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SOIL PHYSICO-CHEMICAL PROPERTIES, NUTRIENT UPTAKE AND SOIL NUTRIENT STATUS UNDER INTEGRATED NUTRIENT MANAGEMENT IN KHARIF SORGHUM (*SORGHUM BICOLOR* L. MOENCH

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ABSTRACT
The present investigation carried out under field condition during 2012 and 2013 with kharif sorghum and rabi chickpea cropping system at ARI Main Farm, Rajendranagar, Hyderabad. Experimental site was clay loam in texture, slightly alkaline in reaction, low in organic carbon as well as low available nitrogen, medium in the available phosphorus and high in available potassium. The experiment was laid out in split plot design with three main treatments and three sub-treatments, replicated thrice. There are 9 treatments which included application of three different manures as a main treatments *viz*., Farm Yard Manure (FYM) Vermicompost, (VC) and Neem Seed Cake (NSC) and their combinations with 0%, 50% and 100% RDF as sub plot treatments. Manures were applied as the recommended doses @ 5 t $ha^{-1}$for FYM and 2.5 t ha^{-1} for VC and NSC. The data recorded for two years indicated that nutrient uptake (N, P and K) under integrated nutrient management in kharif sorghum during both years was significantly increased as influenced by VC, NSC and FYM, in the main plot, 0%, 50%, 100% RDF in the subplot while interactions showed non significant differences concerning the previous parameters.

KEYWORDS: kharif sorghum, rabi chickpea, cropping system, Farm Yard Manure, Neem Seed Cake.

INTRODUCTION
In crop production, nutrient availability from manure has been recognized for many centuries. Before the introduction of inorganic fertilizer manure was the primary source of nutrients for crop production. Recently there has been a renewed interest in use of farmyard manure. This interest is attributed to concerns for maintaining sustainable agricultural production while preserving the environment. For better utilization of resources and to produce crops with less expenditure, INM is the best approach in which combined usage of organic and inorganic sources of plant nutrient not only pushes the production and profitability of field crops, but also helps in maintaining the permanent fertility status of the soil Vidyavathi *et al*. (2012). In India, there is sufficient availability of organic manures like animal dung manure (791.6 mt), crop residues (603.5 mt), green manure (4.50 m ha), rural compost (148.3 mt), city compost (12.2 mt) and biofertilzier (0.41mt) (Bhattacharya and Chakraborthy, 2005) and these may become a good substitute of chemical fertilizers to maintain the soil physico-chemical and biological properties. Integrated use of organic and inorganic through FYM, crop residues of wheat and green manuring of dhaincha improved the organic carbon and cation exchange capacity. Available N, P_2O_5, K_2O and S status of soil increased significantly with organic sources of nutrients over their initial (Sharma *et al*., 2001). Pandey *et al*. (2006) reported that application of manures, irrespective of sources and rates recorded significantly higher soil organic carbon, N, P_2O_5 and K_2O compared to control. Kadam *et al.* (2010) reported that at harvest of soybean, the soil nutrient status was influenced by the application of organic nitrogen sources along with fulvic acid sprays. This is ascribed to presence of soybean crop which enhances the available N status of soil by nodulation.

MATERIALS & METHODS
The field experiment was conducted in black clay loam soil in *kharif* (rainy) and *rabi* seasons of 2012 and 2013 at the Main Farm of Agricultural Research Institute (ARI), Rajendranagar, Hyderabad. The farm is geographically situated at an altitude of 542.6 m above Mean Sea Level (MSL) at 18.5° North latitude and 77.5° East longitude. Experimental site was clay loam in texture, slightly alkaline in reaction (pH), low in organic carbon (O.C) as well as low available nitrogen (N), medium in the available phosphorus (P) and high in available potassium (K) Table 1. The experiment was laid out in split plot design with three main treatments and three sub-treatments, replicated thrice. There are 9 treatments which included application of three different manures as a main treatments *viz*., Farm Yard Manure (FYM) Vermicompost, (VC) and Neem Seed Cake (NSC) and their combinations with 0%, 50% and 100% RDF as sub plot treatments. Manures were applied as the recommended doses @ 5 t $ha^{-1}$for FYM and 2.5 t ha^{-1} for VC and NSC.

TABLE 1: Physio-chemical properties of the experimental site soil

No.	Particulars	Values	Method of analysis
1	Physical properties		
1	Particles size distribution		
a	Sand (%)	28.0	Bouyoucos hydrometer method (Piper, 1966)
b	Silt (%)	27.4	
c	Clay (%)	48.7	
d	Bulk density (g cm^{-3})	1.21	
2	Textural class	Clay	
Chemical properties			
1	Soil reaction pH	8.04	Combined electrode method (Jackson, 1973)
2	Electrical Conductivity EC(dS m^{-1})	1.05	Conductivity Meter (Jackson, 1973)
3	Soil Organic carbon (%)	0.21	Walkley and Black modified method (Walkley and Black, 1984)
4	Available nitrogen (kg ha^{-1})	197.95	Alkaline permanganate method (Subbaiah and Asija, 1956)
5	Available phosphorus (k ha^{-1})	28.7	Olsen's extractant method (Olsen *et al*., 1954)
6	Available potassium (kg ha^{-1})	229.81	Flame photometer method (Jackson, 1973)

RESULTS & DISCUSSION

Effect of integrated nutrient management on nutrient uptake

Uptake of nutrient from soil and external inputs is the product of accumulative concentration of labile forms of nutrient in soil solution, soil physico-chemical properties and phytomass as shoot and root.

Nitrogen uptake (kg ha^{-1})

The data pertaining to nitrogen uptake by *kharif* sorghum at 30, 60 and 90 days after sowing (DAS) and at harvest as influenced by different treatments were presented in Table- 2. Nitrogen uptake (kg ha^{-1}) differed significantly as influenced by application of VC in the main plot at different sampling times *viz*. 60 and 90 DAS but at 30 DAS the uptake showed non-significant difference while at harvest uptake by stover only observed significant with VC compared to FYM and NSC in the two seasons. This might be due to the role of FYM and VC in releasing N and improving N availability in soil Singh *et al*. (2008). The application of inorganic fertilizers, in the sub plot 100 % RDF showed significant difference when compared to 0 % and 50 % RDF at all sampling time *viz*. 30, 60, 90 and at harvest whether by stover or grain. This might be due to rapid increase in dry matter accumulation with RDF of NPK supply. Similar trend in the uptake pattern of nitrogen was also noticed by Tripathi and Karla (1980). Further, increase in nitrogen uptake was due to efficient root system with improved permeability coupled with better absorption due to better availability of nutrients in the soil solution (Sumathi and Rao, 2007). The data regard the interaction between the treatments for nitrogen uptake showed no significant differences in the two years of experiment but however, with every increase in fertilizers RDF application rates at the two levels of NPK, *viz*. 50 %; and 100 % during the two years resulted in increase in nitrogen uptake all through sampling times.

TABLE 2: Effect of integrated nutrient management on nitrogen uptake (Kg ha^{-1}) of kharif sorghum

	30 DAS		60 DAS		90 DAS		At harvest			
							Stover		Grain	
Treatments details	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Main plot- organic nutrients										
FYM @ 5.0 t/ha^{-1}	7.8	8.3	70.3	70.6	196.6	302.6	40.3	72.5	24.9	25.4
VC @ 2.5 t/ha^{-1}	10.1	11.1	82.2	84.5	245.9	341.1	47.5	75.8	26.6	25.9
NSC @ 2.5 t/ha^{-1}	9.9	10.8	64.7	79.6	182.2	320.6	48.8	70.3	26.4	25.5
SEm+	0.8	1.1	1.0	2.7	4.8	5.9	2.0	0.2	0.7	0.2
CD (0.05)	NS	NS	3.0	7.8	14.3	17.8	5.7	0.5	NS	NS
C.V% main plot	16.6	13.2	12.6	21.1	15.2	13.5	15.2	11.4	16.5	15.1
Sub plot chemical fertilizer										
0% RDF	7.4	6.1	64.0	61.4	185.9	228.4	34.4	68.2	21.7	23.3
50% RDF	10.7	10.3	72.9	83.5	197.5	296.2	44.6	73.9	27.3	25.6
100% RDF	12.5	12.7	86.6	110.6	244.9	466.7	59.5	76.5	28.3	27.1
SEm+	1.1	1.0	3.0	7.3	3.6	22.0	3.3	0.3	1.1	0.3
CD (0.05)	3.1	3.1	8.9	21.9	10.8	65.8	9.9	1.0	3.2	0.8
C.V% sub plot	17.3	12.1	12.1	14.1	15.1	10.5	11.9	11.3	12.6	13.2

+0% = Zero RDF, +50%= +50% RDF and +100%= +100% RDF, NS= Not Sign. VC = Vermicompost, NSC= Neem Seed cake and FYM= Farm Yard Manure

Phosphorus uptake (kg ha^{-1})

The data pertaining to phosphorus (P_2O_5) uptake at 30, 60, 90 DAS and at harvest as influenced by different treatments is presented in Table 3, the results in the main plot at 30, 60 and 90. DAS and at harvest, showed that P_2O_5 uptake was not significantly differed except at 90 DAS and at harvest by stover in the year 2013 which only showed significant difference by application of VC and NSC. Pandey *et al*. (2006) reported that application of manures irrespective of sources and rates recorded significantly higher soil N, P_2O_5 and K_2O as compared to control. The data concerning P_2O_5 uptake in the subplot differed significantly with application of fertilizers @ 50 % and 100 % RDF when compared to 0 % RDF at 30, 60 and 90 days after sowing while at harvest only stover differed significantly, but uptake by grain showed non-significant difference for the two years. It was also observed that P_2O_5 uptake increased with increasing RDF application rate however, the increase in the uptake of P_2O_5 could be attributed to chemical and biological process involved due to integrated effects of RDF or RDF + organic sources as it was well known that application of nitrogen increases the availability of P_2O_5 as well because during decomposition of organic manure various organic acids were produced which solubilized phosphatase and other phosphate bearing minerals and thereby lowers the phosphate fixation and increase its availability. Manna *et al*. (2006) also reported that available phosphorus content increased due to addition of FYM over initial and control. Available N, P_2O_5, K_2O and S status of soil increased significantly with organic sources of nutrients over their initial levels (Sharma *et al*., 2001). The interaction between the treatments for phosphorus uptake showed non-significant differences in the two seasons of experiment in P_2O_5 uptake.

TABLE 3: Effect of integrated nutrient management on phosphorous uptake (Kg ha^{-1}) of kharif sorghum

Treatments details	30 DAS		60 DAS		90 DAS		At harvest Stover		At harvest Grain	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Main plot organic nutrients										
FYM @ 5.0 t/ha^{-1}	1.0	1.9	6.4	6.6	16.7	18.5	14.6	13.8	7.5	4.8
VC @ 2.5 t/ha^{-1}	1.2	2.0	6.4	6.2	18.3	22.1	14.7	17.7	7.6	4.9
NSC @ 2.5 t/ha^{-1}	1.2	1.9	6.2	6.4	18.7	19.3	16.5	15.0	8.0	5.0
SEm+	0.1	0.1	0.1	0.2	0.7	0.3	0.7	0.4	0.2	0.2
CD (0.05)	NS	NS	NS	NS	NS	0.8	NS	1.1	NS	NS
C.V% main plot	12.2	16.9	16.7	14.0	13.1	8.1	16.0	14.0	14.9	15.3
Sub plot chemical fertilizer										
0% RDF	0.9	1.4	5.1	5.6	15.2	15.8	11.6	11.7	6.9	4.5
50% RDF	1.2	2.0	6.3	7.4	18.0	19.5	15.2	15.5	7.5	5.1
100% RDF	1.3	2.4	6.6	7.6	20.5	23.6	18.2	19.1	8.4	5.1
SEm+	0.1	0.2	0.2	0.6	0.7	0.7	1.2	1.1	0.6	0.3
CD (0.05)	0.3	0.5	0.4	1.7	2.1	2.1	3.5	3.3	NS	NS
C.V% sub plot	21.7	12.8	16.9	21.0	11.6	10.2	23.0	20.2	22.6	17.2

+0% = Zero RDF, +50%= +50% RDF and +100%= +100% RDF, NS= Not Sign. VC = Vermicompost, NSC= Neem Seed cake and FYM= Farm Yard Manure

TABLE 4: Effect of integrated nutrient management on potassium uptake (Kg ha^{-1}) of kharif sorghum

Treatments details	30 DAS		60 DAS		90 DAS		At harvest Stover		At harvest Grain	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Main plot organic nutrients										
FYM @ 5.0 t/ha^{-1}	23.9	30.2	138.1	139.1	383.5	425.2	336.7	456.8	421.3	427.0
VC @ 2.5 t/ha^{-1}	25.7	32.0	141.7	163.5	385.7	470.6	351.2	468.4	422.2	425.4
NSC @ 2.5 t/ha^{-1}	25.0	29.9	139.5	149.1	377.9	443.9	334.7	404.8	429.3	431.8
SEm+	0.9	0.8	1.3	1.5	1.8	2.9	5.8	3.3	3.3	4.2
CD (0.05)	NS	NS	NS	4.3	5.4	8.5	NS	9.8	NS	NS
C.V% main plot	15.17	15.6	5.35	12.5	10.8	13.7	9.5	14.3	14.5	5.7
Sub plot chemical fertilizers										
0% RDF	19.9	25.4	120.3	126.6	337.7	408.1	316.9	395.6	414.1	416.1
50% RDF	27.6	31.6	140.1	155.9	384.3	455.9	336.5	447.2	429.0	433.4
100% RDF	29.2	35.3	155.9	169.1	420.1	475.7	365.2	487.2	438.1	444.8
SEm$\pm$	2.3	2.1	2.3	2.9	6.4	8.1	4.6	5.7	4.8	4.9
CD (0.05)	7.2	6.1	6.9	9.0	18.4	24.3	13.7	17.7	14.3	14.7
C.V% sub plot	21.4	20.1	15.0	15.9	9.1	11.4	14.0	13.9	13.4	13.4

+0% = Zero RDF, +50%= +50% RDF and +100%= +100% RDF, NS= Not Sign. VC = Vermicompost, NSC= Neem Seed cake and FYM= Farm Yard Manure

Potassium uptake (kg ha^{-1})

The data pertaining to potassium (K_2O) uptake at 30, 60, 90 days after sowing (DAS) and at harvest as influenced by different treatments was given in Table 4. At 30 DAS potassium uptake was not differed significantly between different organic nutrients however, at 60 and 90 DAS potassium uptake was significantly higher with VC, FYM and NSC. Similar results were also reported by Pandey *et al*. (2006), that application of manures, irrespective of sources and rates recorded significantly higher soil organic carbon, N, P_2O_5 and K_2O compared to control. Potassium uptake by stover and grain for subplot treatments with 0 %, 50 % and 100 % RDF at different sampling times, (30, 60, 90 and at harvest) was significantly affected potassium uptake for two seasons. It was also observed as in nitrogen and phosphorus that with every successive increase in application rates of chemical fertilizers (RDF) during the two seasons there is an increase of Potassium uptake but however there are no significant differences between the two level of RDF at 50 % RDF and 100 % RDF. Pagaria *et al*. (1995) reported that, uptake of K was increased with full dose of NPK + 10 t ha^{-1} FYM compared to control. The interaction between the treatments showed non-significant differences in the two the years of experiment in potassium uptake.

Effect of integrated nutrient management on post harvet soil properties after *kharif* sorghum Physico-Chemical properties

Soil reaction (pH), electric conductivity (EC) and soil organic carbon

The effect of manure and fertilizers treatments on soil pH and electrical conductivity (EC) in *kharif* sorghum based cropping system is given in Table 5. Soil reaction (pH) was slightly changed (non-significantly) from its initial value (8.04) and it was found slightly alkalized (8.19) at the end of second cropping season by application of NSC. However, application of sole organic manures (FYM, VC and NSC) and/or when integrated with chemical fertilizers (RDF at 50% and 100%) made slight change in soil reaction. On the other hand, variation in type, rate of organic source and management caused slight alteration in soil pH after first and second cropping season. NSC and NSC+100 % RDF application caused highest rise in soil pH after first and second cropping season when compared with the other organic sources. Similarly Hakeem *et al*. (2007) observed that application of NSC and biofertilizers increased OC, pH and electrical conductivity (EC) slightly. Soil pH depends mainly on the quantity and quality of applied fertilizers with residual acidity and buffering capacity of the soil besides other factors. Among the fertilizers, continuous use of ammonium sulphate and urea lower soil pH due to high residual acidity. Sarkar *et al*., 1989; Welchunma *et al*., 1990; Deepak Kher and Minhas, 1991; Hetrick and Schwab, 1992; Nambiar *et al*., 1989, while reviewing the long term experiments conducted in various parts of India were also made similar observations.

Related to interaction of treatments, application of organic nutrients+100 % RDF caused increase in PH when compared to organic nutrients +50 % RDF after two consecutive years. Singh and Wanjair (2012) found lowered pH of vertisol soil with integrated use of fertilizers and FYM. This was probably because of increased organic acids concentration after decomposition of organic matter. Adoption of integrated nutrient management did slight increase in electrical conductivity (E.C) of soil even after two years of experimentation. Poongothai *et al*. (2002) observed that there was no change in E.C of clay loam soil of Cauvery delta which received green leaf manure or FYM.

TABLE 5: Effect of integrated nutrient management on post harvest kharif sorghum soil properties

Treatments details	pH		E.C		O.C	
	2012	2013	2012	2013	2012	2013
Main plot organic nutrients						
FYM @ 5.0 t/ha^{-1}	8.07	8.16	1.10	1.23	0.31	0.43
VC @ 2.5 t/ha^{-1}	8.06	8.15	1.12	1.22	0.31	0.41
NSC @ 2.5 t/ha^{-1}	8.08	8.19	1.13	1.23	0.32	0.38
SEm+	0.02	0.02	0.03	0.02	0.01	0.02
CD (0.05)	NS	NS	NS	NS	NS	NS
CV% main plot	11.1	9.5	14.3	10.3	16.6	8.3
Subplot chemical fertilizers						
0% RDF	8.06	8.15	1.10	1.21	0.31	0.36
50% RDF	8.07	8.17	1.13	1.23	0.32	0.41
100% RDF	8.07	8.18	1.14	1.23	0.32	0.44
SEm$\pm$	0.05	0.03	0.015	0.04	0.012	0.014
CD (0.05)	NS	NS	NS	NS	NS	0.04
CV% sub plot	18.9	14.3	8.6	9.9	11.5	10.4

+0% = Zero RDF, +50%= +50% RDF and +100%= +100% RDF, NS= Not Sign. VC = Vermicompost, NSC= Neem Seed cake and FYM= Farm Yard Manure

Soil organic carbon (SOC) concentration

Organic matter is the life center for all living organisms in soil *i.e*., microflora, fauna and for high plants. It's an integrated part of soil that affects its physical and chemical properties to a greater extent. Thus much emphasis was placed on the organic matter content of a soil as an indicator of soil productivity and fertility.

The important and significance of soil organic carbon in crop production and its sustainability along with ecological equilibrium were widely dealt in scientific arena. In present study, integrated nutrient management showed non-insignificant but slight improvement in soil organic carbon SOC for the two seasons (Table 6). during 2013 FYM registered the highest SOC (0.43) when compared to VC (0.41) and NSC (0.38) application while in sub plot treatments 100 % RDF was slightly increased soil organic carbon when compared to 50 % RDF and 0 % RDF. Similar trend was reported in the interaction between treatments in which NSC+100 % and FYM +100 % RDF gave the highest soil organic carbon (0.44) followed by NSC+50 % RDF (0.43). Generally, the organic carbon concentration increases by increasing the rate of fertilizers application. Slight but consistent increase in organic carbon had been reported by Sundra Rao and Anoop Krishnan (1963) even under tropical condition.

Available nitrogen, phosphorus and potassium post harvesting *kharif* sorghum

The soil nitrogen along with organic manure plays an important role in plant nutrition. The Indian soils were low in nitrogen because of tropical climate and phosphorus was one of essential nutrients for plant growth because it was vital component of substances in building block of genes and chromosomes. It plays an important role in every plant process that involves energy transfer, the total P-content in Indian soils ranges from 100 to 2000 ppm (Tandon, 1989), while, potassium considered to be one of the major three elements which plays an important role in enzymes activation, water and energy relations, translocation of assimilates, photosynthesis, protein and starch synthesis. During both the years, variation in the status of available NPK after completion of *kharif* sorghum showed non-significant difference in the main plot, subplot and interaction but after *rabi* chickpea they were consistent (Table 6). The interaction showed non-significant difference for the two seasons.

TABLE 6: Effect of integrated nutrient management on post harvest available NPK (Kg ha^{-1}) of kharif sorghum

Treatments details	N		P_2O_5		K_2O	
	2012	2013	2012	2013	2012	2013
Main plot organic nutrients						
FYM @ 5.0 t/ha^{-1}	255.3	261.5	42.4	49.6	318.6	330.1
VC @ 2.5 t/ha^{-1}	258.4	259.1	43.1	50.7	319.8	335.9
NSC @ 2.5 t/ha^{-1}	259.6	261.3	42.2	50.7	321.5	331.8
SEm $\pm$	1.6	1.2	0.5	0.4	1.0	2.1
CD (0.05)	NS	NS	NS	NS	NS	NS
CV% main plot	12.5	21.6	17.0	12.6	14.8	21.0
Subplot chemical fertilizers						
0% RDF	254.1	258.9	41.1	49.2	318.1	329.4
50% RDF	257.4	260.2	42.7	50.6	319.8	333.3
100% RDF	261.8	262.7	43.9	51.2	322.0	335.1
SEm$\pm$	2.6	1.3	1.0	0.8	1.5	2.0
CD (0.05)	NS	NS	NS	NS	NS	NS
CV% sub plot	7.1	11.5	8.3	13.0	11.0	12.0

+0% = Zero RDF, +50%= +50% RDF and +100%= +100% RDF, NS= Not Sign. VC = Vermicompost, NSC= Neem Seed cake and FYM= Farm Yard Manure

The results of available P_2O_5 following the preceding seasons INM treatments than that of the non-INM treatment, showed significant increase in the main plot and subplot for the two seasons while the interaction showed non-significant difference but available potassium in the main plot, subplot and interaction showed non-significant effect for the two years of experiment. Addition of VC, FYM and NSC in addition to NPK at 100 % or 50 % RDF might have conserved NPK and made available in due course by enhanced microbial activity. Increased retention and availability of NPK with the use of organic manure in cropping system have been reported by other researchers as well (Meelu *et al*., 1986; Meelu and Morris, 1988). By considering the sequence of *kharif* sorghum *rabi* chickpea as a whole, application of organic nutrients either FYM 5 t ha,$^{-1}$ VC @ 2.5 t ha^{-1} or NSC @ 2.5 t ha^{-1} in addition to 100 % RDF or 50 % RDF to sorghum had resulted in higher productivity of the sequence. Residual effect of this type of addition of organic manure had resulted in saving NPK recommended to chickpea crop in sequence. Kaleemulla Sharif (1984) reported relatively higher available N content in FYM. Similar results were also reported by Bouche *et al*. (1997) with VC. While, Somani and Saxena (1975) reported increase in P content with incorporation of wheat crop residues and farm yard manure. Generally, due to short experiment period the result showed non-significant differences between all treatments with available NPK after *kharif* sorghum *rabi* chickpea cropping system, however, slight positive variations in such parameters achieved after *rabi* chickpea. This might be due to the ability of chickpea as leguminous crop in fixing nitrogen biologically which enhanced availability of nitrogen, phosphors and potassium.

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