fodder and grain yield (Table 2). FYM, phosphorus and sulphur application significantly increased N, P, K and S uptake by fodder sorghum + cowpea, chickpea and system in both the years. Pooled data of 2 years study revealed that 12.8, 9.8, 8.2 and 9.5% higher N, P, K and S uptake by sorghum + cowpea was with the application of 5 t FYM ha^{-1} as compared to no FYM while the respective increase in above nutrient uptake by

Table 3. Soil nutrient status as influenced by nutrient management in fodder sorghum + cowpea – chickpea cropping system after completion of 2 years field experimentation.

Nutrient management	Organic Carbon (%)			Available N (kgha^{-1})			Available P (kg ha^{-1})			Available K (kg ha^{-1})			Available S (kg ha^{-1})		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Organic manure															
No FYM	0.72	0.735	0.015	227.5	227.2	(-) 0.3	23.9	25.5	1.6	159.7	166.3	6.6	31.7	30.2	(-)1.5
5 t FYM ha^{-1}	0.72	0.782	0.062	227.5	245.9	18.4	23.9	26.5	2.6	159.7	172.4	12.7	31.7	32.5	0.8
SEm$\pm$	-	0.012	-	-	2.5	-	-	0.2	-	-	1.5	-	-	0.7	-
CD ($P \leq 0.05$)	-	0.037	-	-	7.7	-	-	0.7	-	-	4.4	-	-	1.9	-
Phosphorus levels															
No P_2O_5	0.72	0.719	(-) 0.001	227.5	225.7	(-) 1.8	23.9	24.0	0.1	159.7	168.4	8.7	31.7	30.2	(-) 1.0
30 kg P_2O_5 ha^{-1}	0.72	0.755	0.035	227.5	240.0	12.5	23.9	26.2	2.3	159.7	169.9	10.2	31.7	31.0	(-) 0.70
60 kg P_2O_5 ha^{-1}	0.72	0.801	0.081	227.5	244.0	16.5	23.9	27.8	3.9	159.7	169.7	10.0	31.7	32.9	1.19
SEm$\pm$	-	0.015	-	-	3.1	-	-	0.3	-	-	1.8	-	-	0.8	-
CD ($P \leq 0.05$)	-	0.045	-	-	9.0	-	-	0.9	-	-	NS	-	-	NS	-
Sulphur levels															
No S	0.72	0.749	0.029	227.5	233.7	6.2	23.9	25.5	1.6	159.7	169.6	9.9	31.7	28.4	(-) 3.32
20 kg S ha^{-1}	0.72	0.768	0.048	227.5	239.4	11.9	23.9	26.5	2.6	159.7	169.2	9.5	31.7	34.4	2.66
SEm$\pm$	-	0.012	-	-	2.5	-	-	0.2	-	-	1.5	-	-	0.7	-
CD ($P \leq 0.05$)	-	NS	-	-	NS	-	-	0.7	-	-	NS	-	-	1.9	-

Note: A: Initial nutrient status, B: nutrient status after completion of 2 years study and C: Actual gain or loss (B-A) chickpea was 22.6, 23.9, 18.5 and 24.8%. Similarly, N, P, K and S uptake by the system was 14.5, 13, 9.9 and 16.6% higher with 5 t FYM ha^{-1} as compared to no FYM. In case of phosphorus nutrition, 2 years pooled data showed that application of 60 kg P_2O_5 ha^{-1} recorded significantly higher uptake of N, P, K and S by fodder crops (sorghum + cowpea) and whole cropping system as compared to control and 30 kg P_2O_5 ha^{-1} (Table 2).The uptake by chickpea also showed similar trend as compared to control but only P uptake was significantly different at 30 and 60 kg P_2O_5 ha^{-1}. Sulphur application had also significantly increased S uptake by fodder sorghum + cowpea, chickpea and system (Table 2). The N, P, K and S uptake by sorghum + cowpea was 9.9, 10.3, 8.7 and 16.3% higher with 20 kg S ha^{-1} as compared to no S while the respective increase in above nutrient uptake by chickpea was 10.4, 11.6, 9.9 and 14.4%. Similarly, N, P, K and S uptake by the system was 10, 10.6, 8.9 and 15.4% higher with 20 kg S ha^{-1} as compared to no S. Karforma *et al*. (2016) also observed that total removal of N, P and K was highest by the crop having 50% RDN through FYM + 50% RDN through fertilizer + Azotobacter in fodder maize – rapeseed system. Similarly, Choudhary and Prabhu (2016) also recorded higher nutrient uptake in fodder oat under 100% RDF.

Soil nutrient status: Fertility status of soil influenced significantly due to different treatments (Table 3). Soil organic carbon, available NPK and S were significantly higher with the application of FYM. Organic carbon content and available NPK and S status of soil with the application of FYM was 0.782% and 245.9, 26.47, 172.73 and 32.5 kg ha^{-1}, respectively. With the application of phosphorus 30 and 60 kg P_2O_5 ha^{-1}, soil OC and available N and P status enhanced significantly than without phosphorus application. Application of sulphur also improved available P (26.52 kg ha^{-1}) and available S (34.36 kg ha^{-1}) status of soil than control. For a given soil and climatic condition, soil organic carbon is the function of agricultural practices and kind and amount of the plant residue returned to soil. Positive impact of integrated nutrient management of the cropping system on soil fertility status may be attributed to residual effect of applied nutrients and increased turnover of roots and other crop residues associated with increased productivity of the cropping system (Ghosh *et al*., 2012; Karforma *et al*., 2016).

Conclusion

On the basis of two years field study it was concluded that for achieving higher system productivity, enhanced nutrient uptake, increased nutrient use efficiency and improved soil health, 5 t farm yard manure (FYM), 30 kg phosphorus and 20 kg sulphur ha^{-1} should be applied during both the seasons (*Kharif* and *Rabi*) in fodder sorghum + cowpea - chickpea cropping system under semi-arid climate of central India.

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