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BINARY PROBIT ESTIMATION OF FACTORS AFFECTING PESTICIDE ADOPTION FOR THE CONTROL OF YAM TUBER BEETLES IN DELTA STATE, NIGERIA

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ABSTRACT. Yam is a major staple food crop with significant impact on the food security, income generation and employment creation for the various participants in the yam value-chain in Nigeria. However, pest infestation by yam beetles poses serious production constraint to farmers resulting in over 50% of yield losses. Many farmers have adopted the use of pesticides such as chlorpyriphos. pirimiphos-methyl and deltamethrin to control yam beetles and boost output. Therefore, this study was conducted to examine factors that affect pesticide adoption for control of yam beetles in Oshimili Area of Delta State, Nigeria. Data were obtained from a cross-section of 159 yam farmers including 79 adopters and 80 non-adopters of pesticides, drawn from 6 communities with the aid of questionnaire. t-test and binary probit were employed to analyse the data. The choice of the probit model is due to the qualitative nature of the dependent variable (pesticide adoption). Results of t-test revealed that significant ($p < 0.01$) differences existed in age, years of formal education, number of adults per household, farm income and farm size between adopters and non-adopters. The probit model had a good fit with significant LR ratio, 106.67 ($p < 0.001$); a McFadden R^2 of 0.48 with 84.9% of cases correctly predicted. The results also showed that age, years of education, adults per household, farming experience, farm income, access to credit, extension contact as well as training on pesticide application all had significant influence on adoption decision. While the impact of age on the probability of technology adoption was negative, all other variables exerted positive effects. The authors recommended that improved access to farm credit, efficient and effective extension service delivery system and on-farm training on pesticide handling and application be intensified to reduce beetles attack, boost yam yield and improve food security of farming households.

Introduction

Yam, a stem tuber and annual plants commonly grown in Nigeria and other parts of the world, particularly in West Africa, is a major staple food for over 60 million people in the growing regions popularly referred to as "yam zone" of West Africa (IITA, 1988). Besides, it is a major source of carbohydrate intake for majority of the populations in the producing regions (O'Hair, 1990).

Nigeria has been the largest producer of yam since the 1990's with an all-time high output of 37.1 million metric tonnes in 2011 (FAO, 2011). Although national output of the crop has been growing steadily since the beginning of the millennium reaching an average annual growth rate of 5.42% between 2001 and 2006. A drastic fall in production levels between 2007 and 2010 reduced mean annual growth rates to –6.28% (Table 1). In spite of the important role of yam in the socio-economic lives of farmers and those engaged in processing and marketing of the crop, yam production is faced with a number of constraints, particularly the devastating attack of yam tuber beetles with average annual yield losses estimated at over 25% (Arene, 1987; Nweke *et al*., 1991); over 45% (Tobih, 2014).

Table 1. Yam Production in Nigeria and Rest of the World (metric tonnes)

Year	Nigeria	Africa	World	Nigeria's production as % of world output	National annual growth rate (%)
1997	23,972,000	34,127,121	35,529,509	67.3	–
1998	24,768,000	35,645,883	37,067,264	66.8	3.2
1999	25,873,000	37,451,888	38,953,415	66.4	4.3
2000	26,201,000	38,009,739	39,568,980	66.2	1.3
2001	26,232,000	38,401,524	40,007,979	65.6	0.12
2002	27,911,000	40,579,260	42,195,571	66.1	6.0
2003	29,697,000	42,587,640	44,258,102	67.1	6.0
2004	31,776,000	45,204,790	46,935,878	67.7	6.5
2005	34,000,000	47,314,591	49,066,755	69.3	6.5
2006	36,720,000	49,723,354	51,487,245	71.3	7.4
2007	31,136,000	45,873,013	47,742,219	65.2	–17.9
2008	35,017,000	51,085,661	53,077,843	66.0	11.1
2009	29,092,000	45,700,985	47,704,248	61.0	–20.4
2010	34,162,060	46,382,047	48,701,460	59.9	2.1
2011	37,115,510	54,869,955	57,112,941	65.0	17.3

Source: Computed from FAOSTAT (1996–2011)
FAO (2011): FAO Statistics Division.Food and Agriculture Organization, Rome, Italy.

According to Tobih (2011, 2014), the major constraint to yam production in Nigeria is devastating attack on yam tubers, by yam beetles, *Heteroligus* and *Prinoryctes* species. Species of *Heteroligus* reportedly found in the southern parts of Nigeria include; lesser yam beetle *Heteroligus appius* and greater yam tuber beetle, *Heteroligus meles*, is a very serious insect pest of yam in river-rine areas, particularly in the forest zones up to the savannah regions along the Benue–Niger rivers and tributaries (McNamara, Acholo, 1995). Adult beetles feed on tubers making large semi-hemi and hemispherical holes 1–2 cm on the tuber prior to harvest resulting in reduced output, low market value, and a predisposition to fungal and bacteria attacks during storage (Tobih *et al*., 2007).

Yam farmers in Oshimili area of Delta State, Nigeria have suffered severe economic losses on their farm investments over the past three decades as a result of yam beetles attack causing over 50% of yield loss (Tobih, 2014). This is due to the fact that farmers in the area have relied on the use of cultural methods such as delay in planting dates, mulching and wood ash as measures to control the attack of yam beetles on their crops. Although a recent study showed that the use of *Cymbopogun citratus* (lemon grass) and *Ocimum viride* (mosquito plant) leaves as organic mulch showed significant reduction of beetle damage on yam tubers in the study area Tobih (2011), the details of such innovation as well as its cost implications are yet to be disseminated to farmers. Therefore the most effective control measure of yam tuber beetles is the application of pesticides such as pirimiphos-methyl, deltamethrin and chlorpyriphos (Tobih *et al*., 2007; Tobih, 2014), which a number of farmers have currently adopted.

The process of agricultural growth and development in developing countries entails the adoption of new techniques and innovations to boost yield, improve farmers income and guarantee household food security. Adoption is an outcome of a decision to accept and utilise a given innovation. It is a mental process an individual passes from first hearing about an innovation to finally utilizing the technology (Rogers, 2003). However, Feder *et al*. (1985) defined adoption as the degree of use of a new technology in the long-run when the farmer has full information about the new technology and its potential. According to Fernandez-Cornejo *et al*. (1994) the adoption of a new technology by farmers is a choice between two alternatives; in this case of yam farmers the traditional technology (use of mulch, wood ash, delayed planting dates) and the new technology (pesticide application). It is assumed that rational farmers' objective is to maximize utility. Thus, a new technology will likely be adopted if its perceived utility is expected to be higher than the utility of the old technology. Potential benefits from the adoption of new techniques and innovations include increased output, increased profitability and food security of the household.

A number of factors have been shown in the literature to determine the adoption of different agricultural innovations and technologies. They include demographic factors (age, education and religion), economic factors (occupation, income) and farm-specific variables (firm size, type of enterprise), institutional factors and the characteristics of the technology itself (Asfaw *et al*., 2012; Mwangi, Kariuki, 2015). In a study of adoption of integrated pest management techniques (IPM) by vegetable growers in three states in the United States, Fernandez-Cornejo *et al*. (1994) applied a logit model and found farm size, operator labour and family labour to have a positive and significant effect on the probability to adopt the specified technology. In another study of adoption of IPM technology among grape growers in the United States, Fernandez-Cornejo (1998) using a probit model found off-farm work (a proxy for shortage of labour) and farmer experience to exert a negative impact on IPM adoption. This is so because labour availability, particularly the farmer's time, is very crucial to successful application of the IPM technology. The negative effects of experience may be attributed to the correlation of experience with age as older farmers are more reluctant to accept new techniques and innovation. Farmer education was positively correlated with adoption as well as farm size thereby corroborating the results of other studies that the larger the farm size the higher the likelihood of farmers to adopt innovations (Fernandez-Cornejo, 1998).

Other studies on factors influencing the adoption of IPM technology included the work of Samiee *et al*., (2009) in Iran where extension contact was found to be correlated with adoption, while awareness of IPM technology had a positive and significant influence on farmers eventual use of the technology. Ghimire and Kafle (2014) in a study on integrated pest management practice and its adoption determinants among apple farmers in Mustang district of Nepal', analysed eight socio-economic factors that affect adoption of IPM technology with a sample of 40 farmers. Using a probit model, they found that training and membership in farmers group had positive and significant effects, while the impact of farmers age was negative. The authors recommended that for higher adoption and dissemination of IPM techniques, there is need to improve extension service delivery system.

Adejumo *et al*. (2014) conducted a study on factors influencing choice of pesticides used by grain farmers in Southwest Nigeria. Applying a probit model on a sample of 192 farmers, the results showed that education, farming experience and price of grains were positive and significant factors that influenced the choice of pesticides used by the farmers while age of household head exerted negative influence. Furthermore, Obayelu *et al*. (2016) reported that age of farmer also had a negative influence on adoption of pesticide technology among smallholder farmers in Nigeria while the effects of farm income and farm size were positive as they significantly increase the probability of pesticide use.

Nkamleu and Adesina. (2000) examined the effects of socio-economic factors on the probability of using chemical fertilizers and chemical pesticides in peri-urban low land agricultural systems in the Cameroon. Applying a bivariate probit model, the results indicated that female farmers have a lower likelihood of using chemical pesticides while farmers with extension contact have a hihgher probability of adoption. Also, in a study of pesticide use and risk perception among farmers in the cotton belt of Punjab, Pakistan, Khan *et al*. (2015) found that IPM training, education level, and toxicity class of the pesticide were significantly associated with the probability of pesticide overuse by farmers. While the probability of overuse decreased significantly with greater IPM training, a high level of education tended to increase the likelihood of pesticide overuse among coton farmers. In a study of grower adoption of an integrated pest management package for management of mango-infesting fruit flies in Kenya, Korir *et al*. (2015) reported that education and training on IPM technology were the significant factors that determined the adoption of chosen technology with positive influence on farmers adoption decision.

Alhough a number of studies have analysed the effect of farmers' socio-economic factors on adoption of IPM technonology in Nigeria, studies that have examined the determinants of farm-level pesticide use for the control of yam beetles in Delta State, Nigeria are rare if not non-existent. Therefore, the objective of this study was to examine factors that influence the adoption of pesticide for the control of yam tuber beetles in Oshimili area of Delta State. The results of this study will be useful to policy makers, researchers and extension workers to design a strategy for pesticide technology dissemination and use, in order to boost yam production and improve income of yam farmers in communities in the Upper Niger Delta area.

Materials and Methods

Area of study and Sampling Procedure

The location of study is Oshimili area in Nigeria. The area comprised of two local government areas (LGAs); Oshimili North, and Oshimili South, which in addition to seven other LGAs (Aniocha North, Aniocha South, Ika Northeast, Ika South, Ndokwa East, Ndokwa West, and Ukwuani), make up the Delta North Agricultural Zone (Figure 1). It is one of the major food crops production belt in Delta State, Nigeria. Farming is the primary occupation of the people and yam is the second major food crop, after cassava, cultivated in the area. Yam beetles infestation is however endemic in the area with an attack rate of 41–45% (Tobih *et al*., 2007).

Data for the study were collected as primary data from a cross-section of yam farmers using structured questionnaire/interview schedule that were conducted by the researchers, with the assistance of enumerators that were fluent in both English language and Igbo, the local dialect of the people.

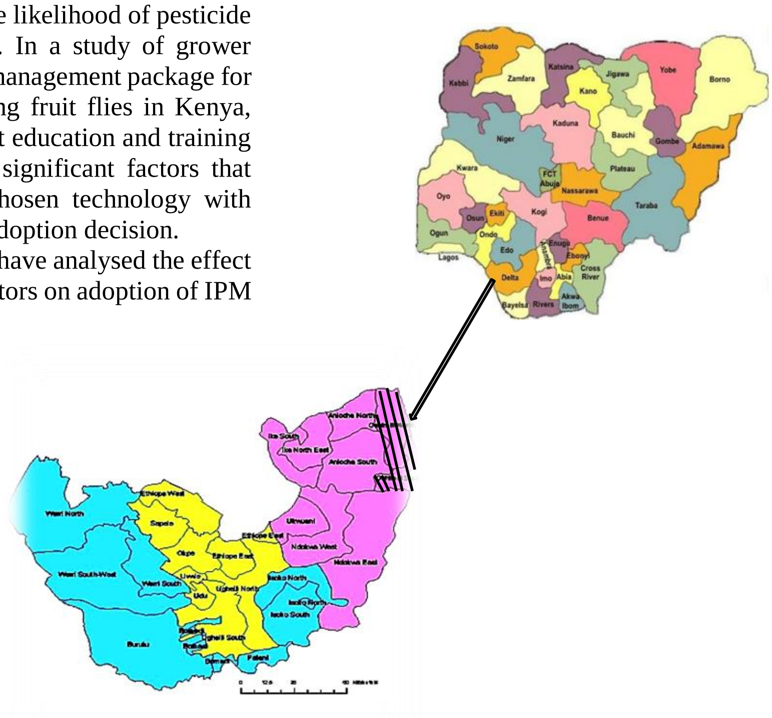

Figure 1. Map of Delta State, Nigeria, showing the study area, shaded

A two-stage sampling procedure was adopted to draw samples for the study. At the first stage, three (3) communities each were drawn out of six (6) major yam producing communities in the two Local Government Areas (LGAs) that comprised the study area, using simple random sampling technique. Secondly, 30 farmers were randomly selected from the six (6) communities, to give a total sample size of 180 respondents for the study. The six (6) communities chosen are Ugbolu, Ebu, Illah, Oko-Anallah, Oko-Igbele, and Oko-Amakom. Data collected included socio-economic characteristics of the farmers, production data, extent of yam beetles infestation and damage to yam tubers. However due to inadequate information supplied by some respondents, 21 questionnaires were discarded and data analysis was based on the response of 159 farmers. The survey was conducted between January and April, 2015.

Probit Model for Pesticide Adoption

The conceptual framework of the analytical model employed in this study is similar to the model that Fernandez-Cornejo (1998) used to estimate, adoption of IPM technology among grape growers in the United States, as well as that of Ghimire and Kafle (2014) in a study on 'integrated pest management practice and its adoption determinants among apple farmers in Mustang district of Nepal'. The model assumes that farmers decisions whether or not to adopt pesticide for the control of yam tuber beetles depends on unobservable utility index (or a latent variable) that is determined by farmer-specific factors such as age, sex, household head's, education; access to extension services and credit; membership in an agricultural association). Studies on adoption of agricultural innovations have applied limited dependent variable models such as the probit or logit function. These distributions are very similar to each other and in most cases their applications have given similar results (Maddala, 1986). In this study, the probit model is used to analyze farmers' adoption decision because it is an appropriate econometric model for the binary dependent variable as the error term is assumed to be normally distributed (Greene, 2008; Gujarati and Porter, 2009; Wooldridge, 2009).

The probit model of pesticide adoption for the control of yam beetles is derived from an underlying latent variable model, which is expressed as:

$$\mathbf{Y_i^* = \beta_0 + \beta_{ij}X_{ij} + e_i}, \qquad \text{(Eq. 1)}$$

where $\mathbf{Y_i^*}$ – an underlying index reflecting the difference between the utility of adopting and not adopting pesticide control of yam beetles;

$\boldsymbol{\beta_0}$ – the intercept;

$\boldsymbol{\beta_{ij}}$ – is a vector of parameters to be estimated;

$\mathbf{X_{ij}}$ – are independent variables which explain pesticide adoption of yam beetles control;

$\mathbf{e_i}$ – the standard normally distributed error term that is independent of $\mathbf{X_j}$ and is symmetrically distributed about zero.

Given the assumptions from the latent variable model, the model for a farmer's adoption of pesticide for the control of yam tuber beetles is derived as:

$$\mathbf{P(Y_i^* = 1|x) = F(\beta_0 + \beta_{ij}X_{ij})}, \qquad \text{(Eq. 2)}$$

where **F** – a cumulative distribution function, the function that ensures the likelihood of adopting pesticide control of yam beetles, and it lies strictly between zero and one.

Therefore, a farmer adopts pesticide control if $Y_i^* > 0$, and otherwise, if $Y_i^* \leq 0$. Therefore, the model to estimate the probability of observing a farmer adopting the pesticide technology can be explicitly stated as:

$$\mathbf{P(Y_i^* = 1|x) = F(\beta X) = \int_{-\infty}^{\beta X} \frac{1}{\sqrt{2\pi}} \exp(-z^2/2) dz} \qquad \text{(Eq. 3)}$$

where **P** – the probability that the ith farmer used pesticides and 0 otherwise;

X – the K by 1 vector of the independent variables;

z – the standard normal variable, *i.e.*;

Z ~ $N(0,\sigma^2)$;

β – the K by 1 vector of the coefficients to be estimated;

F(βX) – the cumulative distribution function of the standard normal distribution which is the integral of the probability density function.

The parameter estimates were obtained by maximum likelihood estimation (MLE) procedure using LIMDEP 7.0 econometric software (Greene, 1998). The descriptive statistics of variables that determine farmers' adoption decision are shown in Table 2.

Regression analyses usually aimed at estimating the marginal effects of an independent variable on the dependent variable, while holding the effects of other independent variables constant. But in the probit model, parameter estimates cannot be interpreted as marginal effects. Therefore, the marginal effect of an independent variable is obtained by calculating the derivative of the outcome probability with respect to an independent variable. The marginal effect associated with a continuous explanatory variable X_k on the probability $P(Y_i = 1 \mid X)$, holding the other variables constant, can be derived as follows:

$$\mathbf{\frac{\partial P_i}{\partial \chi_{ik}} = \phi(X_i'\beta)\beta_k} \qquad \text{(Eq. 4)}$$

where $\boldsymbol{\phi}$ = Cumulative distribution function for the standard normal random variable;

$\boldsymbol{\beta_k}$ = Coefficient of k^{th} explanatory variable.

$\mathbf{(X_i'\beta)}$ = product of the k by 1 vector of the coefficients to be estimated, and transpose of a row vector of values of k regressors for the i-th yam farmer;

$\boldsymbol{\partial P_i/\partial X_{ik}}$ = partial derivative of probability of adoption of pesticide with respect to specified explanatory variable.

Maddala (1986, 1992) and Greene (2008) showed detaled mathematical derivation of the normal probability distribution of the error term of the probit model.

Table 2. Description and Summary Statistics of Variables for the Adoption Model

Variable	Variable description	Mean (Mode)	Std. Deviation	Minimum	Maximum
PESTADOP	1 if the farmer is using pesticides, 0 otherwise	(0)	0.50	0	1
AGE	Age of the farmer in years	51.63	10.37	27	71
SEX	Sex of catfish farmer (1 if male, 0 otherwise)	(1)	0.50	0	1
MRLSTA	Marital status (1 if married, 0 otherwise)	(1)	0.46	0	1
YRSEDU	Years of formal education of the farmer	7.44	4.80	0	16
ADHHLD	Number of adults in farmer's household	2.9524	0.94	2	6
FRMEXP	Farming experience (years)	12.37	6.27	3	30
FARMINC	Farm income in (N,=)	44,079.77	17,991.33	14,376.80	84,031.68
FARMSZE	Land area cultivated with yam (hectare)	0.4118	0.12	0.18	0.74
CRDTACES	Access to credit; 1 if the farmer had access, 0 otherwise	(0)	0.50	0	0
EXTNACES	Access to yam production information; 1 = yes, 0 otherwise	(1)	0.50	1	1
TRNPEST	Training on pest control; 1 if farmer had training, 0 otherwise	(0)	0.49	0	1

Source: Computed from survey data, 2015

Results and Discussion

Socio-economic Characteristics of Respondents

The results of the distribution of the socio-economic characteristics of yam farmers are presented in Table 3. Majority of the yam farmers are male (56.6%) while about 43% of them are female. The result revealed that men dominated yam production in the study area compared to the women folks. The finding is supported by that of Inoni (2010) who reported that yam is regarded as a 'man crop' in the study area. The age distribution of the yam farmers ranged between 27 and 71 years, with an average age of about 52 years. About 47% of the respondents are older than 53 years. Thus the yam producing population appears to be aging. Family labour is a major source of labour supply in smallholder crop farming in Nigeria, and the number of adults per household is a proxy for family labour supply. The number of adults per household ranged from 2 to 7 with an average of 3 persons.

The educational status of farmers was determined by their years of formal education. This ranged from those who had no formal education to those who had university education. Primary school certificate was the modal level of educational attainment by the yam producers. Although about 9% of the respondents had no formal education at all, about 81% of the farmers had some form of formal education. Educated farmers are known to be early innovators that adopt modern agricultural innovations in order to increase overall productivity, than their less educated counterparts. Also they are better able to copy those who adopt innovation first, thereby enhancing wider diffusion of new technologies (Weir, Knight, 2004).

The number of years spent in yam production by the farmers ranged between 3 and 30 years, with mean years of experience of 12.6 years. In fact, about 62% of the farmers have been into yam cultivation for more than 10 years, while 25% have been involved in yam production for upwards of 17 to 30 years.

A great variability was found in income from yam production in the study area. The mean farm income was 63,799.00 with a standard deviation of 18,056.97. In fact, about 60% of the farmers had their income ranged between **N,=** 57,970.00 and **N,=** 105,173.00. High cost of hired labour and agrochemicals are implicated for the low level of farm income found among farmers in the study area. Comparable results were reported by Ike and Inoni (2006) in a study of yam production in South-eastern, Nigeria.

Table 3. Distribution of Socio-economic Characteristics of Yam Farmers (n = 159)

Parameter	Frequency	Mean / (Mode)
Sex		
Male	90(56.6)*	(Male)
Female	69(43.4)	
Age		
27–35	14(8.8)	
36–44	29(18.2)	
45–53	41(25.8)	51.7
54–62	51(32.1)	
63–71	24(15.1)	
Marital status		
Married	111(69.8)	(Married)
Unmarried	48(30.2)	
Adult per household		
2–3	115(72.3)	
4–5	39(24.6)	3 persons
6–7	5(3.1)	
Years of formal educational		
No formal education (0)	30(18.9)	
Attended primary school (3)	1(0.6)	
Primary school certificate(6)	57(35.8)	(Primary school)
Attended secondary school(8–10)	12(7.6)	
Secondary school certificate(12)	44(27.7)	
OND/NCE/HND(14–15)	14(8.8)	
University degree (16–17)	1(0.6)	
Farming experience (years**)**		
3–9	60(37.7)	
10–16	59(37.1)	12.6
17–23	27(17.0)	
24–30	13(8.2)	
Farm income (N,= †)		
34,368–46,168	40(25.2)	
46,169–57,969	23(14.5)	
57,970–69,770	32(20.1)	63,799.00
68,771–81,571	35(22.0)	
81,572–93,372	21(13.2)	
93,373–105,173	8(5.0)	
Farm size (ha)		
0.18–0.29	26(16.4)	
0.30–0.41	56(35.2)	
0.42–0.53	54(34.0)	0.41
0.54–0.65	18(11.3)	
0.66–0.77	5(3.1)	

* Figures in parentheses are percentages; †**N,=** 165.00 =1 US Dollar at the end of harvest in December, 2014

Source: Computed from survey data, 2015.

The size distribution of farms indicated that yam production was characterised by small farm holdings with an average farm size of 0.41 hectares. About 48% of the producers had a range of farms with sizes of 0.42 to 0.77ha. Land fragmentation has been a major challenge to agricultural mechanisation in many parts of Nigeria due to land ownership patterns and tenure systems.

Comparison of Socio-economic Characteristics of Adopters and Non-Adopters

The results of the t-test of mean difference of the socio-economic characteristics of adopters and non-adopters of pesticides for the control of yam beetles are shown in Table 4. The respondents were 159 small-holder yam farmers comprising 79 adopters and 80 non-adopters. The results revealed that there is significant ($p < 0.01$) mean difference between the age of adopters and non-adopters. Apart from farming experience, statistically significant differences were found between adopters and non-adopters in all other socio-economic characteristics of the yam farmers. Mean farm income, years of education and number of adults in a household were higher for adopters than non-adopters. The higher number of adults in adopter households implies that labour availability is likely to be higher among adopters. The significance of these variables indirectly implied their importance as determining factors in the adoption of pesticides for the control of yam tuber beetles in Oshimili area of Delta State, Nigeria.

Table 4. Test of Mean Difference of Socio-economic Characteristics of Adopters and Non-adopters

Characteristic	Adopters	Non-adopters	Mean difference	t-statistic	p-value
Age	47.94	54.99	–7.04	–4.36	0.01***
Years of formal education	9.1	5.88	3.26	4.3	0.01***
Adults in a household	3.41	2.53	0.88	6.34	0.01***
Farming experience	11.48	13.36	–1.88	–1.80	0.07
Farm income	53,640.21	35,388.46	18,251.75	7.03	0.01***
Farm size	0.45	0.38	0.074	4.03	0.01***

*** Statistically significant at 1% level; ** significant at 5% level
Source: Computed from survey data, 2015.

Probit Results of Determinants of Pesticide Adoption

The results of the probit model of factors influencing adoption of pesticide for the control of yam tuber beetles are shown in Table 5. The model had a good fit with a highly significant LR ratio, 106.67 ($p < 0.001$); a McFadden R^2 of 0.48 with 84.9% of cases correctly predicted. Apart from sex of the farmer, all other explanatory variables had statistically significant influence on the probability of adoption of pesticide technology for the control of yam tuber beetles. Adoption decision was found to be negatively and significantly associated with age. As farmers advance in age, risk aversion increases and they are less likely to experiment with new technologies, while younger farmers that are less risk averse are more likely to adopt new techniques of farming. The results further indicated that a 10% increase in age will cause a 0.2% decline in the probability of adoption of pesticide technology. This finding is supported by the report of Ghimire and Kafle (2014), Al-zyoud (2014) and Obayelu *et al*. (2016). Years of formal education is another variable found to have a positive and significant effect on pesticide technology adoption. The more educated farmers are the more open they are to adoption of innovative technologies, as they are more efficient to obtain and understand new techniques in a short period of time compared with their uneducated counterparts. Higher levels of education enhance farmers' awareness of the availability and benefits of new agricultural technologies. Thus, education not only facilitates adoption but also improves productivity among adopters of improved technology.

Table 5. Binary Probit Results of Determinants of Pesticide Adoption (n=159)

Variables	Coefficient	Std. Error	z	p-value	Marginal effects
const	–3.700	1.248	–2.965	0.003	
SEX	0.131	0.280	0.470	0.638	
FRMAGE	–0.040	0.018	–2.231	0.026**	–0.02
MRLSTA	0.287	0.369	0.776	0.438	
YRSEDU	0.077	0.031	2.438	0.015**	0.03
ADHHLD	0.445	0.152	2.920	0.004***	0.18
FARMEXP	0.061	0.027	2.277	0.023**	0.03
FRMINCM	0.0002	0.00001	2.032	0.042**	0.000085
FARMSZE	0.913	1.375	0.664	0.507	
CREDACS	0.800	0.289	2.765	0.006***	0.32
EXSNACS	0.564	0.288	1.962	0.05**	0.23
TRNPEST	0.899	0.333	2.699	0.007***	0.36

McFadden R-squared = 0.48
Number of cases 'correctly predicted' = 135 (84.9%)
Log-likelihood = –56.87355
Likelihood Ratio test: Chi-square(df=11) = 106.67 [0.0000]

*** Statistically significant at 1% level; ** significant at 5% level
Source: Computed from survey data, 2015.

This finding is supported by the report of Korir *et al*. (2015) and Khan *et al*. (2015) where educational level was found to positively affect the adoption of pesticide in Kenya and Pakistan, respectively. Other studies with similar reports include those of Adejumo *et al*. (2014) on factors influencing choice of pesticides used by grain farmers in Southwest Nigeria; and Al-zyoud (2014) on adoption of IPM techniques by greenhouse vegetable growers in Jordan.

The number of adult/household, a proxy for household size is another variable that had positive and significant effects on adoption decision of yam producers. Farmers who have more adults in their households are more likely to adopt the use of pesticide for yam beetle control than those from households with fewer adults. Thus the likelihood of adoption increases with the number of adults per household. Yam production is an arduous task that requires a great deal of human efforts, thus the availability of adults in the household as a source of family labour for a farmer, is an incentive to adoption. The marginal effect shows that a 10% increase in number of adult/household will increase the probability of pesticide adoption by 1.8%. This result is in agreement with those of Damisa *et al*. (2007), Amsalu and de Graaff (2007) and Alarima *et al*. (2011).

Farm income, farming experience and access to credit are other variables that exerted positive and significant effects on pesticide adoption in yam production. Farmers with higher farm income can afford the cost of the innovation and bear the risks associated with pesticide adoption for the control of yam beetles. This finding is consistent with those of Anang and Amikuzuno, (2015) and Obayelu *et al*. (2016). However, the response of technology adoption to farm income is very low as a 1% increase in farm income will result only in 0.000085 likelihood of adoption. The results imply that more experienced famers with improved farm income, and those that have better access to credit, have a higher likelihood to adopt pesticide technology for the control of yam beetles. The results are in consonance with the findings of Al-zyoud (2014) in Jordan on the adoption of pesticide technology. Baffoe-Asare *et al*. (2013) also found farming experience to have a positive and significant influence on the probability of pesticide use among cocoa farmers in the central region of Ghana.

The results furthered showed that access to extension agents, credit access and training on the use of pesticides exerted positive and significant effects, and are the most critical determinants of pesticides adoption as indicated by the marginal effects. This implies that the response of technology adoption to these variables is greater than other variables included in the model. As indicated in Table 5, a 10% increase in access to credit, extension contact and training on pesticide usage will increase the probability of pesticide adoption among yam farmers by 3.2%, 2.3% and 3.6% respectively. Farmers who have access to credit can buy seed yams, pesticides as well as other inputs needed for production, and this must have resulted in higher technology adoption than those with no access to credit. Agricultural extension services are the major source of information to farmers apart from farmers groups. Thus, contact with extension agents will therefore increase a farmer's likelihood of adopting improved technologies. This finding is in consonance with those of Samiee *et al*. (2009) who reported positive and significant influence of extension education and communication channels on the adoption of pesticide technology in Iran, and Nkamleu and Adesina (2000) on adoption of chemical pesticides in Cameroon.

Conclusion

The study analysed the effects of socio-economic factors on adoption of pesticide technology for the control of yam tuber beetles, using a binary probit model. A comparative analysis of socio-economic characteristics of adopters and non-adopters showed that there is statistically significant ($p < 0.01$) difference between the age, farm income, years of formal education, farm size and number of adults per household of adopters and non-adopters. The results of the probit estimates indicated that adoption of pesticide technology is positively and significantly influenced by years of formal education, number of adults per household, farming experience, farm income, access to credit, access to extension contacts and training on pesticide usage and handling. The results further showed that extension contacts, access to credit, and training on the use of pesticides are the most critical variables that influence the adoption decision of yam farmers, as a unit increase in these variables will increase the likelihood of pesticide adoption by 0.23, 0.32 and 0.36 respectively. The implication of these findings is that increased access to institutional support services such as extension, credit, and training are important to technology adoption. Therefore, they should be an integral component of policies and strategies to promote the adoption of innovations among smallholder crop farmers in Delta State, Nigeria.

Conflict of interests

We the authors do not find any conflict of interests with regards to the conception of the study and the preparation of this manuscript for publication.

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