Does Adoption of Low Nitrogen Tolerant Variety Increase Crop Productivity and Welfare of Maize Farming Households? A Preliminary Study

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ABSTRACT

This study examined the effect of adoption of the Low Nitrogen Tolerant (LNT) maize variety on crop productivity and food insecurity status of farming households in Ondo State, Southwest Nigeria. Data were collected using a structured questionnaire. Linear regression with endogenous treatment effect model, descriptive and inferential statistics were employed in the data analysis.

Food insecurity experience scale was used to analyze food insecurity status of maize farming households. The results revealed that household size, membership of farmers' association, extension services and age were significant in determining adoption. The estimated average treatment effect of adopting LNT maize variety on crop productivity and food insecurity was 363.73 kg/ha and -0.28, respectively. Other factors affecting productivity include age, number of male adults, farm size and membership of farmers' association. Household size, credit access and adoption of LNT significantly reduced food insecurity severity. In order to achieve the sustainable development goal of no hunger and sustainable food system, investments in agriculture should go beyond development of improved varieties. Interventions and policies strengthening access to land, social networks and relaxing credit constraints are necessary.

(Keywords: improved variety, maize, nitrogen-use efficiency, welfare, rural households)

INTRODUCTION

Food insecurity is deteriorating across the globe. In 2020, about 12% of the global population was severely food insecure while close to 2.37 billion people lack access to adequate food (Food and Agriculture Organization (FAO), 2021). In Sub-Saharan Africa (SSA), 323.2 million people faced food insecurity at severe levels. The increase in moderate or severe food insecurity from 2019 to 2020 was sharp in Africa with 5.4%. Based on the food insecurity experience scale, 115.7 million are experiencing severe food insecurity in West Africa. Similarly, food insecurity is worsened in Nigeria (FAO, IFAD, UNICEF, WFP and WHO, 2021). In 2021, the country ranks 103rd out of 116 countries with a global hunger index score of 28.3 indicating serious hunger level (Global Hunger Index, 2021).

However, the importance of healthy soil cannot be overemphasized. It has implications on the sustainable productivity of the food system and food security. As a result of overexploitation and limited replenishment of organic and inorganic matters, most soil in SSA is degraded. According to World Bank (WB) (2013), over 80% of Africa's agricultural lands are degraded, thereby, limiting food production. Barbier and Hochard (2016) posits that about one-quarter of people residing in low-income countries have severely degraded land. Consequently, yield gains from improved varieties in Africa are lower than what is obtainable in other regions (Sanchez, 2010; International Fertilizer Development Centre (IFDC), 2013).

Soil fertility has been recognized as a key factor hindering increase in food production (Alliance for a Green Revolution in Africa (AGRA), 2016), poor soils have negative effects on crop yield, agricultural income, food supply and welfare, as a whole (Yamano and Kijima, 2010; Tittonell and Giller, 2013; Barrett and Bovis, 2015). Therefore, it is pertinent to address soil health issues in order to enable smallholders gain from yield increases ensue from adoption of improved varieties.

In SSA, maize is one of the important crops essential to the food security and welfare of over 32 million households (The International Maize and Wheat Improvement Centre (CIMMYT) and International Institute of Tropical Agriculture (IITA), 2011; Fisher, *et al.,* 2015). The crop is predominantly produced by smallholder farmers under stress-prone environment and low soil fertility poses great constraint to maize production (Ragasa, *et al.,* 2013). Hence, addressing the constraints to maize production is crucial to the welfare of millions of people and key to global agricultural development policy (CIMMYT and IITA, 2011).

The limited use of Nitrogen fertilizer among other factors is responsible for the low maize productivity in SSA. The average fertilizer application in this region stands the lowest in the world (Cairns and Prasanna, 2018; Das, *et al.,* 2019). Despite accounting for about 20% of the global land area under maize production, Africa uses less than 4% of the total nitrogen fertilizer application (FAO, 2020).

Furthermore, Nigeria is the second largest producer of maize in Africa (FAOSTAT, 2019). According to FAO (2019), maize is the second most widely cultivated crop next to cassava in the country. Nigeria contributes 43% of maize production in West Africa (FAOSTAT, 2019; Tegbaru, *et. al*., 2020). However, maize productivity has not been able to match up with the population growth. Maize among other cereals such as rice and wheat are low Nitrogen fertilizer use efficient (Galloway and Cowling, 2002; Arisede, *et al.,* 2020). Hence, there is need to enhance the crop's capacity to use nitrogen fertilizer efficiently (Arisede, *et al.,* 2020). Low nitrogen tolerant maize variety, which is efficient in the utilization of available nitrogen in the soil was developed to increase production and enhance welfare of farmers.

In addition, with just less than a decade more to the set time for achieving the sustainable development goals, there is need to address the challenges encountered by smallholders. This will enhance the sustainable transformation of food systems for food security, improved nutrition, and affordable healthy diets for all. The effects of Low Nitrogen Tolerant (LNT) maize varieties on productivity and food security status have not been well established in Nigeria. Hence, the study complements previous studies on the effect of technology adoption on productivity and food security by focusing on LNT varieties. The study also distinguishes itself from previous studies in Nigeria by employing the use of the Food Insecurity Experience Scale (FIES).

The FIES is an important complement to the long-established indicator of hunger, the Prevalence of Undernourishment and other related food insecurity measures, with unique potential for guiding actions aimed at achieving food security targets outlined in the 2030 Sustainable Development Agenda. The FIES is well-aligned with SDG Target 2.1 because it produces indicators that capture people´s access to food of adequate quality and quantity (FAO, 2017). The study suggests pathways whereby food environment could be strengthened by addressing drivers of productivity and food insecurity.

In other to achieve the objectives of this study, answers to the following pertinent questions are provided: Do farmers that adopted LNT maize varieties have higher productivity than those that did not? What is the impact of LNT on maize output of adopters? Does LNT adoption reduce food insecurity of smallholder farmers? From policy perspectives, answers to these questions are relevant in transforming the food system, addressing the challenges of low agricultural productivity, and achieving improvement in welfare especially among small-holder maize farming households in rural communities.

MATERIALS AND METHODS

The Study Area

The study was conducted in Ondo State, Nigeria. The State is bordered by Ekiti State (formally part of the state) to the north, Kogi State to the northeast, Edo State to the east, Delta State to the southwest, Osun State to the northwest, and the Atlantic Ocean to the south. It was formed in February 1976 from the former Western State. The total area is 5,639 square miles (14,606 square km). The population was 3,441,024 people in 2006 (National Population Commission, 2006). The state's tropical climate is divided into two seasons: dry season and rainy season. Agriculture is one of the main occupations in Ondo state. Food and cash crops cultivated in the state include maize, yam, cassava, millet, rice, plantains, cocoa, palm produce, and cashew.

Source of Data, Sampling Technique and Sample Size

Primary data were collected for this study with the aid of well-structured questionnaire. Multi-stage sampling procedure was used in the selection of respondents in the study area. The first stage involved the purposive selection of two (2) rural Local Government Areas (LGAs) high in maize production. In the second stage, four (4) communities were randomly selected from each LGA while the third stage involved random selection of fifteen (15) maize farmers from each of the selected communities. This resulted in the total selection of 120 respondents for this preliminary study. However, only 114 completely filled copies of the questionnaire were used in the analysis.

Analytical Techniques

Descriptive statistics, T-test and linear regression with endogenous treatment effect model were employed in the data analysis. Descriptive statistics and T-test were used to profile and compare the socio-economic/ demographic characteristics of adopters and non-adopters. The food insecurity experience scale was used to estimate the food insecurity status of the households while the linear regression with endogenous treatment effect was used to estimate the impact of adoption on productivity and food insecurity severity. It also isolated the factors influencing adoption, productivity, and food insecurity status of farming households.

The Food Insecurity Experience Scale (FIES)

The FIES is a metric of severity of food insecurity at the individual or household level which depends on people's direct **yes or no** responses to eight brief questions on their access to adequate food. It is a statistical scale. When the eight questions are analyzed together; they form a quantitative tool to measure the prevalence of food insecurity. The food insecurity status was estimated based on the respondent's raw score (an integer number with a value between 0 and 8) which is the sum of affirmative responses given to the eight FIES questions. The raw score, in itself, is an ordinal measure of severity with a lower score indicating less severe food insecurity (FAO, 2017).

The Linear Regression with Endogenous Treatment Effects Model

Following Nkrumah-Ennin and Anang (2019) and adapting to this study, the linear regression with endogenous treatment effects model was used to estimate the impact of a treatment on an outcome of interest. The model allows the estimation of average treatment effect (ATE). Besides the impact parameter, the linear regression endogenous treatment effect model also estimates other parameters (or coefficients) of a linear regression model augmented with an endogenous binary-treatment variable.

The ATET (or ATT) estimated by the model is the same as the ATE when the treatment indicator variable is not interacted with any of the independent variables in the outcome model. The model is estimated by specifying an equation for the endogenous treatment, Z_i (in this study, a model of farmers' adoption of LNT maize variety) followed by specification of an outcome equation, Y_i (for this study, maize output and food insecurity severity of maize farming households). Given an outcome Y_i, which estimates the output/food insecurity, and the endogenous treatment variable, Z_i, which measures adoption, the endogenous treatment-regression model can be specified as follows:

$$Y_i = X_i\beta + \delta Z_i + v_i \qquad (1)$$

$$Z_i = w_i\gamma + u_i \qquad (2)$$

$$\begin{cases} 1, if w_i\gamma + \mu_i > 0 \\ 0, if\ w_i\gamma + \mu_i \leq 0 \end{cases} \qquad (3)$$

Z_i is a dichotomous variable with a value of 1 for farmers who adopt LNT maize variety, and 0 otherwise. X_i is a vector of outcome covariates, w_i is a vector of endogenous treatment covariates, β and γ are unknown parameters, while v_i and u_i are the error terms with the following covariance matrix:

$$\begin{bmatrix} \delta^2 & \rho\sigma \\ \rho\sigma & 1 \end{bmatrix} \quad (4)$$

The covariates X_i and w_i are exogenous because they are unrelated to the error terms. The empirical model for the outcome equation is specified as follows:

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 \dots\dots\dots.. + \beta_n X_n + u_i \quad (5)$$

Where the variables are as defined in Table 1. The empirical model for the treatment equation is similarly specified as follows:

$$Z_i = \gamma_0 + \gamma_1 \beta_1 + \gamma_2 \beta_2 + \gamma_3 \beta_3 \dots\dots\dots\dots + \gamma_n \beta_n + u_i \quad (6)$$

RESULTS AND DISCUSSION

Descriptive Statistics of Socio-economic Characteristics of Respondents

The summary statistics of the respondents is presented in Table 1. The characteristics were compared between two categories of households; those that adopted LNT varieties and the non- adopters. The results showed that maize production in Nigeria is dominated by male-headed households. The tedious nature of the activities involved in maize production could be responsible for this. The mean age was 51 years. This implies that Nigerian farmers are aging. However, the adopters are significantly younger than the non-adopters.

Table 1: Descriptive Statistics and Mean Differences Tests of Socio-economic Characteristics by Adoption.

Variable	Definition	Pooled	Adopters (63.16%)	Non-adopters (36.84 %)	Difference
Age	Age of the household head (Years)	50.55	46.42	54.66	8.24***
Education	Household head's education (Years of schooling)	10.07	10.23	9.78	0.46
Sex	Dummy=1 if household head is male	0. 67	0.65	0. 69	0.04
Household size	Total household size (number)	6.78	7.13	6.19	0.94
Farm size	Total farm size cultivated	2.07	2.18	1.89	0.29
Access to credit	Dummy=1 if respondent has access to credit	0.25	0.29	0.19	0.10
Male adults	Total number of male adults in household	1.84	1.91	1.71	0.20
Primary occupation	Dummy=1 if primary occupation is farming	0.83	0.83	0.83	0.00
Association	Dummy=1 if respondent belong to farmers' association	0.49	0.58	0.44	0.14*
Crop yield	Crop yield (kg/ha)	2157.928	2682.71	1183.333	1499.38 ***
Years spent in village	Number of years of residence in village	16.84	17.70	15.32	2.37
Awareness	Dummy=1 if aware of LNT variety	0.74	0.97	0.33	0.64***
Extension services	Dummy=1 if respondent has access to extension services	0.56	0.78	0.44	0.35***

Source: Estimated by the author

The engagement of youth in Nigerian agriculture could be enhanced by access to adequate productivity enhancing inputs. The mean household size of the two groups was similar with an average of 7 persons. In the same vein, the mean years of schooling was similar with 10years of formal education. Access to credit facilities was low among respondents and more than half of the respondents belong to farmers' association. The primary occupation of majority of the households was farming. Access to extension services and awareness of LNT variety were significantly higher among adopters. There was a significant difference of about 1.5 tonnes/ha between the yield of adopters and non-adopters.

Awareness, Adoption and Sources of information of Low Nitrogen Tolerant (LNT) Maize Variety

The study found that majority (73.68%) of the respondents was aware of the LNT maize variety. Awareness of the improved variety was higher among adopters than non-adopters in the study area (Figure 1). Awareness of improved varieties increases the probability of adoption (Fisher, Habte, Ekere, Abate and Lewin, 2019). However, only 63.16% of the respondents adopted the variety (Figure 2). This implies that uptake of LNT maize variety is relatively high in the study area. This underlines the relevance of extension services and social network links in Nigeria for technology awareness and uptake.

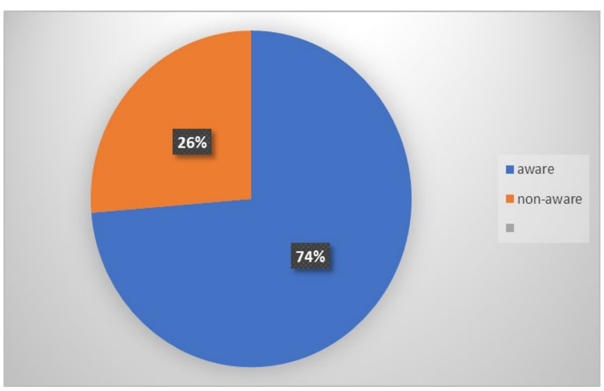

Figure 1: Awareness of LNT Maize Variety.

Though, awareness is important to adoption, however, not all the farmers that were aware of the variety cultivated it. Maize farmers should be encouraged to plant the improved varieties. More so, meeting the needs of a diverse set of farmers should be ensured in development of improved varieties to improve the uptake (Van Aelst and Holvoet, 2016; Fisher *et al.,* 2019).

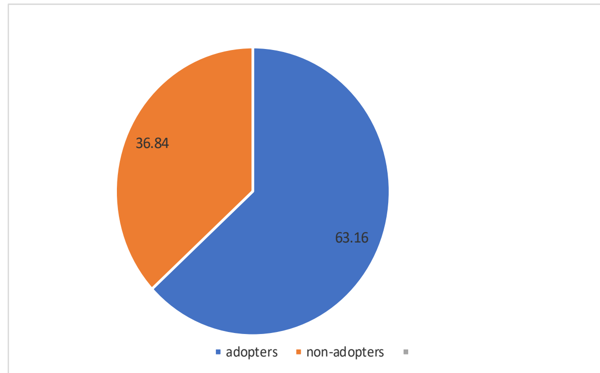

Figure 2: Adoption of LNT Variety.

Considering the sources of information, most of the respondents were aware of the variety through agricultural extension agents. The results showed that 6.1%, 14% and 24.6% of the respondents were aware of the variety through television, radio, friends & family respectively. This indicates that agricultural extension and social network links play essential roles in promoting technology awareness (Rogers, 2010).

The Maximum Likelihood Estimates of Linear Regression with Endogenous Treatment Effect Model on Productivity

The maximum likelihood estimates of the linear regression with endogenous treatment effect model are presented in Table 2. The first column presents the results of the determinants of adoption while the second column presents the determinants of productivity. The second column also shows the average treatment effect of adoption on productivity (output per hectare). The results revealed that age, household size, extension services and membership of farmers association were positive and statistically significant in determining adoption of LNT maize varieties in the study area. However, age ($P < 0.1$) of the household head had a negative influence on adoption.

Access to extension services will increase the likelihood of adoption by 2.78 points. Extension services create awareness and give demonstration to farmers on improved production technologies (Olagunju and Ogunpaimo, 2021). Being a member of farmers' association will increase the likelihood of adoption by 0.60 points. Membership provides prompt information that enhances adoption decisions to farmers and provides safety nets that could also enhance adoption (Dercon and Christiaensen 2012; Baiyegunhi, Akinbosoye and Bello, 2022).

Furthermore, the results show that a unit increase in household size will increase the likelihood of adoption significantly by 10.8% at 5% level of significance. Farming in Nigeria is mostly manual and labor intensive, adoption of improved varieties requires certain cultural practices such as weeding and agrochemicals application. Hence, household members are useful as family labor on the farm. This is consistent with Danso-Abbeam, Ehiakpor and Aidoo (2018). Furthermore, age significantly reduced adoption by 2.7%. The probability of technology adoption reduces as the farmer ages. This might be because older farmers are less innovative and risk averse than younger farmers.

The estimated ATE of adopting LNT maize variety on productivity was 363.73 kg/ha. This implies that adopters of LNT variety have higher productivity than non-adopters. The number of male adults in the household increases maize yield significantly at 1% level. The male adults in the household are helpful in farming activities.

From the result, one more male adult in the farming household will increase yield significantly by 302.79 points. This reveals that the impact of male adults can't be undermined, hence, male-out migration should be discouraged among farming households in rural areas. Furthermore, the coefficient of farm size is positive and statistically significant at 1%. This shows that the larger the farmland cultivated, the higher the productivity. Availability of land could motivate farmers to adopt improved technology and gives room for expansion.

A unit increase in farm size cultivated increases productivity by 173.86 points. This is consistent with Gebeyehu (2016) and Ogujuba, Agholor and Lunga (2021). Similarly, membership of farmers' association significantly increased maize yield at 5%. Membership of farmers association will increase productivity by 584.73 points while age has a negative effect on maize yield. A unit increase in age of farmers will reduce output per hectare significantly by 34.31 points at 5%.

Table 2: Maximum Likelihood Estimates of the Endogenous Treatment Effect Model (Productivity).

Variables	Adoption		Crop Productivity	
	Coefficients	Std. Error	Coefficients	Std. Error
Adoption			**363.729***	**218.7609**
Sex	0.386	0.279	201.600	243.262
Age	-0.027 *	0 .016	-34.309**	14.434
Household size	0.108 **	0 .056	60.787	37.731
Male adults			302.794***	87.598
Primary occupation			272.272	226.256
Education	0.021	0 .026	6.394	24.302
Farmers Association	0.608**	0.277	584.731**	235.678
Farm size			173.855***	43.255
Credit access	0 .030	0.329	324.173	278.648
Awareness	0.022	0.021		
Extension	2.781***	0.584		
Constant	-3.015	0 .938	4103.159***	822.928
/athrho	-2.008***	0.386		
/lnsigma	6.991***	0 .096		

Note: ***, ** and * indicate statistical significance at 1, 5 and 10 per cent level, respectively.
LR test of indep. eqns. (rho = 0): $chi^2(1)$ = 27.09 Prob > chi^2 = 0.0000

The Maximum Likelihood Estimates of Linear Regression with Endogenous Treatment Effect Model on Food Insecurity

Based on the respondent's raw score which is the sum of affirmative responses given to the eight FIES questions, an index was generated for each of the respondents. The study revealed severe food insecurity among respondents. However, food insecurity was lower among adopters (0.61) than non-adopters (0.64).

Similar to the maximum likelihood estimates of linear regression with endogenous treatment effect on productivity, the first column presents the results of the determinants of adoption while the second column presents the determinants of food insecurity severity. The second column also shows the average treatment effect of adoption on food insecurity severity. Considering the factors influencing food insecurity severity, the results indicated that credit access, household size and adoption of LNT Variety have significant effect on food insecurity severity.

The coefficient of the variable for adoption measures the average treatment effect of adoption on food insecurity. From the results, the average treatment effect of LNT variety adoption on food insecurity was -0.277. This implies that LNT maize variety adoption reduces food insecurity severity by 0.277 points. Hence, should be promoted among maize farming households. However, household size positively and significantly (P< 0.1) influenced food insecurity severity. From the results, a unit increase in household size will increase food insecurity severity by 0.13 points. This is consistent with the findings of Otunaiya and Ibidunni (2014) and Obisesan (2018) that household size increases the probability of being food insecure. More so, the larger the household size, the higher the probability of having more dependents.

According to Aboaba, Fadiji and Hussayn (2020), dependency ratio reduces the probability of being food secure in Nigeria. On the contrary, access to credit significantly reduces food insecurity severity. Having enough credit enhances the financial status of farmers to purchase farm inputs, diversify their income and improve food access. This conforms with Mungai (2014); Obisesan (2018) and Akuwe (2020)

Table 3: Maximum Likelihood Estimates of the Endogenous Treatment Effect Model (Food Insecurity).

Variables	Adoption		Food insecurity	
	Coefficients	Std. Error	Coefficients	Std. Error
Adoption			**-0.277*** **	**0.100**
Sex	-0.036	0.312	0.028	0 .053
Age	-0.066***	0.025	-0.002	0 .003
Household size	0.221***	0.076	0.132 *	0.079
Male adults			0.005	0.027
Primary occupation			0.059	0.059
Education	0.014	0.028	-0.002	0.005
Association	0.029*.	0.016	-0.052	0.053
Farm size			0.011	0.013
Credit access	0.503	0 .408	-0.093**	0.038
Awareness	0.118	0.074	0.009	0 .017
Extension	0.945***	0.217	-0.093	0.038
Constant	2.575**	1.033		
/athrho	-0.834**	0.354		
/lnsigma	-1.475***	0.117		

Note: ***, ** and * indicate statistical significance at 1, 5 and 10 per cent level, respectively

Wald test of indep. eqns. (rho = 0): chi2(1) = 5.55 Prob > chi2 = 0.0185

CONCLUSION

This preliminary study examined the adoption of low nitrogen tolerant maize variety and its implication on crop productivity and food insecurity among farming households. There were significant differences in the socio-economic characteristics of adopters and non-adopters. The awareness and uptake of low nitrogen tolerant variety was relatively high. The adoption of LNT maize variety has a positive impact on crop productivity while it had a negative impact on food insecurity severity.

The ATE of adoption on crop productivity and food insecurity severity of adopters were 363.73 kg/ha and -0.27, respectively. Household size, membership of farmers' association, and access to extension services were positive and statistically significant in explaining adoption of LNT maize variety.

Age had negative influence on adoption. Furthermore, number of male adults, membership of farmers' association, farm size and access to extension services significantly increased crop productivity while age significantly reduced it.

Credit access was crucial to reducing food insecurity severity. On the contrary, household size had a positive effect on food insecurity. The study suggests that the yield potential of LNT maize varieties should be enhanced, and additional desirable traits should be taking into consideration in the development of improved varieties.

Farming households should be further supported with investments and interventions to increase land access, enhance land use intensification and improve access to adequate credit. In addition, male-out migration should be discouraged among rural households.

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