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Full Length Research Paper

The effect of tillage systems and mulching on soil microclimate, growth and yield of yellow yam (*Dioscorea cayenensis*) in Midwestern Nigeria

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Yellow yam (*Dioscorea cayenensis*) is one of the major varieties of yam produced in Midwestern Nigeria mainly by traditional farmers. Most of these traditional farmers employ zero tillage system and mulching after planting. But, is this the best practice for optimising yield? This paper examines the effect of tillage systems and mulching on soil microclimatic conditions, growth and yield of yellow yam. To generate the needed data, the physiological approach was employed. An experimental farm that measured 35 x 47 m was established at Agbor, Delta State, Nigeria, for two planting seasons 1997/98 and 1998/99. The microclimatic parameters monitored include air and soil temperatures and relative humidity while the physiological parameters measured were emergence, growth rate, leaf area accumulation and yield. Time series, multiple correlations, chi-square, ANOVA, least square range test and stepwise regression analysis were the statistical tools employed in analysing the data. The results showed that soil moisture at 0-15 cm depth was significantly higher in zero tillage (40 g/g), followed by ridge (30 g/g) and mound (24 g/g) but the reverse was the case with soil temperature where mound tillage (34.2°C) had the highest temperature followed by ridge (31.4°C) and zero (29.5°C). Mulching also significantly influenced the soil microclimatic condition. While soil moisture enhanced yam emergence, soil temperatures favoured the growth, leaf area accumulation and yield. Mound tillage significantly gave the highest yam tuber yield (12.0 t/ha^{-1}), followed by ridge (8.8 t/ha^{-1}) and zero (5.0 t/ha^{-1}). Partially mulched treatment significantly produced the highest yam tubers (10.3 t/ha^{-1}), followed by the unmulched (8.1 t/ha^{-1}) and mulched (7.4 t/ha^{-1}) treatments. The best practice recommended for the production of ware yams is mound tillage that is partially mulched. This recommended practice yielded more than the local practice by 44.6%.

Key words: Tillage systems, yellow yam, Midwestern Nigeria, soil microclimate, mulching, yam yield.

INTRODUCTION

Yam (*Dioscorea cayenensis*) is second to cassava as the most important and cultivated tropical root crop. It is widely cultivated in Nigeria, and because of its multi-purpose uses, it occupies a principal place in farming system of the humid tropical region. While Africa alone represents 90% of the world production of yams, Nigeria accounts for over 70% of the world production (Vernier and Dansi, 2000; Okoh, 2004). Yam production in Nigeria is entirely dominated by small-scale farmers (Baimey, 2006). The production of this crop like every other crop is affected by factors varying from physical, economic to cultural (Obiokoro, 2005). Climate, one of the physical factors, is the most crucial factor, which determines the nature of the natural vegetation, the characteristics of the soils, the crops that can be grown, and the type of farming that can be practised in any region (Obiokoro, 2005).

The most important climatic elements for crop growth and yield are radiant energy, or solar radiation, temperature and water or rainfall (Ekaputa, 2004). Solar radiation in turn determines the thermal characteristics of the environment, namely net radiation, day-length or photoperiod, the air and soil temperatures (Danjuma, 2004). Soil and air temperatures affect the developmental stages more than any other factor (Ayoade, 2002). Of the two, soil temperature is a better indicator of energy condition required for crop development and yield than air temperature (Song, 2003). Temperature and wind determine the state of soil moisture, and the rate of evaporation (Okpemuoghor, 2005). In order to determine the optimum microclimatic condition for crops' growth and yield, various soil surface modification systems such as mulching and tillage are used.

Zero and mound tillage are the commonest planting traditional systems among the indigenous yam growers in Nigeria, while the ridge tillage is restricted to research institutions (Ihebinike, 2000). While the mound tillage is widely practised in the Middle belt and Eastern Nigeria, the zero tillage is very common among indigenous yam growers of the Midwestern Nigeria and both methods are applied in Western Nigeria (Kutugi, 2002; Eborge, 2002; Odjugo, 2003; Obiokoro, 2005). Kutugi (2002) observed that majority of traditional yam growers in the Middle belt of Nigeria are culturally tied to the use of mound tillage and they rejected the use of ridge tillage seeing it as non-cultural and a waste of time. Ihebinike (2000) and Obiokoro (2005) attributed the use of mound tillage in Eastern and Western Nigeria to factors that ranges from culture to erosion problems, rocky and rugged topography of the areas. In Midwestern Nigeria, where this study was carried out, Eborge (2002) and Odjugo (2003) showed that zero tillage is employed by between 85 and 90% of the local yam farmers in yam production. While between 10 and 15% use mound tillage, none applied the ridge tillage system. Akpoyovwire (2005) confirmed the above finding and attributed it to the relatively flat terrain of the region with well-developed deep red-yellow ferralsols.

The traditional yam planting techniques and materials were reported to be the same in different parts of Nigeria, although each region applies varied tillage types. Eborge (2002) reported that 100% of traditional yam farmers in Midwestern Nigeria used the slanting method in planting their yams, while none of the respondents agreed to have used either the vertical or horizontal method. These methods he said are used for cassava planting. Kutugi (2002) and Obiokoro 2005 reported similar findings in the Middle belt and Western Nigeria respectively, but both researchers used oblique method rather than slanting method. Seed yams and yam setts are the common planting materials in the study area. Although Obiokoro (2002) reported significantly better emergence rate in seed yams, Akpoyovwire (2005) showed that the choice of planting materials by traditional yam farmers depends on the planting materials that is available and affordable to them.

Many researchers have studied the effects of soil microclimatic modification systems on crops growth and yield. Various techniques used by traditional farmers in modifying the on-farm microclimate and the efficiency of such techniques in West Africa have been studied and reported (Maduakor et al, 1984; Kutugi, 2002; Madu, 2003; Okoh, 2004; Inyang, 2005; Gbadebor, 2006). Maduakor et al. (1984), Okoh (2004) and Inyang (2005) reported that majority of the traditional yam farmers in Nigeria, Cameroon, Togo and Ghana use different types of mulch materials which range from dry grass, palm fronds to wood shaving. While Okoh (2004) showed that mulch materials improve the soil condition for well-developed roots, Halugalle et al. (1985), Halugalle et al. (1990), Inyang (2005) and Gbadebor (2006) revealed that mulch materials improve soil physico-chemical properties, suppress soil temperature, reduce evaporation and increase the soil moisture, thereby creating enabling soil microclimatic condition for early sprouting of yams. Madu (2003) showed that most traditional farmers in West Africa normally remove mulch materials during the tuber formation stage of yam. During personal interviews with the farmers, some revealed that if the mulch materials are not removed during the tuber formation stage, the soil will be cold and the tuber will not penetrate downward. The effect of the non-removal of the mulched materials at that stage is that long, big, economic or ware yams will not be produced, rather short tubers with greater circumferences that are not so economically viable will be produced. Kutugi (2002) showed that traditional use of mound tillage like the conventional ridge tillage improve the soil aeration and hydrothermal conditions for crops' emergence, root development, crops' growth and yield.

Based on tillage systems, some researchers have worked on the impact of mound and zero tillage on soil water holding capacity and observed that soil moisture content at all depths is significantly higher in zero tillage (Avwunudiogba, 2000; Oamen, 2004). Tisdall and Hodgson (1990), Danjuma (2004) and Agbede (2006), investigated the variation in the yield of root crops planted in ridge and zero tillage and showed that yield in the conventional tillage system is significantly better than the traditional zero tillage. Erhabor (2002) made comparative analysis between yams grown in mound and ridge tillage systems and concluded that on both technical and economic grounds, ridge tillage produced more yam tubers than the mound tillage.

It is obvious from the above analyses that much researches have been carried out in the areas of tillage systems and mulching, but none has compared a complex mixture of ridge, mound and zero tillage systems and mulching and related them to the soil microclimatic conditions as they affect the yield of yellow yam using purely ethnoscientific approach especially in Midwestern Nigeria. Moreover, the traditional yam farmers in the study area mainly employ the zero tillage system with mulching, in planting their yams. While mound tillage is scarcely used by the traditional farmers, ridge tillage is never practised in yam production (Eborge, 2002; Odjugo, 2003). Is the popular zero tillage with mulching among the traditional farmers the best practice for optimising yield? The best tillage system for maximum yield of yam tubers in the study area requires scientific investigation. It is on this premise that the study was designed to analyse the effects of tillage systems and mulching on soil microclimatic conditions, growth and yield of yellow yam in Midwestern Nigeria. Specifically, the objectives were to compare the microclimatic conditions induced by the various tillage systems and mulching, and analyse the impact of these microclimatic conditions on the growth and yield of yellow yam.

MATERIALS AND METHODS

The experimental site was situated at Agbor (60 07'N and 60 11'E) in Delta State, Nigeria. The climate of the study area exhibits the characteristics of a subequatorial climate with an annual mean air temperature of 27°C. The rainfall pattern is that of double peaks or maximal with mean annual rainfall of 2,255 mm. While the mean annual relative humidity is 81%, the sunshine is 5.6 h/day and the soil type is red-yellow ferralsols (Areola, 1982; Avwunudiogba, 2000).

There are three broad approaches to crop weather investigation namely; the physiological approach, the statistical or correlative approach and the simulations approach (Voortman, 1997; Ayoade, 2002). Since there were no available secondary data on yield of yam in the study area, the physiological approach was employed in this study to generate the needed data. To do this, an experimental site that measured 35 x 47 m was established at the College of Education Agbor, Delta State, Nigeria. The planting activity took place for two planting seasons 1997/1998 and 1998/1999. The experiment was a randomised complete block. The farm was divided into 8 replicates and each replicate contained 6 plots. Each plot occupied 5 x 5 m space while each replicate had 5 x 35 m with 1 m inter-replicate spacing. The treatments were ridge (mulched and unmulched), mound (mulched and unmulched) and zero (mulched and unmulched). The common practice by majority of the traditional yam farmers in the study area is zero tillage with mulching. The zero tillage system and mulching therefore constitute the control treatment group.

The mounds, ridges and zero tillage were dug manually using the spade and the giant African hoe. The zero tillage was 0.5 m below the earth surface while the ridge and mound tillage were 0.5 m high. To maintain the height of the mounds and the ridges, soils were dug from the furrows of the ridges and heaped on the ridges while soils in-between mounds were used on the mounds once every month. Planting took place on the 19th March, 1997 and 16th April, 1998 for the first and second planting seasons, respectively. On each plot, 10 yam setts were planted, 60 setts in each replicate and in all, 480 setts of yams were planted. The yellow yam locally called Okwelurefu was planted. In the study area, yellow yam is also called red yam. The selection of this variety of yam among the numerous varieties available locally was because it is one of the most valued and widely planted by the local farmers.

Immediately after planting, mulching of appropriate plots followed. Out of the total 48 plots, 32 plots were mulched and 16 unmulched. At the beginning of the tuber formation stage, that is 18 weeks after planting (WAP), mulch materials were removed from 16 out of the 32 plots that were initially mulched. These plots were called partially mulched treatment. This is to assess the claims of some traditional farmers that if the mulch materials are not removed during the tuber formation stage, ware yams will not be produced. No standardised planting distance between and within crops was maintained because the study is purely indigenous. An attempt to standardise the distance would have meant a deviation from the purely traditional practice this study investigated. The local farmers would not also benefit from the results and recommendations of such standardization because, they according to Ugboh (2002), refuse to operate the equidistant planting technique seeing it as non-cultural and a waste of time. After planting, the distances between and within the treatments were measured and they ranged from 136-148 cm apart.

Because of the ethnoscientific nature of the work, no organic or inorganic fertiliser, nematicide, insecticide, fungicide or herbicide was applied. All noticeable pests such as termites and spittlebugs were controlled using traditionally prepared solution from the neem tree as practised by most traditional farmers, owing to the high cost of insecticides, which is far beyond the reach of most farmers. One yam in each of the treatments was randomly sampled for measurement on four dates that correspond with the four phasic stages of yam namely the root (0-6 WAP), the vine (6-10 WAP), leaves (10-18 WAP) and tuber formation (18-24 WAP) (Onwueme and Sinha, 1999). The growth and developmental parameters were monitored from 1 month after planting (MAP) to 8 MAP. The microclimatic parameters monitored include air temperature, relative humidity and soil temperature at 10, 20, 30 and 50 cm depth. While hygrometers were used to measure the relative humidity, the soil temperatures were measured with soil thermometers. The air temperature was measured using thermographs. The soil moisture between 0-60 cm depth (at 15 cm incremental depth) was determined gravimetrically. The field measurements were taken by 0700 and 1600 GMT

The physiological parameters measured include emergence rate, which was counted daily. The growth rate was measured weekly till 12 WAP using the thread and metre rule. The leaf area index (LAI) was computed monthly using the method described by Nuhu (2005), and yield was measured at the end of each day's harvest using weighing scale. SYSTAT statistical software was used for all the statistical analyses (SPSS, 1997). Correlation, chi-square, ANOVA, least square range (LSR) test and stepwise regression analysis were the statistical tools employed in analysing the data. The strength of relationship between the climatic variables, growth and yield was determined using the correlation while the climatic variable(s) that mostly predict the yield was determined by the stepwise regression analysis. The ANOVA and chi-square were employed to verify whether the differences among the treatments were statistically significant or not.

RESULTS AND DISCUSSION

Soil and hydrothermal characteristics

The moisture content variation among the tillage systems was highest and statistically significant ($p < 0.05$) only at the depth of 0-15 cm. From there, the soil moisture content decreased with increasing depth. At 0-15 cm, soil moisture content ranged from 18-33 g/g in mound, 19-38 g/g in ridge and 23-44 g/g in zero tillage (Figure 1). Mound tillage with a mean of 24 g/g had the lowest soil moisture content followed by ridge (30 g/g) and zero (40 g/g). The computed F-value of 7.26 is higher than the critical value of 3.98 indicating a significant difference in soil moisture content among the tillage types at $p < 0.05$.

At all depths, soil moisture content was higher in the

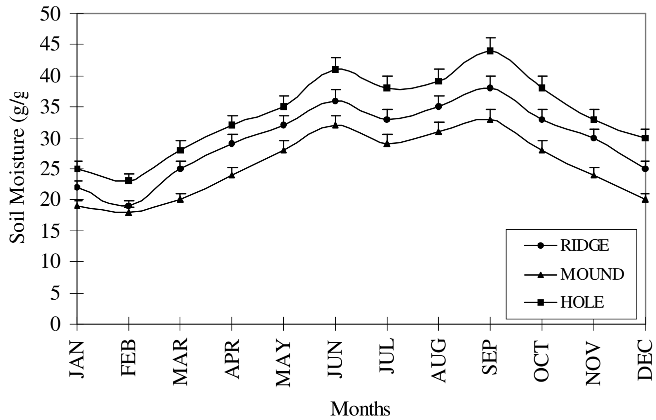

Figure 1. Tillage and soil moisture variation (0-15 cm).

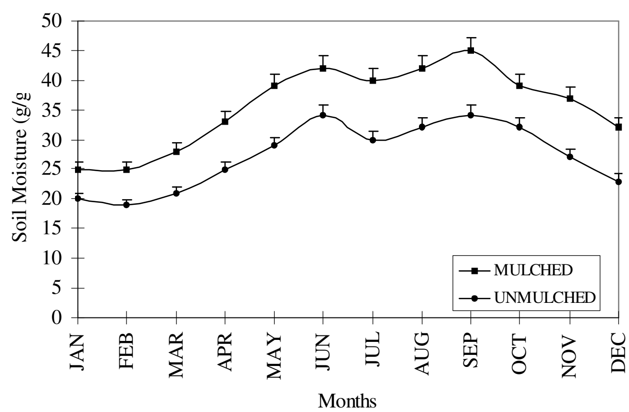

Figure 2. Mulch and soil moisture variation (0-15 cm).

mulched than in the unmulched treatments. At 0-15 cm depth, mulched treatment had a soil moisture mean of 38 g/g (Figure 2), which was significantly ($\chi 2 = 22.66$) higher than unmulched (25 g/g) at $p < 0.05$. Mulch therefore improves the soil moisture regime by decreasing losses caused by surface run-off and evaporation and increases the infiltration capacity during rainfall. This agrees with earlier works in Nigeria (Halugalle et al., 1990; Olasantan, 1999).

Soil moisture was lowest in the month of February and highest in the month of September in all the treatments (tillage and mulch) (Figures 1 and 2). Within the study period, the effect of the dry hot tropical continental wind locally called harmattan was most severe in the month of February. This encouraged much evaporation and dryness of the soil. On the other hand, soil moisture was highest in the month of September, which had the heaviest rainfall that encouraged infiltration

The effect of the tillage systems (ridge, mound and zero) on soil temperature at different depths shows that at all depths (0-50 cm), soil temperature was highest in

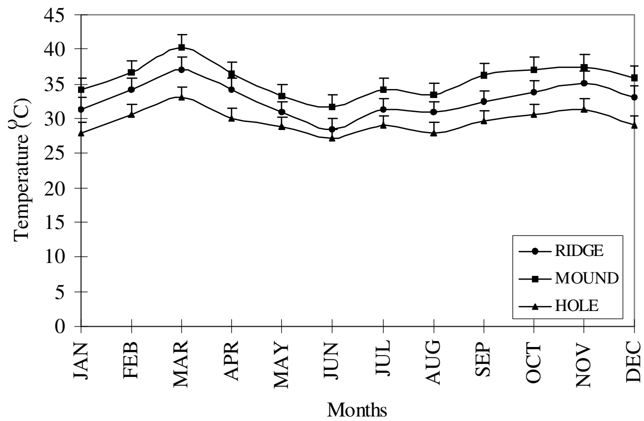

Figure 3. Tillage and soil temperature variation (0-10 cm).

mound followed by ridge and zero. However, the difference in soil temperature among the tillage types is only statistically significant from 0-10 cm depth. At this depth, soil temperature ranged from 31.8 to 40.2°C in mound, 28.5-36.5°C in ridge and 27.1-33.0°C in zero tillage (Figure 3). The mean mound tillage soil temperature (34.2°C) was found to be higher than that of ridge (31.4°C) by 2.8°C and zero tillage (29.5°C) by 4.7°C. Since the ridge and mound were tilled, their bulk density was reduced and this enhanced their pore spaces. This condition must have increased the amount of heat that penetrated them, while the zero tillage treatment reduced heat penetration thus experiencing a lower temperature. Similar result was reported whereby ridge had higher soil temperature than zero tillage (Danjuma, 2004) while others showed that mound had higher soil temperature than ridge (Erhabor, 2002; Adeoye, 2005). The F-value of 11.22 shows that the differences in soil temperature among the tillage types were statistically significant at $p < 0.05$.

The impact of mulch on soil temperatures at 0-10 cm depth reveals that unmulched plots (31.8-39.6°C) exhibited a higher temperature than mulched plots (27.2 - 34.9°C) (Figure 4). While mulch had a mean soil temperature of 29.5°C, that of unmulched was 33.9°C. Mulch suppressed the mean soil temperature by 4.4°C. A difference of 2-7°C between mulched and unmulched plots during the early planting season was observed in Western Nigeria (Olasantan, 1999). The observed difference of $\chi 2 = 6.11$ is more than the critical value of 3.84. This implies that the difference in soil temperature among the mulch types is statistically significant at $p < 0.05$. While soil temperature is supra-optimum in the months of February (36.5°C), March (39.40°C), April (35.8°C) and November (35.6°C) at 10 cm depth in unmulched plots, such condition was only experienced at the peak of the heat wave in March (35.6°C) for mulched plots. Even at 20 cm depths supra-optimum temperature conditions

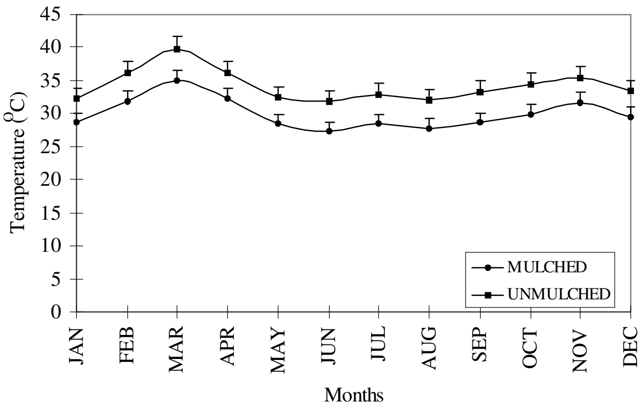

Figure 4. Mulch and soil temperature variation (0-10 cm).

were noticed in unmulched treatments in the months of March (36.1°C) and April (35.4°C). This is in agreement with earlier findings, which observed supra-optimal soil temperature in unmulched treatment in the middle belt of Nigeria (Song, 2003).

Crop emergence rate, growth and leaf area accumulation

The effects of tillage systems on the emergence of yam shows that percentage emergence rate was highest in zero tillage (98.61%), followed by ridge (93.62%) and mound (92.21%) at 6 WAP. Earlier, this pattern in emergence was noticed in soil moisture content (Figure 1). The correlation is not surprising owing to the importance of soil moisture in yam sprouting or emergence. This is further supported by highly significant ($p < 0.01$) and positive correlation between soil moisture at all depths and yam emergence, while significantly negative correlation existed between temperature and emergence of yam (Table 1). The delay in sprouting of yams must have resulted in rot of some yam setts while others sprouted with so many tiny vines especially those of mound tillage. This result strongly agrees with earlier works, which reported that zero tillage had higher emergence rate than mound (Oamen, 2004).

The importance of moisture in yam emergence is further buttressed by the results of mulched and unmulched treatments. It follows that mulched yams (99.12%) had a higher emergence rate than unmulched (90.50%) treatments. In Western Nigeria, emergence and growth rate of yam seedlings were observed to be significantly higher in mulched plots than in the unmulched treatments (Olasantan, 1999). The high rate of emergence associated with mulched treatment must be the basic reason why some traditional farmers in the study area usually mulch their yams immediately after planting.

The growth pattern of yam among the tillage systems shows that mound (545 cm) conspicuously exhibited faster growth rate followed by ridge (462 cm) and zero tillage (396 cm) at 12 WAP. Mulched treatment (527 cm) had a better growth rate than the unmulched (408 cm) at 12 WAP. This result is in line with earlier work, which revealed that mulching increased the height and leaf area accumulation of yam (Madu, 2003). Although, soil moisture appeared the dominant factor in yam emergence, the growth rate took almost a different pattern. Mound tillage with lower soil moisture and higher soil temperature had the fastest growth rate. As shown in Table 1, there is a significant ($p < 0.01$) and positive correlation between the growth of yam and soil temperature at the depths of 10 cm ($r = 0.741$) and 20 cm ($r = 0.462$), while soil moisture at all depths had negative correlation though, not statistically significant.

At the peak of leaf area accumulation, that is, 6 months after planting (MAP), mound tillage (7.3) exhibited the highest LAI, followed by ridge tillage (6.0) and zero tillage (4.8) (Figure 5). This shows that leaf accumulation in mound was higher than that of ridge and zero tillage by 15 and 34%, respectively.

Mulched treatment had higher leaf area accumulation throughout the study period than unnmulched treatment (Figure 6). While the leaf area accumulation was 7.8 at 6 MAP in mulched treatment, it was 4.3 in unmulched plots. Similar finding showed that leaf area accumulation was significantly lower in unmulched than in the mulched plots (Song, 2003). Leaf area accumulation was highly significant ($p < 0.01$) and positively correlated with soil temperature at 10 cm ($r = 0.882$) and 20 cm ($r = 0.861$) depth, but negatively and significantly ($p < 0.05$) correlated with soil moisture at 15-30 cm ($r= -0.611$) and 30-45 cm ($r = -0.496$) (Table 1).

Yam tuber yield

Zero tillage (445) produced more number of tubers followed by ridge tillage (340) and mound (320). Moreover, mulched treatment (396) recorded higher number of tubers followed by partially mulched (382) and the least was unmulched treatment (327).

Although the number of tubers harvested per plot counts in yield evaluation, the best parameter as earlier noted is the weight of the tubers since it is directly related to the size of the tuber and the cost of any yam tuber is determined more by its size, length and weight (Eborge, 2002; Oamen, 2004). For this reason, the tubers were weighed and the result showed that mound tillage which weighed (12.0 t ha^{-1}), ranked first followed by ridge (8.8 t ha^{-1}) and zero (5.0 t ha^{-1}) tillage system (Figure 7). The total yield reduction in zero tillage may in part be related to physical soil impendence as also noticed earlier by (Kang and Wilson, 1986; Walter, 2004; Agbede, 2006).

Table 1. Impact of climatic variables on yam emergence, growth, LAI and yield.

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	E	G	L	Y
X1	1.0													
X2	.625**	1.0												
X3	.567**	.738**	1.0											
X4	.501**	.567**	.740**	1.0										
X5	-.694**	-.664**	-.776**	-.738**	1.0									
X6	-.204	-.252*	-.284*	-.209	-.177	1.0								
X7	-.643**	-.688**	-.787**	-.772**	.904**	.174	1.0							
X8	-.106	-.383*	-.168	-.205	.345*	-.125	.238*	1.0						
X9	-.098	-.045	-.177	-.108	.067	-.197	.042	-.105	1.0					
X10	-.071	-.017	.098	-.147	.142	.072	.133	-.068	-.371*	1.0				
E	-.572**	-.561**	-.509**	-.567**	.721**	.605**	.521**	.321*	-.238	.112	1.0			
G	.741**	.463**	.401**	.252*	-.244	-.200	-.202	.393**	-.214	.222	-.115	1.0		
L	.882**	.861**	.490**	.164	-.105	-.611*	-.496*	-.104	.063	.092	.192	.649**	1.0	
Y	.860**	.741**	.510*	.370*	-.662**	-.604	-.598**	.289*	-.120	.114	-.311*	.510**	.633**	1.0

**Significant at $p < 0.01$; Significant at $p < 0.05$.
X1= Soil temperature (10 cm), X2 = soil temperature (20 cm), X3 = soil temperature (30 cm), X4 = soil temperature (50 cm), X5 = soil moisture (0-15 cm), X6 = soil moisture (15-30 cm), X7= soil moisture (30-45 cm), X8 = maximum temperature, X9 = minimum temperature, X10 = relative humidity, E = yam emergence, G = yam growth, L = yam LAI, and Y = yam yield.

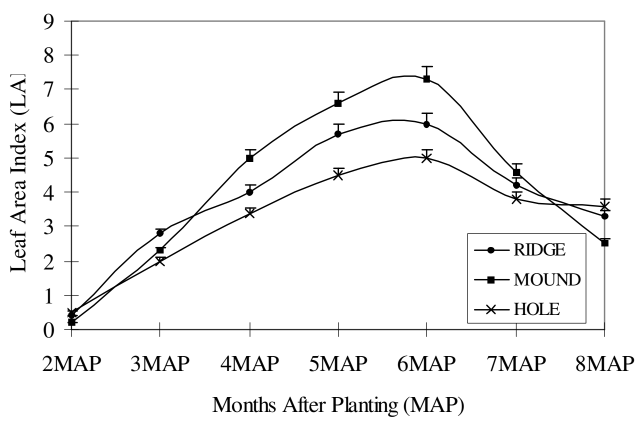

Figure 5. Tillage and yam leaf area index variation.

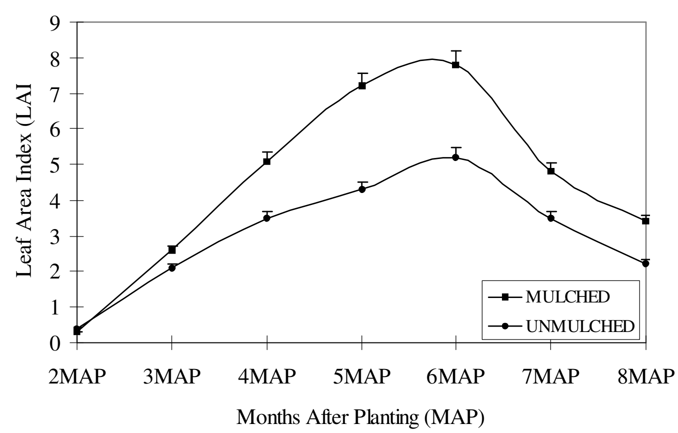

Figure 6. Mulch and yam leaf area index.

The computed F value of 29.5 is more than the critical value of 19.0 indicating a statistical significance at $p < 0.05$. Mound tillage with a smaller number but bigger and heavier tubers recorded the highest weight while zero tillage with more number but smaller and lighter tubers recorded the least. This result agrees with the previous finding of Erhabor (2002), which observed better yield from ridges when compared with flat (zero) tillage and those of Eborge (2002) and Agbede (2006) that noticed significantly higher yield in mound tillage than in ridge, but in complete disagreement with the work of Walker (2004), which showed that yams grown on ridge produced more than those on mound tillage. Applying the LSR test shows that at 5%, the mound tillage yield is statistically different from ridge (3.8) and zero (6.02).

Partially mulched (10.3 t ha^{-1}) had the highest tuber yield followed by unmulched (8.1 t ha^{-1}) and mulched treatment (7.4 t ha^{-1}) (Figure 8). The observed difference ($F = 21.33$) is statistically significant at $p < 0.05$ because it is higher than the critical value of 19.0. The higher yield in partially mulched treatment is as a result of better soil microclimatic management. The mulch must have improved the soil condition for well-developed roots than unmulched treatments (Okoh, 2004). The removal of the mulch during the tuber formation stage increased the soil temperature, a condition needed for the development of long and big tubers (Madu, 2003). This improved thermal condition during the tuber stage resulted to higher yield

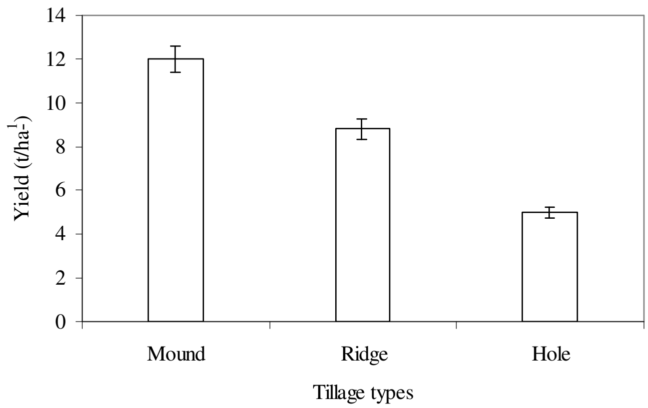

Figure 7. Tillage and tuber yam yield.

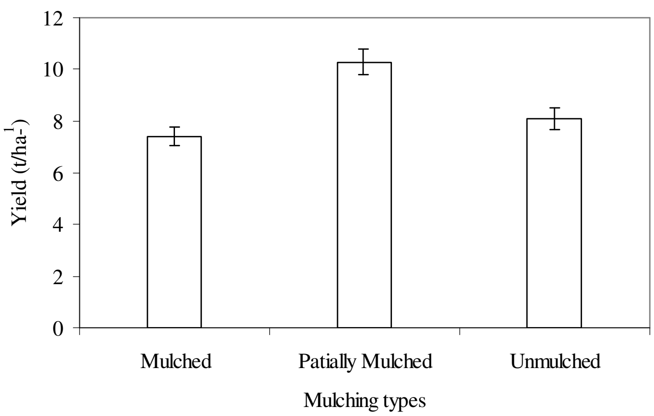

Figure 8. Mulch types and yam tuber yield.

than the mulched treatment, which suppressed the temperature. This is in contrast with the results of Maduakor et al. (1984) and Halugalle et al. (1985), which ascertained that higher yam tuber yield is associated with mulched than unmulched treatment.

The mean yield for this study is 8.6 t ha^{-1}, which is lower than the 9.4-14 t ha^{-1} recorded in Haiti and Ghana by Sergio (2001) and Adamasi (2006). It is also lower than the 10.7 t ha^{-1} of Nigeria's and 9.2 t ha^{-1} of World's average yield (Song, 2003; Onwueme and Sinha, 1999). The lower yield observed in this study could be attributed to the fact that fertilizers were not used, while the studies with higher yield cited above applied fertilizers.

Soil temperatures at all depths were positively and significantly correlated with the yield of yam at $p < 0.01$ except at 50 cm ($r = 0.370$) where it was significant at $p < 0.05$ (Table 1). A significantly negative relationship ($p < 0.05$) was observed between soil moisture, minimum air temperature and yield at all depths. This is a clear indication that high soil moisture content during the tuber formation stage of yam is detrimental to economic tuber

Table 2. Regression between climatic/growth variables and yam yield.

Model	R (Correlation coefficient)	R^2 (Level of explanation)
1	0.860[a]	0.712
2	0.894[b]	0.751
3	0.922[c]	0.810

a: Soil temperature at 10 cm depth.
b: a + soil temperature at 20 cm depth.
c: a + b + leaf area.

yield because it suppresses the soil temperature that enhances the yield. This finding is in line with previous research, which revealed that soil temperature highly correlates with the yield of yam Ekaputa (2004), while high soil moisture content favours leaf area accumulation of yam but reduces its yield considerably (Eborge, 2002).

Combining the climatic and growth variables, the yield of yellow yam was enhanced more by soil temperatures (10 and 20 cm depth) and leaf area accumulation. As shown in Table 2, the best explanatory variable in the regression model is soil temperature at 10 cm depth, which had a correlation coefficient of $r = 0.860$ and explained 71% of the variables. Other variables that entered the regression model were soil temperature at 20 cm depth and leaf area accumulation. All the three variables have correlation coefficient of $r = 0.922$ and explained 81% of all the variables affecting the yield of yellow yam (Table 2).

Attempt was also made to compare the outcome of the best yield of this study with the common practice in the study area. The common practice by majority of the farmers - which is the control treatment combination - in the study area is zero tillage (5.0 t ha^{-1}) and mulching (7.4 t ha^{-1}). This gives an average yield of (6.2 t ha^{-1}). However, for ware yam tuber production, the best practice as revealed by this study is planting the yam using mound tillage (12.0 t ha^{-1}), and partially mulched (10.3 t ha^{-1}); this gives a mean yield of 11.2 t ha^{-1}. The yield of the best treatments in this study is higher than the common traditional practice by 44.6%.

Conclusion

The results of this study reveal that soil moisture at 0-15 cm depth is significantly higher in zero tillage followed by ridge and mound. Mulched treatment has significantly higher soil moisture than unmulched. Soil temperature at 0-10 cm in mound is significantly higher than ridge and zero tillage. Mulched treatment has significantly lower soil temperature than unmulched.

These identified induced soil microclimatic conditions were reflected not only in yam emergence, but also in growth and yield. Treatments with higher soil moisture but lower soil temperature such as zero tillage and mulched treatment has the best emergence rate. On the other hand, treatments with higher soil temperature such as mound tillage and partially mulched treatment favour the yield of yam tubers. This is also supported by the high, positive and significant correlation between soil temperature (r = 0.860) at 10 cm depth and yam tuber yield. This gave a regression coefficient of r^2 = 0.712 thus explaining 71% of yam tuber yield.

Yellow yam tuber yield was observed to be significantly higher in mound tillage (12.0 t ha^{-1}) followed by ridge (8.8 t ha^{-1}) and zero (5.0 t ha^{-1}). Partially mulched treatment (10.3 t ha^{-1}) significantly produced more tubers than the unmulched (8.1 t ha^{-1}) and mulched treatment (7.4 t ha^{-1}).

The common practice by majority of the farmers in the study area is zero tillage and mulching. However, this study reveals a better practice, which can be recommended to the farmers and when employed will increase the farmers' output by at least 44.6%. For ware yam tubers production, the best practice, which can be recommended to yam farmers in the humid tropics, is for them to plant their yam using mound tillage with partial mulching.

REFERENCES

Adamasi CJ (2006). A comparative analysis of the yield of three yam cultivars (white, yellow and water) in Southern Ghana. J. Agric. Dev. 10(1): 78-86.

Adeoye CA (2005). Quantitative analysis of microclimate modification systems near the soil surface. J. Trop. Clim. 5(2): 34-44.

Agbede TM (2006). Effects of tillage on soil properties and yam yield on an alfisol in Southern Nigeria. Soil Tillage Res. 8(1): 1-8.

Akpoyovwire AS (2005). Effects of terrain and culture on the choice of tillage types and production of root crops in Nigeria. J. Agric. Ext. 4(1): 65-84.

Areola (1982). Soils. In Barbour KM, Oguntoyibo JS, Onyemelukwe JO, Nwafor JC. Nigeria in Maps. London: Hodder and Stoughton. pp. 22-23.

Avwunudiogba A (2000). A comparative analysis of soil and nutrient losses on maize plant with different tillage practices in the Ikpoba river basin of south-western Nigeria. Niger. Geogr. J. New Series 3(4): 199-208.

Ayoade JC (2002). Agroclimatology. Ibadan.: Vantage Publishers. p. 129-137.

Baimey HK (2006). Scutellenema bradys as a pathogen of yam in Benin. Ph.D thesis submitted to the Faculty of Natural and Agricultural Science, University of Pretoria, Pretoria, South Africa.

Danjuma BO (2004). Comparison of soil physico-chemical characteristics of different tillage types in North-eastern Nigeria. J. Agric. Environ. 2(1): 1-16.

Eborge EOD (2002). Comparative analysis of the growth and yield of yams under mound and ridge tillage. J. Agric. Dev. 6(2): 54-66.

Ekaputa UN (2004). Agricultural systems. Port Harcourt: UNIK Publishers. pp. 126-134.

Erhabor EA (2002). The effect of tillage types on the yield of two yam varieties. Trop. J. Root Tuber Crops 2(1): 65-71.

Gbadebor PV (2006). The climate, the soils and the West African traditional farmers. AgroEcosystem Bull. 4: 12-17.

Halugalle NR, Lal R, Opara-Nadi OA (1985). Effects of tillage system and mulch on soil properties and growth of yam (*Dioscorea rotundata*) and cocoyam (*Xamthosoma sigillifolium*) on an ultisol. J. Root Crops 11(1-2): 9-22.

Halugalle NR, Lal R, Gichuru M (1990). Effects of five years of no tillage and mulch on soil properties and cassava tuber yield on an acid ultisol in South-eastern Nigeria. Exp. Agric. 21: 235-240.

Ihebinike CRN (2000). The impact of traditional tillage types and practices on the yield of White, yellow and water yams in Eastern Nigeria. Agric. Rev. 1(1): 44-52.

Inyang EU (2005). An evaluation of tillage and storage systems applied by traditional root crop farmers in Cameroon. Agric. Envron. J. 7(2): 15-22.

Kang BT, Wilson JE (1986). Effects of mound size and fertilizers on White Guinea Yam (*Dioscorea rotundata*) in Southern Nigeria. Plant Soil. 61(3): 318-327.

Kutugi AD (2002). Comparative analysis between indigenous and modern tillage practices in the production of *Dioscorea rotundata* and *Dioscorea cayenensis* in the Middle Belt of Nigeria. J. Agric. Environ. 2(1): 53-66.

Madu CPA (2003). Effects of mulching types on the general performance of yellow yam (*Dioscorea cayenensis*) in Eastern Nigeria. J. Agric. Ext. 2(1): 123-131.

Maduakor HO, Lal R, Opara-Nadi OA (1984). Effects of methods of seedbed preparation and mulch on the growth and yield of white yam (Dioscorea rotundata) on an ultisol in south-east Nigeria. Field Crops Res. 9: 119-130.

Mathias-Mundy E, Muchena O, Mckiernan G, Mundy P (1992). Indigenous technical knowledge of private tree management: A bibliographic report. Bibl. Tech. Soc. Change, No. 7.

Nuhu SD (2005). Soil science and management. Lagos: Sunsax Publications. p. 44-47.

Oamen DE (2004). The Influence of Tillage types on the yield of inter–cropped melon and Yam. AgroDev. Envron. Protect. Monograph. 8: 5-8.

Obiokoro OG (2005). Agrometeorology. Onitsha: Dunkwu Publishers. pp. 24-30.

Odjugo PAO (2003). An analysis of the effectiveness of traditional techniques of on-farm microclimate improvement in Midwestern Nigeria. Ph. D. thesis submitted to the Department of Geography, Faculty of Science, University of Ibadan, Ibadan, Nigeria.

Okoh CA (2004). The effect of mulching on soil physico-chemical properties and the yield of White Yam. Trop. J. Root Tuber Crops 4(2): 24-31.

Okpemuoghor ER (2005). Physical Environment. Lagos: Dosumu Press, pp. 152-176.

Olasantan FO (1999). Effects of time of mulching on soil temperature and moisture regime and emergence, growth and yield of white yam in Western Nigeria. Soil Tillage Res. 50(3-4): 215-226.

Onwueme IC, Sinha TD (1999). Field crop production in tropical Africa. Wageningen: CTA Publications. p. 250-266.

Sergio T (2001). Preliminary dignosistic of Haiti yellow yam (*D. Cayenensis*) and Malaya (*Xanthosoma* spp) cropping system. Series TS-04. Haiti Dev. Alt. Inc. pp. 1-13.

Song AB (2003). The impact of modified physical environment on the yield of yellow and water yams in the middle belt of Nigeria. J. Agric. Envron. 1(2): 14-22.

SPSS (1997). SYSTAT for windows, release 7.0.1 standard version. Chicago: SPSS Inc.

Tisdall JM, Hodgson AS (1990). Ridge Tillage in Australia: A Review. Soil Tillage Res. 18(2-3): 127-141.

Ugboh JA (2002). Perception of local farmers in Nigeria to modern agricultural practices. Agric. Rev. 3(2): 67-78.

Vernier P, Dansi P (2000). Participatory assessment and farmers' knowledge on yam varieties (*D. rotunda* and *D. cayenensis*) in Benin. Paper presented at the ISTRC 2000 symposium, Tsukuba, Ibaraki, Japan, Sept. 10-16 2000. pp. 1-17.

Voortman LR (1997). Climatic data analysis and biomass/crop yields potential assessment, FAO/SOW-VU version 1: Concept models and software with examples from Nigeria. Niger. Met. Soc. J. 2(1): 4-10.

Walter WF (2004). The impact of tillage and planting time on the yield of red yam. J. Agric. Environ. 2(1): 53-66.