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Effects of Neem Seed Cake and Inorganic Fertilizer On The Nutrition of Sorghum At Samaru, Northern Nigeria.

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Abstract

Nutrient mining is one of the major threats facing food production in Africa, and inputs of nutrients are required to overcome this constraint. Field study was conducted in the experimental field of Institute for Agricultural Research, Ahmadu Bello University, Samaru-Zaria in the year 2009 and 2010 to evaluate the effect of neem seed cake (NSC) and NPK fertilizer on nutrition of sorghum. Treatments consisted of 4 levels of NSC (0, 1, 2 and 4tons ha^{-1}) and 4 levels of NPK fertilizer (0, ¼, ½ and full of recommended fertilizer rate of 64-32-32 for sorghum). All the sixteen treatments were laid down in randomized complete block design (RCBD) with three replicates using factorial concept. Sorghum seeds were planted two weeks after incorporation of NSC as appropriate and left for 3 weeks during which thinning and first doses of N was applied. After harvest, grain and stover yields, crude protein and tannin contents in grain were determined. Result obtained shows no significant grain and stover yield irrespective of treatment in the two years combined study. Plants treated with 2 ton ha^{-1} + full fertilizer rates gave highest grain yield while 4 ton ha^{-1} + full fertilizer rates recorded the highest stover yield. There was no significant increase in grain crude protein and tannin contents ($p< 0.05$) when all of the treatments were compared with control.

Keywords: *Neem seed cake, Inorganic fertilizer, Nutrition, Sorghum*

Introduction

Grain sorghum (*Sorghum bicolor L. Moench*) production in the savanna zone of Nigeria is limited by the deficiencies of a number of nutrient elements. Soils of this zone in northern Nigeria are generally low in native fertility (Heathcote and Stockinger, 1970). Consequently, under the subsistence or semi-intensive system of agriculture, the average yield of sorghum is generally low (below 0.8t/ha) (Egbe *et al.*, 2009). A possible avenue for yield improvement in this crop is through the use of adapted improved varieties and the use of organic and inorganic fertilizers (Buresh *et al*., 1997; FAO, 1999; Uyovbisere and Elemo, 2000). Lately, the use of local and readily available organic residues as soil amendment in sub-Saharan Africa to improve soil fertility and organic matter status is rapidly gaining widespread support (Agbenin *et al*., 1999).

However, literatures on the use of neem seed cake (NSC) as organic nutrients source on sorghum from this region are scarce. NSC is a by product of oil extraction and *azadiractin* isolation from the neem seed kernels. NSC was found to have a high manurial value and improve the growth of crop (Vanlauwe *et al*., 2001; Tarfa *et* al., 2001; Micheni *et al*., 2004). The addition of NSC to the soil improves the fertility by acting directly on its biological, physical and chemical properties which in turn activate the microbial biomass, improves soil structure, increase water holding capacity and aggregate stability (Vanlauwe *et al*., 2001; Tarfa *et* al., 2001; Micheni *et al*., 2004). NSC also acts as nitrification inhibitor to improve nitrogen use efficiency of mineral fertilizer (Kethar and Kethar, 1995). It was also reported that neem residues can serve as biopesticide in controlling many insects and weeds (Singh *et al*., 1991).

All sorghum varieties contain phenolic compounds, which can influence the colour, appearance and nutritive value of a diet, and they can be divided into three groups: acidic phenolic, flavanoids and tannins. The presence of tannin reduces the nutritional value of a diet, mainly due to a decrease in the use of protein and a reduction in activity of digestive enzymes (Haslam, 1981). In consequence, nitrogen retention in protein and use of amino acids are reduced due to the retention in protein digestibility (Mitaru *et al*., 1984; Elkin *et al*., 1995). The carbohydrates are also affected by tannin, possibly due to the formation of complex compounds which are difficult to digest (Mahamood and Smithard, 1993). Vitamins and minerals, especially those of the B complex, plus iron and calcium are all affected by the presence of tannin in the diet (Bagepalli *et al*., 1982; Chang *et al*., 1993).

The level of tannin in sorghum grains varies from 1.3 to 3.6 % in high tannin sorghum and from 0.1 to 0.7 % in low tannin sorghum (Myers *et al*., 1994). Hamid (2001) reported that low tannin sorghum increased protein content of grains. The increase in tannin content was attributed to solubilization which occurred as the grain took up water or to synthesis of polyphenols during germination. Although, early literature identified tannic acid as an anti nutritional factor in sorghum grain. However, more recent research indicates that tannic acid is not a sorghum component (Dykes and Rooney, 2006). Some sorghum varieties have pigmented testa containing condensed tannins, polyphenolic compounds that possibly give the seed a bitter taste and have been known to reduce intake, digestibility (particularly of protein), growth, and feed efficiency of livestock (Gilani *et al*., 2005; Waniska, 2000).

Environmental factors including agronomic practices affect grain composition. Grain sorghum protein content differs with the location at which the crop is grown (Deosthale and Mohan, 1970; Deosthale *et al*., 1972; Deyoe and Shellenberger, 1965). The level of nitrogen fertilizer also influences the quantity and quality of protein in sorghum (Deosthale *et al*., 1972; Waggle *et al*., 1967). Warsi and Wright (1973) noted that application of nitrogen fertilizer increased the grain yield and protein. Higher protein in response to fertilizer nitrogen was mainly the result of increased accumulation of prolannin, a poor quality protein, in the grain (Sawhney and Naik, 1969). The level of nitrogen fertilizer had no effect on the mineral composition of grain sorghum. However, the mineral content of the sorghum increased with increasing levels of phosphorus fertilizer (Deosthale *et al*., 1972).

Tannins have a yellow-white to brown color and a faint, characteristics odour. Exposure to light deepens the colour. They all taste bitter and are astringent. Water, acetone, and alcohol dissolve tannins readily, but benzene, ether, and chloroform do not. Heating to 210° C (410° F) causes decomposition, accompanied by formation of pyrogallol and carbon dioxide. The chemical property that provides the basis for most uses of tannins is its ready formation of precipitates with albumin, with gelatin, and with many alkaloidal and metallic salts. The ability of tannins to transform proteins into insoluble products resistant to decomposition leads to their use as tanning agents. Ferric salts react with tannins to give bluish-black products that are useful as inks. Tannins are used as mordants for dyeing cloth, as sizes for paper or silk, and as coagulants for rubber. The precipitating properties of tannins are used in clarifying, or cleaning, wines and beer. Tannic acid is valuable as an external medicine because it is astringent and styptic (Microsoft Premium Student DVD Encarta, 2009).

Although application of NSC alone or combine with inorganic fertilizer for maintaining soil fertility and sustain crop production can be particularly attractive in the region as a means of organic matter utilization this need to be weighed along side nutritional effect on sorghum. The aim of this work was to determine the effect of NSC and inorganic fertilizer on nutrition of sorghum and also to determine its grain and stover yield.

Materials and Methods

Pre-cropping site characterization

Field trials were conducted for two years – 2009 and 2010 – to investigate the effect of NSC and NPK fertilizer on nutrition and yield of sorghum on the experimental site of the Institute for Agricultural Research (IAR). Composite soil sample was collected, dried, crushed and sieved through 2 mm sieve. Sub-sample soil was used for physico-chemical analysis (Table 1).

Neem seed cake collection and preparation

NSC was obtained from National Research Institute for Chemical Technology (NARICT) Basawa-Zaria. All foreign materials including uncrushed seed and kernel, stones, leaves and straws were removed and the cake was ground to powder. Sub sample was taken for characterization (Table 2).

Grain analysis

Ground sub samples of the sorghum grains were subjected to proximate analysis for the determination of the crude protein and tannin contents. The crude protein (CP) was calculated using the conversion factor of 5.9 suggested for cereal proteins due to the variation in the CP in feeds (13 – 18 %) (Gilchrist, 1967) following the wet digestion for total N by the micro-Kjeldahl method. Tannin was determined as described by Allen (1989) and the soluble tannins calculated thus:

$$\text{Soluble tannins (\%)} = \frac{C \times V}{10 \times A \times W}$$

Where C = concentration (mg), V = extract volume (cm^3), A = Aliquot volume taken (cm^3) and W = sample weight (g)

Statistical analysis

Data obtained in the two-year trial period were subjected to analysis of variance (ANOVA), using SAS, version 8.1 programme. The differences among the experimental treatments were compared using the standard error (SE) and the Duncan Multiple Range Test (DMRT) tests, for two or multiple comparisons of means at the $P < 0.05$ probability level.

Simple correlation was also carried out to show the relationship between grain yield and N applied as treatments.

Results and Discussion

Soil and Neem seed cake Analysis.

The result of soil analysis (Table 1) shows that, the soil pH is slightly acidic. This is one of the characteristics of Samaru soil which have pH range of 4 – 6.5 (Jones and Wild, 1975). The organic carbon (4.41 g kg^{-1}) and total N (5.25 g kg^{-1}) of the soil are low which indicate the low organic matter content hence, fall within the range of low fertility class for northern Nigeria (Enwezor *et al*., 1990). The available P is 0.37 mg kg^{-1} which is within the low fertility class (< 8.5 mg kg^{-1}); similar report was reported by Jones and wild (1975).The textural analysis revealed sand, silt and clay proportions of 600, 240 and 160 g kg^{-1} respectively given the textural class of sandy loam and also classified as Alfisol (Ojanuga, 1979). Exchangeable bases (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}) were found to be low which can be attributed to the low organic matter content of the soil.

Mean total N and P of the NSC was found to be 4.60% and 0.28% respectively, the result also shows that NSC contained 1.24% K and 26.54% organic carbon (Table 2). This indicates that NSC have above the critical levels of 2.5% and 0.2% for N and P respectively, and would be expected to result in net release of these nutrients on application to the soil (Giller, 2000; Benton *et al*., 2001). However, K value was below critical concentration of 1.9%, which corroborates earlier submission that organic materials do not contain all the essential nutrients that are required by a particular crop in the appropriate amount (Palm *et al*., 2001).

Table 1: Physico-chemical properties of soil used

Characteristics	**Results**
Soil pH (water; 1:2.5 w/v)	6.0
Soil pH ($CaCl_2$; 1:2.5 w/v)	5.3
Organic carbon (g kg^{-1})	4.41
Total N (g kg^{-1})	5.25
Available P (mg kg^{-1})	0.37
<u>Particle sizes (g kg^{-1})</u>	
Clay	160
Silt	240
Sand	600
Textural class	Sandy loam
<u>Exchangeable bases (cmol kg^{-1})</u>	
Ca	2.20
Mg	0.65
K	0.21
Na	0.32
Exchangeable Acidity (cmol kg^{-1})	0.20

Table 2 Chemical characteristics of Neem seed cake used

Parameter	Unit	2009	2009	Mean
N	%	3.85	5.34	4.60
P	%	0.37	0.18	0.28
K	%	1.47	1.00	1.24
Ca	%	0.01	0.01	0.01
Mg	%	0.02	0.02	0.02
OC	%	23.05	30.02	26.54
Lignin	g kg^{-1} DM	30.10	44.67	37.39
Cellulose	g kg^{-1} DM	303.97	316.33	310.15
Polyphenol	g kg^{-1}	13.30	8.00	10.65
C: N		5.99: 1	5.62 : 1	5.81: 1
N: P		4.53: 1	12.71 : 1	8.62: 1
C: P		27.12: 1	71.48: 1	49.30: 1

Effects of NPK fertilizer levels on yield parameters

Grain yield

There was significant difference in grain yield in 2010. However, trend was erratic with increasing NPK across treatments. FRR (2,251.90 kg ha^{-1}) gave the highest grain yield in the two years combined. The present trend with FRR having the highest grain yield further signifies the low fertility and corresponding low yield except with addition of external input. The highest grain yield (3346.81 kg ha^{-1}) was recorded from FRR (optimum NPK recommended rate) which gave increase of 22.15% above the control in 2009 while the least (2362.30 kg ha^{-1}) grain yield was recorded in the ¼ RR for sorghum in the region (Table 3).

Stover yield

Increase in stover yield was recorded with increasing chemical fertilizer (CF) input in 2009, 2010 and the combined (Table 3). The yield obtained in the study was a reflection of the contribution of the treatments to the soil nutrient status. The combined followed the same trend with mean yield between 11,111 kg ha^{-1} in the control and 14,306 kg ha^{-1} for FRR.

Effect of NSC levels on yield parameters

Grain yield

There was significant difference in the sole NSC ($p<0.05$) in 2010. However, there was an erratic pattern was followed with increase in NSC levels. 4 TC gave the highest grain yield of 2,988.8 kg ha^{-1} in 2009 and 1,337.9 kg ha^{-1} in 2010 while the combined recorded the highest mean grain yield of 2,126.60 kg ha^{-1} in 1 TC treatment (Table 3). This signifies that optimum level for NSC treatment is 1 TC.

Stover yield

There was significant increase in stover yield with increasing NSC levels in 2009 and 2010. The yield obtained in the study was a reflection of the contribution of the treatments to the soil nutrient status. The combined followed the same trend with mean yield between 11,233 kg ha^{-1} in the control and 13,594 kg ha^{-1} for 4TC (Table 3).

Table 3: Main effects of NSC and NPK fertilizer on yield parameters

Treatment	2009	2010	combined	2009	2010	combined
	Grain yield (kg ha^{-1})			Stover yield (kg ha^{-1})		
NPK kg ha^{-1} (N)						
0	2845.8	959.94b	2002.5	15625b	28.83	11111
¼RR	2755.3	1330.90a	1939.9	16250ab	30.04	11354
½RR	2639.6	1176.02a	1867.3	16667ab	30.52	12604
FRR	3166	1249.85a	2251.9	18611a	30.45	14306
SE ±	186.58	62.51	210	873.04	0.56	1113.7
NSC tonne ha^{-1} (S)						
0	2713	1159.19ab	1836.5	15208b	6597.2c	11233
1	2922.3	1124.59b	2126.6	16042ab	6458.3c	11684
2	2782.6	1095.01b	1979.3	17500ab	8541.7b	12865
4	2988.8	1337.91a	2119.3	18403a	10000a	13594
SE ±	186.58	62.51	210	873.04	478.13	1113.7
Interaction (N × S)						
N × S	NS	NS	NS	NS	NS	NS

TC= t ha^{-1} neem seed cake FRR=full fertilizer recommendation rate

Effect of treatment interaction factors on yield parameters

Stover yield

Stover yield was not significant in the interactive effect in 2009, 2010 and two years combined. But, highest stover yield of 15,277.76 kg ha^{-1} was recorded from the 4 TC + FRR in the combined (Table 4). This further signifies the importance of the complementary use of NPK and NSC on the yield of sorghum.

Grain yield

In 2010, the highest grain yield (1524.04 kg ha^{-1}) was recorded from treatments that received 1 TC + FRR which gave an increase of 44 % above the control (Table 4). However, no significant difference was observed between NSC and CF treatment, highest grain yield (2,321.56 kg ha^{-1}) was recorded from 2 TC+ FRR with the combined use of NPK and NSC in the two years combined (Table 4). The relatively higher grain yield with the combined use of NPK and NSC inputs at the 1 TC + FRR in 2010 and 2 TC + FRR corroborates the submission of Sanchez (1994) that combining mineral and organic inputs result in greater benefits than either inputs alone through positive interactions on soil biological, chemical and physical properties.

Also, organic resources are seen as complementary inputs to mineral fertilizers and their potential role has consequently been broadened from a short term source of nitrogen to a wide array of benefits both in the short and long term (Vanlauwe *et al*., 2001). Murwira and Kirchmann (1993) reported that a combination of organic-inorganic nutrient sources is thought to improve the synchronization of nutrient release and subsequent uptake by crops. Synchronization which was achieved by incorporating NSC two weeks before planting the sorghum conforms to Okalebo and Woomer (1994) reports that decomposition and residual effects are enhanced when low organic materials are incorporated with a small amount of mineral nitrogen and ploughed into the seed bed, preferably before the successive crop is planted. Neem seed cake, being a high quality organics (N > 2.5%, lignin > 15% and polyphenol > 4%) (Giller, 2000; Palm *et al*., 2001) was incorporated without mineral-N two weeks before sowing of sorghum seeds.

Yield obtained in this study was a reflection of contribution of the treatments to the soil nutrient status. Higher yield obtained in CF amended plots could be attributed to quick release of nutrients from inorganic fertilizer to soil and their uptake by the sorghum plants. Improved yield obtained in neem seed cake (NSC) amended plots in the second cropping season might be due to the cumulative effect of nutrients released by the organic material to soil. NSC used in the study compared favourably with CF in some of the parameters measured. It therefore implied that NSC investigated was as effective as CF in increasing soil nutrients and consequently, the yield of sorghum.

Table 4: Interaction effects of NSC and CF on sorghum yield parameters

Treatment	2009	2010	combined	2009	2010	combined	2009	2010	combined
	Stover yield (kg ha^{-1})			Grain yield (kg ha^{-1})			Grain yield increase (%)		
Control	15000	5138.89	10069.45	2605.45	850.71	1728.08	-	-	-
¼ RR	13611.11	5833.33	9722.22	2362.3	781.2	1571.75	-9.33	-8.17	-8.75
½ RR	15277.78	7916.67	11597.23	2537.6	1042.75	1790.18	-2.6	22.57	9.99
FRR	16944.45	10138.89	13541.67	3346.81	1165.1	2256	28.45	36.96	32.71
1 TC	16388.89	6250	11319.45	3144.67	1367.1	2255.89	20.7	60.7	40.7
1 TC + ¼ RR	17777.78	5833.33	11805.56	2775.34	1301	2115.37	12.45	52.93	32.69
1 TC + ½ RR	15000	8611.11	11805.56	2839.29	1131.44	1796.27	-5.54	33	13.73
1 TC + RR	17500	8611.11	13055.56	2929.73	1524.04	2179.91	8.84	79.15	44
2 TC	15277.78	7500	11388.89	2461.09	1088.57	1931.96	6.52	27.96	17.24
2 TC + ¼ RR	17500	6805.56	12152.78	2835.77	1055.5	1821.72	-0.67	24.07	11.7
2 TC + ½ RR	20000	8194.45	14097.23	2587.93	1088.98	2167.21	24.56	31.29	27.93
2 TC + FRR	16111.11	10416.67	13263.89	3245.43	1471.04	2321.56	21.75	72.92	47.34
4 TC	14722.22	7500	11111.11	3172.08	1330.38	2084.84	8.97	56.38	32.68
4 TC + ¼ RR	18611.11	7361.11	12986.11	3047.64	1360.67	2204.16	16.97	59.95	38.46
4 TC + ½ RR	19166.67	9444.44	14305.56	2593.66	1116.87	1855.27	-0.45	31.29	15.42
4 TC + FRR	19722.22	10833.33	15277.76	3141.99	1191.45	2166.72	20.59	40.05	30.32
SE ±	756.08	414.07	585.075	161.58	54.13	107.855			

Means followed by the same letter (s) within the same column are not significantly different at 0.05 level of probability using DMRT RR= recommended rate FRR= Full recommended rate NS= Not Significant

Effect of NSC and CF on nutritional status of sorghum

Effect of NSC and CF on crude protein

Data on sorghum nutritional status as affected by neem seed cake and inorganic fertilizer in 2009, 2010 and combined are presented in Table 5 for main effects and 6 for interaction. In 2009, the least crude protein content (7.07%) was obtained from 1 TC treatment which was closely followed by the control (7.24%) while the 1 TC + FRR gave the highest crude protein content of 10% in the grain in the same year. In 2010 on the other hand, the least grain crude protein content (7.06%) was obtained from the 2 TC which was closely followed by the 1 TC + ¼ RR, 2 TC + FRR and 4 TC treatments (7.23%) while the control recorded the highest grain crude protein content of 8.44%. However, sorghum grain crude protein showed no significance difference among treatments – sole NPK, and NSC as well as interactions (NPK plus NSC) in 2010 year of the study. 1 TC + FRR and 4 TC + ½ RR gave the highest crude protein content (8.87%) in the two years combined.

Variation in the quantity and quality of crude protein in the grain sorghum for both years could be attributed to the level of nitrogen in the soil. The level of nitrogen fertilizer influences quantity and quality of protein in sorghum (Deosthale and Visweswar, 1972; Waggle *et al*., 1967). Also, Warsi and Wright (1973) noted that application of nitrogen fertilizer increased grain yield and protein. Higher protein in response to fertilizer nitrogen was mainly the result of increased accumulation of prolanin, a poor-quality protein, in the grain (Sawhney and Naik, 1969). Consequently, year 2009 which experienced higher residual mineral-N owing to the legume that preceded sorghum in the first year of the study recorded higher crude protein range(7.07 -9.99%) while 2010 with less residual mineral-N at planting which emanated from the sorghum following sorghum in the second year had less range (7.06 – 8.44%).

Effect of NSC and CF on tannin content

The 2010 grain sorghum recorded a higher tannin concentration in spite of the less crude protein for the year which was contrary to the submission of Myer *et al*. (1994) who reported that high tannin grain sorghum tended to have higher contents of crude protein, lysine, methionine and ether extract than low tannin grain sorghum. However, the level of tannin in the grain sorghum for both years and the combined fall within the range of 1.3 – 3.6% in very high tannin sorghum and 0.1 -0.7% in high tannin sorghum reported by the researchers (Myer *et al*., 1994). The increase in tannin content which was higher than 0.75% threshold level (Berkel and Voragen, 2002) for some treatment plots (Table 6) for the year 2010 could be attributed to solubilization occurring as the grain took up water or to synthesis of polyphenols during germination (Hamid, 2001). For the two years combined, tannin content ranged between 0.47 mg kg^{-1} – 0.81 mg kg^{-1}, thus, the variety used could be classified as containing low tannin except the 1 TC (0.81 mg kg^{-1}) which could be said to be moderate.

Table 5: Main effects of neem seed cake and inorganic fertilizer on grain sorghum crude protein and tannin contents

Treatment	2009	2010	Combined	2009	2010	Combined
	Crude protein (%)			Tannin (mg kg^{-1})		
NPK kg ha^{-1} (N)						
0	7.45b	7.57	7.51	0.42	0.92	0.67
¼ RR	8.36ab	7.70	8.03	0.41	0.94	0.68
½ RR	8.69ab	7.75	8.22	0.37	0.75	0.56
FRR	9.17a	7.44	8.31	0.38	0.81	0.60
SE ±	0.43	0.25	0.28	0.03	0.08	0.07
NSC t ha^{-1} (S)						
0	8.18	7.79	7.99	0.45	0.99	0.72
1	8.32	7.62	7.97	0.36	0.89	0.62
2	8.10	7.49	7.79	0.38	0.81	0.60
4	9.08	7.57	8.33	0.39	0.74	0.57
SE ±	0.43	0.25	0.28	0.04	0.08	0.06
Interaction (N × S)						
N × S	NS	NS	NS	NS	NS	NS

NB: Means followed by the same letter (s) within the same column are not significantly different at p < 0.05
NS=Not Significant

Table 6: Interaction effect of neem seed cake and inorganic fertilizer on grain sorghum crude protein and tannin contents

Treatment	Crude protein (%)			Tannin (mg kg^{-1})		
	2009	2010	Combined	2009	2010	Combined
Control	7.24	8.44	7.84	0.43	0.99	0.71
¼ RR	8.96	8.09	8.52	0.56	0.93	0.75
½ RR	8.26	7.4	7.83	0.39	1.11	0.75
FRR	8.27	7.23	7.75	0.41	0.93	0.67
1 TC	7.07	7.57	7.32	0.39	1.22	0.81
1 TC + ¼ RR	7.93	7.23	7.58	0.39	1.11	0.75
1 TC + ½ RR	8.27	7.91	8.09	0.37	0.58	0.47
1 TC + FRR	10.00	7.74	8.87	0.31	0.64	0.47
2 TC	7.75	7.06	7.40	0.41	0.81	0.61
2 TC + ¼ RR	7.75	7.75	7.75	0.33	0.76	0.54
2 TC + ½ RR	8.26	7.92	8.09	0.37	0.70	0.53
2 TC + FRR	8.62	7.23	7.92	0.41	0.99	0.70
4 TC	7.75	7.23	7.49	0.45	0.64	0.54
4 TC + ¼ RR	8.78	7.75	8.26	0.37	0.99	0.68
4 TC + ½ RR	9.98	7.75	8.87	0.37	0.64	0.50
4 TC + FRR	9.81	7.57	8.69	0.39	0.70	0.54
Mean	8.42	7.62	8.02	0.40	0.86	0.63
CV %	20.23	13.37	13.84	35.52	37.41	27.95
SE ±	0.48	0.18	0.28	0.03	0.08	0.04

Conclusion

The study revealed the influence of NSC and inorganic fertilizer on yield of sorghum considering an increased in grain and stover yield. Moreover, treatment with 2 ton $ha^{-1}$of NSC + full fertilizer rates gave the highest grain yield followed by the treatment with full fertilizer rate. The nutritional status was not adversely affected by combined application of NSC and NPK fertilizer. However, sole application of 1 ton NSC ha^{-1} was found to increase the tannin content in grain sorghum to the moderate class which might affect the nutritional status of the grains adversely.

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