Journal of Agricultural and Crop Research
Vol. 5(3), pp. 32-41, September 2017
ISSN: 2384-731X
Research Paper

Adoption assessment of improved maize seed by farmers in Benin Republic

F. E. Mahoussi[1]* • P. Y. Adegbola[2] • A. Zannou[1] • E. F. Hounnou[1] • G. Biaou[1]

[1]Faculty of Agronomic Sciences of the University of Abomey-Calavi (FSA-UAC). 01BP 526 Cotonou-Benin.
[2]National Institute of Agricultural Research of Benin *(*INRAB*),* 01 BP 884 Recette Principale, Cotonou 01.

*Corresponding author: E-mail: eliseemahoussi@gmail.com. Tel: (229) 97298620.

Accepted 13th September, 2017

Abstract. To contribute to the improvement of productivity of maize, new improved maize seeds have been introduced in various areas favourable to the maize production of Benin. This paper assessed the adoption potentials of the different improved varieties of maize introduced into the maize-growing areas of Benin Republic. The study was carried out in the maize agro-ecological areas of Benin Republic. An exhaustive census was carried out in each village of farmers. This made it possible to have a list of all the farmers by village. Sampling of the farmers was done in a random way in each village of production to have a total of 490 farmers. The average treatment effect (ATE) was used to determine adoption rates and gaps related to maize seed adoption in the studied area. The results showed that from 84% of farmers in the sample who had knowledge of improved maize seeds, 78% of the farmers adopted the improved seed. Each of the four varieties, taken separately, provides the following adoption rates: 16% for the DMR-ESRW, 25% for the EVDT97 STRW, 19% for the TZPB-SR and 15% for the FAABA / QPM. The results also show that the variables “literacy”, “relationship with structures/institutions”, “maize land area in 2013” and “Annual income coming from maize production” are the factors that determined the adoption of improved maize seed in the studied area.

Keywords: Average treatment effect, improved seed, adoption, maize, Benin Republic.

INTRODUCTION

Among the cereals in Benin Republic, maize (*Zea mays* L.) plays an important role both for food security and the national economy of Benin Republic. It is widely cultivated throughout the country and occupies the first place with about 70% of cereal cultivated area (Ministry of Agriculture, of Breeding and the Fishing (MAEP), 2010a). It is a staple food with diversified consumption forms (e.g. fresh maize, grilled maize, pasta, flat cake) (Arouna *et al*., 2011). In addition to its function as a subsistence food, it is the subject of trade both inside the country and in sub-regional markets (Boone *et al.*, 2008). National maize production, which was only 1012630 tonnes in 2010, appeared insufficient and there is a urgent need for increasing maize production. This is due to consequences of several difficulties, including the quality of the seeds used, the high cost of mineral fertilizers and post-harvest losses due to crop mismanagement ((Ministry of Agriculture, of Breeding and the Fishing (MAEP), 2010b).

Seeds are primarily the source of most foods, and therefore have the greatest socio-economic benefit to the human well-being. According to Louwaars and Marrewijk (1999), the development and the use of high-yielding seed varieties have been the technological forces of the effective green revolution, the profitability of agriculture for farmers, the availability of food at affordable prices for the population and the reduction of rural poverty. Seeds are an important factor in agricultural development for all crop production (Aly *et al*., 2007). They contribute about 30% to crop productivity (Dembélé, 2011). Seed quality (varietal purity, specific purity, germination power, vigor, health status, humidity level) could contribute up to 40% to increased yields (Kpedzroku and Didjeira, 2008). Therefore, special attention needs to be given to seeds for an increase in crop productivity. The aim of this paper was to assess the adoption potentials of different improved maize varieties introduced in different agro-ecological areas in Benin Republic.

MATERIALS AND METHODS

Study area

The data used were collected at the national level. The study covers all the agro-ecological areas in Benin Republic with favorable natural conditions for maize production. The climate of the country is characterized by an alternation of dry seasons and rainy seasons. The number of seasons varies according to the area. The southern area is characterized by a bimodal sub-equatorial climate with two rainy seasons.

Sampling procedure and sampling size

An exhaustive census was carried out in each village. This allowed having a list of all the farmers per village. Sampling of farmers was done randomly in each village. A total of 490 farmers were selected in all the agro-ecological areas favorable to growing maize areas. The choice of the famers to inquire in the village was carried out in a random way, using a table of random number, by using the command "aléa" of the Excel spreadsheet.

Method of data analysis

Theoretical approach of adoption assessment

The adoption rate estimation approach used in this paper is based on modern theories of micro-economic assessment of the impacts of policy interventions (Heckman, 1990, 1997; Imbens and Angrist, 1994; Angrist *et al*., 1996; Blundell and Costa, 2002; Wooldridge, 2002). These methods make it possible to correct both the non-knowledge bias and the selection bias due to the incomplete diffusion of improved seeds in the population and the selection bias of the beneficiary population.

Let Y (income) be an outcome indicator on which the effect of a technology change to be determined; Y_1 and Y_0 two random variables that represent the income level of a farmer i if he uses (Y_1) or not (Y_0) the new technology. Let D_i be the binary variable, with D_i = 1 when the farmer adopted the technology and D_i = 0, otherwise. The causal effect of adopting the technology for the farmer i is the difference between Y_1 and Y_0**.**

$$\Delta_i = Y_1 - Y_0 \qquad (1)$$

The fundamental problem of impact assessment results in the non-observation of the counterfactual corresponding to each technological change. In other words, when a technological change occurs, one cannot observe what the different results would be without the change, and if it does not occur, one cannot observe what would happen if the change really occurred (Diagne, 2003; Holland, 1996; Bassolé, 2004).

It is therefore impossible to observe both Y_1 and Y_0 for the same person. Yi is defined as follows:

$$Y_i = D_i Y_1 - (1 - D_i) Y_0 \qquad (2)$$

The average treatment effect (ATE) was estimated as described by Moffitt (1991) as follows:

$$ATE = E_i(\Delta_i) = E(Y_1 - Y_0) = E(Y_1) - E(Y_0) \qquad (3)$$

The ATE measures the effect or impact of treatment on a randomly selected person in the population, which is the same as the average effect of treatment on all members of the population (Woodbridge, 2002). This effect is determined without bias if the non-beneficiary population is well defined. This would mean that the latter is similar to the population of the participants and that the only observable difference between these two populations is participation in the program. Such an effect is possible only if the choice of participants to the program was made randomly.

The impact is in most cases defined by the average treatment effect on treated (ATET or ATE1) (Rosenbaum and Rubin, 1983):

$$ATET = E_i(\Delta_i | D_i = 1) = E_i(Y_1 - Y_0 | D_i = 1)$$
$$= E(Y_1 | D_i = 1) - E(Y_0 | D_i = 1) \qquad (5)(6)$$

The counterfactual is defined as $E(Y_0 | D_i = 1)$, which is the average level of the indicator Y that adopters or beneficiaries would have if they had not adopted or benefited from technology or policy. Since this expression is not observed, what is observable and which could be an approximation of the counterfactual is $(Y_0 | D_i = 0)$. This is the average level of Y within non-adopters or non-recipients of technology or policy. The difficulty of any impact study is the unbiased determination of $(Y_0 | D_i = 0)$ in order to have a good approximation of $(Y_0 | D_i = 1)$. Any gap between the counterfactual and this approximation would justify the existence of a selection bias. By adding and subtracting $(Y_0 | D_i = 1)$ to the expression $E(Y_1 | D_i = 1) - E(Y_0 | D_i = 0)$ where the counterfactual is replaced by its proxy:

$$E(Y_1|D_i = 1) - E(Y_0|D_i = 0) = E(Y_1|D_i = 1) - E(Y_0|D_i = 1) + E(Y_0|D_i = 1) - E(Y_0|D_i = 0) \quad (7)$$

$$= E(Y_1 - Y_0|D_i = 1) + E(Y_0|D_i = 1) - E(Y_0|D_i = 0) \quad (8)$$

$$= ATET + \left[E(Y_0|D_i = 1) - E(Y_0|D_i = 0\right] \quad (9)$$

The expression in brackets defines the potential selection bias:

$$BS = E(Y_0|D_i = 1) - E(Y_0|D_i = 0) \quad (10)$$

This bias could also come from an unobservable difference between the two populations

Formulation of the adoption assessment model

To estimate the adoption and diffusion rate of maize varieties and the determinants of adoption, the approach based on the estimation of the Average Treatment Effect (ATE) of Imbens and Wooldridge (2009) was used. As shown by Diagne (2005) and Demont (2007), the ATE methodology allows the coherent identification of the estimation of the potential adoption rate of the population, which is the adoption rate when all individuals in the population are exposed to the technology. They show that the ATE measures the effect of an average treatment on an individual basis chosen at random in the population which exactly corresponds to the potential adoption rates of the population when exposure is treatment. This methodology is necessary because the adoption rates usually calculated are biased (Imbens and Angrist 1994, Heckman, 1996; Wooldridge, 2002; Diagne, 2005; Adegbola *et al.*, 2007). This is the selection bias. This bias results from the fact that maize producers who have not been exposed to improved seeds cannot adopt them, even if they would do if they had learned of its existence. Similarly, the determinants of the effects of adoption cannot be estimated consistently from simple probit, logit or tobit models without controlling the non-exposure bias. In our study, "treatment" refers to the exposure of farmers to improved maize seed.

The ATE makes it possible to have ATE1[1] as well as ATE0[2] (measures the effect of diffusion, that is, the proportion of farmers who have adopted at least one improved seed without being directly exposed, but having known it by diffusion effect). As the name suggests, ATE1 measures the effect of treatment within the subpopulation of farmers who received treatment. The estimation of the ATE undoubtedly requires control of whether or not access to improved seed information is used and the use of other variables such as socio-economic and demographic variables and institutional variables. This leads to the following conditional adoption probability:

$$prob(A_i = 1|D_i = 1) = E(A_i|D_i^* > 0) \quad (11)$$

With Ai the decision to adopt or reject improved maize seed. It takes the value 1 when the farmer adopts and 0 otherwise.

Di is a binary variable with the value 1 if the producer is informed of the improved seed and 0 if not.

Equation 12 can be used to estimate consistently the rates and determinants of adoption of improved maize seed by specifying the linear model (Wooldridge, 2002; Adegbola *et al.*, 2006):

$$E(A|x, D) = \mu + \chi D + \alpha_x + \xi D(x - \bar{x}) \quad (12)$$

Where xi is the set of socio-economic variables affecting the adoption of x their respective average; **x**, ξ and α the parameters to be estimated. χ accurately represents the rate of adoption within the ATE population. ATE parameters can be estimated using several alternatives: parametric, nonparametric and semi parametric (Imbens and Wooldridge, 2009). In this study, we used the parametric estimation procedure described in detailed by Diagne and Demont (2007). The parametric estimation of ATE is based on the following equations that identify the ATE (x) based on the conditional independence hypothesis (Diagne and Demont, 2007).

$$\begin{aligned} ATE(x) &= E(y_1 / x) \\ &= E(y / x, w = 1) \\ &= g(x, \beta) \end{aligned} \quad (13)$$

where **g** a known function (eventually non-linear)of vectors of the covariants x; **β** an unknown parameter that can be estimated from the standard least squares (LS) and the estimation of maximum likelihood (MLE) using observations (y_i, x_i) from the sub-sample of exposed farmers (w = 1) only; with y as the dependent variable and x the vector of the explanatory variables. The variable w is an indicator of the exposure to improved maize technology, where W_i = 1 represents the exposure of the individual i and W_0= 0 otherwise. With an estimated parameter $\hat{\boldsymbol{\beta}}$, the predicted values g(x_i ,$\hat{\beta}$) are calculated for all observations i of the sample (including observations in the unexposed subsample) and ATE, ATT and ATU are estimated.

Taking the mean of the predicted g(x_i ,$\hat{\beta}$)i = 1,…,n through the complete sample (for ATE) and the respective subsamples (for ATT and ATU):

[1] Average Treatment Effect on the treated
[2] Average Treatment Effect on the untreated

$$\hat{ATE} = \frac{1}{n}\sum_{i=1}^{n} g(x_i, \hat{\beta}) \quad (14)$$

$$\hat{ATT} = \frac{1}{n_1}\sum_{i=1}^{n} w_i g(x_i, \hat{\beta}) \quad (15)$$

$$\hat{ATU} = \frac{1}{n-n_1}\sum_{i=1}^{n} (1-w_i) g(x_i, \hat{\beta}) \quad (16)$$

The effects of the determinants of adoption as measured by the marginal effects K of the vector of dimension K of the covariants x at a given time are estimated as follows:

$$\frac{\partial E(y_i|\bar{x})}{\partial x_k} = \frac{\partial g(\bar{x}, \hat{\beta})}{\partial x}, \quad k = 1,........, k \quad (17)$$

Where x is the *k-th* component of x.

To identify the factors that determine the adoption of improved maize seeds, the ATE model will be used with a binomial probit specification. The dependent variable we try to explain here refer to knowledge (those who have heard or not of the variety) and the adoption of at least one of the improved seed varieties.

Description of the variables used in the model

Dependent variable

The dependent variable for this model is the adoption of improved maize seeds in Benin "Adopt", taking two values: $Y_i = 1$ for the adoption of improved maize seed, $Y_i = 0$ if producer did not adopt

Independent variables

The independent variables introduced in the model include variables related to the respondent's productive resources and socio-demographic and economic characteristics of the household. The variables related to socio-demographic characteristics are the control variables of the model.

Literacy "**Alph**" affects the adoption of improved seed. Indeed, farmers who are able to read and write in their local languages have the facilities to interact with other actors in the agricultural sector and thus gain new experiences in order to achieve the production objectives. Literacy, which is a form of education (Because it aims the same objective) aims at achieving the same result. Ahouandjinou *et al.* (2010) showed that literacy favors the adoption of shea mill in North Benin because it allows the respondents to apprehend the importance of this technology and consequently its choice.

The gender of the respondent **"sex"** is a binary variable that takes the value 0 when the producer is a woman and 1 for the man. The adoption of technology may be better for men than for women or the opposite. According to Bindlish and Evenson (1997), female farmers are more likely to seek contact with agricultural extension services than male farmers because they want to compensate for their limited access to credit and other inputs by using more of extension programs. However, Nambiro *et al.* (2006) found that male-headed households in Kenya are likely to receive an extension visit. In our study, it is expected that the gender variable of the head of household will be negatively related to the probability of participating in the extension program on storage innovations.

The number of years of experience "**Expmac"** in maize production is a continuous variable that can have a positive or negative influence on the use of technologies. The more a farmer has experience the more he becomes aware of the constraints in their production systems and need the specialized knowledge. This has led Adesina and Seidi (1995) and Adesina and Forson (1995) to confirm that experience was positively related to the adoption of new technologies. Farmers with more years of experience may be those who use technologies more or vice versa. It has been shown that farmers with long experience have had time to realize the positive contribution of the new technologies which they adopt more or less easily (Adesina, 1995; Nkamleu and Coulibaly, 2000).

Research and extension structures "**Relastru**": It is set to 1 if the farmer receives technical support from extension workers and 0 otherwise. Contact is considered as an indispensable element in the adoption of new technologies (Linder, 1987; Rogers, 2003). It is through contact that the farmer accesses information about the existence of a new technology and the associated benefits. Cameron (1999) argued that the constant contact of extension workers with farmers improves and reinforces the decision to adopt a technology. So the scarcity of the contact or its disappearance leads to the abandon of the different technologies. Extension provides farmers with information about the availability and properties of the new technology and the technical skills to use it (Wozniak, 1997). A positive sign is expected from this variable.

The membership in a group or farmer cooperative **"Group**" is a binary variable whose expected influence is positive. The presence of a group allows the contact of a locality with the support structures or the extensionists. In order to make efficient use of scarce resources, agricultural extension programs use groups of farmers assuming that messages will spread through the group to other farmers. In addition, several studies have shown that groups encourage their members to change their attitudes. Therefore, farmer groups are the main points of contact for extension workers (Bindlish and Evenson, 1997; Guerin, 1999). It is assumed that belonging to a group has a positive influence on the probability of adopting technological innovations.

Table 1. Description of the independent variables used in the model.

Variables	Meaning	Expected effects
Alph	Alphabetization	Positive
Relastru	Relationship with structures	Positive
Forma	Special training received on the use of improved varieties	Positive
Supma13	Maize land area in 2013	Positive
Group	Membership of a group or association of maize farmers	Positive
Sexe	Sexe	Positive
Expmac	Number of years of experience in maize production	Positive or negative
Part10	Annual agricultural income from maize production	Positive or negative

Source: January-February Survey of 2015.

The Annual income coming from maize production **"Part10"** indicates household investment potential in improved maize seed innovations. More the producer's income is raised, more it tends to grant a place of choice to agriculture. For instance, Negatu and Parikh (1999) found that farmers with higher incomes are more likely to have a positive perception of marketing a new variety of wheat than farmers with low income. Farmers with a part of 1 over 10 of the annual income from high maize production would able to use the technological innovations (improved maize seed) as recommended or modify them to increase its efficiency. Therefore, it is assumed that maize farmers with higher part over 10 of income are likely to have positive perceptions of the characteristics of these innovations. Thus, a positive sign is expected for the coefficient of the variable share of the annual agricultural income derived from maize production.

The variable training received **"Forma"** plays an important role in the adoption of improved seeds. The decision to adopt or reject the decision to adopt with or without modification a new agricultural technology is based on a comparison of the expected utility. The expected utility maximization framework explains the role of information in shaping the adoption decision process (Dimara and Skuras, 2003). This framework describes the formation of the decision-making process for the adoption of agricultural innovations and its connected factors. Thus, it is through these trainings that farmers become acquainted with the technologies, acquire the notions and information necessary to enable them to assess the acceptability of technologies. The human capital assets (education, skills and training) of the head of household affect the adoption profitability of modern technology, as they reflect the unobservable productive characteristics of the decision-maker, such as agricultural skills and entrepreneurship (Carletto *et al.*, 1999). A positive sign is expected from the coefficients of this variable.

Land, known as an essential substrate in agriculture, is a development issue. The area of land available, the land sown for growing maize and improved seeds "Supma13" are a continuous variables which, according to this study, positively influences the probability of improved seed adoption. For Mahama *et al.* (2001), plant seed selection contributes to increased yields and increased productivity on a given area by mitigating crop pressure on marginal areas and traditional fallows. In this sense, the activity will contribute to reducing deforestation by limiting the extension of cultivated land. (Table 1)

Statistical analysis

The ATE approach was used with specification of the probit model. It covers 8 potentially explanatory variables (independent variables) of the adoption of maize seeds. The correlation matrix of the independent variables included in the model allowed us to verify the variables with strong collinearity. In addition, some descriptive statistics have also been compiled. The software Stata 13.0 has been used for this analysis.

RESULTS AND DISCUSSION

Descriptive statistics of the variables included in the model

Relationship between the types of seed used, access to credit, and specific trainings on the use of improved varieties

The relationship between the types of seed used and access to credit in kind or cash and the relationships between the types of seed used and the particular trainings received on the use of improved varieties was presented in Table 2. It was revealed that 13% of the maize producers using improved seeds received credit in kind or in cash compared to 11% of the producers using local seeds. Also, about 37% of producers who have received specific training on the use of improved varieties use improved seeds versus 16% of producers using local seeds. The particular training received on the use of

Table 2. Relationship between the types of seed used, access to credit in kind or cash and the specific training received on the use of improved seed (percentage).

Types of improved seed	Access to credit		All together	Training received		All together
	Yes	No		Yes	No	
Improved	13 (39)	87 (252)	100 (291)	37 (107)	63 (184)	100 (291)
Locals	11 (11)	89 (92)	100 (103)	16 (16)	84 (87)	100 (103)
Both	22 (20)	78 (71)	100 (91)	45 (41)	56 (50)	100 (91)
All together	14 (70)	86 (415)	100 (485)	34 164)	66 (321)	100 (485)
Chi2(2) = 5.6201**				Chi2(2) = 21.6527***		

* means sig. at 5%, ** means sig. at 1% and *** means sig. at 0.1%. Source: January-February Survey of 2015

Table 3. Adoption status, institutions and the types of zone (extension structure).

Parameter	Modalities	Status of adoption	
		Adopters	Non-adopters
	UCP	20.91 (55)	9.10 (4)
Structures (proportion)	SCDA	74.52 (196)	77.27 (34)
	INRAB	1.14 (3)	2.27 (1)
	Others	3.43 (9)	11,36 (5)
	Total	100 (263)	100 (44)
Chi2(3) = 8.3628**			
	CEF	30.60 (112)	17.27 (19)
Types of zone (proportion)	PMA	19.13 (70)	10.91 (12)
	SCDA	50.55 (184)	71.82 (79)
Total	Total	100 (110)	100 (366)
Chi2(2) = 15.8800***			

* means sig. at 5%, ** means sig. at 1% and *** means sig. at 0.1%. Source: January-February Survey of 2015

improved seeds could therefore be considered as a variable facilitating the intensity of the use of improved maize seeds in Benin Republic.

Relationship of adoption status with institutions

Approximately 21% of adopters have relationship with the communal union of farmers (UPC), compared with 9% among non-adopters (Table 3). Thereafter, 75, 1 and 3% of the adopters y have relationship with the Communal Sector for Agricultural Development (SCDA), the National Institute of Agricultural Research of Benin (INRAB) and other institutions respectively, as against 77, 2 and 11% among non-adopters. This can be explained by the role assigned to each institution in the production and distribution of improved seeds.

In fact, INRAB is just responsible for the production of basic seeds and the Regional Agricultural Development Center (CARDER) in turn organizes the transfer of certified seed production to farmers' organizations and private multipliers (Non-Governmental Organization (NGO) and projects, basic organization) and provides technical support for improved seeds production. This justifies the weak relationship between producers (having adopted improved seeds) and INRAB (around 1%) and the high rate of this relationship with the SCDA (Communal Sector for Agricultural Development) (75%) and the Communal Union of farmers (UCP) (21%). As for the type of zone, the analysis in Table 3 shows that approximately 31% of adopters are in relationship with the CEF, about 19% in relationship with the PMA and 51% with the SCDA. It is also noted that 72% of non-adopters are in relationship with the SCDA, 17% with the CEF and 11% with the PMA. The relationship with these extension structures is a key factor in the adoption of improved maize seed.

Knowledge of improved seeds by source

Table 4 shows that 83% of maize producers have knowledge of improved seeds from the formal source (CARDER, INRAB, CEF agents and PMA agents) and the rest through the informal source (farmers and other actors). Approximately 80% of the farmers were informed

Table 4. Knowledge of improved seeds by source.

Improved maize seed	Sources of information (proportion)						Total
	CARDER	INRAB	Producer	PMA agents	CEF agents	Other factors	
TZPB-SR	13.3 (60)	0.22 (1)				1.77 (8)	15.29 (69)
TZL COMP4C4	0.22 (1)					0.22 (1)	0.44 (2)
FAABA/QPM	14.20 (64)	0.22 (1)	0.22 (1)			3.55 (16)	18.18 (82)
DT SR-W	0.67 (3)					0.22 (1)	0.89 (4)
IWDSyn	0.22 (1)						0.22(1)
DMR-ESRW	12.20 (55)	0.22 (1)				3.55 (16)	15.96 (72)
DMR-ESRW/QPM	9.53 (43)	0.44 (2)		0.44 (2)	0.22(1)	2.22 (10)	12.86(58)
EVDT97 STRW	20.40 (92)			0.44 (2)		4.88 (22)	25.72 (116)
AK94 DMR-ESRY	3.77 (17)					0.44 (2)	4.21 (19)
TZE|Composite 3 DT	0.66 (3)						0.66 (3)
2000 Syn. EEW	4.43 (20)					1.11 (5)	5.54 (25)
Total	79.6 (359)	1.1 (5)	0.22 (1)	0.88 (4)	0.22 (1)	17.96 (81)	100 (451)

Source: January-February Survey of 2015; **( )** = Number of producers concerned.

Table 5. Results of the estimation of improved seed adoption coefficients and their marginal effects.

Variables	Coefficients	Std. Err.	dy/dx (Marginal Effects)
Years of experience in production	-0.0062326	0.0081292	-0.0015515
Literacy	0.2910612*	0.1722456	0.069136*
Relationship with structures	0.7108511***	0.1709239	0.1969698***
Belonging to a group	0.2416739	0.1960786	0.0569273
Logarithm of maize land area	0.2528888***	0.0949962	0.0629527***
Training received	0.0066387	0.1854724	0.0016513
Annual agricultural income	-0.0798377**	0.0427027	-0.0198744**
Sex	-0.3176279	0.4239691	-0.0679176
_cons	0.8269964*	0.4927451	
Number of observations = 388			
Prob> chi2 = 0.0000			
Log likelihood = -168.44985			
LR chi2(8) = 41.22			
Pseudo R2 = 0.1090			
% Correct prediction = 82.5			

Source: January - February Survey of 2015; Legend: * means sig. at 5%, ** means sig. at 1% and *** means sig. at 0.1%.

about improved seeds through CARDER versus 1%, 1% and about 18% respectively for INRAB, PMA agents and other actors.

We can conclude that the main sources of information about improved maize seed are CARDER followed by other actors.

Factors affecting the adoption of improved maize seed

The model has good predictive and estimated properties for all the improved seeds studied (Table 5). Indeed, the likelihood ratio (-126.65) is significant at 1% level of significance. Moreover, the percentage of correct prediction of the model is 82.6%, so there is a good agreement between the probabilities calculated and the frequencies of the responses observed. From the eight independent variables introduced in the model, only four variables have influence on the adoption of improved maize seeds in the studied area:

Literacy has a positive influence on the probability of adoption of improved maize seed. This means that there is a proportional relationship between adoption and literacy. Indeed, the more the literacy level of a farmer, the greater is the probability of adopting improved maize

Table 6. Adoption rate, potential and gap for improved maize seed adoption.

Seeds	Number of observations (N)	Number of farmers exposed (Ne)	Number of adopters (Na)	ATE (potential adoption rate)	ATE1 (adoption rate among exposed)	ATE0 (adoption rate among non-exposed)	Jea (common adoption and exposure rate)	Adoption gap (GAP= ATE– Jea)	Bias of population selection (PBS=ATE1-ATE)	Adoption rate in the general population (Na/N)	Rates of those who know (Ne/N)	Rates of those who know and have adopted (Na/Ne)
TZPB-SR	244	52	48	0.86 (0.07)*	0.87 (0.07)*	0.85 (0.07)*	0.19 (0.01)*	- 0.67 (0.05)*	0.01 (0.01)*	19.67 (0.02)*	21.31 (0.02)*	92.30 (0.11)*
FAAB/QPM	325	57	49	0.84 (0.05)*	0.85 (0.05)*	0.84 (0.06)*	0.15 (0.01)*	-0.69 (0.05)*	0.009 (0.04)*	15.07 (0.02)*	17.54 (0.02)*	85.96 (0.11)*
DMR-ESRW	350	65	55	0.79 (0.05)*	0.84 (0.05)*	0.78 (0.05)	0.16 (0.01)*	-0.63 (0.04)*	0.05 (0.02)*	15.71 (0.02)*	18.57 (0.02)	84.62 (0.10)*
EVDT97 STRW	389	111	102	0.82 (0.05)*	0.87 (0.03)*	0.80 (0.05)*	0.25 (0.01)*	-0.57 (0.04)*	0.05 (0.02)*	26.22 (0.02)*	28.53 (0.02)*	9.89 (0.08)*
All improved varieties	384	323	303	0.93 (0.02)*	0.93 (0.01)*	0.93 (0.03)*	0.78 (0.01)*	-0.15 (0.01)*	0.001 (0.00)*	78.90 (0.02)*	84.11 (0.02)*	93.80 (0.02)*

Source: January-February Survey of 2015; *: * means sig. at 1%.

seed. Literacy plays an important role in enabling farmers to understand the importance of using technology appropriate to their work. The fact that the farmer is literate could lead him to understand the economic benefits of adopting agricultural innovations in general and improved maize seeds in particular. This result shows that literacy and formal education play so much an important role in determining the farmer's ability to allocate the inputs needed to meet the production targets. This is what leads certain authors to assert that formal education favors the adoption of new technology (McBride and El-Osta, 2002; Ouédraogo, 2003; Bravo-Ureta *et al.*, 2005; Adégbola and Adékambi, 2008). Promoting literacy would increase the probability of adopting improved maize seeds by 7%.

The variable *relationship with structures* positively influences the adoption of improved maize seeds. This variable is important in adoption and informs about innovations, including improved high-yield seeds. These structures provide important information on the benefits of using improved maize seed. Improving the adoption rate of improved seeds requires the efficiency of decentralized government services and structures. An improvement in the farmers' relationship with the structures would increase their probability of adopting improved maize seeds by 20%.

Maize land area in 2013 positively influenced the probability of adopting improved maize seeds. This means that the greater the farm size devoted to maize, the higher the probability that the farmer will adopt the improved seeds. This result shows that maize growers with large farm size would adopt more of improved maize seed for production. This variable has a positive marginal effect on the adoption of improved maize seed. An increase in the farm size allocated to maize would increase the probability of adopting improved maize seeds by 6%.

Annual income coming from maize production affects the probability of adopting improved seed negatively. This can be explained by the fact that this income is not sufficient to allow farmers to take the risk of adopting this new technology. To illustrate that, we have an average of 4.6 over 10 for the annual income coming from maize production. This part (4.6) appears to be less important (for maize, which is the main speculation in the household) for farmers to opt for the adoption of improved maize seed.

Potential for adoption of improved maize seeds

The results in Table 6 are presented in two parts. Firstly, the potential for improved seed adoption (all improved varieties); secondly, the adoption potential of each improved maize seed. These results expressed the impact of knowledge on the use of improved seeds. Indeed, the results of the diffusion of improved seed (all improved varieties) revealed that 84% of the farmers were aware of the improved seeds. This incomplete diffusion limits the adoption rate to 78%, while the potential adoption rate was 93%. This leads to an adoption gap of 15%. As the selection bias (Potential Bias Selection, PBS) is not significant, it follows that all the farmers have the same chance to adopt improved seeds. This demonstrates the consistency of the adoption of improved seeds among all farmers in the studied areas covered. From these results, one can believe that all the seeds that have been the subject of this study have shining situations.

In order to see specifically which seeds are more adopted, the study determined the same elements for the different types of seeds that were subject of the study. It was observed that farmers were not informed or poorly informed about some seeds (TZL COMP4C4, TZE Composite 3x4, DMR-ESRW / QPM, TZE Composite 3 DT, TZEE-SRW and 2000 Syn. EEW). In addition, a very small number of farmers were exposed to the varieties DT SR-W (4 over 490) and IWDSyn (2 over 490) with a single adopter in each case. Taking into account these aspects, only four varieties were concerned. The variety TZPB-SR showed only 19% of adopter over 86% of potential adoption rate. Farmers do not have the same chance to adopt this variety because the potential selection bias of this variety is significant. For the variety FAABA / QPM, only 15% of the farmers adopted it with an adoption potential of 84%; leading to a considerable deviation of 69%. As for the selection bias (PSB), it is not significant. Therefore, all the farmers have the same chance to adopt this variety of seeds. The variety DMR-ESRW has an adoption potential of 79%, but only 16% of the farmers effectively adopted it. As a result of this low adoption rate, we note a large difference of 63%. Farmers do not have the same chance to adopt this variety of seed because the selection bias are significant. For the variety EVDT97 STRW, 25% of farmers adopted it with a potential adoption rate of 82%. This creates a significant deviation of 57%. But farmers don't have the same chance to adopt this seed variety because the selection bias (PSB) are significant. In summary, when all improved varieties are taken together, improved seeds have a good adoption rate (78%) with a low adoption gap (15%). On the other hand, when seed varieties are taken separately, there is a low adoption rate with adoption gaps of at least 60%. It is then urgent to accentuate the actions on these four varieties by refocusing for example the actions of the research centers, the farmers Organizations (OP) and the non-Governmental Organizations (NGO) in charge with the development, the multiplication and the distribution of the maize seeds improved, by reinforcing their technical capabilities, economic and organizational.

CONCLUSION

The objective of this study was to assess the socio-economic factors related to the access and adoption of various improved maize seeds by farmers in the maize production areas of Benin Republic. It was observed that changes in maize production due to endogenous or exogenous technological responses to reduce the constraints remain unclear. The Average Treatment Effect shows that over 84% of farmers in the sample who have knowledge of at least one of the improved maize seeds, 78% adopted the improved seed. Moreover, for all improved seeds, 93% of farmers should have adopted improved seeds if they did not have this incomplete diffusion. This equates to a gap (adoption gap) of 15%.

On the other hand, taking separately four of the improved seed varieties, we have a low adoption rate (16% for DMR-ESRW, 25% for EVDT97 STRW, 19% for TZPB-SR and 15% for FAABA / QPM) with adoption gaps of at least 60%. In addition, the results of the probit model show that variables such as literacy, relationship with structures/institutions, maize land area in 2013, and annual income coming from maize production determine the adoption of improved maize seeds.

The objectives of the agricultural extensions programs should be reorienting. It will be about elaborating the strategies permitting to persuade the peasants in relation to the economic and social advantages that overflow the use of seeds improved. Also, it would be necessary that the state implies the producers more in the different decision makings and the processes of improvement of the different technologies through the approach of innovation platform.

REFERENCES

Adégbola PY, Arouna A, Hennou L, Adekambi S (2010). Taux et déterminants de l'adoption des innovations technologiques développées par l'INRAB entre 2000 et 2006. Rapport définitif. p. 135.

Adegbola PY, Adekambi SA, Ahouandjinou MC, Yabi JA (2008). Taux et déterminants de l'adoption des variétés améliorées d'ignames développées par l'IITA. IITA, PAPA, IFAD. p. 25.

Ahouandjinou MC, Adegbola PY, Yabi JA, et Adekambi SA (2010). Adoption et impact socio-économique de la semi-mécanisation du procédé de transformation des amandes de karité en beurre au Nord-Bénin, p. 27.

Aly DJ, Padonou E (2007). Influence du mode d'égrenage sur la qualité des semences certifiées de maïs dans le Département de l'Atlantique (Sud-Bénin). In : Badu-Apraku B. *et al.*, eds. Proceedings of the fifth biennial regional maize workshop, Demand-driven technologies for sustainable maize production in West and Central Africa, 3-6 May, 2005, IITA-Cotonou, Benin. Ibadan, Nigeria: WECAMAN/IITA, pp. 355-362.

Angrist JD, Imbens GW, Rubin DB (1996). Identification of causal effects using instrumental variables, J. Am. Stat. Assoc. 91:444-472.

Arouna A, Adégbola PY, Biaou G (2011). Analyse des coûts de stockage et de conservation du maïs au SudBénin. *Bull. Rech. Agron.* Bénin, 2:13-23.

Bassolé L (2004). Programme d'insfrastructures rurales et bien-être des ménages : Analyse en terme d'indicateurs antropométriques des enfants ; CERDI-CNRS, Université d'Auvergne 65, France.

Boone P, Stathacos CJD, Wanzie RL (2008). Évaluation sous-régionale de la chaine de valeurs du maïs. Rapport technique ATP n° 1. Bethesda, MD, USA: Abt Associates Inc.

Bravo-Ureta BE, Solis D, Cocchi H, Quiroga RE (2005). The impact of soil conservation and output diversification on farm income on Central American hillside farming. Agric. Econ. 35:271-275.

Blundell, R, Costa DM (2002). Alternative approaches to evaluation in empirical microeconomics J. Hum. Resour. 44/3:565-640.

Dembélé S (2011). Système semencier et législation semencière en Afrique de l'Ouest : enjeux et perspectives. *In*: Actes de la Conférence IER-FASD, 5-7 Octobre 2011, Bamako, Mali. Bamako: INSAH/CILSS. http://www.syngentafoundation.org/_temp/Syste`me_s emencier_et_le´gislation_S_Dembe´le´.pdf, (20/10/2015).

Diagne A, Demont M (2007). Taking a New Look at Empirical Models of Adoption: Average Treatment Effect estimation on adoption rate and its Determinants. Forthcoming in Agricultural Economics, Vol. 37 2007. p. 20.

Diagne A (2005). Taking a New Look at Empirical Models of Adoption: Average Treatment Effects of Adoption Rates and their Determinants. Cotonou: WARDA.

Diagne A (2003). Evaluation de l'impact. Synthèse des développements méthodologiques récents, ADRAO/Conakry, p. 15.

Heckman J (1990). "Varieties of selection bias," American Economic Review 80, 313-318.

Heckman J (1996). Identification of causal effects using Instrumental Variables: Comments. J. Am. Stat. Assoc. 91(N°434):5.

Heckman J (1997). Instrumental variables: a study of the implicit assumptions underlying one widely used Estimator for Program Evaluations. J. Hum. Resour. 32:441-462.

Imbens GW, Angrist JD (1994). Identification and estimation of local Average Treatment Effects. Econometrica. 62:467-476.

Imbens GW, Wooldridge JM (2009). Recent Developments in the Econometrics of Program Evaluation. J. Econ. Lit. 47(1):5-86.

Kpedzroku A, Didjeira A (2008). Guide de production de semences certifiées maïs–sorgho–riz–niébé. Collection brochures et fiches techniques 1. Lomé: ITRA/ICAT/CTA.

Louwaars MP, Marrewijk GAM (1999). Seed supply systems in developing countries, CTA, Wageningen, The Netherlands.

Ministère de l'Agriculture, de l'Élevage et de la Pêche, MAEP (2010a). Annuaire de la statistique : campagne 2009-2010. Cotonou, Bénin: MAEP.

Ministère de l'Agriculture, de l'Élevage et de la Pêche, MAEP (2010b). Plan stratégique de relance du secteur agricole (PSRSA). Version finale. Cotonou, Bénin: MAEP.

McBride DW, El-Osta HS (2002). Impacts of the adoption of genetically engineered crops on farm financial performance. J. Agric. Appl. Econ. 34(1):175-191.

Moffitt R (1991). "Program Evaluation with Non-experimental Data", Eval. Rev. 15(3):291-314.

Negatu W, Parikh A (1999). The impact of perception and other factors on the adoption of agriculture technology in the Moretan Jiru Woreda (District) of Ethiopia. Agric. Econ. 21:205-216.

Ouedraogo R (2003). Adoption et intensité d'utilisation de la culture attelée, des engrais et des semences améliorées dans le centre nord du Burkina. CEDRES, Université de Ouagadougou, Burkina Faso, p. 107.

Rosenbaum PR, Rubin DR (1983). The central role of the propensity score in observational studies for causal effects. In *Biometrika.* 70:41-55 Tradeport, Country-Facts Guinea.

Rubin D (1977). Assignment to Treatment on the Basis of a Covariate, J. Educ. Stat. 2:1-26.

Wooldridge J (2002). Econometric analysis of cross cross-section and panel data. The MIT press, Cambridge, Massachusetts, USA pp. 603-644.