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Full Length Research Paper

Neem seed cake and inorganic fertilizer amendments for sustained productivity of maize (*Zea Mays)* on Nigerian Savannah Alfisols

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Low fertility level of soil is among the major constraints of crop production in Nigerian savannah. Field trails were therefore conducted during 2008 and 2009 cropping seasons to evaluate the potentials of neem seed cake (NSC)- a residues obtained after oil extraction from the seed of neem tree (Azadiracta indica)- in combination with NPK fertilizers for sustained productivity of maize. Three levels (0, 2 and 4) tons ha^{-1}of NSC and that of NPK fertilizers (0, ¼ and ½ optimum fertilizer recommendation (OFR) for maize in Samaru-Zaria, Nigeria) were solely applied and in combination using randomized complete block design in 12m^{2}plots with three replication. OFR (120:60:60 NPK) and recommended rate (NRR) for combined NSC and inorganic fertilizers (4:1) were included as checks. The plots were managed manually and monitored for growth parameters, at harvest yield parameters were measured, and plant and soil were sub-sampled for analysis. Result showed that combination of NSC and NPK significantly ($p<0.005$) increased maize number of leaves and sterm girth as well as leaf area and height ($p<0.001$). Significant increased ($p<0.001$) were also recorded on maize grains yield, stover yield total dry matter yield and relative yield increase also, maize harvest index was significantly ($p<0.005$) higher from the treated plots compared to control. No significant increase was found on maize N, P and K concentration however, N and P uptake from the treated plots were higher ($p<0.005$) than control. Result also showed no significant improvement on some selected soil properties after cropping nonetheless, NSC can still serve as good choice organic amendment. Combine application 4 tons ha^{-1}NSC + ¼ OFR was significantly higher in all the growth and yield parameters monitored and statistically similar with 2 tons ha^{-1}NSC + ¼ OFR except for stover yield therefore, application of 2 tons ha^{-1}NSC + ¼ OFR was recommended considering the economic level of the farmers and cost of inorganic fertilizers in the study area. Further research should also be conducted to explore the full potentials of NSC

Keywords: neem seed cake, inorganic fertilizers, Alfisols, productivity.

INTRODUCTION

Nigerian savannah has dominance by Alfisols followed by presence of Ultisols, Entisols, Vertisols and Inceptisols (USDA, 1975; Kang and Spain, 1986). The soils are made up of low activity clay (LAC) with kaolinite as dominant clay fraction (Gallez et al., 1975; Ojanuga, 1979). Moberg and Esu (1991) reported that kaolinite and Fe $(OH)_2$ forms 80-90% of clay fraction of the soils. The soils are highly weathered with weak surface aggregation which is primarily induced by Fe and Al (Dudal and Deckers, 1993; Salako, 2003). This gives it coarse textured surface which when unprotected becomes prone to severe compaction and accelerated erosion (Lal et al., 1980; Odunze, 2006). The soils reaction are generally medium to slightly acidic (Jones and Wild, 1975) and has supra optimal soil temperature (Cunningham, 1963). They are inherently low in fertility, cation exchange and water holding capacities due to the low level of soil organic matter. Thus, N, P and S mineralization is insufficient for crop growth (Uyovbisere et al., 1999; Salako, 2003; Adeboye, 2004; Daudu, 2004). Given these constraints, sustainable crop production is achieved through good soil management

Table 1: Fertilizer eleven treatment combinations

S/N	Treatment
1	Control
2	2 TC
3	4 TC
4	¼ OFR
5	½ OFR
6	2 TC + ¼ OFR
7	2 TC + ½ OFR
8	4 TC + ¼ OFR
9	4 TC + ½ OFR
10	OFR
11	NRR (1:4 ratio of inorganic fertilizer and neem seed cake)

TC = t ha^{-1} neem seed cake
OFR = optimum fertilizer recommendation rate
NRR = NARICT recommended rate

practices which includes supplements of organic and inorganic fertilizers, minimum/conservation tillage, mulching, avoidance of bush burning and management of crop residues, crop rotation, cover cropping and contour farming. Combined use of organic and inorganic fertilizers formed the back bone of integrated soil fertility management (ISFM) approach, which is known to increase nutrient use efficiency and reduce environmental stress (Bationo, 2008). Combined organic and inorganic fertilizer render longer lasting effects of nutrients and soil physical properties than does either source used alone (Uyovbisere et al., 1999; Tarfa et al., 2001; Okalebo et al., 2004 and Bationo, 2008). This is because of the nutrients supply by both organic and inorganic amendments as well as the effect of organic amendment on improving soil structure leading to adequate water retention, nutrient and air circulation for crop growth and development. Other advantages derived are increasing pH and buffering capacity of soil, CEC and overall soil biological condition. Different organic materials available in the savannah agro-ecology of Nigeria were combined with inorganic fertilizer and shown a positive result, these includes FYM, crop residues, compost, animal manure and municipal waste however, little attention was given on potentiality of agro-forestry. Neem (*Azadiracta indica)* tree is found abundantly in the study area and its leaves, seed were shown to contain substantial nutrients thus can serve as an alternative organic materials for sustained productivity of soil. Neem seed contains oily azadiractin compound which has medicinal and insecticidal properties thus when extracted from the seed residues are left popularly known as neem seed cake (NSC). The present study aimed at evaluating NSC and NPK fertilizers on sustained productivity of maize.

MATERIALS AND METHODS

The study was carried out during 2008 and 2009 cropping seasons on an Alfisols at the Experimental Research Farm of the Institute for Agricultural Research (IAR) Samaru-Zaria (lat. 11º 11' N, long. 7º 38' E) with altitude of 686m above sea level in the Northern Guinea savanna of Nigeria. The area is characterized by two seasons; dry season (November – April) and rainy season (May – October). It also has mono-modal rainfall pattern ranging from 950-1270 mm with annual mean of 1110 mm. The mean annual temperature is 25 ºC. The soil was classified as sandy loam, kaolinitic, ultic haplustalf (Ojanuga, 1979). NSC was obtained from the National Research Institute of Chemical Technology (NARICT) Basawa-Zaria, Nigeria. Foreign materials such as uncrushed seeds and kernels, stones, leaves and straw were initially removed from the cake and then passed through 2mm stainless sieve and sub-samples were taken for characterization. NPK fertilizers was obtained from the local market to simulate farmer's source of fertilizer materials. A composite surface soil sample (0 – 15 cm) was taken from the experimental site before land preparation. It was thoroughly mixed, air-dried, crushed, passed through 2mm stainless sieve and used and used for pre-planting analysis. The treatments consists of three levels of NSC (0, 2 and 4 tha^{-1}) and three rates of inorganic fertilizer (0, ¼ and ½ of the optimum fertilizer recommendation for maize in Samaru; 120-60-60 N, P_2O_5 and K_2O respectively). The optimum fertilizer recommendations as well as NARICT's recommendation (1:4 ratio of inorganic fertilizer and the NSC) were included as checks. The eleven treatment combinations were as in Table 1.

The treatments in three replicates were laid down in randomized complete block design on plot size of $12m^2$, neem seed cake was incorporated into appropriate plots and allowed to incubate for two weeks, after which maize (*Zea mays* var. SAMMAZ 12), an extra early variety developed by Institute for Agricultural Research, Samaru, Zaria was planted and monitored the growth parameters. The field was manually weeded at two, four and six weeks after sowing. The first dose of NPK fertilizer was applied at 3 weeks after sowing and top dressing of urea was done at 6 weeks after sowing. At harvest total dry matter yield was measured latter grains yield and stovers yield were determined separately.

Table 2: Characterization of the soil used before cropping

Parameter	Results
Particle sizes (g kg^{-1})	
Sand	560
Silt	340
Clay	100
Textural class	Sandy loam
pH (water)	5.2
pH ($CaCl_2$)	4.7
Org. C (g kg^{-1})	5.6
Total N (g kg^{-1})	0.6
Available P (mg kg^{-1})	15.05
Exchangeable cations (cmol kg^{-1})	
K	0.18
Ca	2.71
Mg	0.85
Na	0.22
$H^+ + Al^{3+}$	0.65
ECEC	4.43

Table 3: Chemical properties of Neem seed cake

Parameter	Result g kg^{-1}
OC	374
N	26.7
P	38.7
K	2.1
Ca	5.4
Mg	3.2
Fe	0.9
Mn	0.02
Zn	0.21
CHO	410
OM	646.64
C:N	14

OM = (% OC x 1.729). (Juo, 1979).

They were also sub-sampled, dried and grinded for the determination of N, P and K concentration and the following were calculated as thus:

- Nutrient uptake = $\frac{\text{Nutrient concentration}}{\text{Total dry mater yield}} \times 100$
- Harvest index (HI):= $\frac{\text{Grains yield}}{\text{Total dry mater yield}} \times 100$
- Relative yield increase = $\frac{\text{Yield}_{\text{treatment}} - \text{Yield}_{\text{control}}}{\text{Yield}_{\text{chemical fertilizer}} - \text{Yield}_{\text{control}}} \times 100$

(Sharief et al., 2006; Daudu et al., 2007)

At the end of each cropping seasons soils were sub-sampled from the field and analyzed for selected properties. All data were subjected to analysis of variance (ANOVA) using statistical computer package of SAS (9.1). Where F- ratios were found to be significant, treatments means were separated using student t test.

RESULT AND DISCUSSION

Characterization of soils and neem seed cake

The result on particle size distribution analysis showed a proportion of 560, 340 and 100 g kg^{-1} for sand, silt and clay respectively (Table 2) giving the textural class of sandy loam. The organic carbon content was low (5.6 g kg^{-1}) which could be attributed to the sandy nature of the soil and low rate of soil organic matter. This could encourage a rapid leaching of captions and consequent low CEC values (Jones, 1973; Iwuafor, 1979; Enwezor et al., 1990). The soil reaction was slightly acidic both in water (5.2) and $CaCl_2$ (4.7), the values are within the range reported by Jones and Wild (1975). The pH value in water was higher than that in salt indicating the possession of net negative charge in the soil colloidal complex (Balasubramanian and Nnadi, 1980). This also signified that exchangeable aluminium toxicity may not be a problem in the soil (Kamprath, 1972). Total N content, available P and exchangeable K were low, indicating poor nutrient reserve of the soil. The soil therefore, falls in the low fertility class (Enwezor et al., 1990; Aduayi et al., 2002). Sucessiful crop production from these soils is therefore accomplished through proper nutrients managements and supplementation.

NSC showed quite distinct chemical properties (Table 3). Organic carbon, N and P contents were high compared to that of the soil used for the study. The

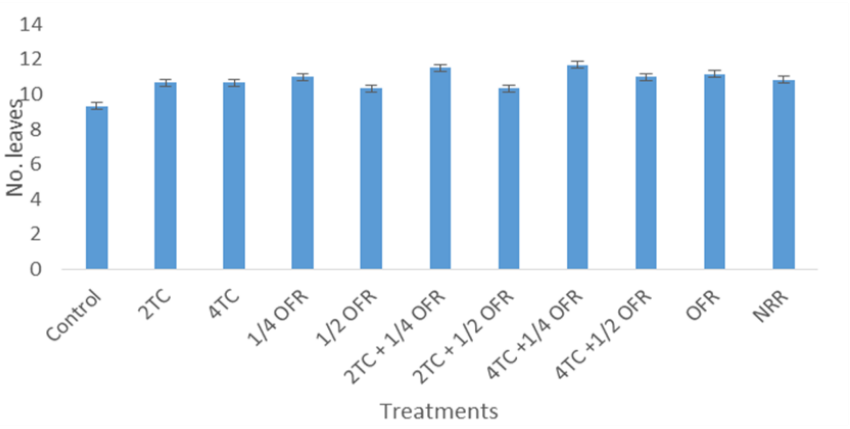

Figure 1: Effect of NSC and NPK on Maize number of leaves

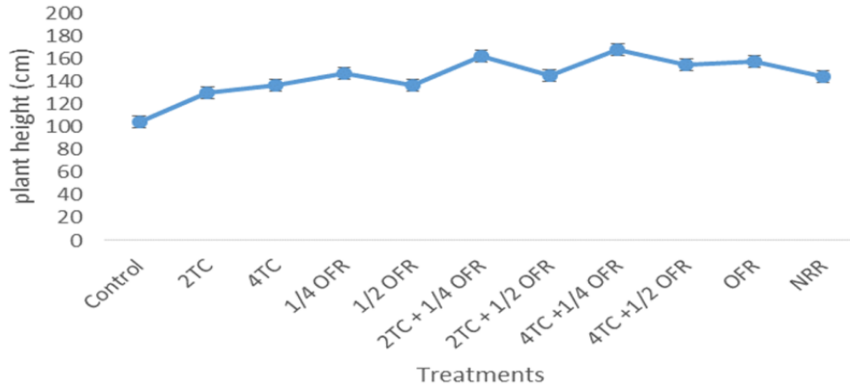

Figure 2: Effect of NSC and NPK on Maize plant height

presence of other nutrients (K, Ca, Mg and micronutrients) in the cake indicates its potential for nutrient supply for crop growth. The organic matter in the NSC (646.64 g kg^{-1}) suggested the ability of NSC to improve the physical, chemical and biological properties of the soil. Nitrogen and P contents of the cake differs from the earlier work reported by Agbenin et al. (2008). In their study they found out that NSC contains higher N than P content while the reverse was the case in this study. However, variations in contents of organic amendments have been reported to depend on source, geographical location and genetic characteristics of the plant (Mengel and Kirkby, 1979). The narrow C:N ratio (14) would result in its rapid decomposition by soil microbial activity.

Growth responses of maize on application of NSC and NPK fertilizers

Combined application of NSC and NPK fertilizers significantly ($p<0.005$) increases maize number of leaves. The plots with 4TC + ¼ OFR recorded higher number of leaves (Figure 1)with the remaining treatments statistically higher than control implying increase in plant growth with increasing nutrient supply from both organic and inorganic sources which is one of the benefits of an integrated soil fertility management.

There were significant ($p<0.001$) differences in plant height between each of the treated plots and the control. Moreover, the tallest plants were from plots with combined application of the amendments and OFR (Figure 2) thus, integrated nutrient supplements ensure all round nutrient availability through rapid release of nutrient from the inorganic source for early uptake by crop seedling as well slow and continuous release from the organic material after mineralization.

The control recorded lowest stem girth ($p<0.005$) and was statistically similar with 2TC, 4TC and ½ OFR. While the rest of the treatments were higher and at far in stem girth except application of 4TC + ½ OFR which is statically lower than combined application of 4TC + ¼ OFR (Figure 3). Proper maize fertilization is known to affect its growth parameters which contribute significantly to the yield (Ogunlela et al, 1988). This is achieved through rapid tissue growth and development

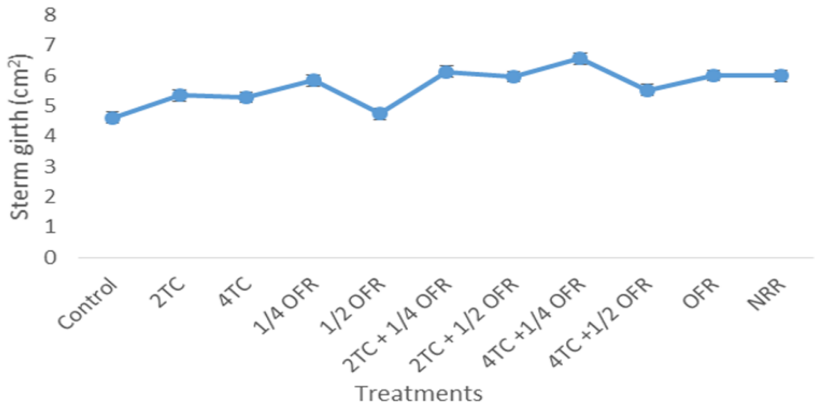

Figure 3: Effect of NSC and NPK on Maize stem girth

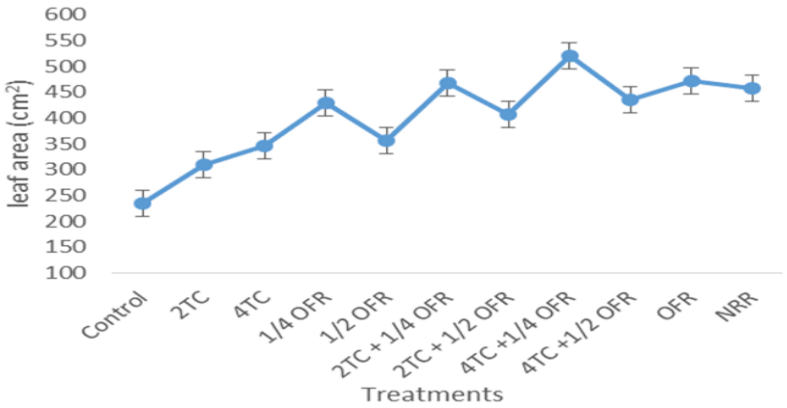

Figure 4: Effect of NSC and NPK on Maize leaf area

due adequate nutrients supply, proper uptake provided other factors remains optimum leading to yield increase.

Treatments significantly ($p<0.001$) increased leaf area compared to control except application of 2TC. Combination of NSC and ¼ OFR showed (Figure 4) higher leaf area and statistically similar with OFR, NRR and 4TC + ½ OFR. An improvement in leaf area could translate into increased yield as there would be wider surface area for photosynthetic reactions to take place (Adediran et al, 1999; Solomon et al. 2008).

Crop plant basically requires nutrients, water, air and space for its growth and development. Part of these nutrients are required in large quantity like C, N, P and K while some like Fe, Zn and Cu are required in small quantity which all of them are essential because plants cannot complete its life circle in their absence and their deficiency can only be corrected by their supplement. C, H and O are abundantly provide by nature mostly by photosynthesis while elements like N, P, and K are coming from the soil and considering the low fertility level of the savanna Alfisols these cannot be provided adequately to crop therefore successful production is only achieved through their external supplement. Inorganic fertilizer provides only nutrients to the crop which just one out its basic requirement but when it is combined with organic manure in the soil the other requirements can be indirectly achieved through general improvements of soil condition which ensures stable aggregate for good water infiltration and retention in soils, adequate air circulation within the soil pores, available nutrients and normal condition for their uptake leading to their rapid transportation into the various crop meristems for physiological process and increase in growth.

Yield responses of maize on application of NSC and NPK fertilizers

The effect of treatments on maize yield was significant ($p\leq0.001$). An increase in stover yield was observed with combination of NSC and NPK fertilizers which was statistically higher than their sole application (Figure 5). Moreover, there was a significant difference between

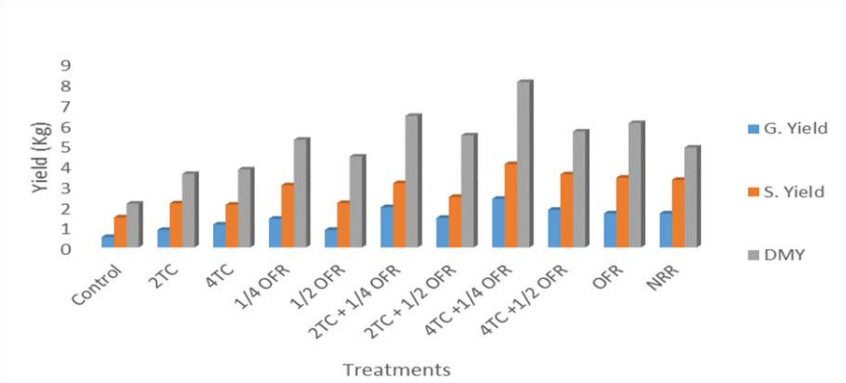

Figure 5: Effect of NSC and NPK on Maize yield

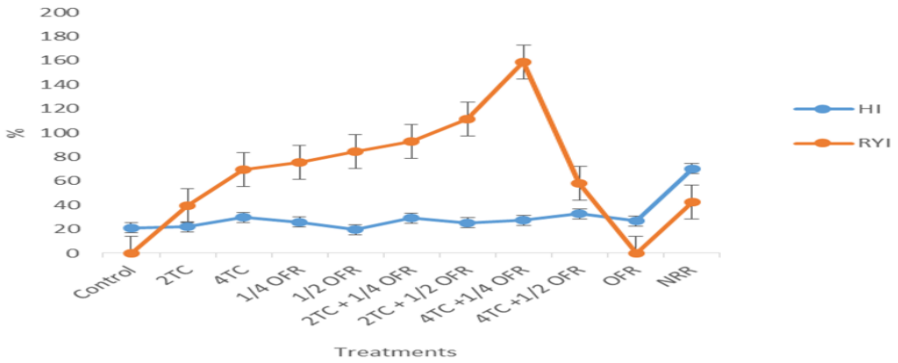

Figure 6: Effect of NSC and NPK on Maize HI and RYI

sole NSC and sole IF treatments as OFR recorded a higher stover yield over the two rates of NSC. Combined application of 4TC + ¼ OFR gave the highest stover yield (3, 3897 kg ha^{-1}) and control had the least (1, 222.25 kg ha^{-1}). Combination of NSC and NPK fertilizers recorded higher grain yield than their sole applications except for OFR. Control plot recorded the least grain yield (425 kg ha^{-1}) while plants treated with 4TC + ¼ OFR gave the highest (1, 979.17 kg ha^{-1}). An increase in total dry matter was observed with increasing sole NSC while sole NPK application ¼ OFR and OFR were higher than ½ OFR. Combined application of 4TC + ¼ OFR gave the highest total dry matter yield of 6, 722.25 kg ha^{-1} while control gave the least (1, 777.75 kg ha^{-1}). The non-significant differences observed between sole NSC and control treatments on stover and grain yields as well as total dry matter yield are clear indications that NSC alone cannot produce the expected yield on the soil and suggest the need for an integrated soil fertility management system (FAO, 1999; Vanlauwe, 2001). In the system inorganic fertilizer component would provide nutrients for crop growth during early vegetative growth stage while the organic component provides nutrients at the later stage of crop development. Daudu et al. (2007) reported an increase in maize performance and yield due to combined application of organic materials and inorganic fertilizers This also helps in improving soil physicochemical condition by increasing aggregate stability of soil particles, hence increased infiltration and water retention (Tan, 2000). The yield increases with combined application of the amendments demonstrated that soil nutrient were initially limited for maize production (Uyovbisere et al. 1999). Though inorganic fertilizer stimulated high yield in this short period of study relative to NSC, maize production solely on the application of inorganic fertilizer in the savanna may not be sustainable because of its high cost and scarcity to farmer as well as its adverse effects on soil properties (Tarfa et al., 2001). But the little a farmer can get will be combined with the organic manures for enhanced crop productivity and fertility of soils.

Combine application of NSC and NPK fertilizers significantly ($p<0.005$) increases maize harvest index (HI). However, NRR recorded higher HI while the treatment means of the rest was statistically similar. The harvest index determines how many photosynthates are transformed into economic yield as it is the ratio of economic yields to biological yield therefore, significant increase in harvest index between the treatments and control indicates the combined effect of NSC and inorganic fertilizers contributed in the maximization of the biological activity (Bekeko, 2014). There were significant ($p<0.001$) increases in yield from the treatments relative to OFR and control, 4TC + ¼ OFR and 2TC + ½ recorded higher relative increases (RYI) of 158.88% and 111.31% respectively while 2TC recorded the least of 39.74% (Figure 6). This indicates that inorganic fertilizer in combination with NSC can supply adequate nutrients

Table 4: Effect of NSC and NPK on maize nutrients concentration

Treatments	Plant N	Plant P	Plant K
	%		
Control	0.678	5.028	1.475
2TC	0.797	4.123	1.983
4TC	0.728	5.055	2.067
1/4 OFR	0.982	4.237	1.478
1/2 OFR	0.725	5.117	1.665
2TC + 1/4 OFR	0.983	4.378	1.662
2TC + 1/2 OFR	0.670	4.173	1.495
4TC +1/4 OFR	0.853	4.158	1.723
4TC +1/2 OFR	0.820	5.368	1.678
OFR	0.887	4.427	1.787
NRR	0.823	5.117	1.623
	NS	NS	NS

NS= not significant

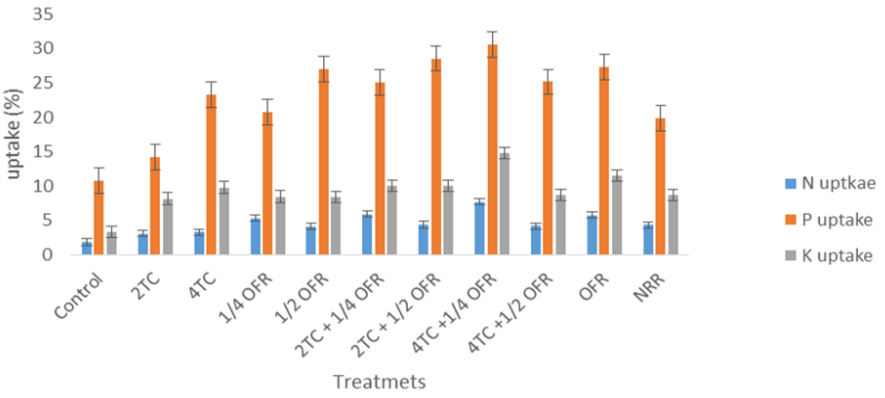

Figure 7: Effect of NSC and NPK on Maize nutrient uptake

for maize yield and improved the soil fertility condition arising from the capacity of NSC to maintain the productivity of the soil (Daudu et al., 2007).

Effect of NSC and NPK fertilizers on maize nutrients concentration and uptake

Result of the separate and combined analysis showed no significant differences on maize nutrients concentration however, from the combined date there was an increase in plant N from all the treatments higher than that of control except 2TC + ½ OFR and combined amendments recorded higher N than their sole application with 2TC + ¼ OFR having higher N% of 0.983. P also was observed increased with increasing sole application of the amendment with 4TC + ½ OFR recording higher P (5.368%) while 2TC was the least (4.123%). All the treatments recorded higher K than control and was observed to increase with increasing sole amendments while the reverse was the case for NPK when combined with NSC (Table 4). Significant differences were recorded on the effect of treatments on P ($p<0.001$) and K ($p<0.005$) uptake from the result of first trial while the second year trial showed no significant difference of treatments effect on N, P and K uptake. However, significant effect of the treatments on N and P were observed ($p<0.005$) from the combined analysis. Increase in N, P and K uptake were observed with increasing application rates of NSC and IF (Figure 7) though, the differences in some cases were not statistically significant implying that NSC or IF alone

Table 5: Effect of NSC and NPK fertilizers on some selected soil properties after cropping

Treatment	pH CaCl2	OC %	N	P	K	EA cmol kg^{-1}	Ca	Mg	Na
Control	4.600	0.645	0.056	15.167	0.372	0.667	2.990	0.802	1.253
2TC	4.650	0.880	0.063	12.688	0.535	0.483	3.507	0.722	1.472
4TC	4.717	0.767	0.060	13.853	0.372	0.733	3.368	0.908	1.537
1/4 OFR	4.600	0.672	0.066	13.418	0.448	0.767	2.907	0.662	0.880
1/2 OFR	4.633	0.615	0.058	10.792	0.385	0.733	3.962	1.107	1.345
2TC + 1/4 OFR	4.650	0.622	0.052	14.438	0.515	0.700	3.323	0.802	1.380
2TC + 1/2 OFR	4.633	0.647	0.060	13.667	0.505	0.700	3.313	1.023	1.422
4TC +1/4 OFR	4.633	0.873	0.083	15.167	0.485	0.667	2.972	1.050	1.443
4TC +1/2 OFR	4.667	0.647	0.053	13.125	0.622	0.767	3.223	0.782	1.328
OFR	4.717	0.673	0.066	12.833	0.575	0.733	3.277	0.813	1.440
NRR	4.633	0.793	0.078	13.265	0.407	0.733	3.053	0.803	1.362
	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS= not significant

could increase nutrient uptake in maize (Tarfa et al., 2001)

Application of NSC with IF virtually increased N, P and K uptake over their sole applications. Highest N, P and K uptakes were recorded for 4TC + ¼ OFR while control recorded the least. The increase in uptake with fertilization was higher for P than for N and K and could be attributed to the high P content in NSC. The observed differences in N, P and K uptake from the combine application of the amendments over their sole applications could be attributed to the relatively higher nutrient supply and the improvement of soil physical, chemical and biological conditions. Soil nutrients and rainfall are the major constraints of maize production in the savannah of northern Nigeria. The yields are typically low due to scarce rainfall and low nutrient reserve from the soil therefore, appropriate nutrients management leads to increased crops yield and higher crop recovery of the applied nutrients (Ademba et al., 2014) through rapid absorption, faster growth and attaining full maturity within the shortest period of rainfall.

Effect of NSC and NPK fertilizers on some selected soil properties after cropping

Effect of treatments on some selected soil properties are shown in Table 5. No significant difference was observed from the separate and combined analysis. This is most probably due to the short term incorporation of NSC. Similar results have been reported by some researchers in the region. For instance, experiment conducted by Yar'adua (2007b) demonstrated insignificant changes in soil properties due to one season incorporation of the NSC. Similarly, Uyovbisere and Elemo (2000) incorporated foliage of *Parkia* and neem + inorganic fertilizers for two years and reported no significant increase in soil chemical properties. The field trial conducted by Solomon et al. (2008) in Calabar recorded no significant effects on soil texture, pH, OC, total N, BS and ECEC. However, the insignificant differences may be substantial in the lowly buffered and kaolinitic soils of the savanna (Uyovbisere and Elemo, 2000). The non-significant differences could also be attributed to the slow decomposition of NSC such that absorbed plant nutrients were not enough to warrant a significant change in the soil. The water logged condition experienced during the first year trial could also have contributed to slow down activities of NSC decomposers (microorganism) due to persistent anaerobic environment, and leaching effect of the available nutrients below the rooting zone of the crop. The ability of NSC to improve soil fertility when complemented with inorganic fertilizer no doubt has good potential if applied for long term (Tarfa et al., 2001; Yar'adua 2007a).

CONCLUSION

NSC has substantial N, P and other nutrients contents and high residue quality to be used as organic nutrient source for improving the fertility and productivity of savanna Alfisols. Complementary application of NSC and inorganic fertilizer increased growth, grain yield and yield parameters as well as total biomass yield. Similarly, due to the non-significant differences observed between 4TC + ¼ OFR and 2TC + ¼ OFR treatments on maize yield which all gave higher yields than the optimum fertilizer recommendation rate, combined application of 2TC + ¼ OFR is recommended for maize considering

economic constrain of our farmers. Soil physicochemical properties can be improved if the above management practice is adopted over years. Further field studies are required to validate the result obtained from this study as well as to study the long term effect of the amendments on soil physicochemical properties, since their significant changes were not observed during the short period of this study.

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