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Full Length Research Paper

The impact of tillage systems on soil microclimate, growth and yield of cassava (*Manihot utilisima*) in Midwestern Nigeria

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Cassava is the most widely cultivated root crops among traditional farmers in the Midwestern Nigeria. Majority of the traditional farmers employ the zero tillage system. It is unclear if zero tillage is the best practice for optimizing yield? This study investigates the impact of tillage types on soil microclimatic condition, growth and yield of cassava in Midwestern Nigeria. An experimental area that measured 17 by 47 m was established in Agbor, Delta State, Nigeria for two planting seasons 1997/1998 and 1998/1999. 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 correlation, chi-square., ANOVA and stepwise regression analyses 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, followed by ridge and mound. The reverse is true with soil temperature. Ridge tillage (9.6 t ha^{-1}) significantly produced more cassava tubers, followed by mound tillage (7.5 t ha^{-1}) and zero tillage (5.2 t ha^{-1}). The conventional ridge tillage method is recommended because it yielded more than the local practice of the zero tillage by 46%.

Key words: Nigeria, tillage types, microclimate, hydrothermal, ethnoscience, cassava yield.

INTRODUCTION

All agricultural systems are man-made ecosystems that depend on many factors to function like the natural ecosystem (Robinson, 1994). These factors could be biotic or abiotic found within the crop environment. Of the two, Kazim (2003) observes that the most influential in crops growth and yield are the abiotic factors. The abiotic factors comprise the climate and soil. Kerang (2002) indicates that the emergence, growth and yield of cassava are influenced by both biotic and abiotic factors. Woghiren (2004) and Agbogidi (2006) reveal that the emergence and growth of cassava were observed to be higher in ridge than mound tillage. Ujuanbi (2002) and Odumorsor (2003) show that cassava emergence and growth are higher in ridge than zero tillage. Hong et al. (2006) indicate that cassava growth rate is significantly higher in mound tillage than in zero tillage.

Analysing the environmental factors that enhance the yield of cassava, Emetitiri (2004) reveals that climatic factor (rainfall) has the highest and strongest positive correlation with cassava yield, followed by soil. Rabiu and Hong (2002) are of the opinion that soil temperature is the predictor variable, which determines the yield of cassava. It is along this line that Hong et al. (2005) reveals that mound tillage, which has the highest soil temperature, is better for cassava yield than ridge. In contrast Woghiren (2004) and Ageh (2005) observe that cassava yield is better in ridge than mound tillage. In between these, are the findings of Keyamu (1999) and Agbogidi (2006), which indicate that there is no significant difference between cassava yield in ridge and mound tillage.

The Federal Government of Nigeria has been creating awareness on and encouraging Nigerians and foreign farmers to produce cassava in Nigeria, not only for domestic consumption but also for export. Adegbite (2007) reveals that peasant farmers produce 95% of the total cassava in Nigeria. In this study area, the peasant or traditional cassava farmers mainly employ zero tillage system in planting their cassava. While mound tillage is scarcely used, the traditional farmers do not practise the ridge tillage system. Is the popular zero tillage among the traditional farmers the best method for optimum cassava production in the study area? This study investigates the impact of tillage systems (zero, mound, and ridge) on soil microclimate and the yield of cassava in Midwestern Nigeria.

MATERIALS AND METHODS

The experimental site was situated at Agbor (6^0 07'N and 6^0 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 27^0C. The rainfall pattern is that of double peaks or maximal with mean annual rainfall of 2,255 mm. The mean annual relative humidity is 81%, the sunshine is 5.6 h/day and the soil type is red-yellow ferralsols (Areola, 1982 and Avwunudiogba, 2000).

An experimental area that measured 17 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 design. The farm was divided into 8 replicates and each replicate contained 3 plots. Each plot occupied 5 x 5 m space while each replicate had 5 x 47 m with 1 m inter-replicate spacing. The treatments, which were randomly allotted to each plot, were ridge, mound and zero tillage.

The ridges, mounds 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 10/6/97 and 14/6/98 for the first and second planting seasons respectively. In the study area, cassava is planted twice in a year. The early planting takes place between March and April, while late planting occurs between June and July. This study investigated the late planting because majority of earlier researches focussed on early planting (Ossom and Onochie, 1994; Hong et al., 2005 and Agbogidi, 2006), whereas Enomate (2005) shows that the profit margin of cassava planted late (June / July), which matures in the dry season, is significantly higher than the early planting. An improved variety (TMS 30555) locally referred to as `Lagos´ was planted. The selection of this variety of cassava among the numerous varieties available locally was because it is most valued and widely planted by the local farmers. On each plot, 21 cassava stems (20 - 25 cm long) were planted.

Since this study is purely indigenous, no standardised planting distance between and within crops was maintained. 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 70 - 78 cm apart.

Due to the ethnoscientific nature of the study, 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 cassava in each of the treatments was randomly sampled for measurement on three dates that correspond with the root, leave and tuber stage.

The growth and developmental parameters were monitored from 1 month after planting (MAP) to 10 MAP. The microclimatic parameters monitored include air temperature, relative humidity and soil temperature at 10, 20 and 30 cm depth. The depth of 30 cm was chosen because cassava is a relatively deep-rooted crop. The air temperature was measured using thermometers. Hygrometer and soil thermometers were used in measuring relative humidity and soil temperatures respectively. The soil moisture between 0 and 30 cm depth (at 0 - 15 cm incremental depth) was determined gravimetrically. Relative humidity, air and soil temperatures were measured at 0700 and 1600 GMT daily while soil moisture was measured monthly.

The physiological parameters measured comprise the emergence rate, which was counted daily. The growth rate was measured weekly till 10 MAP 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 immediately after 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, time series and stepwise regression analyses 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 observed differences among the treatments were statistically significant or not. The growth rate and leaf area accumulation were analysed using the time series. The difference between the climatic parameters, growth and yield of the two planting seasons were statistically the same so, the mean of the two seasons is presented and analysed.

RESULTS AND DISCUSSION

Soil hydrothermal condition

The effects of the tillage systems (ridge, mound and zero) on soil temperature at the depths of 10 and 20 cm is shown in Figure 1a and b. At both depths, soil temperature was highest in mound followed by ridge and zero. Since the ridge and mound were tilled, their bulk density was reduced and this enhanced their pore spaces. These conditions increased the amount of heat that penetrated them. The ridge with its elongated heat transfer exhibited lower temperature characteristics than the circular heat movement in the mound as also earlier noticed by Okafor (2005). The zero-tillage reduced heat penetration during the day thereby experiencing lower temperature. However at night, heat radiation is also restricted because of its higher bulk density. This resulted in the zero tillage recording a relatively higher soil temperature in the mornings.

At the depth of 0 - 30 cm, almost the same pattern was exhibited by soil moisture content. Soil moisture was

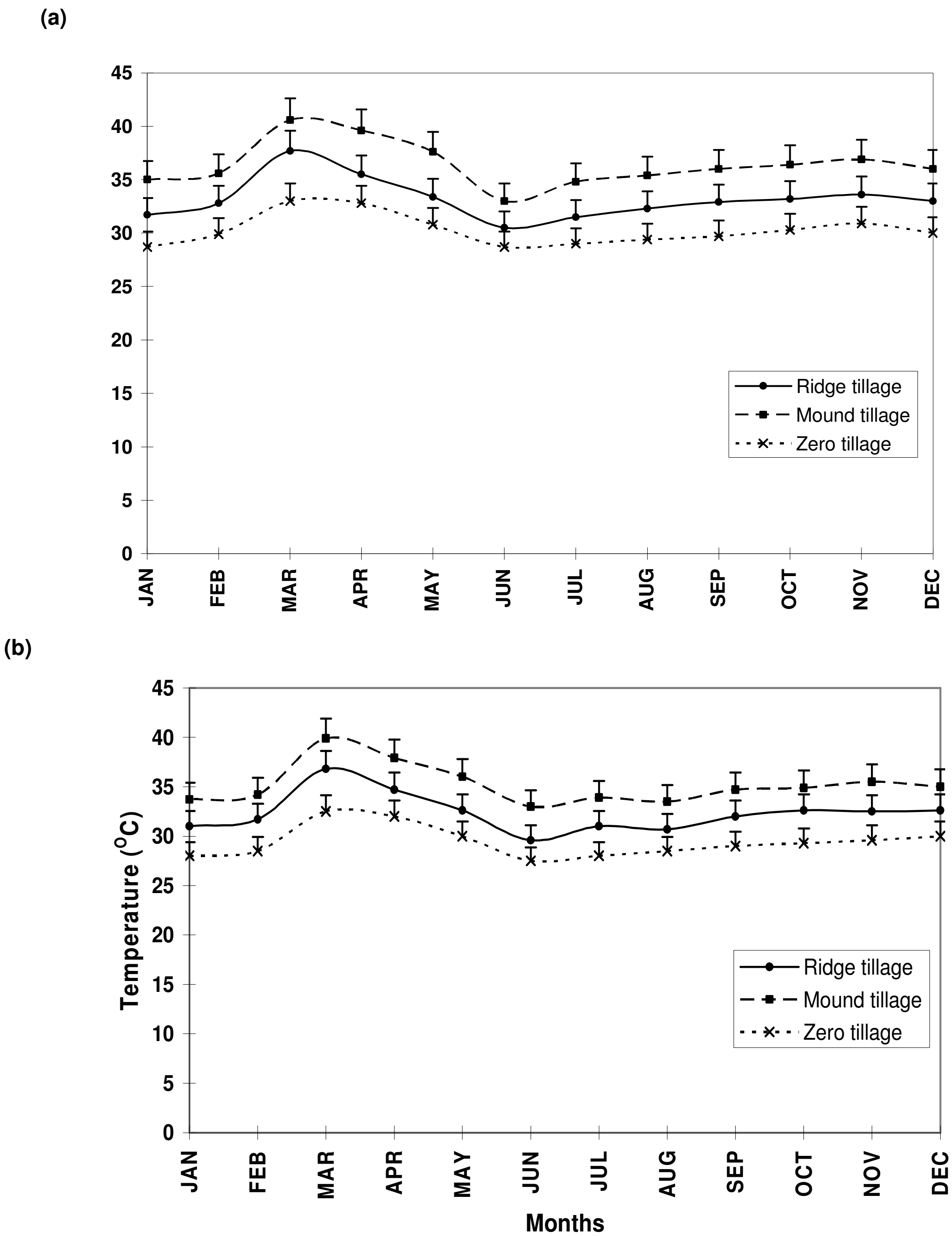

Figure 1. Tillage and soil temperature at (a) 10 cm depth (b) 20 cm depth.

clearly higher in the zero tillage followed by ridge and mound (Figure 2a - b). The moisture content variation among the tillage systems. The trend analysis shows that soil moisture was higher at the depth of 0 - 15 cm than 15 - 30 cm. Surface evaporation enhanced the differences in soil moisture between the tillage systems at the 0 - 15 cm depth, while the more stable soil environmental conditions at the deeper depths (15 - 30 cm) resulted in the reduced variation among the tillage content was lowest in February, during the peak of dry season. From the later part of February, the soil moisture started to increase with the onset of rains. The increasing trend continued until September that had the highest water content. But with the receding rains and the beginning of dry season with its higher temperature that encouraged evaporation (Kerang, 2002), a gradual de-

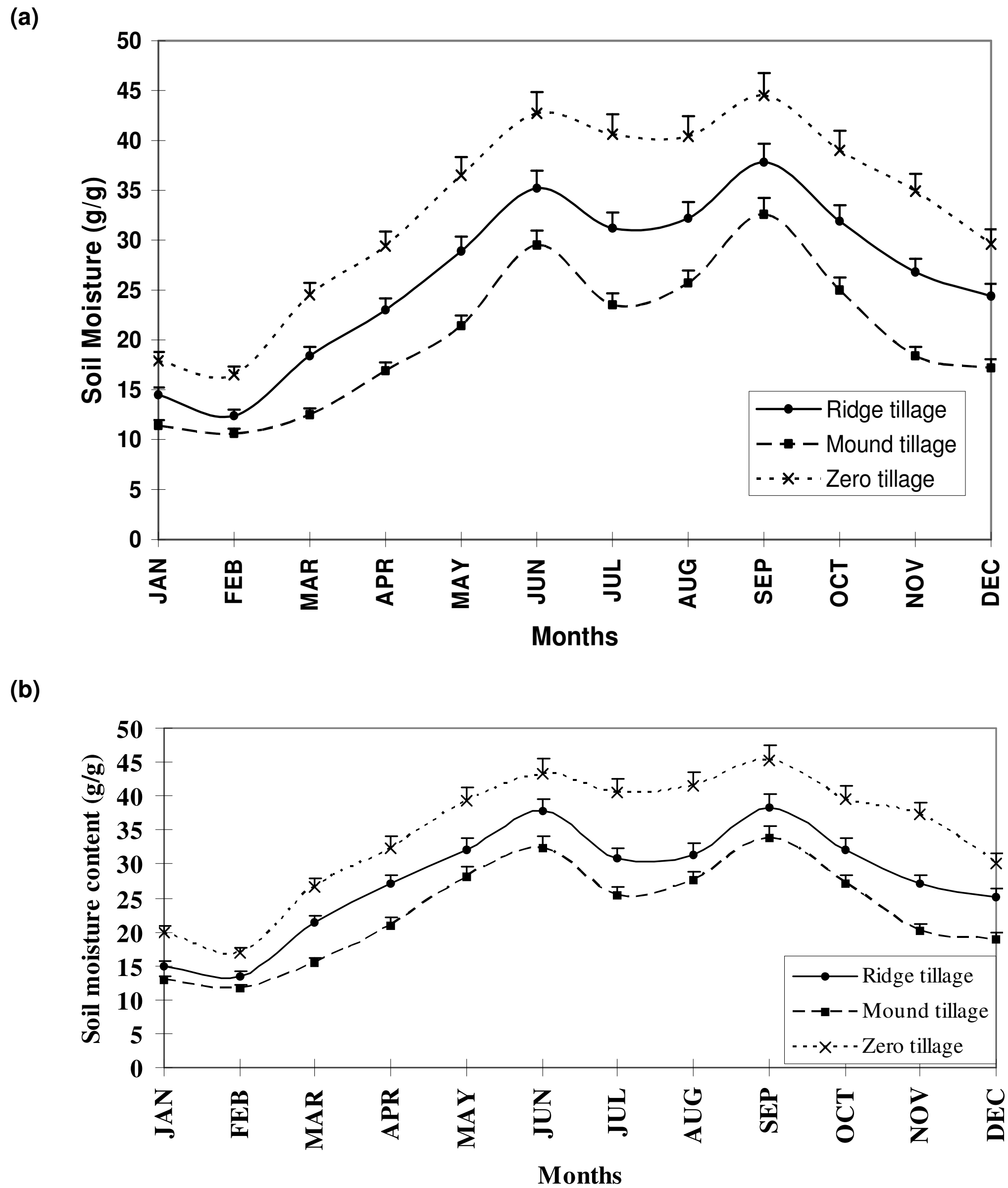

Figure 2. Tillage and soil moisture content at (a) 0 - 15 cm (b) 15 - 30 cm.

crease in soil moisture was noticed between September and November at all depths (Figure 2 a and b). With the emergence and dominance of the atmosphere by the Northeast Trade Wind and its harmattan characteristics, a sharp decrease in soil moisture content is observed from November to February.

Crop emergence, growth and leaf area accumulation

Cassava emergence rate was highest between 9 DAP and 13 DAP in all the tillage types (Figure 3). Mound tillage (99.7%), which was drier and hotter, significantly recorded the highest emergence rate at 17 DAP, followed by ridge (97.2%) and zero (92.9%). However, this does not mean that cassava always needs a hot and dry environment to geminate rather; the outcome of this study is based on the time of planting. The cassava stems were planted at the heart of the rainy season (June) when moisture was abundant and temperature suppressed. Temperature at this time was the limiting factor that is why treatments with higher temperature sprouted earlier with greater frequency. Ujuanbi (2002), who planted cassava during the onset of rains (March) in Western Nigeria, had a contrary result when he observed that cassava emergence was higher in zero tillage with higher soil moisture content than ridge. Soil temperatures were positively and significantly correlated at $p < 0.01$

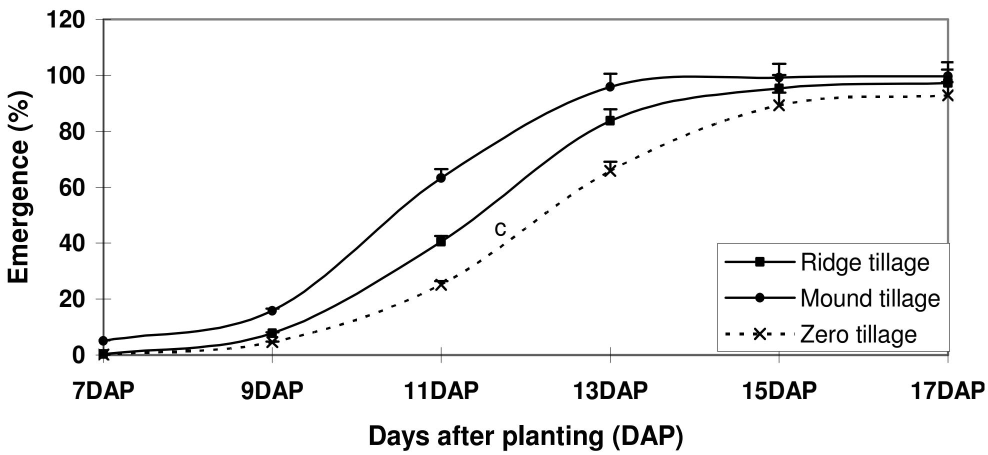

Figure 3. Tillage and cassava emergence.

Table 1. Correlation between climatic variables and crops growth, LAI and yield.

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	E	G	L	Y
X_1	1.0											
X_2	.601**	1.0										
X_3	.517**	.728**	1.0									
X_4	.664**	.776**	.728**	1.0								
X_5	.498*	.493*	.258	.252	1.0							
X_6	-.431*	-.145	-.135	.485*	.480*	1.0						
X_7	-.001	-.097	-.038	.025	-.193	.081	1.0					
X_8	-.006	.021	-.158	.122	.084	.121	-.428*	1.0				
E	.502**	.570**	.488**	-.534**	-.244	.524**	.000	-.022	1.0			
G	-.251	-.316*	-.236	.771**	.444**	-.138	-.102	.543**	.485*	1.0		
L	-.689**	-.513**	-.261	.567**	.451**	-.041	-191	.419*	.256	.678**	1.0	
Y	-.335	-.474*	-.437*	.888**	.631**	-.399*	-.077	.215	.104	.655**	714**	1.0

* = Significant at 0.05 level ** = Significant at 0.01 level
X_1 = Soil Temperature at 10cm X_2 = Soil Temperature at 20cm
X_3 = Soil Temperature at 30cm X_4 = Soil Moisture at 0 – 15cm
X_5 = Soil Moisture at 15 – 30cm X_6 = Maximum Temperature
X_7 =Minimum Temperature X_8 = Relative Humidity
E = Emergence Cassava (17 DAPG= Growth
L = Leaf area index Y= Yield

levels with cassava emergence. While soil moisture at all depths and maximum temperatures were negatively correlated, minimum temperature displayed zero or neutral relationship with cassava emergence (Table 1).

The trend as shown in Figure 4 reveals that mound tillage had the fastest growth for the first 3 MAP. From 4 MAP, ridge recorded the highest growth rate until 10 MAP, while zero tillage had the least growth rate. The slow growth rates experienced by all tillage types between 6 MAP and 8 MAP could be ascribed to the water stress at this period (December – February).

The growth pattern exhibited by the zero tillage (with the highest soil moisture content Figure 4) proved that availability of soil moisture alone is not enough to explain the growth rate of cassava, neither does the drought experienced during the dry season was severe enough to adversely limit the growth of other tillage types. (Figure 2 and 4). This could move us to believe the opinion of Obodete et al. (2007) who states that although climatic elements are prominent factors in dictating the growth pace of crops, the effects of tillage system cannot be over looked. Thus, mound and ridge tillage, which usually have better soil structures and root development than zero tillage (Odeghe, 2002), proved to have supported higher growth rate that was also sustained during the peak of dry season with its associated water stress. This

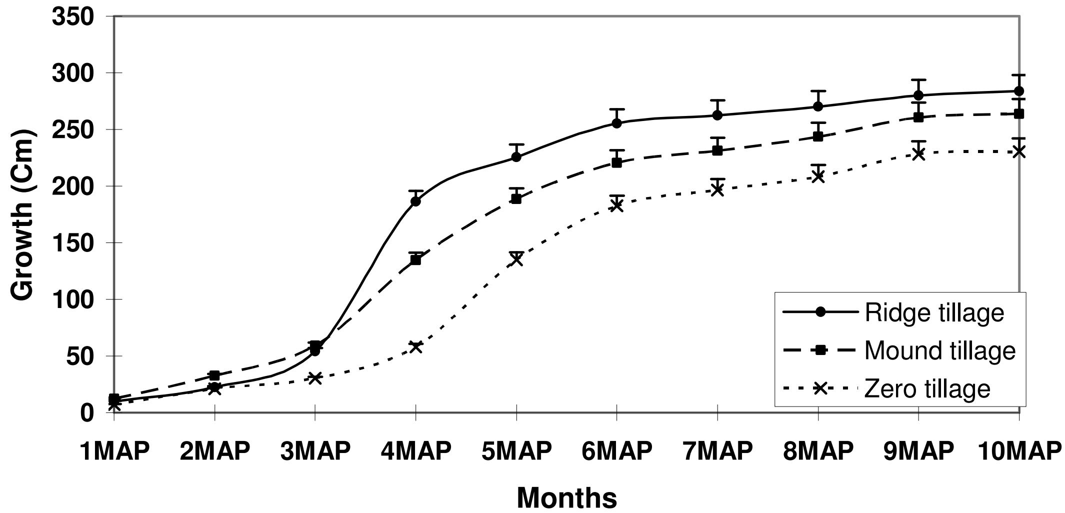

Figure 4. Tillage and cassava growth.

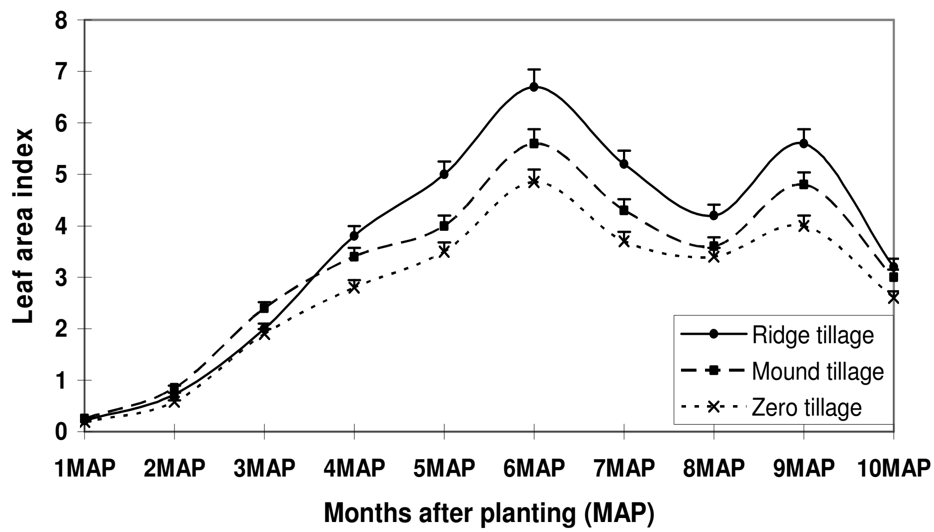

Figure 5. Tillage and leaf area index (LAI).

agrees with the findings of Odumosor (2003), which shows that ridge tillage with better bulk density, and aeration provides the most favourable microenvironment for cassava and yam growth than the zero tillage.

Soil moisture at all depths and relative humidity were positively and significantly related to cassava growth at $p < 0.01$ while soil temperature at all depths, minimum and maximum temperatures were negatively correlated with cassava growth. It is the importance of soil moisture to cassava growth that prompted Atikpakpa (2006) to stress the point that acute water deficit is limiting to cassava growth. Onwueme and Sinha (1999) and Obodete et al. (2007) recommend that drought condition in tuber crops should be avoided during the growth stage since it both retards the growth and also affect the yields drastically.

At 6 MAP and during the tuber stage, zero tillage (4.1) recorded the least leaf area index (LAI) in cassava, followed by mound (5.2) and ridge (6.0) (Figure 5). Akparobi et al. (2001) observe a similar leaf area accumulation of 3.6 and 3.5 in zero tillage in Ibadan and Jos respectively at 6 MAP. Leaf area accumulation was highest in mound tillage for the first 3 MAP and thereafter, the ridge tillage then topped the list. The peak of the LAI in all the tillage types was 6 MAP. There was a

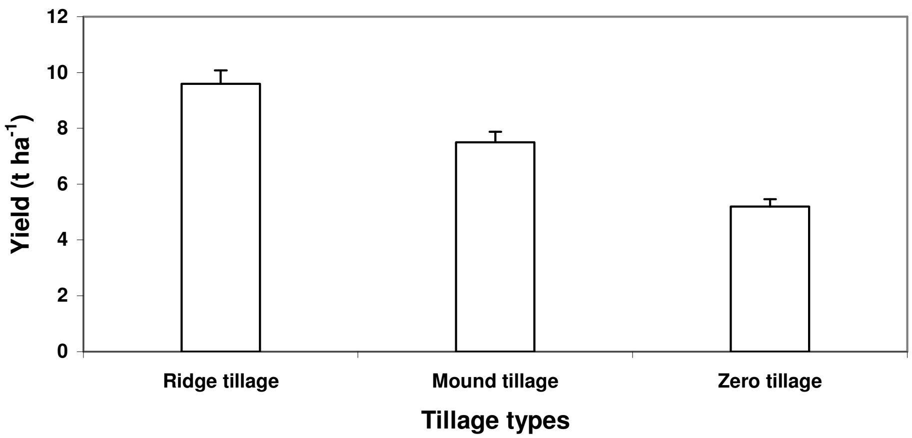

Figure 6. Tillage and cassava yield.

Table 2. Regression between climatic and growth variables and cassava yield.

Correlation	Level of explanation (%)
0.888[a]	0.789
0.898[b]	0.806
0.906[c]	0.821

a. Predictor = soil moisture at 0 - 15 cm depth
b. Predictors = a + crop height
c. Predictors = a + b + soil moisture at 15 - 30 cm depth.

decrease in leaf area accumulation between 7 MAP and 8 MAP due to water stress occasioned by reduced rainfall and, by implication, soil moisture content in the months of December through February (Figure 2a and b). After the water stress period of December through February, and with the onset of rains in the month of March, LAI started rising again. The increase could not be sustained because of the onset of maturity, which normally results in shedding of leaves. This conforms to the work of Odeghe (2002), which states that cassava leaf area accumulation is higher in ridge than bed and mound tillage systems.

The peak of leaf area accumulation is attained at 6 MAP in all the treatment types, and a sharp drop from 6 MAP to 8 MAP. This corresponds with the peak of water stress and with the on-set of rains, leaf area rose once more as noticed at 9 MAP. This increasing leaf accumulation could not be sustained as a result of the on-set of maturity that is usually followed by shedding of leaves. This invariably decreased the LAI at 10 MAP. Soil temperatures (0 - 30 cm depth), minimum and maximum temperatures were negatively correlated with cassava leaf area. On the other hand, soil moisture (0 - 30 cm depth) was positively related with leaf area stage of cassava, which is significant at $p < 0.01$ levels. The dry season coincides with the leaf area stage. Temperature is thus not a limiting factor but soil moisture. Adequate soil moisture is therefore necessary for proper cassava leaves development. In the same vain, Odeghe (2002) reveals that there was a negative but significant relationship between soil temperature and leaf area of cassava.

Cassava tuber yield

Ridge tillage (9.6 t ha^{-1}) topped the list of cassava tuber yield, followed by mound tillage (7.5 t ha^{-1}) and zero tillage 5.2 (t ha^{-1}) Figure 6. The yield of ridge was higher than that of mound by 22% and zero tillage by 46%. This agrees with the results of Woghiren (2004) and Ageh (2005), which show that ridge tillage produce more cassava tubers than mound in Western Nigeria. However the result disagrees with that of Hauser et al. (2000) and Agbodigi (2006), which observe that cassava yield is not affected by tillage in Southern Cameroon and Eastern Nigeria respectively, while Jongruasup et al. (2003) note that cassava yield was higher in no-tillage in the Khon Koen Province of Thailand. Although mound tillage is not as popular as the zero tillage in cassava production in the study area, its yield is 31% higher than the popular zero tillage. Hong et al. (2005) earlier observe that cassava tuber yield is better of in mound tillage in Adamawa State, Nigeria. The mean yield of 7.4 t ha^{-1} is recorded in this study, which is lower than Africa's average yield of 9.10 t ha^{-1} (Onwueme and Sinha, 1999), but the ridge tillage (9.6 t ha^{-1}), which recorded the highest yield in this study, is comparable with the Africa's mean yield. The lower tuber yield in this study could be attributed to the fact that no fertilizer or manure was applied in this work while the African mean referred to above used fertilizers.

As shown in Table 1, soil moisture at all depths, and relative humidity are positively correlated with the yield of cassava at $p < 0.01$. On the other hand, soil temperature at all depths, maximum and minimum temperatures are inversely related to cassava yield at $p < 0.05$. In Table 2, soil moisture at 0 - 15 cm depth is the key predictor variable that explained the yield of cassava. Soil moisture at 0 - 15 cm depth with a correlation of $r = 0.888$, explained 79% of the factors that affected the yield of cassava tubers. This indicates that cassava planted during the rainy season and which mature during the dry season, needs conservational method like mulching and irrigation (Atikpakpa, 2006 and Obodete et al., 2007) to conserve and maintain adequate soil moisture for the tubers to develop well. Other variables included in the regression model that also contributed to the yield are both climatic and growth variables. These include cassava height and soil moisture at 15 - 30 cm. The three variables combined had a strong correlation of $r = 0.906$ and explained 81% of the yield. Soil moisture that stands out as the most determining factor in cassava yield is a total deviation from the work of Ossom and Onochie (1994) which shows that soil temperature is the descriptor variable during the tuber and maturity stages. The reason for the different results is clear. In this research, cassava was planted during the rainy season and matured during the dry season while that of Ossom and Onochie was early planting which matured toward the end of the rainy season where soil moisture is not a limiting factor.

Conclusion

The delay in emergence in the zero tillage with higher soil moisture content and lower soil temperature led to a substantial number of rotten stems. Tillage types induce the soil hydrothermal condition. Soil temperature at 0 - 20 cm depth is significantly higher in mound, followed by ridge and zero tillage. The reverse is true with soil moisture content. The effect of the induced soil microclimatic condition is reflected not only in the cassava emergence, but also in the growth and yield. Mound tillage with the lowest soil moisture and highest soil temperature recorded the best emergence rate, while ridge topped the growth rate and yield. Cassava tuber yield is observed to be significantly higher in ridge tillage (9.6t ha^{-1}), followed by mound tillage (7.5 ha^{-1}) while the popular traditional zero tillage (5.2 ha^{-1}) recorded the least yield. This study reveals a better practice – ridge tillage – that can be recommended to the farmers in the tropical humid region. If this recommended method is practised it will increase yield by 46%.

Apart from the ridge tillage, mound tillage, which is also a traditional method, could also be practised because its yield is better than the zero tillage by 31%. Although mound and ridge tillage produced more than the zero tillage, the ridge tillage is recommended as the best practice for two reasons. One, the yield in ridge tillage is higher, and two, mounds are difficult to construct with the use of tractors, but ridges are easily constructed by tractors. The practise of ridge tillage will lead to mechanized farming and better output for big time farmers who can afford buying or hiring tractors, but this is above the financial capability of the peasant farmers in the study area, except if they could form farmers' cooperatives that will allow them have easy access to bank loans.

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