I.J.S.N., VOL.5 (4) 2014: 608-615 ISSN 2229 – 6441

INTERNATIONAL JOURNAL OF SCIENCE AND NATURE

www.scienceandnature.org

ASSESSMENT OF NEEM SEED CAKE AMENDMENT ON SOIL PROPERTIES BY FACTOR ANALYSIS

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ABSTRACT
Soil acidity is one of the major threats posed in the use of local organic inputs to ameliorate soil nutrient mining facing crop production in Africa. Field trials were conducted to assess the influence and inter-relationships of neem seed cake (NSC) and chemical fertilizer (CF) on soil chemical properties in 2009 and 2010. Experiment was laid down using a factorial combination of four levels of NSC and straight chain fertilizers at 0, ¼, ½ and full of the recommended CF for sorghum production in a randomized complete block design replicated thrice. Eleven measured soil properties representing chemical/ nutrient indicators were subjected to factor analysis (FA), using principal components extraction and varimax rotation on their standardized values. Results obtained on the influence of NSC on soil properties showed that organic carbon was significant in both years while exchangeable potassium was only significantly ($P<0.05$) higher in sole treatments compared to the sole NPK and interaction which were not statistically different in 2010. 'Soil potential exchange capacity,' had significant highest positive and negative inter-relationships between ECEC, Ca, Mg and available P which has significant influence on acidifying capacity and nutrient availability. Soil pH and exchangeable acidity were the most discriminating factor in factor component 2 which, influenced biomass yield and return of biomass to the soil (nutrient availability). Although, nitrogen concentration is the dominant factor in assessing soil quality, the most discriminating factor in neem seed cake amended soil is the exchangeable calcium and magnesium, with mean load of 0.89 and 0.80, respectively.

KEY WORDS: influence, inter-relationships, neem seed cake, soil properties, factor analysis.

INTRODUCTION

Good management of agricultural production systems such as soil resources is a response to challenges posed by world food crisis. Consequently, the information on soil physical and chemical properties which are key determinants of soil quality is essential when testing different options of soil fertility maintenance and improved crop productivity that would be affordable, environmentally benign and sustainable. 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). Thus, it is pertinent to explore and evaluate the potentials of locally available organic wastes as soil amendments. The sustainability of soil productivity using inorganic and organic inputs can be secured by management of the chemical properties which include soil pH, organic matter, available phosphorus, total nitrogen, potassium, cation exchange capacity and exchangeable acidity. However, these properties influence the fertility status of the soil in varying degree, with soil pH and exchangeable acidity been of utmost concern since they cause changes in the soil which affect nutrient uptake by crops (Agbenin *et al*., 2008; Mohammed *et al*., 2013a). Multivariate analysis statistics offers a convenient framework within which one can analyse the structure of data matrices and the possible cross-correlations between variables (Pachepsky and Rawis, 2005). In the context of principal component analysis, a set of so-called components is formed, allowing quantifying the internal variability of the data set analysed by means of a reduced set of variables (Toth *et al.*, 2008). Factor analysis was used to investigate the role of eleven soil properties analyzed at harvest of sorghum in the determination of the effect of treatments on soil properties. These analyses were performed to identify the parameters which play a role in soil physico-chemical properties as influenced by treatments. On the basis of the rotated component matrix it was then possible to identify the most significant variables within the group of components and the degree of inter-relationship.

MATERIALS & METHODS

Experimental Site Characteristics

Two-year field study was conducted during the rainy season of year 2009 and 2010 at the experimental farm of the Institute for Agricultural Research (IAR), Samaru (11°11' N and 7 °38' E) within the northern Guinea Savanna zone of Nigeria. Samaru soil is classified as an Alfisol using the USDA soil classification system (Soil Survey Staff, 1975). Composite sample was obtained from twenty points at random, air-dried, sieved through a 2 mm sieve and subjected to routine analysis following standard procedures (IITA, 1989) for initial soil characterization.

Treatment and Experimental Layout

The field experiment was laid out in a randomized complete block design (RCBD) with three replications. The treatment consisted of factorial combinations of four levels of NSC (0, 1, 2 and 4 tons ha^{-1}) and four rates of chemical fertilizer (CF) package (0, ¼, ½ and full recommended fertilizer rates of 64 kg N, 32 kg P_2O_5, 32 kg K_2O for sorghum). Plot size was 6m × 4.5m giving a gross plot size of $27m^2$ 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. Sorghum variety, *Samsorg 17 (SK-5912)* was planted at five seeds per hill and at a spacing of 0.25m within row and 0.75m inter-row. Phosphorus (P_2O_5) and potassium (K_2O) 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 (WAP). The first dose of nitrogen (N) levels at 0, 0.023kg (4 kg ha^{-1}), 0.047kg (8 kg ha^{-1}) and 0.094kg (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 (3 WAP). The second split dose (three-quarter) of the N requirements were applied 6 WAP at 0, 0.070kg (12 kg ha^{-1}), 0.141kg (24 kg ha^{-1}) and 0.282kg (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 6 WAP.

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.

Analysis of Neem Seed Cake (NSC)

The organic material, neem seed cake whose oil was expelled mechanically 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. NSC was allowed to incubate for two weeks before planting of seed to a depth of 0.15m at four different levels: 0, 1, 2, and 4 tons ha^{-1} corresponding to 0, 38.5, 77.0 and 154.0 kg N ha^{-1} in the first year.

Statistical analysis

Soil data at harvest 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. To understand the underlying relationships among the soil chemical properties, factor analysis was used to group the soil properties according to their covariance (Johnson, 1978) using IBM SPSS version 20.0. The database contains information on the soil pH in water and calcium chloride, exchangeable acidity, organic carbon, exchangeable bases, available P, N and effective cation exchange capacity. Factor Analysis was performed with reference to the whole dataset and estimates of the initial factors obtained from principal component analysis. The number of factors to be retained was chosen on the basis of the relative proportions of the variance explained by the Eigenvalue (standardized variance associated with a particular factor). To simplify the interpretation of the results, VARIMAX rotation with Kaiser normalization was used. On the basis of the rotated component matrix, it was then possible to identify the most significant variables within the group of components and the degree of inter-relationship between them.

RESULTS & DISCUSSIONS

The data on the soil physico-chemical properties are presented in Table 1. 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 $CaCl_2$ 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 concentration in the soil. Calcium and magnesium are however 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) have 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).

TABLE 1: Physico-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

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 amount (Palm *et al*., 2001).

Effect of NSC and CF on selected soil properties

There were no significant differences in all the parameters measured between all the treatment sets except for exchangeable potassium in 2010 (Table 3a). However, the effect of the NSC treatment was significant on available phosphorus in 2009 and organic carbon in both years (Table 3b). The results on soil physico-chemical properties suggest slight additional benefits of combined application of NSC with CF. Application of CF decreased pH over years which were consistent with acid producing nature of fertilizer due to its nitrogen and phosphorus content (Pestov, 1994). This implies that continous use of CF will increase soil acidity and consequently crop yield reduction. The remarkable decrease over years corroborates the submission of Bache and Heathcote (1969) that sandy parent materials and low organic matter content have rendered the savanna soils low in buffering capacity, hence significant changes in the soil pH. Organic carbon (OC) increased with increasing levels of NSC (Table3b). However, the low OC in 2010 compared with 2009 conforms to the findings of Papendick (1994) who reported a decrease in soil organic matter levels following cultivation. The non-significant available phosphorus observed between control and treatment plots in 2010 could be attributed to the ability of the soil to maintain equilibrium concentration of solution P with the adsorbed P; since solution P was rapidly replenished by P from labile inorganic P (P_i) minerals and by biochemical mineralization of labile organic P (P_o) (Van Noordwijk *et al*., 2004). The better physico-chemical properties obtained with the application of NSC compared to CF may be due to addition of other soil conditioning substances in the organic material which are absent in the chemical fertilizer (Mohammed *et al*., 2013a).

The results presented in Table 4 showed that four factors were extracted in 2009. Factor 1 explained 21% of the variance in the original variables and factor 2 explained an additional 20% of the variance while factor 3 and 4 explained 13% each of the variance in the original variables respectively. In 2010 on the other hand, five factors were extracted (Table 4). Factor 1 explained 26% of the variance in the original variables and factor 2 explained an additional 16% of the variance while factor 3, 4 and 5 explained 13%, 12% and 11% of the variance in the original variables respectively. The factor components (FCs) with eigenvalues > 1 were retained, since eigenvalues < 1 indicated the factor could explain less variance than an additional soil property. Eigenvalues from the correlation analysis indicated that the first four FCs accounted for 66% of the variance of soil properties standardized value (Table 4) in 2009 while the first five FCs accounted for 80% of the variance of soil properties standardized value in 2010.

In 2009, the FC 1 explained 21% which included exchangeable calcium, exchangeable magnesium and effective cation exchange capacity (ECEC) (communality estimates varied between 0.62 and 0.89 for different variables in 2009) as the major contributing variables (Table 4). The FC 2 accounted for 20% which included pH_{water}, exchangeable K, Na and available P (communality estimates varied between 0.48 and 0.81) as the major contributing variables (Table 4). The FC 3 and FC 4 both explained 13% of the total variance which included exchangeable acidity (EA) and pH_{CaCl2} in FC 3, and organic carbon (OC) and nitrogen in FC 4 (communality estimates for EA = 0.53 and for pH_{CaCl2} = 0.64 from FC 3 whereas FC 4 had communality estimates for OC = 0.53 and nitrogen = 0.76).

In 2010, the FC 1 explained 26% which included exchangeable calcium, exchangeable magnesium and effective cation exchange capacity (ECEC) (communality estimates > 0.90) as the major contributing variables (Table 4). The FC 2 accounted for 16% which included pH_{water}, exchangeable acidity and available P (communality estimates varied between 0.61 and 0.82) as the major contributing variables (Table 4). The FC 3 and FC 4 both explained 13% of the total variance which included exchangeable K and Na (communality estimate for K = 0.80 and for Na = 0.68) in FC 3, while FC 4 included pH_{CaCl2} and organic carbon (OC) (communality estimates for pH_{CaCl2} = 0.69 and for OC = 0.86). The FC 5 explained 11% of total variance which included nitrogen (communality estimates for N = 0.76) as the major contributing variable (Table 4).

In 2009, FA reduced 11 measured soil properties into four FC groups that explained 66% of the total variability. FC 1 was directly related to 'soil potential exchange capacity properties' which explained 21% of the total variance (Table 4) with a positive loading of exchangeable calcium, magnesium and ECEC explaining the major variation of exchange capacity of the treatment. The FC 2, named 'soil additional potential nutrients' explained 20% of variance with a positive loading from pH_{water}, exchangeable K and sodium and a negative loading from available P (Table 4). The positive loading from pH_{water} would have contributed to the loss of pH-dependent charges. Thus, the increase in pH with increase in treatments resulted in more positively charged ions in the soil; evident from the high positive loading from K and Na, and the negative loading from available P. FC 3, called 'soil acidifying properties' explained 13% of the variance had positive loading from EA and a negative loading for pH_{CaCl2}. However, this acidifying effect favoured the release of available P, evident from the positive loading in FC 3. The FC 4 called 'organic properties' explained 13% of the variance had positive loading from organic carbon and nitrogen.

In 2010, FA reduced the 11 measured soil properties into five FC groups that explained 80% of the total variability (Table 4). FC 1 was directly related to 'soil potential exchange capacity properties', which explained 26% of the total variance (Table 4). The FC 2 named, 'soil acidifying properties' explained 16% of the total variance (communality estimates was between 0.61 to 0.82 for different variables) as the major contributing variables, with positive loadings for EA (0.76) and available P (0.63), and a negative loading for pH_{water} (-0.67) (Table 4).

TABLE 3a: Main effects of NSC and CF on selected soil properties

Treatment	Exchangeable Potassium cmol kg^{-1}			Exchangeable Magnesium cmol kg^{-1}			Exchangeable Sodium cmol kg^{-1}			Exchangeable Calcium Cmol kg^{-1}			Exchangeable Acidity cmol kg^{-1}		
	2009	2010	combined	2009	2010	combined	2009	2010	combined	2009	2010	combined	2009	2010	combined
NPK kg ha^{-1} (N)															
0	0.10	0.07b	0.08	0.41	0.84	0.62	0.25	0.07	0.16	2.10	3.12b	2.61	0.39	0.27ab	0.33
¼ RR	0.11	0.07ab	0.09	0.40	1.11	0.76	0.29	0.08	0.18	2.18	3.85a	3.01	0.44	0.29ab	0.37
½ RR	0.18	0.09a	0.13	0.40	1.02	0.71	0.25	0.09	0.17	2.02	3.63ab	2.82	0.43	0.33a	0.38
FRR	0.11	0.06b	0.08	0.41	1.05	0.73	0.25	0.06	0.16	2.01	3.33ab	2.67	0.41	0.26b	0.33
SE ±	0.004	0.00	0.02	0.00	0.09	0.08	0.002	0.001	0.01	0.05	0.16	0.13	0.004	0.001	0.02
NSC t ha^{-1} (S)															
0 TC	0.10	0.05b	0.08	0.39	1.16	0.77	0.26	0.05	0.15	2.08	3.50	2.79	0.43	0.28	0.36
1 TC	0.10	0.09a	0.09	0.39	0.72	0.56	0.26	0.09	0.17	1.94	3.20	2.57	0.44	0.31	0.38
2 TC	0.12	0.08a	0.10	0.43	1.13	0.78	0.28	0.08	0.18	2.13	3.60	2.87	0.42	0.28	0.35
4 TC	0.17	0.08a	0.13	0.41	1.02	0.72	0.26	0.08	0.17	2.15	3.63	2.89	0.38	0.28	0.33
SE ±	0.004	0.00	0.02	0.00	0.09	0.08	0.002	0.001	0.01	0.05	0.16	0.13	0.004	0.001	0.02
Interaction (N × S)															
N x S	NS	NS	NS	NS	NS	NS	NS	NS	NS	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
TC = ton ha^{-1} NSC
RR = recommended rate
FRR = full recommended rate

TABLE 3b: Main effects of NSC and CF on selected soil properties

Treatment	pH_{water}			pH_{CaCl2}			Organic carbon g kg^{-1}			Available Phosphorus mg kg^{-1}			Total Nitrogen kg ha^{-1}		
	2009	2010	combined	2009	2010	combined	2009	2010	combined	2009	2010	combined	2009	2010	combined
NPK kg ha^{-1} (N)															
0	5.81	4.90	5.35	5.23	4.44	4.84	5.56	5.15	5.36	13.71	12.54	13.13	0.76	0.62	0.69
1/4RR	5.79	4.89	5.37	5.11	4.42	4.76	5.74	5.52	5.63	14.44	15.31	14.98	0.57	0.67	0.62
1/2RR	5.82	4.94	5.38	5.09	4.38	4.74	5.66	5.42	5.54	13.85	12.40	13.13	0.67	0.66	0.67
FRR	5.79	4.86	5.33	5.20	4.38	4.79	6.27	5.45	5.86	15.17	15.02	15.09	0.62	0.75	0.68
SE ±	0.02	0.01	0.05	0.01	0.003	0.03	0.01	0.004	0.03	3.56	4.01	0.78	0.04	0.00	0.06
NSC t ha^{-1} (S)															
0 TC	5.78	4.89	5.33	5.19	4.40	4.80	4.83b	4.81b	4.82b	15.02ab	13.13	14.07	0.60	0.69	0.64
1 TC	5.75	4.88	5.32	5.18	4.40	4.79	5.52ab	5.00ab	5.26b	15.60a	14.22	14.91	0.69	0.67	0.68
2 TC	5.88	4.89	5.38	5.15	4.41	4.78	5.80ab	5.64ab	5.72ab	12.40b	12.62	12.51	0.54	0.70	0.62
4 TC	5.81	4.93	5.37	5.11	4.42	4.76	7.08a	6.07a	6.58a	14.15ab	15.53	14.84	0.79	0.63	0.71
SE ±	0.02	0.01	0.05	0.01	0.003	0.03	0.01	0.004	0.03	3.56	4.01	0.78	0.04	0.00	0.06
Interaction (N × S)															
N x S	NS	NS	NS	NS	NS	NS	NS	NS		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
TC = ton ha^{-1} NSC
RR = recommended rate
FRR = full recommended rate

TABLE 4: key results of the factor analysis for the complete dataset. Factor loadings have been omitted when eigenvalue is less than 1

	F1		F2		F3		F4		F5	Communalities estimates	
Variable	2009	2010	2009	2010	2009	2010	2009	2010	2010	2009	2010
pH_{water}	0.04	0.32	**0.87**	**-0.67**	-0.19	0.45	-0.14	0.23	-0.11	0.81	0.82
pH_{CaCl2}	-0.14	0.14	0.00	-0.16	**-0.79**	-0.14	-0.04	**0.72**	-0.32	0.64	0.69
Exchangeable acidity	-0.40	-0.12	-0.16	**0.76**	**0.48**	0.15	0.34	-0.08	-0.32	0.53	0.72
Organic carbon	0.34	-0.01	-0.14	0.22	0.05	0.48	**0.62**	**0.64**	0.42	0.53	0.86
Exchangeable calcium	**0.87**	**0.90**	-0.10	0.30	0.12	-0.09	0.18	0.05	0.01	0.82	0.91
Exchangeable magnesium	**0.65**	**0.95**	0.06	0.04	-0.35	-0.11	-0.25	0.04	0.04	0.62	0.91
Exchangeable potassium	0.06	-0.14	**0.74**	0.32	0.15	**0.79**	0.17	0.13	-0.17	0.6	0.98
Exchangeable sodium	0.21	0.28	**0.64**	0.04	0.38	**0.50**	-0.11	-0.48	-0.36	0.62	0.68
Available phosphorus	0.12	-0.25	**-0.61**	**0.63**	0.31	-0.20	-0.02	0.18	0.29	0.48	0.61
Nitrogen	-0.17	0.24	0.09	-0.12	-0.07	0.33	**0.85**	-0.35	**0.68**	0.76	0.76
Effective cation exchange capacity	**0.86**	**0.96**	0.21	0.24	0.31	-0.07	0.05	0.02	-0.01	0.89	0.099
% of variance	21.10	26.24	19.844	16.39	12.63	13.00	12.58	12.50	11.47		
Cummulative % of variance	21.10	26.24	40.94	42.63	53.57	55.62	66.15	68.12	79.59		
Eigenvalue	2.32	2.89	2.18	1.80	1.39	1.43	1.38	1.37	1.26		

The rotation converged in 12 iterations. Factor scores of variables in bold letters indicate the major contributors in the group. F - factor

Types of mutants	Doses (Gy) 50		100		150		200		250		300	
	No	%	No	%	No	%	No	%	No	%	No	%
Plant type												
Dwarf	9	0.12	3	0.24	2	0.06	4	0.11	5	0.27	12	0.87
Tall	3	0.04	2	0.16	25	0.79	4	0.11	4	0.22	2	0.14
Single tiller	-	-	-	-	10	0.31	-	-	-	-	-	-
Grain type												
Long slender	12	0.16	3	0.24	5	0.16	18	0.48	2	0.11	2	0.14
Fine grain	-	-	-	-	12	0.38	-	-	-	-	-	-
Awned grain	20	0.27	2	0.16	4	0.13	8	0.21	4	0.22	-	-
Duration												
Early (108-120days)	13	0.17	5	0.40	20	0.63	12	0.32	4	0.22	5	0.36
Late (130-141 days)	29	0.39	2	0.16	12	0.38	15	0.39	13	0.70	-	-
Sterility												
Completely sterile (> 70%)	8	0.11	6	0.48	3	0.09	2	0.05	1	0.05	-	-
Partially sterile (20-70%)	10	0.14	10	0.79	25	0.79	20	0.53	8	0.43	5	0.36
Total	104	1.41	33	2.62	118	3.71	83	2.19	41	2.20	26	1.88
Total number of plants studied	7380		1260		3180		3780		1860		1380	

The FC 3, called 'soil additional potential nutrients' explained 13% of the total variance which included Na and K (communality estimates for Na = 0.68 and for K = 0.80) as the major contributing variables. FC 4 was the 'organic potential properties' which included SOC and pH_{CaCl2} explained 12% of the total variable (communality estimates for pH_{CaCl2} = 0.69 and for OC = 0.88) while FC 5 was called the 'soil highly potential nutrient properties' which included nitrogen explained 11% of the total variance (communality estimate for N = 0.76) as the major contributing variable (Table 4).

The 'soil potential exchange capacity' has significant influence on acidifying capacity and nutrient availability. Significant highest positive and negative inter-relationships were observed between ECEC, Ca and Mg, and available P. SOM and N influenced water holding capacity and nutrients in soil system, which was essential for sorghum production. Soil N influenced early growth of sorghum in 2009 whereas inherently low soil N status in 2010 allowed for a clear manifestation of treatment effect. Thus, NSC being a slow nutrient releasing organic amendment had plants with an initial slow growth but the two weeks incorporation was adequate as it synchronized nutrient release later in the year with period of optimum uptake (grain filling) by the sorghum plants. The dominant factor in assessing soil quality varied with N concentration. Soil pH and EA were the most discriminating factor in FC 2 which influenced biomass yield and return of biomass to the soil (nutrient availability). However, NSC did not acidify the soil to the same degree under field conditions as it did in the laboratory and greenhouse controlled-system studies because protons generated from the nitrification of NH_4-N were neutralized by OH^- ions released by plant roots when NO_3-N was absorbed (Boumann *et al*., 1995; Mohammed, 2009; Mohammed *et* al., 2013b). Also, the production of carbonates of Ca and Mg evident from the positive loading of Ca and Mg in FC 5, simultaneously with certain free organic acids formed tend to make the environment alkaline aside modification of acidity of the environment by plants themselves (Leeper, 1964).

CONCLUSION

Factor analysis was used to explain the relative importance of eleven measured soil properties on the fertility status following application of NSC and CF. The aim was to explore the influence and inter-relationships which can be extracted by performing factor analysis of variables which are available from soil physico-chemical properties after cropping. Chemical properties which include pH, exchangeable acidity, organic carbon, available phosphorus, total nitrogen and exchangeable bases from two-year sorghum field trial were employed in the analysis. The results reveal that although the dominant factor in assessing soil quality varied with nitrogen concentration, exchangeable calcium and magnesium are the most discriminating factor of neem seed cake amended soil. Exchangeable calcium and magnesium which are classified as the 'soil potential exchange capacity' had positive loadings of 0.89 and 0.80 in the mean of the two years combined data of factor component 1. This property had significant influence on acidifying capacity and nutrient availability following application and cropping of the soil.

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