American-Eurasian Journal of Sustainable Agriculture, 3(3): 348-353, 2009
ISSN 1995-0748

This is a refereed journal and all articles are professionally screened and reviewed

## ORIGINAL ARTICLE

# Effects of Tillage Methods on Soil Properties, Nutrient Content, Growth and Yield of Tomato on an Alfisol of Southwestern Nigeria.

[1]Adekiya A.O., [2]Agbede T.M. and [2]Ojomo A.O.

[1]*Department of Crop, Soil and Pest Management, Federal University of Technology, P.M.B. 704, Akure, Ondo State, Nigeria.*
[2]*Department of Agricultural Engineering, Rufus Giwa Polytechnic, Owo, Ondo State, Nigeria.*

Adekiya A.O., Agbede T.M. and Ojomo A.O.: Effects of Tillage Methods on Soil Properties, Nutrient Content, Growth and Yield of Tomato on an Alfisol of Southwestern Nigeria, *Am.-Eurasian J. Sustain. Agric., 3(3): 348-353, 2009*

**ABSTRACT**

Information on the tillage requirements of tomato is inadequate and contradictory. Five tillage methods were compared as to their effect on soil physical and chemical properties, leaf nutrient concentration and yield of tomato (Lycopersicon esculentum, Mill). Tillage methods compared during 2006 and 2007 for the early and late seasons on Oxic Tropuldalf at Owo in rainforest zone of Nigeria were manual clearing, manual mounding, ploughing, ploughing plus harrowing and ploughing plus harrowing plus ridging. Ploughing plus harrowing plus ridging produced the highest mean fruit weight (8.16 t/ha), plant height, tap root length followed by manual mounding (7.05 t/ha), ploughing plus harrowing (6.24 t/ha) and ploughing (5.81 t/ha). The lowest yield (5.03 t/ha) was produced by manual clearing. The tillage treatments had lower bulk densities and higher leaf N, P, K, Ca and Mg compared with manual clearing. Soil bulk density was negatively correlated with leaf nutrient concentration in both years. Ploughing plus harrowing plus ridging improved nutrient availability and yield of tomato on an Alfisol because of reduced soil bulk density. Compared with manual clearing, manual mounding, ploughing, ploughing plus harrowing and ploughing plus harrowing plus ridging increased tomato fruit yield by 40, 16, 24 and 62%, respectively. Ploughing plus harrowing plus ridging is recommended for commercial production of tomato on Alfisol of humid tropics.

***Key words:*** Tomato; Tillage; Bulk density; Soil properties; Nutrient content; Yield

## Introduction

Tomato yields are as high as 13.52 and 21.9 t/ha in tropical Africa and the world, respectively. In Nigeria, the yield is as low as 10 t/ha (FAO, 1993). It has been noted that tomato productivity in farmer's field in Nigeria is low due to low soil fertility and inadequate soil management (Adekiya and Ojeniyi, 2002). Akinfasoye et al. (1997) observed that although tomato is one of the most important vegetable crops in Nigeria, over 95% of land areas in southwest Nigeria have low medium levels of phosphorus (P) to support tomato production. The major factors that contribute to low fertility include inappropriate tillage. Tillage is one of the ways of managing soil fertility. Managing of soil is a key to intensifying agriculture and improving production. According to Lal (1987), many constraints to food crop production in tropical Africa are related to tropical soils. Ndaeyo et al. (1995) suggested that the challenge of food in continuous cropping systems in the humid and sub-humid tropics of Nigeria is to manage the fragile soil to ensure sustained productivity. In Africa, there are many examples of unsuccessful farm projects which failed as a result of ill-adapted tillage techniques (Mashall, 1991). Tillage operations have been known to influence soil nutrient status, conservation and release. Information on this for most Nigerian soils is inadequate and conflicting especially for tomato.

**Corresponding Author:** Agbede, T.M., Department of Agricultural Engineering Technology, Rufus Giwa Polytechnic, P. M. B. 1019, Owo, Ondo State, Nigeria.
Tel: 08038171300;
E-mail: agbedetm@yahoo.com

Adeoti and Olarewaju (1990) studied the influence of no-tillage, manual tillage and tractor tillage on soil physical properties and yield of tomato grown on a sandy loam soil in savannah zone of Nigeria. The fruit yield in the manual and tractor plots were 67 and 157% higher than on the untilled plots. Babalola and Olaniyi (1997) at Ibadan southwest Nigeria investigated the effect of tillage, staking and mulching on tomato. Manual tillage have greater number of leaves and fruits compared to no tillage, however in the humid and sub-humid zone of southwest Nigeria consisting of Ibadan, Ikenne (humid) and Ilora (sub-humid), the yield of tomato on no-tillage and conventional tilled soils were not different (Omidiji *et al.,* 1995). It appears that effect of tillage methods on tomato depends on microclimate and soil type. This work studies effect of traditional manual clearing, manual mounding and conventional methods on soil properties, growth and fruit yield of tomato in rainforest zone of southwest Nigeria.

## Materials and methods

### *Field Experiment and Tillage Treatments:*

*A* 2-year field study was conducted at Owo ($7^0$ 12'N, $5^0$ 35'E) in the rainforest zone of southwestern Nigeria during the growing seasons of 2006 and 2007. The soil at the experimental site is a sandy clay loam, Oxic Tropuldalf (USDA) or luvisol (FAO) derived from quartz, gneiss and schist (Adepetu *et al.,* 1979). The surface soil (0-15 cm) at the start of the experiment had a pH (water) of 6.2, organic matter 2.3 g $kg^{-1}$, total nitrogen 0.2 g $kg^{-1}$, available P 4.2 mg $kg^{-1}$, exchangeable K 0.28 cmol $kg^{-1}$, exchangeable Ca 2.4 cmol $kg^{-1}$ and exchangeable Mg 1.6 cmol $kg^{-1}$. The site at the commencement of the experiment was dominated by weeds such as Siam weed (*Chromolaena odorata* (L) King and Robinson), Water leaf (*Talinum triangulare*) and Haemorrhage plant (*Aspilia africana*). The experiment was conducted in two seasons (early and late) of each year.

Five tillage treatments were replicated three times in a randomized complete block design. The treatments were (a) manual clearing (MC): clearing with cutlass and weeds removed from the plots, (b) manual mounding (MM): manual construction of mound using traditional hoe after weeds were removed from plots, (c) ploughing (P): ploughing with tractor mounted disc plough at about 15 cm soil depth, (d) ploughing plus harrowing (P+H): ploughed and harrowed once with tractor mounted disc plough and harrow at about 15 cm soil depth (e) Ploughing plus harrowing plus ridging (P+H+R): ploughed and harrowed and ridged once with tractor mounted disc plough, harrow and ridger to about 15 cm soil depth. The same tillage methods were used in both years. Each plot was 12 x 10 m and there were 120 plants per plot spaced 1 m x 1 m. In April and August each year, 3 weeks old (local variety) of tomato seedlings were transplanted for early and late planting respectively. Two manual weedings were done with hoe before harvesting. Fertilizer was not applied during the experiment.

### *Determination of Soil Properties:*

Two weeks after transplanting, certain soil physical properties were evaluated at 2 weeks interval. Six steel core samples collected from 0-15 cm below each plot were used for the evaluation of bulk density, total porosity and gravimetric water content after placement of samples in oven set at $100^0$C for 24 hours. Total porosity was calculated using particle density. Soil temperature at 15.00 hour was determined with a soil thermometer inserted to 10 cm depth and the mean value was computed.

Soil samples were obtained from 0-15 cm below each plot at 5 sites per plot at the beginning of harvest to determine soil chemical properties. The samples were composited, air-dried and passed through a 2 mm sieve before making the determinations as described by Carter (1993). The organic matter content was determined using dichromate oxidation method (Nelson and Sommers, 1996). Total N was determined by the micro-Kjeldahl digestion method (Bremner, 1996), available P was determined colorimetrically after Bray-P1 extraction (Frank *et al.,* 1998). Exchangeable calcium, potassium and magnesium were extracted with ammonium acetate. Thereafter, K was determined on flame photometer and Ca and Mg were determined by the EDTA digestion method (Hendershot and Lalande, 1993).

### *Leaf Analysis:*

At mid-flowering stage of each crop (early and late) in each year, leaf samples were collected randomly from each plot, oven-dried at $80^0$C for 48 h before grinding . Leaf N was determined by the micro-Kjeldahl digestion method. Ground samples were dry ashed at $500^0$C for 6 h in a furnace and digested with nitric-perchloric-sulphuric acid mixture for determination of P, K, Ca and Mg. Leaf P was determined colorimetrically by vanadomolybdate method, K was determined using flame photometer, and Ca and Mg by the EDTA titration method (AOAC, 1990).

*Determination of Yield Components:*

Ten plants were selected per plot for bi weekly determination of plant height. Fruits weights were evaluated between 72 and 90 days after transplanting. The plants were excavated for the measurement of tap root length.

*Statistical Analysis:*

The mean values of soil properties, nutrients content and growth and yield attributes of tomato were subjected to analysis of variance and the significant of treatment means were compared using the least Significant difference (LSD) at p=0.05 probability level (Hinkelmann and Kempthorne, 1994).

**Results and Discussion**

Soil physical properties at the end of 2006 and 2007 are as shown in Table 1. Manual mounding (MM) and ploughing plus harrowing plus ridging (P+H+R) produced relatively low soil bulk density, moisture content and relatively high soil temperature compared with other treatments. Manual clearing (MC) produced the highest bulk density in both years (1.74 Mg $m^{-3}$ in 2006, 1.75 Mg $m^{-3}$ in 2007) followed by ploughing (P), ploughing plus harrowing (P+H) and lowest was produced by ploughing plus harrowing plus ridging (P+H+R) (1.40 Mg $m^{-3}$ in 2006, 1.41 Mg $m^{-3}$ in 2007). The lower bulk density of tilled plots was attributed to the loosening effects of tillage (Agbede, 2006). The bulk high density recorded for manually cleared soil is usually consistent with the significantly low mean porosity recorded for the treatment.

The soil moisture content in manually cleared soil was higher than in manually mounded or other tractor treatments. The moisture content in manually cleared soil is consistent with its lower porosity. The turbulent movement of atmospheric air into soil, which enhances water evaporation, occurs through the larger pores (Ojeniyi and Dexter, 1983). Also, the higher soil temperature on manually mounded (MM) and ploughing plus harrowing plus ridging (P+H+R) is consistent with their high porous soils which should have reduced heat conduction in soil and consequently increased water evaporation.

Table 2 shows soil chemical properties produced by different tillage methods. Manual clearing (MC) method resulted in lower values of soil organic matter, N, P, K, Ca and Mg contents in years 2006 and 2007 (Table 2). Ploughing plus harrowing plus ridging (P+H+R) had higher concentrations of soil organic matter, N, P, K, Ca and Mg compared with other tillage treatments. The findings that tillage treatments had higher concentration of nutrients compared with manual clearing (MC) might be due to enhanced mineralization of soil organic matter and consequent release of nutrients since tillage is known to enhance mineralization of soil organic matter (Janzen *et al.,* 1998).

Table 3 shows data on leaf nutrient content of tomato as affected by different tillage methods in 2006 and 2007. There was a significant (p=0.05) effect of tillage on leaf N, P, K and Ca in both years. The values for Mg were not significant. Often times concentrations were higher in ploughing plus harrowing plus ridging (P+H+R) and manual mounding (MM) compared with other tillage treatments. The findings that the tomato plants on manually cleared soil had inferior status of leaf nutrient content is consistent with their higher values of bulk densities and associated inferior root growth which should have reduced nutrient uptake. The correlation (r) between soil bulk density and leaf N, P, K, Ca and Mg for the year 2006 were -0.90, -0.95, -0.96, -0.97 and -0.55 (p=0.05, N=4), respectively. The correlation of leaf N, P, K, Ca and Mg in year 2007 were -0.94, -0.96, -0.88, -0.99 and -0.67 (p=0.05, N=4), respectively. Ojeniyi (1993) also found that surface hoeing increased uptake of N, P and K by maize (Zea mays L.) in the humid zone of Nigeria.

Smaller mean values of plant height were recorded for manual clearing (MC) compared with other tillage treatments (Table 5). Ploughing plus harrowing plus ridging (P+H+R) had the highest value, this could also be attributed to its lower bulk density. Ploughing plus harrowing plus ridging (P+H+R) produced the highest tomato yield (average of 8.16 t $ha^{-1}$ in both years) followed by manual mounding (MM) (7.05 t $ha^{-1}$), ploughing plus harrowing (P+H) (6.24 t $ha^{-1}$) and ploughing (P) (5.81 t $ha^{-1}$). The least was produced by manual clearing (MC) (5.03 t $ha^{-1}$) and this was significantly lower than other tillage treatments (Table 6). The higher tomato yield recorded for conventional tillage treatments compared with manual clearing (MC) could also be adduced to their lower bulk densities. The differences in soil bulk density probably dictated differences in tomato growth, yield and nutrient content between untilled manual clearing (MC), manual mounding (MM), ploughing (P), ploughing plus harrowing (P+H) and ploughing plus harrowing plus ridging (P+H+R). Babalola and Olaniyi

(1997) also attributed poor growth of tomato in untilled soils to high soil bulk density and compaction. A nutrient such as phosphorus diffuses through the soil very slowly. Plants can only obtain sufficient P for normal growth by continuously extending their roots into soil where P content has not been depleted. The rate of root growth is however dependent on the degree of compaction of the soil, and P uptake was found to decline as bulk density of soil increased by compaction (Adekiya, 2000). Furthermore, the high bulk density meant low porosity and poor aeration and oxygen concentration around roots, hence poor yield. This is consistent with the findings of Zeroni *et al.,* (1983) that fruit yield increased linearly with the concentration of oxygen around the roots.

**Table 1:** Mean values of soil physical properties produced by different tillage methods in 2006 and 2007

| Tillage methods | Bulk density (M $gm^{-3}$) E | L | Mean | Porosity (%) E | L | Mean | Moisture content (%) E | L | Mean | Temperature ($^0C$) E | L | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | | | | | | | | | | | | |
| MC | 1.74 | 1.74 | 1.74 | 33.1 | 33.1 | 33.1 | 12.30 | 14.40 | 13.30 | 27.2 | 27.1 | 27.2 |
| MM | 1.48 | 1.48 | 1.48 | 43.1 | 43.1 | 43.1 | 9.60 | 11.40 | 10.50 | 31.1 | 31.8 | 31.5 |
| P | 1.68 | 1.69 | 1.69 | 35.4 | 35.0 | 35.2 | 10.40 | 12.40 | 11.40 | 29.0 | 30.0 | 29.5 |
| P+H | 1.65 | 1.65 | 1.65 | 36.5 | 36.5 | 36.5 | 10.30 | 12.30 | 11.30 | 29.2 | 30.0 | 29.6 |
| P+H+R | 1.40 | 1.40 | 1.40 | 46.2 | 46.2 | 43.3 | 9.40 | 11.60 | 10.50 | 31.0 | 32.0 | 31.5 |
| LSD (0.05) | 0.07 | 0.07 | | 2.0 | 2.0 | | 0.6 | 0.6 | | 1.8 | 1.8 | |
| 2007 | | | | | | | | | | | | |
| MC | 1.74 | 1.75 | 1.75 | 33.1 | 32.7 | 32.9 | 11.20 | 10.20 | 10.70 | 28.3 | 28.0 | 28.2 |
| MM | 1.49 | 1.49 | 1.49 | 42.7 | 42.7 | 42.7 | 8.40 | 8.60 | 8.50 | 32.7 | 32.6 | 32.7 |
| P | 1.69 | 1.69 | 1.69 | 35.0 | 35.0 | 35.0 | 9.30 | 9.50 | 9.40 | 30.4 | 30.2 | 30.3 |
| P+H | 1.65 | 1.65 | 1.65 | 36.5 | 36.5 | 36.5 | 9.00 | 9.30 | 9.15 | 30.5 | 30.3 | 30.4 |
| P+H+R | 1.40 | 1.41 | 1.41 | 46.2 | 43.2 | 43.1 | 8.40 | 8.50 | 8.45 | 32.1 | 32.1 | 32.1 |
| LSD (0.05) | 0.07 | 0.07 | | 2.0 | 2.0 | | 0.6 | 0.6 | | 1.8 | 1.8 | |

MC= Manual clearing; MM= Manual mounding; P= Ploughing; P+H= Ploughing plus harrowing; P+H+R= Ploughing plus harrowing plus ridging E = Early season tomato crop
L = Late season tomato crop

**Table 2:** Soil chemical properties produced by different tillage methods

| Tillage methods | Organic matter (g $kg^{-1}$) 2006 | 2007 | N (g $kg^{-1}$) 2006 | 2007 | P (mg $kg^{-1}$) 2006 | 2007 | K (cmol $kg^{-1}$) 2006 | 2007 | C (cmol $kg^{-1}$) 2006 | 2007 | Mg (cmol $kg^{-1}$) 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MC | 1.80 | 1.65 | 0.18 | 0.17 | 3.0 | 2.6 | 0.26 | 0.23 | 3.3 | 2.5 | 0.90 | 0.45 |
| MM | 2.40 | 2.20 | 0.25 | 0.23 | 4.1 | 3.9 | 0.33 | 0.30 | 4.1 | 3.6 | 1.00 | 0.70 |
| P | 2.10 | 1.90 | 0.20 | 0.17 | 3.4 | 3.2 | 0.29 | 0.26 | 3.8 | 3.0 | 1.0 | 0.75 |
| P+H | 2.10 | 1.95 | 0.23 | 0.20 | 4.0 | 3.7 | 0.29 | 0.27 | 3.9 | 3.2 | 1.0 | 0.60 |
| P+H+R | 2.60 | 2.40 | 0.26 | 0.23 | 4.4 | 4.3 | 0.37 | 0.35 | 4.3 | 3.9 | 1.1 | 0.92 |
| LSD (0.05) | 0.20 | 0.25 | 0.03 | 0.02 | 0.3 | 0.5 | 0.04 | 0.04 | 0.4 | 0.4 | NS | NS |

MC= Manual clearing; MM= Manual mounding; P= Ploughing; P+H= Ploughing plus harrowing; P+H+R= Ploughing plus harrowing plus ridging NS = Not significant

**Table 3:** Leaf nutrient content produced by different tillage methods

| Tillage methods | N (g $100g^{-1}$) 2006 | 2007 | P (g $100^{-1}$) 2006 | 2007 | K (g $100g^{-1}$) 2006 | 2007 | Ca (g $100g^{-1}$) 2006 | 2007 | Mg (g $100g^{-1}$) 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|---|---|
| MC | 1.11 | 1.09 | 0.30 | 0.22 | 2.10 | 1.98 | 0.26 | 0.25 | 0.10 | 0.10 |
| MM | 2.26 | 2.25 | 0.39 | 0.37 | 3.01 | 2.90 | 0.43 | 0.40 | 0.23 | 0.21 |
| P | 1.20 | 1.25 | 0.30 | 0.29 | 2.30 | 2.50 | 0.28 | 0.30 | 0.24 | 0.20 |
| P+H | 1.96 | 1.99 | 0.31 | 0.30 | 2.75 | 2.90 | 0.28 | 0.31 | 0.24 | 0.20 |
| P+H+R | 2.30 | 2.60 | 0.39 | 0.38 | 3.50 | 3.30 | 0.43 | 0.49 | 0.24 | 0.21 |
| LSD (0.05) | 0.09 | 0.15 | 0.07 | 0.07 | 0.2 | 0.35 | 0.08 | 0.1 | NS | NS |

MC= Manual clearing; MM= Manual mounding; P= Ploughing; P+H= Ploughing plus harrowing; P+H+R= Ploughing plus harrowing plus ridging NS = Not significant

**Table 4:** Mean values of tap root length (m) produced by different tillage methods.

| Tillage methods | 2006 E | L | 2007 E | L | Mean |
|---|---|---|---|---|---|
| MC | 0.09 | 0.08 | 0.10 | 0.12 | 0.10 |
| MM | 0.18 | 0.17 | 0.17 | 0.17 | 0.17 |
| P | 0.12 | 0.11 | 0.13 | 0.13 | 0.12 |
| P+H | 0.14 | 0.15 | 0.16 | 0.16 | 0.15 |
| P+H+R | 0.22 | 0.21 | 0.20 | 0.21 | 0.21 |
| LSD (0.05) | 0.03 | 0.02 | 0.02 | 0.02 | |

MC= Manual clearing; MM= Manual mounding; P= Ploughing; P+H= Ploughing plus harrowing; P+H+R= Ploughing plus harrowing plus ridging E = Early season tomato crop
L = Late season tomato crop

**Table 5:** Mean values of plant height (m) produced by different tillage methods.

| Tillage methods | 2006 | | 2007 | | |
|---|---|---|---|---|---|
| | E | L | E | L | Mean |
| MC | 0.40 | 0.41 | 0.40 | 0.38 | 0.40 |
| MM | 0.50 | 0.50 | 0.50 | 0.47 | 0.49 |
| P | 0.40 | 0.42 | 0.44 | 0.39 | 0.41 |
| P+H | 0.45 | 0.45 | 0.46 | 0.41 | 0.44 |
| P+H+R | 0.55 | 0.56 | 0.56 | 0.51 | 0.55 |
| LSD (0.05) | 0.08 | 0.08 | 0.08 | 0.07 | |

MC= Manual clearing; MM= Manual mounding; P= Ploughing; P+H= Ploughing plus harrowing; P+H+R= Ploughing plus harrowing plus ridging E = Early season tomato crop
L = Late season tomato crop

**Table 6:** Mean values of tomato yield (t $ha^{-1}$) produced by different tillage methods.

| Tillage methods | 2006 | | 2007 | | |
|---|---|---|---|---|---|
| | E | L | E | L | Mean |
| MC | 4.83 | 5.52 | 4.43 | 5.34 | 5.03 |
| MM | 6.85 | 7.44 | 6.45 | 7.46 | 7.05 |
| P | 5.61 | 6.29 | 5.21 | 6.15 | 5.81 |
| P+H | 6.01 | 6.73 | 5.67 | 6.55 | 6.24 |
| P+H+R | 7.94 | 8.65 | 7.56 | 8.49 | 8.16 |
| LSD (0.05) | 0.55 | 0.64 | 0.49 | 0.71 | |

MC= Manual clearing; MM= Manual mounding; P= Ploughing; P+H= Ploughing plus harrowing; P+H+R= Ploughing plus harrowing plus ridging E = Early season tomato crop
L = Late season tomato crop

Therefore, tomato grown on an Alfisol of the humid tropics requires tillage for reducing bulk density, increasing porosity and soil organic matter mineralization and enhancing root growth, nutrient uptake and yield.

*Conclusion:*

Differences in soil bulk density and porosity caused by tillage induced variation in growth, nutrient content and yield of tomato. Manual clearing had high bulk density and therefore poor yield and cannot be substituted for any of the tillage treatments on an Alfisol of southwest Nigeria due to significant loss in yield of tomato. Conventional tillage especially ploughing plus harrowing plus ridging improved nutrient availability and yield of tomato because of reduced soil bulk density and therefore recommended for commercial production of tomato.

## References

Adekiya, A.O., 2000, Effects of soil preparation methods on soil properties and performance of tomato. M.Sc. Dissertation, Federal University of Technology, Akure.

Adekiya, A.O. and S.O. Ojeniyi, 2002. Evaluation of tomato growth and soil properties under methods of seedling bed preparation in an Alfisol in the rainforest zone of southwest Nigeria. Soil Tillage Research, 64: 275-279.

Adeoti, J.S. and J.D. Olarewaju, 1990. Influence of manual and tractor drawn tillage tools on soil properties and tomato yield. AMA Agric. Mechanization in Asia, Africa and Latin America, 21: 13-16.

Adepetu, J.A., A.A. Adebayo, E.A. Aduayi and G.O. Alofe, 1979. Preliminary survey of the fertility status of soils in Ondo State under traditional cultivation. Ife J. Agric., 1: 34-149.

Akinfayose, J.A., A.O. Olufolaju, F.M. Tairu and A.R.A. Adenawola, 1997. Effect of different phosphorus levels on the yield of four varieties of rainfed tomato. In: Proceeding 15th HORTSON Conference NIHORT, Ago-Iwoye, pp: 65-66.

Agbede, T.M., 2006. Effect of tillage on soil properties and yam yield on an Alfisol in southwestern Nigeria. Soil Tillage Research, 86: 1-8.

AOAC., 1990. Official methods of Analysis of the Association of Official Analytical Chemists, Washington DC., pp: 123-126.

Babalola, L.A. and J.O. Olaniyi, 1997. Effect of some management practices on the performance of tomatoes (*Lycopersicon esculentum* Mill). In: Proceeding 15th HORTSON Conference, Ibadan., pp: 101-103.

Bremner, J.M., 1996. Nitrogen-total. In: Sparks, D.L. (Ed.), Methods of Soil Analysis. Part 3. Chemical Methods. Second edition, SSSA Book Series No. 5, ASA and SSSA, Madison, WI, USA, pp: 1085-1121.

Carter, M.R., 1993. Soil Sampling and Method of Analysis. Canadian Society of Soil Science, Lewis Publishers, pp: 823.

FAO., 1993. Food and Agriculture Organisation of the United Nations Year Book of Production, FAO, Rome, pp: 254.

Frank, K., D. Beegle and J. Denning, 1998. Phosphorus. In: J.R. Brown (Ed.), Recommended Chemical Soil Test Procedures for the North Central Region, North Central Regional Research Publication No. 221 (revised), Missouri Agric. Exp. Stn. Columbia, MO., pp: 21-26.

Hendershot, W.H. and H. Lalande, 1993. Ion exchange and exchangeable cations. Soil Sampling and Methods of Analysis. In: Carter, M.R. (Ed.), Canadian Society of Soil Science, vol. 19. Lewis Publishers, London, pp: 167-176.

Hinkelmann, K. and O. Kempthorne, 1994. Design and Analysis of Experiments, vol. 1. Introduction to Experimental Design. John Wiley & Sons, New York, pp: 495.

Janzen, H.H., C.A. Campbell, R.C. Izanrrable, B.H. Ellert, H. Juma, McGill and R.F. Zenter, 1998. Management effects of soil storage on the Canadian Practices. Soil Tillage Research, 47: 187-203.

Lal, R., 1987. Managing the soil of sub-Sahara Africa. Science, 236: 1069-1076.

Mashall, A.M., 1991. Land degradation and desertification in Africa. Proceedings of the second African Soil Science Society, Cairo., pp: 407-422.

Ndaeyo, N.U., E.A. Aiyelari. and A.A. Agboola, 1995. Evaluation of different tillage practices for monocultural cowpea (Vigna unguiculata (L.) Walp) production in Ibadan southwestern Nigeria. African Soil., 28: 475-488.

Nelson, D.W. and L.E. Sommers, 1996. Total carbon, organic carbon and organic matter. In: Page, A.L., R.H. Miller and D.R. Keeney (Eds.), Methods of Soil Analysis, Part 3. Second ed. SSSA Book Series No. 5, SSSA, Madison, WI, USA, pp: 961-1010.

Ojeniyi, S.O., 1993. Nutrient availability and maize yield under reduced tillage practices. Soil Tillage Research, 26: 89-92.

Ojeniyi, S.O. and A.R. Dexter, 1983. Changes in the structure of tilled soil in a growing season. Soil Tillage Research, 3: 39-46.

Omidiji, M.O., J.B. Oyedokun and S.O. Anjuwon, 1995. Evaluation of some tillage methods for food crop production in southwestern Nigeria. In: Proceedings International Soil Science (Commission IV and VI) organised by the Soil Science Society of Nigeria 21-26th July, Ibadan, Nigeria, pp: 48-55.

Sheldrick, B. and C. Hand Wang, 1993. Particle-size distribution. In: Carter, M.R. (Ed.), Soil Sampling and Methods of Analysis. Canadian Society of Soil Science, Lewis Publishers, Ann Arbor MI., pp: 499-511.

Zeroni, M., J. Gale and J. Ben-Asher, 1983. Root aeration in a deep hydroponic system and its effect on growth and yield of tomato. Scientia Hortic., 19: 213-220.