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Study into tillage-mulch package for production of sweet potato (*Ipomoea batatas* L) effect on soil properties and yield

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A B S T R A C T

Field experiments were carried out during 2014 cropping season at Omuo-Ekiti and Kabba. Omuo falls within the forest zone while Kabba is in the southern guinea savanna zone of Nigeria. The experiment at the two sites was to study the effect of tillage and mulch combinations on soil physical and chemical properties and sweet potato (Ipomoea batatas L.) performance. The trial consisted of 2 x 5 factorial combinations of two tillage methods: no-tillage (NT) and manual tillage (MT) and five levels of mulch, siam weed (Chromolaena odorata), {0, 5, 10, 15 and 20 t/ha}.These were laid out using split plots design arranged in a randomized complete block with each treatment replicated four times. There were no significant differences in the values of soil moisture content, soil temperature, porosity and bulk density between Omuo and Kabba sites. Omuo site has significant values of soil organic matter (SOM), total N, K and sweet potato tuber yield compared with Kabba site. Omuo has 1.8 t/ha (10%) higher sweet potato yield compared with Kabba. No-tillage treatment has higher soil moisture content, SOM, N, P, K, Ca, Mg and higher tuber yield compared with manual tillage, The yield difference between NT and MT was 2.9 t/ha (16.7%). Application of mulch increases the yield components of sweet potato compared with no mulch application. The increase in yield as mulch rates increases was adduced to increase in soil organic matter from the mulch. There were however no significant differences between 15 and 20 t/ha mulch levels. Mulch applied at 15 t/ha was found to be suitable for sweet potato in tropical Alfisol. Therefore for soil fertility conservation and performance of sweet potato, no-tillage and 15 t/ha siam weed mulch is recommended.

Key words: *Manual tillage; no-tillage; Nigeria; soil chemical properties; soil physical properties; soil organic matter; siam weed.*

Introduction

Sweet potato (Ipomoea batatas L.) is produced largely in the tropics. The tuber is eaten boiled, fried and baked or made into syrup and also serves as raw materials for the manufacture of starch, glucose and alcohol (Yasmin et al., 2007). The leaves are also used as vegetables in some communities in Nigeria and widely used as fodder for livestock. The tuber is an excellent source of anti-oxidants and carotenes chiefly in the orange flesh colour varieties thus providing cheap and rich source of vitamin A for poor people (Woolfe, 1992).

Despite the numerous benefits, most tropical tuber crops especially sweet potato is not managed optimally, thus resulting in low yields. Among the most important factors affecting yield of crops like sweet potato include continuous cultivation on the same land which leads to soil nutrient exhaustion, physical degradation and low yield. More so sweet potato like any other tuber crop is a heavy feeder exploiting greater volume of soil for nutrient and water (Osundare, 2004). Study into appropriate soil management package for enhanced productivity of sweet potato is rare although the fragile nature of tropical soils required appropriate and integrated soil management for sustaining high soil and crop productivity.

Sweet potato is often planted on ridges and mounds, whereas it is established by research that no-tillage is important in soil and water conservation and has been favourable to crops performance in the humid zones (Adekiya and Ojeniyi, 2002; Agbede, 2008). Tillage affects soil properties such as temperature, moisture content, bulk density, porosity and infiltration which affect crops performance. If intensively performed or mechanised it causes rapid degradation of soil physical, chemical and biological qualities especially in humid zones of southern Nigeria. Hence there is need to study effects on no-till method in sweet potato cultivation.

Mulch on the other hand is a layer of plant residue applied to the surface soil to conserve moisture and improve soil fertility (Akanbi and Ojeniyi, 2007). It is a common practice recommended for tropical small holder farming. The technique improves biotic activity and adds nutrients thereby improving soil fertility and crops yield.

In order to alleviate the problems of low soil fertility and soil quality affecting yield of sweet potato with repetitive cultivation, there is the need to develop an organic no-till bared soil management for sustainable production of the crop. It is already established that total dependence on chemical fertilizer has failed to sustain crop production in the tropics (Ojeniyi, 2000; Ano and Agwu, 2005). The importance of no-tillage and mulching in soil and water conservation, growth and yield of crops in Nigeria has been reported (Agele et al., 1999). However research information is scarce on response of sweet potato to tillage and mulching in different agro ecological zones of Nigeria. Ossom et al. (2001) in Papua New Guinea reported the benefits of applying mulches to sweet potato to stabilize yield.The main objective of this work was to develop tillage- mulch package for sustaining soil quality and yield of sweet potato.

Materials and methods

Field experiments were carried out during 2014 cropping season at Omuo-Ekiti (Lat 7^o 31'N long 5^o 49'E) and Kabba (Lat 7^o 51'E long 6^o 45'E). Omuo falls within the forest zone where the rich tropical forest once thrived while Kabba is in the southern guinea savanna zone of Nigeria. The top of the soil at both sites were sandy loam. The two sites were both Alfisol. Omuo has a rainfall of 1250-1460 mm per annum and mean temperature of 27^oC. The site has tropical humid vegetation with distinct wet and dry seasons. The wet season is from late March to October with little dry season in August. Kabba has an annual rainfall of between 1000-1256 mm, with an annual mean temperature of 32^oC. Rainfall is also bimodal. The experiment at the two sites was to study the effect of tillage and mulch combinations on soil properties and sweet potato (Ipomoea batatas L.) performance.

Experimental design and treatment

The experiments were laid out using split plots design arranged in a randomized complete block with each treatment replicated four times. The area used in each site was 697 m^2 in size having a total of 8 main plots and each main plot has 5 sub-plots. Each main plot measured 19 x 2.5 m with discard of 3 m within the main plots and 2 m in between sub-plot and 2 m round the whole plot. The trial consisted of 2 x 5 factorial combinations of two tillage methods {(1) No-tillage, NT i.e. manual clearing with cutlass and weeds removed from plots before planting on flat without primary or secondary tillage operation and (2) Manual tillage, MT i.e. preparation of ridges by heaping the soil surface layer using the traditional hoe after cleared weeds were removed from the plots} and five levels of mulch, siam weed (Chromolaena odorata), {0, 5, 10, 15 and 20 t/ha}. These were combined to make 10 treatments. Tillage operation was carried out in May at the two sites.

Planting of sweet potato and application of siam weed mulch

After tillage operations, planting of 30 cm sweet potato vines variety TIS87/0087 obtained from National Root Crop Research Institute, Umudike, Nigeria was done in May 2014 at the spacing of 0.5 x 1m while mulch application followed a day after the planting. Fresh siam weed collected from a nearby farm and hedge containing green tender stems and the leaves equivalent to 0, 5, 10, 15 and 20 t/ha was applied to cover the soil. Weeding operation was done manually at 3 and 8 weeks after planting at each site

Determination of soil properties

One month after planting sweet potato / mulch application, determination of certain soil physical properties in all plots at the two sites commenced and this was done at one- month interval on four occasions. Six samples were collected at 0-10 cm depth from each plot using a steel cone sampler and were used for evaluation of bulk density, total porosity and gravimetric water content after oven-dried at 100^oC for 24 h. Total porosity was calculated from the values of bulk density and particle density. Soil temperature was determined at 15.00 h with a soil thermometer inserted to 10 cm depth. Six readings were made per plot at each sampling time at 1-month interval and mean data were computed.

Prior to commencement of experiment, soil samples randomly collected from 0-20 cm depth were thoroughly mixed inside a plastic bucket to form a composite which was later analysed for physical and chemical properties. At the harvest in each location, another set of composite samples were collected per plot basis and similarly analysed for routine chemical analysis as described by Carter (1993). The soil samples were air-dried and sieved using a 2 mm sieve before making the determinations. Soil organic matter was determined by the procedure of Walkley and Black using the dichromate wet oxidation method (Nelson and Sommers, 1996), total N was determined by micro-Kjeldahl digestion method (Bremner, 1996), available P was determined by Bray-1 extraction followed by molybdenum blue colorimetry (Frank et al., 1998). Exchangeable K, Ca and Mg were extracted using 1.0 N ammonium acetate. Thereafter, K was determined using a flame photometer and Ca and Mg were determined by EDTA titration method (Hendershot and Lalande, 1993). Soil pH was determined in soil water (1:2) medium using the digital electronic pH meter. Particle size analysis was done using Bouyoucos hydrometer method (Sheldrick and Hand Wang, 1993). Soil bulk density was determined using the core method (Campbell and Henshall, 1991).

Yield components

Ten plants from the sub-plots were randomly selected for the yield determination. Yield parameters assessed included tuber length, tuber diameter, number of tubers, tuber girth and tuber weight. These were determined at harvest (5 months after planting)

Statistical analysis

The data collected were subjected to analysis of variance (ANOVA) using the SAS and Microsoft Office Excel 2007 packages and treatment means were compared using the Duncan's multiple range test (DMRT).

Results

The data shown in Table 1 are the results of the physical and chemical properties of the sites before experimentation. The soils at both sites are sandy loam and slightly acidic. The soil bulk densities were high, though Kabba site higher than Omuo site. At both sites, the organic matter and total N were low. Available P was moderate. Exchangeable K was adequate in Omuo and low in Kabba site. Exchangeables Ca and Mg were adequate at both sites according to the standard recommended for crop production in ecological zones of Nigeria (Akinrinde and Obigbesan, 2000)

Table 1: Soil physical and chemical properties of the sites before experimentation

Parameter	Omuo	Kabba
Sand (%)	66	66
Silt (%)	18	15
Clay (%)	16	19
Textural class	Sandy loam	Sandyloam
Bulk density (Mg/m^3)	1.31	1.42
Total porosity (%)	50.6	46.4
pH (water)	5.6	5.9
Organic matter (%)	2.38	2.45
Total N (%)	0.15	0.13
Available P (mg/kg)	12.1	10.3
Exchangeable K (cmol/kg)	0.18	0.14
Exchangeable Ca(cmol/kg)	3.2	2.9
Exchangeable Mg (cmol/kg)	1.2	0.9

Table 2: Effect of sites, tillage methods and mulch rates on soil physical properties (0-10 cm depth)

	Moisture content (%)	Temperature (^oC)	Total porosity (%)	Bulkdensity (Mg/m^3)
Site (S)				
Omuo	11.96a	31.0a	55.5a	1.18ab
Kabba	11.86a	31.5a	54.0ab	1.22a
Tillage method(T)				
No-tillage (NT)	12.03a	30.9ab	54.3ab	1.21a
Manual tillage (MT)	10.20b	31.6a	55.8a	1.17ab
Mulch rate (M) (t/ha)				
0	11.39a	34.7d	50.6e	1.31e
5	12.34b	32.6c	54.7d	1.20d
10	14.90c	31.4b	55.8c	1.17c
15	15.85d	29.1a	57.4b	1.13b
20	17.10e	28.6a	59.2a	1.08a
S x T	ns	ns	Ns	Ns
S x M	ns	ns	Ns	Ns
T x M	ns	ns	Ns	Ns
S x T x M	ns	ns	Ns	Ns

Values followed by similar letters under the same column are not significantly different at p = 0.05 according to Duncan's multiple range test (DMRT): ns = not significant

Effect of sites, tillage methods and mulch application on soil physical properties

Table 2 shows the results of the effect of sites, tillage methods and siam mulch applications on the soil physical properties. There were no significant differences in the values of soil moisture content, temperature, porosity and bulk density between Omuo and Kabba sites. However, Omuo site had slightly lower bulk density and higher porosity compared with Kabba site.

Among tillage methods, NT had significantly higher soil moisture content compared with MR. There were no significant differences in soil temperature, porosity and bulk density between NT and MR.

Application of mulch increased soil moisture content, porosity and reduced soil temperature and bulk density significantly compared with no application of mulch. Increasing mulch levels from 0- 20 t/ha increased moisture content and porosity of the soil. Similarly increasing mulch level decreases soil temperature significantly, however there were no significant differences between application of mulch at 15 and 20 t/ha in terms of soil temperature. There were significant reduction of bulk density of the soils as mulch levels increases from 0-20 t/ha. There were no significant differences in the

interaction between site (S) and tillage method (T) i.e. S x T, sites and mulch (M) i.e. S x M, tillage and mulch i.e. T x M and S x T x M for moisture content, soil temperature, porosity and bulk density.

Effect of sites, tillage methods and mulch application on soil chemical properties

Table 3 shows the results of the effect of sites, tillage methods and mulch application on soil chemical properties. Soil pH did not produce any significant difference between Omuo and Kabba sites. Omuo site had significantly higher values of soil organic matter (SOM), total N and K compared with Kabba site. The values of P, Ca and Mg were not significantly different between both sites.Tillage methods also influenced soil chemical properties significantly with NT having higher values of SOM, N, P, K, Ca and Mg compared with MT. The values of soil pH were not significantly different between NT and MT soils.

Application of mulch increased soil pH, SOM, N, P, K, Ca and Mg significantly compared with no application of mulch. Increasing level of mulch from 0-20 t/ha increased soil pH, SOM, N, P, K, Ca and Mg. However, for all soil nutrients, except pH, application of mulch at 15 and 20 t/ha did not produce any significant different. SOM, N and K only produced significant interaction between S x T and T x M. Other interactions have no significant effect.

Table 3: Effect of sites, tillage methods and mulch rates on soil chemical properties

	pH (water)	Organic matter (%)	N (%)	P (mg/kg)	K (cmol/kg)	Ca (cmol/kg)	Mg (cmol/kg)
Site (S)							
Omuo	5.96a	2.49a	0.16a	13.5a	0.32a	3.80ab	1.30a
Kabba	5.91a	2.24b	0.14b	13.0a	0.27b	4.07a	1.20ab
Tillage method(T)							
No-tillage	5.96a	2.51a	0.16a	13.7a	0.28a	3.92a	1.34a
Manual tillage	5.90a	2.23b	0.14b	12.2b	0.25b	3.51b	1.21b
Mulch rates (M) (t/ha)							
0	5.09a	1.18a	0.130a	7.8a	0.154a	2.07a	0.40a
5	5.93b	2.06b	0.148b	11.9b	0.250b	2.89b	1.33b
10	6.06c	2.39c	0.155b	14.1c	0.287c	3.50c	1.45c
15	6.26d	2.96e	0.170c	16.4d	0.382de	5.84de	1.51cd
20	6.33e	3.18e	0.178c	16.6d	0.400e	6.08e	1.63d
S x T	Ns	*	*	ns	*	Ns	Ns
S x M	Ns	Ns	ns	ns	Ns	Ns	Ns
T x M	Ns	*	*	ns	*	Ns	Ns
S x T x M	Ns	Ns	ns	ns	Ns	Ns	Ns

Values followed by similar letters under the same column are not significantly different at p = 0.05 according to Duncan's multiple range test (DMRT); * = significant at 5% and 1% level of probability; ns = not significant

Table 4: Effect of sites, tillage methods and mulch rates on yield components of sweet potato

	Number of tubers/plant	Tuber length (cm)	Tuber girth (cm)	Tuber weight (t/ha)
Site (S)				
Omuo	12.13a	17.1a	17.23a	19.8a
Kabba	12.43a	15.2b	16.30ab	18.0b
Tillage method(T)				
No-tillage (NT)	12.31a	15.39a	16.88a	20.2a
Manual tillage (MT)	12.25a	15.15a	16.58a	17.3b
Mulch rate (M) (t/ha)				
0	8.1a	12.05a	11.97a	14.3a
5	11.1b	14.53b	15.83b	18.0b
10	12.8c	15.19b	16.87b	19.0c
15	14.3d	16.77c	18.67cd	22.6de
20	15.4e	16.82c	19.33d	23.1e
S x T	ns	ns	Ns	*
S x M	ns	ns	Ns	ns
T x M	ns	ns	Ns	ns
S x T x M	ns	ns	Ns	ns

Values followed by similar letters under the same column are not significantly different at p = 0.05 according to Duncan's multiple range test (DMRT); * = significant at 5% and 1% level of probability; ns = not significant

Effect of sites, tillage methods and mulch application on yield components of sweet potato

Data in Table 4 shows the results of the effect of sites, tillage methods and mulch application on yield components of sweet potato. Tuber weight and tuber length of sweet potato were higher significantly at Omuo compared with Kabba. Number of tubers per plant produced no significant result between Omuo and Kabba. Omuo site produced higher tuber girth of sweet potato that was not significantly different from Kabba site. Omuo site had 1.8 t/ha (10%) higher sweet potato yield compared with Kabba site.

Number of tubers per plant, tuber length and girth of sweet potato did not produce any significant value between NT and MT, but NT had significantly higher value of tuber weight compared with MT. In fact the yield difference between NT and MT was 2.9 t/ha (16.7%).

Application of mulch increased the yield components of sweet potato significantly compared with no application. Increasing mulch level from 0-20 t/ha significantly increased number of tubers, tuber length, tuber girth and tuber weight of sweet potato. Tuber girth at 5 and 10 t/ha mulch levels were similar statistically. There was also no significant difference in mulch application between 15 and 20 t/ha for tuber length, girth and weight of sweet potato. The yield difference between no application of mulch and 20 t/ha mulch level was 8.8 t/ha (61.8%).

Discussion

Among tillage methods, NT had significant higher moisture content compared with MT. The higher moisture content of NT compared with MT is consistent with its lower porosity. The turbulent movement of atmospheric air into soil which enhanced water evaporation occurs through larger pores. Hillet et al. (1975) had earlier reported that no-till plots were protected by layer of low conductivity (dry soil) on the surface which reduces evaporation losses. Though not significant, the slight higher bulk density and lower porosity of NT compared with MT could be attributed to no-tillage and compaction. This implies that continuous exposure of untilled soil to rainfall without tillage will compact the soil and therefore increase the bulk density of the soil.

It was reported that mulch increased soil moisture content, porosity and reduced soil temperature and bulk density significantly compared with no application of mulch. The higher moisture and porosity and lower temperature associated with mulch could be adduced to reduction of evaporation losses. The reduction in bulk density observed in mulch plots compared with no mulch plots can be adduced to increase in SOM resulted from the degraded residues by soil microorganisms.

The reported improvement in soil physical properties as mulch rates increases from 0-20 t/ha could be adduced to increase in SOM as the mulch level increases. Opara-Nadi and Lal (1987) found that surface applied mulch at 4 to 6 t/ha created more favourable soil physical properties compared with low mulch rates on Alfisol of southwest Nigeria.

The results that Omuo site had significant values of SOM, total N and exchangeable K compared with Kabba site could be adduced to the initial chemical properties of the soil. Omuo site is inherently higher in SOM, N and K compared with Kabba site.

The significant higher values of SOM, N, P, K, Ca and Mg reported in NT compared with MT soils could be related to presence of organic matter. The low values of SOM, N, P, K, Ca and Mg recorded for MT compared with NT plots could also be due to inversion of top soil during land preparation which could have brought less fertile subsoil to the surface.

The results that mulch plots increased SOM, N, P, K, Ca and Mg compared with unmulch plots attested to the fact that the siam weed mulch is rich in these nutrients and affirmed that these nutrients are released into the soil by decomposed mulches. The increase in the values of SOM, N, P, K, Ca and Mg with applied rates of mulch could be due to increase in organic matter

It was reported that tuber weight and length of sweet potato were significantly higher at Omuo compared with Kabba. This can be related to the soil chemical properties of Omuo site. Omuo site had higher values of SOM, N and K compared with Kabba. N and K are very important for tuber crops especially potato. K is specifically important for tuber formation in crops (Ngongi, 1977;Obigbesan, 1973; Agbede et al. 2013). The higher tuber yield at Omuo site can also be related to its lower bulk density and higher porosity (though not significant) compared with Kabba site. The reduced bulk density and increased porosity would have enhanced soil aeration, resulting from both a greater soil surface to soil volume has enhanced root growth (tuber length) and nutrient uptake and tuber yield.

The significant higher value of tuber weight of potato in NT plots compared with MT plots could be related to the higher values of soil chemical properties and moisture content of NT compared with MT. The excess water in NT compared with MT and soil nutrients especially N would also aid tuber expansion and water accumulation at the expense of starch formation and fresh matter formation. Whereas K availability would enhance starch formation.

The increase in yield components of sweet potato as a result of mulch application can be due to reduce bulk density and soil temperature and increase moisture content, porosity, SOM, N, P, K, Ca and Mg due to the mulch. The increase in the yield component of sweet potato as a result of increase in rates of mulch could be due to increase availability of SOM, N, P, K, Ca and Mg in the soil. It can also be adduced to the fact that moisture content and porosity increases and bulk density and temperature reduces as level of mulch increase, which means better soil structures are formed; better yield of potato. The non-significant between15 and 20 t/ha mulch levels implies that the mulch at 15 t/ha is adequate for sweet potato and any further increase in mulch will be of no economic value. This is also the same as the soil chemical properties at this mulch level. Therefore no-tillage with 15 t/ha siam weed mulch is suitable for sweet potato production.

Conclusion

Differences in soil chemical properties (SOM, N and K) caused by the initial soil properties induces variation in the tuber weight and length between Omuo and Kabba sites. No-tillage treatment had higher moisture content, SOM, N, P,

K, Ca and Mg compared with manual tillage, hence higher tuber yield. Application of mulch increases the yield components of sweet potato compared with no mulch application. The increase in yield as mulch rates increases was adduced to increase in soil organic matter from the mulch. There were however no significant differences between 15 and 20 t/ha mulch levels. Mulch applied at 15 t/ha was found to be suitable for sweet potato in tropical Alfisol. Therefore for soil fertility conservation and performance of sweet potato, no-tillage and 15 t/ha siam weed mulch is recommended.

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