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Maize (*Zea-Mays*) performance at different cultivation systems

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Abstract

Three acres of land each were allotted to two different cultivation systems. It was a 2 × 2 × 3 factorial design with 2 seasons- 1st planting year and 2nd planting year; 2 cultivation systems- plough only tagged PO with three replicates PO1, PO2, PO3; and plough-harrow-plough tagged PHP with three replicates PHP1, PHP2, PHP3. A high yield breed of flour maize (*Amylaceace*), well-treated yellow colour of 70 days maturity period was planted. Among the parameters measured were the weights of the grains and harvest indices, same conditions were provided for all the plots in term of fertilizer, herbicides and same soil types. One way ANOVA was used for the statistical analysis. The results shows that significant ($p = 0.000$, $p<0.05$) different was observed between the yield of maize and different cultivation systems in the first planting and second planting years. Significant ($p = 0.001$; $p<0.05$) different was observed between the harvest index of maize and different cultivation systems in the first planting and second planting years. The R^2 values for the correlation coefficients for the harvest index were 0.38 for the first year and 0.95 for second year. The highest figure of merit was 0.0469 kg/acre/Naira for plot PO while plot PHP had 0.0356 kg/acre/Naira. This was 31.74% increment in the figure of merit for the plough only plot PO over the plough-harrow-plough plot PHP.

Keywords:, cultivation systems, harvest indices, weights, yield

1.0 Introduction

Maize (*Zea-Mays*) belongs to the family *Graminae*, genus *Zea* and species *Mays*, sometimes referred to as corn by some people. It is cultivated throughout the tropics of which Nigeria is one. It is a monocotyledonous plant with male and female flowers or tassels that are wind pollinated, it is a fibrous rooted crop that can grow laterally to a depth of 90 centimetres (cm) in the soil and about 3 metres high on soil surface. The leaves are alternate with parallel veins on the cylindrical stands of solid nodes and internodes (Obi, 1999). The grains are borne on a lateral cob, it is often cross-pollinated, its fruits consist of sheath, grains and husk and the fruit is of achene type.

There are several varieties like *Evarta* (pop-corn), *Trinicata* (pod corn), *Amylaceace* (flour corn), *Indurata* (flint corn), *Saccharata* (sweet corn) e.t.c. Most of these do well on silt loam soil with average yield potentials of between 2.5 and 3 tonnes per hectares in Nigeria south western states (Osun State, 2010) and the common specie planted is *Amylaceace* (flour corn). In the United States of America (USA), the yield was about 10-12 tonnes/hectare and in India yield was about 8-10 tonnes/hectare (Lamidi, 1998). However, of recent, these have dropped, in USA the yield was 10.34 metric tons /ha and in India, it was 2.06 metric tons/ha (NUEweb, 2010) due to global climatic change. Yet, there are high discrepancies between these yields in these countries and in Nigeria, the reasons for these high discrepancies are due to the nature of soil management practices of using organic and inorganic fertilizers and also the breed of maize planted. At any particular site, the response of crop yields to application of fertilizers depends on the standard of crop and soil management (Allan, 1986). Maize needs about 89 cm to 150 cm rainfall per annum and temperature 21^0C to 24^0C for maturity and dryness.

1.1 Worldwide production of maize and consumption

In 2010, worldwide production of maize was 884,405,181 metric tons, with the largest producer, the United States, producing 37.44%, China 21.02%, and third Brazil with 6.64%. Africa produces less than 5% of world total and the largest African producer was South Africa with 1.52% followed by Nigeria with 7.31 metric tons, 0.87% of world total production (FAOSTAT, 2012). This was not the same for each of these leading countries of the world in maize production as was in year 2000 with the largest producer, the United States, producing 42.51%, China 17.9%, and third Brazil with 5.38%. Africa produces less than 4.5% of world total then and the largest African producer was South Africa with 1.93% followed by Nigeria with 4.11 million tons, 0.69% of world total production (FAOSTAT, 2012). According to FAO (2007) estimates, 158 million hectares of maize are harvested worldwide. Africa harvests 29 million hectares (18.35%), with Nigeria, the largest producer in Sub-Saharan Africa, harvesting 3%. Most maize production in Africa is rain fed. Irregular rainfall can trigger famines during occasional droughts. Besides this, the UN Food and Agriculture Organization (FAO, 2008) says crop losses in sub-Saharan Africa amount to $200 million a year. As a result scientists at the International Institute of Tropical Agriculture (IITA) continue reminding Nigerian farmers about how to improve soil and crop harvests (IITA, 2013) especially as Nigeria ranked low among nations in maize production in the world, 1.10, Spain 9.11; USA 8.92; Canada 7.82; Italy 7.74; Egypt 7.71; Argentina 6.47 all in metric tons/ha (NUEweb, 2010).

Worldwide consumption of maize is more than 116 million tons, with Africa consuming 30% (i.e. 34.8 million tons) and sub-Saharan Africa 21%. However, Lesotho has the largest consumption per capita with 174 kg per year. Eastern and Southern Africa uses 85% of its production as food, while Africa as a whole uses 95%, compared to other world regions that use most of its maize as animal feed (FAO, 2007). Africa consumes 34.8 million tons of maize per year and Nigeria produces 0.87% of world maize in 2010 and consumes more than 3% of total world production, thus need to import. This has to stop when production per hectare which is now at 1.10 metric tons/ha, is increased per each of the State of the country and that is why Osun State cannot be left out. Since Nigeria as a whole is a tropical country, Osun State has tropical soil (oxisols) and Ila-Orangun where the project was carried out is full of intensely weathered soils of tropical environments.

1.2 Tillage systems

For planting cereals, there are three main systems of cultivation namely 1. Conventional, where plough (mouldboard plough) followed by disc harrow and/or tined cultivator, drill are used; 2. Reduced, where tined cultivation followed by disc harrow and/or tined harrows, drill are used and 3. Direct drill, where seeds are planted in slit in the soil with minimum disturbance. Mouldboard plough is the only cultivation implement that is capable of producing complete inversion of a soil surface and weeds and surface trashes could be buried completely (Verma, 2008). Thus with careful ploughing, a spraying treatment for weeds may be avoided. 'Reduced cultivation' is used for ploughing carried out at shallow depths, less than half those in conventional ploughing systems with weed control effects of furrow slices inversion still retained.

Due to the rate at which the natural resources are being used and are not accordingly replenished by either by man or nature; due to environmental degradation and deforestation, the soil is being depleted of its much needed nutrients and micro-organisms. These soils eventually are not able to support the growth of crops and thereby necessary measures are needed to salvage the situation.

1.3 Harvest Index of maize

Harvest index which is defined as the yield in kilogramme of the useable parts per unit sum of yield in kilogramme of the useable parts and yield in kilogramme of the non-useable parts. The useable parts were the grains, the husks (use for fuel in cooking or burn for ashes in soap making) and dry leaves to feed farm livestock. For maize, the non-useable parts were the leafless dry stands (after the leaves for animal feeds have been removed) and their dry fibrous roots.

What are the methods needed to improve upon the soil for the purpose of maize crop growth? How would soil matrix be reduced for increased porosity and thus increase soil aeration/permeability for water and crops' roots? Which is important between soil with high specific heat of water and dry soil/ warmed soil to initiate germination and root growth? Are burying of weeds and trashes important factors in cultivation in the tropical countries to control weeds and erosion? What yield will result from any of the factors of cultivation mentioned above? What contributions would keeping plant residues on the surface of soil have towards reducing soil erosion?

The study investigated the effects of soil cultivation on the performances of maize in relation to its yield and total cost of cultivation with the aim of increasing total yield of maize production among farmers in Nigeria.

2.0 Material and Methods

The research was a 2 × 2 × 3 factorial design with 2 seasons- 1st planting year and 2nd planting year; 2 cultivation systems- plough only and plough-harrow-plough and at 3 replicates each. Both cultivations were mechanical in nature as commercial farming was to be encouraged. Six acres of land in size on a well-drained soil in a plain area was cleared and tilled in Ila-Orangun, a tropical forest town at 14^0 E (longitude) east of Greenwich meridian and 7^0 N (latitude) north of the equator, it is in Osun State of Nigeria. Three acres each were allotted to two different cultivation systems namely plough only tagged PO with three replicates PO1, PO2, PO3; and plough-harrow-plough tagged PHP, also with three replicates PHP1, PHP2, PHP3. Ploughing depth in all cases was about 180 mm on the average (Joubert and Simalenga, 1999). A high yield breed of flour maize (Amylaceace), well-treated yellow colour of 70 days maturity period was planted in April, to be harvested in July in the first year. There was only one planting in a year; this was to have the same conditions for the experiment, late maize was not planted since rainfall is usually at its peak in the tropics between August and September and sometimes October. At each time, three replicates were made for each of the experiment. Seeds were supplied after planting to make sure that the rows were complete with seedlings.

Spacings were the same in all the plots, NPK fertilizers were used with equal quantity applied. Individual plants were not considered such that no biasness may be brought in, totality of a plot was taken into consideration in all the readings. Such that the roots of the seedlings will not be disturbed at all during the growth, 1 kg of atrazine was dissolved in 200 litres of water for each acre.

During harvest, cobs were harvested in such a way that the chaff were gathered together for weights' measurement, similarly the husk, leaves gathered for livestock feed and remaining straws and fibrous roots (carefully shaken to remove attached soil particles) on the field. The shelling of maize was done manually to be able: 1 to remove, separate and keep properly the seeds/grains, husks, chaffs etc and 2. To separate the good grains from the 'bad' ones for each plot and their respective weights were recorded. Harvest indices (dimensionless ratio) were then determined using kilogrammes of the useable and non-useable parts. The useable parts and the non-useable parts [organically useable (because they fertilise the soil)] of which weights were taken (after collections) in such a way that none of these parts taken for measurements was allowed to torn away, this was to have nearly accurate values. The weights of the useable and non-useable parts were expressed per acre and then expressed per hectare since harvest index is a dimensionless ratio.

3.0 Results and Discussion

Table 1 shows the weight per acre for different plots, in replicates and their total for the useable and non-useable parts of the yield of maize for grains (both good and bad), husk, leaves, chaff and dry stumps/fibrous roots. These yields of *grain only* in the different replicates when compare to what were obtained per hectare or acre in USA (10,000 - 12,000 kg/ha or 4,000 - 4,800 kg/acre) and India (8,000 – 10,000 kg/ha or 3,200 – 4,000 kg/acre), were 30% - 33% of that of

USA yield and 35% - 40% of that of India (Lamidi, 1998). The reasons are not only due to the breed of maize planted but also due to their managerial ability of their soil in term of cultivation systems, the methods of harvest and handling.

Table 1: Yield of Maize in different plots at different planting years

	Useable parts					Non-useable parts			
Parts	Cultivation System		Planting year,1st	Planting year,2nd	Parts	Cultivation System		Planting year,1st	Planting year,2nd
	Plot	Repl.				Plot	Repl.		
	PO	PO1	1240	1400	Chaff, kg/acre	PO	PO1	200	220
		PO2	1390	1440			PO2	185	300
		PO3	1315	1390			PO3	300	320
	PHP	PHP1	1520	1760		PHP	PHP1	210	260
		PHP2	1730	1630			PHP2	220	240
		PHP3	1670	1720			PHP3	270	308
Husk, kg/acre	PO	PO1	220	230	Straw/ dry leaves, kg/acre	PO	PO1	300	280
		PO2	256	300			PO2	260	280
		PO3	270	286			PO3	290	300
	PHP	PHP1	210	280		PHP	PHP1	508	530
		PHP2	300	320			PHP2	412	500
		PHP3	320	300			PHP3	545	500
Leaves (for livestock, kg/acre)	PO	PO1	560	480					
		PO2	520	522					
		PO3	545	595					
	PHP	PHP1	380	480					
		PHP2	520	440					
		PHP3	580	600					

Pl. = plot; Repl. = Replicates

Different resulted yields of maize at different planting years were observed with different cultivation systems, the results show that significant ($p = 0.0000$; $p<0.05$) different was observed between the yield of maize and different cultivation systems in the first planting year and second planting year. The mean values were statistically different from each other in their respective planting years, Table 2a.

Harvest indices for the first year were greater than their corresponding values for the second year in both plots of the experiment (Figure 1). Although the same soil was used with the same conditions of farming common for both years, it can be concluded that the cumulative effect of tillage operations on the plots in the second year was significant over the first year, thus with the same conditions if cultivation continues, harvest index may still be greater for successive years provided law of diminishing returns is not yet set in.

Moreover, significant ($p = 0.001$; $p<0.05$) different was observed between the harvest index of maize and different cultivation systems in the first planting and second planting years. The mean values were not statistically different from each other in their respective planting years, Table 2b. The R^2 value for the correlation coefficients for the harvest index were 0.38 for the first year and 0.95 for second year, this was respectively low, weak correlation and high stronger correlation at both years. But in both there were evidence of inter-relationship between the harvest index and the cultivation systems. This accounts for differences in the yields of maize production per acre and these are due to the level of tillage, soil types, maize breeds, land tenure system that does not allow choice of land for farmers and the global climatic change, (IITA, 2008).

For Figure 2 and 3, the results of the regression analysis show that there were stronger correlations between the different cultivation systems and the yield of the maize per acre or hectare with R^2 values 0.85, 0.88 for Figure 2 and 0.79 and 0.91 for Figure 3. Also, the regression equations as shown in equations 1- 4 revealed stronger relationships between the independent variable Y (different cultivation methods) and total yields of useable and non-useable parts X of the replicates. The results of the non-useable was different from other regression, showing its non-uniformity and uncomfortability in the stream of events, thus the reason for low yield may be as a result of some other factors apart from soil, management used, maize breed and climatic changes.

For Figure 2

$$Y_{useable} = -0.166X^3 + 21.64X^2 - 32.47X + 20.67 \qquad R^2 = 0.85 \qquad (1)$$

$$Y_{useable} = 4.666X^3 - 48.71X^2 + 241.6X + 19.04 \qquad R^2 = 0.88 \qquad (2)$$

For Figure 3

$$Y_{non-useable} = -2.277X^3 + 28.66X^2 - 40.77X + 492 \qquad R^2 = 0.79 \qquad (3)$$

$$Y_{non-useable} = -2.407X^3 + 12.77X^2 + 38.75X + 444.6 \qquad R^2 = 0.91 \qquad (4)$$

Table 2a: Mean values of yield of maize (useable, non-useable) at different planting years

Useable, non-useable parts	1st Planting year		2nd Planting year	
	PO	PHP	PO	PHP
Grain	1315.00[a]	1630.00[ab]	1410.00[b]	1703.33[bc]
Husk	250.67[a]	280.00[b]	272.00[a]	300.00[b]

Leaves	543.00[a]	493.33[b]	535.00[a]	506.67[b]
Chaff	228.33[a]	233.33[a]	280.00[b]	270.30[b]
Straws	284.00[a]	489.00[b]	286.67[a]	570.00[ab]

Means with the same letters along the same row are not significantly different ($p<0.05$)

Table 2b: Mean values of harvest index at different planting years

1st planting year	2nd planting year
PO	PHP
0.80[a]	0.81[a]
0.83[a]	0.80[a]
0.78[a]	0.79[a]

Means with the same letters along the same column are not significantly different ($p<0.05$)

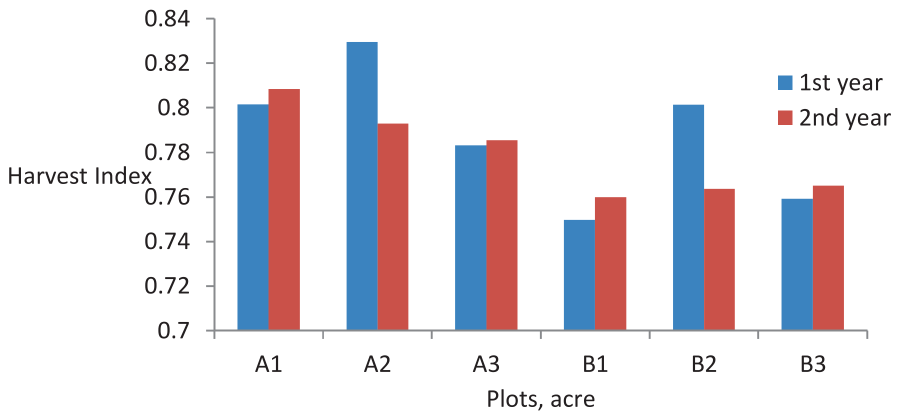

Figure 1: Harvest Indices for different plots at both years.

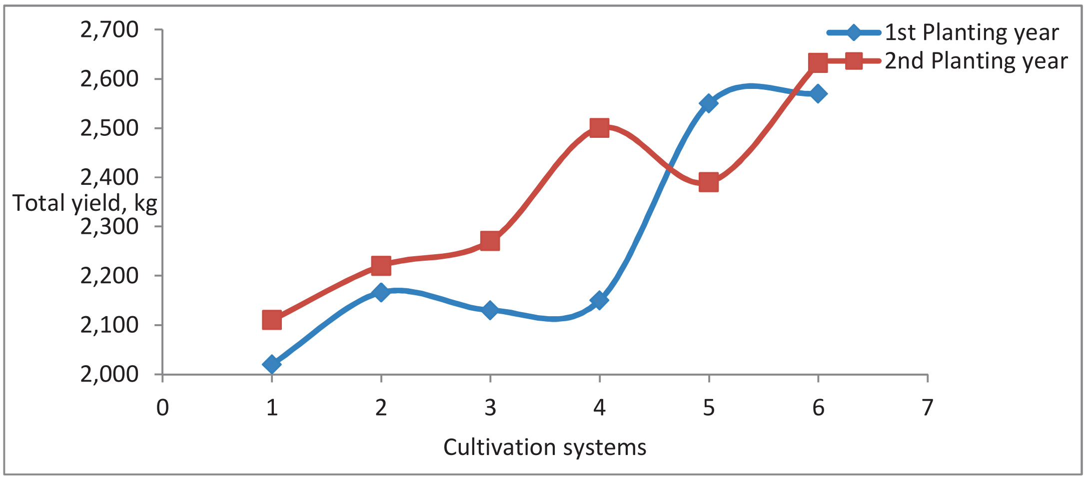

Figure 2: Total yield of useable parts for different plots at both years.

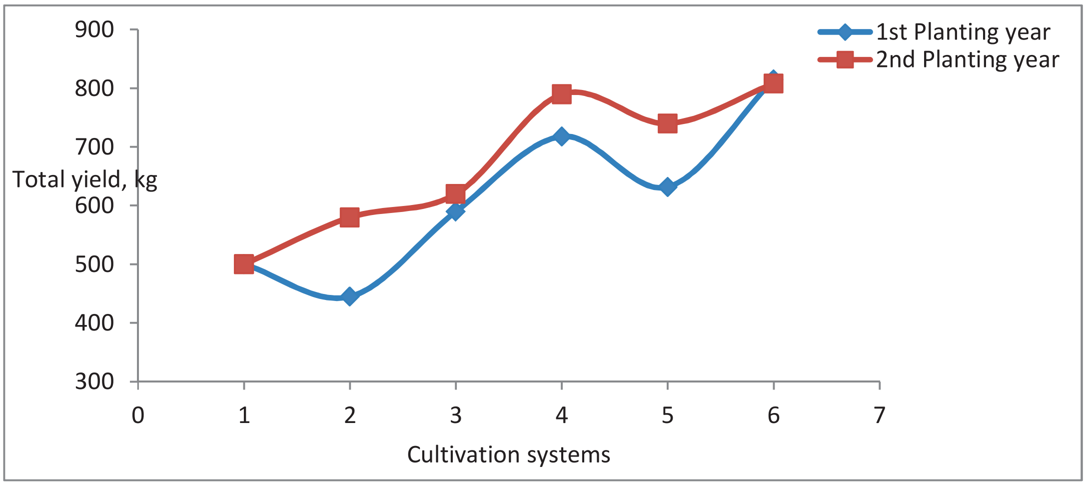

Figure 3: Total yield of non-useable parts for different plots at both years.

3.1 Cost Implications

The cost of different cultivation methods: pre- and post-planting operations; the costs of herbicides, seeds, labour and others like harvesting and shelling and collection of the materials like dry leaves or leafless stumps/roots of maize were estimated and shown in Table 3. Since the plots were of equal areas and many operations were common to both methods, like clearing, tilling, harvesting and shelling, their cost estimates were nearly the same. However, discrepancies in the cost of labour for harvesting and shelling were as a result of differences in the volume of their yields, another area of differences between the plots cultivated was in the volume of herbicides used in different plots. The price quoted were the local prices of products or labour and others in the area as at the time.

Table 3: Cost estimate (naira, #) of some pre- and post-planting operations

Plots	Cost of tilling /acre, #	Cost of herbicides /acre, #		Cost of seeds /acre	Costs of labour /acre, #				TPC /acre, #
		Pre-emt	Pst-emt		Pltg.	Sprg.	Hvsg., Trpt.	Shlg.	
First planting year									
PO	5,000	1,800	3,600	2,500	3,000	1,000	7,000	3,500	27,400
PHP	15,000	1,800	1,800	2,500	3,000	1,000	8,500	5,500	39,100
Second planting year									
PO	5,000	2,200	4,200	2,500	3,300	1,000	7,000	3,300	28,500
PHP	15,000	2,200	2,200	2,500	3,300	1,000	9,500	5,500	41,200

Pre-emt= pre-emergent herbicides; Pst-emt= post-emergent herbicides; Pltg= planting; Sprg= spraying; Hvsg = harvesting; Trpt= transportation; Shlg= shelling; TPC= Total production cost

Table 4: Cost estimate (naira, #) of grains

Planting year	Plots	Price cost of grains/kg, #	Total Transportation cost/weight, #	Price cost, #	Figure of merit kg/#
1st	PO	50	4,300	**65,750**	**0.0415**
	PHP	50	4,800	**70,500**	**0.0321**
2nd	PO	50	6,500	**82,000**	**0.0469**
	PHP	50	6,600	**85,167**	**0.0356**

The detail economic analysis was conducted. Table 4 shows the figure of merit which is defined as yield in tonnes/ha per unit total production cost (Feddes *et al.*, 1999) evaluated for the plots. The highest figure of merit was 0.0469 kg/acre/Naira for plot PO while plot PHP had 0.0356 kg/acre/Naira. This was 31.74% increment in the figure of merit for the plough only plot PO over the plough-harrow-plough plot PHP.

4.0 Conclusions

The following conclusions were arrived at:

There was significant different between the yield of maize and different cultivation systems in the first planting year and second planting year.

Harvest indices for the first year were greater than their corresponding values for the second year in both plots of the experiment.

There were stronger correlations between the different cultivation systems and the yield of the maize per acre or hectare with high R^2 values.

Non-uniformity in harvest indices and total yield of maize in all cultivation systems may be as a result of some other factors apart from soil types, management used, maize breed and climatic changes.

There was 31.74% increment in the figure of merit for the plough only plot PO over the plough-harrow-plough plot PHP.

5.0 Recommendations

The following recommendations were made:

Cultivation methods need to be improved upon for good soil aeration for crop roots growth. Weeds may be buried on farms and allowed to decay, then pulverized using plough and harrow, this controls growth of weed and control erosion in the tropics and will help to increase the yield of maize per hectare from its present value of 1.1metric tons/ha to justify cost of tillage.

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