IMPACT OF TECHNOLOGICAL CHANGE ON OUTPUT OF POTATO PRODUCTION IN PLATEAU STATE, NIGERIA.

ANIEDU O.C[1]. AND ONYENWEAKU C. E[2].

[1]National Root Crops Research Institute, Umudike, P M B 7006, Umuahia, Abia State, Nigeria.
[2]Michael Okpara University of Agriculture, Umudike P M B 7267, Umuahia, Abia State, Nigeri**a.**

ABSTRACT

This study assessed the impact of technological change on output, of potato in Plateau State, Nigeria. It was carried out in four Local Government Areas Jos south, Bokkos, Mangu and Barkin Ladi were purposively randomly selected from eight noted for potato production. The sample size was 240 households but only 182 were used in the analysis of the data. The primary data were collected using structured questionnaire and data were collected forthnightly. Two improved potato varieties (Nicola and Lady Christy) and one local variety (Empi) were used in this study. The production systems were Furrow/Flood Irrigation and Manual watering. Cobb-Douglas production functions were estimated for the potato varieties and production systems. Chow's test's were carried out to test for structural shifts in production functions, for production system and varietal effects, homogeneity of slopes and differences in intercepts. The results showed that under Furrow/Flood Irrigation Production System, R^2 was 0.48 for Lady Christy, 0.60 for Empi, 0.29 for Lady Christy and 0.21 for Nicola. The coefficients of the variety dummy variable were positive and statistically significant at 5% level, indicating that Nicola and Lady Christy gave higher yields than Empi (Local variety). The coefficients of the production systems dummy variables were not significant even at 10% level, so there was no difference between the yields of the improved varieties and the local variety in the two production systems. Covariance analysis for the three potato varieties grown in the two potato production systems were statistically significant at 10% level. The introduction of Nicola and Lady Christy caused a shift upwards of the Empi (Local variety) production function. There was homogeneity in the slopes of the production functions and so confirmed that the potato production functions were factor neutral. There was a decreasing returns to scale for almost of the production functions.

KEYWORDS*: Technological change, output of potato, Production function.*

INTRODUCTION

Background Information

Potato (*Solanum tuberosum* .L) which originated in South America was first introduced into Nigeria in the later part of the 19th century and early 20th century by Europeans, notably the tin miners in Jos Plateau and the Germans in the Cameroons (Stanton, 1960, Ifenkwe, 1981).

Early potato production in Nigeria was centered around Zaria and Plateau provinces,. Annual production was however low until the beginning of the second World War in 1944, (William, 1962). Plateau Province accounted for about 67% of the total potato production in 1944. After World war two, production did not substantially increase until 1973 (Okonkwo *et al* 1995a). After 1960, there was an attempt by the post colonial government of Nigeria to increase potato production. Seed tubers were imported from the United Kingdom by the then Ministry of Agriculture, Northern Region in collaboration with the Pankshin Native Authority for distribution to selected farmers. As demand for seed increased, a seed multiplication scheme was established by the Ministry of Agriculture, Jos and Pankshin Native Authority. This seed multiplication scheme contributed to increased potato production recorded in the early seventies. However, the varieties imported were low yielding and susceptible to major diseases and pests of potato in the area.

Potato is a tuber crop, grown in high altitude areas with low temperatures. The high altitude areas for potato production in Nigeria are the Jos plateau (1400m) in Plateau State, Mambilla Plateau (1800m) in Taraba State,

Biu Plateau (800m) in Borno State and Obudu Hills in Cross River State(Ugwu *et al*, 1998).
The major potato producing areas in Plateau State include the following Local Government Areas: Jos East, Jos North, Jos South, Bassa, Mangu, Barkin Ladi, Bokkos and Pankshin. Okonkwo *et al* 1995a, stated that the potato crop is the most efficient tuber crop in Nigeria in terms of tuber yield and number of days to maturity. It matures in about 80-90 days and yields of 15 to 30 tonnes per hectare have been reported in farmers' fields. Since it has short maturity period, two or more crops of potato are possible in a year, making it the highest yielding tuber crop in the country.

Statement of Research Problem
Potato production was introduced into Jos Plateau Nigeria in the 1940's by the colonial government (Stanton, 1960; Ifenkwe, 1981). Since then, potato production is in the hands of small holder farmers. These farmers obtain an average of 4.65t/ha which is about 40% of the potential tuber yield obtained in research fields. Reasons for the relatively low net return per hectare of potato on small-holder farms include: land area cultivated, low soil fertility, poor management practices, prevalence of pests and diseases, poorly organized seed supply and tuber storage problems (Fawole and Akoroda, 2000).
To address the problem of potato production in Nigeria, the potato programme of National Root Crops Research Institute, Umudike was established at Kuru, Jos in 1976. (Okonkwo *et al* 1995a). According to Ifenkwe (1981) and Okonkwo (1992), farmers yields have progressively increased from 5 tonnes per hectare in 1973 to about 10 tonnes per hectare in 1986. The improved yields reflect the gains which have been made over the years in breeding and selection for high yielding varieties with resistance to major pests and diseases, improved quality of planting materials and better husbandry practices in Jos plateau.
Srivastava and Heady (1977), observed that new technology in agriculture (high yielding varieties, mechanical aids etc) is never adopted simultaneously by all farmers. They also discovered that the application of biochemical innovations tends to reduce the inequality in the distribution of income of rural areas. This is due to the fact that the technology is scale-neutral and thus can be used by both small and large farmers. In addition, this type of technology is labour-using in nature and thus tends to increase the demand for labour and also the share of income going to labour. The extent to which the benefits of biochemical innovation are widely distributed depend on two factors: (a) the distribution of land ownership and (b) the impact of innovation on the demand for labour. (Grabowski, 1987).

Objectives
The objectives of the study were to estimate and examine production functions for potato under different production systems in the study; Investigate if there was any structural shift in production functions between production systems and potato varieties. Additionally it was to determine whether the technological change introduced by production systems and potato varieties is factor neutral or factor biased.

Hypotheses
The following hypotheses were tested:
(i) There is an absence of structural shift in production functions between production systems and potato varieties.
(ii) The production of different potato varieties under different production systems is factor-neutral.
(iii) The production functions are operating at constant returns to scale.

METHODOLOGY
The Study Area
The study was carried out in Plateau State. Jos Plateau is located between Longitude 8°40' and 9°50'E and latitude 9° and 10°45'N. It is almost at the centre of Nigeria and has borders with Bauchi State in the North-East, Kano State in the North, Kaduna State in the North-West. In the South, it has boundary with Benue and Taraba

States. (Okonkwo *et al.*, 1995b).
Jos Plateau's elevation ranges from 1,100m 1400m above sea level and is the second highest highland in Nigeria after the Mambilla Plateau (1800m). The highest temperatures of about 30°C are recorded in the months of March to May each year while the lowest temperatures of about 20°C are between December and January. Potato requires an optimum temperature of 10°C for tuberization. Jos Plateau meets this condition in both the rainy and dry seasons. In the dry season, potato is planted in late October or early November to take advantage of the low December and January
temperatures for tuberization. Generally, potato is planted between the last week of April and end of May each year (Okonkwo *et. al*., 1995b).

Sample Size and Sampling Technique
A total of 240 farm households were chosen randomly from four Local Government Areas out of eight that make-up Jos Plateau. ie, Barkin Ladi, Jos South, Mangu, and Bokkos. Jos Plateau was purposively chosen because potato is the most important crop grown there. First, four Local Government Areas were randomly selected from the eight in Jos Plateau. Then two villages were randomly selected from each Local Government Area. Lastly, thirty households were randomly selected from each village. The sampling frame was the list of potato farmers for each Local Government Area/Village selected, obtained from the Plateau State Agricultural Development Programme (PADP).

Method of Data Collection
Primary data were collected using structured questionnaire, which was distributed to the respondent farm households by the Extension Agents in the four Local Government Areas selected for the study. Data were collected from the households fortnightly by the eight Extension Agents involved in the data collection for this study. Data collection lasted from 7th November, 2005 to 3rd May, 2006. However, only 182 potato farmers responded to my interview.

Production Function Estimation
Following Onyenweaku (1997), four Cobb-Douglas production functions were specified for potato as:

$$LnY_o = a_o + a_1LnX_1+a_2lnX_2+a_3lnX_3+a_4ln_4+a_5lnX_5+e_1 \quad \text{---------- 1}$$
$$LnY_N = b_o+b_1lnX_1+b_2lnX_2+b_3lnX_3+b_4lnX_4+b_5lnX_5+ e_2 \quad \text{----------2}$$
$$LnY_p = c_o+c_1lnX_1+c_2lnX_2+c_3lnX_3+c_4lnX_4+c_5lnX_5+e_3 \quad \text{----------3}$$
$$LnY_p = d_o+d_1lnX_1+d_2lnX_2+d_3lnX_3+d_4lnX_4+d_5lnX_5+d_6D+e_4 \quad \text{----------4}$$

Where :

Ln	=	Natural logarithm
Y	=	Yield of potato (kg/ha)
X_1	=	Weight of potato seed (kg/ha)
X_2	=	Fertilizer input (kg/ha)
X_3	=	Labour input (Mandays/ha)
X_4	=	Capital input (N/ha)
X_5	=	Farm size (Hectare)

Capital input comprise depreciation charges on agricultural tools and equipment, repair and operating expenses on implements, costs of machine hire and interest charges. D is the production system or variety dummy variable which takes the value of unity for one system or variety and zero for another production system or variety. a_1 a_5, b_1 b_5, c_1 c_5, and d_1 d_5 are the regression parameters to be estimated, i.e. is the stochastic

term and the subscripts O, N and P stand for old production system or potato variety, new production system or potato variety and the pooled data respectively.

RESULTS AND DISCUSSION

Estimation of Potato Production Functions.

The production function equations for potato varieties under different production systems estimated by the method of ordinary least squares are presented in Table 1.

Under Furrow/Flood irrigation production system, the production functions show that the proportion of the total variation in yield or productivity accounted for by the combined effects of the explanatory variables. The R^2 value was 0.48 for Lady Christy, 0.46 for Empi and 0.15 for Nicola. Only the coefficients of seed potato and fertilizer were statistically significant in all the equations.

For the pooled data with variety dummy, the co-efficient of the dummy variable was positive and statistically significant at 10 percent, indicating that Nicola and Lady Christy gave higher yields than Empi (Local variety) under Furrow/Flood irrigation production system.

Under Manual watering production system, the production function showed that the proportion of the total variation in productivity accounted for by the explanatory variables. The R^2 value was 0.60 for Empi, 0.29 for Lady Christy and 0.21 for Nicola. Variables with statistically significant coefficients were seed potato and fertilizer. The coefficient of the dummy variable was positive and statistically significant at one percent, indicating that Nicola and Lady Christy gave higher yields than Empi (Local variety) under Manual watering production system.

Finally for Empi (Local Variety) grown under both Furrow/Flood irrigation and Manual Watering production systems, the production functions for the pooled data showed that 43 percent of the total variation in productivity are respectively accounted for by the explanatory variables.

The coefficient of the dummy variable was positive but not significant even at 10% level, indicating that Empi (Local variety) gave the same yield in Furrow/Flood irrigation and Manual watering production systems. The coefficient of seed potato was significant at 1 percent while those of fertilizer and Farm size were significant at 10 percent.

Table 1 Estimated Production Functions For Different Varieties of Potato Under Various Production Systems

Production System	Variety	Sample Size	Intercept	Seed LnX_1	Fertilizer LnX_2	Labour input LnX_3	Capital Size LnX_4	Farm LnX_5 D	R^2	F-Calculated
Furrow/Flood irrigation	Nicola	32	8.749** (2.274)	0.058 (0.282)	0.265 (1.111)	-0183 (-0.785)	-0.242 (-1.150)	-0.146 (-0.704)	0.143	0.871
Furrow/Flood irrigation	Christy Lady	30	-4.030 (-1.347)	0.343** (2.280)	0.708*** (3.379)	-0.047 (-0.279)	-0.011 (-0.069)	-0.236* (-1.283)	0.482	4.469***
Furrow/Flood irrigation	Empi(Local)	30	1.098 (0.554)	0.287* (1.379)	0.226 (1.064)	0.274* (1.719)	0.314** (2.035)	0.002 (0.009)	0.462	4.116***
Furrow/Flood Irrigation pooled		92	0.659 (0.404)	0.204** (1.946)	0.331*** (2.910)	0.094 (0.918)	0.065 (0.669)	-0.157* (-1.575)	0.250	5.742***
Furrow/Flood Pooled with Variety Dummy		92	1.679 (0.996)	0.171** (1.641)	0.265** (2.273)	0.103 (1.016)	0.053 (0.550)	-0.082 (-0.780)	0.206** (1.971)	0.283 5.593***
Manual watering	Nicolas	30	5.423** (1.994)	0.266 (1.290)	-0.083 (-0.407)	0.155 (0.739)	0.062 (0.281)	0.198 (0.875)	0.208	1.260
Manual watering	Christy Lady	30	3.132 (1.085)	0.225 (1.147)	0.554*** (2.808)	-0.220 (-1.095)	-0.059 (-0.316)	0.110 (0.573)	0.292	1.979

Impact Technological change Potato production

Manual watering Empi(Local)	30	-1.590	0.611***	0.323**	-0.090	-0.192	-0.217*	0.600	7.204***
		(-0.570)	(3.811)	(1.843)	(-0.643)	(-1.242)	(-1.506)		
Manual watering Pooled	90	-49.101**	0.180**	0.302***	0.067	0.141*	0.081	0.148	2.920***
		(-1.649)	(1.770)	(2.973)	(0.618)	(1.362)	(0.723)		
Manual watering Pooled with	90	-31.267	0.122	0.295***	- 0.025	0.091	0.014	0.332***	0.233 4.211***
Variety Dummy		(-1.078)	(1.229)	(3.034)	(-0.228)	(0.906)	(0.124)	(3.039)	
Furrow/Flood and Nicolas Manual watering Pooled	62	6.311***	0.135	0.022	0.090	-0.019	-0.033	0. 338	0.442
		(2.668)	(0.928)	(0.146)	(0.620)	(-0.130)	(-0.221)		
Furrow/Flood and Nicolas Manual watering with production system Dummy.	62	6.332***	0.151	-0.001	0.134	-0.068	0.041	0.178	0.461 0.598
		(2.706)	(1.033)	(-0.006)	(0.899)	(-0.450)	(0.251)	(1.168)	
Furrow/Flood and Christy Manual watering Lady Pooled	60	-0.191	0.032***	0.506***	0.036	-0.131	0.041	0.358	6.03***
		(-0.096)	(2.803)	(4.397)	(0.288)	(-1.130)	(0.360)		
Furrow/Flood and Christy Manual watering with production system Lady Dummy	60	-0.224	0.296***	0.542***	-0.045	-0.008	-0.014	-0.303***	0.422 6.455***
		(-0.118)	(2.696)	(4.877)	(-0.368)	(-0.069)	(-0.121)	(-2.421)	
Furrow/Flood and Empi Manual watering (Local) Pooled	60	0.453	0.459***	0.247**	0.025	0.132	-0.190**	0.428	8.086***
		(0.296)	(3.540)	(1.920)	(0.233)	(1.235)	(-1.727)		
Furrow/Flood and Empi Manual watering with production system (Local) _dummy	60	0.319	0.456***	0.262**	0.028	0.119	-0.202**	0.032	0.429 6.629***
		(0.193)	(3.473)	(1.809)	(0.252)	(0.981)	(-1.645)	(0.234)	

Source: Field Survey 2006. ***Significant at 1% level ** Significant at 5% level * Significant at 10% level t-value in parentheses

Tests for Production System and Varietal Effects.

(a) Test for Production System Effect:

The results of the statistical tests for difference in production systems for the different potato varieties are presented in Table 2.

The calculated Chows F-statistics 8.529, 9.783 and 14.640 were significant at one percent for Nicola Lady Christy and Empi (Local variety) grown in the two production systems.

This implies that the production functions of the three potato varieties differ significantly in the two production systems. This indicated that there was a structural break or shift in potato production in Plateau State. The introduction of new potato varieties (Nicola and Lady Christy) caused a structural break in production relations and shifted the Empi (Local variety) production function.

(b) Test For Varietal Effects In Potato

Tests for varietal effects are shown in Table3. For Nicola, Lady Christy and Empi (Local Variety) grown under Furrow/Flood irrigation production system, the calculated Chow's F-ratios were 6.058 and 18.03 which were statistically significant at one percent. This implies that there were significant differences between the production functions of Nicola. Lady Christy and Empi (Local Variety) grown under the Furrow/Flood irrigation production system.

Similarly, significant varietal effects were confirmed for Nicola, Lady Christy and Empi (Local Variety) grown under Manual watering production system.

Table 2 Test for Production System Effect In Potato.

Production System	Variety	$\sum e^2$	Df	F-calculated
Furrow/Flood Irrigation	Nicola	14.349	26	
Manual Watering	Nicola	6.950	24	8.529***
Pooled		24.796	56	
Furrow/Flood Irrigation	Lady Christy	5.836	24	
Manual Watering	Lady Christy	3.656	24	9.783***
Pooled		11.429	54	
Furrow/Flood Irrigation	Empi(Local)	3.831	24	
Manual Watering	Empi(Local)	6.419	24	14.690***
Pooled		13.383	54	

Source: Field Survey, 2006. *** Significant at 1% level.

Table 3. Test For Varietal Effects In Potato

Production System	Variety	$\sum e^2$	Df	F-calculated
Furrow/Flood Irrigation	Empi Vs Nicolas	14.349	26	6.058***
Furrow/Flood Irrigation	Empi Vs Lady Christy	5.836	24	18.03***
Furrow/Flood Irrigation	Empi	3.831	24	
Pooled		31.412	86	
Manual Watering	Empi Vs Nicola	6.950	24	8.072***
Manual Watering	Empi Vs Lady Christy	3.656	24	13.338***
Manual Watering	Empi	6.419	24	
Pooled		26.879	84.	

Source: Field Survey, 2006 *** Significant at 1% level.

Tests For Homogeneity of Slopes and Differences In Intercepts.

(a) Tests For Homogeneity of Slopes

The results of the tests for homogeneity of slopes in the production functions for Furrow/Flood Irrigation production system, Manual Watering production system and potato varieties (Nicola, Lady Christy and Empi (Local Variety) are presented in Table 4. For Nicola grown under Furrow/Flood irrigation and Manual watering production systems, Lady Christy and Empi (local variety) grown under the two production systems, the Chows F-statistics were not significant. These results confirm homogeneity of slopes or that the production functions were factor neutral.

(b) Test for differences in intercepts of Potato Production Functions.
Table 5 shows the results of the statistical tests for differences in the intercepts of the production functions. For Nicola and Empi (local variety) grown under Furrow/Flood irrigation and Manual Watering Production systems, the Chows F-statistics were statistically insignificant. These results imply homogeneity of intercepts or that their yields or productivities are the same. However, heterogeneity in intercept are confirmed for Lady Christy grown under Furrow/Flood irrigation and Manual Watering Production systems.

Table4: Tests for Homogeneity of Slopes of Potato Production Functions

Production System	Variety	$\sum e^2$	Df	F-calculated
Furrow/Flood Irrigation	Nicola	14.349	26	
Manual Watering	Nicola	6.950	24	0.932
Pooled With Dummy		24.196	55	
Furrow/Flood Irrigation	Lady Christy	5.836	24	
Manual Watering	Lady Christy	3.656	24	0.553
Pooled with Dummy		10.291	53	
Furrow/Flood Irrigation	Empi(Local)	3.831	24	
Manual Watering	Empi(Local)	6.419	24	2.00
Pooled with Dummy		13.369	53	

Source: Field Survey 2006.

Table 5: Test for Differences in Intercepts of Potato Production Functions

Production System	Variety	Nature of Analysis	$\sum e^2$	Df	F-calculated
Furrow/Manual Watering	Nicola	Pooled	24.796	56	1.364
Furrow/Manual watering	Nicola	Pooled with dummy	24.196	55	
Furrow/Manual Watering	Lady Christy	Pooled	11.429	54	5.866*
Furrow/Manual Watering	Lady Christy	Pooled with dummy	10.291	53	
Furrow/Manual Watering	Empi (Local)	Pooled	13.383	54	0.056
Furrow/Manual Watering		Pooled with dummy	13.369	53	

Source: Field Survey 2006.

Return to Scale of Estimated Potato Production Functions.
Table 6 presents the calculated returns to scale of the estimated potato production functions in both Furrow/Flood irrigation and Manual Watering production systems. Almost all the returns to scale were less than one except that of Empi (Local). This confirmed that there was a decreasing return to scale in all the estimated potato production functions. This conforms to one of the assumptions of production function analysis. So the hypothesis of constant return to scale for the potato production functions is rejected.
This result means that a simultaneous 1% increase in all input variables results in a less than 1% increase in potato productivity.

Table 6: Returns to Scale of Estimated Potato Production Functions.

Production System	Variety	Return to Scale
Furrow/Flood Irrigation	Nicola	-0.248
Furrow/Flood Irrigation	Lady Christy	0.757
Furrow/Flood Irrigation	Empi (Local)	1.103
Furrow/Flood Irrigation pooled		0.537
Furrow/Flood Irrigation Pooled with dummy		0.51
Manual Watering	Nicola	0.598
Manual Watering	Lady Christy	0.61
Manual Watering	Lady Christy	0.435
Manual Watering Pooled		0.771
Manual Watering Pooled with dummy		0.497
Furrow/Manual Watering Pooled	Nicola	0.195
Furrow/Manual Watering Pooled with dummy	Nicola	0.257
Furrow/Manual Watering Pooled	Lady Christy	0.772
Furrow/Manual Water Pooled with dummy	Lady Christy	0.771
Furrow/Manual water pooled	Empi (Local)	0.673
Furrow/Manual water pooled with dummy .	Empi (Local)	0.663

Sources: Field Survey, 2006.

SUMMARY AND CONCLUSION

Summary

The results indicated that under Furrow/Flood irrigation production system, R^2 value was 0.48 for Lady Christy, 0.46 for Empi and 0.15 for Nicola, while in Manual watering production system it was 0.60 for Empi, 0.29 for Lady Christy and 0.21 for Nicola. In both production systems, only seed potato and fertilizer had statistically significant coefficients. The coefficients of the variety dummy variable was positive and statistically significant, indicating that Nicola and Lady Christy gave higher yields than Empi (Local variety).The coefficients of the production systems dummy variables were statistically insignificant, indicating that the yields of both the improved varieties and the local variety were similar in the two production systems.

The calculated Chow's F-statistics for the three varieties of potato grown in the two production systems were statistically significant. Indicating structural shift in the potato production function. So the introduction of Nicola and Lady Christy caused a shift upwards of the Empi (Local variety) production function. Hence the hypothesis that there is an absence of structural shift in the production function of potato was rejected.

There were significant varietal effects since the covariance analysis gave F-ratios that were statistically significant. So there were significant differences between the production functions of Nicola, Lady Christy and Empi (Local variety) under the two production systems. There was homogeneity of the slopes of the production functions and so confirmed that the potato production functions were factor-neutral. Therefore we accept the hypothesis that the production of the different potato varieties under different production systems is factor-neutral.

The intercepts for the production functions of Nicola and Empi (Local variety) were the same but statistically different in Lady Christy. This implied that the yields of Nicola and Empi (Local variety) were the same in the two production systems but that of Lady Christy differed.

There was a decreasing returns to scale for almost all the production functions except for Empi (Local Variety) grown under Furrow/Flood irrigation production system. Hence we rejected the hypothesis of constant returns to scale.

CONCLUSION

From the results obtained in this study, the following major conclusions were drawn; the introduction of improved potato varieties (Nicola and Lady Christy) caused an upward shift in the production function of the local variety (Empi). The introduction of high yielding Nicola potato variety into Jos Plateau was biased in favour of land and capital but against labour and fertilizer in Furrow/Flood irrigation production system. Lady Christy was biased in favour of land, capital and labour but against fertilizer.

The estimated potato production functions were factor neutral because the calculated Chow's F-Statistic were statistically insignificant. Almost all the potato farmers were operating in the rational region of production, since the computed returns to scale were less than unity.All the factors of production gained under the new production technology in absolute terms but the percentage gain varied between factors and technology groups. The improved varieties (Nicola and Lady Christy) gave higher yields than the local Variety (Empi) in both production systems ie Furrow/Flood irrigation system and manual watering.

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