

Neem Seed Cake Nitrogen Fertilizer Equivalencies as Assessed by Sorghum at Samaru, Northern Nigeria

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ABSTRACT

Application of organic materials is imperative for soil and crop sustainability of the generally inherent low fertility soils in the northern guinea savanna of Nigeria. Consequently, a field study was set up at the Institute for Agricultural Research (IAR), Zaria during the cropping seasons of 2009 and 2010 to establish the chemical fertilizer equivalent value of neem seed cake (NSC), and also investigate rainfall pattern in relation to evapotranspiration rates in the region as these two weather determinants affect the planting dates. The experiment consisted of sorghum plots to which milled NSC (with % N greater than 3) and urea (inorganic N source) were applied. Factorial combination of four levels of NSC (0, 1, 2 and 4 t ha⁻¹) and four rates of chemical fertilizer package (0, ½, ¼ and full recommended fertilizer rates of 64 kg N, 32 kg P₂O₅, 32 kg K₂O for sorghum), making a total of sixteen treatments laid in a randomized complete block design and replicated three times. Results obtained for the cumulative above ground biomass yield in the two-year study indicated that a combination of both NSC and inorganic nutrient source gave higher sorghum biomass yield than when each was applied separately. Although, the 1 and 4 tonnes levels of NSC gave grain yields that were higher than when in combination with NPK, none of the NSC-amended plots recorded a grain yield that was equal to or greater than the recommended optimum inorganic fertilizer rate for sorghum in the region. On the average, the nine treatment combinations of NSC and NPK gave fertilizer equivalent values for the nitrogen contained in them ranging from 35.09 to 60.08. It is therefore recommended that NSC be used complementarily with mineral fertilizer as a source of nitrogen in the ratio 1:0.25.

Key words: Mineral-N, N-recovery, neem seed cake, nitrogen fertilizer equivalent, sorghum.

INTRODUCTION

Sorghum is the fifth most important cereal on world's population basis after wheat, maize, rice and barley (Godbharle et al., 2010). Nigeria is the third largest producer of sorghum in the world, with current annual production of about 2.8 million metric tonnes (United Nation, Food and Agricultural Organization, 2012). The bulk of its estimated production of about 8 million tonnes (NAERLS; 1996) are grown in the Northern Guinea and Sudan/Sahel ecologies; this covers states like Kaduna, Kano, Jigawa, Zamfara, Sokoto, Kebbi, Borno, Plateau, Bauchi, Adamawa and Gombe (Aba et al., 2005). Sorghum, like other cereals, is an excellent source of starch and protein and can be processed into starch, flour, grits and flakes which can be used to produce a wide range of industrial products (Palmer, 1991).

A major component of successful crop production is the availability of adequate plant

Nutrients, especially nitrogen (N) to which grain sorghum is most responsive. Dominant soils of the Northern Guinea savanna are Alfisols and Ultisols, which cover 60% of the region (Odunze et al., 1996). These soils have a dominance of low activity clays in the surface horizon (Frye et al., 1982; Esu and Ojanuga, 1985) with accompanying low exchange capacity. The soils are therefore fragile and easily degraded under continuous cultivation (Lal, 1975; Jones, 1976; FAO, 1978). Consequently, crop production is not profitable without addition of external inputs.

Good management of agricultural production systems such as soil resources is a response to challenges posed by world food crisis. Lately, the use of local and readily available organic residues for soil amendment in sub-Saharan Africa to improve soil fertility and organic matter status is rapidly gaining widespread support (Agbenin et al., 1999).

It is pertinent therefore to exploit and evaluate

the potentials of locally available organic wastes as soil amendments.

The neem tree- *Azadirachta indica* (Dongoyaro), offers great potential for agricultural, industrial, and commercial exploitation, and is potentially one of the most valuable of all arid-zone trees. It shows promise for pest control, reforestation, and improving human health (Vietmeyer, 1992). The neem foliage and neem seed cake (NSC), have been demonstrated to have high soil fertilization potential, particularly with respect to nitrogen release (Radwanski, 1969; Kethar, 1974; Kethar and Kethar, 1995; Idris et al., 1995; Agbenin et al., 1999 and 2008; Uyovbisere et al., 1999). Consequently, it could be one panacea for the maintenance of soil fertility for sustained crop production which is a major challenge facing agriculture and food security in Nigeria and most other developing countries (Mokwunye, 1991; Murwira et al., 2002).

Fertilizer equivalency (FE) is the specific amount of an organic material that can have the same effect on crop yield as a certain amount of inorganic fertilizer (Mugendi et al., 2009). These values directly relate the value of an organic material to a manufactured fertilizer that is readily plant-available. Consequently, knowledge of FE values reduces the risk of insufficient or excessive plant nutrition while maximizing crop nutritional benefits from organic residues (Alley and Vanlauwe, 2009). The capacity to determine nitrogen availability of NSC soil amendments is necessary to ensure that this material will provide sufficient fertilization to the growing crop and cause minimal environmental degradation. Thus, a two-year field study using sorghum as a bio-indicator was used to evaluate nitrogen availability of NSC.

MATERIALS AND METHODS

The study was conducted during the rainy seasons of year 2009 and 2010 on the experimental site of the Institute for Agricultural Research Farm, Zaria in the Northern Guinea Savanna of Nigeria. The experiment was laid out in a randomized

Complete block design (RCBD) with three replications. Treatments consisted of factorial combinations of four levels of NSC (0, 1, 2 and 4 t ha⁻¹) and four rates of chemical fertilizer package (0, ¼, ½ and full recommended fertilizer rates of 64 kg N, 32 kg P₂O₅, 32 kg K₂O for sorghum). Plot size was 6 × 4.5m, giving a gross plot size of 27m² with six (6) and four (4) rows in the gross and net plots, respectively. The field was ploughed, harrowed and ridged using tractor in the first year. The organic material, neem seed cake was obtained from the National Research Institute for Chemical Technology, Basawa-Zaria and incorporated along the middle of the ridge after all land preparation operations were done. NSC was allowed to incubate for two weeks before planting of seed to a depth of 0.15 m with four manure levels: 0, 1, 2, and 4 tonnes ha⁻¹ corresponding to 0, 38.5, 77.0 and 154.0 kg N ha⁻¹. A total of sixteen treatments were investigated: 0 NSC + 0 NPK, 0 NSC + ¼ NPK, 0 NSC + ½ NPK, 0 NSC + Full NPK, 1 NSC + 0 NPK, 1 NSC + ¼ NPK, 1 NSC + ½ NPK, 1 NSC + Full NPK, 2 NSC + 0 NPK, 2 NSC + ¼ NPK, 2 NSC + ½ NPK, 2 NSC + Full NPK, 4 NSC + 0 NPK, 4 NSC + ¼ NPK, 4 NSC + ½ NPK, 4 NSC + Full NPK, where ¼, ½ and Full are proportion of optimum recommended fertilizer rate of 64-32-32 for sorghum in the region.

Sorghum variety, Samsorg 17 (SK-5912) was planted at ten seeds per hill at a spacing of 0.25 m within row and 0.75 m inter-row. Phosphorus (P₂O₅) and potassium (K₂O) levels at 0, ¼, ½ and full recommended rates being 0, 0.12kg (8 kg ha⁻¹), 0.24kg (16 kg ha⁻¹) and 0.48kg (32 kg ha⁻¹) Single superphosphate and 0, 0.036kg (8 kg ha⁻¹), 0.072kg (16 kg ha⁻¹) and 0.144kg (32 kg ha⁻¹) of Muriate of potash respectively were applied at planting in accordance to the factorial design. The seedlings were thinned to two plants per stand at three weeks after planting.

The first doses of nitrogen (N) levels at 0, 0.023 kg (4 kg ha⁻¹), 0.047 kg (8 kg ha⁻¹) and 0.094 kg (16 kg ha⁻¹) of Urea being one-quarter of the 0, ¼, ½ and full of the recommended rates were applied after first weeding at three weeks after planting and first weeding.

The second split doses (three-quarter) of the N requirements were applied at six weeks after planting at 0, 0.070 kg (12 kg ha⁻¹), 0.141 kg (24 kg ha⁻¹) and 0.282 kg (48 kg ha⁻¹) of Urea as appropriate. Weeds were controlled with broad spectrum (Round up) and pre-emergence herbicide: (Vestrazine) applied two weeks before land preparation and immediately after planting, respectively. However, during the season, hoe weeding and non-selective herbicide (Miazone) were used within the treatment plots and the alley/ discard. The ridges were re-moulded at six weeks after planting.

It was necessary to control stem borer attack in the second year. Consequently, Best action - a systemic and contact insecticide was used. The study was conducted on the same site and plots were maintained in both years of the study period. In the second year, plots were prepared manually to maintain plot properties. The old ridges were scattered and re-moulded with the hoe and the appropriate NSC level incorporated thereafter to incubate for two weeks. All other operations were carried out as in the first year. During the cropping season for 2009 and 2010, designated sample areas within each plot were permanently marked to represent the harvest area. The harvest area (net plots) was 12 m² in both years. All the experimental plots in the trial were considered for the assessment of the crop yields and yield components. Parameters considered before crop maturity and harvest were: plant stand per net plot at harvest (maturity); days to 50% panicle emergence and 50% flowering. At maturity, the net plots per treatment were harvested for both grain and stover yield. Harvesting was done by cutting panicles from each stand when all sorghum heads were properly dry enough for threshing. The stovers within the harvest area were cut at ground level to determine stover weight per net plot. The following parameters were calculated:

1. Relative yield at each fertilizer level, RY (%)

$$RY = \frac{\text{Yield}_{\text{treatment}}}{\text{Yield}_{\text{optimum chemical fertilizer}}} \times 100 \quad (\text{Chien } et al., 1990)$$

2. Relative yield increase, RYI (%)

$$RYI = \frac{\text{Yield}_{\text{treatment}} - \text{yield}_{\text{control}}}{\text{Yield}_{\text{optimum chemical fertilizer}} - \text{Yield}_{\text{control}}} \times 100$$

(Chien *et al.*, 1990)

3. Fertilizer Equivalence was obtained from the best fit regression line exhibited by the response of grain yield to the inorganic fertilizer N alone (Jokela, 1992; Murwira *et al.*, 2002). Fertilizer equivalencies (FE) of treatments were obtained using a quadratic function with the equation:

$$y = c + bFE + aFE^2 \quad (\text{Murwira } et al., 2002)$$

The following formula for solving quadratic equations was used to solve the regression equation for FE:

$$FE = -b \pm \sqrt{(b^2 - 4ac)/2a}$$

Where a, b, and c are constants obtained from the quadratic function, y is the yield from a particular treatment plot and FE is the fertilizer response obtained from the formula for solving quadratic equations above.

4. Percent fertilizer equivalence values: In order to compare the fertilizer responses of the treatments, the % fertilizer equivalence (FE) values were calculated according to the following method:

$$FE (\%) = \frac{FE \times 100}{N \text{ applied}}$$

Where FE = fertilizer response obtained from the formula for solving quadratic equations, and N applied = actual amount of N applied in each plot (Mugendi *et al.*, 2009).

STATISTICAL ANALYSIS

The yield data were subjected to ANOVA and their means separated using Duncan Multiple Range Test (DMRT) at $P < 0.05$ using SAS version 8.1 computer package. Treatment effects on soil N availability and sorghum yield were analyzed using Genstat for windows (Release 12.1)

RESULTS AND DISCUSSION

The soil was sandy loam in texture and low in clay content (160 g kg⁻¹). The soil was characteristically low in organic carbon content (4.41 g kg⁻¹) and CEC (5.20 cmol kg⁻¹) (Jones and Wild, 1975; Uyovbisere and Lombin, 1991). The low level of organic carbon coupled with the associated sandy texture (Table 1), would encourage rapid leaching of cations (Jones, 1973; Enwezor *et al.*, 1989), and consequently the soil would be low in CEC. The soil was slightly acidic, with pH-value in CaCl₂ solution (5.3) lower than that in water (6.0), indicating that the soil possesses a net negative charge in the colloidal complex (Daudu, 2004). The pH value in water was above 5.0 indicating that exchangeable Al toxicity may not be a problem in this soil (Kamprath, 1972). Exchangeable bases: calcium (2.20 cmol kg⁻¹), magnesium (0.65 cmol kg⁻¹), potassium (0.21 cmol kg⁻¹) and sodium (0.32 cmol kg⁻¹) were all low concentrations in the soil. Calcium and magnesium were the dominant cations on the exchange sites of the soils summed together. The effective cation exchange capacity of the soil was 3.58 cmol kg⁻¹ calculated as the summation of exchangeable bases and acidity which is low. This makes the soil easy to acidify because the ability to hold on the basic cations is low. The generally low initial content of soil nutrients implies that there would be the possibility of a good response to applied nutrients, which is an important criterion in selection of experimental sites (Stevenson, 1982; Palm, 1995).

Characteristics of the neem seed cake used for the study

The chemical properties of the organic material showed that there was much variation in the nutrient contents of the NSC used in the study (Table 2). The compositions reflected differences in the sources, as neem seed from different geographical locations vary widely in their chemical compositions (Radwanski, 1969; Mengel and Kirkby, 2001). Also, the quality of NSC is determined by the amount of oil left in it, as well as the process by which the extraction

was done (Espanol, 2009). Although, all the nutrients in the NSC may not be available to a crop, the information can provide a qualitative estimation of the organic material (Palm *et al.*, 1997). Both N (38.50 g kg⁻¹ in 2009 and 53.40 g kg⁻¹ in 2010) and P (3.70 g kg⁻¹ in 2009 and 1.80 g kg⁻¹ in 2010) values of the NSC used in the study for the two years (Table 2) were above the critical levels of 2.5% and 0.2%, respectively, and would be expected to result in net release of these nutrients on application to the soil (Palm *et al.*, 1997; Giller, 2000; Benton, *et al.*, 2001). Also, the low lignin content (< 15%) coupled with the narrow C: N ratio (5.99 and 5.62 in 2009 and 2010 samples, respectively) would result in fast decomposition and release of nutrients (Okalebo and Woomer, 1994). Consequently, incorporation directly into soil with annual crops at planting would be expected to give better results in terms of improving the synchronization of nutrients release and subsequent uptake by the crop (Murwira and Kirchmann, 1993; Giller, 2000; Palm *et al.*, 2001). On the contrary, the K and Ca values were below the critical or standard concentrations of 1.9% and 1.0%, respectively while Mg was approximately equal to the standard value of 0.2% (Benton, *et al.*, 2001). This corroborates earlier submissions that organic materials do not contain all the essential nutrients that are required by a particular crop in the appropriate amounts (Palm *et al.*, 2001).

Effect of NSC and NPK fertilizer on grain and stover yield

An increase in stover yield was observed with increasing rate of organic or inorganic inputs (Table 3). Yield obtained in the study was a reflection of the contribution of the treatments to the soil nutrient status. Higher stover yield obtained in NPK amended plots in 2009 could be attributed to the quick release of the nutrients to the soil and their uptake by the sorghum plants. Improved yield obtained in NSC amended plots in the second cropping season might be due to the cumulative effect of nutrients released by the organic material to the soil.

Stover yield was generally higher in 2009 than 2010 (Table 4). Yields from NSC applied at 0 t/ha (15625 kg ha⁻¹ and 7256.9 kg ha⁻¹ in 2009 and 2010 respectively) and at 1 t/ha (16250 kg ha⁻¹ and 7326.4 kg ha⁻¹ in 2009 and 2010 respectively) were statistically the same while differences were found with increase in NSC inclusion level at 2 tonne ha⁻¹ (16667 kg ha⁻¹ and 8229.2 kg ha⁻¹ in 2009 and 2010 respectively). Yields from the application of NSC at 2 tonne ha⁻¹ was also statistically different from the 4 (18611 kg ha⁻¹ and 8784.7 kg ha⁻¹ in 2009 and 2010 respectively) tonne ha⁻¹ level (Table 3).

Yields from the NSC + CF treatments were higher than any of the NPK treatments alone in the year 2010 (Table 4). This corroborates with Oikeh (1997) findings, who observed that supplying N in a smaller first split dose and larger amounts later in the season results in a yield depression when the native soil fertility was low. The crop suffered N deficiency, which cannot be overcome by giving a high dose of N later in the season. Hence, yields from plots amended with NPK plus NSC in the second year were relatively higher in comparison with plots amended with inorganic fertilizer only (Table 4).

There was no significant difference in grain yield for the NPK, NSC and combined (NPK plus NSC) treatment in 2009 (Table 3). In 2010 on the other hand, significant differences were observed in the sole NPK ($p < 0.01$) and NSC ($p < 0.05$) while there was no significant interaction between NPK and NSC on grain yield. 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 $\frac{1}{4}$ RR for sorghum in the region (Table 4).

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, while the $\frac{1}{4}$ RR recorded the least (781.20 kg ha⁻¹) (Table 4). However, no significant difference was observed between NSC and CF treatment, highest grain yield

was recorded with the combined use of NPK and NSC (Table 4).

The highest grain yield recorded above corroborates the submission of Sanchez (1994) that combining mineral and organic inputs result in greater benefits than either input 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., 2002). 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.

Also, grain yield differences among sole NSC treatments (Table 3) could be related to N and P availability to crops and release patterns by the NSC. High yields obtained in the sole treatments ($\frac{1}{4}$, $\frac{1}{2}$ and Full) could be attributed to nutrients being readily available from the fertilizers. Nutrients from NSC must first undergo decomposition before they are available for crop uptake. Consequently, relatively higher p-value of 0.0016 was obtained from sole NPK treatment plots as against the 0.0441 p-value obtained in the sole NSC amended plots. Although, both values were statistically significant. The non-significant interaction between NPK and NSC ($p = 0.2666$) implies that irrespective of proportion of combination of the two soil

amendments, grain yield would be constant. Since, synchronization is such that nutrients of the mineral fertilizer are released at the initial growth stage when that from the NSC was immobilized, to be released at a later growth stage when that from the inorganic source might have been exhausted. This was evident from the vibrant and thick canopy cover of the combined treatment plots on the field as against the scanty and light canopy cover of the sole NPK and NSC treatments.

Fertilizer equivalence of NSC

The high FE values of 145.32 and 163.41 obtained at 1 tonnes NSC application level for years 2009 and 2010 respectively, were the highest for both years (Table 5). This could be attributed to the high residual mineral-N from cowpea preceding sorghum in 2009. Sanginga et al. (2001) reported that a grain legume in rotation with cereal benefits the crop beyond available N although these were often translated into fertilizer equivalency values. However, the higher FE value of 2010, which indicates residual effect of NSC in 2009, implied that NSC performed better in terms of increasing sorghum grain yields than an equivalent amount of mineral fertilizer (Table 5). This corroborates with other findings of Bationo et al. (2007) and Mugendi et al. (2009) who reported N equivalency values of above 100% in their studies with different organic amendments. These high yields from application of 1 tonne ha⁻¹ NSC treatments could also be inferred as being due to positive effects of the NSC on soil physical and chemical properties, such as moisture retention and addition of micronutrients at this incorporation level. Also, NSC with percent fertilizer equivalency of about 100% would be classified as high quality organic material that can be recommended for direct application as N sources (Delves, 2004). The good performance of this organic amendment in increasing sorghum yield indicates that the lignin content of 3.01% may be a good critical value, as high levels of lignin above 4% have resulted in poor performance (Delve, 2004).

The FE for the NSC soil amendments studied with %N > 2.5 (3.85 in 2009 and 5.34 in 2010) were positively correlated ($r = 0.73$ in 2009 and 0.76 in 2010, $P = 0.01$) to their N content, showing dependency of FE of this organic material on its N content. The linear functions indicated that an increase of 0.1% N in NSC could result in about 7% increase in fertilizer value in both years. Critical level of N content of NSC for the transition for increasing crop yield relative to 0N was 236.49 kg ha⁻¹ in 2009 and 295.09 kg ha⁻¹ in 2010 (Figure 1).

In the treatment combinations of neem seed cake and inorganic fertilizer, the 1 TC + $\frac{1}{4}$ RR with fertilizer equivalency of 35.86 and 79.52 gave highest percent fertilizer equivalency values of 65.80 and 114.62 in years 2009 and 2010, respectively. At this inclusion level of NSC and a quarter rate of N (16 kg N ha⁻¹) in the soil studied, a total of 54.50 and 69.38 kg N ha⁻¹ respectively, was applied which together with the residual mineral-N gave a significantly higher percent fertilizer equivalency value. In years 2009 and 2010, application of 2 TC + FRR, though had higher grain yield (3245.43 and 1471.04 kg ha⁻¹ respectively) as against 2775.34 and 1301.00 kg ha⁻¹ respectively for the former, had less percent equivalencies (42.61 and 57.77 respectively) which implied that there was an increase in sorghum grain yield perhaps, due to luxury consumption. This was also the case for grain yield, where the 4 TC + $\frac{1}{4}$ RR and 4 TC + FRR treatments recoded 3047.64 kg ha⁻¹ and 3141.99 kg ha⁻¹ respectively (Table 6). Furthermore, percent fertilizer equivalence (% FE) of 30.30 and 25.61 (Table 6) were obtained at the 4 TC + $\frac{1}{4}$ RR and 4 TC + FRR treatment combination respectively. The 1 TC + $\frac{1}{4}$ RR also would not be recommended as a suitable combination because about 102.5 and 117.38 kg N ha⁻¹ (50% of $\frac{1}{4}$ NPK plus 1 tonne NSC) was used to produce an additional 154.39 (5.26%) and 223.04 (14.63%) kg ha⁻¹ grains in 2009 and 2010 respectively.

CONCLUSION AND RECOMMENDATIONS

The $\frac{1}{4}$ NPK plus 1 tonnes NSC with fertilizer equivalency of 35.86 gave the highest percent fertilizer equivalency value of 65.80 which implied that at this inclusion level, the NSC amendment has other beneficial roles other than the addition of soil N, such as addition of micronutrients and better water holding capacity. The high equivalency values obtained in this study could also be attributed to the synergetic effects of nutrient supply. The role of NSC in improving yields was well demonstrated in this study. However, the study should be conducted for an extended period of time to investigate the residual effect of these organics on the chemical properties of the soil, especially decreasing soil pH and increasing exchangeable acidity which have been observed in laboratory studies.

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Table 1: Physical and chemical characteristics of experimental site, IAR Farm, Samaru and Greenhouse Soil sample

Soil property	Amount in soil
Particle sizes (g kg^{-1})	
Clay	160
Silt	240
Sand	600
Textural class	Sandy loam
pH (H_2O ; 1:2.5 w/v)	6.00
pH (0.01M CaCl_2 ; 2.5 w/v)	5.30
Bray-1 P (mg kg^{-1})	0.368
Organic Carbon (g kg^{-1})	4.41
Total N (g kg^{-1})	5.25
Exchangeable cations (cmol kg^{-1})	
K "	0.21
Ca "	2.20
Mg "	0.65
Na "	0.32
Cation exchange capacity "	5.20
Effective cation exchange capacity "	3.58
Exchangeable Acidity (cmol kg^{-1} soil)	0.20
Extractable micronutrients (mg kg^{-1})	
Zn "	5.00
Fe "	24.29
Cu "	1.50
Mn "	3.06

*ECEC = TEB + EA

Table 2: Selected chemical characteristics of the neem seed cake used in the study for the two years

Parameter	Unit	2009	2010
N	g kg ⁻¹	38.50	53.40
P	g kg ⁻¹	3.70	1.80
K	g kg ⁻¹	14.70	10.00
Ca	g kg ⁻¹	0.14	0.14
Mg	g kg ⁻¹	0.02	0.02
OC	g kg ⁻¹	230.50	300.20
Lignin	g kg ⁻¹ DM	30.10	44.67
Cellulose	g kg ⁻¹ DM	303.97	316.33
Polyphenol	g kg ⁻¹	13.30	8.00
C: N		5.99 : 1	5.62
N: P		4.53 : 1	12.71
C: P		27.12: 1	71.48
pH _{water}		5.2	4.0
pH _{CaCl2}		4.8	3.9

Table 3: Sorghum yield as affected by neem seed cake and inorganic fertilizer application

	2009	2010	Combined	2009	2010	Combined
	Grain yield (kg ha ⁻¹)			Stover yield (kg ha ⁻¹)		
Treatment						
NPK kg ha ⁻¹ (N)						
0	2845.8	959.94b	2002.5	15625b	7256.9b	11111
1/RR	2755.3	1330.90a	1939.9	16250ab	7326.4b	11354
1/RR	2639.6	1176.02a	1867.3	16667ab	8229.2ab	12604
FRR	3166	1249.85a	2251.9	18611a	8784.7a	14306
SE±	186.58	62.51	210	873.04	478.13	1113.7
NSC ton 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

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; NSC = Neem Seed Cake; NS= Not Significant

Table 4: Effect of NSC and NPK fertilizer on sorghum yield

Treatment	2009	2010	combined	2009	2010	combined	2009	2010	combined
	Stover yield (kg/ha ⁻¹)			Grain yield (kg/ha ⁻¹)			Grain yield increase (%)		
Control	1500	5138.89	10069.45	2605.45	850.71	1728.08	-	-	-
1/4RR?	13611.11	5833.33	9722.22	2362.30	781.20	1571.75	-9.33	-8.17	-8.75
1/2RR?	15277.78	7916.67	11597.23	2537.60	1042.75	1790.18	-2.6	22.57	9.99
FRR	16944.45	10138.89	13541.67	3346.81	1165.10	2256.00	28.45	36.96	32.71
1TC	16388.89	6250	11319.45	3144.67	1367.10	2255.89	20.7	60.7	40.70
1TC+1/4RR	17777.78	5833.33	11805.56	2775.34	1301.00	2115.37	12.45	52.93	32.69
1TC+1/2RR	15000	8611.11	11805.56	2839.29	1131.44	1796.27	-5.54	33	13.73
1TC+RR	17500	8611.11	13055.56	2929.73	1524.04	2179.91	8.84	79.15	44.00
2TC	15277.78	7500	11388.89	2461.09	1088.57	1981.96	6.52	27.96	17.24
2TC+1/4RR	17500	6805.56	12152.78	2835.77	1055.50	1821.72	-0.67	24.07	11.70
2TC+1/2RR	20000	8194.45	14097.23	2587.93	1088.98	2167.21	24.56	31.29	27.93
2TC+RR	16111.11	10416.67	13263.89	3245.43	1471.04	2321.56	21.75	72.92	47.34
4TC	14722.22	7500	11111.11	3172.08	1330.38	2084.84	8.97	56.38	32.68
4TC+1/4RR	18611.11	7361.11	12986.11	3047.64	1360.67	2204.16	16.97	59.95	38.46
4TC+1/2RR	19166.67	9444.44	14305.56	2593.66	1116.87	1855.27	-0.45	31.29	15.42
4TC+RR	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			