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Socio-economic determinants of the adoption of cashew grafted plants in Benin

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ABSTRACT

In Benin, cashew nuts represent a socio-economic and strategic interest for farmers and the government. Cashew grafted plants have been introduced to improve productive performance. Therefore, it is essential to better assess the current adoption level of cashew grafted plants and the drivers behind it, in order to stimulate their large-scale adoption in Benin. To achieve this objective, a stratified random sample was used to select a total of 395 cashew farmers across 23 municipalities in Benin. Based on the neoclassical theory of profit maximisation, the counterfactual Average Treatment Effect (ATE) estimation framework has been used to assess the adoption rate of cashew grafted plants as well as the drivers behind their knowledge and adoption. The findings revealed a very low adoption rate of cashew grafted plants among farmers. Farmers' perception of cashew grafted plants, level of satisfaction with the characteristics of cashew grafted plants, extension contact, household income, and household assets were the main factors determining the adoption of cashew grafted plants in Benin. Adoption constraints due to hydraulic stresses, shocks from climatic disturbances, and technical production also limited the adoption of cashew grafted plants. The study further recommends policy measures to facilitate the accessibility and availability of cashew seedlings to increase adoption and production. The government should also subsidise cashew seedlings to encourage young farmers and women, and to avoid price volatility.

Contribution/Originality: This study is among the first to analyze the adoption of grafted cashew plants in Benin by integrating farmers' perceptions, satisfaction, and socio-economic factors within a counterfactual ATE framework. It provides empirical evidence to guide policy decisions and promote the large-scale dissemination of grafted plants in cashew farms.

1. INTRODUCTION

Africa produces more than 50% of the world's cashew crop but processes only 10% of its total production, or 50% of its capacity (Adesina & Baidu-Forson, 1995). Benin is one of the sub-Saharan African countries with an economy primarily based on agriculture. The cashew sector is one of the flagship higher value-added sectors in the Government Action Program (GAP (Government Action Program), 2016) due to its high potential to contribute to employment and income generation, its contribution to food and nutrition security, and its high export potential (African

Development Bank, 2019). Benin is the eighth-largest cashew nut producer in the world, with an estimated production of 160,000 tons in 2022 (International Trade Centre, 2022). Every year, there is a dynamic expansion of cashew orchards by farmers. In 2017, a total of 200,000 hectares was cultivated by 192,000 producers (DSA/MAEP, 2017).

The social and economic role of cashew nut production in Benin cannot be denied. It employs millions of people in rural areas. Besides, cashew nuts contribute 3% to the gross national product (GNP) and 7.4% to the gross domestic product (GDP). Nevertheless, cashew production in the country still faces many challenges. Cashew producers' plantations across the country are full of cashew tree stumps, and cashew productivity remains very low. Recent data showed cashew nut yields are in the range of 250-400 kg/ha, due to the use of unimproved plant material and inadequate farmers' agricultural practices. Yet, under optimal growing conditions, local varieties can reach more than one ton of nuts per hectare (Masawe, 2010). To optimize cashew production yields, the production of grafted plants is a means of renewing and enhancing the current vegetative production potential. Indeed, the strain of cashew planting material is derived from a selection based on parameters related to the assessed productivity of the cashew nuts, their quality, and their tolerance to pests and diseases. These grafted plants provide cashew trees that are genetically identical to the mother plant and thus constitute an alternative that not only increases orchard yields but also the homogeneity of yields per tree.

Thus, capacity-building activities for cashew seed producers were undertaken to enable them to produce a sufficient quantity and quality of grafted plants. In addition, two grafting processes for cashew plants have been developed to produce successful plants in the nursery. These are grafted by veneer, which is the most used method by cashew seed producers, with an 84% success rate, compared to 65% for the single grafting process (Kodjo, N'Djolosse, Tandjiékpon, & Maliki, 2016). To support the availability and access to inputs (grafts) for cashew planting material production, a national collection (germplasm) with 30 in situ efficient cashew mother trees was established (Kodjo et al., 2016), as well as 30 cashew trees with plants grafted from the grafts of selected mother trees. However, the increase in raw cashew nut production is more attributable to the expansion of cultivated area than to improvements in orchard productivity. The physical unavailability of plants, high purchase prices, and low membership in cooperatives have limited the adoption of these plants (Eteka & Faaki, 2017).

While significant research has been conducted in the cashew sector in Benin, there is still limited data on the evaluation of the adoption of grafted plants. In particular, very few studies in Benin have revealed the level of adoption of grafted plants and the socio-economic and institutional factors underlying it. This study aims to fill this gap by answering the following questions: Are grafted plants integrated into the cashew tree growing system over the past ten years? What is the level of knowledge and use of grafted plants in cashew production areas in Benin? What are the socio-economic factors that explain the levels of knowledge and adoption of grafted plants in cashew tree production in Benin? The results of the study will further support the development and promotion of cashew production in Benin. Ultimately, the results of this research will also facilitate the development of more effective approaches for the dissemination of grafted plants and thus encourage wider adoption to boost local production and the national economy.

2. RESEARCH METHODS

2.1. Study Area

This study was conducted in Benin. The primary unit of observation for the study was cashew producers. A multi-stage sampling procedure was used to select the primary units, which were the municipalities. The focus was particularly on municipalities that have been considered for various cashew nut research programs over the last decade. The municipalities are located in six geopolitical zones out of the twelve in the country that are most favorable to cashew nut production. These are Atacora, Donga, Borgou, Zou, Plateau, and Collines (N'djolosse et al., 2020). This delineation of the study area allowed for better targeting of cashew producers exposed to information on cashew grafted plants. Based on the number of cashew producers in each selected municipality, the minimum sample size of cashew producers to survey was determined using (Yamane, 1967) formula.

$$n_0 = \frac{N}{(1+Nd^2)} \quad (1)$$

Where: n_0 is the minimum sample size, N is the total number of cashew producers in all the selected municipalities, and d is the desired level of precision. We use 5% as the margin of error for this study. The application of the formula resulted in a minimum size of approximately 395 cashew producers to be surveyed.

As for the number of cashew producers to be surveyed in each municipality, proportional stratified sampling was used based on the formula.

$$n_i = \frac{N_i}{N \times n_0} \quad (2)$$

Given the particularity of the technology under study, the selection of cashew producers was purposive. First, nursery managers were contacted to provide a complete list of their customers who were considered to be users of grafted plants. From the list provided, the first half of the sample in each district was randomly selected. The second half of the sample was selected by the same random approach from the different cashew-producing villages identified.

2.2. Household Survey and Data Collection

Data collected are essentially related to the socio-economic characteristics of cashew producers, the different types of plant material used, cashew producers' knowledge of grafted plants, sources of information, adoption or non-adoption of cashew grafted plants, the reasons for using or rejecting the technology, and their perceptions of grafted plants.

The data were collected through interviews based on the quantitative approach (questionnaire) with cashew producers. Upstream, the bibliographic synthesis allowed us to situate the state of the question by analyzing the available information on the main studies on the cashew nut sector in general and those related to the adoption and diffusion of cashew nut technologies and innovations, as well as their determinants, in particular. Secondary data were obtained from the documentation available at the library of the National Institute of Agricultural Research of Benin (INRAB), the documentation centres and databases of the Territorial Agency for Agricultural Development (ATDA), and from projects and programs working in the cashew subsector.

2.3. Analytical Framework

In this study, the adoption of grafted plants in cashew production system is based on the counterfactual Average Treatment Effect (ATE) estimation framework introduced by Diagne and Demont (2007). Indeed, Probit, Logit, and Tobit models traditionally used in the adoption analysis are based on the assumption that farmers are homogeneously exposed to technology (Mwololo, Nzuma, Ritho, Ogutu, & Kabunga, 2020). According to Kabunga, Dubois, and Qaim (2012), this assumption of homogeneity implies that all farmers are aware and have knowledge about the technology attributes. In addition, Diagne and Demont (2007) noted that the estimators commonly used to estimate the adoption rate suffer from non-exposure bias or selection bias. These authors argue that non-exposure bias makes conventional models less consistent because the non-exposure bias suggests that farmers who have not been exposed to the technology cannot adopt it. This implies that some non-adopters are unaware of the technology, and therefore, their non-adoption is not a voluntary choice. In addition, the classical adoption model cannot be used to estimate the determinants of the effect of exposure without consistently controlling for non-exposure bias (Ouédraogo, Houessionon, Zougmoré, & Partey, 2019). Therefore, the Average Treatment Effect estimation framework of Diagne and Demont (2007) overcomes the problem of non-exposure bias and provides a better estimation of the factors that influence the adoption of grafted plants in cashew tree production. Based on a randomly selected sample comprising exposed and non-exposed samples to the technology, the ATE framework uses the exposed subsample to estimate the effect of a treatment on the treated (Mwololo et al., 2020). Following these authors, we consider the lack of awareness and knowledge of grafted plant attributes as the main constraints to adoption.

Let N be the sample size, e, the binary indicator for exposure to the grafted plants, with e=1 if producers are aware and w=0 otherwise, and the binary indicator for knowledge of attribute (a=1 if farmer has knowledge and a=0 otherwise. N_e and N_a denote respectively the exposed and adopters. There are two outcomes, namely, population and individual-level outcomes. According to Diagne and Demont (2007), the three population outcomes (sample exposure rate, sample adoption rate and the adoption rate among the exposed) are expressed as follows.

Sample exposure rate: N_e/N_a.

Sample adoption rate: N_e/N.

Adoption rate among the exposed: N_a/N_e.

Let y be the decision to adopt or reject the grafted plant (y=1 when the farmers adopt the technology and y=0 otherwise). If w is the awareness variable, with w=1 if the producer is aware and w=0 otherwise, the probability of adopting grafted plants in cashew tree production is expressed as follows.

$$prob\ (y = 1|w = 1) = E(y| > 0) \quad (3)$$

The treatment effect for producer i is the difference $y_{i1} - y_{i0}$ (Diagne & Demont, 2007). Then, according to Wooldridge (2010), the expected population adoption rate impact of exposure to grafted plants is expressed as follows.

$$ATE = E(y_1 - y_0|x) \quad (4)$$

ATE is the potential population adoption outcome, E is a population adoption function, x is a set of explanatory variables that influence the adoption of grafted plants. The ATE among the exposed farmers, given the producers' characteristics, denoted ATE_1 can be defined as follows.

$$ATE_1(x) = E(y_1 - y_0|x, w = 1) \quad (5)$$

The expected adoption impact in the non-exposed subpopulation is commonly denoted ATE_0 can be exposed as follows.

$$ATE_0(x) = E(y_1 - y_0|x, w = 0) \quad (6)$$

Following Diagne and Demont (2007) and Nguezet, Diagne, Okoruwa, Ojehomon, and Manyong (2013), the parametric approach is used to estimate the ATE parameters.

$$ATE(x) = E(y_1|x) = E(y|x, w = 1) = g(x, \beta) \quad (7)$$

Where g is a known (possibly nonlinear) function of the vector of covariates x β is an unknown parameter which can be estimated using a standard Least Square (LS) or maximum likelihood estimation (MLE) procedure using observations (y_1, x_1) from the sub-sample of awareness farmers (w=1), only with y as dependent variable and x as the vector of explanatory variables. With an estimated parameter $\hat{\beta}$ the predicted values $g(x_1, \hat{\beta})$ are computed for all the observations i in the sample (including the observation in the non-exposed subsample), and the ATE, ATE_1, and ATE_0 are estimated by taking the average of the predicted $g(x_1, \hat{\beta})$ i=1,…,n across the full sample (for ATE) and respective subsample (for ATE_1, and ATE_0) (Nguezet et al., 2013).

$$A\hat{T}E = \frac{1}{n} \sum_1^n g(x_1, \hat{\beta}) \quad (8)$$

$$A\hat{T}E_1 = \frac{1}{n_e} \sum_1^n w_i\, g(x_1, \hat{\beta}) \quad (9)$$

$$A\hat{T}E_0 = \frac{1}{n - n_e} \sum_1^n (1 - w_i)\, g(x_1, \hat{\beta}) \quad (10)$$

According to the effect (Nguezet et al., 2013), the effects of the determinants of adoption as measured by K marginal effects of the K-dimensional vector of covariates x at a given point x¯are estimated as follows.

$$\frac{\partial E(y_1|\bar{x})}{\partial x_k} = \frac{\partial g(\bar{x}, \beta)}{\partial x_k}, k = 1, \dots \dots \dots K \quad (11)$$

x_k is the K-th component of x.

The population adoption gap ($G\hat{A}P = J\hat{E}A - A\hat{T}E$ and the population selection bias ($P\hat{S}B = A\hat{T}E_1 - A\hat{T}E$) parameters can be estimated using the parametric regression-based estimator.

However, Diagne and Demont (2007) state that exposure bias makes conventional models less consistent because non-exposure bias implies that some non-adopters are simply not informed about the technology, and thus their non-adoption is not a deliberate decision. This approach helps to address the non-exposure bias in the adoption process. This approach was used to estimate the population adoption rate and the determinants of grafted plants in cashew tree production.

Explanatory variables included in the empirical model are as follows: gender of the household head (1 if male, 0 otherwise), age (in years), household size (number of persons eating from the same pot), access to formal education (1 if educated, 0 otherwise), household income (total income from farm and off-farm activities), extension contact (1 if in contact with extension services, 0 otherwise), training participation (1 if participated in agricultural training in the past five years, 0 otherwise), producer's perception of grafted plants (1=Strongly disagree, 2=Disagree, 3=Agree, 4=Strongly agree), access to credit (1 if had access, 0 otherwise), cooperative membership (1 if a member, 0 otherwise), farm-market distance (distance between the farm and the nearest market in kilometers), and farm size (total land cultivated in hectares). Table 1 provides an overview of the explanatory variables used in the analysis and their expected signs (Table 1).

Table 1. Dependent variables and explanatory variables of awareness and adoption of grafted cashew plants.

Variables	Variables description	A prior sign.
Farmers' characteristics		
Sex	Binary variable taking the value 1 if the farmer is a man and 0 otherwise.	-
Age	Quantitative variable expressing the age of a household head	+/-
Household active member	Quantitative variable expressing the number of active members of the cashew farmer's household	+/-
Education	Binary variable taking the value 1 if the farmer is educated and 0 otherwise.	+
Agricultural training	Binary variable taking the value 1 if the farmer has participated in a training course on cashew production and 0 otherwise	+
Share of cashew income in total income	Quantitative variable expressing the proportion of cashew nut income in total household income	+
Household income	Quantitative variable representing total household income	+
Farmers' perception of cashew grafted plants		
Perception of the attributes of grafted plants	Aggregate variable obtained from the appreciation of the farmers on twelve characteristics of the grafted plants (measured using the four-point Likert scale "1 = Totally disagree...... 4 = Totally agree")	+
Satisfaction on cashew grafted plants	Aggregate variable obtained from the degree of satisfaction of the farmers on seven characteristics of the cashew grafted plants (measured using the three-point Likert scale "1 = Not satisfied; 2 = Indifferent; 3 = Satisfied").	+
Institutional factors		
Membership of farmers' group	Binary variable takes the value of 1 if the farmer is a member of group and 0 otherwise	+
Access to extension service	Binary variable takes the value of 1 if the farmer has access to extension service and 0 otherwise	+
Access to credit	Binary variable takes the value of 1 if the farmer has access to credit and 0 otherwise	+
Distance to market	Quantitative variable expressing the distance from the village of the farmer to the nearest market	-
Environmental characteristics		
PDA2	Binary variable takes the value of 1 if the farmer is in agricultural development pole 2 and 0 otherwise.	+
PDA4	Binary variable takes the value of 1 if the farmer is in the agricultural development pole 4 and 0 otherwise.	+
Farm size	Quantitative variable expressing the land availability on the household	+

3. RESULTS AND DISCUSSION

3.1. Socio-Economic Characteristics of Respondents

Table 2 presents the socio-economic characteristics of the respondents. Women accounted for only 8% of the sample. This implies that men are more involved in cashew production than women. This gender disparity is particularly attributed to the physically demanding nature of certain cashew production activities. On the other hand, women appear to be more active in processing and selling cashew nuts (Ingram et al., 2015).

The average age of the respondents was approximately 50 years. However, the adopters of cashew grafted plants were younger than the non-adopters, with a statistically significant difference at the 1% level. These results contrast with related studies on technology adoption, which suggest that older farmers have more farming experience and are therefore more likely to adopt new agricultural technologies (Shahzad & Abdulai, 2020).

Table 2. Socio-economic characteristics of the respondents.

Characteristics	Non-adopters N=278	Adopters N=117	Overall N=395	T-test
Age	51.02 (13.33)	46.67 (12.72)	49.73 (13.29)	3***
Gender	0.92 (0.26)	0.92 (0.27)	0.92 (0.27)	0.04
Household size (Active member)	6.51 (4.20)	6.02 (3.57)	6.37 (4.03)	1.11
Education	0.54 (0.49)	0.71 (0.49)	0.59 (0.49)	-3.09***
Agricultural training participation	0.71 (0.45)	0.83 (0.37)	0.74 (0.43)	-2.77***
Cashew income	4.03 (2.35)	4.03 (2.33)	4.03 (3.60)	-0.02
Household income	1967249 (2573568)	2367121 (2586167)	2085881 (2580482)	-1.40*
Cooperative membership	0.54 (0.50)	0.76 (0.43)	0.61 (0.49)	-4.18***
Extension contact	0.43 (0.49)	0.66 (0.47)	0.50 (0.50)	4.26***
Access to credit	0.32 (0.46)	0.38 (0.49)	0.34 (0.47)	1.23
Distance to market	3.55 (4.36)	4.97 (7.14)	3.97 (5.36)	2.43***
Farm size	17.23 (17.23)	18.79 (14.62)	17.69 (16.50)	0.85

Note: * and *** indicate significance levels at 10% and 1% respectively, () represents the standard deviation.

The average household size among adopters and non-adopters of cashew grafted plants was 6 persons. Larger households are generally expected to have more available labor for agricultural activities. Similar results were found by Oyetunde-Usman, Olagunju, and Ogunpaimo (2021).

Furthermore, about 59% of the producers had received formal education, with a significant difference between adopters and non-adopters. More cashew grafted plant adopters (83%) had participated in agricultural training within the past five years and had more frequent contact with extension services (66%) compared to non-adopters (43%). The proportion of cooperative membership was also higher among adopters (75%) compared to non-adopters (50%).

Regardless of adoption status, the estimated average household income was 2,085,881 FCFA, and the average cultivated land size was 18 hectares. Access to agricultural credit remained low overall (34%) with no significant difference between the two groups. The average distance from farm to market was approximately 4 km, with adopters located closer to markets than non-adopters. Indeed, the distance between a market, where farmers can buy some of the farm inputs such as cashew seedlings, and the farm where it would be applied can influence farmers' adoption decisions (Zakaria, Alhassan, Kuwornu, Azumah, & Derkyi, 2020).

3.2. Knowledge and Utilization of Grafted Plants in Cashew Tree Production in Benin

Farmer's awareness and utilization of cashew grafted plants were presented in Figure 1. The result showed that 92% of cashew producers had been exposed to cashew grafted plants. The main sources of information included projects and programs involved in the cashew sector (34% of respondents), agricultural extension services (on average 30% of farmers surveyed), and peer-to-peer exchanges among producers (20% of respondents) (Table 3).

Despite this high level of awareness, actual utilization during the 2020 cropping season remained low. Only 30% of respondents reported the use of grafted cashew plants during this season. This gap between exposure and adoption highlights a persistent challenge in translating knowledge into practice.

These findings reveal the pivotal role that projects and programs play in the development of the agricultural sector, specifically in disseminating innovation. However, they also suggest that awareness alone is insufficient to drive widespread adoption. Structural barriers such as access to inputs, technical support, or perceived risks may be limiting farmers' willingness or ability to integrate grafted cashew plants into their production systems.

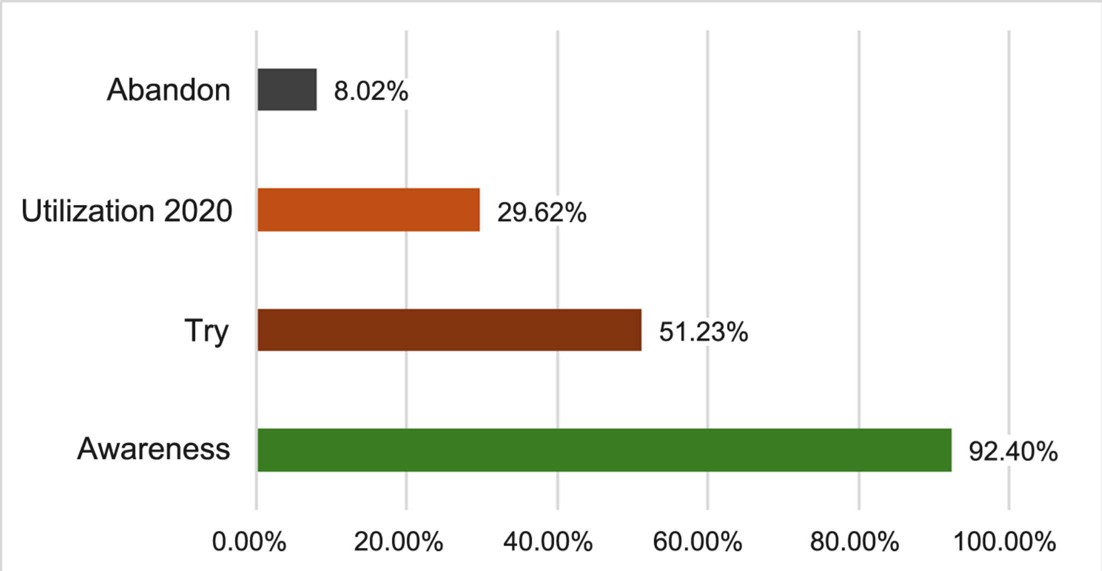

Figure 1. Knowledge and utilization of cashew grafted plants.

Table 3. Main source of information for grafted cashew plants.

Variables		Pooled
Number of years of information		2.84 (2.11)
Information source (%)	Extension services	30.49
	Research	1.10
	Cooperatives	6.04
	Pairs	20.33
	Projects/NGOs	34.07
	Nurserymen	6.87
	Radio	1.10

3.3. Drivers Force Cashew Grafted Plants Awareness

The key drivers influencing farmers' awareness of cashew grafted plants are reported in Table 4. The analysis revealed that education, membership in farmers' groups, and access to extension services are the main factors affecting farmers' awareness of cashew grafted plants.

Access to education had a positive and significant effect on awareness. Education increased farmers' awareness of cashew grafted plants by 55%. This implies that educated farmers are more likely to be exposed to cashew grafted plants, likely due to their greater ability to process technical information and engage with institutional actors.

Similarly, membership in farmers' groups was positively associated with awareness of cashew grafted plants and increased it by 68%. This highlights the importance of agricultural cooperation in facilitating knowledge exchange and exposure to agricultural innovations. Access to extension services also emerged as a critical factor, reinforcing institutional support in the diffusion and adoption of agricultural innovations.

Table 4. Drivers' force of awareness of cashew grafted plants.

Variables	Coefficients	Statistics
Education (1=Yes; 0=Otherwise)	0.55***	2.59
Membership of farmers' group (1=Yes; 0=Otherwise)	0.68***	2.80
Agricultural training (1=Yes; 0=Otherwise)	0.36	1.55
Access to extension service (1=Yes; 0=Otherwise)	0.42*	1.68
Distance to village	0.007	1.03
Year of experience in cashew production	-0.008	-0.75
Constant	0.52*	1.83
Number of observations	*393*	
Log of likelihood	-88.62	
LR Chi2	34.76***	
Pseudo R^2	0.16	

Note: * and *** indicate significance levels at 10% and 1% respectively.

3.4. Adoption Rate of Cashew Grafted Plants

The results of the estimation of the adoption rate of cashew grafted plants are presented in Table 5. This table presents detailed adoption indicators. A large majority of respondents (92.41%) report being informed about the existence of cashew grafted plants. Farmers' access to information is often mediated through their social networks, which significantly influence their exposure to innovation-related knowledge (Klerkx, van Mierlo, & Leeuwis, 2012; Temple, Kwa, Tetang, & Bikoi, 2011).

Among informed producers, the adoption rate reaches 32%, while the joint exposure and adoption rate is slightly lower at 30%. In contrast, the adoption rate among non-informed producers is only 17%. This highlights the critical role of awareness in adoption decisions. Despite the high level of awareness, the overall adoption rate remains low. This may be attributed to limited technical competence in graft management, insufficient availability of cashew grafted seedlings, and inadequate access to technical support (Ndèye, 2017). These findings raise concerns about the reliability and quality of the information received by producers, as less credible information may mislead them in the use of the technology (Lindner, Pardey, & Jarrett, 1982; Naveed, Anwar, & Bano, 2021).

The potential adoption rate, estimated at 31%, reflects the expected adoption level if all producers were informed.

The table also shows an adoption gap of −0.01 and a population selection bias of 0.01, suggesting that informed producers are only slightly more likely to adopt than the average farmer.

These results emphasize the need for strengthened and credible extension services to improve both the reach and the quality of information dissemination.

Table 5. Adoption rates of grafted cashew plants.

Variables	Overall
Information on grafted plants (%)	92.41
Potential rate of adoption (ATE)	0.31***
Adoption rate among the informed producers (ATE_1)	0.32***
Adoption rate among the non-informed producers (ATE_0)	0.17***
Common adoption and exposure rates (JEA)	0.30***
Adoption gap (GAP=JEA-ATE)	-0.01***
Population selection bias (PBS=ATE_1-ATE)	0.01
Number of exposed/Number of observations	0.92***
Number of adopters/Number of observations	0.30***
Number of adopters/Number of exposed	0.32***

Note: *** indicate significance levels at 1% respectively.

3.5. Determinants of Adoption of Grafted Cashew Plants

Table 6 presents the factors influencing the adoption of grafted cashew plants. The model was statistically significant, as indicated by the Chi-square test at the 1% significance level. Furthermore, the adoption of grafted seedlings is explained by 41% of the explanatory variables (Pseudo R^2=0.41).

The determinants of the adoption of grafted seedlings included cashew producers' perception of grafted plants, their degree of satisfaction with the characteristics of grafted plants, extension contact, income, and agricultural assets. Indeed, the more skeptical the producer was about the potential benefits of grafted plants, the more willing they were to adopt them. Furthermore, as indicated above, the characteristics of the grafted plants in terms of yield and fruit structure (apple and nuts) were also the most important parameters in the producers' adoption decision.

Table 6. Econometric results for factors affecting the adoption of grafted plants.

Variables	Coefficients	P-value
Gender	-0.37	0.26
Age	-0. 19	0.55
Education	0.24	0.21
Household size (Active members)	-0.04*	0.06
Agricultural training	0.15	0.54
Cashew income	0.05	0.22
Agricultural income	0.23**	0.04
Cooperative membership	0.27	0.19
Extension contacts	0.46**	0.02
Credit access	-0.04	0.83
Distance between the village and the nearest periodic market	0.02	0.19
Perceptions of grafted plants	0.67***	0.004
Satisfaction with the characteristics of the grafted plants	1.05***	0.00
Development pole 2	0.28	0.75
Development pole 4	-0.1	0.93
Total land size	0.001	0.86
Constant	*-6.39****	*0.009*
R^2	0.41	
Wald Chi-square	136.88***	
Number of observations	395	

Note: *, ** and *** indicate significance levels at 10%, 5% and 1% respectively.

Adoption of agricultural technologies is strongly influenced by farmers 'perceptions. As noted by Rogers (2003), perception precedes uptake of innovation. Farmers must first recognize the relevance and potential of innovation before integrating it into their practices. The way farmers perceive the impact of a new technology on their current situation plays a decisive role in their adoption decisions (Ton, Hinnou, Yao, & Adringa, 2018).

Adesina and Baidu-Forson (1995) have shown that farmers' decisions to adopt new improved sorghum varieties in Burkina Faso are strongly correlated with perceptions of the technology's characteristics, including yields, processing quality, soil adaptability, and flood tolerance. Similarly, in the context of cashew production, farmers' perceptions of cashew grafted plants, particularly regarding yield performance and other characteristics, emerge as key determinants of adoption.

Extension contact plays a critical role in the adoption decision of cashew grafted plants among producers. The findings are consistent with those of Lambrecht, Vanlauwe, Merckx, and Maertens (2014). These authors believe that regular contact with extension agents allows farmers to be better informed about the new technologies available as well as their nature, and thus influences the adoption decision. In other words, regular contact improves the efficiency of technology use via learning (Alene & Manyong, 2006; Ton et al., 2018). The role of extension in the technology diffusion system is indisputable. Strengthening extension services would therefore allow for better support to farmers in learning about new technologies and in accelerating the adoption process (Ricker-Gilbert & Jones, 2015).

Household income also determines the adoption decision of grafted plants among producers. Lambrecht et al. (2014) found similar results indicating that capital constraints are important for the continued adoption of mineral fertilizers. These results also corroborate those of Dercon and Christiaensen (2011), who had shown that in a context of widespread poverty, farm household income is a key determinant of fertilizer adoption in poor countries. Generally, farm households are characterized by low purchasing power, and this could reduce their motivation to adopt new technology due to investment needs and their greater vulnerability to the risks associated with this technology (Alene & Manyong, 2006; Hailu, Abrha, & Weldegiorgis, 2014). Moreover, for farmers with low purchasing power, if there is no assurance that the new technology will improve their initial situation, acquiring it could be at the cost of temporarily forgoing other needs, making the adoption decision even more difficult (Ton et al., 2018). In other words, a higher income for producers could provide them with greater access to new technologies (Hailu et al., 2014), which most often require significant financial resources (Chabi et al., 2020).

4. CONCLUSION

This study explores the adoption of grafted cashew plants using a latent variable framework, with determinants estimated through a Probit model. The results show that the adoption rate of grafted plants remains low. In addition, information and regular contact of producers with agricultural extension agents have a positive effect on the adoption of grafted cashew plants. It will therefore be necessary to strengthen extension services to allow farmers to be better informed about grafted cashew plants and to improve the efficiency of the use of this new technology available through learning.

This capacity building will also help to better support the producers in the process of adopting grafted plants and to have a better knowledge of them. In this way, the rate of adoption of grafted cashew plants will be improved. The productive potential of cashew trees derived from grafted plants, the growth rate of the plants, and the resistance ability against pests represent key factors in the adoption decision of producers, while the poor access to grafted cashew plants constitutes a rejection factor.

Thus, to encourage or lead producers to adopt grafted seedlings, development agents must support research in the establishment of grafted cashew plants with high productive potential while taking into account the resistance status and growth rate of these plants. Also, access to grafted cashew plants must be facilitated in such a way as to allow producers, regardless of their level of income, to be concerned with grafted plants and to adopt them.

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Institutional Review Board Statement: Ethical approval for this study was granted by the Ethics Committee of the National Institute of Agricultural research of Benin (INRAB), Benin under protocol number (IRB No. 0141/INRAB/DAF/SRH/SA), dated 2 January 2021. Informed verbal consent was obtained from all participants prior to data collection, and all data were anonymized to protect participants' confidentiality.
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
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