European Journal of Agriculture and Forestry Research
Vol.5, No.4, pp.1-15, December 2017
Published by European Centre for Research Training and Development UK (www.eajournals.org)

EFFECT OF NEEM SEED CAKE AND INORGANIC FERTILIZER ON YIELD OF TOMATO AND SOIL PROPERTIES IN NORTHERN GUINEA SAVANNA OF NIGERIA

Oyinlola E.Y[1], Paul O. O[2] and Uyovbisere E.O[1]

[1]Ahmadu Bello University Zaria Nigeria

[2]Punjab Agricultural University Ludhiana, India.

ABSTRACT: *Field trials were conducted at the Institute for Agricultural Research Irrigation Farm, Samaru Zaria, in the northern Guinea savanna ecological zone of Nigeria in 2009/2010, 2010/2011 dry seasons to study the integrated effect of neem seed cake and inorganic fertilizer on tomato. The treatments consisted of three levels of NSC (0, 2 and 4 t ha^{-1}) and four levels of inorganic fertilizer (0, ¼, ½ and Full Fertilizer recommended Rate (FFR, NPK 15:15:15) for tomato in northern Guinea savanna of Nigeria. The treatments were laid out in a Randomized Complete Block Design (RCBD) with three replications. Mean fruit weight and fruit yield were determined. Matured ripe fruits were analyzed for biochemical properties such as reducing sugars, total soluble solids, ascorbic acid and titratable acidity. Effect of treatments on soil properties were also determined by analyzing the treated soils after harvest. Results obtained showed that tomato responded positively to the treatments. Highest fruit yield of 14.54 and 19.70 t/ha were obtained from 2tons/ha neem seed cake + ½ Fertilizer rate in 2009/2010 and 2010/2011 respectively. Although the effect of complementary application of NSC and inorganic fertilizer on tomato was not significant among the treatments of such combinations, highest fruit yield increase over the control were 103.1% and197% for 2009/2010 and 2010/2011 respectively. Effects of treatments on ascorbic acid, titratable acidity, total soluble solids and reducing sugars were not significant. The concentrations of plant tissue N, P and K were higher than the control at the end of second year of experiment. In the first year of trial pH (H_2O) varied from 6.2 to 6.7, whereas in the second year, it varied from 6.1 to 6.3. The values of soil OC and N increased over the years. Combinations of 2NC + ½ FR and 4NC + ½ FR proved superior for tomato fruit yield and mean fruit weight than other treatments in this study.*

KEYWORDS*:* Fertilizer, Neem seed cake, inorganic, Tomato, Yield.

INTRODUCTION

Tomato (*Lycopersicon esculentum*) is a widely grown crop which is a good source of minerals and vitamins (FAO, 2007; Calman *et al*. 2010). In Nigeria, tomato is grown throughout the year, the best period for tomato production in the Nigerian savanna is the cooler period of the dry season and the incidence of pests and diseases is minimal (Anonymous, 2000).

High fruit yield and good fruit quality need the application of external inputs such as inorganic fertilizers. Application of inorganic fertilizers has been found to improve crop yield, however, its continuous use is hindered by its paucity, high cost, imbalance in soil nutrients and soil acidity (Lombin *et al.*, 1991; Akinrinde and Okeleye, 2005). It has been reported that application of both organic and inorganic inputs are needed to increase crop production in West Africa tropics. (Buresh *et al.*, 1997; FAO, 1999). Organic inputs are needed to maintain the

ISSN: 2054-6319 (Print), 2054-6327(online)

physical and chemical health of the savanna top soils while inorganic fertilizers are needed to supply a sufficient amount of nutrient to the growing crop (Vanlauwe *et al.*, 2001). The use of Neem seed cake as organic inputs served as organic manure (OM) in this study, improved soil physical and chemical properties and yields of crops. Complementary application of both organic and inorganic inputs will also reduce the quantity of OM required, because of the bulkiness of OM. The integrated use of organic and inorganic nutrient supply has been reported to improve the performance of crops than their sole application (Lombin *et al*., 1991; Chude *et al*., 2006; Ayeni, 2008; Ayoola and Makinde, 2009). Krupnit et al., (2004) reported that combined use of organic and Inorganic fertilizer reduced cost and amount of fertilizer required by crops.

Neem (*Azadirachta indica A*. Juss) is found in abundance in the savanna agro-ecological region of Nigeria where it is used mainly as shelter belt to control desertification. The neem product namely; bark, leaves and seeds are very useful for medicinal and agricultural purposes (NRC, 1992; Uyovbisere and Elemo, 2007). Neem seed cake (NSC) is a by-product of Neem oil extraction and *azadiractin* from the neem seed kernels. Neem seed cake was found to have high manurial value; Indian farmers have traditionally used deoiled neem cake (NSC) as fertilizer on their fields (NRC, 1992). It improves the growth and yield of crops because it contains essential nutrients necessary for the growth of crops (Ketkar and Ketkar, 1995, Agbenin, 1999; Agbenin, 2008; Garba and Oyinlola, 2014; Oyinlola *et al*., 2014). The dual activity of NSC as fertilizer and pest repellent has made it a favoured input (Neem Foundation, 2007). Interest is therefore being geared towards the use of local and readily available organic residues for soil amendment in Northern Guinea savanna of Nigeria to improve soil fertility and organic matter status. The objectives of the study were to determine:

1. The nutrient potentials of neem seed cake,
2. The effect of neem seed cake and inorganic fertilizer on yield of tomato fruits and their biochemical properties.
3. Effect of treatments on some soil properties.

MATERIALS AND METHODS

Experimental Site

The study was carried out in 2009/2010 and 2010/2011 dry seasons (November 2009 – April 2010 and November 2010 – April 2011) at the Irrigation Research Farm of the Institute for Agricultural Research, Ahmadu Bello University, Zaria (lat. 11^{o} 11'N; long 7^{o} 38'E) in the Northern Guinea savanna (GGS) zone of Nigeria with altitude of 686m above sea level. The area is characterised by two seasons; the dry season (November-April) and raining season (May-October). The rainfall is mono-modal and ranges from 950-1270mm with a mean of 1100mm and mean annual temperature of 25^{o}C. The soil of the site had been classified as Typic Haplustalf in the USDA System or Orthic Acrisol in the FAO System (Ogunwole *et al*., 2001).

Soil and Neem Seed Cake Sampling Collection and Preparation

Soil samples were collected from the experimental site at a depth of 0-0.3m during land preparation. The soil samples were air-dried, crushed, and mixed thoroughly, sieved with 2mm

ISSN: 2054-6319 (Print), 2054-6327(online)

sieve and sub-sample taken for laboratory analysis. Neem seed cake was obtained from National Research Institute for Chemical Technology (NARICT) Bassawa-Zaria. All foreign materials including uncrushed seeds, kernel, stones, and straws were removed from the cake and ground to powder. Subsample was taken to the laboratory for both chemical and bio-chemical analysis.

Laboratory Analyses

Soil Analysis

Soil samples were analyzed for pH (H_2O and $CaCl_2$), in a 1:2.5 soil: solution ratio using the glass electrode pH meter (Pye Unicam Model 290 MK2). Soil textural class was estimated using the hydrometer method as described by Gee and Bauder (1986). Organic carbon (OC) estimation of the sample was determined using the dichromate oxidation method (Nelson and Sommers, 1982), total nitrogen by the kjeldhal method (Bremner, 1965) and soil phosphorus content was determined by Bray 1 method (Bray and Kurtz, 1945), while ammonium acetate was used for determination of exchangeable bases, (Ca, Mg, K and Na). The concentrations of K and Na were determined with flame photometer, while Ca and Mg concentrations were determined with Atomic Absorption Spectrophotometer (AAS), UNICAM, 969.

Neem seed cake preparation and analysis

Organic carbon (OC), and total N were determined with the method described by Okalebo *et al.,* 2002. Wet digestion method of Anderson and Ingram, (1993) was used for the determination of total P. The NSC was digested in triacid mixture (H_2SO_4-HNO_3-$HClO_4$) and K content was determined with flame photometer, while Ca, Mg concentrations were determined with AAS as described by Juo, (1979). Carbohydrate content of the cake was determined by acid detergent fibre method as described by Okalebo *et al.,* (2002) while the protein content was determined by multiplying the total N content by a factor of 6.25.

Plant Tissue Analysis

Ground plant samples were digested with a mixture of HNO_3, H_2SO_4 and $HClO_4$ acids and the contents of N, P and K were determined as described above.

Fruit analysis

Titratable acidity of tomato fruit was determined by titrating 10ml of the fruit juice with 0.1N NaOH, Ascorbic acid content was determined by titration with 2,6-dichlorophenolindophenol (AOAC, 1975), Reducing sugar was determined with fehlings solution A and B. Total soluble solids was determined by oven drying method (Gould, 1994).

Experimental Treatments

Treatments consisted of three levels of neem seed cake (0, 2, 4 t ha^{-1}, and four levels of inorganic fertilizer (0, ¼, ½ and full optimum fertilizer rate for tomato in northern Guinea savanna of Nigeria). The experimental design was RCBD with 3 replications. The land was ploughed, harrowed and prepared into beds of 3m x 3m ($9m^2$) separated by 0.75m irrigation channels. Appropriate weights of the cake (NSC) for each plot was weighed, broadcasted, mixed thoroughly with the soil in the plot and allowed to equilibrate for two weeks before transplanting.

ISSN: 2054-6319 (Print), 2054-6327(online)

Tomato seeds were raised in the nursery and transplanted at four weeks after sowing (WAS). Inorganic fertilizer (P and K) were applied at 2 weeks after transplanting while N fertilizer was applied in 2 split doses at 2 and 6 weeks after transplanting (WAT).

All plots were uniformly watered twice a week, weeding was done manually with hoe. Fungicide and insecticide were sprayed fort-nightly starting from 4 WAT to control fungi and insect attack.

At flowering, plant samples were taken from each plot for the determination of N, P and K concentrations. Ripe fruits from each plot were harvested, weighed and recorded at weekly. Data were collected on fruit size and fruit yield. Fresh tomato samples were taken for ascorbic acid, total soluble solids, reducing sugars and titratable acidity analyses. Second trial was carried out on the same site, the plot positions were maintained and they received the same treatment as the first year. Data collected were subjected to SAS statistical analysis (SAS Institute, 1999) and the means were compared using LSD.

RESULTS AND DISCUSSION

Soil Analysis

Table 1 summarizes the pre-planting soil physicochemical parameters. The result of the particle size distribution analysis showed a proportion of 516, 366 and 118 g/kg for sand, silt and clay respectively giving the textural class of sandy loam. The soil reaction was acidic both in water (6.2) and $CaCl_2$ (5.7). This is a common feature of soils of the NGS which have a pH range of 4.0 – 6.5 (Jones and Wild, 1975). Organic carbon content of the soil was low (9.6 g/kg). This could be attributed to the sandy nature of the soil and high mineralization rate of incorporated organic residues of soils in the region could also account for its soil organic matter content. Total N content of the soil (0.12g/kg) was low due to leaching, while the available P content of the soil (16.0 mg/kg) was below the critical level of 20.0 mg/kg Bray 1 extractable P recommended for the zone (Enwezor, 1990). Exchangeable Ca and K contents were low which indicated low fertility of the soil. From the results, the soil falls in the low fertility class (Enwezor *et al*., 1990; Chude *et al*., 2012); for sustainable crop production, application of external input is mandatory.

Table 1: Pre-planting soil physico-chemical properties

Characteristics	**Results**	**Characteristics**	**Results**
Soil pH (H_2O)	6.2	Sodium	0.04
Soil pH ($CaCl_2$)	5.7	CEC	7.8
Organic carbon (g/kg)	9.6	Exchangeable acidity	0.1
Total Nitrogen (g/kg)	1.2	Textural analysis (g/kg)	1.2
Available P (mg/g)	16.9		16.0
Exchangeable bases (cmol kg^{-1})		Sand	516
Calcium	0.29	Clay	116
Magnesium	0.12	Silt	366
Potassium	0.08	Textural class	Sandy loam

ISSN: 2054-6319 (Print), 2054-6327(online)

Neem Seed Cake Analysis

The result of chemical and biochemical analysis of Neem seed cake (NSC) showed that it contained 27.3 g/kg N, 41 g/kg P, 10 g/kg Ca, 19 g/kg K, 3.0 g/kg Mg and OC 374 g/kg (Table 2). Neem seed cake can be efficient source of nutrients to crop. The concentrations of macronutrients in the NSC are within the tolerable limits allowed for organic fertilizer (FAO, 1994).Carbohydrate contents of NSC (545.5 g/kg) reflect its ability to improve soil organic mater contents through increasing carbon which is an index of soil organic matter (Micheni, 2004). The NSC had low CN ratio of 13.7:1 which is less than 20:1, above which N immobilzation will set in (Tisdale *et al*., 2003). Hence, mineralization of nutrients is made possible and faster.

Table 2: Chemical and Biochemical properties of the neem seed cake used for the study

Properties	**Result (g/kg)**
Total N	27.3
Total P	41.0
OC	374
Calcium	4.8
Magnesium	3.0
Potassium	1.9
Protein	170.6
Carbohydrate	545.5
C:N	13.7

Effects of Treatments on Mean Fruit Weight and Fruit Yield

Application of sole inorganic fertilizer on mean fruit weight of tomato was highly significant ($P < 0.01$) in 2009/10 (Table 3). Full fertilizer Rate (FFR) treatment produced the highest mean fruit weight of 138.3g while the control produced the least (61.5g), however there were no significant differences in the results obtained for ¼ FR ½FR and FFR treatments, the results gave 63.3, 123 and 125% increment above control respectively. In 2010/11, effect of sole inorganic fertilizer on mean fruit weight was not significant; plants treated with ½FR produced tomato fruits with the highest fruit weight (74.6g) while the least (64.2g) was from the control. The increase in the fruit weight in the control plot could be attributed to nutrients from root residue resulting from the previous trial and also nutrient leaching could have been the main factor for the slight reduction in fruit weight in the FFR plot.

Sole application of neem seed cake (NSC) on mean fruit weight was not significant in the two year trials; however, 2 t/ha NSC (2NC) produced the highest mean fruit weight (120.4g) in 2009/2010, while 4NC produced the highest fruit weight (72.6g) in 2010/2011 (Table 3). Complementary application of inorganic fertilizer and NSC was not significant on tomato fruit weight in both years (Table 4). 2NC + ½FR produced the highest fruit weight (143.3g) in 2009/2010 with an increase of 160.5% above control while plants treated with 4NC + ½FR produced the highest mean fruit weight (80g) in 2010/11 with an increase of 37% above control.

Mean fruit weight (size) of tomato is an important trait for tomato fruit quality; an increased size means higher water content and consequently lower total soluble solids (Santamaria *et al*., 2004).

ISSN: 2054-6319 (Print), 2054-6327(online)

Effect on Fruit Yield

Effect of sole neem seed cake (NSC) application on fruit yield was not significant in both years trial (Table 3). Plants treated with 2 t/ha NSC produced the highest fruit yield of 10.10 t/ha and 17.2t/ha in 2009/2010 and 2010/2011 with increases of 23.2% and 8.2% above control respectively

Application of sole inorganic fertilizer on tomato fruit yield was highly significant ($P<0.01$) in both years (Table 3). Plants treated with ½FR gave the highest fruit yield of 11.80 t/ha in 2009/2010 which was similar with the results obtained from FFR. The least (5.40 t/ha) fruit yield was obtained from the control. Fruit yield obtained for ¼ FR, ½ FR and FFR gave increases of 62.6, 119 and 86.5% above control respectively.

In 2010/2011 trial, FFR produced the highest tomato fruit yield of 19.00 t/ha, the result obtained for ¼ FR, ½ FR and FFR were statistically similar (Table 3) with yield increases of 31, 38.4 and 50% above control respectively.

Complementary application of inorganic fertilizer and NSC was not significant in all the years of trial (Table 4). Plants treated with 2NC + ½ FR gave the highest fruit yield of 14.54 t/ha and 19.70 t/ha with increases of 197% and 103% above control in 2009/2010 and 2010/2011 respectively. Increase in crop performance and yield due to combined application of organic and inorganic fertilizers had been reported for crops (Saha Mondal, 2006; Ayeni, 2008; Ayoola and Makinde, 2009; Atere and Olayinka, 2012; Garba *et al*., 2014) and also for tomatoes (Chude *et al*., 2006; Oyinlola *et al*., 2014).

Table 3. Effect on sole application of Neem seed cake and Inorganic fertilizer on mean fruit weight and yield of Tomato

Treatments	Mean fruit weight (g)		Fruit yield (t/ha)	
	2009/10	2010/11	2009/10	2010/11
Neem Seed cake (t/ha)				
Control	55	58.4	8.2	15.9
2	120.4	68.6	10.1	17.2
4	102.1	72.6	8.7	16.3
LOS	NS	NS	NS	NS
Inorganic fertilizer				
Control	61.5b	64.2	5.4c	12.7b
¼ FR	100.4a	66.8	8.8b	16.7a
½ FR	137.2a	74.6	11.8a	17.6a
FFR	138.3a	71.6	10.1ab	19.1a
LOS	**	NS	**	**

ISSN: 2054-6319 (Print), 2054-6327(online)

Table 4. Interaction of neem seed cake and inorganic fertilizer on mean fruit weight and fruit yield of tomato

Treatments	Mean fruit weight (g)			Fruit yield (t/ha)		
	2009/2010	**2010/2011**		**2009/2010**	**2010/2011**	
2NC + ¼ FR	134	67.0		10.3	17.30	
4NC + ¼ FR	76	64.0		8.03	16.04	
2NC + ½ FR	143.3	72		14.54	19.70	
4NC + ½ FR	132.3	80		10.73	14.00	
2NC + FFR	139	70		10.07	19.13	
4NC + FFR	136.2	78		10.3	19.40	
LOS	NS	NS		NS	NS	

NC = Tons per hectare neem seed cake. FR = Fertilizer recommended rate.

FFR = Full fertilizer recommended rate (125 Kg ha^{-1}).

½ FR = (62.5 Kg ha^{-1}). ¼ FR = (31.25 Kg ha^{-1}), LOS= Level of significance, NS= Not significance, **=Significance

Ascorbic Acid (Vitamin C)

Ascorbic acid (AA) contents of tomato fruits ranged from 47.1-49.5 mg/100g in 2009/2010 and 35.62-37.01 mg/100g in 2010/2011(Table 5). Though the effects of treatments on AA contents of tomato fruits were not significant (P>0.05) in both years plants treated with 2NC + ¼ FR gave the highest AA contents in 2009/2010 and 2010/2011. Ascorbic acid contents of tomato could be affected by soil condition, plant nutrition, cultivation practices light intensity previous to maturity, treatment with growth regulators and insecticide (Gould, 1974).

Ascorbic acid is one of the important parameters used to determine nutritional value of tomato as it has beneficial effect on human health (Caliman *et al*., 2010). The main functions of Ascorbic acid (Vitamin C) are in the prevention of scurvy and maintenance of skin and blood vessels (Lee and Kader, 2000).

Titratable Acidity (TA)

Effect of treatments on titratable acidity (TA) were not significant (P>0.05) in both years. (Table 5) The highest TA of 0.64 mg/100g was obtained from 4NC + FFR treatment in 2009/2010; while plants treated with 2NC gave the highest TA (0.31 mg/100g) in 2010/2011. Titratable acidity influences the degree of sourness and consequently the flavor of tomato fruit (Stevens *et al*., 1977). Citric acid is the most abundant acid in tomatoes and the largest contributor to the total TA (Stevens *et al*., 1972, Baldwin *et al*., 2008). Two other acids that contribute significantly to TA are malic and glutamic acids. Although, malic acid is typically present at only one tenth the level of citric acid, malic to citric ratio can vary considerably between different tomato cultivars (Stevens *et al*., 1972, and Anthon *et al*., 2011).

ISSN: 2054-6319 (Print), 2054-6327(online)

Table 5: Complementary application of neem seed cake and inorganic fertilizer on Ascorbic acid and Titratable acidity.

Treatments	Ascorbic acid (mg/100ml)			Titratable Acidity (mg/100g)		
	2009/2010	2010/2011	Mean	2009/2010	2010/2011	Mean
Control	47.1	36.00	41.55	0.31	0.31	0.31
2 NC	48.4	36.63	42.52	0.50	0.31	0.41
4 NC	48.2	36.36	42.28	0.37	0.29	0.33
¼ FR	49.4	36.47	42.94	0.42	0.29	0.36
½ FR	49.2	36.33	42.77	0.55	0.29	0.42
FFR	48.5	36.06	42.28	0.61	0.26	0.44
2NC + ¼ FR	49.0	36.2	42.6	0.56	0.28	0.42
4NC + ¼ FR	49.5	37.01	43.26	0.41	0.30	0.36
2NC + ½ FR	48.4	36.91	42.66	0.49	0.30	0.40
4NC + ½ FR	47.1	35.81	41.46	0.44	0.27	0.36
2NC + FFR	48.4	37.00	42.71	0.61	0.25	0.43
4NC + FFR	48.9	35.62	42.26	0.64	0.28	0.46
LOS	NS	NS		NS	NS	

NC = Tons per hectare neem seed cake. FR = Fertilizer recommended rate.

FFR = Full fertilizer recommended rate (125 Kg ha^{-1}).

½ FR = (62.5 Kg ha^{-1}). ¼ FR = (31.25 Kg ha^{-1}), LOS= Level of Significance.

Total Soluble Solids (TSS)

Total soluble solids was not significantly ($P > 0.05$) affected by treatments in both years of study (Table 6). In 2009/2010 TSS varied from 8.1-10% and in 2010/2011from 8.35 – 10.37%. In 2009/2010 the highest TSS was from 2NC+FFR and 4NC+FFR, while least TSS was from the control. In 2010/2011 trial, the highest TSS was from 4NC+½FR while the least was from 2NC treatment. (Stevens *et al*., 1977) reported that Soluble solids are of prime concern in fresh market tomato production because of its important contribution of sugars and acids that make the overall flavor of the fruit.

Reducing Sugars (RS)

Reducing sugarsof tomato fruits varied from 13.1 -14.7 mg/100g in 2009/2010 and 6.01-7.38 mg/100g in 2010/2011(Table 6). Highest RS obtained were from 4NC and 2NC in 2009/2010 and 2010/2011 respectively. Treatments imposed on the plants did not have any significant effect on the RS contents of fruits in both years and the results obtained for both years did not take any particular trend. It has been reported that approximately half of the total solids in tomato fruits are reducing sugars (RS) which consist of fructose and glucose with slightly more fructose than glucose (Young *et al*., 1993, Caliman *et al.*, 2010, Wiilkerson *et al.,* 2013). Reducing sugars and acids contribute to sweetness and sourness in tomato and are also major factors in overall flavor intensity (Stevens *et al.*, 1977, Baldwin *et al.*, 2008).

ISSN: 2054-6319 (Print), 2054-6327(online)

Table 6: Complementary application of neem seed cake and inorganic fertilizer on Total soluble solids (TSS) and Reducing sugars (RS).

Treatments	Total soluble solids (%)			Reducing sugars (%)		
	2009/2010	2010/2011	Mean	2009/2010	2010/2011	Mean
Control	8.1	8.6	8.35	13.93	6.69	10.31
2 NC	8.8	8.4	8.60	14.2	7.38	10.80
4 NC	8.3	10.34	9.32	14.7	6.86	10.79
¼ FR	8.6	8.53	8.57	14.6	6.41	10.51
½ FR	9.93	8.9	9.42	13.6	6.61	10.11
FFR	9.93	9.34	9.64	14.3	6.62	10.46
2NC + ¼ FR	9.93	9.43	9.68	13.2	6.82	10.01
4NC + ¼ FR	8.3	9.17	8.74	13.8	6.56	10.18
2NC + ½ FR	9.93	8.76	9.35	13.13	6.71	9.92
4NC + ½ FR	8.7	10.4	9.54	14.13	6.67	10.40
2NC + FFR	10	8.9	9.45	13.5	6.01	9.80
4NC + FFR	10	9.4	9.7	14.6	6.65	10.63
LOS	NS	NS		NS	NS	

NC = Tons per hectare neem seed cake. FR = Fertilizer recommended rate.

FFR = Full fertilizer recommended rate (125 Kg ha^{-1}).

½ FR = (62.5 Kg ha^{-1}). ¼ FR = (31.25 Kg ha^{-1}), LOS Level of significance

Nutrient (NPK) Concentrations of Plant

Concentration of nitrogen (N) in tomato plant varied from 2.01-3.09 g/kg in 2009/2010 and 2.2-3.39 g/kg in 2010/2011. Plants treated with 4NC + FFR gave the highest N concentration in 2009/2010 while FFR treatment gave the highest N concentration in 2010/2011. Sole application of neem seed cake increased N concentration in tomato plants in both years of study. Effects of treatments on phosphorus concentration of tomato plant was not significant (P> 0.05) in 2009/2010. Phosphorus concentration varied from 1.64-2.05 g/kg in 2009/2010 and 1.61-2.14 g/kg in 2010/2011. Phosphorus concentration did not follow a particular trend, but P increased with increase in sole NSC application in 2010/2011. Plants treated with 2NC + ¼ FR and 4NSC + ¼FR gave highest plant tissue P concentrations in 2009/2010 and 2010/2011 respectively.

Plant tissue potassium (K) concentration varied from 3.16 to 4.59% in 2009/2010 and 2.01 to 2.28% in 2010/2011. Effect of treatments on plant tissue K was not significant (P > 0.05). Potassium concentration did not follow any particular trend, but the highest K-concentration was obtained from plants treated with 4NC + ½FR in 2009/2010 and ½ FR in 2010/2011. The result obtained in this study is in line with the report of Garba *et al*., 2014 who did not obtain any significant difference in plant tissue concentrations of N, P and K after fertilizing maize with NSC and inorganic fertilizer.

ISSN: 2054-6319 (Print), 2054-6327(online)

Table 7: Complementary application of neem seed cake and inorganic fertilizer on plant nutrients (NPK).

Treatments	2009/2010			2010/2011		
	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)
Control	2.01	1.64	3.36	2.90	1.61	2.06
2 NC	2.36	1.85	3.54	3.08	1.87	2.16
4 NC	2.97	1.81	4.10	3.15	1.96	2.18
¼ FR	2.36	1.91	3.39	2.21	1.90	2.16
½ FR	2.28	1.71	3.60	2.34	2.07	2.28
FFR	2.92	1.53	3.16	3.39	1.99	2.20
2NC + ¼ FR	2.65	2.05	3.30	3.09	2.05	2.25
4NC + ¼ FR	2.95	2.00	3.96	2.45	2.14	2.20
2NC + ½ FR	2.86	1.71	3.66	2.80	1.88	1.94
4NC + ½ FR	2.16	1.67	4.59	2.90	2.11	2.01
2NC + FFR	2.66	1.64	3.42	3.27	1.86	2.14
4NC + FFR	3.09	1.75	3.97	2.80	2.03	2.14
LOS	NS	NS	NS	NS	NS	NS

NC = Tons per hectare neem seed cake. FR = Fertilizer recommended rate.
FFR = Full fertilizer recommended rate (125 Kg ha^{-1}).
½ FR = (62.5 Kg ha^{-1}). ¼ FR = (31.25 Kg ha^{-1}), LOS Level of significance.

Post Harvest Soil properties

Effect of treatments on soil properties is shown in Table 8. In 2009/2010 trial, pH (water) of soils varied from 6.2 to 6.7. All the treated soils have pH greater than pre-cropped soil except treatments 10 and 11 which have the same pH with the pre-cropped soil pH (6.2). In 2010/2011, pH (water) varied from 6.1-6.3, which signified that the treatments had negative effects on the pH of the soil; the ability of inorganic fertilizers and NSC to increase the acidity of the soil had been reported by Enwezor *et al*., (1990) and Agbenin *et al*., (2008).

Organic carbon (OC) varied from 5.9 to 7.2 g/kg in the treated soils in 2009/2010. All these values were below the pre-cropped value of 9.6 g/kg. The control had the least OC value of 5.9 g/kg, while 4 NC + FFR recorded the highest OC value of 7.2.

In 2010/2011, organic carbon varied 5.8 to 10.3 g/kg. 4NC + ½ FR treatment recorded the highest OC content while the least was from the control. Higher values of OC were recorded for 2010/2011 trial. This implied that there was a build up of soil organic matter from the 2 year annual applications. The result is in line with the report of Ayeni (2008).

Total N varied from 0.76 to 1.05 g/kg, in 2009/2010 trial. All these values were below the pre-cropped soil N of 1.2 g/kg. In 2010/2011 trial, total N values varied from 0.7 to 1.23 g/kg which was slightly higher than the first year result.

In 2009/2010, soil phosphorus content varied from 6.5 to 13.9 mg/kg, on the other hand in 2010/2011, P varied from 3.0 to 7.13 mg/kg. The values of CEC in 2009/2010 varied from 7.0 to 10.2 Cmol/kg, while in 2010/2011 (table 9), it varied from 6.5 to 8.6 cmol/kg. The non significant effect of the treatments on the post harvest soil properties had been reported by other workers, Uyovbisere and Elemo (2000) who incorporated foliage of *Parkia* and neem in addition to inorganic fertilizers for two years reported no significant difference in soil chemical

ISSN: 2054-6319 (Print), 2054-6327(online)

properties, similar results were recorded in the field trial reported by Solomon *et al*. (2008) with neem extract recorded no significant effects on soil properties.

Table 8: Effect of neem seed cake and inorganic fertilizer on soil properties in 2009/2010 trial.

Treatments	pH Water	pH $CaCl_2$	OC (g/kg)	N (g/kg)	P (mg/kg)	CEC cmol/kg
Control	6.4	5.7	5.9	0.88	6.50	8.7
2 NC	6.3	5.7	6.0	0.82	7.80	8.1
4 NC	6.3	5.8	6.4	1.05	11.54	10.1
¼ FR	6.7	5.7	7.0	1.05	4.20	7.5
½ FR	6.3	5.7	7.0	0.94	7.40	10.2
FFR	6.3	5.6	6.0	1.05	10.40	7.0
2NC + ¼ FR	6.5	5.7	6.4	0.76	7.00	7.6
4NC + ¼ FR	6.7	5.7	6.5	0.88	6.90	7.5
2NC + ½ FR	6.3	5.7	6.9	0.88	8.20	7.7
4NC + ½ FR	6.2	5.8	6.7	0.88	13.90	9.0
2NC + FFR	6.2	5.6	6.8	0.76	9.30	8.0
4NC + FFR	6.3	5.5	7.2	0.94	8.64	8.8

NC = Tons per hectare neem seed cake. FR = Fertilizer recommended rate.

FFR = Full fertilizer recommended rate (125 Kg ha^{-1}).

½ FR = (62.5 Kg ha^{-1}). ¼ FR = (31.25 Kg ha^{-1})

Table 9: Effect of neem seed cake and inorganic fertilizer on soil properties in 2010/2011 trial.

Treatments	pH (Water)	pH ($CaCl_2$)	OC (g/kg)	N (g/kg)	P (mg/kg)	CEC (cmol/kg)
Control	6.1	5.6	5.8	0.80	3.00	6.50
2 NC	6.3	5.5	9.5	1.23	3.20	7.18
4 NC	6.2	5.5	9.9	1.11	3.50	8.05
¼ FR	6.3	5.4	9.0	1.11	4.67	7.00
½ FR	6.2	5.4	8.6	0.93	3.80	8.33
Full FR	6.3	5.4	9.8	1.00	5.09	7.12
2NC + ¼ FR	6.2	5.5	9.3	1.23	3.64	7.37
4NC + ¼ FR	6.2	5.4	9.3	1.17	4.10	7.49
2NC + ½ FR	6.1	5.5	9.9	1.00	4.56	7.63
4NC + ½ FR	6.1	5.5	10.3	0.94	5.10	8.07
2NC + FFR	6.2	5.4	8.9	0.88	7.13	7.39
4NC + FFR	6.2	5.5	8.2	0.70	5.00	6.98

NC = Tons per hectare neem seed cake. FR = Fertilizer recommended rate.

FFR = Full fertilizer recommended rate (125 Kg ha^{-1}). ½ FR = (62.5 Kg ha^{-1}). ¼ FR = (31.25 Kg ha^{-1})

ISSN: 2054-6319 (Print), 2054-6327(online)

CONCLUSIONS

This study revealed that NSC contains some essential elements necessary for the growth and yield of tomato. Complementary application of Neem seed cake and inorganic fertilizer improved the mean fruit weight and fruit yield of tomato relative to the control. These treatments 2NC + ½ FR and 4NC + ½ FR proved superior for tomato fruit yield and mean fruit weight than other treatments in this study. The fruit parameters determined were improved relative to the control, but there was no significant effect of the treatments on the parameters. The values of soil OC and N increased over the years.

RECOMMENDATIONS

The research was carried out under irrigation condition. It is therefore recommended that similar study be conducted under rain-fed condition and also in other locations of the region. Meanwhile, for good productivity of tomato and sustainability of soil quality in the study area, combined use of Neem seed cake and ½ RF (62.5 Kg ha^{-1}) should be applied.

Acknowledgements

This work forms a part of the Artemisia Research Program, Institute of Agricultural Research, Ahmadu Bello University (ABU) Zaria. The financial assistance is gratefully acknowledged. We are also grateful to the administration of Soil Science Department ABU, Zaria for providing the facilities to carry out this research.

REFERENCES

Agbenin, J.O., Agbaji, E.O., Suleiman, I., Agbaji, A.S. (1999). Assessment of Nitrogen mineralization potential and availability from neem seed residues in a savanna soil. *Boil Fert. Soil* 29:408-412.

Agbenin, J.O., Ibitoye, S.O., Agbaji, A.S. (2008). Nutrients mineralization from deoiled neem seed in a savanna soil from Nigeria. *Communications in Soil Science and Plant analysis*, 39:524-537.

Akinrinde E.A., Okeleye K.A. (2005). Short and long term effects of sparingly soluble phosphates on crop production in two contrasting Nigerian Alfisols. *West Africa Journal of Applied Ecolology*. 8:141-150.

Anderson, J.M., Ingram, J.S.I. (1993). Tropical soil biology and fertility: A hand book of methods (2nd edition) CAB International Wallingford, UK.

Anonymous, (2000). Growing Tomatoes in Nigeria. Commercial crop guide series. United States Agency for International Development; (USAID) and information communication for Agricultural growth in Nigeria. pp 1-4.

Anthon, G.E., LeStrange, M., Barrette, D.M. (2011). Changes in pH, acids, sugars and other quality parameters during extended vine holding of ripe processing tomatoes. *Journal of the Science of Food and Agriculture*, 91(7):1175-1181.

Atere, C.T. and Olayinka, A. (2012). Effect of Organo-mineral fertilizer on soil chemical properties, growth and yield of soybean. *African Journal of Agricultural Research*, 7 (37), 5208-5216.

ISSN: 2054-6319 (Print), 2054-6327(online)

Ayeni, L.S. (2008). Integrated application of cocoa pod ash and NPKfertilizer on soil chemical properties and yield of tomato. Am-Eur. J. Sustain. Agric.2(3):333-337.

Ayoola, .O.T, Makinde, E.A. (2009). Maize growth, yield and soil nutrient changes with N-enriched organic fertilizer. *African Journal of Food and Agricultural Nutrition and Development.* 9 (1):580-592.

Baldwin, E. A., Goodner, K., Plotto, A. (2008). Interaction of volatiles, sugars, and acids on perception of tomato flavor andflavor descriptors. *Journal of Food Science*, 73 (6) 294-307.

Bray, R.H., and Kurtz, L.T. (1945). Determinations of total, organic and available forms of phosphorus in soils. *Soil Science*. 59: 39-45.

Bremner, J.M. (1965). Total nitrogen. In: C.A. Black (eds.) Method of soils analysis. Agronomy No. 9 Part 2, Amer. Soc. Agronomy, Madison, Wisconsin.

Buresh, R.J., Sanchez, P.A. and F. Calhoun (ed.) (1997). Replenishing soil fertility in Africa. *SSSA Spec. Publ.* 51. SSSA and ASA, Madison,WI.

Caliman, F.R.B., Da Silva, D.J.H., Stringheta, P.C., Fontes, P.C.R., Moreira, G.R., Mantovani, E.C. (2010). Quality of Tomato grown under a protected environment and field conditions. *IDESIA* (Chile) 28 (2) 75-82.

Chude, V.O., Olayiwola, S.O., Daudu, C., Ekeoma, A. (2012): Fertilizer use and management practices for crops in Nigeria. 4th edition Federal Fertilizer Department, Federal Ministry of Agriculture and Rural Development. Abuja. 224pp.

Enwezor, W.O.I., Udo, E.J., Ayotade, K.A., Adepetu, J.A., and Chude, V.O. (1990). Literature review on soil fertility investigation in Nigeria (In five volumes): Federal Ministry of Agriculture and Natural Resources: Lagos, Nigeria. 281pp.

FAO, Food and Agriculture Organisation of the United Nations (1994). Standards for Organic Fertilizers. In: Organic recycling in Asia and the Pacific. RAPA Bulletin 10: pp86.

FAO, Food and Agriculture Organisation of the United Nations (1999). Soil Fertility initiative for Sub-Saharan Africa. *Proceedings of Soil Fertility initiative, Food and Agriculture Organisation Consultation*, Rome 19-20 Nov 1999, FAO Rome.

FAO, Food and Agriculture Organisation of the United Nations (2007). Production Year Book. FAO, Food and Agriculture Organisation. Rome, Italy.

Garba, J and Oyinlola, E. Y. (2014). Neem seed cake and inorganic fertilizer amendments for sustained productivity of maize (zea mays) on Nigerian savanna Alfisols. *Journal of Agricultural Economics, Extension and Rural Development*. 2 (8):146-155.

Gee, G.W., and Bauder, J.W. (1986). Particle size analysis. In: Bluter A (ed.) *Method of soil analysis* part 2 (2nd edition) No. 9 ASA Inc. Madison, Washington, D.C.

Gould, W.A. (1974). Tomato production, processing ang quality evaluation. AVI Publishing Company Inc. Connecticut. USA.

Jones, M.J. and Wild, A. (1975). Soils of the West African Savanna. Commonwealth Agric. Bureau, Commonwealth Bureau of Soils Technical Comm. No. 55 Harpended, England.

Juo, A. S. R. (1979) *Selected methods for soil and plant analysis.* International Institute of Tropical Agriculture (1979) Manual series No. 1p 1-53.

Ketkar, C.M., Ketkar, M.S. 1995. Neem seeds crush and deoiled cake as manure and nitrification inhibitors. In Schumutterer H. (ed.) The neem tree. VHC, New York, P531-540.

Krupnik, T. J., Six J., Ladha, J.K., Paine, M.J. and Kessel, C.V.(2004). An assessment of fertilizer nitrogen recovery by grains crop. In agriculture and the nitrogen. Assessing the impacts of fertilizer use on food production and the environment (scope 65). (Mosier et al eds). Island press, London. Pp 193 -208.

ISSN: 2054-6319 (Print), 2054-6327(online)

Lee, S.K. and Kader, A.A. (2000). Preharvest and postharvest factors influencing vitamin Ccontent of horticultural crops. Postharvest Biology and Technology, 20, 207-220.

Lombin, G., Adepetu, J.A. and Ayodele, K.A. (1991). Complementary use of organic manures and inorganic fertilizers in arable crop production. *Proceedings of the organic fertilizer seminar*. FPDD. Fed. Min. of Agric. And Nat. Res. Abuja. 146-162pp.

Micheni, A, Kihanda, F. and Irunges, J. (2004): Soil organic matter: The basis for improved crop production in arid and semi-arid climates of Eastern Kenya. In: Bationo, A. (ed.) Managing nutrient cycles to sustain soil fertility in sub-Saharan Africa. Academy Science Publishers, Kenya.

Neem Foundation, (2007). Organic farming and neem. http:// www.neemfoundation.org/organic %20farming.htm (reprieved; June, 2010)

Nelson, D.W. and Somners, L.E. (1982). Total carbon, organic carbon and organic matter. In: A.L. Page *et al.* (eds.). Method of soil analysis. Part 2 (2nd edition) Agron. Monograph 9. ASA and SSSA, Madison, W.I.

NRC (National Research Council), (1992). *Neem: A tree for solving global problems.* National Academy Press. Washington, D.C. USA.

Ogunwole, J.O., Babalola, O.A., Oyinlola, E.Y. and Raji, B.A. (2001). A pedological characterization of soils in the Samaru area of Nigeria. *Samaru Journal of Agricultural Research*. 17:71-77.

Okalebo, J.R., Gatha, K.W., and Woomer, P.L. (2002). *Laboratory methods of soil and plant analysis.* A working manual, 2nd Ed. TSBF_CITA and SACRED Africa, Nairobi; Kenya.

Oyinlola E.Y., .Magaji[1], E.A., Garba, J and Mohammed, K.O. (2014) Effect of neem seed cake and inorganic fertilizer application on soil properties, and on growth, nutrient concentrations and uptake of Tomato (*Lycopersicon esculentum mill.*). *Nigeria Journal of Soil and Environmental Research.* 12:91-100.

Saha Mondal, S.S. (2006). Influence of integrated plant nutrient supply on growth, productivity and quality of baby corn (Zea mays) in Indo-Gangetic plains. Indian Journal of Agronomy, 51: 3 202-205.

Santamaria, P., Cantore, V., Conversa, G., Serio, F. (2004). Effect of right salinity level on water use, physiological responses, yield, and quality of tomato. *Journal of Horticultural science. Biotechnology.* 79: 59-66.

SAS Institute, (1999). SAS User's Guide. SAS Inst. Cary, N.C., USA.

Solomon, M.G., Okon, P.B., and Umoetok, S.B.A. (2008) Effect of Neem extracts on soil properties, microbial population and leaf area of fluted pumpkin (*Telfairia occidentalis*). *Research Journal of Agronomy.* 2(1):12-17.

Stevens, M.A. (1972). Citrate and malate concentration in tomato fruits: Genetic control and maturational effects. *Journal of America Society for Horticultural Science.* 97:655-668.

Stevens, M.A., Kader, A.A and Albright-Houlton, M. (1977) Intercultivar variation in composition of locular and pericarp portions of fresh market tomatoes. *Journal of America Society for Horticultural Science.* 102:689-692.

Tisdale, S.L., Nelson, W.L., Beaton, J.J. and Havlin, J.L. (2003). Soil fertility and fertilizers. 5th Edition, Prentices Hall of India, New Delhi – 110001.

Uyovbisere, E.O., and Elemo, K.A. (2000). Effect of inorganic fertilizer and foliage of Azadirachta and Parkia species on the productivity of early maize. *Nigeria Journal of Soil Research.* 1:17-22.

Vanlauwe, B., Aihou, K., Aman, S., Iwuafor, E.N.O., Tossah, B.K., Diels, J., Sanginga, N., Lyasse, O., Merckx, R., and Deckers, J. (2001). Maize yield as affected by Organic

ISSN: 2054-6319 (Print), 2054-6327(online)

Inputs and Urea in the West Africa Moist Savanna. *Agronomy journal.* 93 (6), 1191-1199.

Wilkerson, E.D., Anthon, G.E., Barrette, D.M., Sayajon, G.G., Santos, A.M. and Rodriguez-Saona, L.E. (2013). Rapid assessment of quality parameters in processing tomatoes using hand-held and benchtop infrared spectrometer and multivariate analysis. *Journal of Agricultural and food Chemistry.* 61, 2088-2095

Young, T.E., Juvik, J.A. and Sullivan, J.G. (1993). Accumulation of the components of Total solids in ripening fruits of Tomato. *Journal of America Society for Horticultural Science.* 118(2):286-292.

ISSN: 2054-6319 (Print), 2054-6327(online)