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Determinants of Biofortified Beans Adoption in Nyagatare District, Eastern Province of Rwanda

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Abstract: **Agriculture sustains the livelihoods of about 80% of Rwandans. Large improvements in the productivity of staple crops have been taken into consideration in Rwanda. Biofortified bean varieties as improved bean varieties have been disseminated and marketed in Rwanda since 21012 by RAB in partnership with Harvest Plus through different channels and systems like seed back, agro-dealers, direct marketing, ... Those beans have high content of Iron and proteins thus they have high price on Rwandan market. As improved varieties, their growers can realize high yield more than 2 Mt Ha^{-1}. However in general perspective the average bean yields in the country have been disappointing, the survey results of 2013 of NISR indicate 731 Kg ha^{-1} for bush bean but as pertains to biofertified beans so far no study done to indicate wheather these adopted biofortified bean varities have increased yield per ha. But the major challenge behind this has been the adoption of the biofertified beans by small holder farmers.This is why the study is initiated with the objective to investigate factors influencing farmers to the adoption of biofortified beans. The method used is stratified survey with 197 respondents selected by multi stage random sampling and cluster sampling. Thereafter qualitative and quantitative methods of data collection have been used to gather the data. Data have been analyzed using Probit model and descriptive analysis have been used to analyze data from the field. The results showed that, farmers' group membership and bean farm size cultivated influenced adoption of biofortified beans. Farmers' membership has negative influence on biofortified beans adoption while total bean areas cultivated showed positive influence on biofortified bean adoption with P<0.001 at 5% significant level. The research recommends policy makers to put more emphasis in land consolidation policy as the major driver to increase the adoption of biofortified beans.**

Keywords: **Biofortified bean varieties, Adoption, Probit model.**

1. INTRODUCTION

Common bean *(Phaseolus vulgaris L.)* is the world's most important food legume for direct human consumption. Average per capita consumption of common bean in the main bean production areas is higher in Africa, estimated at 31.4kg/year (Schoonhoven and Voysest, 1991). High in nutrients and commercial potential, common bean holds great promise for fighting hunger, increasing income and improving soil fertility in Sub Saharan Africa. The crop occupies more than 3.5 million hectares in sub-Saharan, accounting for about 25% of the global production but production is concentrated in the densely populated areas of East Africa, the lakes region and the highlands of southern Africa (http://webapp.ciat.cgiar.org/ciatinfocus).

Common bean is an important subsistence crop for smallholding farmers in Rwanda. It is often referred to as the meat of the poor because of its high protein content and affordability. Beans are also vital sources of micronutrients such as iron, reducing iron deficiency caused by the lack of diversity in the starch-based diets of the poor. Rwanda has one of the highest per capita bean consumption in the world (Kalyebara and Buruchara, 2008), confirming that bean is a key crop for food security. Beans provide 32 and 65 percent of calories and protein intake in the Rwandan diet, whereas protein sourced from animal provides only 4 percent of the protein intake (Asare-Marfo, et al., 2011, CIAT, 2004).

Previous studies have found that nearly all rural households in Rwanda cultivate beans (Asare-Marfo, et al., 2011, Larochelle, et al., 2013). Beans are grown twice a year in many farming systems.

Beans are mainly grown by small scale farmers with a very minimum input use except seed. Despite a slight increasing yield trend, beans productivity and yield levels at the farm level have remained relatively low and even decreasing in some areas (FAO, 2005). This contributes to lower bean availability and accessibility to the majority of households. Farmers are increasingly interested in improved bean varieties which respond to their priority needs to increase productivity (i.e. drought and disease/pest tolerance) and also with good marketability, good cooking/eating qualities. One way to address this situation is to carry out participatory bean breeding with farmers, facilitate them to identify their preferred varieties and ultimately access seeds of these varieties.

The production of bean can be affected by land size allocated to bean production, production assets, group membership and type of seed variety planted significantly influence output; while cost of transport, quantity consumed at home, quantity stored for food, market price and storage losses influence marketable supply. Improved bean production will go a long way in solving the problems of solving food security, poverty, malnutrition as well as increase revenue generation and employment. Improved accessibility of markets is critical for increased rural incomes in smallholder farming.

The analysis of constraints hindering use of improved varieties with stakeholders revealed that the main constraint to adoption of bean improved varieties was associated with limited accessibility to seed (PABRA, 2005).

With aim of food security, fighting against hidden hunger in Rwandan society, increasing bean production and improving small holder's farmers, biofortified beans varieties have been disseminated in the country.

Since 21012, the collaboration between the government funded research program at Rwanda Agriculture Board (RAB), international partners such as International Center for Tropical Agriculture (CIAT) and Harvest Plus, has disseminated ten biofortified beans varieties which are biofortified varieties as improved bean varieties which have 40% more iron than typical bean, through developed effective distribution channels that promoted like direct marketing, Agro-dealers, seed swap, pay back and Cooperatives in different regions of Rwanda.

To enhance production of biofortified beans and earning income, the farmers should within their existing land holdings, expand proportion of land under bean production, adoption of best practices and using improved inputs, and actively participate in farmer group's activities for easier access to inputs and markets.

This research has assessed the factors influencing the adoption of biofortified bean varieties in Nyagatare district of eastern province in Rwanda which used to grow bush bean.

2. METHODOLOGY

2.1 Study Area:

This research was conducted in eastern province of Rwanda in Nyagatare District in four sectors: Karangazi, Katabagemu, Mimuli, Nyagatare and Rukomo. Nyagatare district grows bush bean.

2.2 Description of the study area:

Nyagatare district is the largest and second most populated district in Rwanda. It is located in Eastern Province. Nyagatare occupies the northeastern extremity of Rwanda bordering Uganda in the North, Tanzania in the East, Gatsibo District in the South, and Gicumbi District of the Northern Province in the West. See the map of this district on figure 1 below. Nyagatare has an area of 1741 km^2, what makes it the largest district in Rwanda. With a population of 466,944 in 2012, Nyagatare is the second most populated district of Rwanda only after Gasabo District of Kigali City with 530,907 inhabitants. This is an 83% increase from 2002 since the population was only 255,104. This sharp rises in the population is due to the major movement of the population from other parts of the country in search of land.

The District of Nyagatare is characterized, in general, by lowly inclined hills separated by dry valleys for a long period of the year (June – October). The District is located in the granite low valley whose altitude is 1513.5m. This kind of topographical layout constitutes an important potentiality for modern and mechanized agriculture.

Following the government policy in place, and following the agro ecological conditions, beans and maize, have been chosen as priority crops to be grown in Nyagatare, since 2007 (CIP, 2007)

Also the agriculture polices in Rwanda taking in place is to shift from subsistence agriculture to commercial agriculture. The reason why the government prioritized the use of improved varieties, maximizing the use of inputs so that to get the high yield possible. The biofortified beans varieties as improved bean varieties rich in iron and protein are disseminated for the purpose of getting high yield and fighting against malnutrition.

The biofortified bean disseminated and grown in Nyagatare is the variety named RWR 2245. It is bush bean, grown in low and medium altitude zones, the potential yield of 2.5Mt/ha, resistant to pests and diseases, flooding and drought tolerant (RAB, bean information guide 2012). The reason why RAB in partnership with Harvest Plus have made possible effort in disseminating this variety this district (New times article, October 11, 2014)

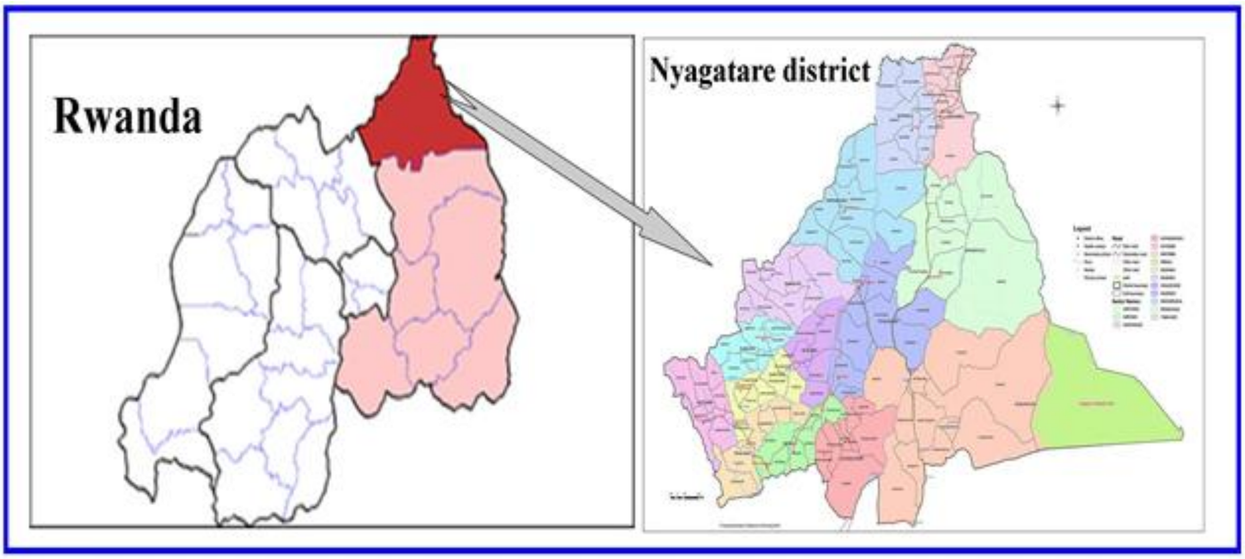

Figure 1: Nyagatare district map

2.3 Data collection:

Primary data have been collected through personal and face-to-face interview using the questionnaires. Totally, 197 randomly selected household heads have been covered under the survey. The targeted groups were: farmer cooperatives growing biofortified beans working with RAB and HarvestPlus or not and individual farmers working with/not with RAB or Harvest Plus in the same areas with those cooperatives growing beans. Four cropping seasons have been considered in data collection: 2014B, 2015A, 2015B and 2016A. Cropping season **A** in Rwanda, starts in September and take an end in January of the following year and **B** starts from February to ends in June of the same year.

The interview schedule was first tested at the farm level on 10 randomly selected farm households. Pre-test enabled to know whether farmers will clearly understand the interview schedule. As a result, some unnecessary questions have been deleted but those found important have been incorporated in the final version of the interview schedule (questionnaire).

2.4 Empirical models:

Accordingly, bean farmers who were not growing biofortified bean variety (RWR 2245) in 2016 A agricultural season (started in September 2015 and ending up in January 2016), were considered as non adopters, while farmers who were growing RWR 2245 were considered as adopters.

The adoption status choice was studied through a binary choice model where it is assumed that the decision of the i^{th} farmer to adopt or not depends on an unobservable variable Ii that is determined by more than one explanatory variable, represented by Xi.

The main models commonly used to analyze factors influencing such binary dependent variables include the Logit and the Probit model (Gujarat and Porter, 2009). Both models are estimated by maximum likelihood and the only difference between the two is that the Logit model assumes a logistic distribution while the Probit assumes the cumulative normal function. The analysis has employed Probit binary.

The regression model has illustrated as follows; Ii=β1+β2Xi…………………………………………….

Where Xi represents a set of independent variables influencing the decision of ith farmer. The unobservable variable Ii is related to the actual decision to adopt Y=1 if the farmer adopter and Y=0 otherwise, such that assuming that the unobservable variable Ii is normally distributed with the similar mean and variance, the probability that the farmer will decide to make any of the above decision can be expressed as:

Pi=P(Y=1/X)=P(Zi≤β1+β2i) F(β1+β2Xi)

Where P(Y = 1/ X) is the probability that a farmer will adopt given the values of the explanatory variables and Zi is the standard normal variable. F is the standard normal cumulative distribution function, while β1 is the constant term and β2 is the coefficient to be estimated.

If X represent a vector of determinants of the farmer's decision then the basic form of binomial Probit model with I as the predictor variable is reduced to;

Y= βo+βiX1+β2X2...........βjXj+Ɛ………………..

Where βo is the constant term….βj and β1 are the coefficients to be estimated, Ɛ is the error term and X1 and Xj are the explanatory variables.

Thus, the function has been expressed generally as:

Y = f (Marital status of respondent, Household size, Sex of household head, Education of respondent, Age of respondent, human capital investments , group membership, gender, experience, farm size, distance to market, , and acceptance behavior of the farmer to the variety)

3. RESULTS AND DISCUSSION

3.1 Statistical Description of the Socio-economic Characteristics of Sample households:

3.1.1 Household personal and demographic characteristics:

Characteristics like age, gender, family size and education level of the household heads are very important proxy indicators for individual behaviors and are commonly used as explanatory variables for adoption decisions. This section deals with these variables.

The selected sample consisted of 197 of which 107 (54.31%) have been adopted the cultivation of biofortified beans and 90(45.69%) non-adopters as it is described in table 1 below.

Table 1: Adoption of biofortified beans in sampled farmers

Full		**Adopters**		**Non-adopters**	
No	**%**	**No**	**%**	**No**	**%**
197	**100**	107	54.31	90	45.69

The sampled people were all farmers and household heads. Among adopters group, 53(58.1%) were male and 53(51.0%) were female. While in non-adopters group 39(41.9%) were male and 54(49.0%) were female. The analysis has shown that there was no statistical significant difference (P =0.318) between gender in adopting the biofortified beans. Meaning that to be a man or woman has no influence to the decision to adopt or not. Among the interviewed farmers 13 were single, 140 were married and 44 were widowed. 13 single were adopters, 140 married; 85 (60.7%) were adopters and 55 (39.3%) were not, among 44 widowed; 9(20.4%) were adopters and 35(79.6%) were not. It is seen that the marital status has influenced the adoption of biofortified beans at confident level of 95% with P<0.001.

As it is described in table 2b below, the mean age of all the sampled farmers was 39.03 years, with the mean age for adopters and non-adopters farmers being 36.72 and 41.77 years respectively. It is thus evident that adopters' farmers had a higher prime age than non-adopters farmers. Similarly, t-tests were significant at 5% level, which revealed that adopters' farmers had a significantly lower mean age than non-adopters farmers.

It was observed that the mean total household size was 4.82 members, where 4.47 and 5.24 members of adopters and non adopters groups respectively at P<0.001 with statistical difference among groups at 5% of level. In the HH size, the mean members under 16 years old were 1.6 and 1.6 in adopters and non adopters group respectively with no statistical significant difference (P=0.4898). The mean of members between 16 and 65 years old were 3.6 and 3.0 in adopters and non adopters group respectively with statistical significant difference (P=0.0014). As it is presented in table 2b, there was no member above 65 years in HHs members in sampled farmers.

The results further showed that majority of the sampled farmers acquired only 6 years of formal education. The mean age for adopters group were 7 years while for non-adopters group were 5 years of school. Those ages have been recorded considering the total number of years in school from first year of primary. The results showed a significant difference with P= 0.001 at 95% degree of confidence. See the table 2b above.

Table 2a: Household personal and demographic Characteristics of Adopters and non-adopters (summary statistics variables)

Variable	Category	Total		Adopters		Non-adopters		t- test P-value
		No	%	No	%	No	%	
Household gender	Male	93	47.2	54	58.1	39	41.9	0.9966 0.318
	Female	104	52.8	53	51	51.0	49.0	
Household Martial status	Single	13	6.6	13	100.0	0	0.0	6.1584 <0.001*
	Married	140	71.07	85	60.7	55	39.3	
	Widowed	44	22.33	9	20.4	35	79.6	

*, significant at 95%

Table 3 b: Household personal and demographic Characteristics of Adopters and non-adopters (summary statistics variables)

Variable	Unit	Full		Adopters		Non-adopters		t-value P-value
		Mean	SD	Mean	SD	Mean	SD	
Household age	Years	39.03	8.32	36.72	8.14	41.77	7.719	4.4384 <0.001*
Household education	Years	6.52	2.84	7.16	2.43	5.75	3.11	-3.5736 0.0002*
Family Size	Number	4.82	1.90	4.47	2.00	5.24	1.70	2.8677 0.0023*
Household under 16	Number	1.62	1.08	1.62	1.25	1.62	0.82	-0.0023 0.4898
Household between 16-65	Number	3.28	1.44	3.00	1.41	3.62	1.40	3.0372 0.0014*
Household above 65	Number	0	0	0	0	0	0	

*, significant at 95%

3.1.2 Farm characteristics:

Total land holding and Total bean areas:

The results in Table 3 presented, the mean of land holding were 0.84 ha and 2.59 ha for non adopters and adopters respectively. It was statistically significant at 5% of level with P=0.0006, which means that the bigger the land, the more the adoption of growing biofortified beans increases. The mean total bean size were 1.19 ha and 4.03 ha for non adopters and adopters respectively. The total bean farm size become bigger than the total land holds because some farmers borrow some land to grow beans. Also the mean total bean areas showed significant statistical difference at 5% of level with P<0.001, which means that the means for bean areas of Adopters group were greater than non adopters significantly.

Livestock:

As it is described in table 3 below, the mean of livestock were 9.18 and 5.58 of adopters and non –adopters respectively. It is statistically significant of P=0.0139 at 5% of level. Livestock means, the source of income and farm yard manure to use in growing crops including beans. This significance means, the more livestock is big the more adoption increases.

Table 4: farm characteristics of biofortified beans adopters and non-adopters (summary statistics variables)

Variable	Unit	Full		Adopters		Non-adopters		t-test P-value
		Mean	SD	Mean	SD	Mean	SD	
Livestock	Number	7.54	11.46	9.18	12.43	5.58	9.90	-8.7342 0.0139*
Land holding	Hectare	1.79	3.77	2.59	4.39	0.84	2.58	-3.3127 0.0006*
Total land bean areas	Hectare	2.73	3.78	4.03	4.51	1.19	1.67	-5.6502 <0.001*

*, significant at 5% of level

3.1.3. Institutional factors:

Farmers' group membership:

It was found that 90 (97.8%) adopters were member of farmers group (cooperative) and 17 (16.2%) were not in farmers group while 2 (2.2%) non adopters were in cooperative and 88 (83.8%) were no in cooperatives with a strong statistical significant of P<0.001 at 95%. As it is described in table 2a, it is thus evident that to participate in farmers group has influenced the decision to adopt to grow biofortified beans. Meaning that farmers group help farmers to gain information and extension services easily see the table 5 below.

The distance between household resident and the nearest market:

The results in Table 5 present findings and, the mean distance to the nearest market by walking were 51 minutes for both adopters and non-adopters. They were no statistical significant difference between the two groups as the sample design was to consider the neighboring adopters and non adopters. The analysis showed P=1.000 at 5% of level.

Extension services:

The Extension services have been measured by counting different training on bean value chain gained by farmers. The results shows that the mean of training gained were 2.47 and 0.12 by adopters and non-adopters respectively. It was also statistical significant difference with P<0.001 at 5% of level.

Table 5: Institution characteristics of biofortified beans adopters and non-adopters

Variable	Unit	Full		Adopters		Non-adopters		P-value
		Mean	SD	Mean	SD	Mean	SD	
Extension services (trainings)	No	1.40	2.22	2.47	2.47	0.12	0.70	<0.001*
Distance to the nearest market	Minutes	51.77	34.89	51.77	36.37	51.77	33.26	0.0004 0.4998
Variable	**Category**	**Total**		**Adopters**		**Non-adopters**		**t- test P-value**
		No	**%**	**No**	**%**	**No**	**%**	
Farmers group membership	Yes	92	46.7	90	97.8	2	2.2	19.8308 <0.001*
	No	105	53.3	17	16.2	88	83.8	

3.2 Effect of factors influencing adoption of biofortified beans:

As it is described in the table 6, the analysis of Probit model of significant factors influencing biofortified bean adoption among adopters and non adopter only, family members hold between 16 and 65 of years old, farmers group membership, extension serves measured by trainings gained by bean farmers, total land bean size and total land holding are significant with P values 0.0015, <0.001, 0.0354, 0.0032 and 0.0202 respectively at 5% of level on adoption of biofortified beans. Farmers' membership has negative influence on adoption of biofortified beans. It means that, as far as farmers are not in farmers' group, the adoption decreases and vice-versa. Also considering the government policy in place, in many rural areas of Rwanda, farmers are sensitized to be organized through in which, different agriculture information are given to the farmers. (CIP, 2007)

The total land holding size influences adoption and it has negative influence on adoption of biofortified bean variety in Nyagatare district which due to that the policy in place regarding to land consolidation and growing one chosen crop (CIP, 2007).

The findings also implies that extension service as a source of information regarding biofortified beans has a positive influence on the farmers' adoption decision as Alene et al. (2000) stated that extension services are among the prime movers of the agricultural sector and have been considered as a major means of technology dissemination.

These figures show that the difference in livestock ownership between adopters and non-adopters was statistically significant which imply that having large number of livestock is correlated with adopting biofortified bean in Nyagatare district. Similar results were reported by Mulugeta (2009) that livestock ownership affects farmers in adopting old coffee stumping technology in dale woreda, Ethiopia. This implies that possession of large number of livestock served as a proxy for the capacity of bearing risks in using credit. Livestock may also serve as a proxy for oxen ownership, which could be important for farm operations of small holder farmers.

Total land holding has positive influence on biofortified beans which means as far as you hold a big land, the adoption of biofortified beans increases. This confirms the output from the government policy in place on land consolidation and cultivates one chosen crop (CIP, 2007)

Table 6: Maximum Likelihood estimates for factors affecting biofortified beans adoption

Variables	Coef.	Std. Err.	P>|z|
Household gender	1.5937	0.7372	0.1306
Household age	0.0301	0.0259	0.2438
Marital status	0.1876	0.3007	0.5328
Family size	0.4238	0.2475	0.0869
Family members 16-65 age	-1.0719	0.3369	0.0015*
Farmers' group membership	-0.7616	0.1889	0.001*
Extension serves (trainings)	1.8654	0.4913	<0.0001*
Education ages	-0.1103	0.0752	0.1425
Total livestock	-0.0579	0.0275	0.0354*
Distance to the nearest market	0.0031	0.0062	0.6229
Total land holding	-0.5495	0.1865	0.0032*
Total bean size	0.6584	0.2835	0.0202*
Probit regression Number of observation: 197	Log likelihood = -20.93534 Wald chi2(12) = 44.93 Prob > chi2 = 0.0000		

*, significant at 95%

4. CONCLUSION

Biofortified beans adoption has been influenced by total land holding, total land bean size, farmers' group membership, extension services and livestock. All those factors have direct relationship with the government programs in place regarding land use consolidation. They also describe the effort made by Harvest Plus disseminating biofortified beans agricultural practices in Rwanda especially in the study areas of Nyagatare district.

The research recommends policy makers to put more emphasis in land consolidation policy as the major driver to increase the adoption of biofortified beans. Also recommend to researchers to work on the influence of behavioral factors on biofortified beans. It recommends also to researchers to determine the effect of biofortified beans of bean farm yield as far as farmers' income which can contribute to the adoption level.

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