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THE EFFECT OF TILLAGE TYPES ON MICROCLIMATIC CONDITION AND YIELD OF INTER-CROPPED VEGETABLES IN MIDWESTERN NIGERIA.

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ABSTRACT

This paper examined the effect of tillage types on microclimatic condition and the yield of inter-cropped vegetables (okra, tomatoes, pepper and garden egg) in Midwestern Nigeria. Climatic data (air and soil temperature, soil moisture, rainfall, and relative humidity) and physiological parameters (emergence, growth, leaf area and yield) of the crops were collected at the agroclimatology experimental farm situated at the University of Benin, Benin City, Nigeria, between March and November 2004 and 2005. The data were analysed using time series, product moment correlation, stepwise regression, analysis of variance, and least square range test. The results show that soil temperature at 5 -cm and 10 -cm depths was highest in mound followed by ridge, bed and hole tillage, while the reverse pattern was displayed by soil moisture at 0 - 15 -cm depth. Bed tillage favoured the yield of tomatoes (19.84 t ha^{-1}), okra produced more in ridge (10.46 t ha^{-1}), while pepper (12.23 t ha^{-1}) and garden egg (15.73 t ha^{-1}) had higher yields in mounds. While mono - cropping yielded more than mixed cropping, the latter reduced crops yield by between 8.41% and 41.28%. If mixed cropping is to be practiced, the only economically viable combinations are okra/pepper and garden egg/pepper.

KEYWORDS: Tillage types, microclimate, intercropping, vegetables and yield.

INTRODUCTION

The microclimatic conditions by which crops grow vary with different tillage and cropping systems (Kapia, 2002). The variation is most pronounced in an inter-cropped environment (Benjamin, 1998). It has been shown that inter-cropping reduces soil temperature and enhances soil moisture (Mutium, 2002). Tillage types such as mound, ridge, bed and hole or zero-tillage have been found to alter the microclimate of crops environment (Nwokedi, 2003). While some studies noted that mound tillage is drier and hotter than ridge tillage (Ghuman and Lal, 1991; Kapia, 2002), others posited that ridge has higher temperature and lower moisture than flat tillage (Benjamin, 1998). On the advantages of inter-cropping, research has shown that crops grown in mixtures in a given area and time, will lead to increased efficiency in the utilisation of environmental factors such as light, nutrients, water, more efficient utilisation of labour, and reduction of adverse effects of diseases, pest and weeds. It also provides insurance against crop failure and enhances sustained productivity, facilitates higher gross returns, and offers protection for soil against soil erosion thus conserving valuable top soils (Halugalle and Ezumah, 1991; Kebeerathuma et al., 1995; Avwunudiogba, 2000).

Although, much attention has been given to inter-cropping, previous inter-cropping researches in the tropics, focussed on two crops or less using a tillage type (Amator, and Ponnen, 1999; Adeniyi, 2001; Anigboro, 2001; Tizie, 2003; Ogidigben, 2004). Those on monoculture also used a tillage type (Bello, 2002; Omunu, 2003; Dibie, 2003, 2005; Daura, 2004), while studies that employed different tillage types focussed on one crop (Canaday, Wyatt and Tyler, 1999; Mbambe, 2002; Maroise and Wright, 2003). In this research, we investigated the relationship between tillage systems, microclimatic condition and the growth and yield of multiple mixtures containing okra (*Hibiscus esculentus*), tomatoes (*Lycopersicon esculentum*), pepper (*Capsicum annum)* and garden egg (*Solanum macrocarpon)*

The high rate of unemployment and underemployment in Nigerian cities has forced many to engage in market gardening. While the majority of market gardeners use the hole tillage system, the minority employ the bed tillage system. Mound and ridge tillage are hardly used for vegetable production in the study area. The best tillage systems for the crops grown under the market gardening require scientific studies. We investigated combining crops in different tillage types, to determine which tillage type and what crops combination would benefit the farmers more.

MATERIALS AND METHODS

The field experiment was conducted between March and November, 2004 and 2005 at the University of Benin, Benin City (6.20°N, 5.37°E) in Midwestern Nigeria. Benin City is within the equatorial climatic belt of Koppen's Am climatic classification. It has some forms of rainfall throughout the year but with marked distinct rainy and dry season. The dry season spans from November to February and the rainy season prevails between March and October. While it has an annual rainfall of above 2000mm, its mean monthly temperature and relative humidity is above 28°C and 80% respectively. The soil is classified as a sandy clay, siliceous, isohyperthermic oxic Peleudult (Avwunudiogba, 2000).

The land was left fallow for 4 years with elephant grass and siam weed as dominant vegetation. The experiment was a randomised complete block split-plot design. The land was divided into three replicates. Each replicate was divided into four main plots tillage types (ridge, bed, mound and hole). Each main plot was divided into 15 subplots that contained the 15 crop combinations. These treatments included okra only, tomatoes only, garden egg only, pepper only, okra/tomatoes, okra/garden egg, okra/pepper, tomatoes/garden egg, tomatoes/pepper, garden egg/pepper, okra/tomatoes/garden egg, okra/tomatoes/pepper, tomatoes/garden egg/pepper, garden egg/pepper/okra, and okra/tomatoes/garden egg/pepper. In order to accommodate the same number of crop stands and maintain the same plant density per crop, the sole crop plots occupied plot area of 3 x 3 m, the two crops 6 x 6 m, three crops 9 x 9 m and the four crops 12 x 12 m.

The land was cleared between March 10-16, plots were prepared, and crops were planted on March 26, 2004 and the second season planting took place on March 22, 2005. The crops were planted on 60-cm centres. Three to four seeds were planted for each crop. Three weeks after planting (WAP) pruning took place. Direct seeding and removal was practised, leaving the healthiest crop in each stand. Because research in the tropics has shown that transplanting reduced plant growth in the first two weeks after transplanting pepper and tomatoes, which

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led to a lowered yield by 25-48% (Onoku, 2000; Anigboro, 2001).

Immediately after planting, measurement of hydrothermal and soil condition of the experiment began. The air temperature, rainfall, and relative humidity were measured using thermographs, rain gauges and hygrographs respectively. The soil temperature at 5 -cm and 10 -cm depths was measured with soil thermometers while the soil moisture at the 0-15 cm depth was determined gravimetrically. These depths were chosen because the crops investigated are not very deep-rooted crops. Climatic variables were monitored daily at 800 and 1600 GMT, while the soil moisture content was determined once a month, between the months of March and November, 2004 and 2005.

The physiological parameters monitored included the emergence rate counted daily for 12 days after planting (DAP). Growth rate was measured every two weeks by measuring the changes in plant height, while the Leaf Area Index (LAI) was determined every two weeks for 18 weeks after planting (WAP) in okra and tomatoes and 30 weeks for garden egg and pepper using the following expression (Kapia, 2002).

$$LAI = \frac{\text{Leaf Area Per Plant}}{\text{Ground Area}}$$

Productivity of the inter-cropping system was assessed by calculating Land Equivalent Ratio (LER) (Okobido, 2002).

$$LER = \sum_{I=1}^{n} \frac{Y1}{Ym}$$

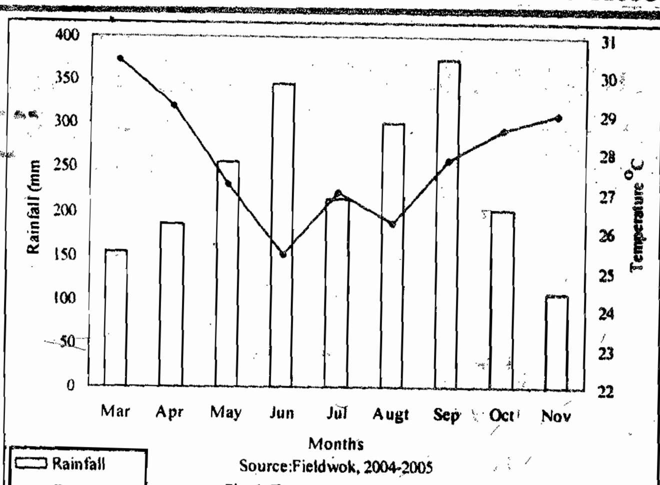
Where Y1 = yields of a component crop in the inter-crop.
Ym = yield of a component crop in the monoculture.
n = number of crops involved.

The first application of poultry manure took place 2 WAP and was repeated 10 WAP at the rate of 12 t ha-[1]. This falls within the 8-15 t ha-[1] of poultry manure recommended for the crops being investigated (Argerich, Poggi and Lipinski, 1998; Odeleye, Odeleleye and Olaleye, 2005). The data were analysed using time series, product moment correlation, stepwise regression, analysis of variance (ANOVA) and least square range test (LSR). The time series was employed to analyse the trends displayed by the climatic and growth parameters. To assess the nature of the relationship between the dependent variable (yield) and independent variables (climatic elements), the product moment correlation was used. While the stepwise regression analysis helped to identify the variable that principally explain the yield of the crops, the ANOVA and Least Square Range (LSR) assisted in determining whether the observed differences in tillage types and yield are statistically significant. The difference between the measured parameters and yield in 2004 and 2005 were not statistically significant hence, the mean data of both years is presented and analysed.

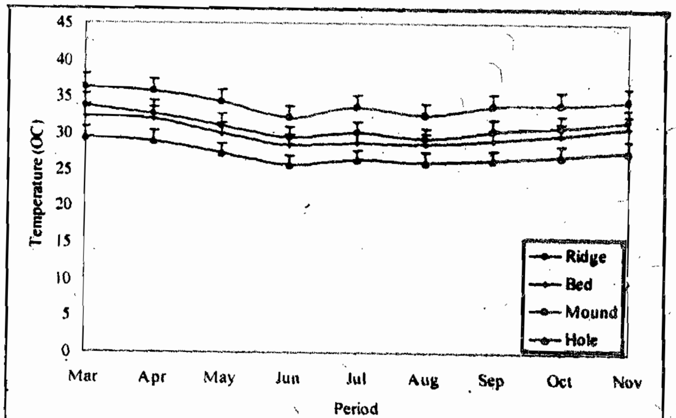
RESULTS

Microclimatic condition

Figure 1 shows an increasing rainfall from March to June, the first peak (346 mm). A short dry season occurred in July (215 mm), which led to a decline in rainfall in that month. The second rainfall peak (the highest rainfall amount) occurred in September (374 mm). Thereafter, a very sharp decreasing rainfall trend followed until November. Mean monthly air temperature showed a downward trend from March (30.4°C) to June (25.4°C), which had the lowest temperature. The short dry season that occurred in July (27°C) resulted to an increase in temperature. The increasing intensity in rainfall in August brought about a drop in temperature (26.2°C), which thereafter showed a rising trend until November (29°C).



Source:Fieldwok, 2004-2005
Fig. 1: Temperaure and Rainfal Variation

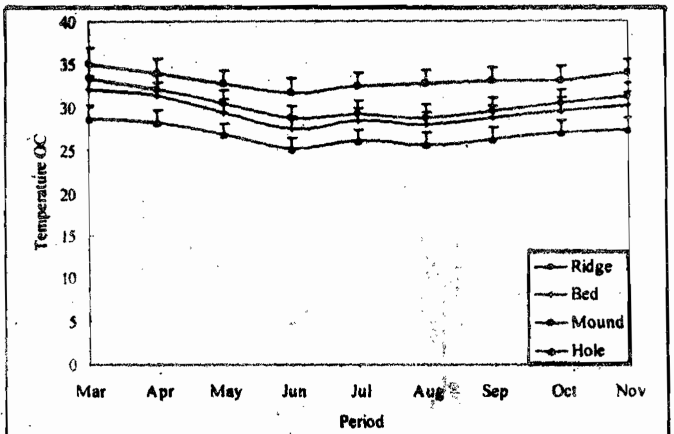


Source: Fieldwork, 2004-2005
Fig.2: Tillage and Soil Temterature at 5cm Depth

The pattern of relative humidity is closely related to that of rainfall except, the highest relative humidity was recorded in the month of June (88%) followed by September (87%) and the least occurred in March (76%). The relatively low temperature in June may have enhanced the higher relative humidity when compared with September that had higher temperature.

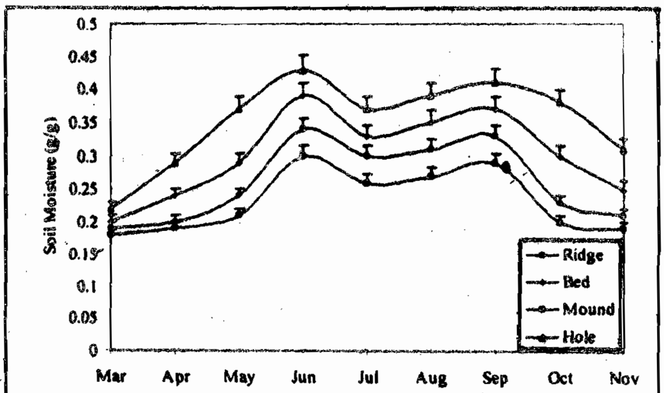
The soil temperature at the 5 -cm depth during the growing season ranged from 25.7 °C to 36.3°C with mound tillage having the highest temperature, by 2°C to 7°C throughout the season followed in descending order by ridge, bed and hole tillage (Fig 2). There was a 4°C to 5°C decrease in temperature from March until June, which had the lowest soil temperature. Soil temperature at the 10 -cm depth also exhibited the same pattern. Temperatures were lower at the 10-cm depth and while supra-optimal temperatures were observed in March (36.3°C) and April (35.7°C) for mound and ridge tillage at 5 -cm depth, such was not observed at the 10 -cm depth (Fig. 3).

Seasonal soil moisture content at the 0-15 -cm depth (Fig 4) ranged from 0.18 to 0.43 g/g and showed a pattern opposite of soil temperature (Fig 1). Hole tillage had the highest soil moisture content (0.22-0.43 g/g) followed by bed (0.20-0.40 g/g), ridge (0.19-0.36 g/g) and mound (0.18-0.32 g/g). Soil moisture content (F = 18) was statistically significant among the tillage types at $p < 0.05$. The tilled soils in mound, ridge and bed tillage, must have loosened the soil bulk density which allowed for more heat penetration and soil moisture evaporation, hence their significantly higher temperature and lower soil moisture when compared with hole tillage that had minimal tillage.



Source: Fieldwork, 2004-2005

Fig.3: Tillage and Soil Temperature at 10cm Depth



Source: Fieldwork, 2004-2005

Fig.4: Tillage and Soil Moiture content at 0-15cm Depth

Tillage types and crops emergence

Crops emerged more rapidly from hole tillage (99.1%), followed by bed (98.1%), ridge (96.9%) and mound (95.9%) treatments. This pattern was closely related to soil moisture. This relationship is not coincidental because during the planting period, temperature was abundant, while rainfall and soil moisture were limiting. The finding shows the importance of soil moisture in enhancing crop emergence in the humid tropics. Emergence of okra, tomatoes, garden egg and pepper with ($F = 6.6$) at 12 DAP was significantly influenced by tillage management at $p < 0.05$. Another notable feature was that hole and bed tillage attained their peak emergence at least a day before the other treatments. This could be attributed to their higher soil moisture content that enhanced early emergence.

The relationship between hydrothermal condition and crop emergence was analysed by correlating climatic variables with emergence of each crop (Table 1). Soil moisture, rainfall and relative humidity had a significant correlation with emergence of all the crops. In all the crops, soil moisture at 0-15 cm depth had the highest significant correlation ($p < 0.01$) followed by rainfall and relative humidity. Employing stepwise regression, soil moisture alone explained 82, 74, 71, and 78% of the variability in okra, tomatoes, garden egg and pepper emergence, respectively.

Tillage, crops growth and leaf area accumulation

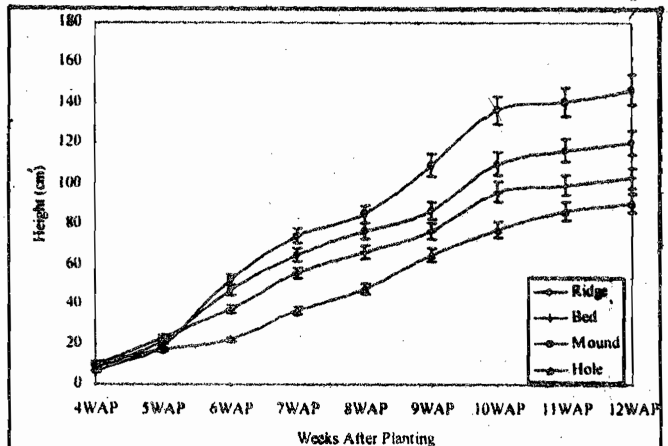
The impact of tillage on growth (height of crop) shows that at 12 WAP, we recorded the highest growth in ridge-tilled tomatoes, followed in descending order by mound tillage, bed tillage and hole tillage (Fig. 6). Pepper also maintained this growth pattern at (18 WAP). While the hole tillage was

Table 1: Correlation between Climatic Variables and Emergence Rate

	AT	ST5	ST10	SM	RF	RH	OK	TM	GE	P
AT	1.00									
ST5	.76**	1.00								
ST10	.75**	.78**	1.00							
SM	-.89**	-.81**	-.66**	1.00						
RF	-.90**	-.80**	-.75**	.94**	1.00					
RH	-.61**	-.53*	-.31	.69**	.88**	1.00				
OK	-.76**	-.30	-.14	.90**	.86**	.77**	1.00			
TM	-.53**	-.41*	-.11	.85**	.71**	.74**	.75**	1.00		
GE	-.21	-.53*	-.51*	.84**	.74**	.70**	.82**	.80**	1.00	
P	-.72**	-.80**	-.61**	.88**	.80**	.65**	.81**	.88**	.76**	1.0

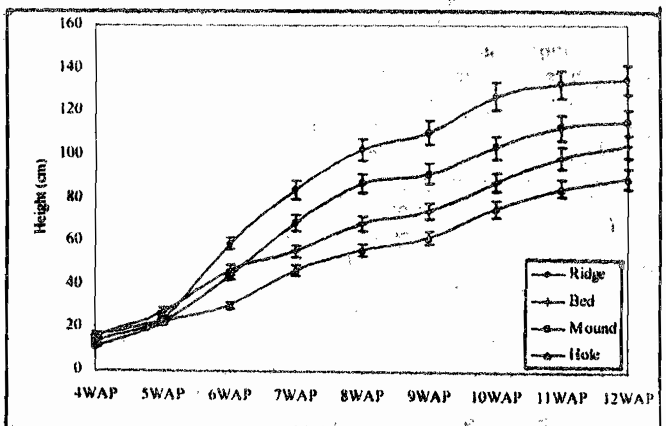
* Significant at 0.05 level; ** Significant at 0.01 level

AT= Air Temperature; ST5= Soil Temperature 5cm; ST10= Soil Temperature 10 cm; SM= Soil Moisture; RF= Rainfall; RH= Relative Humidity; OK= Okra; TM= Tomatoes; GE= Garden Egg; P= Pepper



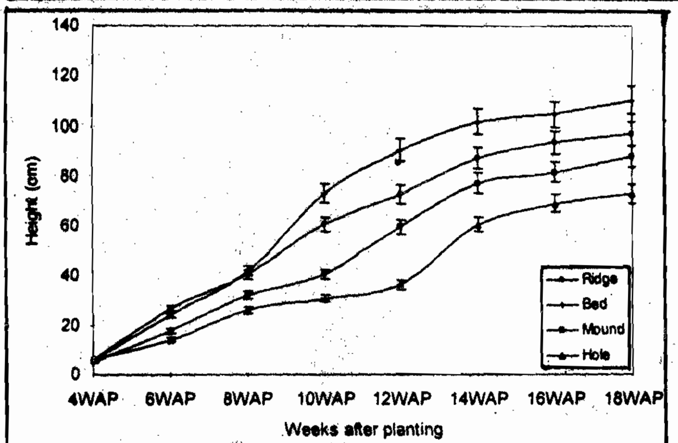
Source: Fieldwork, 2004-2005

Fig.5: Tillage and Okra Growth,



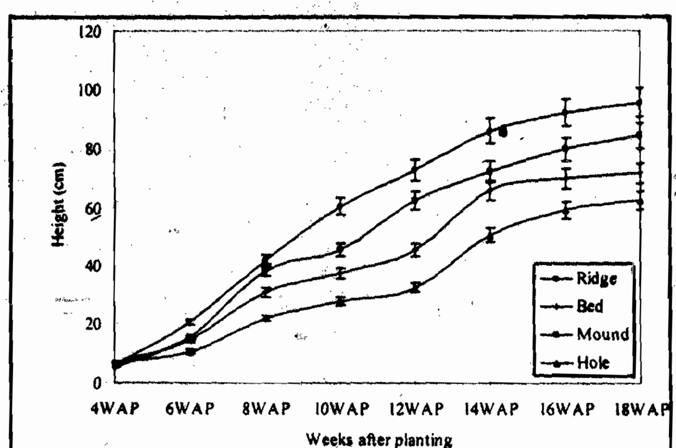
Source: Fieldwork, 2004-2005

Fig. 6: Tillage and Tomatoes Growth



Source: Fieldwork, 2004-2005

Fig.7: Tillage and garden egg growth



Source: Fieldwork, 2004-2005

Fig. 8 Tillage and pepper growth

permanently lower in garden egg, bed tillage conspicuously had the fastest growth, followed by ridge and mound tillage (Fig. 7). Ridge tillage favoured the growth of okra at 12 WAP while the second, third and fourth positions went to mound, bed and hole tillage (Fig. 5). The computed F= 20.24 showed that the growth differences among tillage types is statistically significant at $p < 0.05$.

To determine the climatic conditions that favoured the growth rate of the crops, the climatic variables were correlated with the growth parameters where all climatic variables had a positive correlation with growth rate (Table 2). This result is an indication that favourable climatic variables are paramount for adequate growth. Correlation values show that soil temperature had the highest significant effect on the crops' growth. While soil temperature at 5 -cm depth enhanced the growth of okra ($r = 0.87$) and tomatoes ($r = 0.93$), pepper ($r = 0.94$) and garden egg ($r = 0.90$) growth was enhanced more significantly by soil temperature at 10-cm depth. These observed correlations are statistically significant at $p < 0.01$ (Table 2). From the stepwise regression result, soil temperature at 5 -cm explained 78% and 81% of okra and tomatoes growth respectively while it was soil temperature at 10 -cm that explained 75% and 82% of garden egg and pepper growth respectively.

Like the growth rate, the leaf area was permanently lower in all the crops in hole tillage. Okra attained the peak of leaf area accumulation at 12 WAP where crops in mound tillage (7.90) had the highest leaf area, followed by ridge (6.67), bed (6.13) and hole tillage (5.02) (Fig 9.). Tomatoes in ridge culture (5.87) had the highest leaf area at 14 WAP followed by bed (4.62), mound (4.23) and hole tillage (3.9) (Fig. 10). This trend

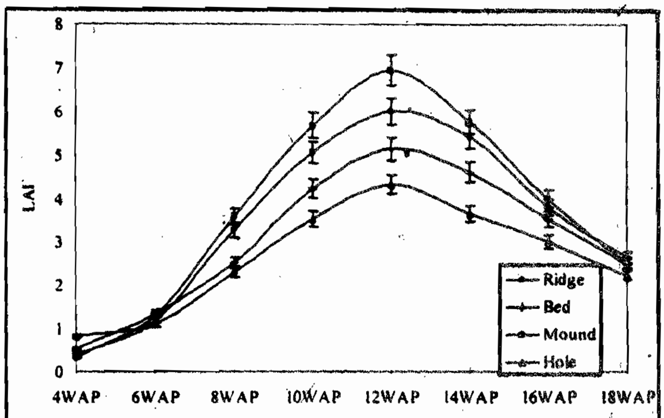
Table 2: Correlation between Climatic Variables and Growth Rate

	AT	ST5	ST10	SM	RF	RH	OK	TM	GE	P
AT	1.00									
ST5	.70**	1.00								
ST10	.64**	.75**	1.00							
SM	.20	-.86**	-.88**	1.00						
RF	-.92**	-.90**	-.81**	.93**	1.00					
RH	-.67**	-.63**	-.50*	.76**	.94**	1.00				
OK	.62**	.87**	.85**	.53*	.50*	.31	1.00			
TM	.73**	.93**	.89**	.24	.42*	.26	.55*	1.00		
GE	.67**	.88**	.90**	.46*	.53*	.35*	.89**	.60**	1.00	
P	.70**	.74**	.94**	.50*	.45*	.40*	.83**	.66**	.89**	1.0

* Significant at 0.05 level; ** Significant at 0.01 level

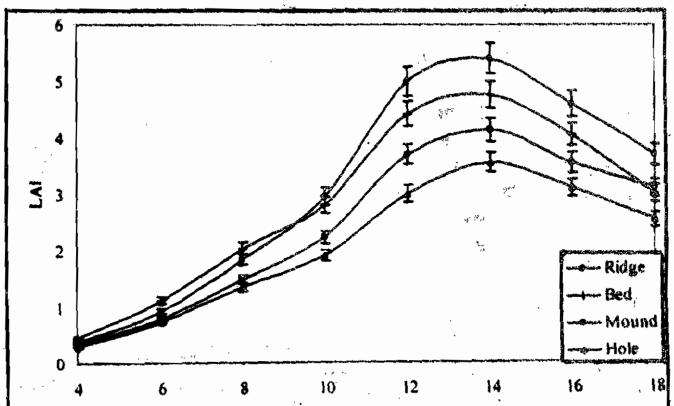
AT= Air Temperature; ST5= Soil Temperature 5 cm; ST10= Soil Temperature 10 cm; SM= Soil Moisture;

RF= Rainfall; RH= Relative Humidity; OK= Okra; TM= Tomatoes; GE= Garden Egg; P= Pepper



Source: Fieldwork, 2004-2005

Fig.9: Tillage and Okra LAI



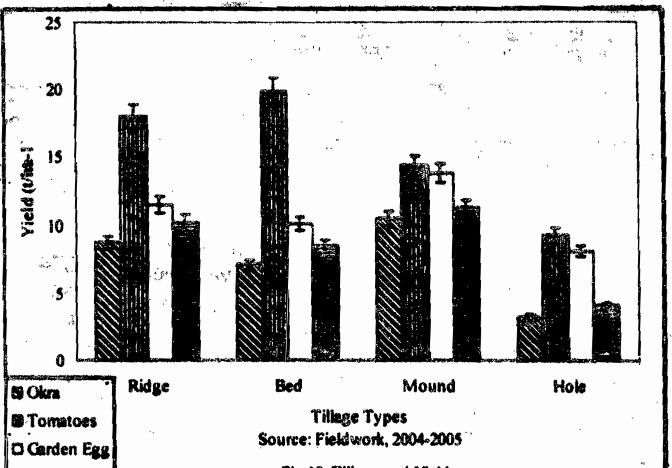
Source: Fieldwork, 2004-2005

Fig.10: Tillage and Tomatoes LAI

was also exhibited by garden egg at 20 WAP when it had its highest leaf area in the ridge (7.79), bed (6.6) and mound (6.54), which were greater than hole tillage (5.48) (Fig. 11). At the peak of pepper leaf area accumulation 18 WAP, bed tillage (6.94) topped the list followed in descending order by ridge (6.1), mound (5.89) and hole (5.09) (Fig. 12). The F-ratio of 14.0 shows that the leaf area differences among tillage types is statistically significant at $p < 0.05$.

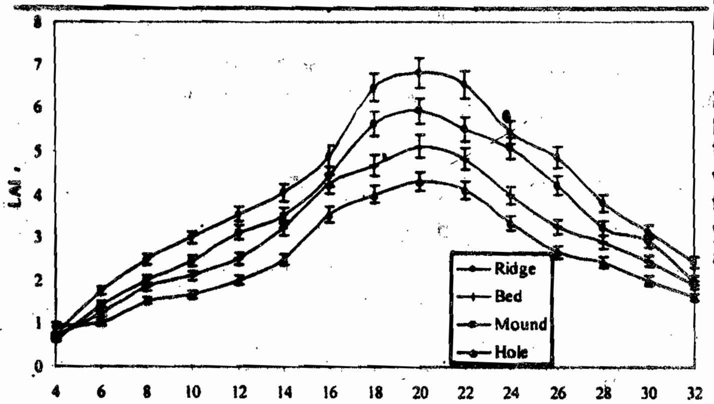
Tillage and crops yield

As shown in Figure 13, Bed tillage (19.84 t ha^{-1}) favoured the yield of tomatoes, followed by ridge (17.91 t ha^{-1}), mound (14.32 t ha^{-1}) and hole (9.32 t ha^{-1}) (Fig. 4). Okra produced more in ridge tillage (10.46 t ha^{-1}), followed by mound (8.82 t ha^{-1}), bed (7.14 t ha^{-1}) and hole (3.24 t ha^{-1}). Pepper had its highest yield in mound (12.23 t ha^{-1}) followed by ridge (10.24 t ha^{-1}), bed (8.49 t ha^{-1}) and hole (4.11 t ha^{-1}). The same pattern as in pepper was exhibited by garden egg where the best yield was recorded in mound 13.73 (t ha^{-1}), followed by ridge (11.47 t ha^{-1}), bed (10.31 t ha^{-1}) and hole (8.14 t ha^{-1}). In all the crops combined, mound tillage had the highest yield of 13.03 t ha^{-1}, followed by ridge (12.42 t ha^{-1}), bed (11.45 t ha^{-1}) and hole (6.20 t ha^{-1}). The observed difference in the yield (F = 17.50) was statistically significant at $p < 0.05$. Because yields were statistically different among tillage types, LSR was employed and the result shows that hole tillage (-4.53) is significantly different ($p < 0.05$) from ridge (1.79), bed (0.71) and mound (2.04) which did not differ significantly. From the foregoing, it is clear that okra produced more in ridge tillage while bed favoured tomato production, and mound is best for pepper and garden egg production.



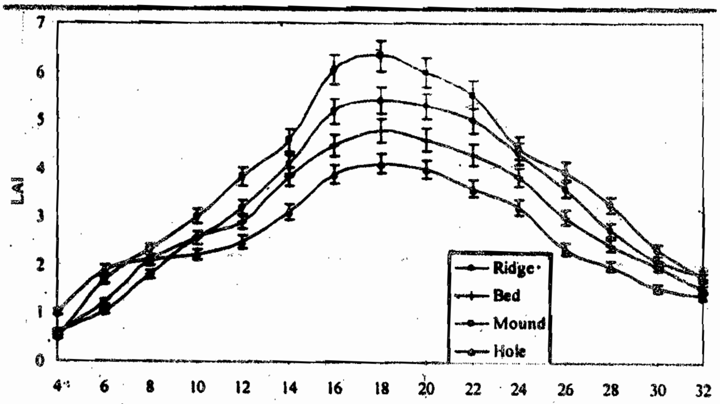
Source: Fieldwork, 2004-2005

Fig.13: Tillage and Yield



Source: Fieldwork, 2004-2005

Fig.11: Tillage and Garden Egg LAI



Source: Filedwork, 2004-2005

Fig. 12: Tillage and Pepper LAI

The nature of the relationship between climatic variables and yield was also investigated and the result is presented in Table 3. The result revealed that soil and air temperature significantly at $p < 0.01$ had the highest correlation with the yield of all the crops. As for okra and tomatoes, soil temperature at 5-cm depth was most closely associated with yield, while soil temperature at the 10-cm depth was most closely associated with yield of pepper and garden egg.

Table 3: Correlation between Climatic Variables and Yield

	AT	ST5	ST10	SM	RF	RH	OK	TM	GE	P
AT	1.00									
ST5	.63**	1.00								
ST10	.60**	.52*	1.00							
SM	-.74**	-.68**	-.61**	1.00						
RN	-.80**	-.76**	-.79**	.74**	1.00					
RH	.86**	-.66**	.58*	.77**	.80**	1.00				
OK	.76**	.82**	.79**	-.34	-.21	.26	1.00			
TM	.96**	.83**	.79**	.13	-.43*	-.51*	.49*	1.00		
GE	.69**	.87**	.82**	.40*	.30	.11	.74**	.52*	1.00	
P	.60**	.74**	.88**	.51*	.36*	.23	.77**	.60**	.88**	1.0

* Significant at 0.05 level; ** Significant at 0.01 level

AT= Air Temperature; ST5= Soil Temperature 5 cm; ST10= Soil Temperature 10 cm; SM= Soil Moisture; RF= Rainfall; RH= Relative Humidity; OK= Okra; TM= Tomatoes; GE= Garden Egg; P= Pepper.

To determine the climatic parameter(s) that are best associated with the yield of the crops, the yield values were regressed against the climatic parameters and the result is shown in Table 4. In okra yield, the most closely associated

Table 4: Predictor Variables for each of the Crops

Crops	Regression Value	Level of Explanation (%)
Okra	0.819a	67
Tomatoes	0.958c	83
Garden eggs	0.867a	75
Pepper	0.826b	77

a = Soil Temperature at 5 -cm b = Soil Temperature at 10 -cm
c= Air Temperature

predictor variable was soil temperature at 5-cm depth, which had a correlation of r = 0.819 and explained 67% of the variables in the yield. Tomato yield had air temperature as the best variable, with correlation of r = 0.962 and explained 83% of the yield variation. Temperature at the 10-cm soil depth was closely associated with garden egg yield having a correlation of r = 0.867 explaining 75% of the variation in yield. Pepper's yield had a correlation of r = 0.876 with soil temperature at 10 -cm depth and this climatic variable alone explained 77% of the yield variation (Table 4).

In the study area, farmers usually practice more of mixed cropping. This study combined crops in order to determine whether crops combinations provided more yields than the mono-crops. The yield result for the various crop combinations is presented in Table 5. The yield of individual crops is higher than the average of the combined crops. The two crops combination reduced the yield of the crops between 8.41% and 27.78%. The three crops combination reduced the yield from 23.13% to 36.37%, while the four crops combination led to a drop of 41.28% in yield. Okra/pepper with a land equivalent ratio (LER) of 0.92 was the best combination closely followed by garden egg/pepper (0.91).

DISCUSSION

A double rainfall peak (June 346 mm) and (September 374 mm) with short dry season in-between (July 215 mm) was recorded. This double rainfall peaks with a short dry season in-between is a characteristic of equatorial and sub-equatorial climate (Nwokedi, 2003). Relative humidity exhibited a close pattern with that of rainfall except, the highest relative humidity was recorded in the month of June (88%) followed by September (87%). The increasing rainfall and humidity suppressed air temperatures. These observed climatic patterns and differences are similar to the ecological climatic conditions of the study area (Umukoyibo, 2004).

This study has been able to establish that soil temperature at 5 -cm and 10 -cm depth was highest in mound followed by ridge, bed and hole tillage. Soil moisture at 0-15 -cm depth shows the reverse pattern from that observed for soil temperature. This agreed with the findings of Benjamin (1998) and Mbambe (2002) which showed an inverse relationship

Table 5: Yield Variation in Mono and Inter-crops (t/ha-^{1})

Crops	Yield	Sum of Combinations	Reduction in Yield	Percentage Reduction	LER*
Okra	7.42				
Tomatoes	15.35				
Garden egg	10.91				
Pepper	8.52				
Okra/Tomatoes	17.61	22.77	5.16	22.66	0.77
Okra/Garden egg	15.54	18.33	2.79	15.22	0.85
Okra/Pepper	14.58	15.94	1.34	8.41	0.92
Tomatoes /Garden egg	20.47	26.26	5.79	22.05	0.78
Tomatoes/Pepper	17.24	23.87	6.63	27.78	0.72
Garden Egg/Pepper	17.62	19.42	1.8	9.27	0.91
Okra/Tomatoes/Garden egg	22.52	33.60	11.08	32.98	0.67
Okra/Tomatoes/Pepper	19.91	31.29	11.38	36.37	0.64
Tomatoes/Garden egg/Pepper	23.81	34.78	10.97	31.54	0.68
Garden Egg/Pepper/Okra	20.64	26.85	6.21	23.13	0.77
Okra/Tomatoes/ Garden egg/Pepper	24.78	42.2	17.42	41.28	0.59

*LER = Land Equivalent Ratio.

between soil moisture and soil temperature in Eastern Nigeria and Southern Kenya respectively. In all the crops, soil moisture enhanced emergence, hence emergence rate was highest in hole tillage, followed by bed, ridge and mound. This result corresponds with other studies in Agbor, Benin City and Asaba (all within the same ecological zone of this study), where soil moisture increased the emergence rate of okra, tomatoes and pepper during the onset of rains (Aisagbonbuonmwan, 2001; Odjugo and Atedhor, 2001; Ogidigben, 2004). While the fastest growth rate of okra was found in mound tillage, it was bed in garden egg and ridge in tomatoes and pepper. Soil temperature at 5 -cm and 10 -cm depth and air temperature were the dominant factors during the growth and leaf area stages of all the crops. This finding agrees with those of (Amator and Ponnen, 1999 and Odjugo and Atedhor, 2001).

Bed tillage (19.84 t ha^{-1}) favoured the yield of tomatoes, okra produced more in ridge tillage (10.46 t ha^{-1}), while garden egg (13.73 t ha^{-1}) and pepper (12.23 t ha^{-1}) were better off in mound tillage. These yields were comparable to average yield of these crops in the tropical region (Mbaye and Moustier, 1998; Anigboro, 2001; Odjugo and Atedhor, 2001; Kapia, 2002; Mbambe, 2002 and Nwokedi, 2003). All the tillage types significantly yielded more than the no-tillage types. This agrees with researches both in the temperate and tropical regions which show that soil tillage not only improves the soil condition for root development but also enhances the growth and yield of the crops (Canaday, Wyatt and Tyler, 1999; Mbanbe, 2002; Marois and Wright, 2003; Odjugo, 2003 and Mitchell, Pinston and Caylor, 2003) Soil temperature at the 10 -cm depth is the predictor variable and most closely associated with the yield of okra and pepper. Soil temperature at the 5 -cm depth is the predictor variable that explained mostly the yield of tomatoes and garden egg. This indicate s that farming practices that enhance soil temperature during the fruiting period should be encouraged and those that suppressed soil temperature such as mulching should be discouraged. Mulching was observed to have suppressed soil temperature considerably (Odjugo and Atedhor, 2001; Ekakitie, 2001; Odjugo, 2003; Ogidigben, 2004).

Although, mixed cropping is common in the study area, this study has shown that it is most economically viable to practise monoculture in the vegetables studied because intercropping reduced their yield by between 8.41-41.28%. This falls within the range of other research works in Nigeria and Africa where intercropping reduced the yield of tomatoes and okra by 8.9-85.1% (Adeniyi, 2001 and Tizie, 2004). Okobido (2002) showed that there is no significant difference between sole cropping and mixed cropping if the LER is 90% or more. Going by this recommendation, two–crop combination like okra/pepper and garden egg/pepper with LER of 0.92 and 0.91 respectively could be practiced. The combination of okra/garden egg is marginally viable.

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