**Economic Impacts of Legume Varieties and Rotations:**

**The Case of Faba-beans in the Wheat – Based Production Systems of Morocco**

**Yigezu. A. Yigezu1\*, Tamer El-Shater1, Mohamed Boughlala2, Zewdie Bishaw1, Abdul-Aziz Niane1, Aden Aw-Hassan1**

**1**International Center for Agricultural Research in the Dry Areas (ICARDA)

**2**[Institut National de la Recherche Agronomique (INRA)](http://www.inra.org.ma/)

\* Corresponding Author: ICARDA, Amman, P.O. Box, 950764 Amman 11195, Jordan; e-mail – y.yigezu@cgiar.org

**Abstract**

While the impacts of cereal-legume rotations on soil health are well documented, the literature on their economic benefits is scanty. By applying the propensity score matching and endogenous switching regression methods to a nationally representative sample of 1,230 farm households from the wheat-based production systems in Morocco, this paper provided empirical evidence that: 1) the adoption of improved faba-bean varieties led to 206.2 kg/ha (16%) increase in yields, US$100/ha (11%) higher net returns, and 16 kg/capita/year (28%) increase in faba-bean consumption; 2) The adoption of faba-beans - wheat rotations led to 26% higher yields and 38% higher net returns from the subsequent wheat crop; and 3) the adoption of both improved faba-bean varieties and faba-beans-wheat rotations led to 33% higher total farm income. At the current average national adoption level of 23%, improved varieties led to about 15.7 thousand tons (14%) higher total national faba beans production per year. Therefore, along the biophysical and environmental benefits documented elsewhere, these results suggest that the introduction of improved varieties of legumes as rotation crops in wheat-based systems can also be justified on economic and food security grounds. Enhancing wider adoption of improved varieties and legume-cereal rotations through, creating better access to extension and certified seed delivery services and other means is important.

Key words: improved varieties; rotation; faba-beans; wheat; adoption; impact.

**1. Introduction**

Faba beans are of great importance in legume–cereal rotations in various cropping systems. It is used as a break crop for cereals (Amanuel et al., 2000; Lopez-Bellido et al., 2006) and has the potential to enhance N and P nutrition of cereals when grown in rotation (Habtemichial et al., 2007; Nuruzzaman, et al., 2005). Faba bean can also improve the economic value of a subsequent cereal crop by enhancing the yield and increasing the protein content of the grain. It can also provide a range of other potential rotational benefits that are not directly related to N such as enhanced P availability (Pypers et al., 2007; Jemo et al., 2006; Nuruzzaman et al., 2005), favourable microbial community in the rhizosphere (Marschner et al., 2004; Yusuf et al., 2009) and breaking soil-borne disease cycles (Jensen et al., 2010; Peoples et al., 2009).

During the growth of faba bean, a high amount of N2 is fixed often resulting in a positive N balance when crop residues are incorporated in the soil after grain harvest. Net N gains due to residue incorporation of about 84 kg N ha-1 have been reported (Amanuel et al., 2000). Several studies reported savings of up to 100–200 kg N ha-1 in the amount of N-fertilizers applied to cereals following faba beans. Kirkegaard et al. (2008) and Habtemichial et al. (2007) have also found wheat yield increases of 20–36 % in the faba bean–wheat rotation compared to a barley–wheat rotation. Legume-cereal rotations are also known to reduce the demand for labour for weed control as well as in reducing soil erosion (Lawson et al.*,* 2007; Reddy et al., 1986; Becker and Johnson, 1998; Tarawali et al., 1999).

Faba bean is one of the most important legumes for its high protein content and nutritional value (Crepona et al., 2010). The crop is widely cultivated for use in both human food and animals feed. Faba bean seeds contain relatively high proteins, carbohydrates, vitamins B, antioxidants and minerals. Protein content in different varieties varies from 26% to 41% (Picard, 1977). Carbohydrate contents varies from 51% to 68%, of which major proportion (41–53%) is contributed by starch (Cerning et al., 1975). Common bean exhibits significant antioxidant activities such as flavonoids, polyphenols and phenolics which may provide excellent dietary source for natural antioxidant for chronic disease prevention and health promotion (Oomah et al., 2006).

As described above, the biophysical impacts of legume-cereal rotations are well documented in the literature. However, the choice of crops grown in any season is largely inﬂuenced by market forces, and farmers are under pressure to maximize proﬁts by growing the same crop repeatedly on the same land. This is leading to monoculture or shortened rotations in many parts of the world with its resultant effect of declining soil health and hence yield potentials (holding all other factors constant) as well as expected profits.

Some work has been done on the economic impacts of legume-rotations which is mostly in the developed world (see the review by Preissel et al., (2015)). However, little is known about their economic and nutritional impacts in the context of smallholders especially in the developing world in general and in Morocco in particular. The results of Schilizzi and Pannell (2001) which is a case study from Australia may be of some relevance to the Mediterranean countries, but the landholding size and economic conditions of farmers in Australia and the Mediterranean countries in the North African and West Asian regions are different. Moreover, none of the previous studies assessed the combined economic impacts of adoption of improved varieties and rotations. The objective of this study is therefore to document the individual and combined impacts of the adoption of improved faba bean varieties and their rotation with cereals on farm income and food and nutrition security of smallholder farmers in Morocco. By so doing, this paper aims at providing evidence on the economic viability of legume-cereal rotations and adoption of improved legume varieties. The findings of this research are expected to be instrumental in influencing policy and current extension in favour of diversification and hence in reversing the current trend of increased mono-cropping in Morocco as well as well as many other developing countries.

**2. Faba Beans in the Study Area**

Morocco is a lower-middle-income country in North Africa with a population of 33 million people, a per capita GDP of US$3,054 and a GINI index of 40.9 (World Bank, 2012). Two thirds of the rural population are poor earning less than US$1.25/day. Agriculture plays an important role in the Moroccan economy. Its contribution to GDP and total national employment during the 2010-2014 period averaged about 17% and 45% respectively. The sector also provides indirect support for 60% of the population and generates almost 25% of export revenue. Eighty per cent of the 14 million rural inhabitants depend on revenues from the agricultural sector for their livelihoods. Reducing poverty is an important priority of the government of Morocco and is a necessary condition to improve the state of food security, sustainable development and improve livelihoods.

Faba bean is an important crop in Morocco providing nutritional, biological and economic benefits to smallholder farmers. In the late 1970s, a collaborative program between Institut National de la Recherche Agronomique (INRA) called Station Centrale des Légumineuses Alimentaires and the Food Legume Improvement Program of the International Centre for Agricultural Research in the Dry Areas (ICARD) was established. From 1989 to 1991, ICARDA decentralized the faba bean program to Morocco with the purpose to serve the North African faba bean breeding programs. Two faba bean projects Réseau Maghrébin de Recherche sur Fève (REMAFEVE) and Amélioration de la Culture de Légumineuses Alimentaires (ACLA) were implemented from 1992-2002, to develop improved varieties of faba bean and other legume species (Fatemi et al., 2006). Since 1982, several INRA varieties of faba bean were registered in the national catalogue including other crops. Among these are three small-seeded faba bean varieties called Alfia5, Alfia17 and Alfia21 and three large-seeded faba bean varieties called Defes, Karabiga and Loubab (Fatemi et al., 2006). Similar efforts have been exerted for the release of improved varieties of other leguminous crops such as chickpeas and lentils and cereals such as wheat and barley.

Despite all these efforts, while the area under cereals increased by 19% from an average of 4.4 million ha in the period 1961 - 1979 to an average of 5.2 million ha in the period 2001 – 2014, area under grain legumes dropped in the same period by 13% from an average of about 458 thousand ha to about 400 thousand ha. Particularly, the area dedicated to faba-beans has dwindled where it declined from an average of about 200 thousand hectares between the late 1980s and early 1990s to an average of about 120 thousand ha in Mid-1990s and more recently rebounded to an average of about 190 thousand ha between 2010 and 2014. Likewise, while adoption of improved varieties of cereals showed modest increases, the adoption of improved varieties of legumes in general and Faba-beans in particular remains very low with very low yields. For example, the average yields of faba-beans during the period 2001 and 2014 was about 0.71 ton/ha which is 58% lower than the world average of 1.7 ton/ha (FAOStat, 2016).

**3. Data**

Data for this study came from a large sample household survey conducted in 2013 covering twenty one major wheat producing provinces in Morocco. These provinces account for about 79% of total number of wheat growing farmers and 81% of national wheat area in the country. They are found in the four agro-ecological zones suitable for wheat production namely: the favourable zone, intermediate zone, unfavourable south and the mountains zone. Provinces in the remaining two agro-ecological zones in Morocco (the Saharan zone and the Unfavourable Oriental Zone) are excluded from the survey as wheat production in these zones is either non-existent or less important.

A total sample of 1230 farm households was drawn for this study using a stratified sampling approach where provinces, districts and villages were used as strata. The total sample was distributed proportionally across 292 villages in 56 districts that were randomly drawn from the 21 study provinces. Distribution of samples across the 21 provinces selected for the survey is provided in Table 1 below.

Table 1: Distribution of Sample Households across the 21 Provinces

| Region | Province | Sample statistics |
| --- | --- | --- |
| # ofdistricts | # ofvillages | Number of Households |
| Male headed | Women headed | Total |
| Chaouia-Ouardigha | Benslimane | 3 | 10 | 26 | 1 | 27 |
| Berrechid | 2 | 13 | 40 | 3 | 43 |
| Settat | 3 | 33 | 80 | 2 | 82 |
| Doukkala-Abda | El Jadida | 3 | 16 | 70 | 6 | 76 |
| Sidi Bennour | 2 | 17 | 63 | 5 | 68 |
| Safi | 3 | 19 | 128 | 2 | 130 |
| Fes-Boulemane | Fes | 1 | 1 | 8 | 0 | 8 |
| Moulay Yacoub | 2 | 7 | 52 | 0 | 52 |
| Gharb-Chrarda-Bni Hces | Kenitra | 3 | 17 | 49 | 10 | 59 |
| Sidi Slimane | 1 | 8 | 17 | 1 | 18 |
| Sidi Kacem | 5 | 22 | 63 | 4 | 67 |
| Marrakech-Tensift-Alhaouz | El Kelaa | 2 | 12 | 36 | 2 | 38 |
| Rehamna | 2 | 12 | 75 | 2 | 77 |
| Meknès-Tafilalet | El Hajeb | 3 | 7 | 22 | 0 | 22 |
| Khenifra | 2 | 11 | 58 | 0 | 58 |
| Meknes | 1 | 11 | 29 | 0 | 29 |
| Rabat-Salé | Khemisset | 4 | 25 | 61 | 6 | 67 |
| Tadla-Azilal | Beni Mellal | 3 | 7 | 89 | 1 | 90 |
| Taza-Alhoceima-Taounate | Taounate | 4 | 24 | 117 | 7 | 124 |
| Taza | 5 | 14 | 75 | 0 | 75 |
| Guercif | 2 | 6 | 20 | 0 | 20 |
| Total Sample  |  | 56 | 292 | 1178 | 52 | 1230 |

**4. Methodology**

***4.1 Propensity Score Matching (PSM)***

It has been common in previous studies to assess the impact of technology adoption either by examining the differences in mean outcomes of adopters and non-adopters or by using simple regression procedures which control for adoption status (Nguezet, et al., 2011). Critics have pointed out that such simple procedures are flawed because they fail to appropriately deal with problems associated with selection biases in observational data collected through household surveys (Rubin, 1974; Rosenbaum and Rubin, 1983; Rosenbaum, 2002; Lee, 2005). Such approaches often lead to the establishment of causality between adoption and other variables that are subjected to confounding errors.

Propensity score matching is one of the multivariate methods used in comparative studies to construct treated and matched control samples that have similar distributions on many covariates. The purpose of propensity score matching is to reduce bias due to observed covariates in comparative observational studies (Rubin and Thomas 2000). PSM is one of the non-parametric estimation techniques that do not depend on functional form and distributional assumptions. The method is intuitively attractive as it can be used to compare the observed outcomes of technology adopters with the outcomes of counterfactual non-adopters (Heckman et al., 1998). The details of the PSM method are well documented in several studies (e.g., Rosenbaum and Rubin 1983; Heckman et al., 1998; Daheja and Wahba, 2002; Caliendo and Kopeinig, 2008).

In this paper, we use PSM to find a group of treated individuals (adopters) similar to the control group (non-adopters) in all relevant pre-treatment characteristics, where the only difference is that one group adopted the improved faba bean and the other did not. The semi-parametric matching method which does not require an exclusion restriction or a particular specification of the selection equation is used to construct the counterfactual and reduce the effects of selection bias on impact estimates.

The propensity score is most often estimated using a logistic regression model, in which treatment status (which in our case is the dummy variable for adoption of faba bean taking a value of 1 when the farmer is an adopter and 0 when the farmer is a non-adopter) is regressed on observed characteristics of the farmer. The estimated propensity score is therefore the predicted probability of a farmer adopting improved faba bean given his characteristics (which are captured by the explanatory variables included in the logistic regression). The propensity score for each observation is then obtained by substituting the corresponding values of each covariate for each observation into the estimated logistic regression where the estimated coefficients are used in the computation (Rosenbaum and Rubin 1985). In this study, the logistic model is estimated to identify the factors influencing adoption of improved faba bean as follows:

 (1)

where (2)

Adoption is a dichotomous dependent variable taking a value of 1 if the improved faba bean takes place and 0 otherwise; Xi is the vector of observed farmer, farm and non-farm characteristics that are believed to determine adoption and hence are included in the model; βi are parameters to be estimated; is error term of the model; and is the base of natural logarithms.

The main purpose of the propensity score estimation is to balance the observed distribution of covariates across the groups of adopters and non-adopters (Lee, 2013). Since we do not condition on all covariates but on the propensity score, balancing test is normally required after matching to ascertain whether the differences in the covariates in the two groups in the matched sample have been eliminated, in which case, the matched comparison group can be considered a plausible counterfactual (Ali and Abdulai, 2010). Several versions of balancing tests exist in the literature: test for mean differences within strata (Dehejia and Wahba, 2002), test for standardized differences (Rosenbaum and Rubin 1985), test for the joint equality of covariate means between treatment and comparison groups using the Hotelling or F-tests (Smith and Todd 2005), comparison of the pseudo R2 and p-values of the likelihood ratio test of the joint insignificance of all the covariates (Sianesi, 2004) and the mean absolute standardized bias (MASB) between adopters and non-adopters (Rosenbaum and Rubin, 1985). We use the mean absolute standardized bias (MASB) between adopters and non-adopters because it has key advantage where as opposed to model-based methods, outcome data is not involved in the matching for which repeated attempts to balance covariates do not bias estimates of the treatment effect on outcome variables. The intuition behind this check for balance within strata is the close analogy between randomized block experiments and propensity score methods.

The main problem with using the MASB approach is that there is no clear criterion for testing the success of PSM. However, in empirical studies, it is often assumed that MASB below 3% or 5% after matching is acceptable (Caliendo and Kopeinig, 2008). Rosenbaum and Rubin (1985) argue that, after matching, total bias in excess of 20% should be considered as large.

Following Sianesi (2004), we also make comparison of the pseudo R2 and p-values of the likelihood ratio test of the joint significance of all the regressors obtained from the logistic regression before and after matching the samples. After matching, there should be no systematic differences in the distribution of covariates between the two groups. As a result, the pseudo-R2 should be lower and the joint significance of covariates should be rejected (or the p-values of the likelihood ratio should be insignificant).

***4.2******Endogenous switching regression (ESR) models***

To complement the impact estimates from the PSM technique and to assess consistency of the results to different assumptions, the endogenous switching regression (ESR) technique (Maddala and Nelson, 1975) was applied to the same data. Both PSM and ESR are used to measure the impacts of improved faba bean on farm households’ welfare particularly on farm income and per capita wheat consumption.

The endogenous switching regression model can be used to estimate and make pairwise comparisons of: (a) the expected net income of a typical adopter farm household (b) the expected net income of the typical non-adopter household; and to investigate the expected net income in the counterfactual hypothetical cases of (c) if the typical adopter did not actually adopt and (d) if the typical non-adopter were to adopt. Following Di Falco (2011) and Shiferaw et al. (2014), the conditional expectations for net income in the four cases are presented in Table 2 and defined as follows:

Cases (a) and (b) along the diagonal of Table 2 represent the expectations for the typical farmers in each of the adopter and non-adopter categories respectively based on actual observations in the sample. Cases (c) and (d) represent the counterfactual expected net incomes. Suppose that:

TT = treatment effect which measures the effect of the treatment (i.e., adoption) on the treated (i.e., farm households that actually adopted) which, when averaged across all adopter households gives the average treatment effect on the treated (ATT).

TU = treatment effect on the untreated which measures the effect of the treatment (i.e., adoption) on the untreated (i.e., farm households that actually did not adopt), which when averaged across all non-adopter households gives the average treatment effect on the untreated (ATU).

BHi = the average effect of base heterogeneity for farm households that adopted (i =1), and that did not adopt (i =2)

TH= Transitional heterogeneity = BH1-BH2

Then, we can estimate each of these effects as follows:

*ATT* =*E (y*1*i* |*Ai* =1*)* – *E (y*2*i*|*Ai* =1*)*

=**X1i\****(***β1** − **β2***)* + *(σ*1*η* − *σ*2*η)\*λ*1*i*

*ATU* =*E (y*1*i*|*Ai* =0*)* – *E (y*2*i*|*Ai* =0*)*

=**X2i\****(***β1** − **β2***)* + *(σ*1*η* − *σ*2*η)\*λ*2*i*.

*BH*1 =*E (y*1*i*|*Ai* =1*)* – *E (y*1*i*|*Ai* =0*)*

= *(***X1i** − **X2i***)\****β1i** + *σ*1*η\*(λ*1*i* − *λ*2*i)*.

*BH*2 =*E (y*2*i*|*Ai* =1*)* – *E (y*2*i*|*Ai* =0*)*

= *(***X1i** − **X2i***)\****β2i** + *σ*2*η\*(λ*1*i* − *λ*2*i)*.

Where If farm households actually adopted improved faba bean; if farm households did not actually adopt;

 : Net income if farm households were to adopt;

: Net income if farm households were to not adopt;

Table 2: Average Expected Net income (SP/ha); Treatment and Heterogeneity Effects

|  |  |  |
| --- | --- | --- |
|  | Decision Stage |  |
| Subsamples Effects | To Adopt | Not to Adopt | Treatment |
| Farm households that adopted | (a) | (c) | TT |
| Farm households that did not adopt | (d) | (b) | TU |
| Heterogeneity effects | BH1 | BH2 | TH |

Note: (a) and (b) represent the expected net income (SP/ha) of the typical adopter and the typical non-adopter respectively; (c) and (d) represent the counterfactual expected net incomes (SP/ha) of the typical adopter if they didn’t adopt and the typical non-adopter if instead they were to adopt respectively. The Stata software (Stata, 2009) was used for all econometric estimation in this study.

**5. Results and Discussions**

**5.1 Impacts of the new faba bean technologies on yield and food security**

The results show that adoption of improved varieties provide on the average 174.6 kg/ha (15%) yield gain for adopters. If non adopters were to adopt the improved varieties, they would have obtained 178.6kg/h higher yields. Showing comparable benefits to both adopters and non-adopters (Table 3).

Table 3: Treatment Effects on Yield (kg/ha) from Propensity Score Matching

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Group | Treatment group | Control group | Difference | S.E. | T-stat |
| Unmatched | 1407.2 | 1155.3 | 251.8 | 14.2 | 17.8a |
| ATT | 1355.8 | 1181.1 | 174.6 | 27.4 | 6.4a |
| ATU | 1161.7 | 1340.3 | 178.6 |  |  |
| ATE |  |  | 176.8 |  |  |

a and b show significance at 0.01 and 0.05 levels

As the main objective of this section is one of measuring the impacts of adoption of improved varieties, we will provide only a brief discussion of the regression estimates. Quantities of inputs (nitrogen and DAP fertilizers) are found to have positive and significant effects on yield for adopters. This finding is in line with others as many studies showed that phosphorus application increases grain yields and its components (El Kalla et al., 1999; Bolland et al., 2000). Although the faba bean can fi x N, it is often suggested to apply small amounts of fertilizer N at planting. The application of 20 kg N/ha at planting time has been shown to be beneficial for faba bean to enhance biological fixation (R’kiek, 1994). While DAP fertilizers has positive and significant effects on yield for non-adopters , nitrogen fertilizer has negative and significant effects on yield for non-adopters as they shows that non-adopters are using more nitrogen fertilizer than the recommended amount. Age (Years), number of years of education, faba bean area (Ha) also give higher yields. The use of certified seeds also leads to higher yields than uncertified seeds showing clear advantage to certified seeds (Table 4).

Estimates of treatment effects from ESR are provided in Table 5 below. The results show that adopters of improved varieties on the average obtain about 194.2 kg/ha (16.2%) more yield than the counterfactual (i.e., what they would have obtained if they had not adopted). Taking an average grain price of 7.31 MAD/kg and ignoring the cost implications of adoption of improved faba bean varieties, this yield gain would translate into a gain in gross revenue of 1,420 MAD/ha (US$165/ha)[[1]](#footnote-1). At the current average adoption level of 1.2 ha/family, each farm household obtains about 233 kg per year more yield and 1,703 MAD (US$197.6) per year.

Table 4: Full information maximum likelihood estimates of the endogenous switching regression model for yields (kg/ha)

| Independent Variables | Yield Equation for Adopter | Yield Equation for Non-Adopter | Adoption of improved faba bean (No=0,Yes=1) |
| --- | --- | --- | --- |
| Coef. | Std.Er | Coef. | Std.Er | Coef. | Std.Er |
| Age (Years) | 0.048 | 0.028\* | 0.011 | 0.010 | 2.059 | 1.145\* |
| Number of years of education | 0.054 | 0.020\*\*\* | 0.006 | 0.006 | 1.902 | 0.897\*\* |
| Number of family members working on own farm (Person days/ha) | 0.013 | 0.013 | 0.007 | 0.005 | -0.661 | 0.330\*\* |
| Get a credit from a bank {1=yes, 0=No} | -0.008 | 0.012 | 0.001 | 0.005 | 1.565 | 0.349\*\*\* |
| Off-farm employment {1=yes, 0=No} | -0.031 | 0.017\* | 0.008 | 0.007 | 0.323 | 1.260 |
| Faba bean area (Ha)  | 0.084 | 0.022\*\*\* | 0.001 | 0.008 | 3.518 | 1.225\*\*\* |
| Total cropped area (Ha) | -0.041 | 0.016\*\*\* | -0.014 | 0.009 | -0.714 | 0.866 |
| Walking distance from seed sources (km) | 0.012 | 0.007\* | 0.006 | 0.003\*\* | -0.304 | 0.304 |
| Was the seed you used certified? {1=yes, 0=No} | 0.009 | 0.001\*\*\* | 0.009 | 0.011 | 3.193 | 1.028\*\*\* |
| Price of seed | 0.574 | 0.141\*\*\* | -0.015 | 0.008\*\* | 0.842 | 0.465\* |
| Farm in favorable zone{1=yes, 0=No} | -0.041 | 0.024\* | 0.008 | 0.005 | 0.387 | 0.456 |
| Farm in intermediate zone {1=yes, 0=No} | -0.013 | 0.021 | 0.012 | 0.006\*\* | 0.878 | 0.592 |
| Are you active or leader in the community |  |  |  |  | 1.915 | 1.265 |
| Quantity of nitrogen fertilizer used (kg/ha) | 0.006 | 0.003\* | -0.006 | 0.002\*\*\* | 0.673 | 0.147\*\*\* |
| Quantity of DAP fertilizer used (kg/ha) | 0.031 | 0.017\* | 0.134 | 0.005\*\*\* | 1.611 | 1.211 |
| Amount of seed used(kg/ha) | -0.021 | 0.047 | 0.027 | 0.014\* | 3.962 | 1.508\*\*\* |
| Constant | 5.769 | 0.398\*\*\* | 6.305 | 0.081\*\*\* | -40.740 | 15.298\*\*\* |
| Log likelihood | 603.5 |  |  |  |  |  |
| Rho | -4.679 | 1.401\*\*\* | -3.728 | 1.163\*\*\* |  |  |
| sigma | -3.256 | 0.041\*\*\* | -3.256 | 0.041\*\*\* |  |  |

Table 5: Average Expected Treatment and Heterogeneity Effects on Yield (kg/ha) from Endogenous Switching Regression

|  |  |  |
| --- | --- | --- |
|  | Decision Stage |  |
| Subsamples Effects | To Adopt | Not to Adopt | Treatment |
| Farm households that adopted | (a) 1394.1 | (c) 1199.9 | 194.2\*\*\* |
| Farm households that did not adopt | (d) 1274.1 | (b) 1152.9 | 121.2\*\*\* |
| Heterogeneity effects | 120 | 47 | 73 |

Given that ESR is potent in correcting for biases both from observable and unobservable factors, the 1.2 % higher yield effects from ESR relative to PSM shows that unobservable factors such as skills of the farmers who have adopted the technology are important in explaining the differences in yield effects. In this particular case, the unobservable factors are leading to underestimation of the yield impacts which ESR was able to correct while PSM couldn’t.

**5.2 Impacts on faba bean income**

Estimates of the treatment effects on net margins from PSM are provided in Table 6 below. The results show that adoption of improved faba bean varieties provide on the average 707.6 MAD/ha (9%) higher net faba bean income for adopters. If non adopters were to adopt the improved varieties, they would have earned 719.7 MAD/ha more net income showing that the benefit to both adopters and non-adopters is almost the same. Given the average area under improved varieties per family of 1.2 ha, a typical adopter family currently earns 863.6 MAD of additional net faba bean income each year.

Table 6: Treatment Effects on Net Margins (SYP/ha) from Propensity Score Matching

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Group | Treatment group | Control group | Difference | S.E. | T-stat |
| Unmatched | 8998.5 | 7773.2 | 1225.4 | 107.2 | 11.43a |
| ATT | 8657.8 | 7950.2 | 707.6 | 213.5 | 3.31 a |
| ATU | 7793.6 | 8513.3 | 719.7 |  |  |
| ATE |  |  | 714.3 |  |  |

a and b show significance at 0.01 and 0.05 levels

The Estimates of the Endogenous Switching Regression (ESR) are provided in Table 7 below. Like the yield equation, DAP fertilizer has positive and significant effects on net margins while nitrogen fertilizer has negative and significant effects on net margins for non-adopters.

Table 8 presents the estimates of treatment effects from ESR. The results show that adoption of improved faba bean varieties provide on the average 932.8 MAD/ha (12%) higher net faba bean income for adopters. If non adopters were to adopt the improved varieties, they would have earned 559 MAD/ha more net income showing that the benefit to those who already adopted is higher, which may explain why they adopted while the others have not.

Table 7: Full information maximum likelihood estimates of the endogenous switching regression model for net income

| Independent Variables | net income Equation for Adopter | net income Equation for Non-Adopter | Adoption of improved faba bean (No=0,Yes=1) |
| --- | --- | --- | --- |
| Coef. | Std.Er | Coef. | Std.Er | Coef. | Std.Er |
| Age (Years) | 0.030 | 0.024 | 0.005 | 0.011 | 1.096 | 0.438\*\*\* |
| Number of years of education | 0.033 | 0.021 | 0.005 | 0.007 | 1.202 | 0.268\*\*\* |
| Number of family members working on own farm (Person days/ha) | 0.032 | 0.014\*\* | 0.007 | 0.006 | -0.676 | 0.302\*\*\* |
| Get a credit from a bank {1=yes, 0=No} | -0.024 | 0.014\* | 0.001 | 0.006 | 1.394 | 0.248\*\*\* |
| Off-farm employment {1=yes, 0=No} | -0.039 | 0.019\*\* | 0.011 | 0.008 | 0.417 | 0.343 |
| Faba bean area (Ha)  | 0.100 | 0.019\*\* | -0.004 | 0.009 | 2.885 | 0.403\*\*\* |
| Total cropped area (Ha) | -0.027 | 0.019 | -0.016 | 0.011 | -0.204 | 0.401 |
| Walking distance from seed sources (km) | 0.024 | 0.007\*\*\* | 0.008 | 0.004\*\* | -0.304 | 0.117\*\*\* |
| Was the seed you used certified? {1=yes, 0=No} | 0.022 | 0.013\* | -0.007 | 0.013 | 2.603 | 0.474\*\*\* |
| Price of seed | 0.826 | 0.117\*\*\* | -0.014 | 0.009 | 0.782 | 1.598 |
| Farm in favorable zone{1=yes, 0=No} | -0.032 | 0.022 | 0.006 | 0.006 | -0.061 | 0.363 |
| Farm in intermediate zone {1=yes, 0=No} | -0.009 | 0.017 | 0.012 | 0.007\* | 0.493 | 0.226\*\* |
| Are you active or leader in the community |  |  |  |  | 1.676 | 0.358 |
| Quantity of nitrogen fertilizer used (kg/ha) | 0.005 | 0.004 | -0.007 | 0.003\*\*\* | 0.696 | 0.086\*\*\* |
| Quantity of DAP fertilizer used (kg/ha) | 0.018 | 0.014 | 0.150 | 0.006\*\*\* | 1.916 | 0.227\*\*\* |
| Amount of seed used(kg/ha) | -0.087 | 0.057 | 0.035 | 0.017\*\* | 4.110 | 1.122\*\*\* |
| Constant | 7.469 | 0.381\*\*\* | 8.125 | 0.095\*\*\* | -38.282 | 7.422\*\*\* |
| Log likelihood | 569.4 |  |  |  |  |  |
| Rho | -5.409 | 1.634\*\*\* | -4.499 | 1.342\*\*\* |  |  |
| sigma | -2.998 | 0.086\*\*\* | -3.070 | 0.040\*\*\* |  |  |

Table 8: Average Expected Treatment and Heterogeneity Effects on Net Income (MAD/ha) from Endogenous Switching Regression

|  |  |  |
| --- | --- | --- |
|  | Decision Stage |  |
| Subsamples Effects | To Adopt | Not to Adopt | Treatment |
| Farm households that adopted | (a) 8955.3 | (c) 8022.5  | 932.8\*\*\* |
| Farm households that did not adopt | (d) 8266.8 | (b) 7707.9 | 558.9\*\*\* |
| Heterogeneity effects | 688.5 | 314.6 | 374 |

Given that ESR is potent in correcting for biases both from observable and unobservable factors, the 3% higher effects on net income from ESR relative to PSM shows that unobservable factors such as skills of the farmers who have adopted the technology are important in explaining the differences in net income effects

**5.3 Impacts on Consumption**

The results show that adoption of improved varieties of faba-beans provide 17.3 kg/capita/year (30%) gain in faba bean consumption for adopters (Table 9). If non adopters were to adopt the improved varieties, they would have consumed 13 kg/capita/year (19%) more faba bean showing that the benefit to those who already adopted is higher, which may provide part of the explanation for why a large number of farmers did not adopt the improved faba bean varieties.

Table 9: Treatment Effects on faba bean Consumption (kg/capita/year) from Propensity Score Matching

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Group | Treatment group | Control group | Difference | S.E. | T-stat |
| Unmatched | 77.6 | 56.7 | 20.9 | 2.3 | 8.9a |
| ATT | 75.1 | 57.8 | 17.3 | 4.9 | 3.5a |
| ATU | 56.1 | 69.01 | 13 |  |  |
| ATE |  |  | 14.9 |  |  |

a Shows significance at 0.01 level

The Estimates of the Endogenous Switching Regression (ESR) are provided in Table 10 below. Total faba bean area and Price of seed, farm in favorable zone, farm in intermediate zone, quantity of nitrogen fertilizer used (kg/ha) seem to have positive and significant effects on faba bean consumption among adopters only while get a credit from a bank, off-farm employment and Quantity of DAP fertilizer used (kg/ha) have positive and significant effects on faba bean consumption among non-adopters

Estimates of treatment effects from ESR are provided in Table 11 below. The results show that adopters of improved varieties on the average consume about 21.3 kg/capita/year (39%) more faba bean than the counterfactual (i.e., what they would have consumed if they had not adopted). If non adopters were to adopt the improved varieties, they would have consumed 15.6 kg/capita/year (35%) more faba bean showing that the benefit to those who already adopted is much higher – a possible explanation for why a large number of farmers did not adopt the improved faba bean varieties yet.

Table 10: Full information maximum likelihood estimates of the endogenous switching regression model for faba bean Consumption (kg/capita/year)

| Independent Variables | Yield Equation for Adopter | Yield Equation for Non-Adopter | Adoption of improved faba bean (No=0,Yes=1) |
| --- | --- | --- | --- |
| Coef. | Std.Er | Coef. | Std.Er | Coef. | Std.Er |
| Age (Years) | 0.091 | 0.139 | 0.004 | 0.050 | 1.565 | 0.7124\*\* |
| Number of years of education | -0.081 | 0.093 | -0.040 | 0.032 | 1.251 | 0.488\*\*\* |
| Number of family members working on own farm (Person days/ha) | 0.036 | 0.067 | 0.004 | 0.027 | -0.768 | 0.471\* |
| Get a credit from a bank {1=yes, 0=No} | 0.035 | 0.062 | 0.040 | 0.024\* | 0.159 | 0.3818616 |
| Off-farm employment {1=yes, 0=No} | 0.111 | 0.087 | 0.077 | 0.034\*\* | 0.610 | 0.5472955 |
| Faba bean area (Ha)  | 0.393 | 0.120\*\*\* | -0.050 | 0.039 | 4.144 | 1.280\*\*\* |
| Total cropped area (Ha) | -0.178 | 0.082\*\* | -0.040 | 0.046 | 0.444 | 0.939 |
| Walking distance from seed sources (km) | -0.047 | 0.037 | 0.017 | 0.015 | -0.248 | 0.216 |
| Was the seed you used certified? {1=yes, 0=No} | 0.105 | 0.065 | -0.045 | 0.059 | 2.073 | 0.707\*\*\* |
| Price of seed | 2.078 | 0.890\*\* | 0.034 | 0.039 | 0.583 | 0.620 |
| Farm in favorable zone{1=yes, 0=No} | 0.530 | 0.2152\*\*\* | 0.007 | 0.027 | 1.209 | 0.519\*\* |
| Farm in intermediate zone {1=yes, 0=No} | 0.569 | 0.203\*\*\* | -0.007 | 0.030 | 1.337 | 0.462\*\*\* |
| Are you active or leader in the community |  |  |  |  | 2.139 | 0.931\*\* |
| Quantity of nitrogen fertilizer used (kg/ha) | 0.055 | 0.020\*\*\* | 0.000 | 0.012 | 0.254 | 0.106\*\*\* |
| Quantity of DAP fertilizer used (kg/ha) | -0.114 | 0.145 | 0.203 | 0.025\*\*\* | 1.148 | 0.606\*\* |
| Amount of seed used(kg/ha) | 0.110 | 0.237 | 0.013 | 0.072 | 2.088 | 1.289\* |
| Constant | -0.872 | 2.240 | 2.998 | 0.408\*\*\* | -29.880 | 8.814\*\*\* |
| Log likelihood | 63.620 |  |  |  |  |  |
| Rho | 5.763 | 2.036\*\*\* | -1.356 | 0.210\*\*\* |  |  |
| sigma | -1.547 | 0.096\*\*\* | -1.638 | 0.041\*\*\* |  |  |

Table 11: Average Expected Treatment and Heterogeneity Effects on faba bean Consumption (kg/capita/year) from Endogenous Switching Regression

|  |  |  |
| --- | --- | --- |
|  | Decision Stage |  |
| Subsamples Effects | To Adopt | Not to Adopt | Treatment |
| Farm households that adopted | (a) 75.9 | (c) 54.6  | 21.3\*\*\* |
| Farm households that did not adopt | (d) 60.3 | (b) 44.7 | 15.6\*\*\* |
| Heterogeneity effects | 15.6 | 2.39.9 | 5.7 |

Given that ESR is potent in correcting for biases both from observable and unobservable factors, the 9% higher consumption effects from ESR relative to PSM shows that unobservable factors are important in explaining the differences in consumption effects. In the case of consumption, the unobservable factors are leading to underestimation of the yield impacts which PSM failed to correct for while ESR did.

* 1. **Potential national impacts**

Assuming that on the average, the adoption levels and yield impacts in the other faba bean growing areas that are not covered by the survey are also the same, Morocco has been producing a total of 19116 tons more faba bean due to the adoption of improved varieties.

Likewise, the total net income gain due to a 23% adoption of improved varieties.. Morocco is earning a net faba bean income gain of about 2.63 billion MD or US$0.27 billion per year.

If adoption of improved varieties were to increase to higher levels, Morocco would benefit all the more (Table 12).

Table 12: Potential impacts of improved faba bean varieties with different levels of assumed Adoption levels

|  |  |
| --- | --- |
| Assumed adoption level | Realized/Potential gain |
| Production (tons) | Net Income (billion MAD) | Net Income (billion US$) |
| Current level (23%) | 19,116 | 2.63 | 0.27 |
| 50% | 41,557 | 5.68 | 0.58 |
| 60% | 49,868 | 6.82 | 0.69 |
| 70% | 58,180 | 7.96 | 0.81 |
| 80% | 66,491 | 9.09 | 0.92 |
| 90% | 74,802 | 10.23 | 1.04 |
| 100% | 83,114 | 11.37 | 1.15 |

**5.5. Impact of wheat –faba bean rotation on the wheat yield, net income and total income.**

Our results showed that 26% higher yields were obtained by wheat farmers rotating with faba-beans than cereal-cereal and other rotations. Wheat-faba bean rotations also increased wheat net return by 38% (Table 13). The results also show that the combined effect of the adoption of improved varieties of faba beans and rotations is an increase in total farm income of 33%.

Table 13: Impact of baba bean –wheat rotation on wheat yield and net farm income

|  |  |  |  |
| --- | --- | --- | --- |
| Planted after Faba-beans | Variety of faba-bean | Wheat yield (kg/ha) | Net income |
| No | NA | 739.2 | 1844.4 |
| Yes  | Local | 849.1 | 2391.5 |
| Yes  | Improved | 1221.5 | 3454.8 |
| Yes  | Any (regardless of variety) | 1040.3 | 2937.7 |

**6. Conclusion**

This study found that only 3 out of 13 faba bean varieties in farmers’ hands were improved varieties covering only 23% of total faba beans area. Farmers reported that only 17% of total faba bean seeds used was certified originating from seed companies while the remaining 83% was uncertified - 63% kept from previous harvest and 20% bought from local seed retailers.

The adoption of improved faba bean varieties leads to 194.2 kg/ha (16.2%) increase in yields, US$.1108.2/ha (12%) higher net returns and 21.3 kg/capita/year (39%) increase in faba bean consumption and hence equivalent gains in protein, carbohydrate and starch intakes for every household member of the adopter households. All these results show that the improved varieties of faba-beans are contributing to livelihoods improvements and nutrition security at household level. Moreover, 26% higher yields were obtained by wheat farmers rotating with faba-beans than cereal-cereal and other rotations.

Wheat-faba bean rotations also increased wheat net returns by 38%. At the same time the results show that the combined effect of the adoption of improved varieties of faba beans and rotations is an increase in total farm income of 33%. At current adoption level of 23%, improved varieties of faba beans led to additional production of about 19.1 thousand tons per year (16.5%). All these results show that along with the soil health benefits and hence the sustainability of farming documented elsewhere, legume-cereal rotation can be justified on economic grounds with clear contribution to national food and nutrition security. The main lessons drawn from these findings are that: 1) there is an urgent need for more research to develop new improved varieties and 2) there is a need to strengthen the extension service and certified seed delivery systems to enhance the adoption of improved varieties and develop farmers’ awareness and appreciation towards legume-cereal rotation. These findings point to the need for policy and extension intervention to enhance diversification among smallholders and reverse the current trend of increasing monoculture in the wheat-based production systems of Morocco.

**Acknowledgements:** Funding for this research was obtained from CRP-WHEAT and the EU-IFAD project on Enhanced small holder wheat cropping systems to improve food security under changing climate in the drylands of West Asia and North Africa.

**References**

Ali, A. and A. Abdulai, 2010. The adoption of genetically modified cotton and poverty reduction in Pakistan. *Journal of Agricultural Economics*, 61 (1): 175 -192.

Amanuel, G., R.F. kuhne, Tanner, D. G. and P.L.G. Vlek, 2000. Biological nitrogen fixation in faba bean (Vicia faba L.) in the Ethiopian highlands as affected by P fertilization and inoculation. *Biol. Fertil. Soils,* vol. 32: 353-359.

Becker, M., and D. Johnson, 1998. The role of legumes fallow in intensiﬁed upland rice-based cropping systems in West Africa. *Nutrient Cycling in Agroecosystems*, vol. 53(1):71–81.

Bolland, M. D. A., K. H. M. Siddique, and R. F. Brennan, 2000. Grain yield responses of faba bean (Vicia faba L.) to applications of fertilizer phosphorus and zinc. *Australian Journal of Experimental Agriculture*, 40: 849–857.

Daheja, R. and S. Wabha, 2002. Propensity score matching methods for non-experimental causal studies. *Review of Economics and Statistics*, 84(1):151-161.

Di Falco, S., M. Veronesi, M. Yesuf, 2011. Does adaptation to climate change provide food security? A micro-perspective from Ethiopia. *American Journal of Agricultural Economics*, 93 (3): 829–846.

Caliendo, M. and S. Kopeinig, 2008. Some practical guidance for the implementation of propensity score matching. IZA Discussion Paper No. 1588, University of Cologne.

Cerning J., A. Saposnik, A. Guilbot, 1975. Carbohydrate composition of horse beans (*Vicia faba*) of different origins. *Cereal Chem*, Vol. 52:125–138.

Crepona K., P. Marget, C. Peyronnet, B. Carrouéea, P. Arese, G Duc, 2010. Nutritional value of faba bean (*Vicia faba* L.) seeds for feed and food. *Field Crop Res*, vol. 115:329–339

El Kalla, S. E., A. K. Mostafa, A. A. Leilah, and A. A. Rokia, 1999. Mineral and bio-phosphatic fertilization for intercropped faba bean and onion. *Egyptian Journal of Agricultural Research*, vol. 77: 253–271.

Greene, W. H., 1998. Limdep: User’s Manual. Bellport, NY: Econometric Software Inc.

Habtemichial, K.H, B.R. Singh, J.B. Aune, 2007. Wheat response to N2 fixed by faba bean (Vicia faba L.) as affected by sulfur fertilization and rhizobial inoculation in semi-arid Northern Ethiopia, *J Plant Nutr Soil Sci*, vol. 170:412–418.

Heckman, J.J., 1979. Sample Selection bias as a error specification bias. *Econometrica,* 47(1): 153-161.

Heckman, J., H. Ichimura, and T. Petra, 1998. Matching as an econometric evaluation estimator. *Review of Economic Studies*, vol. 65: 261-294.

Lawson, Y. D., I. Dzomeku, and Y. Drisah., 2007. Time of planting Mucuna and Canavalia in an intercrop system with maize. *Journal of Agronomy*, vol. 6:534–540.

Jemo M., R.C. Abaido, C. Nolte, M. Tchienkoua, N. Sanginga, W.J, Horst, 2006. Phosphorus benefits from grain legume crops to subsequent maize grown on acid soils of southern Cameroon. Plant Soil 284:385–397

Jensen E. S., M.B. Peoples, H. Hauggaard-Nielsen, 2010. Faba bean in cropping systems. *Field Crops Res* vol. 115:203–216.

Kirkegaard J., O. Christen, J. Krupinsky, D. Layzell, 2008. Break crop benefits in temperate wheat production. *Field Crops Res,* vol. 107:185–195.

Lee, M., 2005. Micro-econometrics for policy, program and treatment effects. Advanced Texts in Econometrics. Oxford University Press.

Lee, W. S., 2013. Propensity score matching and variations on the balancing test. *Empirical Economics*, 44, 47-80.

Lopez-Bellido, L., R.J. Lopez-Bellido, R. Redondo, J. Benitez, 2006. Faba bean nitrogen fixation in a wheat-based rotation under rain fed Mediterranean conditions: effect of tillage system, *Field Crops Res,* vol. 98:253–260.

Maddala, G.S. and F.D. Nelson, 1975. Switching regression models with exogenous and endogenous switching. *Proceeding of the American Statistical Association* *(Business and Economics Section)*, 423-426.

Marschner P, R.G. Joergensen, H.P. Piepho, A, Buerkert, 2004. Legume rotation effects on early growth and rhizosphere microbiology of sorghum in West African Soils. *Plant Soil* vol. 264:325–334.

Nguezet, P.M.D., A. Diagne, V.O. Okoruwa, V. Ojehomon, 2011. Impact of Improved Rice Technology (NERICA varieties) on Income and Poverty among Rice Farming Households in Nigeria: A Local Average Treatment Effect (LATE) Approach. *Quarterly Journal of International Agriculture*, vol. 50: 267-291.

Nuruzzaman M, H. Lambers, M.D.A. Bolland, E.J. Veneklaas, 2005. Phosphorus benefits of different legume crops to subsequent wheat grown in different soils of Western Australia. *Plant Soil*, vol. 271:175–187

Oomah B., N. Tiger, M. Olson, 2006. Balasubramanian P. Phenolics and antioxidatives activities in narrow-leafed lupins (*Lupinus angustifolius* L.) *Plant Food Hum. Nutr*. Vol. 61:91–97. [[PubMed](http://www.ncbi.nlm.nih.gov/pubmed/16804740)].

Peoples, M.B., J. Brockwell, D.F. Herridge, I.J. Rochester, B.J.R. Alves, S. Urquiaga, R.M. Boddey, F.D. Dakora, S. Bhattarai, S.L. Maskey, C. Sampet, B. Rerkasem, D.F. Khan, H. Nielsen, E.S. Jensen, 2009. The contributions of nitrogen-fixing legumes to the productivity of agricultural systems, *Symbiosis,* vol*.* 48, 1–17.

Picard, J., 1977. Some results dealing with breeding protein content in *Vicia faba* L. Protein quality from leguminous crops; EVR 5686 EN, Commission of European Communities, Coordination of Agricultural Research, pp. 339.

Preissel, S., M. Reckling, N. Schläfke, P. Zander, 2015. Magnitude and farm-economic value of grain legume pre-crop benefits in Europe: A review. *Field Crops Research*, vol. 175: 64 – 79.

Pypers P, M. Huybrighs, J. Diels, R. Abaidoo, E. Smolders, R. Merckx, 2007. Does the enhanced P acquisition by maize following legumes in a rotation result from improved soil P availability? *Soil Biol Biochem*, vol. 39:2555–2566.

Reddy, K. C., A. Soffes, G. Prine, and R. Dunn, 1986. Tropical legumes for green manures. II. Nematode populations and their effects on succeeding crop yields. *Agronomy Journal*, vol. 78(1):5–10.

R’Kiek, C., 1994. Synthèse des travaux de recherche. Edts INRA, 10 p.

Rosenbaum, P. R., 2002. Observational Studies. 2nd ed. Springer-Verlag, New York.

Rosenbaum, P. R. and D. B. Rubin, 1985. Constructing a control group using multivariate matched sampling methods that incorporate the propensity score. *The American Statistician*, 39(1): 35-39.

Rosenbaum, P. R. and D. B. Rubin, 1983. The central role of the propensity score in observational studies for causal effects. *Biometrica*, vol. 70: 41-55.

Rubin, D., 1974. Estimating Causal Effects of Treatments in Randomized and Non-randomized Studies, *Journal of Educational Psychology*, vol. 66: 688-701.

Rubin, D. B. and N. Thomas, 2000. Combining propensity score matching with additional adjustments for prognostic covariates. *Journal of the American Statistical Association*, vol. 95: 573–585.

Schilizzi, S. and D.J. Pannell, 2001. The economics of nitrogen fixation. *Agronomie*, vol. 21(6-7): 527-537.

Shiferaw, B., M. Kassie, M. Jaleta, C. Yirga, 2014. Adoption of improved wheat varieties and impacts on household food security in Ethiopia. *Food Policy*, vol. 44: 272-284.

Sianesi, B., 2004. An evaluation of the active labor market programs in Sweden. *The Review of Economics and Statistics*, 186(1), 133-155.

Smith, J. and P. Todd, 2005. Does Matching Overcome Lalonde’s Critique of Nonexperimental Estimators? *Journal of Econometrics*, vol. 125:305-353.

StataCorp, 2009. Stata Statistical Software: Release 11. College Station, TX: StataCorp LP.

Tarawali, G., V. Manyong, R. Carsky, P. Vissoh, P. Osei-Bonsu, and M. Galiba, 1999. Adoption of improved fallows in West Africa: lessons from mucuna and stylo case studies. *Agroforestry Systems*, 47(1–3):93–122.

World Bank, 2012. Food price watch, poverty reduction and equity group. Washington, D.C. World Bank, August. <http://siteresources.worldbank.org/EXTPOVERTY/Resources/336991-1311966520397/Food-PriceWatch-August-2012.pdf>

Yusuf, A. A., E.N.O. Iwuafor, R.C. Abaidoo, O.O. Olufajo, N. Sanginga, 2009. Grain legume rotation benefits to maize in the northern Guinea savanna of Nigeria: fixed-nitrogen versus other rotation effects. Nutr Cycl Agroecosyst 84:129–239.

Zain El Abidine, F., S. Bouazza, and Fouad, A. Andaloussi, 2006. Amélioration génétique de la fève et féverole In La création variétale à l’INRA : Méthodologie, acquis et perspectives. F. Abbad Andaloussi et A. Chahbar editors, Pp 141-160, INRA, Rabat, Morocco.

1. The exchange rate in 2012 was: 1US$= 8.62 Moroccan Dirhams (DH) [↑](#footnote-ref-1)