Adoption assessment of improved maize seed by farmers in Benin Republic

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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 farmers 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; Y₁ and Y₀ two random variables that represent the income level of a farmer i if he uses (Yᵢ) or not (Y₀) the new technology. Let D be the binary variable, with Dᵢ = 1 when the farmer adopted the technology and Dᵢ = 0, otherwise. The causal effect of adopting the technology for the farmer i is the difference between Y₁ and Y₀.

Δᵢ = Yᵢ − Y₀ \tag{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 Y₁ and Y₀ for the same person. Yi is defined as follows:

Yᵢ = DYᵢ − (1 − Dᵢ)Y₀ \tag{2}

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

ATE = Eᵢ(Δᵢ) = E(Yᵢ − Y₀) = E(Yᵢ) − E(Y₀) \tag{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 = Eᵢ(Δᵢ | Dᵢ = 1) = Eᵢ(Yᵢ − Y₀ | Dᵢ = 1)

= E(Y₁ | Dᵢ = 1) − E(Y₀ | Dᵢ = 1) \tag{5}(6)

The counterfactual is defined as E(Y₀ | Dᵢ = 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 (Y₀ | Dᵢ = 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 (Y₀ | Dᵢ = 0) in order to have a good approximation of (Y₀ | Dᵢ = 1). Any gap between the counterfactual and this approximation would justify the existence of a selection bias. By adding and subtracting (Y₀ | Dᵢ = 1) to the
expression $E(Y^1_i | D^1_i = 1) - E(Y^0_i | D^1_i = 0)$ where the counterfactual is replaced by its proxy:

$$E(Y^1_i | D^1_i = 1) - E(Y^0_i | D^1_i = 0) = E(Y^1_i | D^0_i = 1) - E(Y^0_i | D^0_i = 1)$$

$$= E(Y^1_i - Y^0_i | D^0_i = 1) + E(Y^1_i | D^0_i = 1) - E(Y^0_i | D^0_i = 0)$$

$$= ATE + E(Y^1_i | D^0_i = 1) - E(Y^0_i | D^0_i = 0)$$

(7)

(8)

(9)

The expression in brackets defines the potential selection bias:

$$BS = E(Y^0_i | D^1_i = 1) - E(Y^0_i | D^1_i = 0)$$

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:

$$prob(A_i = 1 | D_i = 1) = E(A | D_i > 0)$$

(10)

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):

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

(11)

Where $x_i$ is the set of socio-economic variables affecting the adoption of $x$ their respective average: $x$, $\xi$ and $\alpha$ the parameters to be estimated. $\gamma$ 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 detail 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).

$$ATE(x) = E(y_i | x)$$

$$= E(y | x, w = 1)$$

$$= g(x, \beta)$$

(12)

(13)

where $g$ a known function (eventually non-linear) of vectors of the covariants $x$; $\beta$ 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 $W_i = 0$ otherwise. With an estimated parameter $\beta$, 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 $g(x, \hat{\beta})$ 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
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.

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

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
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 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 (UPC) (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.

<table>
<thead>
<tr>
<th>Improved maize seed</th>
<th>CARDER (proportion)</th>
<th>INRAB (proportion)</th>
<th>Producer (proportion)</th>
<th>PMA agents (proportion)</th>
<th>CEF agents (proportion)</th>
<th>Other factors (proportion)</th>
<th>Total (proportion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TZPB-SR</td>
<td>13.3 (60)</td>
<td>0.22 (1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15.29 (69)</td>
</tr>
<tr>
<td>TZL COMP4C4</td>
<td>0.22 (1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FAABA/QPM</td>
<td>14.20 (64)</td>
<td>0.22 (1)</td>
<td>0.22 (1)</td>
<td></td>
<td></td>
<td></td>
<td>18.18 (82)</td>
</tr>
<tr>
<td>DT SR-W</td>
<td>0.67 (3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.89 (4)</td>
</tr>
<tr>
<td>IWDSyn</td>
<td>0.22 (1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.22(1)</td>
</tr>
<tr>
<td>DMR-ESRW</td>
<td>12.20 (55)</td>
<td>0.22 (1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15.96 (72)</td>
</tr>
<tr>
<td>DMR-ESRW/QPM</td>
<td>9.53 (43)</td>
<td>0.44 (2)</td>
<td>0.22 (1)</td>
<td></td>
<td></td>
<td></td>
<td>12.86(58)</td>
</tr>
<tr>
<td>EVDT97 STRW</td>
<td>20.40 (92)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25.72 (116)</td>
</tr>
<tr>
<td>AK94 DMR-ESRY</td>
<td>3.77 (17)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.21 (19)</td>
</tr>
<tr>
<td>TZE</td>
<td>Composite 3 DT</td>
<td>0.66 (3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000 Syn. EEW</td>
<td>4.43 (20)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.54 (25)</td>
</tr>
<tr>
<td>Total</td>
<td>79.6 (359)</td>
<td>1.1 (5)</td>
<td>0.22 (1)</td>
<td>0.88 (4)</td>
<td>0.22 (1)</td>
<td></td>
<td>100 (451)</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficients</th>
<th>Std. Err.</th>
<th>dy/dx (Marginal Effects)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years of experience in production</td>
<td>-0.0062326</td>
<td>0.0081292</td>
<td>-0.0015515</td>
</tr>
<tr>
<td>Literacy</td>
<td>0.2910612*</td>
<td>0.1722456</td>
<td>0.069136*</td>
</tr>
<tr>
<td>Relationship with structures</td>
<td>0.7108511***</td>
<td>0.1709239</td>
<td>0.1969698***</td>
</tr>
<tr>
<td>Belonging to a group</td>
<td>0.2416739</td>
<td>0.1960786</td>
<td>0.0569273</td>
</tr>
<tr>
<td>Logarithm of maize land area</td>
<td>0.2528888***</td>
<td>0.0949962</td>
<td>0.0629527***</td>
</tr>
<tr>
<td>Training received</td>
<td>0.0066387</td>
<td>0.0427027</td>
<td>-0.0198744**</td>
</tr>
<tr>
<td>Annual agricultural income</td>
<td>-0.0798377**</td>
<td>0.1854724</td>
<td>-0.01079176</td>
</tr>
<tr>
<td>Sex</td>
<td>-0.3176279</td>
<td>0.4239691</td>
<td>-0.0679176</td>
</tr>
<tr>
<td>_cons</td>
<td>0.8269964*</td>
<td>0.4927451</td>
<td></td>
</tr>
</tbody>
</table>

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.

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

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

Adoption rate of improved maize seeds positively influences the adoption of improved maize seeds. This means that the larger 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 maize seeds 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 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.

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