Assessment of weed management strategies and intercrop combinations on cassava yield in the middle belt of Nigeria

Udensi Udensi
University of Port Harcourt

Okoye B.C
National Root Crops Research Institute

Paul Baiyeri
University of Nigeria

African Journal of Agricultural Research Vol. 6(26), pp. 5729-5735, 12 November, 2011
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR11.428
ISSN 1991-637X ©2011 Academic Journals

Full Length Research Paper

Assessment of weed management strategies and intercrop combinations on cassava yield in the middle belt of Nigeria

A. E. Agahiu[1], U. E. Udensi[2,3]*, G. Tarawali[3], B. C. Okoye[4], R. O. Ogbuji[1] and K. P. Baiyeri[1]

[1]Department of Crop Science, University of Nigeria, Nsukka, Nigeria.
[2]Department of Crop and Soil Science, University of Port Harcourt, Nigeria.
[3]International Institute of Tropical Agriculture (IITA), P. M. B. 5320, Ibadan, Nigeria.
[4]National Root Crop Research Institute, Umudike P. M. B. 7006, Umuahia, Abia State, Nigeria.

Accepted 25 August, 2011

This study assessed the determinants of weed management strategies on yield of cassava in Kogi State, Nigeria using the ordinary least square regression analysis. A multi-stage random sampling technique was used to select 450 cassava farmers in the state in 2009. The result showed that there was a significant difference in the yield of cassava between plots applied with herbicides and plots without herbicide application. The common herbicides used by the farmers were Primextra Gold®(Atrazine 370 g + S-metolachlor 290 g per litre), Galex®(Metobromuron 250 g + Metolachlor 250 g per litre), Cotoran multi® 500EC (Fluometuron 250 g + metolachlor 250 g per litre), Codal Gold® 412.5DC (250 g prometryn + 162.5 g per litre) and Fusilade Forte® 150 EC (150 g Fluazifop-p-butyl per litre) and Dual Gold® (960 g S-metolachlor per litre). Except Fusilade Forte® that was applied post-emergence to the weeds, the herbicides were mostly applied preemergence to both crops and weeds. Mean yield of cassava for plots applied with herbicides was 8,199 kg/ha and 6,999 kg/ha for plots with zero herbicide application. The study found a significant ($p \leq 0.05$) negative relationship between age of farmer and cassava yield. Education, use of herbicides, hand weeding, slashing and intercrop with melon had a significant ($p \leq 0.01$) positive relationship with cassava yield. The coefficients for household size, farming experience and intercrop with okra (*Abelmoschus esculentus* L. Moench) were positively associated with cassava yield at 10.0% level of probability. Implicit in these results is that weed management strategies should be aimed at the use of herbicides, subsequent hand weeding or slashing, as well as intercrop with crop such as okra and melon (*Colocynthis citrullus* L.). Also to encourage experienced farmers to remain in production, there should be policy advocacy on free education and intensification of extension education to farmers.

Key words: Weed management, cassava yield, ordinary least square regression.

INTRODUCTION

Cassava (*Manihot esculenta Crantz)* is an important staple food and cash crop in several tropical African countries especially Nigeria where it plays a principal role in the food economy (Agwu and Anyaeche, 2007). It is Africa's second most important staple food crop after maize, in terms of calories consumed (Nweke, 1994). In Nigeria, cassava is a staple food crop, and it contributes about 15% of the daily dietary energy intake of most of the population and supplies about 70% of the total calories intake of about 60 million people in country (Ezulike et al., 2006). Nigeria is the world's largest producer of cassava, with about 45.75 million metric tones (FAO, 2007). Cassava is one of the dominant components in crop mixtures in Nigeria especially in the south-eastern part of the country (Ikeorgu and Iloka, 1994). It is considered to be a food security crop because yields are generally reliable. For many Nigerians,

*Corresponding author. E-mail: u.udensi@cgiar.org, ueudensi@yahoo.co.uk.

cassava is a dual purpose crop, namely a staple food and a source of income (IITA, 1990; Nweke, 1994).

A cropping system is an aspect of farming system or agricultural production system which consists of one or more enterprises, or business activities in which sets of resources and inputs are uniquely managed by the farmer in the production of one or more commodities to satisfy human needs for food, fibre, various products, monetary income and other objectives (Okigbo, 1982). Intercropping as a cropping system, involves the growing of two or more crops in proximity to promote interaction between them (Ibeawuchi, 2007). In line with this definition, other authors (Okigbo, 1978; Wahua, 1982, and Ikeorgu, 1983) explained that intercropping is the growing of two or more crops simultaneously on the same field such that the period of overlap is long enough to include their vegetative stage. Further to this definition, Gomez and Gomez (1986) stated that where the overlap in time is too small, for example, only four weeks out of a growing season of 3 to 4 months, the term relay crop is used.

Intercropping is a common feature of agriculture in the tropical Africa as well as in the Asian and American tropics (Papendick et al., 1976; Okigbo, 1978; Kurt, 1984; Dalrymple, 1971). Specific intercropping systems have developed over the centuries in the different regions and they are closely adapted to the prevailing ecological and socio-economic conditions. Cassava may be grown in pure stand but is commonly grown in mixture with other crops, especially maize (*Zea mays*), yam (*Dioscorea* spp), 'egusi' melon (*Colocynthis citrullus*) and vegetables (Okigbo and Greenland, 1976)

Weed infestation is a constraint in cassava production, and the control is currently the cornerstone of increased production in Nigeria. Weed control is by far the most labour-demanding field operation in cassava production. Cassava is generally susceptible to weed infestation because of its initial slow growth after planting (Alabi, 1997). Like many other crops grown in the tropics, cassava is susceptible to early weed competition during the first 3 to 4 months after planting. Weed competition reduces canopy development, tuberization, tuber number and weight. It also predisposes the crop to pest and disease infestation. Reduction in tuber yield as a result of weed competition varies from 40% in the early branching varieties to nearly 70% in the late or non-branching varieties (IITA, 1990). Absence of weed control in crop farm resulted to crop losses of up to 100% (Nyam, 2005). For full expression of its genetic potentials and improvement in yield capacities, one of the operations in cassava production is weed management (Madukwe, 2000). Hand weeding is probably the oldest method of weed control and consists of hand-pulling, hand-slashing and hoeing which have consistently proved inefficient and costly too. In technologically advanced countries, hand-pulling is used merely to supplement other improved weed control methods (Kerkhoven, 2003). The use of herbicides for weed control in cassava have not only been found effective, but have been proven to be cheap if applied timely and correctly (Chikoye et al., 2001). Similarly, Chikoye et al. (2002) have shown that chemical control in cassava was cheaper than hoe weeding. Among pre-emergence herbicides, atrazine and metolachlor at 2.5 kg a.i./ha, fluometuron at 2.0 to 3.0 kg a.i./ha or diuron at 2.0 kg a.i./ha used singly or in combination with alachlor or metolachlor at 3.0 and 2.0 a.i./ha respectively have proved effective for weed control in cassava in the humid tropics (Akobundu, 1980). All of these herbicides were also listed as the common herbicides for weed control in cassava based cropping system in the middle belt of Nigeria.

The use of intercrop to smother weeds has been successful (Rao and Shetty, 1976). Recent studies have also addressed intercropping as an option for an integrated weed management, particularly in farming systems with low external inputs (Liebman, 2000; Schoof and Entz, 2000; Rana and Ral, 1999). It seems when used in conjunction with correct timing of hoe-weeding, the practice could prove satisfactory to small-holder farmers. Its appeal is enhanced by the added food value obtained from the component crops. The choice of the method must, however, be based on the optimum economic returns and resources available. This study was designed to assess weed management options and intercrop combination for cassava production in Kogi State.

METHODOLOGY

The study area is Kogi State, located in the middle belt of Nigeria. It lies between latitude 6°30'N and 8°51'N and longitude 5°51' and 8°00' E. A multi stage randomized sampling technique was used in selecting 450 cassava farmers from the three agricultural zones in the state. In the first stage, five local government areas in each zone were purposively selected. In the second stage, five communities were randomly selected in each local government area. Finally in the third stage, 6 farmers were randomly selected from each community for detailed study. The major crops produced in the state include; cassava, yam, maize, guinea corn, melon, pigeon pea, rice, sugarcane, and plantain/banana. However, maize, melon, okra and pepper were the most frequent crops implicated in the intercrop with cassava. The choice of weed management technique depended on the component crop for intercrop with cassava; and according to the farmers will also inform on the choice of herbicides. Majority of the farmers planted their cassava on heaps. Plant population in the farmers' fields varied from 6,667 to 15,000 plants/ha, and the spacing often depends on the availability of cassava stems and heap spacing. The herbicides listed by farmers as been used in cassava based cropping system were. Primextra Gold®(Atrazine 370 g + S-metolachlor 290 g per litre), Galex®(Metobromuron 250 g + Metolachlor 250 g per litre), Cotoran multi® 500EC (Fluometuron 250 g + metolachlor 250 g per litre), Codal Gold® 412.5DC (250 g prometryn +162.5 g per litre) and Fusilade Forte® 150 EC (150 g Fluazifop-p-butyl per litre) and Dual Gold® (960 g S-metolachlor per litre). However, most frequently mentioned herbicides Primextra Gold, Galex and Fusilade Forte. Majority of the farmers own knapsack sprayers (CP 15, CP3 and Jackto models), and the herbicides were applied pre- emergence at the recommended rates of between 3 to 5 L/ha with the knapsacks delivering a spray volume of between 200 to 250 L/ha. The predominant weeds were *Panicum maximum* Jacq., *Bracharia lata* (Schumach) C.E. Hubbard, *Chloris pilosa*. Schumach, *Pennisetum polystachion* (L.) Schult*, Bracharia deflexa* (Schumach) C.E. Hubbard*, Imperata cylindrical* (L.) Raeuschel*, Commelina benghalensis* L.*, Tridax procumbens* L.*, Ageratum conyzoides* L.*, Panicum repens* L., *Mariscus alternifolius* Vahl, *Digitaria horizontalis* Willd.*, Andropogon tectorum* Schum. & Thonn., and *Mimosa invisa* Mart.

Cassava yield was determined by sample harvest taken from two diagonal transects of 25 m^2 area from five farmers in each community.

Analytical procedures

The log-linear model derived from the Cobb-Douglas functional form was the econometric model specified for explaining yield of cassava from plots treated with any of the herbicides mentioned above and plots without herbicides (Ukoha, 2000). This functional form is the most popular in applied research because it is easiest to handle mathematically (Koutsoyiannis, 1979). Evidence from most studies depicts that the Cobb-Douglas functional form gives the best results than other functional forms. It is only when satisfactory results are not obtained from this model that other forms will be tried out (Ukoha, 2000). The model is described thus:

$$Y = a_0 + a_1 \ln Z_1 + a_2 \ln Z_2 + a_3 \ln Z_3 + a_4 \ln Z_4 + a_5 \ln Z_5 + a_6 \ln Z_6 + a_7 \ln Z_7 + a_8 \ln Z_8 + a_9 \ln Z_9 + a_{10} \ln Z_{10} + a_{11} \ln Z_{11} + a_{12} \ln Z_{12} + a_{13} \ln Z_{13} + a_{14} \ln Z_{14} + a_{15} \ln Z_{15} + e$$

Where:
Y = Cassava output in kg
Z_1 = Sex (dummy variable; male=1, female=0)
Z_2 = Age of farmer in years
Z_3 = Educational level of farmer in years
Z_4 = Marital status (dummy variable; married=1, single=0)
Z_5 = Household Size
Z_6 = Farming experience in years
Z_7 = Variety planted (dummy variable; 1=branching, 0=non-branching)
Z_8 = Weeding frequency in numbers
Z_9 = Herbicide application (dummy variable; 1=yes, 0=no)
Z_{10} = Hand weeding (dummy variable; 1=yes, 0=no)
Z_{11} = Slashing (dummy variable; 1=yes, 0=no)
Z_{12} = Intercrop with maize (dummy variable; 1=yes, 0=no)
Z_{13} = Intercrop with melon (dummy variable; 1=yes, 0=no)
Z_{14} = Intercrop with okro (dummy variable; 1=yes, 0=no)
Z_{15} = Intercrop with pepper (dummy variable; 1=yes, 0=no)
e = error term
a_1 to a_{15} = Coefficients to be estimated
In = natural logarithm
Yield (tons/ha) = Sample output (kg) × 10 / Area harvested (m^2)

RESULTS AND DISCUSSION

A total of 450 farming households were surveyed; 73% of the respondents were male and 27% were female (Table 1). The percentage of the farmers who by age (≥ 41years) were considered active were more than 45%, while 6% were below the age of 30 years. However, 49% of the population was made up of farmers who were within the age range of 41 years and above (Table 1). Majority (57%) of the respondents had primary school education, while 33% had no formal education and only 9% had secondary education. Majority (89%) of the farmers were married while less than 5% were single, divorced or widowed. The average household size was about 6 persons, ranging from 3 to 15 persons. Only 0.6% has a fairly large household size of 12 to 15 members that could be a source of labor. In the study area, farming was in the hands of those with more than 10 years of farming experience. However, the average number of years of farming was about 25.5 years. Only about 3% of the population had cassava growing experience greater than 31 years. Land acquisition in Kogi State was 100% by inheritance, and the entire population involved in cassava production in the state grew their crops on ridges. Forty-five percent of the respondents grow cassava on farms ranging between 3.5 and 4.0 ha.

Determinants of cassava yield as influenced by weed management strategies and intercrop combinations

Table 2 shows the regression analysis of the determinants of cassava yield as influenced by weed management strategies and intercrop combinations on cassava yield in Kogi State. The study found age, to be negatively and significantly ($p \leq 0.5$) related to yield of cassava. This implies that increasing age would lead to decreased yield in cassava. This result agrees with earlier and similar studies (Okoye et al., 2007; Ajibefun and Aderinola, 2004) who found out that ageing farmer would be less energetic to work, and may be reluctant to adopt herbicide technology.

Education, use of herbicides, hand weeding, slashing and intercrop with melon had a positive relationship with cassava yield at 1.0% level of probability. Education might be regarded as a factor for increased output. This implies that any increase in education, would increase output. Generally education is thought to create a favorable mental attitude for the acceptance of new practices especially those of information-intensive and management-intensive practices (Waller et al., 1998; Caswell et al., 2001). These management practices include; use of herbicides, weeding, slashing and intercrop with melon.

The coefficients for household size, farming experience and intercrop with okra had a positive relationship with cassava yield at 10% level of probability (Table 2, Figure 1). Larger households are more likely to provide the labor that might be required by improved weed control technologies. In addition, a larger household size would be expected to increase the probability of adopting improved weed control technologies. Effiong (2005) reported that a relatively large household size enhances the availability of labor.

The coefficients for marital status, variety (branching and non-branching), weeding frequency, maize and pepper intercrop were positive but not significant.

Table 1. Socio-economic characteristics of the cassava farmers in Kogi State.

Variable	Frequency	Percentages
Gender		
Male	328	72.9
Female	122	27.1
Age range		
21-30	29	6.4
31-40	202	44.9
41 and above	219	48.7
Educational level		
Non-formal	149	33.1
Primary	258	57.3
Secondary	42	9.3
Tertiary	1	0.2
Marital status		
Single	18	4.0
Married	401	89.1
Divorced	15	3.3
Widowed	16	3.6
Household size		
0-3	161	35.8
4-7	260	57.9
8-11	26	5.8
12-15	3	0.6
Farming experience		
1-10	50	11.1
11-20	251	55.8
21-30	135	30.0
31-40	12	2.7
41 and above	2	0.4
Farm size		
0.5-1.0	112	24.8
1.5-2.0	128	28.4
2.5-3.0	7	1.6
3.5-4.0	203	45.1

Source: Field survey, 2009.

The results in Table 3 show the unpaired t-test statistics between the yields of cassava on plots where farmers applied herbicides and plots where farmers did not use herbicides. The survey result indicated that there was a significant yield difference between those who used herbicide and those who did not use herbicides. Majority of the surveyed farmers (62.4%) did not use herbicide for weed control in cassava , while the farmers (37.6%) that used herbicide however, had 14.6% yield advantage compared to those that did not use herbicide (Table 3). Some of the reasons advanced for non herbicide use included: ignorance on the part of the farmers, lack of training on its use, cost of sprayer, non-availability of these chemical at most of the rural markets, fear of damage to crop and the general attitude of farmers towards change. The mean yield of cassava for farmers who applied herbicides and farmers who did not apply herbicide was 8,198.74 and 6,999.004 kg/ha,

Table 2. Regression analysis of the determinants cassava yield in Kogi State.

Variable	Parameter	Coefficient	Standard error	t-value
Constant term	a_0	8.5904	0.6432	13.36***
Sex	a_1	0.0990	0.1833	0.54
Age	a_2	-0.0365	0.1721	-2.12**
Education	a_3	0.4522	0.1322	3.42***
Marital status	a_4	0.0215	0.1889	0.11
Household size	a_5	0.0761	0.0447	1.70*
Farming experience	a_6	0.2679	0.1368	1.96*
Cassava variety grown	a_7	0.1823	0.1613	1.13
Weeding frequency	a_8	0.1813	0.1663	1.09
Herbicide application	a_9	1.3213	0.2787	4.74***
Hand weeding	a_{10}	1.1504	0.3832	3.00***
Slashing	a_{11}	0.6859	0.2564	2.68***
Intercrop with maize	a_{12}	0.1241	0.2024	0.61
Intercrop with melon	a_{13}	1.2005	0.4106	2.92***
Intercrop with okra	a_{14}	0.5640	0.3161	1.78*
Intercrop with pepper	a_{15}	0.8344	1.7329	0.48
R^2		0.6519		
F-ratio		7.3728		

Source: SPSS survey data, 2009. *, ** and *** = significant at 10, 5 and 1%, respectively.

Table 3. Unpaired *t*-test statistics between the yields of cassava (Kg ha^{-1}) on plots applied with herbicides and plots without herbicides.

Variable	Observation	Mean	Standard error	Standard deviation
No herbicide	281	6999.004	107.3395	1799.338
Herbicide	169	8198.74	115.5777	1502.51
Combined	450	7449.571	84.35371	1789.412
Difference		-1199.736	157.734	
Degrees of Freedom	402.93			

Table 4. Unpaired *t*-test statistics between the yields of cassava (Kg ha^{-1}) on intercropped plots and plots without intercrop.

Variable	Observation	Mean	Standard error	Standard deviation
No intercrop	322	7164.746	96.36626	1729.231
Intercropped	128	8166.086	154.093	1729.231
Combined	450	7449.571	84.35371	1789.412
Difference		-1001.34	181.7446	
Degrees of freedom	233.263			

respectively. The t-statistics was 7.606 while the probability level for t was at 1.0%

Similarly, 28.4% of the farmers who intercropped cassava with other crops had 12.3% yield advantage compared to 71.5% of the farmers who did not intercrop cassava with any other crop (Table 4 and Figure 1). The mean yield of cassava for farmers who used intercrop and farmers who did not intercrop cassava was 8,166.09 and 7,164.75 kg/ha, respectively. The t-statistics was 5.509 while the probability level for t was at 1.0%.

In cassava, weed control with herbicides (pre-emergence and post-emergence herbicides) is feasible even at the smallholder farm level according to the respondents.

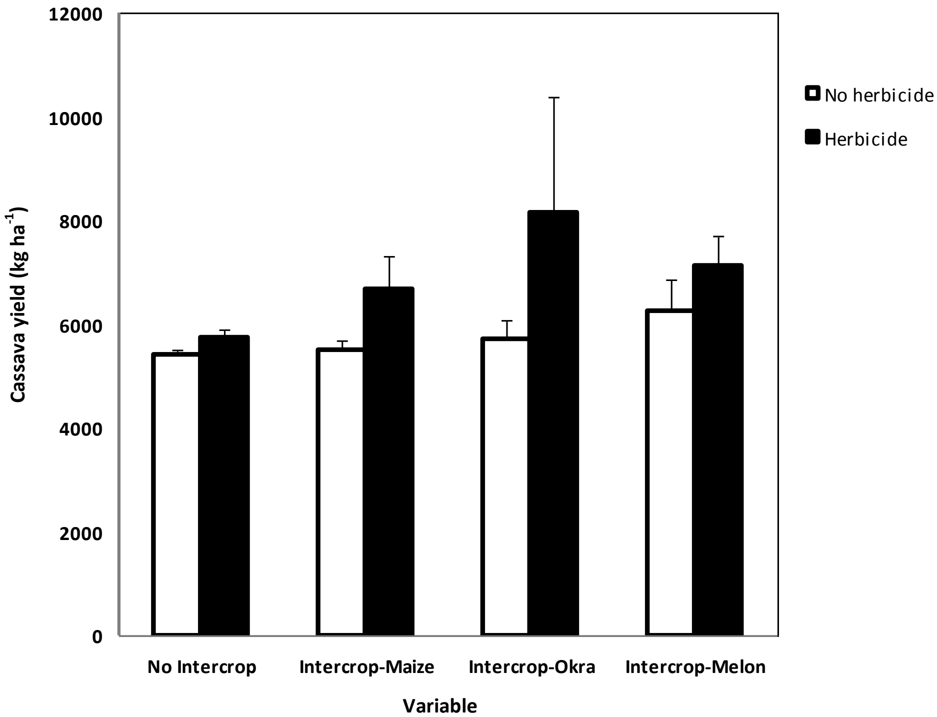

Figure 1. Cassava root yield in intercrop with and without Herbicide. Vertical bars are the standard errors of the mean.

Herbicides are likely to become increasingly important as a means of weed control in cassava especially where labor is in short supply or is expensive and where farm size is large. With the issue of food security and industrial potentials of cassava the use of herbicides or its integration with other option such as the use of melon and okra for weed control will sustain productivity and product for cassava based industries. However, for adequate crop safety farmers require good knowledge of herbicides activity in relation to cassava based cropping systems. The use of herbicides may lead to increased farmer holding with associate increase in productivity. However, productivity without adequate market and processing infrastructure, may lead to glut and loss of income. Hand weeding and slashing will continue to be expensive, as well as the drudgery associated with it especially, where farmers cannot afford alternative means like herbicides. This will lead to low productivity, and this will impact negatively on food security and farmers livelihood. Intercrop with melon and okra without herbicide will have limited weed control benefit, because both crops are short season crops and once harvested exposes the cassava to weed competition. However, when integrated with herbicide will provide long lasting weed control.

Conclusion

All factors directly related to cassava productivity should be directly aimed at encouraging the youths who are agile and stronger to adopt weed management strategies in cassava production. Free education could be advocated to enable them enhance their capacity to adopt new innovations in cassava production and weed management. Awareness among the farmers is a primary tool towards the adoption or use of any modern technology. Hence, a well established and functional extension system is needed to educate farmers on the appropriate skills required to use and apply herbicides correctly to minimize damage to crop and the associated health and environmental hazards. Intercropping has the potentials of providing year-round ground cover in crop production, and its importance as a tool for weed management in small farm-holding can be boosted withn the integration of herbicide. However, to harness this attributes of intercropping farmers need to know compatible crop mixtures, population, spatial arrangement and appropriate sequences of planting to minimize interplant competition and achieve ground cover for a prolonged period.

REFERENCES

Alabi JYM (1997). Junior Agriculture-An Introduction to Agricultural Science, Africana Educational Publishers, Onitsha, 10 pp.

Ajibefun IA, Daramola AG (2004). Efficiency of Micro Enterprises in the Nigerian Economy. AERC Research paper 134. African Economic Research Consortium, Nairobi.

Agwu AE, Anyaeche CL (2007). Adoption of Improved Cassava

Varieties in Six Rural Communities of Anambra State, Nigeria. Afr. J. of Biotechnol., 6: 089-098.

Ayeni AO (2000). Hand/Mechanical Weed Management as an Option in Nigerian Agriculture. Niger. J. Weed Sci., 4: 71-77

Caswell M, Fuglie K, Ingram C, Jans S, Kascak C (2001). Adoption of Agricultural production practices: Lessons learned from the US. Department of Agriculture area studies project. US Department of Agriculture, Washington, DC. Resource Economics Division, Economic Research service [2001] Series: Agric. Econ. Report, p. 792.

Chikoye D, Ekeleme F, Udensi UE (2001). Cogongrass suppression by intercropping cover crops in corn/cassava systems. Weed Sci., 49: 658-667.

Chikoye D, Manyong VM,.Carsky RJ, Ekeleme F, Gbehounou G, Ahanchede A (2002) . Response of speargrass [*Imperata cylindrica* (L.) Raeuschel] to cover crops integrated with handweeding and chemical control in maize and cassava. Crop Prot. 21: 145–156.

Dalrymple DG (1971). Social and economic aspects. In Survey of multiple cropping in less developed nations. U.S. Department of Agriculture, Washington, DC. Economic. Research. Service, Foreign Agricultural. Economic. Report. 91: 37-59.

Effiong EO (2005). Efficiency of production in selected livestock enterprise in Akwa-Ibom State, Nigeria. unpublished Ph.D Dissertation. Department of agricultural economic, Michael Okpara University of agriculture, Umudike, p. 120.

Ezulike TO, Nwosu KI, Udealor A, Eke- Okoro ON (2006). *Guide to Cassava Production in Nigeria. Extension Guide No. 16*. National Root Crops Research Institute, Umudike, Nigeria, p. 10.

FAO (2007). Food and Agriculture Organization, Database Results, FAO 2007..

Gomez AA, Gomez KA (1986). Multiple Cropping in the Humid tropics of Asia. IDRC. Ottawa Ontario, 13 pp.

IITA (1990). International Institute of Tropical Agriculture: Cassava in Tropical Africa: A reference manual. Chayce Publication Services, United Kingdom, 176 pp.

Ikeorgu JEG (1983). Micro-Environmental Changes under Cassava (*Manihot esculanta* Crantz) Maize (*Zea mays*) Intercrops growth with Okro (*Abelmoschus esculentus* L) and Melon (*Colocynthis vulgaris* L) A Ph.D thesis.

Ikeorgu JEG, Iloka AW (1994). On-farm Evaluation of the Effects of Three Contrasting Maize Varieties on the Productivity of Cassava/Maize Intercrop in South-Eastern Nigeria. In: Proceedings of the fifth triennial symposium of the International Society of Tropical Root Crops, Africa Branch, Kampala, Uganda, 22(28): 243-246.

Ibeawuchi II (2007). Intercropping - A Food Production Strategy for the Resource Poor farmers. Nat. Sci., *5*:1-14

International Institute of Tropical Agriculture (IITA) (1990). The research horizon for cassava as a cash crop. Annual Report, pp. 9-11

Koutsoyiannis A (1979). Modern Microeconomics, 2nd (ed), (London and Basinagstoke): The Macmillan Press Ltd., p. 75.

Kurt GS (1984). Intercropping in Tropical Smallholder Agriculture with Special Reference to West Africa. GTZ, pp. 1-233.

Kerkhoven GJ (2003). Effect of Efficient Weeding on Yields or Irrigated Cotton in Eastern Kenya PANS, 16: 596-605.

Liebman M, Davis AS (2000). Integration of soil, crop and weed management in low-external-input farming systems. Weed Res., 40: 27-47

Nweke FI (1994). Farm level practices relevant to cassava plant protection. Afr. Crop Sci. J., 2: 563-582

Nyam T (2005). Opening address: In Chikoye, D., J. Ellis-Jones, A. F. Lum, G. Tarawali and T. Avav (editors):Reducing Poverty through improved *Imperata* control. Proceedings of the second *Imperata* management stakeholders' conference, held in Makurdi, Benue State, Nigeria, 14-15 September 2004, IITA, Ibadan, Nigeria, p. 119.

Okigbo BN (1978). Cropping Systems and Related Research in Africa. AAASA occasional publications series.

Okigbo BN (1982) Farming System Research, An overview of its definitions, concepts and scope. Paper presented at the training workshop on farming system research NIFOR, Benin, Nigeria.

Okigbo BN Greenland DJ (1976). Intercropping Systems in Tropical Africa. In. R. L.Papendick, A.Sanchez and G.B. Triplet (editors). Multiple Cropping ASA. Special publication No. 27 Madison W.I. USA, pp. 63-101.

Okoye BC, Onyenweaku CE, Asumugha GN (2007). Allocative Efficiency of Small-Holder Cocoyam Farmers in Anambra State, Nigeria. Niger. Agric. J., 38: 70-81

Papendick RL, Sanchez PA, Triplett GB (1976). Multiple Cropping ASA Special Publication. 27, Am. Soc. Agronomy Madison, USA.

Rana KS, Pal M (1999). Effect of intercropping systems and weed control on crop-weed competition and grain yield of pigeon pea. Crop Research 17: 179-182.

Rao MR , Shetty SVR (1976). Some biological aspect of intercropping systems on crop-weed balance, Indian J. Weed Sci., 8: 32-43.

Wahua TAT (1982). Cropping Systems Research in Tropical Africa. Paper presented at the Federal University of Science and Technology. Training Workshop on Farming Systems NIFOR Benin, July 30 – August 5, 1982.

Waller BE, Hoy CW, Henderson JL, Stinner B, Welty C (1998). "Matching Innovations with Potential Users: A Case Study of Potato IPM practices." Agric. Ecosyst. Environ., 70: 203-215.