Effect Of Biofortified Beans Adoption On Socio-Economic Welfare Of Farmers In Eastern Rwanda

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Abstract: Common bean has emerged to be an important staple food as well as cash crop for the majority of farmers in Rwanda. Productivity is a function of the usage of improved inputs like seeds, fertilizers, combined with farm management practices. Although biofertified beans have been introduced as improved varieties, their adoption is disappointing. This study was initiated with the objective to assess the effect of adoption of biofortified beans on social economic welfare of farmers in Nyagatare district, Eastern province of Rwanda. Stratified survey was used with 197 households' heads' selected by multi stage random sampling and cluster sampling. Qualitative and quantitative methods were then used for data collection. Propensity Score Match was performed to determine the effect of adoption on bean yield and income between adopters and non-adopters groups. The results showed that in four agriculture seasons considered 2016 A, 2015 B, 2015 A and 2014 B, Average Total Effect (ATE) between the yield of adopters and non-adopters were 334.0625, 499.3531, 185.4956 and 241.575 respectively, and were significantly different ($p < 0.05$). Application of propensity score matching on income between two groups of farmers overlapped due to backyard farmers. Biofertified beans proved potential for high production and income than local bean varieties.

Keywords: Adoption, Biofortified beans, ATE, overlapping and backyard farmers

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. In Rwanda, common bean is an important subsistence crop for smallholding farmers. 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).

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Previous studies have found that nearly all rural households in Rwanda cultivate beans (Asare-Marfo, et al., 2011, Larochelle, et al., 2013). Beans are food/nutrition security crop and source of cash income. As a short-duration crop (2.5 - 4 moths), they are also a key for helping to shorten the hunger periods and for providing quick cash (personal observation). Their early maturity and capacity to provide a range of food products (leaves "Umushogoro" as well as, fresh pods and dry grain) also helps provide a more balanced diet to vulnerable community members (the under-five, pregnant mothers and chronically ill people). 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 has been 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. At the household farmer level, the access has access to the sufficient quantities of seeds of their preferred varieties with adequate physical quality, at the right time of planting (Sperling and Cooper, 2003). As the majority of small scale farmers (poor and marginalized) operate in low input systems, their seed security is not guaranteed when they produce enough food and put some in reserve to be used as seeds for the next season.

Biofortified beans production in Rwanda

In Rwanda, bean is the crop that receives the most research attention, followed by sweet potato and banana (Karangwa, 2007). The bean research program at Rwanda Agriculture Board (RAB), formally Institut des Sciences Agronomiques du Rwanda (ISAR), in collaboration with international partners such as International Center for Tropical Agriculture (CIAT) and Harvet Plus, has released nearly 100 bean varieties over the last four decades (PABRA, 2012, RAB, 2012).By that partnership, ten biofortified bean varieties have been released from those 100 varieties (Harvest Plus, 2013). Biofortified beans varieties have 40% more iron than typical bean varieties. Develop a self-sustaining seed market that serves the needs of small farmers on an ongoing basis. Develop a bean brand for grain market. Develop effective distribution channels that promote beans. Develop/increase health and nutrition awareness. Develop best farming techniques, e.g. climbers, and promote the use of fertilizers (and other approaches to increase productivity). Develop a market information channel that helps small farmers improve their production and market planning. Most farmers who sell beans do so immediately after harvest and may later purchase beans for food and even seed. Most (88%) of farmers cite their social networks (neighbors, extended family and friends) as their main sources of information about new varieties (Harvest Plus, 2013). The majority of seed "recyclers" and new seed acquirers got their (original) seeds from local markets. Beans are being sold to primary traders on rural markets at small distances from the farm. Wholesalers are based in and around Kigali and receive their supplies from a network of traders. Typically, retailers will collect beans from the wholesalers, but they may also collect them directly from primary traders. Subsistence cultivation of beans in Rwanda: Input Supply-Production-Consumption. Commercial cultivation in rural areas: Input Supply-Production-Primary trader-Consumption. Commercial cultivation of beans for urban areas: Input Supply-Production-Primary trader-Wholesale-Retail-Consumption (Harvest Plus, 2013). Smallholder market participation is highly influenced by factors of production as well as transaction costs. (Key et al., 2000) have alluded that high transaction costs is one of the key reasons for smallholder farmers' failure to participate in markets and supply the right quantity of produce. (Abdulai and Birachi, 2009).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 seeds (PABRA, 2005). Adoption of biofortified beans production is of considerable importance because it is expected to improve bean productivity, increase income, and reduce hidden hunger and improving rural livelihoods as it is recognized as an important source of human dietary protein and calories. But in general perspective in Rwanda average bean yields is disappointing, (NISR, 2014) reported that the general bean production was 731.4 kg/ha for bush bean and 1024.6 kg/ha for climbing bean, but as pertains to biofertified beans so far no study done to indicate whether these adopted biofortified bean have increased yield per ha. No research shows that biofortified bean adopters have increased their income against non-adopters. This research has investigated the effect of adoption of biofortified beans on socio-economic welfare of famers in Nyagatare district, eastern province which used to grow bush beans. This research also has assessed the effects of the adoption of those beans on bean farm production to the farmers' adopters while analyzing the economic effect to adopters compared to non-adopters. Also it has provided the measures to be taken in father more dissemination of biofortified bean varieties process

Methodology

Study Area

This research was conducted in eastern province of Rwanda in Nyagatare District. Nyagatare district grows bush bean. 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 of Rwanda 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. RWR 2245 is biofortified bean variety used to grown in Nyagatare district. It is bush bean, grown in low and medium altitude zones, the yield of 2.5Mt/ha, resistant to pests and diseases.(RAB, 2012).

Data collection

The population of interest were cooperatives cultivating biofortified bean varieties working with Rwanda Agriculture Board (RAB) and Harvest Plus or not and individual farmers working/not with RAB or Harvest Plus growing beans in the same areas with those cooperatives in different sectors of Nyagatare district. The sample unity was farmers' household heads. 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 in four sectors of Nyagatare district: Karangazi, Katabagemu, Mimuli, Nyagatare and Rukomo. 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)

Data analysis
Data collected were screened, coded and analyzed using the Statistical Package for Social Sciences (SPSS), 16th version and STATA with Probit and Propensity Score Matching (PSM)

Empirical models
Accordingly, farmers who were not grown biofortified bean variety (RWR 2245) in 2016 A, and growing local varieties were considered as non-adopters, while farmers who were growing RWR 2245 were considered as adopters. To determine the effect of adoption of biofortified beans on bean farm yield and determining the effect of adoption of biofortified beans on farmers' income have been analyzed using propensity score matching model.

Propensity score matching
The observable variables eliminate sample selection bias (Heckman and Navarro, 2004). PSM constructs a statistical comparison group by matching every individual observation of adopters with an observation with similar characteristics from the group of non-adopters. In essence, matching models create the conditions of an experiment in which adopters and non- adopters are randomly assigned, allowing for the identification of a causal link between action choice and outcome variables. The seminal explanation of the PSM method is available from Rosenbaum and Rubin (1983), and its strengths and weaknesses are elaborated, for example, by Dehejia and Wahba (2002), Heckman et al. (1998), Caliendo and Kopeinig (2008), and Smith and Todd (2005). Propensity score matching is a two-step procedure. First, a probability model for adoption of biofortified bean varieties is estimated to calculate the probability (or propensity scores) of adoption for each observation. In the second step, each adopter is matched to a non-adopters with similar propensity score values, in order to estimate the average treatment effect for the treated (ATT). Several matching methods have been developed to match adopters with non-adopters of similar propensity scores

Results and Discussions
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.

Table 1: *Adoption of biofortified beans in sampled farmers*

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

1. The effect of adoption of biofortified beans on adopters and non-adopters'bean farm yield

1.1 Effect of adoption on bean farm yield for season A, 2016
In agriculture season 2016 A, the sampled farmers 197, only 102 have grown beans where adopters were 52 and non adopters were 50. The average yield in adopters group was 1527.059 kg ha^{-1} while in non adopters group, the average yield was 840.4444 kg ha^{1}. The analysis showed a statistical significant difference between those two groups with P <0.001 at 95% of confidence level. This means, the farmers who have grown the biofortified bean variety (RWR 2245) obtained high yield than the farmers grown non biofortified bean varieties. This also shows that the average yield of bean has increased in this 2016 A agriculture season compared to the low yield published by the National Institute of Statistics of Rwanda (NISR) where the average bean yield was 731.4 kg ha^{-1} for bush bean in 2013 B. (NISR, 2013). With the percentage of bean yield increase of 80%, the analysis from propensity score matching has shown the ATT (ATET) were 673.4913 kg ha^{-1} while the ATE was 660.2295 kg ha^{-1}. This means that the adopters were better of getting 660.2295 kg ha^{-1}more than non-adopters while the average treatment effect on treated were 673.4913 kg ha^{-1}, and they were statistical significant with P<0.001 at 5% of level. See Table 2 and 3.

1.2 Effect of adoption on bean farm yield for season B, 2015
As it is shown in the Table 2 and 3, In agriculture season B 2015, beans have been grown by 196 farmers in 197 sample size meaning that only one farmer did not grow beans in sampled population with 106 and 90 adopters and non-adopters respectively. The average yield in adopters group was 1440.247 kg/ ha while in non-adopters group, the average yield was 825.4918 kg ha^{-1} with the 75% of yield increase between adopters and non-adopters. The statistical significant of P<0.001 at 95% of confidence level between adopters and nonadopters, was realized. The ATT and ATE were 620.2469 kg $ha^{-1}$and 621.0001 kg ha^{-1} surplus in yield between adopters and non-adopters. This yield is also higher than that published by the National Institute of Statistics of Rwanda (NISR) in 2013 B. (NISR, 2013). But it has not yet reached the potential yield of 2Mt presented by Harvest Plus. Where the potential yield between 2000 to 2500 kg/ha for biofortified bean can be realized. (Lister, 2012)

1.3 Effect of adoption on bean farm yield for agriculture season 2015 A
For 2015 A, only 98 farmers in the sample of 197 farmers have grown beans with 47 and 52 of adopters and non-adopters respectively. Here the average yield of 831.0185 and 1609.748 kg/ha has been realized among non adopters and adopters respectively. ATET and ATE were 809.7473 kg $ha^{-1}$and 799.7833 kg ha^{-1} respectively. Thus, the farmers' adopters have benefited more yield than non adopters. The P value was less than 0.001 at confidence interval of 95%. It was found that the RWR 2245 growers have more yield than those farmers growing non biofotified ones with double increased yield between adopters and non-adopters (100%). But still the yield found is greater than that

published by the National Institute of Statistics of Rwanda (NISR) in 2013 B. (NISR, 2014). However, it has not yet reached the potential yield of 2Mt presented by Harvest Plus. Where the potential yield between 2000 to 2500 kg/ha for biofortified bean can be realized. (Lister, 2012). Table 2 and 3.

1.4 Effect of adoption on bean farm yield for season 2014 B

In 2014 B, both sampled farmers have grown beans with 90 and 107 adopters and non-adopters respectively. The average yield of adopters was 1088.993 kg ha^{-1} while it was 732.6473 kg ha^{-1} for non adopters. There was statistical significant difference among both groups with P<0.001 where the ATET and ATE were 397.7493 kg ha^{-1} and 367.4302 kg ha^{-1} respectively. It means that even if the mean yields are low compared to the previous season, the adopters' farmers benefited more. This yield of 732.6473 kg ha^{-1} from non adopters group is similar to the average yield of 731.4 kg ha^{-1} published by NISR, 2014. See the Tables 2 and 3. The yields found in both seasons, were high in adopters groups more than non adopters with the percentage increase of 91%. This yield increase in adopters group is in accordance with the findings by Gichangi, et al. (2013) who conducted a research on Assessment of Production and Marketing of Climbing Beans by Smallholder Farmers in Nyanza Region, Kenya, who said that, the level of adoption of improved variety influence the amount of yield obtained. This justify the hypothesis, that we reject Ho saying that the adoption of biofortified beans has no effect on bean farm yield and accept the H1 that adoption of biofortified beans has effect on the bean farm yield.

Table 2: *Effect of adoption of Biofortified beans on adopters and non-adopters' bean farm yield in 4 agriculture seasons (Analysis of t test with equal variances)*

Season	Full Obs	Full Mean (Kg ha^{-1})	Non-adopters Obs	Non-adopters Mean (Kg ha^{-1})	Adopters Obs	Adopters Mean (Kg ha^{-1})	Diff Mean (Kg ha^{-1})	%	t-test P-value
2016 A	102	1190.483	50	840.4444	52	1527.059	-686.6142	80	-8.9858 <0.001*
2015 B	196	1157.962	90	825.4918	106	1440.247	-614.7556	75	-14.450 <0.001*
2015 A	99	1224.811	52	830.235	47	1661.363	-831.1277	100	-13.032 <0.001*
2014 B	197	621.672	98	426.9274	99	814.4494	-387.522	91	-3.3686 0.0005*

**, significant at 5% of level significant*

Table 3: *Estimation of treatment effect analysis based on matching algorithms on farmers bean yield (the surplus of yield in favor of adopters against non-adopters)*

Season	Surplus	AI Robust Obs	Coef.	Std. Err.	Z	P>|z|	[95% Conf. Interval]	
2016 A	ATET	102	673.4913	81.12328	8.30	0.000	514.4925	832.49
	ATE	102	660.2295	83.02714	7.95	0.000	497.4993	822.9597
2015 B	ATET	196	620.2469	40.71277	15.23	0.000	540.4513	700.0425
	ATE	196	621.0001	40.94257	15.17	0.000	540.7541	701.2461
2015 A	ATET	99	809.7473	66.92813	12.10	0.000	678.5705	940.924
	ATE	99	799.7833	66.40426	12.04	0.000	669.6334	929.9333
2014 B	ATET	197	397.7493	116.0828	3.43	0.001	170.2312	625.2674
	ATE	197	367.4302	111.1734	3.31	0.001	149.5344	585.326

Estimator: Propensity-Score Matching Treatment model: Probit Number of matches (m) = (5)

2. The effect of adoption of biofortified beans on adopters and non-adopters' income

As it is described in Table 4 and 5, the amount of money received from sales of beans depended on the quantity of bean harvested, the quantity sold and availability of market. The mean income observed from money earned from sales of bean in adopters group, in 2016 A, 2015 B, 2015 A and 2014 B were 689462.8 RWF, 644919.4 RWF, 741714.3 RWF and 431959.8 RWF respectively. While the means income in non adoption group in 2016 A, 2015 B, 2015 A and 2014 B were 39454 RWF, 52710.11 RWF, 37090.38 RWF and 58668.04 RWF respectively. The ATET and ATE which measure the surplus of money in favor of adopters, were 820847.5 and 701218 Rwandan francs respectively in 2016 A, 1,153,805 and 1,150,131Rwandan francs respectively in 2015 B, 996919.9 and 834456.4 Rwandan francs respectively in 2015 A and 730460.5 and 722503.1 Rwandan francs. The analysis showed a statistical significance among the two groups with P<0.001 at 95% level of significant. This let us rejecting the hypothesis Ho that states, Adoption of biofortified beans does not increase farmers income. Those are very big effects between money earned among those two groups see the graphs below as they describe the location of income earned by the total bean yield sold.

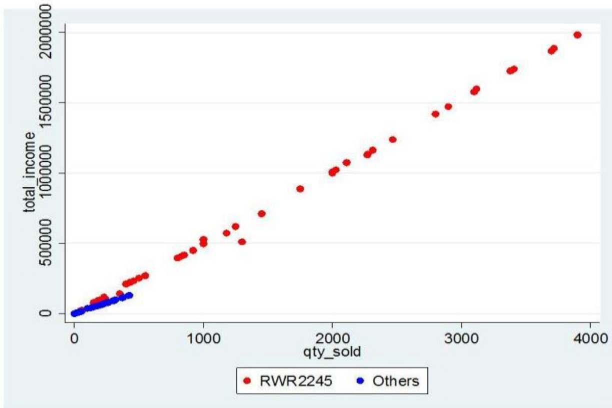
***Table 4:** Effect of adoption of Biofortified beans on farmers' income (analysis of t test with equal variances from sales of bean)*

Season	Unit	Full Obs	Mean	Non-adopters Obs	Mean	Adopters Obs	Mean	Diff	t test P-value
2016 A	Rwandan francs	102	442783.8	50	24664	52	844822.1	-820158.1	-6.0885 <0.001
2015 B	Rwandan francs	196	675433.4	90	52124.44	106	1204658	-1152534	-6.5391 <0.001
2015 A	Rwandan francs	81	514310.1	35	37090.38	46	1042298	-733876.9	-6.0730 <0.001
2014 B	Rwandan francs	197	440441.9	98	71640.82	99	805517.7	-733876.9	-5.3963 <0.001

*, significant at 5% level of significance

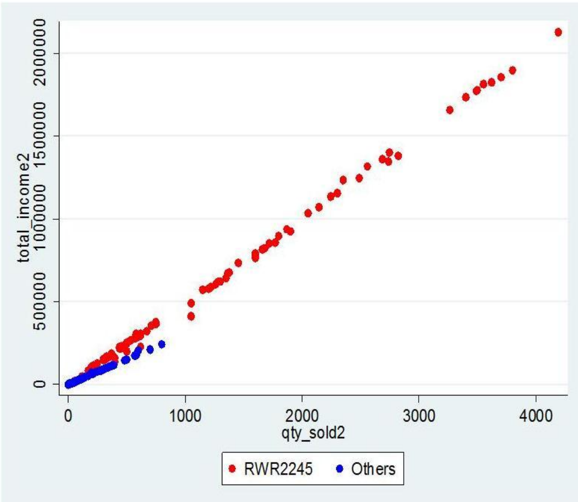
Due toa very big difference between the averages of income between the two groups. the analysis of the effect of adoption of biofortified bean to the income of the groups using propensity score matching, have been overlapped due to backyard farmers (that have less than 100 ms of farm, that to be matched with those hold big land is impossible). This is because, the non-adopters group produced on small scale land, get less yield, sold very low quantity on the low price, all of those resulted in the very big difference of income earned compared to adopters group. This caused the overlapping of the income analysis. See the figures below generated by propensity score matching analysis in every single season

***Figure 1:** The distribution of adopters and non-adopters income gained from sales of bean in 2016 A (income in Rwandan francs)*



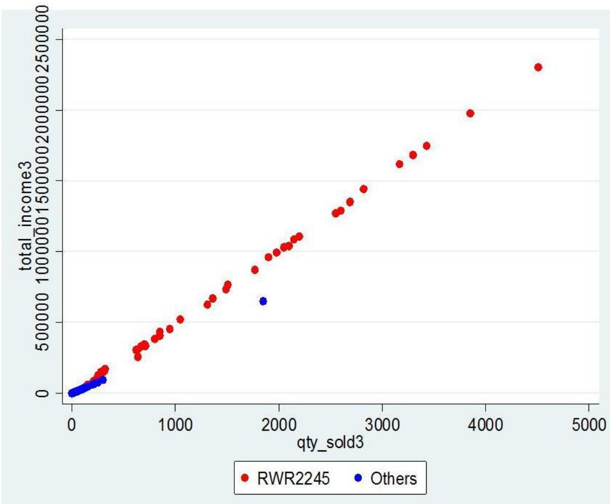
RWR2245: Biofertified bean variety grown in Nyagatare. **qty_sold:** quantity of bean sold in 2016A. **total_income**: total money earned from sales of bean in 2016 A

Figure 2: *The distribution of adopters and non-adopters income gained from sales of bean in 2015 B (income in Rwandan francs)*



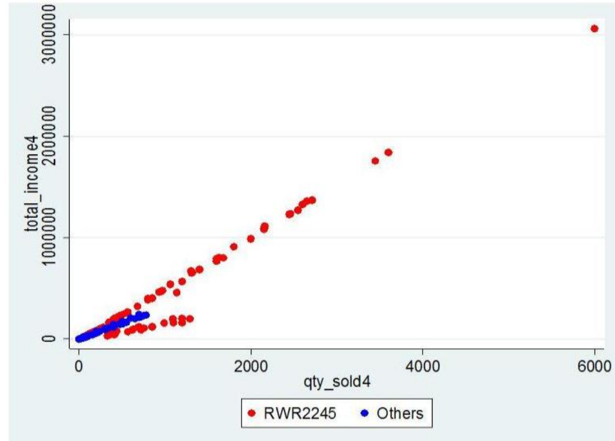
RWR2245: Biofertified bean variety grown in Nyagatare. **qty_sold2**: quantity of bean sold in 2015 B. **total_income2:** total money earned from sales of bean in 2015 B

Figure 3: *The distribution of adopters and non-adopters' income gained from sales of bean in 2015 A (income in Rwandan francs)*



RWR2245: Biofertified bean variety grown in Nyagatare. **qty_sold4**: quantity of bean sold in 2014 B. **total_income3:** total money earned from sales of bean in 2015 A

Figure 4: *The distribution of adopters and non-adopters income gained from sales of bean in 2014 B (income in Rwandan francs)*



RWR2245: Biofertified bean variety grown in Nyagatare. **qty_sold4**: quantity of bean sold in 2014 B. **total_income4:** total money earned from sales of bean in 2014 B

Conlusion

The aim of this study was to determine the effect of biofortified beans adoption on socio-economic welfare of farmers in eastern Rwanda. It was based first on assessing the effect of biortified beans on farmers bean yield then determining the effect of increased yield on farmers' income. The mean yield in different four seasons considered 2016 A, 2015 B, 2015 A and 2014 B have been shown the statistical significant difference between adopters and non adopters with significant average total effect at 95%. The mean yield in all four seasons in this study was found to be 86% for the yield increase in adopters. With propensity score matching, the average total effect between the farm bean productivity was statistical significant among adopters and non-adopters at 95% of level, and also the effect of income from sales of beans, was statistical significant among adopters and non adopters at 95% of level of significant. The results of the study indicate significant effect of income in comparison of treated to their counter parts on amounts of money received from sales of bean sold, this means the reliability of the findings and correlation. This is due to backyard farmers found in non adopters' group. Which results that, the non-adopters group grew local varities hence get low yield and low prices

Recommendation

In view of the major findings and the above conclusions, the following recommendationsare drawn; the government (local or/and country) and other Non-Governmental Organization (NGOs) should do their part in creating awareness, facilitating the access and mobilizing farmers to adopt the biofertified beans so that farmers can improve their agricultural productivity and then change their livelihood. Adoption of the biofertified bean varieties was observed to improve the productivity of the adopting farmers which provides them with high yield. Therefore, GOs and NGOs should facilitate the non-adopters to adopt the biofertified beans through creating cooperative opportunities while supporting the adopters to continue adopting. Hence, farmers can produce more and by connecting to markets and selling their products, they can improve their livelihood. This study was to determine the effect of biofortified beans adoption on socio-economic welfare of farmersin the study area. However, it didn't analyze intensity of adoption of biofertified beans and the cost of production in the study area. Thus, further studies are recommended to provide empirical evidence about the intensity of adoption of biofertified bean varieties and cost of production in the study area.

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