British Journal of Applied Science & Technology
5(2): 150-165, 2015, Article no.BJAST.2015.015
ISSN: 2231-0843

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Smallholder Farmers' Preferences for Improved Cocoa Technologies in Ghana

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/BJAST/2015/12911
Editor(s):
(1) Ahmed Mohamed El-Waziry, King Saud University, College of Food and Agriculture Sciences, Kingdom of Saudi Arabia.
Reviewers:
(1) Anonymous, University of Nottingham, Malaysia.
(2) Anonymous, Aksum University-Shire Campus, Ethiopia.
Complete Peer review History: http://www.sciencedomain.org/review-history.php?iid=713&id=5&aid=6481

Original Research Article

Received 23rd July 2014
Accepted 21st August 2014
Published 10th October 2014

ABSTRACT

The cocoa (*Theobroma cocoa Linn*.) is the main foreign exchange earner and the backbone of the Ghanaian economy. However, over the years the production levels begun to dwindle and in the attempt to resuscitate the industry, the government introduced a technology package and social intervention to address it. The technology package consists of 25 unique attributes (classes of characteristics or components), of which some farmers adopted test part of it and left out others. The study seeks to determine socioeconomic factors influencing farmers' choice decision process and preferences for attributes of the technology packages. The results from the multinomial logit regression model revealed that availability of labour, gender, farm size, age of the cocoa farm, years of cocoa farm ownership and number of cocoa bags harvested per annum are the key

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variables influencing farmers' choices. Moreover, farmers who have long experience in cocoa cultivation and have had some form of training on the technology packages have high probability to adopt entire categories or classes of the technology package. Thus, institutional policy arrangement which emphasizes on training and targeting experience farmers will go a long way to enhance production level in the country.

Keywords: Cocoa; improve technology; farmers' preferences; adoption.

1. INTRODUCTION

The cocoa (*Theobroma cacao Linn*.) industry is dominated by smallholder farmers and it is the backbone of the Ghanaian economy, contributing approximately 5% of GDP in 2008 (Mhango [1]) and as major source of foreign exchange and fiscal earnings (Bulir [2]; McKay and Arytee [3]). The cocoa subsector employs greater proportion of the labour force in the country (FASDEP [4]). Since its introduction into Ghana in the seventh century from Sao Tome and Principe, cocoa has played a major role in the socioeconomic development of the nation. In fact, Ghana was the leading exporter of cocoa in sub-saharan African throughout the 19th and later the part of 20th century, until her position as the leading exporter of cocoa was taking by Cote D'lvoire. In 1965 Ghana exported well over 560,000 metric tonnes of cocoa beans the highest volume ever; and this declined to 154,000 metric tonnes in the 1980s (Appiah [5]). This observation is as a result of numerous problems besetting the industry, particularly years of economic stagnation and neglect, over aged cocoa farms and aging farmers, reluctant of the youth to take up farming as vocation due to status problem as well as high level poverty rate associated with smallholder cocoa farmers due to low producer price being paid by Ghana Cocoa Board (COCOBOD) (Vigneri [6]). In addition to these socioeconomic problems, the biophysical dimensions beset the industry, disease and pest became a major problem notable black pod and capsids, which transmit (vector) swollen shoot virus disease. In addition, the fertility levels of soils under most cocoa farm declined due to years of active mining of the cocoa plant without proactive effort to replenish them with artificial inorganic base fertilizers. This stemmed from general non-availability and affordability of inputs by smallholders. These myriads of problems reflected the general decline in the production levels of cocoa in the country. However, it has been suggested that given the right technological support through research and development as well as intensification, Ghana has the potential to increase her current production level of 300-400kg per hectare to comparable levels of countries such as Cote D'lvoire, Malaysia and Indonesia, which are producing 800kg, 1800kg and 1000kg per hectare respectively (Ampofo [7]; Anon [8]; Anim-Kwarpong and Frimpong [9]; Ministry of Finance [10]). In the attempt to resuscitate the cocoa industry, the government of Ghana under the auspices of COCOBOD introduced a pilot project in 2001 code name CODAPEC and Cocoa High-Tech technology consisting of packages of cocoa technologies and social intervention developed by Cocoa Research Institute of Ghana (CRIG). The positive impact of this intervention was realized by Ghana recording a historical production level of 1,004,194 metric tonnes in 2011(Ghana Cocoa Board [11]). However, this programme did not cover all the cocoa growing districts across the nation due to budgetary constraint. But other cocoa growing districts that were not covered realizing the benefits in terms of cocoa yields decided to adopt this novel technology package. Moreover, the discrete nature of the technology package prompted some farmers to choose test part or partially adopt components of the total package. Nonetheless, the CODAPEC and Cocoa High-Tech technology package consist of 25 unique attributes (Baffoe-Asare et al. [12]). The objective of this study was to determine the socioeconomic factors influencing cocoa farmers' adoption or choice decision-making process in the Central Region of Ghana through application of multinomial choice analysis.

2. CODAPEC AND COCOA HIGH-TECH TECHNOLOGY

In general, cocoa technology encompasses all the body of traditional knowledge and skills acquired over generations that go into production, processing and subsequent marketing of the cocoa beans (Laryea [13]). However, in the attempt to increase the productivity of old and new farms over decade of decline in cocoa production as result of rising cost of control of black pod and capsids which spread swollen shoot virus disease, the government of Ghana introduced in 2001 mass spraying exercise with acronym Improved Cocoa Disease and Pest Control progamme

(CODAPEC) (Aneani et al. [14]). The CODAPEC recommended the use of three main insecticides; Actara 240SC, Confidor 200 SL and Akate Master for the control of capsids and six fungicides; Champion 80WP, Funguran-OH50WP, Nordox Super 75WP, Ridomil Gold 66Plus WP, Kocide 101WP, Metalm 72WP for control of black pod and related fungal disease (see Table1) (Duker & Sakpaku [15]; Abankwah et al. [16]; Adjinah & Opoku [17]). CODAPEC amongst other things provided free inputs and labour for the control of capsids and black pod disease on pilot project. However, due to budgetary constraints on the part of the government the coverage was limited and the frequency of spraying under CODAPEC was inadequate in spite of its positive impact on cocoa production levels (Ofori-Frimpong [18]). Thus, farmers were expected to compliment the effort of the government with additional spraying schedules and those who were not covered under the project (Aneani et al. [19]). According to Ofori-Frimpong [18] cocoa "High Technology" is defined as the sustainable cocoa production by which the farmer increases and maintains productivity through soil fertility maintenance at levels that are economically viable, ecologically sound and culturally acceptable using efficient management resources. Nevertheless, over the years most cocoa agronomic research objectives focus on pest control and management as well as improve yield breeding programmes to the detriment of cocoa production and soil interface (Ofori-Frimpong [18]). However, cocoa as tree crop actively mined the soils of essential nutrients and these nutrients are lost through harvesting under traditional cocoa agroforestry system without being compensated for by artificial application of fertilizers. This tremendously led to decline in cocoa productivity per unit area as compared to that of Cote D'Ivoire and Malaysia. Cocoa High-Tech technology therefore addresses these deficiencies in the agronomic practices. Cocoa High-Tech technology package involves frequent weeding; planting high yielding hybrid cocoa varieties and judicious application of inorganic fertilizers (Aneani et al. [14]).There are two main fertilizer formulations under High-Tech technology (see Table 1), these are granular fertilizers (trade name: Assasewura and Cocofeed) and liquid fertilizers (trade name: Sidalco Balanced and Sidalco Potassium rich) (Ofori-Frimpong [18]). In addition, cocoa high-tech technologies emphasized on improved harvesting and drying technologies (Bosompem et al. [20]). The socioeconomic dimension of CODAPEC and Cocoa High-Tech technologies was to address chronic poverty amongst smallholder cocoa farmers and to reduce rural-urban migration of the productive youth through improve income and living standards from receipts of foreign exchange contribution of cocoa earnings (Vigneri [6]), and by paying consistent incremental and realistic producer prices reflecting world market trends. In addition, CODAPEC and Cocoa High-Tech technologies seek to reduce environmental degradation emanating from deforestation through conversion of virgin forest lands for cocoa production as a result of decrease in soil fertility and coupled with low yields of existing cocoa farms (Bosompem et al. [20]; Ofori-Frimpong [18]).

3. MATERIALS AND METHODS

3.1 Study Area and Data Collection

This study is based on cross-sectional survey of data collected from five cocoa growing districts in the Central Region of Ghana. On-farm and farm household surveys were conducted from December 2009 to February 2010 to generate socioeconomic, demographic, agroecological and agronomic data for 2009 cocoa crop season. These data set were generated to model their impact on smallholder cocoa farmers' choice decision making process on the adoption CODAPEC and Cocoa High-Tech technologies. In this study, we employed multistage random sampling method to delimit districts, farming communities and finally farm households. At the first stage of random sampling, five districts were selected from eight cocoa growing districts. These districts were *Cape Coast, Twifo Praso, Twifo Nyinase, Assin Foso* and *Assin Breku*. In the subsequent stages of sampling procedure, five communities were randomly selected from each of the five aforementioned cocoa growing districts. Thus in all, a total of 250 smallholder farm households were selected from 25 communities. Structured questionnaires were administered as the main instruments for data acquisition. However, five enumerators were trained and test items or instruments were pretested prior to administration of the questionnaire to remove any inconsistencies. This was done to ensure that the test instruments elicit the information sought for from cocoa farmers. In order to augment primary data collected from the smallholder farm households, focus group discussion or interviews were conducted with stakeholders or major players in the cocoa industries and opinion leaders within the communities.

3.2 Analytical and Conceptual Framework

The discrete nature or multiplicity of attributes in CODAPEC and Cocoa High-Tech technologies implies that farmers have wide range of selection portfolios to handle. The probability of an individual cocoa farmer to choose from sets of technology attributes is more or less influenced by the said individual socioeconomic and biophysical characteristics. Hence, the usual modeling approach involve multiple choice in adoption process is the application of multinomial logit (Deressa et al. [21]; Hassan & Nhemachena [22]; Nkamleu & Kielland [23]; Ochieng et al. [24]). Multinomial logit (MNL) modeling has simple computational advantage over other forms of multinomial modeling (Tse [25]; Ochieng et al. [24]). In addition, it allows analysis of decisions across more than two categories and facilitates in the determination of choice probabilities for different categories (Nkamleu & Kielland [23]; Madalla [26]). Moreover, MNL is appropriate under condition of dealing with data sets that consist of individual specific characteristics (Green [27]).

Table 1. Percentage distribution of adopters and non-adopters of CODAPEC and cocoa High-Tech technology packages used as dependent (response) variable in multinomial Logit modelling (N=250)

Technology Package/Class/ Components	Code	Description of technology attributes	Adopters (%)	Non-adopters (%)
Cultural maintenance	CM1	Removal of basal chupons and overhead canopies	98.88	1.12
	CM2	Weeding of the cocoa farm regularly	96.88	3.12
	CM3	Removal of dead husks and pods	93.20	6.80
	CM4	Maintaining some trees in cocoa farm	85.20	14.80
	CM5	Removal of all hosts on the farm(e.g. mistletoe)	73.60	26.40
	CM6	Drainage	27.60	72.40
	CM7	Use of deep pit to bury dead husks and pods.	20.00	80.00
Fertilizer	FERT1	Use of Assasewura fertilizer(NPK/ 10:10:10)	98.40	1.60
	FERT2	Use of Sidalco (NPK/ 6:0:20 + TE (trace elements)	39.60	60.40
	FERT3	Use of Cocoafeed (NPK/ 0:30:20)	25.60	74.40
	FERT4	Application of the fertilizer at the beginning of the rainy seasons	92.00	8.00
	FERT5	Broadcasting method	83.20	16.80
	FERT6	Ring application method	24.80	75.20
Fungicide	FU1	Use of Ridomil(6% metalaxyl-M and 60% copper (1) oxide)	64.40	35.60
	FU2	Use of Nordox(Cuprous oxide)	59.60	40.40
	FU3	Use of Champion(Cupric hydroxide)	30.40	69.60
	FU4	Use of Funguran(Cupric hydroxide)	24.80	75.20
	FU5	Use of Kocide 101(Cupric hydroxide)	18.80	81.20
	FU6	Use of Gold 66(Cuprous oxide + mefenoxam)	4.80	95.20
Fermentation and drying		Use of sun drying of cocoa beans	100.00	0.00
		Use of less than 5 days for fermentation	4.80	95.20
		Use of 5-7 days for fermentation	95.20	4.80
Application of insecticide	INSE1	Spraying of *Akate* master(Bifenthrin)	85.20	14.80
	INSE2	Spraying of Confidor(Imidacloprid)	80.40	19.60
	INSE3	Spraying of Actara(Thiamethoxam)	54.00	46.00
	INSE4	Spraying of 2-tankful of Chemical and water mixture per acre	50.80	49.20

Let Y be random sample of farmers taking on the values = {1, 2, 3, 4…..N} with each individual farmer having sets of selection portfolios or choice option (j = 0, 1, 2, 3……J) for CODAPEC and Cocoa High-Tech technologies (Table 1). Where vector X_i is of the form K x 1; denotes socioeconomic, agronomic and biophysical characteristics or attributes of each smallholder cocoa farm household. However, under perfect state conditions X_i affects the response probabilities ($Prob(Y=j|X_i)$; j = 0, 1, 2, 3……J. The MNL model for adoption choice decisions of CODAPEC and Cocoa High-Tech technologies is specified as relationship between the probabilities of choosing option j and set of explanatory variables X_i (Nkamleu & Kielland [23]; Deressa et al., [21]; Green [27]).The conceptual model is given as:

$$\Pr ob(Y=j\,|\,X)=\frac{e^{\beta_j X_i}}{1+\sum_{k=0}^{J}e^{\beta_k X_i}}$$

j = 0, 1, 2, 3……J (1)

However, it is more appropriate to normalized equation (1) by setting $\beta_0 = 0$ to remove problem of indeterminacy. This stemmed from the fact that probabilities sum up to one. It is J parameter vectors required to compute probabilities of J+1 choices. Hence, the probabilities can be estimated as:

$$\Pr ob(Y=1\,|\,X)=\frac{e^{\beta_j X_i}}{1+\sum_{k=1}^{J}e^{\beta_k X_j}}$$

j = 0, 2, 3…..J $\beta_0 = 0$ (2)

Moreover, from equation (2), if J = 1 then this implies that J log-odd ratios of the model can be computed as follows (Green [27]):

$$\ln\left[\frac{P_{ij}}{P_{ik}}\right]= X_i\left(\beta_j-\beta_k\right)=X_i\beta_j \quad ;\ \text{if } k = 0 \qquad (3)$$

The reduced linear form of equation (3) is (Ochieng et al. [23]):

$$Y=\beta_0+\sum_{j=1}^{J}\beta_j X_i+\varepsilon \qquad (4)$$

Where β_0, β_j and β_k in the MNL model are vectors of parameters to be estimated, ε is the error term and X_i are the characteristics of cocoa farmers which influence adoption CODAPEC and Cocoa High-Tech technologies. The coefficients or parameter estimates in the MNL model are difficult to interpret. In addition, linking β_j with J^{th} outcomes could be misleading (Green [27]). This is because the parameters of MNL model indicate directional effects of the independent variables on response variables, but not the actual magnitude of change or probabilities (Deressa et al. [28]). For the purposes of interpretation, usually marginal effects of the explanatory variables are obtained as given below (Green [27]):

$$\delta_j=\frac{\partial P_j}{\partial X_i}=P_j\left[\beta_j-\sum_{K=0}^{J}P_k\beta_k\right]=P_j\left[\beta_j-\bar{\beta}\right] \qquad (5)$$

β_j can be computed or estimated with known econometric and statistical software packages; in this instance STATA 10.0 was employed. Moreover, in this analysis the base outcome or reference category was normally set to zero (0) suggesting non-adoption of the technology packages. The adoption options of seven groups or components of CODAPEC and Cocoa High-Tech technologies, and their corresponding 25 attributes are described in the Table 1.

3.3 Empirical Model

The dependent variables in the empirical estimation are the choice of seven groups or classes of CODAPEC and Cocoa High-Tech technologies and their 25 options of attributes or measures (Table 1). Each group or class under technology package was estimated separately using its corresponding measures or attributes as dependent categories in the MNL model.

The explanatory variables for this study consists of household characteristics such as gender, age, education, household size, experience, years of cocoa farm ownership and availability of labour; institutional factor such as training; and on-farm characteristic such as number of cocoa bags harvested in a year, farm size and age of the cocoa farm (Table 2). These independent variables were selected to run the MNL model based on available literature. The descriptive statistics of these variables are shown in Table 2.

Harvbags is variable used in the study to measure or capture the number of bags of cocoa harvested in a year by the farmer. The number of cocoa bags harvested from the cocoa plantation by the cocoa farmers gives an indication to the level of their income. Income is one of the socioeconomic variables that strongly relates to adoption of agriculture technology (Knowler and Bradshaw [29]; Franzel [30]). Thus, famers who realize or harvest large numbers of cocoa bags at the end of crop season, invariably have higher income and will readily adopt technology that will increase their yield levels (Norris and Batie [31]). The only exceptions to this are farmers with other sources of income from non-agricultural related activities.

avlabour is a dummy variable that measures or captures cocoa farmers' access to available labour on both formal and non-formal sector of labour market for their on-farm activities in the cocoa production process. It is dummied, Yes for 1 and No for 0. Labour availability is strong determinant in choice decision for adoption of any technology. It can be either negatively or positively associated with adoption, depending on the nature of the novel technology (Burke [32]; Tersbol et al. [33]).

gender is a dummy variable that indexes social role rather than sex of the household head. It has value 1 for male and 0 for female. In general, male-headed households are resource endowed than their female counterpart particularly in tropical rural Africa. Male-headed households have readily access to information about new technology and they are not confronted with traditional social barriers as in the case of female-headed households (Asfaw and Admassie [34]). Moreover, depending on the nature of the technology, due to social role some on-farm work activities and task are designated as female work (Valdivia [35]). Hence, gender has strong influence on adoption decision making process (Nchinda and Mendi [36]; Von Billow and Sorensen [37]).

Age as used in this study, is the age of the farmer or household head. This could be either male, de facto or de jury head of the cocoa farm household. Age is documented in some adoption studies as proxy to experience (Deressa et al., [21]; Nkamleu et al. [38]). Some studies have reported that age has no influence on adoption of new technology (Zhang and Flick [39]; Bekele and Drake [40]). However, adoption is found to be positively associated with age (Bayard et al., [41]); whereas, other studies have indicated negative association of age with adoption decision (Shiferaw and Holden [42]; Anley et al. [43]). Moreover, younger farmers tend to be more innovative, proactive and less risk averse, and apt to implementing new ideas. In this study, it is therefore hypothesized that age as heuristic variable has both negative and positive impact on adoption of CODAPEC and Cocoa High-Tech technology.

edu measures the level of education of the cocoa farmer. Higher education increase farmers' ability to access information on novel technology. In addition, education enhances farmers' capacity to be receptive to new ideas and it increases their creative power. Thus, education is usually hypothesized to be positively associated with adoption of new technology (Ervin and Ervin [44]; Lin [45]).

hhsize denotes the size of the household. In cocoa production, most farm household relied on their family members for the provision of labour for both on and off-farm day-to-day major activities. Most of the CODAPEC and Cocoa High-Tech technology packages are labour intensive. Large families with more labour endowment will readily adopt labour intensive technology (Croppenstedt et al. [46]). However, this is inconclusive in that farm households with large family size tend to have high dependency ratios and will be compelled to divert test part of their labour to off-farm activities to support their families (Yirga [47]). Moreover, labour can also be channeled into increase land area of food production to support large family size.

The influence of *training* can be seen from two main perspectives. Training will reinforce individual farmer's level of competencies in conducting specific psychomotor skills to perfection in the implementation of CODAPEC and Cocoa High-Tech technology packages. Secondly training gives an insight to the technical challenges that could be encountered by the farmer during on-farm implementation of the technology (Meenambigai and Seetharaman [48]). This could easily be addressed through effective demonstration during the training. Moreover, training helps the farmer to appreciate the benefit that could be derived from the new technology (Chi and Yamada [49]). Thus, it expected to be positively related to adoption (Birkhaeuser et al. [50]). However, in this study training was indexed as "*yes*" equal to one (1) and "*no*" equal zero (0). Where "yes" captures whether the farmer has had any form of training on the new technology from Produce Buying Companies and/or Ghana Cocoa Board. In the effect, training can also be used to capture the impact of extension and educational activities in the cocoa subsector.

Table 2. Definition and descriptive statistics of sampled farm households: These are independent variables used in the empirical analysis in the multinomial logit model (N=250)

Variable	Description	Values/ Measures	Continuous variables*		Categorical variables*	
			Mean	S.D.	(Percentages)	
harvbags	This variable measures the total number of bags of cocoa harvested and sold by the household head in a year.	Numbers	21.57	18.3		
avlabour	This dummy variable and captures access or availability of labour for on-farm activities in cocoa production to the cocoa farmer.	Yes=1 No =0	-	-	1=58.0	0=42.0
gender	This variable measures social role of the household head.	1=Male 0=Female	-	-	1=76.0	0=24.0
age	This is the age of the household head.	Years	50.87	11.4	-	-
edu	This variable determines whether the household head has had any formal education or not. It is a measure of educational attainment	Yes=1 No =0			1=60.8	0=39.2
hhsize	This is the total number of individual in the household who eat from common cooking pot.	Number	8.08	4.8	-	-
training	This variable captures whether the household head (farmer) has received some form of training on CODAPEC and High-tech technologies.	Yes=1 No=0	-	-	1=28.0	0=72.0
yownership	The number of years cocoa farm ownership of the household head.	Years	18.03	9.7	-	-
farmsize	The total area or size of landholding under cocoa cultivation.	Hectares	3.97	4.9	-	-
cocoaage	This represents the age of the cocoa farm.	Years	17.12	8.5	-	-
experience	This captures number of years of cocoa farming experience of the household head.	Years	21.72	8.4	-	-

Y*ownership* is variable used in the MNL model to measure the length or number of years by which the individual farmer has been owner of a cocoa farm. In Ghana, many farmers play a caretaker role for other cacao farmers. Caretaker farmers are paid in cash or in kind at the end of the crop season. However, they have responsibility of day-to-day management of the cocoa farm and act in the capacity of the farm owners in their absence (absentee farmers). There is marked distinction between *experience* and the years of ownership of cocoa farm. Experience in this study, was captured as years of cultivation of cocoa farm. One unique thing about experience is that it helps individual farmer concern to effectively address technical or practical problems related to agronomic principles that will emanate in the course of implementation of the new technology on the field. Experience has direct influence on choice decision process of adoption of new technology (Namwata et al., [51]; Baffoe-Asare et al. [12]; Ikani et al*.* [52]).

Farmsize is a measure of land holding under cocoa cultivation. Large farm size is often associated with greater wealth and increased capital availability, which invariably increases invest in new technology. However, farm size has both negative and positive impact on adoption of agricultural technology (Bradshaw et al. [53]; Norris and Batie [31]).

Cocoaage denotes the age of the cocoa farm. In general, the productivity of cocoa farm decline with passing of age of the cocoa trees. Farmers will readily spend money on technology package that will increase productivity of old cocoa farm. In such a scenario, the input cost should be less than the returns from the additional or marginal yield as result of the new technology. Conversely, if the capital expenditure as result of the new technology does not commensurate with the returns it will negatively impact on adoption. However, according to Anim-Kwapong and Frimpong [9] cocoa farmers in general feel reluctant to invest on input for old cocoa farms due to perceived low returns.

4. RESULTS AND DISCUSSION

4.1 Field Survey and Household Characteristics

Table 1 shows the percentage distribution of adopters and non-adopter of specific technology attributes under various components or groups of technology package within CODAPEC and Cocoa High-Tech technology. In general, high adoption levels under cultural maintenance package were recorded, ranging from 73.6% to 98.8% for specific attributes. However, 72.4% and 80% of the farmers did not adopt (non-adopters) the construction of drainage systems, and the use of deep pit to bury dead husks and pods respectively. These cultural practices are designed to control and reduce potential outbreak of black pod disease (*Phytophthora megakarya* and *Phytophthora palmivora*), without the farmer necessarily resorting to the frequent application of fungicides (Ndoumbe-Nkeng et al., [54]). *Phytophthora megakarya* and *Phytophthora palmivora* thrive under water logged, humid and unhygienic farming conditions, particularly in dead infected plant material. A good sanitation practices reduce incidence of black pod disease in the cocoa farms (Opoku et al. [55]).

Cocoa as a tree plantation crop can be on the land for years and continuously mining the soil for nutrients. This could lead to decline in soil fertility and subsequent low yields. To address decline in yields as trees ages and coupled with low soil fertility over the years, mixed specific varieties of compound fertilizers with various mode of applications were recommended under CODAPEC and High-Tech technology. The use of "*Assasewura"* fertilizer (NPK/ 10:10:10) is very popular amongst the farmers registering 98.4% adoption. However, other forms of fertilizers recorded low rate of adoption. *Sidalco* (NPK/ 6:0:20 + TE (trace elements)) and *Cocoafeed* (NPK/ 0:30:20) recorded highest levels of non-adopters 60.40% and 74.40% respectively. The use of broadcasting as mode of fertilizer application registered 83.2% of adoption, as compared to ring method which recorded 24.8 %.This might stemmed from the fact that ring method of fertilizer application is laborious and high demanding. However, it is most efficient, non- wasteful and environmentally sound as well as economical way of applying fertilizer as compared to broadcasting. Nevertheless, most of the farmers observed the strict adherence to application of compound fertilizers at the onset of the rains; recording 92% of adoption level. The use of fungicide in the control of black pod disease under the technology package comes with wide range of different formulations to reduce disease resistance. The general observation was that Ridomil (6% Metalaxyl-M and 60% copper (1) oxide) and Nordox (Cuprous oxide) recorded relatively high proportion of adoption levels at 64.4% and 59.6% respectively. However, the other four recommended fungicides Champion (Cupric hydroxide), Funguran (Cupric hydroxide), Kocide 101(Cupric hydroxide) and Gold 66(Cuprous oxide + mefenoxam) registered high rate of non-adoption levels at 69.6%, 75.2%, 81.2% and 95.2% respectively. These four brands of fungicides seem not to be popular amongst 250 cocoa farm households interviewed in the Central Region of Ghana. Almost 250 cocoa farmers interviewed employed sun drying method (100%) and 5-7 days to ferment (95.2%) the cocoa beans. These results are very encouraging in that these processing procedures enhance the quality of the cocoa beans and give them the unique aroma, thus attracting premium price in the world market.

The control of capsids (*Sahlbergella singularis* and *Distanfiella theobroma*) is one of the major constraints in the cocoa production. These insect pests can cause serious economic damage leading to low or virtually no yield in the cocoa farms (Ayenor [56]). In addition, continuous application of insecticides could lead to insecticides resistance by target pest. Thus, it is recommended that multiple insecticides should be employed and at best integrated pest management. In this study, we recorded relative high percentage of adoption for three main recommended insecticides under CODAPEC and High-Tech technology package. These are as follows *Akate* master (Bifenthrin) 85.2%, Confidor (Imidacloprid) 80.4 and Actara (Thiamethoxam) 54% of adoption levels for 250 cocoa farm household interviewed.

4.2 Control and Management of Black Pod Disease with Fungicides

The econometric model results of the socioeconomic determinants of farmers' choice decision making process on the use of fungicide in the control and management of black pod disease is shown in Table 3. The base category in the model is non-adoption. The model was estimated with maximum likelihood procedure. The chi-squared result was highly significant

(P<0.0001) suggesting that the model has a strong explanatory power. The availability of labour is significantly increasing the probability of Kocide. Thus, suggesting that female cocoa farmers are more likely to adopt Ridomil and Kocide than their male counterparts. Household size (hhsize) is significant and positively related to adoption of Funguran. Large household size increases the probability of farmers using Funguran. Training on the use of fungicides and general CODAPEC and High-Tech technology package promotes the adoption of Champion and Kocide, and also reduce the probability of farmers adopting Gold 66^{+}. On the other hand, years of cocoa farm ownership (yownership) was observed to be significant and negatively related to adoption of champion. Moreover, farm size (farmsize) significantly decreased the probability of adoption of Ridomil and Kocide; rather it increased the probability of cocoa farmers using Nordox. The results indicated old cocoa farm is strongly associated with the use of Champion. Thus, the age of the cocoa farm (cocoaage) was significant and positively related to adoption of Champion. One of the interesting results was that experience increased the probability of the cocoa farmers adopting the whole of recommended fungicides package under CODAPEC and High-Tech technology. Experience was significant and positively related to almost all the fungicides recommended for the control of blackpod disease under the technology package.

the cocoa farmers using of Ridomil, Champion, Funguran, and Kocide on their farms. However, gender was negatively related to Ridomil and

4.3 Adoption of Sound Fertilizer Application Practices

Table 4 presents the estimated results of the multinomial logit model of factors influencing farmers' choice decision to adopt sound fertilizer application practices. The model log likelihood of chi-squared was significant (*P*=0.0003) suggesting strong explanatory power. The pseudo R^2 was 22.2% above the statistical threshold of 20%, thus confirming farmers' choice decision making process could be attributed to fitted covariates. The base outcome or category is non-adoption.

The wealth of the farmers is captured as number of cocoa bags harvested (harvbags) per annum. The empirical result suggests that *harvbags* is significant and positively related to adoption of Sidalco fertilizer. As the wealth of the household increase or as the number of cocoa bags harvested in a year increases there is a switch from the use of other fertilizers to the use of Sidalco fertilizer. Moreover, increase in labour availability and age of household head lead to a decrease in the probability of adoption of Sidalco fertilizer.

Table 3. Parameter estimates of the multinomial logit model for control and management of black pod disease (*Phytophthora megakarya* and *Phytophthora palmivora*) with fungicides

Variable	Coefficient					
	FU1	**FU2**	**FU3**	**FU4**	**FU5**	**FU6**
Harvbags	0.0016157	0.0006443	-0.000337	-0.0069821	0.0029523	-0.0227733
Avlabour	0.6549711****	-0.4333702	0.4270729**	0.5990889*	0.4304736**	1.301650
Gender	-0.3636563*	-0.2001642	-0.2308224	-0.1758565	-0.5028911**	-0.660020
Age	-0.0011613	-0.0040546	-0.0023564	-0.0275621	-0.0050525	-0.0370262
Edu	0.1793396	-0.1330032	0.044074	0.6079409	0.1545885	0.2821897
Hhsize	-0.0040014	0.0189234	-0.0187397	0.0548795*	0.0041532	-0.20001018
Training	0.3079693	-0.2222828	0.4243000**	-0.0541767	0.4771683**	-1.634635***
Yownership	-0.0082526	0.0122145	-0.0300051**	-0.016223	-0.012707	-0.0953928
Farmsize	-0.0617486*	0.0402426**	0.0095452	0.0086663	-0.0844272**	0.0061436
Cocoaage	-0.0035087	-0.0054265	0.0210607*	0.0326816	0.0116458	0.0489375
Experience	0.0440415****	0.0875065****	0.0638284****	0.1010883****	0.0252076**	0.0495355

P<0.10; P<0.05**; P<0.01***; P<0.001****, Log likelihood =-2223.1196, LR Chi^2 (77) = 266.28, Prob>Chi^2 = 0.0000, Pseudo R2= 0.3565; Base outcome or category is non-adoption, FU1: Use of Ridomil; FU2: Use of Nordox; FU3: Use of Champion; FU4: Use of Funguran; FU5: Use of Kocide 101; FU6: Use of Gold 66^{+}.*

Table 4. Parameter estimates of the multinomial logit model for adoption of fertilizer application package

Variable	Coefficients					
	FERT1	**FERT2**	**FERT3**	**FERT4**	**FERT5**	**FERT6**
Harvbags	0.0220940	0.0050976*	0.0025064	0.0021111	0.0030048	0.0012596
Avlabour	-0.0870882	-0.7185545***	-0.382849	0.3363931	-0.0673197	-0.1042263
Gender	0.0265941	0.4544858	0.0526601	0.834048**	-0.0147063	-0.0037357
Age	-0.0080977	-0.0426555***	-0.0130527	-0.0234146	-0.0121186	-0.0107127
Edu	-0.0374864	0.0989647	-0.177816	-0.1956461	0.1455910	-0.002950
Hhsize	0.0188800	0.0838443	0.059989***	0.0427493	0.0045493	0.0222464
Training	-0.2068213	-1.155277***	-0.6910869***	0.5470319	-0.2097634	-0.1548823
Yownership	0.0045088	0.0231835	0.0333797**	0.0377909**	0.005039	0.004815
Farmsize	0.0026189	0.0200261	0.0031691	-0.019225	0.0044475	0.0073938
Cocoaage	-0.0002818	0.0124891	-0.0347941**	-0.021134	0.0054773	0.0004485
Experience	0.02484820***	0.0896018****	0.0611093****	0.0587631	0.0279135***	0.0281096***

P<0.10; P<0.05**; P<0.01***; P<0.001****, Log likelihood =-2456.8977, LR Chi^2 (66) = 122.62, Prob>Chi^2 = 0.0003, Pseudo R2= 0.2224, Base outcome or category is non-adoption, FERT1: Use of Assasewura fertilizer; FERT2: Use of Sedalco; FERT3: Use of Cocoafeed; FERT4: Application of the fertilizer at the beginning of the rainy seasons; FERT5: Broadcasting method; FERT6: Ring application method*

Gender is one of the strong explanatory variable of farmer choice decision making process, was observed to be significant and positively related to application of the fertilizers at the beginning of the onset of the rainy seasons. However, male cocoa farmer is more likely to apply fertilizer at the beginning of the rain season than the female counterpart. In addition, the results suggest that increase in household size invariably increase the adoption of Cocoafeed. On the contrary, training which is expected to enhance the adoption of the technology packages under fertilizer usage, rather decreases the adoption of Sidalco and Cocoafeed by the cocoa farmers. The number of years that cocoa farmers have been in charge of cocoa farm (i.e. years of ownership) positively influence their decision to adopt Cocoafeed and the application fertilizer at the beginning of the rainy season. As the cocoa farm ages (*Cocoaage*), the farmers switched from the use of Cocoafeed to other fertilizers. Experience of the cocoa farmers in sound agronomic practices of cocoa cultivation increase their decision to adopt almost all the entire package under fertilizer application.

4.4 Improvements in On-farm Cultural Practices

Table 5 presents multinomial analysis of factors influence farmers' decisions to adopt improved on-farm cultural practices under CODAPEC and High-Tech technology package .The number of cocoa bags harvested (harvbags), which represent the wealth of the household negatively affected the maintenance of remnant trees on cocoa farm as standard agroforestry practise (Table 5). The surprising result is the negative relationship between education and adoption of maintenance remnant trees in cocoa agro forestry system. In addition, the results indicated that the use of deep pit to bury dead husks and pods is significant and positively related to years of ownership of cocoa farm by the farmers. Thus, the farmers' decision to adopt this sanitation measure against spread of black pod disease and capsids infestation is borne out of long years of ownership of cocoa farmer. However, the age of cocoa farm (cocoaage) is significant and negatively related to maintenance of some trees on cocoa farm, the removal of all hosts on the farm and the use of deep pit to bury dead husks and pods. Experience enhances the adoption of almost all the entire technology package under cultural practices.

Under fermentation technology and drying of cocoa beans, it was observed that increasing household size (hhsize) was significant and negatively associated with non-adoption (Table 7). Thus, increasing household size increases adoption decision of cocoa farmers to use 5-7 days for fermentation and sun drying method for the cocoa beans. In this empirical analysis, the base outcome or category is the use of sun drying for cocoa beans (Table 7). All other explanatory variables considered in the model were not statistically significant.

Table 5. Parameter estimates of the multinomial logit model for approved on-farm cultural practices

Variable	Coefficient						
	CM1	**CM2**	**CM3**	**CM4**	**CM5**	**CM6**	**CM7**
Harvbags	-0.0007115	-0.0005921	-0.0003592	**-0.0231803***	-0.0000591	-0.0005781	-0.0006042
Avlabour	0.1376278	0.1358816	0.121103	0.507542	0.115579	0.2132497	0.2493866
Gender	0.1900272	0.0998125	0.2026802	0.0635325	0.075426	0.2189726	0.188807
Edu	-0.1640297	-0.1872798	-0.2840739	**-0.6282635***	-0.2251127	-0.312784	-0.473925
Age	-0.0005018	-0.0036941	-0.006496	0.0183127	0.0010513	0.0038942	-0.0189167
Hhsize	0.0028392	0.0057606	0.0100687	-0.0140061	-0.0042242	-0.0159497	0.0332571
Training	-0.011091	-0.0053718	-0.0283832	-0.2392247	0.0395555	-0.0155146	-0.2580501
Yownership	0.0001618	0.0034576	0.0023855	0.0116601	0.001809	-0.0047496	0.0360467*
Farmsize	0.0041496	0.0031644	0.0027986	0.0548188	-0.01178851	-0.0076794	-0.0231868
Cocoaage	-0.0036312	-0.0076891	-0.0002043	-0 .0744517***	-0.0103217***	-0.0076794	-0.0422653**
Experience	0.0267653***	0.0236614	0.0268691***	0.0777779****	0.0342492***	0.0350772****	0.0464198****

P<0.10; P<0.05**; P<0.01***; P<0.001****, Log likelihood =-3288.7206, LR Chi^2 (77) = 85.63, Prob>Chi^2 = 0.0004, Pseudo R2= 0.2129, Base outcome or category is non-adoption, CM1: Removal of basal chupons and overhead canopies; CM2: Weeding of the cocoa farm regularly; CM3: Removal of dead husks and pods; CM4: Maintaining some trees in cocoa farm; CM5: Removal of all hosts on the farm; CM6: Drainage; CM7: Use of deep pit to bury dead husks and pods*

4.5 Control and Management of Cocoa Capsids with Approved Insecticides

In cocoa agroecosystem the control and management of capsids is one of the major pests constraints affecting meaningful cocoa production activity. Capsids (*Sahlbergella singularis* and *Distanfiella theobroma*) infestation can dramatically lead to yield reduction and the lost of entire plantation (Ayenor [56]). The results of multinomial logit modeling on farmers' choice decision for selecting various forms of insecticides in the control and management of capsids are shown in Table 6. The number of cocoa bags harvested (harvbags) in a year was observed to be negatively related to adoption of Akate master, the use of two tank full of water in mixing the insecticides prior to spraying and positively related to adoption of Confidor. Labour availability significantly and positively influences the probability of a farmer adopting Akate master, Actara and mixing the insecticide with required standard amount of water. However, gender is positively related to the use of Akate master and Confidor. Age explains for decision to choose Akate master and strict adherence to mixing the recommended insecticide with required standard amount of water before spraying.

Training and experience were explanatory or independent variables strongly influence the probability of the farmer adopting the total packages. Thus, farmers who have had some form of training on CODAPEC and High-Tech technology package and long experience in cocoa cultivation show high probability to adopt entire package. Moreover, increasing years of ownership of cocoa farm decrease the adoption of Akate master and the use of standard amount of water in the formulation before spraying.

Table 6. Parameter estimates of the multinomial logit model for control and management of cocoa capsids (*Sahlbergella singularis* and *Distanfiella theobroma*) with approved insecticides

Variable	Coefficient			
	INSE1	INSE2	INSE3	INSE4
Harvbags	-0.0054252**	0.0177628***	-0.0029891	-0.0096363*
Avlabour	0.383374*	0.18911485	0.3904175**	0.6602136***
Gender	0.4280328*	0.8103365***	0.2895593	0.334285
Age	0.0182423*	0.0119681	-0.0038628	0.0234398**
Edu	0.3157773	-0.3443479	-0.3412155	-0.4222486
Hhsize	-0.0040193	-0.0081795	0.0151066	0.0072601
Training	0.6365906***	0.6319563***	0.4415277*	0.8906991****
Yownership	-0.0292118*	-0.0242563	-0.012496	-0.0403211***
Farmsize	0.0489545**	0.0927278****	0.0222195	0.0455408
Cocoaage	0.005745	0.0011691*	0.0118026	0.008022
Experience	0.0848649****	0.117335***	0.078074****	0.1072835****

P<0.10; P<0.05**; P<0.01***; P<0.001****, Log likelihood = -1449.1841, LR Chi^2 (56) = 199.62, Prob>Chi^2=0.0000, Pseudo R2= 0.3644, Base outcome or category is non-adoption; INSE1: Spraying of Akate master; INSE2: Spraying of Confidor; INSE3: Spraying of Actara; INSE4: Spraying of 2-tankful of Chemical and water mixture per acre*

Table 7. Parameter estimates of the multinomial logit model for fermentation and drying technologies

Variable	Coefficient	
	Non Adoption	Use of 5-7 days for fermentation
Harvbags	-0.0759537	0.0000812
Avlabour	-32.71445	0.0622634
Gender	0.2765592	-0.0047157
Age	-0.0817688	0.0054290
Edu	-1.103237	0.0340916
Hhsize	-0.5776309**	0.0046045
Training	1.007266	-0.0206600
Yownersip	0.1160675	-0.0009724
Farmsize	-0.1107552	0.0021440
Cocoaage	-0.0003591	-0.0002429
Experience	-0.1401911	0.0025096

P<0.10; P<0.05**; P<0.01***; P<0.001****, Log likelihood= -362.414, LR Chi^2 (22) =32.18, Prob>Chi^2= 0.0744, Pseudo R2 = 0.0425, Base outcome or category is the use of sun drying for cocoa beans*

In principle, farmers who have large tract of cocoa farmland or farm size show high propensity to adopt Akate master and Confidor. Nevertheless, as cocoa farm ages over time horizon the farmers show increasing probability to switch to the adoption of Confidor insecticides in the control and management of capsids and related insect pests.

5. CONCLUSION AND POLICY IMPLICATION

The study analyzed the determinants of cocoa farmers' preferences for technology attributes of CODAPEC and High-tech technologies, a social intervention with sole aim of boosting cocoa productivity and improve living standard of cocoa farmers in Ghana. The study uses multinomial logit model to investigate factors influencing cocoa farmers' choice of attributes of CODAPEC and High-tech technologies. Two hundred and fifty (250) cocoa farm households were interviewed to generate socioeconomic and agronomic data to run MNL model. The empirical results indicated that availability of labour, farm size, age of household head de facto or de jury, gender, training, age of cocoa farm, number cocoa bags harvested per annum, household size, years of cocoa farm ownership and experience are key explanatory variables determining farmers' decision to adopt the technology packages. In general, it was observed that training and experience were major determinant for adoption of entire technology packages. Thus, institutional arrangement that focus on training particularly on-farm demonstration will go a long way to increase adoption levels of these technology packages amongst smallholder cocoa farmers who constitute the majority in the cocoa industry. Moreover, these will invariably increase the productivity of cocoa farms per unit area comparable to countries such Cote d'Ivoire, Malaysia and Indonesia. Policy directive should be such that cocoa marketing companies, cooperative organizations and Ghana COCOBOD would be adequately resourced to embark on effective extension work to offer on - farm demonstration and training to the farmers. In the light of experienced farmers adopting the entire technology package, they should be targeted as agents for change and as resource persons for the dissemination of information on CODAPEC and High-tech technologies. The initial objectives of the programme to offer free mass spray to farmers should be continued, since farmers with very old cocoa farms are very reluctant to adopt recommended agrochemicals such fertilizer, fungicides and insecticides. These will prevent old and abandoned cocoa farms from being a source or conduit of infestation of capsids and infection for blackpod disease to new farms, if total and comprehensive control were to be achieved. Policy makers should raise the awareness of the importance of the coverage of the programme to the entire cocoa producing district in the country.

The study provides two suggestions for future research. First, there is the need to examine the cocoa farmers' preference for input types in order to establish a link between the input choice of these farmers and the adoption of the cocoa production technologies. Second, an analysis of labour allocations of cocoa farmers in the lean (minor) season would also provide valuable insight into the adoption of cocoa production technologies at different times of the year.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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