
# Perception and Adoption of Artificial Pollination Technology in Cocoa Production: Evidence from Ghana

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**Abstract**
This study examined the perception and adoption of artificial pollination among cocoa farmers in Ghana. It used cross-sectional data collected from 206 cocoa farmers selected through multi-stage sampling technique. Descriptive statistics as well as Tobit and Cragg double hurdle regression models were the methods of analysis. With an adoption rate of 49%, the study revealed that cocoa farmers have a positive perception towards adoption of artificial pollination technology. The results also showed that age of farmer, extension visits, yield and household size have significant positive effects on the probability of adoption of artificial pollination among cocoa farmers, whereas farm size has a significant negative effect on adoption. Leveraging on the positive perception generated, we encourage extension agents to sensitize farmers on the importance of artificial pollination through continuous awareness creation and promotion of the benefits of adopting the technology. Furthermore, given cocoa farmers' positive perception on artificial pollination, Ghana's cocoa production and marketing regulatory body (COCOBOD) should take steps in implementing the technology. Implementers of this technology should also target younger farmers since age has a negative influence on adoption of artificial pollination. Finally, this paper contributes to literature by focusing on the perception and the factors that influence adoption of artificial pollination in cocoa production which currently has not been researched and documented in the cocoa production literature.

**Keywords**: Adoption; Artificial Pollination; Cragg Double Hurdle; Perception; Tobit Regression;
GEL CODES: C24;O31;Q16

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## 1. Introduction

Over the last decade, Africa has strongly been recognized as the leading producer of cocoa in the world. Averagely, Africa's cocoa production has increased at an annual rate of about 3% since 2000 (Wessel & Quist-Wessel, 2015). World Cocoa Foundation (2014) mentioned that Ghana, after Cote d'Ivoire is the major cocoa producer in the world, representing about 20% of worldwide cocoa production. In Ghana, the cocoa industry alone offers employment to more than 80,000 smallholders (Asamoah & Baah, 2003), accounting for 19% of households in rural areas, and contributing between 70% - 100% of their yearly household incomes (Breisinger et al., 2008). Therefore, the role of cocoa for smallholders' livelihoods cannot be overemphasized.

In Ghana, the forest agro-ecological regions of the country are the main areas suitable for cocoa production, with 56.5% of the total annual cocoa production supplied by Western Region (Codjoe et al., 2013). Cocoa as a cash crop offers basic earnings for the buying of food and is very essential in communities where food security is problematic (Osei-Bagyina, 2012). Cocoa farming is encouraged because of its high price vis-à-vis other crops, securing property rights, quick maturation, all year round yields and its great contribution to smallholder incomes (Franzen & Mulder, 2007).

On average, Ghana's dried cocoa beans yield stands at 350 kg/ha. This is low compared to 1700kg/ha for Malaysia and 800kg/ha for Ivory Coast (Bosompem et al., 2011). Poor pollination, low level of adoption of production technologies and farmers' wrong use or applications of innovations account for the low cocoa yields recorded annually in Ghana's cocoa farms (Aneani & Ofori-Frimpong, 2013). Most cocoa farmers are still using natural means and unsophisticated technologies and methods, even with the emergence of numerous new technological advancements to improve cocoa yield in this era of climate change (Bosompem et al., 2011).

Cocoa is an entomophilous species and the gluey pollen is transferred primarily by *Forcipomyia* (*Ceratopogonidae)* midges (Soria, 1980). Due to the nature of its pollen transfer, fluctuations in rainfall causing less or irregular rain may influence midges which mostly flourish in moist humid conditions (Claus, 2018). To sustain significant growth in the production of cocoa, there is the need to consider the ecosystem to enhance system parameters which have positive influence on yields of cocoa (Gockowski & Sonwa, 2011). One ecosystem service that has a strong relation with cocoa yield is pollination. Bos et al. (2007) asserts that pollination of cocoa has been a matter of great concern since 1925. This is largely because about more than 90% of flowers found on a cocoa tree fall off after opening which leads to about just 10% of the flowers well pollinated. Pollination of cocoa is largely dependent on midges whose growth, development and survival depend on how moist or humid the farm is.

Artificial pollination has been found to be the best option that can help solve the problems associated with natural pollination (Vera-Chang et al., 2016**;** Forbes et al., 2019; Toledo-Hernández et al., 2020). Artificial pollination happens when there is a human intervention in the pollination process. It is the mechanical process used to pollinate plants when natural pollination is limited. It is used to increase the quantity as well as the quality of fruits on tree crops such as cocoa (Forbes et al., 2017).

In order to solve the problems associated with natural pollination, artificial pollination is recommended. However, the perception of cocoa farmers, their behaviors when it comes to the issue of artificial pollination as well as their beliefs may have significant effect in adopting artificial pollination (Ehiakpor et al., 2016). As a result, it is important to understand their perception concerning the adoption of artificial pollination and the factors that influence adoption of the technology. This paper addresses two questions, viz. Q1: what is the perception of farmers on the adoption of artificial pollination in cocoa farms? and Q2: What are the factors influencing the adoption as well as the extent of adoption of artificial pollination in cocoa farms? Most empirical studies on artificial pollination have focused on the science behind the technology as well as the benefits of its adoption (Groeneveld et al., 2010; Chautá-Mellizo et al., 2012; Forbes et al., 2019). Frimpong-Anin et al. (2013) also considered farmers' awareness of the technology. While acknowledging the great findings of these studies, they were silent on the perception of farmers about adoption of artificial pollination. Also, none of them reported on the factors that determine the adoption as well as extent of adoption of artificial pollination by cocoa farmers.

The contribution of this study is twofold. First, there is little or no empirical research on the perception and factors that determine farmers' adoption of artificial pollination. This study seeks to examine the perception and factors that influence farmers' adoption of artificial pollination. This will help stakeholders in the cocoa industry know what farmers think about the technology on which appropriate policy measures could be promulgated. Secondly, this study will help stakeholders within the cocoa industry to be able to develop appropriate strategies aimed at ensuring the adoption of artificial pollination in cocoa production. This is expected to help improve the yields of Ghana's cocoa farms.

The rest of the paper is organized as follows. The next section presents a brief literature review on cocoa pollination. This is followed by the research methodology. Section four presents the results and discussion. Finally, we conclude and make recommendations for policy in section five.

## 2. Literature review

Agricultural innovations' role of increasing overall farm income is well documented in the technology literature. One such innovation is artificial pollination. It is believed that artificial pollination reduces production cost, improves environmental benefits, and increases crop yield among others (Kassie et al., 2009; Kyei, 2019). Forbes et al. (2019) found that, artificial pollination, regardless of the intensity, significantly led to increases in both fruit set and yield of cocoa. Sánchez-Estradaand and Cuevas (2020) also found that during the "on" season (that is, the season where most trees display abundant flowers), artificial pollination led to an increase in the number of final fruit sets and yield which led to higher profits. Vera-Chang et al. (2016) studied three methods of artificial pollination in clonal cacao against natural pollination. They found that natural pollination had the least number of flowers pollinated as well as the lowest fruit weight. Toledo-Hernández et al. (2020) found that a partial hand pollination of just 13% of easily accessible flowers or trees without fertilizers or insecticides resulted in 51% increase in yield of cocoa. A 100% hand pollination of the entire tree increased the yield by 161% as well as led to an increase of net income from $994/ha to $1,677/ha. Gupta et al. (2017) also reported an increase in yield as well as the fruit quality and hastening of the physiological maturity period as a result of artificial pollination.

Akinwale and Folarin (2018) studied factors that influence farmers' adoption of cocoa hybrid technology in Oyo State, Nigeria. They found farmer's age and farming experience as the factors that influenced farmers' likelihood of adoption of hybrid cocoa. They also found that high cost of agrochemicals is a major constraint towards the adoption of hybrid cocoa. Ilesanmi and Afolabi (2020) found gender, level of education, source of information and visit by extension agents as important factors in the adoption of improved cocoa technologies. Djokoto et al. (2016) also found that being male, having small household size, having young cocoa trees, access to extension services and access to credit positively influenced the adoption of organic cocoa technology. A study by Nabhani et al. (2016) also found competitiveness pressure and perception of cost as factors that determine adoption of technologies by cocoa farmers. Furthermore, Ali et al. (2018) found farmers engagement in off-farm economic activities, extension contacts, farm size, hired and family labour and the value of productive farm assets to be the factors that determine adoption of fertilizer among smallholder cocoa farmers. Bosompem (2019) found predictors of adoption of precision agriculture technology by cocoa farmers to be level of education of cocoa farmers, row planting of cocoa, credit from financial institutions and relative advantage of precision agricultural technologies versus the perceived ease of use of precision agriculture technology by farmers. Kuboja et al. (2020) studied the factors that influence the adoption of beehive technology in Miombo Woodland of Tanzania. They reported that the probability of adoption of beehive technology was influenced by age of household head, years of formal schooling, access to credit and access to extension services. Finally, the decision to adopt organic fertilizer in Ghana's cocoa production is affected by educational level, farming experience, farm size, income, secondary occupation, distance from agro input shop and extension contact (Avane et al., 2021).

## 3. Methodology

### *3.1. Data*

The study employed both primary and secondary data. Detailed structured questionnaires with open and close ended questions were employed to gather the responses of the respondent cocoa farmers within each community. The questions sought to elicit information on the personal and household characteristics of respondents, information on farm characteristics and output. Institutional factors such as being a member of a farmer based organization as well as perception and the benefits of artificial pollination were also elicited. Secondary data was also obtained from Cocoa Health and Extension Division

(CHED)-COCOBOD, magazines, journals and articles. The study was conducted in the Amenfi West District in the Western Region of Ghana. The population of the study was cocoa farmers in Amenfi West District. According to the 2010 Population and Housing Census, 10,021 farmers in general are engaged in the cultivation of cocoa, constituting about 70% of the total population engaged in crop farming and tree cultivation in the District. A total of 206 cocoa farmers from the district were sampled and interviewed for the study. This sample size was determined following Mendenhall et al. (1993) sample size determination formula given by:

$$n = \frac{NZ^2P(1-p)}{d^2(N-1) + Z^2P(1-P)}$$

Where $n$ is the sample size to be determined, $N$ is the population of cocoa farmers in the Amenfi West District, $Z$ is the 95% confidence level Z-statistic (1.96), $d$ is the margin of error at 95% confidence level, $p$ is an estimated population proportion (0.5) and $q$ is the difference between 1 and p ($q = 1 - p$). For the purpose of this study, the level of margin of error was set to $\pm$ 0.0686 which falls within the acceptable margin of error for sample size determination (Suresh and Chandrashekara, 2012). Also, since the exact proportion is not certain, a value of 0.5 (50%) was used (Mendenhall et al., 1993). This is because, given the level of precision, '$p$' of 0.5 has the largest sample size.

The study employed the multi-stage sampling technique in selecting the 206 cocoa farmers. In the first stage, the Amenfi West district was purposively selected. This was because of its popularity as a cocoa producing area in Ghana. In the second stage, simple random sampling approach was used to select five (5) communities from the district. Finally, forty (40) farming households were randomly selected from each community using a list of cocoa farmers obtained from agricultural extension agents operating in the district. Close to twenty (20) adopters of artificial pollination technology and twenty (20) non-adopters from each community were considered for the study. These farmers were interviewed to ascertain the success or failure of the artificial pollination technology as well as their interest in the programme and extent of adoption.

The descriptions of the variables used in the model are presented in Table 1. It specifically describes the variables, their measurements as well as their prior expectations. Table 2 presents the socio-economic characteristics of the respondents. It shows that the average age of the smallholder cocoa farmer was 39.40 years. Among the adopters the average age was 36.19 years, while the non-adopters had an average age of 42.60 years. These results indicate that most of the respondents were within their productive age in terms of capacity to work and adopters were younger than non-adopters. Also, according to Ajewole (2010), heads of household who are young are more likely to adopt artificial pollination on their farms than older household heads. This may probably be because the younger farmers might have been exposed to new farming technologies and won't mind trying it out (Mwangi & Kariuki, 2015). Older farmers on the other hand might want to stick to their conventional ways of farming and might be a bit hesitant to changes. Thus, they are less dynamic and innovative in terms of technology adoption (Enete & Igbokwe, 2009). This finding is consistent with Golge (2016) who also found adopters to be younger than non-adopters.

From Table 2, the average number of years spent in school among the respondent was 9.71 years. The average number of years of schooling among adopters and non-adopters were 9.64 and 9.80 respectively. This indicates that most of the respondents had averagely, junior high school education. Orinda (2013) argues that education could likely allow farmers to make efficient decisions and be early adopters who can take advantage of new technologies. Furthermore, as shown in appendix 1, out of the 206 respondents, 16% had no formal education. Among adopters, 12% out of the 103 respondents had no formal education whiles 19% out of the 103 non-adopters had no formal education. This shows that literacy was predominant among the adopters than it was with the non-adopters. This could be because the most educated family members with better capacity to interpret different information have a tendency of influencing household's decision to adopt artificial pollination (Kassie et al, 2009).

In terms of household size, the mean household size of the farmers was 11.15 out of which on the average 6.47 were adults aged 18 years and above and 5.00 were children less than 18 years. Among adopters, the average house size was 11.93 with an average of 7.86 being adults older than 18 years and 4.16 being children less than 18 years whereas among the non-adopters, the average household size was 10.36 with an average of 5.57 adults 18 years and older and an average of 4.84 being children below 18 years. The household size was higher among the adopters. This presents some benefits in terms of labour supply to the farmers as artificial pollination is labour intensive (Ajewole, 2010).

Furthermore, on cocoa farming experience, Table 2 shows that on average, a respondent has been in the cocoa farming job for 15.50 years. Among the adopters, the average farming experience was 12.53 years whiles among non-adopters, the average farming experience was 8.46 years. Farming experience helps farmers to evaluate the advantages of agricultural technologies as such experience farmers seem to have better information and knowledge accumulated over time (Obisesan, 2014).

The average agricultural farm size of the respondents was 4.30 hectares of which an average of 3.22 hectares had been demarcated for cocoa production. Among the adopters, the average agricultural farm land was 3.63 hectares of which 2.77 hectares have been demarcated for cocoa production. Non-Adopters on the other hand, had an average of 5.00 hectares of agricultural farm land of which an average of 3.70 hectares had been demarcated for cocoa production. The average total yield for the respondents was 373.7 kg/ha of cocoa during the major season and 138 kg/ha during the minor season. The average yield for adopters was 533 kg/ha during the major season and 202.7 kg/ha during the minor season. Non adopters make an average yield of 255 kg/ha of cocoa during the major season and 90 kg/ha during the minor season. The major season is normally between March and July, and the minor season is normally between September and November (Kyei-Mensah et al., 2019).

**Table 1: Description of explanatory variables**

| Variable | Description of variable | Unit of measurement | A priori Expectation |
|---|---|---|---|
| *APA* | Artificial pollination adoption | Binary; 1 = If Adopted, 0 = Otherwise | |
| *Gen* | Gender of farmer | Binary; 1=Male, 0= Female | + |
| *Age* | Age of farmer | Continuous; years | +/- |
| *MStat* | Marital status of farmer | Binary; 1=Married, 0= otherwise | + |
| *Edu* | Educational level of farmer | Continuous; years of formal education | +/- |
| *HHS* | Household size of farmer | Continuous; number of household members | + |
| *FSize* | Cocoa farm size cultivated | Continuous; acres cultivated | + |
| *Ext* | Extension contact | Binary; 1=access to extension contact, 0= otherwise | + |
| *FBO* | Membership in Farmer Based Organization | Binary; 1= yes, 0 =otherwise | + |
| *Cred* | Access to credit | Binary; 1=access to credit, 0 =otherwise | + |
| *Offinc* | Off-farm income | Continuous; amount in Ghs | + |

Source: Authors' construct 2019

Generally, respondents make an average of GH¢406.08 per month from non-farming activities. The average income earned by adopters from non-farming activity was GH¢395.83 per month. and GH¢416.33 per month for non-adopters. The results show that though adopters had less acres of land and its corresponding demarcation for cocoa production relative to non-adopters, they make a rather more harvest compared to the non-adopters, both in major and minor cocoa seasons. This could probably be because of the farm technology they adopted (Gelgo et al., 2016). Also, it showed that non-adopters get most of their income from non-farming activities than the adopters. This could probably be because they don't employ farm technology and therefore tend to get less yield which implies less income and thus will solicit to other form of occupation to help support their home. Furthermore, the average parcels of land from the land allocated for cocoa production was 0.77 hectares on the overall. However, among adopters the average was

0.80 hectares and 0.74 hectares for the non-adopters. Generally, the parcels of lands from the cocoa farm were the same across board, that is, there was no statistical difference between them at 10%, 5% and 1% significant levels.

Finally, Table 2 shows that the average distance to the nearest market was 4.45km. Among adopters the average distance to the nearest market was 5.85km while the average for the non-adopters was 2.90. This implies that most of the non-adopters do not have their markets close to them. This disagrees with IFPRI (2012) and Martey et al. (2014) that the closer the distance to the nearest market the lower the adoption of agricultural technology.

**Table 2: Descriptive Statistics (N=206)**

| | Total | | | | Adopters | | | | Non-Adopters | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Min | Max | Mean | SD | Min | Max | Mean | SD | Min | Max | t-statistics |
| ***Household Characteristics*** | | | | | | | | | | | | | |
| Age | 39.40 | 11.42 | 16 | 75 | 36.19 | 7.03 | 24 | 57 | 42.6 | 13.85 | 16 | 75 | 4.01*** |
| Actual number of years of formal education | 9.71 | 3.86 | 1 | 20 | 9.64 | 3.60 | 1 | 17 | 9.80 | 4.15 | 1 | 20 | 0.06 |
| Household size | 11.15 | 4.66 | 1 | 25 | 11.93 | 3.76 | 4 | 21 | 10.36 | 5.32 | 1 | 25 | 2.21* |
| Number of Adult members in the household (>18 years) | 6.47 | 3.23 | 0 | 16 | 7.36 | 3.04 | 3 | 16 | 5.57 | 3.18 | 0 | 15 | 3.76*** |
| Number of Children in the household (<18 years) | 5.00 | 2.69 | 0 | 15 | 4.16 | 2.00 | 0 | 12 | 4.84 | 3.24 | 0 | 15 | 0.77 |
| How many years have you been cultivating cocoa | 15.50 | 10.70 | 3 | 50 | 12.53 | 7.95 | 3 | 40 | 18.46 | 12.22 | 4 | 50 | 4.04*** |
| ***Farm Characteristics*** | | | | | | | | | | | | | |
| Agricultural Land Size | 10.62 | 6.57 | 3 | 40 | 8.96 | 3.20 | 3 | 27 | 12.28 | 8.43 | 3 | 40 | 3.51*** |
| Cocoa Land Size | 7.97 | 6.23 | 2 | 40 | 6.85 | 2.98 | 3 | 24 | 9.09 | 8.17 | 2 | 40 | 2.38** |
| Number of Parcels of Cocoa Farm | 1.91 | 0.74 | 1 | 3 | 1.98 | 0.79 | 1 | 3 | 1.84 | 0.69 | 1 | 3 | 1.06 |
| Number of Bags Harvest (Major Season) | 25.11 | 13.09 | 2 | 84 | 30.27 | 13.89 | 12 | 84 | 19.94 | 9.87 | 2 | 50 | 6.03*** |
| Number of Bags Harvest (Minor Season) | 9.28 | 4.96 | 2 | 28 | 11.50 | 5.13 | 4 | 28 | 7.06 | 3.62 | 2 | 21 | 7.13*** |
| Non-Farming Activity Income (GHC) | 406.08 | 257.12 | 10 | 1200 | 395.83 | 246.40 | 10 | 1200 | 416.33 | 267.84 | 10 | 1100 | 2.80*** |
| ***Institutional Factors*** | | | | | | | | | | | | | |
| Distance to nearest market (km) | 4.45 | 5.05 | 1 | 18 | 5.85 | 4.71 | 1 | 14 | 2.9 | 4.98 | 1 | 18 | 9.871*** |

Source; Survey Estimation, 2019 (+ P<0.1; *P<0.05; **P<0.01; ***P<0.001)

*3.2. Theoretical, Conceptual and Analytical Frameworks*

The perception of cocoa farmers on the adoption of artificial pollination in cocoa production was analyzed descriptively. This was done by measuring the cocoa farmers' perception on some general statements concerning artificial pollination using a five (5)-point likert scale (Wongnaa and Boachie, 2018). Each scale is given a weight in a descending order starting from ten (10) to two (2). That is, scale 5 is given a weight of 10, 4 is given a weight of 8, 3 is given a weight of 6, 2 is given a weight of 4 and 1 is given a weight of 2. On the whole, the farmers were asked to rate thirteen (13) attributes (statements) about artificial pollination using the 5-point likert scale where 1 denotes strongly agree, 2 denotes agree, 3 denotes neutral, 4-denotes disagree and 5 denotes strongly disagree. However, for the purpose of percentage calculation, the top 2 extremes were combined to represent "agree" and "disagree". The perception index of each statement is then computed by summing the product of each score on the scale and the weight divided by the product of the highest weight and the total score for all the scales. The formula for computing the perception index is given as:

$$\text{Perception Index (PI)} = \frac{\sum w * q}{Total\ Square\ (\sum q) * highest\ weight\ (10)} \qquad (1)$$

Following Adesina and Zinnah (1993), Batz et al. (1999) and Borges et al. (2019), the adoption of artificial pollination innovation by smallholder cocoa farming households is grounded on the theory of utility maximization. Rationally, the smallholder's objective is to maximize his/her utility in line with a set of constraints. According to this theory, adopting an innovation may influence both production as well as consumption decisions of the farmer. Therefore, the farming household either employs more inputs in farming or shifts to other income-generating activities which increase his/her utility with the same land asset. A particular farming household will adopt the technology if the worth of the expected utility as a result of adoption surpasses the utility of a non-adopter farming household. Let $U_p(w)$ be the indirect utility derived by the smallholder for adopting the technology, $U_N(w)$ be the utility derived by the smallholder for not adopting the technology and $w$ be a set of benefits. The choice by the farming household to whether or not adopt the technology is observed but the decision stage of a particular choice is unobserved. We therefore denote the decision choice by a latent variable, $D_i$. To specify this latent variable, it is assumed that the choice of the smallholder to whether or not adopt the technology depends on an unobservable utility threshold, $U^*(w)$. The farmer obtains the utility threshold by comparing his/her utility resulting from adoption and the utility resulting from non-adoption such that:

$$U^*(w) = U_p(w) - U_N(w) \qquad (2)$$

Therefore, given this utility threshold level, the latent variable may be defined as:

$$D_i = 1\ if\ U^*(w) > 0\ and\ D_i = 0\ if\ U^*(w) \leq 0 \qquad (3)$$

Since the decision to whether or not adopt is binary, the choice model that can estimate the probability of farming households' adoption of artificial pollination given the observed covariates may be given as:

$$Y_i = X^t\beta + \mu \quad (4)$$

where $Y_i$ is farmers' decision to whether or not adopt the technology, $X^t$ is a vector of independent variables influencing the decision to adopt, $\beta$ is a vector of unknown parameters and $\mu$ is a random error term. Farmers have the option to either adopt or not adopt the technology, a decision which is assumed to be influenced by certain socio-economic factors including age, sex, marital status, education, household size, farm size, output, non-farm income, extension contact, membership of farmer-based organization, access to credit, among others. Adoption of artificial pollination is aimed at reducing poverty and increase food security through improved productivity and income of cocoa farmers.

Cocoa farmers' decision to adopt artificial pollination and the extent of adoption is a dependent variable that takes on an interval with positive probability and continuously distributed over the interior of the interval. Models commonly used in modelling such a dependent variable include the Tobit model (Tobin, 1958) for the extent of adoption or the Heckman model (Heckman, 1979) or Cragg double hurdle model (Cragg, 1971) for separate modelling of the probability of adoption and the extent of adoption. However, the Tobit model has the assumption that the factors influencing the decision to adopt a technology and the extent of adoption have the same effect on these two decisions. Thus, it cannot handle the situation where the adoption and the extent of adoption are possibly influenced by different factors or by the same factors but in different ways (Cragg, 1971). The Heckman model has an advantage over the Tobit in that, it observes the process in a two-step or stage decisions, and as such allows for the use of different sets of explanatory variables (Heckman, 1979). The Cragg Double Hurdle model, on the other hand, is a modification of the Tobit model and the Heckman model due to its flexibility. The Cragg Double Hurdle model is similar to the Heckman model. However, it assumes that there is a possibility of zero observations in the second stage once the first stage is passed, which may arise as a result of an individual's choice or random circumstances, but the Heckman model assumes that there will be no zero observations (Heckman, 1979).

A cocoa farmer makes his/her adoption in two steps. Firstly, the farming household decides on whether or not to adopt the technology. This is called the discrete adoption decision. In the second stage, the individual farmer decides on the proportion of available cocoa farm land to pollinate through artificial pollination. This is called the numerical/quantity/continuous decision. The adoption decision (i.e. whether a farmer decides to adopt or not) is dichotomized and is influenced by several socioeconomic and institutional factors, whereas the quantity decision is a continuous variable. The adoption model in the Double Hurdle model, which is the first stage, is estimated using the probit model (Wongnaa et al., 2021) specified as:

$$D_i = 1 \; if \; Z_i\delta + U_i > 0 \; and \; D_i = 0 \; if \; Z_i\delta + U_i \leq 0 \quad (5)$$

The continuous decision model representing the second stage, is estimated using truncated regression and is specified as:

$$Y_i^* = x_i\beta + \varepsilon_i \quad (6)$$

$$Y_i^* = Y_i^* \; if \; D_i = 1 \; and \; Y_i^* > 0 \quad (7)$$

$$U_i \approx N(0{,}1); \; \epsilon_i \approx N\; (0, \sigma^2 \quad (8)$$

Empirically, both the first and second stage models are specified as:

$$APA = \beta_0 + \beta_1 Gen_i + \beta_2 Age_i + \beta_3 MStat_i + \beta_4 Edu_i + \beta_5 HHS_i + \beta_6 FSize_i + \beta_7 Ext_i + \beta_8 FBO_i + \beta_9 Cred_i + \beta_{10} Offinc_i + \varepsilon_i \quad (9)$$

where the dependent variable $(APA)$, is either the discrete or the continuous decision variable. All other variables have being presented, defined and described in Table 1. To determine whether the Tobit or the Cragg Double Hurdle model fits our data, the likelihood ratio test was used. Following Wiredu et al. (2015), computation of the likelihood ratio statistic was done using the log likelihoods of the probit, Tobit and truncated regression models. The statistic is specified as:

$$L = 2(LR_{Probit} + LR_{Truncated} + LR_{Tobit} \quad (10)$$

where $LR$ in equation (10) represent the log likelihoods of the probit, truncated and Tobit regressions. To justify the use of a two-step model, the estimated $L$ from equation (10) should be greater than the chi-square distribution with degrees of freedom equal to the independent variables and the intercept used in the models. The Tobit model however will be used if the estimated $L$ is less than the critical value (Mal et al., 2012). In a situation where the estimated $L$ is greater than the critical value, Heckman's two-step model or the Cragg double hurdle model can be used. Heckman's two-step model further accounts for selectivity bias. The first step of the heckman model also involves estimation of a probit model. The second stage of Heckman's model is estimated using equation (11). That is,

$$V = E(q|q^* > 0) = x\delta + \lambda(xy)\varphi \quad (11)$$

where $V$ represents the extent of adoption and $\varphi$ is the error term. The inverse Mills ratio, $\lambda$, which corrects selectivity bias, is seen on the right-hand side of equation (11). If $\lambda$ is significant, then it suggests that the extent of adoption relies on the discrete decision (Marchenco and Genton, 2012). The Cragg double hurdle model does not consider this condition. The Cragg double hurdle model provides a simpler approach when selectivity bias is absent (i.e. when $\lambda$ is insignificant). The second stage of the Cragg double hurdle model is also a truncated regression without the inverse Mills ratio as specified in equation (12). Given the insignificance of the Mills ratio (Table 5), the current study employs the Cragg Double Hurdle model in modelling adoption and extent of adoption of artificial pollination in Ghana's cocoa production.

$$V = E(q|q *> 0) = x\delta + \varphi \quad (12)$$

## 4. Results and Discussion

### *4.1. Rate of Adoption of Artificial Pollination*

Table 3 shows that 50% of respondents were adopters and 50% non-adopters. It is however interesting to note that 57% of both adopters and non-adopters were males and 43% were females. Similar results were observed among adopters and non-adopters in Gelgo's (2016) report. More males adopt artificial pollination probably because of the better exposure they have to varied innovations and trainings delivered by extension agents.

Also, male heads are more likely to attend community meetings and visit demonstration plots or research centres as compared to females (IFPRI, 2012).

Table 3 also shows that 98% of adopters were married whereas 2% were divorced or separated whiles among the non-adopters, 76% were married, 12% were single, 4% were divorced or separated and 8% were widows. The proportion of respondents who were married was predominant among adopters than non-adopters. This could probably be because of the substantial worry that married family units need to improve yield at negligible conceivable expense over the constrained and contending assets. Married households concern to improve their households' welfare increases their participation in agricultural technology adoption (Martey et al, 2013).

The nature of cocoa farm land ownership of the respondent was also summarized in Table 3. The results show that cocoa farm land ownership among the adopters were distributed as follows; 58% were family-owned land, 24% were self-owned land and 18% were share cropped. Non-adopters on the other hand had 39% of the farm lands being family own land, 37% being self-owned land and 24% being share cropped. This indicates that most of the adopters were using family lands to cultivate their cocoa. The implication is that adopters will have more responsibilities as portions of the returns from their farms will need to reach even extended family members, hence are likely to adopt other forms of productivity enhancing technologies.

Furthermore, Table 3 shows that 85% of adopters were members of farmer-based organizations while those of non-adopters belonging to farmer-based organization were 42%. This indicates that most of the adopters were members of farmer-based organizations. This could probably be because being a member of such organization allows a farmer to tap into the experience of other farmers as well as attend some trainings and seminars which are likely to influence a farmer's decision to adopt artificial pollination. Martey et al. (2013) argues that farmers who are members of such organizations can easily have access to production technology information. The frequency of discussion among members of a group also enhancees communication for development (Ehiakpor et al., 2016). The result further indicates that, among adopters, 95% receive extension services, against 60% of non-adopters who receive extension visits. This indicates that adopters have better access to the extension officers than non-adopters. Farmers who have regular visits from extension officers are more likely to adopt agricultural production technologies (Kassie et al., 2009). In the same vein, the number of extension visits increased the possibility of agricultural innovation adoption in Nigeria (Ajewole, 2010).

On access to credit, Table 3 reveals that 83% of adopters had access to credit whiles only 22% of non-adopters had access to credit. This indicates that more adopters had access to credit. This is probably because adopters are ready to adopt technology that can help them make more yield to enable them pay off their credit burdens. The availability of credit also enables them to finance the labour burden of artificial pollination (Shita et al., 2018).

**Table 3: Characteristics of the Cocoa Farmers (N=206)**

| | **n=206** | **Adopters (103)** | **Non-Adopters (103)** |
|---|---|---|---|
| **Variables** | Percentage (%) | Percentage (%) | Percentage (%) |
| ***Gender of Cocoa Farmers*** | | | |
| Male | 57 | 57 | 57 |
| Female | 43 | 43 | 43 |
| ***Marital Status of Cocoa Farmers*** | | | |
| Married | 87 | 98 | 76 |
| Single | 6 | 0 | 12 |
| Divorced/Separated | 3 | 2 | 4 |
| Widower | 4 | 0 | 8 |
| ***Nature of Land Ownership*** | | | |
| Owned | 30 | 24 | 37 |
| Family | 49 | 58 | 39 |
| Share cropping | 21 | 18 | 24 |
| ***Membership of farmer Base organization*** | | | |
| Yes | 63 | 85 | 42 |
| No | 37 | 15 | 58 |
| ***Extension visits (Access)*** | | | |
| Yes | 78 | 95 | 60 |
| No | 22 | 5 | 40 |
| ***Access to credit*** | | | |
| Yes | 108 | 52 | 85 |
| No | 98 | 48 | 18 |

Source: Survey Estimation, 2019

*4.2. Farmers' Perception of Adoption of Artificial Pollination*

From Table 4, the Cronbach's Alpha of 0.735 indicates a high level of internal consistency for the scale and the sample used for this study (George & Mallery, 2016). Table 4 also presents the results on cocoa farmers' level of agreement with some perception statements with regards to the adoption of artificial pollination in the production of cocoa. The least perception index of 35.58 was whether farmers perceived artificial pollination to help them visibly acknowledge the differences in yield relative to natural pollination. The highest perception index was 57.08 which assessed farmers' perception as to whether artificial pollination enhanced sharing and diffusion of knowledge amongst participants and neighbours. This could arise because some of the farmers in the quest to adopt artificial pollination will seek knowledge from colleague farmers and neighbours. Farmers adoption of artificial pollination has improved cocoa production through increased yield. This is evidenced in the socio-economic characteristics, which point out to the fact that farmers adopting artificial pollination have higher yields than non-adopters even though less

**Table 4: Perception Index (N=206)**

| Statements | Mean | SD | Perception Index | $\chi 2$ Statistics |
|---|---|---|---|---|
| AP enables farmers to visibly acknowledge the difference in yield compared to naturally pollinated farms | 4.22 | 0.89 | 35.58 | 5.985 |
| AP enhance acquisition of knowledge, skills and technique on new improved agricultural technologies and interventions | 3.92 | 0.92 | 41.60 | 5.438 |
| AP enhance sharing and diffusing of knowledge amongst participant and neighbors | 3.15 | 1.25 | 57.08 | 3.153 |
| AP is proven enhance effective utilization and/or adoption of new/improved agricultural technologies and improved farming practices | 3.56 | 1.00 | 48.74 | 13.283* |
| With AP, farmers decide the size of land and a specific need and come up with an action plan to address such needs together | 3.49 | 1.16 | 50.30 | 8.191 |
| AP encourage smallholder farmers to learn through participation, building on their own knowledge and practices and blending them with new ideas | 3.7 | 1.01 | 45.98 | 21.395** |
| AP enable farmers to plan their farm involvements into other crop establishments | 3.65 | 1.10 | 47.04 | 6.296 |
| AP enable farmers to diversify their income sources from yield increase | 3.5 | 0.99 | 50.06 | 2.813 |
| AP has improved farming production through increased yield | 3.33 | 1.04 | 53.42 | 7.793 |
| The timing of AP was satisfactory | 3.26 | 1.18 | 54.78 | 8.177 |
| The approach of AP implementation was effective | 3.28 | 1.18 | 54.50 | 12.835* |
| The implementation of AP was participatory | 3.25 | 1.06 | 54.98 | 4.329 |
| AP implementation emphasizes on cocoa productivity (increase in yield) of the farmers' farm, and it empowers farmers to improve their socio-economic conditions | 3.31 | 1.22 | 53.96 | 1.037 |

**Reliability Statistics**

| Cronbach's Alpha | Cronbach's Alpha Based on Standardized Items | N of Items |
|---|---|---|
| 0.729 | 0.735 | 13 |

Source; Survey Estimation, 2019

Note: (+ P<0.1; *P<0.05; **P<0.01; ***P<0.001; AP is artificial pollination) acreage is used by the adopters. Farmers also perceive that artificial pollination enables them to diversify their income sources. This statement, which had a perception index of 50.08 contradicts the findings of Munyuli (2011) and Frimpong-Anin (2013).

*4.3. Factors Influencing Adoption and the Extent of Adoption of Artificial Pollination*

The likelihood ratio test was used to determine the model that best fits the data used in the study. From Table 5, the likelihood ratio statistic is less than the 5% critical significance level, hence we accept the alternate hypothesis of a Tobit model. This therefore makes the Tobit model the ideal model to be used in explaining the factors that influence adoption of artificial pollination as well as the extent of adoption. Hence, the following discussions are based on the Tobit model.

From Table 5, age, extension visits, yield, farm size and household size had significant effects on the adoption of artificial pollination. An increase in the age of a household by one year will decrease the likelihood of adoption as well as the extent of adoption of artificial pollination by 2.9%. Thus, an increase in age of the household head tends to discourage the adoption of artificial pollination. This could probably be because as the household head becomes older, he/she might not have the strength to explore the artificial pollination technology due to the high labour demands/requirements of the technology. This finding is consistent with those of Akinwale and Folarin (2018) who studied factors that influence farmers’ adoption of hybrid cocoa technology in Oyo State, Nigeria. They found the age of farmers to be a significant factor in the adoption of hybrid cocoa.

The result on extension visits reveals that one additional meeting with the extension officer increases the likelihood of artificial pollination adoption as well as the extent of adoption by 7.1%. This means that extension visit had a statistically significant positive effect on the extent of adoption of artificial pollination. Extension visit plays a key role in making known to farmers information related to agricultural productivity enhancing technologies. Kassie et al. (2009) opined that extension officers establish demonstration plots where farmers get hands-on learning and can experiment with new farm technologies which enhance adoption of new technologies. The results of Gelgo (2016), Djokoto et al. (2016), Ali et al. (2018), Ilesanmi and Afolabi (2020), Kuboja et al. (2020) as well as Wongnaa and Babu (2020) also revealed that an increase in frequency of meeting with extension officers increases the chances of adopting agricultural technologies.

Yield had a positive significant relationship with the extent of adoption of artificial pollination. Table 5 shows that a unit increase in the yield of farmers increased their likelihood of adoption of artificial pollination by 7.9%. Thus, as yield increases, the likelihood of adoption of artificial pollination increases. Farmers who are already having low yields sometimes get discouraged, hence their lack of interest in the technology. Farmers with higher yields are people who would probably follow all the protocols in farming, hence their familiarity with past technologies makes them candidates for new technologies. Ghimire et al. (2015) also found that yield has a positive influence on the adoption of improved rice varieties among rural farm households in Central Nepal.

Farm size had a negative statistically significant relationship with extent of adoption of artificial pollination. An increase in farm size of farmers by one acre decreased their likelihood of adoption of artificial pollination by 4.5%. Thus, the larger the farm size, the lower the adoption of artificial pollination. This could probably be because, as farm size increases, there will be a need for more labour which might not be available to assist with the application of the technology, hence the lower the likelihood of adoption. This finding supports similar findings reported by Ilesanmi and Afolabi (2020) but contradicts those of Ali et al. (2018), who found farm size to be positively related to adoption of cocoa productivity enhancing technologies.

Finally, household size had a positive statistically significant relationship with the likelihood of adoption of artificial pollination as well as the extent of adoption. Thus, a one member addition to the household increases their likelihood of adopting artificial pollination by 3.4%. According to Mignouna et al. (2011) and Mwangi et al. (2015), the size of a household is simply used as a measure of labour availability. It determines adoption process in that, a larger household has the capacity to relax the labour constraints required during introduction of new technologies. This finding is consistent with the findings of Tedla (2011) and Wongnaa et al. (2018) who found a positive relationship between household size and adoption of agricultural technologies. According to Tedla (2011), the positive correlation of peasant farmers of Northern Ethiopia’s adoption of fertilizer and their household size was as a result of the expected increase in labour in the family. Mubarak et al. (2019) also reported a positive relationship between household size and participation in cocoa production technologies interventions.

**Table 5: Tobit, Cragg and Heckman Regression Results**

| | Tobit model | | | Probit model | | | Truncated regression | | Heckmann model | |
|---|---|---|---|---|---|---|---|---|---|---|
| Adoption and Extent of Adoption | Coefficient | Std. Err. | dy/dx | Coef. | Std. Err. | dy/dx | Coef. | Std. Err. | Coef. | Std. Err. |
| Gen | 0.027 | 0.087 | 0.027 | -0.008 | 0.279 | -0.0012 | 0.023 | 0.276 | -0.007* | 0.003 |
| Age | -0.029 | 0.007 | -0.029*** | -0.074 | 0.019 | -0.011*** | -0.032 | 0.021 | -0.003 | 0.071 |
| MStat | 0.351 | 0.232 | 0.351 | 0.73 | 0.671 | 0.112 | -0.324 | 0.533 | 0.427*** | 0.119 |
| FBO | 0.087 | 0.155 | 0.087 | 0.215 | 0.455 | 0.033 | -0.516 | 0.467 | 0.404*** | 0.094 |
| Ext | 0.711 | 0.202 | 0.711*** | 1.119 | 0.514 | 0.172* | 0.005 | 0.429 | 0.258** | 0.102 |
| Experience | 0.002 | 0.126 | 0.002 | 0.657 | 0.173 | 0.101*** | 0.309 | 0.159 | -0.112 | 0.189 |
| Distance | 0.189 | 0.046 | 0.189 | -0.065 | 0.117 | -0.01 | -0.1 | 0.125 | 0.02 | 0.127 |
| Offinc | -0.063 | 0.044 | -0.063 | 1.8 | 0.455 | 0.277*** | 0.623 | 0.432 | -0.05 | 0.078 |
| Yield | 0.789 | 0.146 | 0.789*** | -0.661 | 0.351 | -0.102+ | -0.207 | 0.329 | -0.138 | 0.22 |
| FSize | -0.447 | 0.131 | -0.447*** | -0.172 | 0.392 | -0.027 | 0.097 | 0.388 | 0.376+ | 0.21 |
| HHS | 0.338 | 0.124 | 0.338*** | 0.897 | 0.382 | 0.138* | 0.14 | 0.324 | -0.17 | 0.116 |
| Edu | -0.032 | 0.062 | -0.032 | -0.029 | 0.196 | -0.005 | -0.085 | 0.177 | 0.4583 | 0.2767 |
| Constant | -2.066 | 0.562 | | -5.622 | 1.792 | | 1 | 1.405 | 0.766 | 0.861 |
| Sigma | 0.5 | 0.039 | | | | | 1.114 | 0.129 | 0.414 | 0.064 |
| Number of obs = | 206 | | | 206 | | | 115 | | 206 | |
| LR chi2(12) = | 198.26 | | | 171.4 | | | - | | - | |
| Prob > chi2 = | 0.000 | | | 0.000 | | | 0.7517 | | 0.000 | |
| Pseudo R2 = | 0.4614 | | | 0.6 | | | - | | - | |
| Log likelihood = | -115.69605 | | | -57.047648 | | | - | | -188.553 | |
| Wald chi2(12) | - | | | - | | | 8.42 | | 73.52*** | |
| Censored obs | - | | | - | | | - | | 91 | |
| Uncensored obs | - | | | - | | | - | | 115 | |
| /athrho | - | | | - | | | - | | 0.607 | 0.513 |
| /lnsigma | - | | | - | | | - | | -0.882 | 0.155 |
| rho | - | | | - | | | - | | 0.542 | 0.363 |
| Mills ratio (λ) | - | | | - | | | - | | 0.224 | 0.182 |

LR test of indep eqns. (rho = 0); chi2(1) = 0.61; Prob > chi2 = 0.4339

Source; Survey Estimation, 2019 (+ P<0.1; *P<0.05; **P<0.01; ***P<0.001) while dy/dx denote marginal effect

## 5. Conclusion and Recommendations

Pollination of cocoa has been a matter of great concern since 1925, largely because about more than 90% of flowers found on a cocoa tree fall off after opening, causing just about 10% of the flowers to be well pollinated. Artificial pollination is considered the best option that can help solve the problems associated with natural pollination. For most cocoa farmers to embrace the technology, it is important to understand their perception concerning the adoption of artificial pollination as well as the factors that influence adoption of the technology. This study therefore examined cocoa farmers' perception and adoption of artificial pollination technology using cross-sectional data collected from the Amenfi West district of Ghana. The study revealed that cocoa farmers perceived the use of artificial pollination as visible, and that they could tell the difference in yield before and after the usage of the technology. Out of thirteen (13) statements that were used to assess the perception of farmers on the use of artificial pollination, the least perception index was 35.58 and the highest was 57.08. This indicates that farmers have positive perception about artificial pollination. This implies that farmers will be ready to adopt the technology, given the fact that they have positive perception about the technology. Also, the results from the Tobit regression analysis showed that an increase in the age of the farmers, extension officer visits, average yields, and household size would significantly increase the likelihood of a cocoa farmer adopting artificial pollination technology. On the contrary, an increase in farm size will decrease adoption of artificial pollination by cocoa farmers.

In terms of theoretical implication, the major novelty of this study was to study the perception and factors that influence adoption of artificial pollination in Ghana's cocoa production. The theory of utility maximization was also extended by applying it in the adoption of artificial pollination. The study recommends that continuous awareness creation and promotion of artificial pollination technology should be done by extension agents, especially on ecological and environmental benefits associated with the use of the product, since contact with extension officers increases the likelihood of adoption. Furthermore, given the fact that perception of farmers on artificial pollination is positive, COCOBOD should take steps in implementing the technology. Governments and stakeholders who may want to undertake this technology should target younger farmers since age has a negative influence on the adoption of artificial pollination. To further make the implementation of artificial pollination better, implementation should target farmers with high yields, since their high yields indicates their attention to agronomic practices.

## Limitations and Directions for Future Research

Every study has some limitations and for that matter the findings from this study must be assessed within the light of certain limitations. First, the study was conducted in just one district in the western region of Ghana and this raises an issue of generalizability. Future studies that may consider selecting more districts across the cocoa farming regions may be more insightful. Second, this study concentrated on only the perception and factors that influence adoption. Future studies may consider studying the impact of adoption of artificial pollination on the welfare of cocoa farmers.

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## APPENDIX

**Appendix 1: Educational Level**

| | Total | | Adopters | | Non-Adopters | |
|---|---|---|---|---|---|---|
| Education | Frequency | Percentage | Frequency | Percentage | Frequency | Percentage |
| No Formal | 32 | 16% | 12 | 12% | 20 | 19% |
| Primary | 110 | 53% | 63 | 61% | 47 | 46% |
| JHS | 48 | 23% | 20 | 19% | 28 | 27% |
| Secondary | 16 | 8% | 8 | 8% | 8 | 8% |
| Tertiary | 0 | 0% | 0 | 0% | 0 | 0% |
| Total | 206 | | 103 | | 103 | |

Source; Survey Estimation, 2019