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SMALLHOLDER FARMERS' USE AND PROFITABILITY OF LEGUME INOCULANTS IN WESTERN KENYA

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ABSTRACT

Research on the use of *Rhizobia* inoculants has been conducted in Africa since 1950s. However, the technology has not been widely applied by farmers on the continent. In Kenya, wide-scale adoption of this innovation among the smallholder farmers is still low. The aim of this study was to examine factors that drive the use of BIOFIX® *Rhizobia* inoculant, a product of Kenya, and its profitability in smallholder farms. Data were collected from 210 soybean (*Glycine max)* farmers in western Kenya. Logit and tobit regression models were used to assess drivers of the inoculants use and gross margin analysis to examine profitability. The area under the crop, distance to local markets, knowledge of legume root nodules, education level, contacts with organisations promoting biological N fixation (BNF) technologies, group membership, soybean market and location of the farm based on agro-ecological zone were factors that determine the use of the inoculants. There was a significant difference in yields between farmers who inoculate soybean (864 kg ha^{-1}) and those who do not (686 kg ha^{-1}) (P<0.01). The difference in gross margin achieved by inoculant users (US$ 278 ha^{-1}) and non-users was highly significant (P<0.01).

Key Words: *Glycine max*, gross margin, soil fertility

RÉSUMÉ

La recherche sur l'utilisation des inoculants de *Rhizobia* a été conduite en Afrique depuis les années 1950. Par ailleurs, la technologie n'a pas été largement appliquée par les fermiers du continent. Au Kenya, l'adoption à large échelle de cette innovation parmi les petits exploitants des terres est encore basse. L'objet de cette étude était d'examiner les facteurs qui déterminent l'utilisation de l'inoculant BIOFIX®*Rhizobia,* un produit du Kenya, et le bénéfice y relatif. Les données étaient collectées sur 210 fermiers du soja (*Glycine max)* à l'Ouest du Kenya. Les modèles de régression de Logit et tobit étaient utilisés pour évaluer les facteurs qui conditionnent l'utilisation des inoculants et l'analyse de la marge bénéficiaire pour examiner la profitabilité. La superficie occupée par la culture, la distance aux marchés locaux, la connaissance des nodules des racines des légumineuses, le niveau d'éducation, le contact avec d'autres organisations de promotion des technologies de fixation de N biologique (BNF), l'appartenance au groupe des fermiers, le marché du soja et la localisation de la ferme sur base de la zone agro-écologique étaient des facteurs qui déterminent l'utilisation des inoculants. Il n'y avait pas de différence significative dans les rendements entre les fermiers qui inoculent le soja (864 kg ha^{-1}) et ceux qui n'utilisent pas cette technologie (686 kg ha^{-1}) (P<0.01). La différence de la marge bénéficiaire acquise par les utilisateurs des inoculants (US$ 278 ha^{-1}) et les non utilisateurs était hautement significative (P<0.01).

Mots Clés: *Glycine max*, marge bénéficiaire, fertilité su sol

INTRODUCTION

Poor soil fertility continues to challenge food security and rural wellbeing in sub-Saharan Africa. Nutrient depletion is a key factor in low soil fertility as nutrients removed through crop off-take and other loses are not adequately replaced. This is widespread across Kenya and sub-Saharan Africa at large. Nitrogen is the most affected due to its high uptake, vulnerability to leaching, losses in gaseous form and through crop harvest (Stoorvogel *et al.*, 1993). The use of inorganic fertilisers to alleviate the problem is limited by high cost leading to very low usage per unit area. This is occasioned by failure to use the recommended fertiliser application rates by smallholder farmers.

In response to the challenges highlighted above, a new paradigm has developed around Integrated Soil Fertility Management (ISFM). One goal of ISFM is to develop and promote soil fertility replenishment technologies that are suitable for different types of resource-poor farm households (Crowley and Carter, 2000). One such technology is the use of *Rhizobia* inoculants that enhance BNF, which can be a cost effective alternative of alleviating low soil fertility problem (Giller, 2001). Many soils contain *Rhizobia,* but often in small populations, non-effective to many host legumes or ineffective or partly-effective as symbiotic nitrogen fixers. At the same time, native *Rhizobia* may pose a barrier to infection and subsequent nodulation by commercial inoculants (FAO, 1984; Thies *et al.*, 1991). This requires inoculation with an elite *Rhizobia* strain in high quality formulations.

Inoculant production in Kenya was initiated as part of the Microbial Resources Centre Network (MIRCEN) that was established by the University of Nairobi in 1977 (Karanja *et al.,* 1998). The Centre developed an inoculant known as BIOFIX®, that was later licensed and marketed by MEA Limited, which started production in 2010. BIOFIX® for soybean contains the *Bradyrhizobium japonicum* strain USDA 110, a widely used industry standard and contains $>10^9$ *Rhizobia* g^{-1} in an organic carrier material (Lupwayi *et al.*, 2000). This is one of the main legume inoculant commercially available in East Africa and is steadily being promoted among farmer groups and agro-dealer associations (Wafulah, 2013), assisted by the N2Africa programme (Woomer, 2013).

Woomer *et al.* (1997) identified lack of information concerning inoculants availability and use as an important constraint to use of the technology, and this problem has persisted. This study was conducted to assess factors influencing the use of BIOFIX® inoculants among small-scale farmers in western Kenya.

METHODOLOGY

Study area. The study was conducted in Bungoma West, Bondo and Mumias districts in western Kenya, where the N2Africa Programme (www.n2africa.org) promotes BNF technologies among smallholder farmers, including best practices for soybean cultivation. The choice of districts was based on the number of groups working with N2Africa and on agro-ecological zoning.

Bungoma West district is situated in Western Province, along the Uganda border. It receives rainfall ranging between 1400 to 2200 mm yr^{-1} depending on elevation. The predominant soils are Acrisols and Ferralsols (FAO, 1977), and maize is the dominant crop.

Mumias district is also situated in Western Province to the south of Bungoma, and receives about 1700 mm rainfall yr^{-1}. The predominant soils are Acrisols, Luvisols and Gleysols (FAO, 1977).

Bondo district is situated in Nyanza Province along Lake Victoria. Its rainfall is lower ranging from 900-1,200 mm per *annum*. The predominant soils are mainly Cambisols and Vertisols (FAO, 1997), and farmers cultivate maize, beans, cassava and other food crops.

Conceptual and empirical methods. Decision-making on the use of improved technologies by farmers is a complex process. Several authors (Feder *et al.,* 1985; Doss, 2006; Everett, 2003; Eelko, *et al.,* 2009) have proposed a theoretical model where in the technology-adoption process; an individual passes through the stages of knowledge, persuasion, decision, implementation (adoption) and confirmation (post-adoption assessment). Leagens (1979) argued that the decision to adopt an innovation or a new technology is a behavioral response arising from a set of alternatives and constraints facing the decision maker. These alternatives and constraints can be grouped into incentives and disincentives. Adoption proceeds when the incentives outweigh the disincentives. Economically, incentives are the returns, while disincentives are the costs. If benefits are more than the costs, the farmers are motivated to take up technologies due to the expected high return on investment.

We used Logit regression to model the factors that are likely to determine the use of BIOFIX®; while the Tobit regression was used to estimate the effects of various factors on the extent of BIOFIX® use. Logit model is specified as follows (Gujarati, 2004):

$$[ln[P(X)]/[P(1-P(X)] = \beta_0+\beta_1X_1+\beta_2X_2+...+\beta_nX_n+\varepsilon \quad (1)$$

Where:

β_0 = the intercept and $\beta_1, \beta_2,..\beta_n$, = the regression coefficients; X_1, X_2, X_n = the independent variables (explanatory variables) and ε = the error term. The dependent variable is the natural log of the probability (P) of using a particular technology or technological component (X), divided by the probability of not using it (1-P).

Logistic, Probit and Tobit regression models are commonly used for binary or dichotomous outcome (Woodridge, 2002). Logit and Probit regressions are statistical techniques in which the probability of a dichotomous outcome (use or non-use in this case) is related to a set of explanatory variables that are hypothesized to influence the outcome. The Probit and Logit models often provide identical substantive conclusions, and are quite similar except at their tails. However, Sirak and Rice (1994) argue that Logit regression is more flexible and is often chosen if the predictor variables are a mix of continuous and categorical variables.

The implicit functional form estimated to assess the factors determining the decision to use BIOFIX *Rhizobia* inoculants is given by:

Use of Rhizobia inoculant (BIOFIX®) = f (log of age, gender, household size, education level, distance to the local market, distance to soybean collection center, log of household income, area under crops, membership in soybean producer group, number of contact with organisations promoting BNF, access to credit, whether farmer applies nitrogenous fertiliser to legumes, perception of root nodules, region variables) +ε

The Tobit model was specified using the following relationship:

$$Y = \beta_0+\beta_1X_1+\beta_2X_2+...+\beta_nX_n+\varepsilon \quad (2)$$

Where:

Y = the area under inoculated soybeans in hectares; β_0 = the intercept; $\beta_1, \beta_2,... \beta_n$, = the regression coefficients of independent variables (X_1, X_2, X_n, respectively), and ε = the error term.

The implicit functional form of the model estimate to examine the level of BIOFIX use is as follows:

Area under inoculated Soybean (hectare) = *f* (log of age, relationship to household head, household size, education level, distance to the local market, distance to soybean collection center, log of household income, area under crops, membership in soybean producer group, number of contact with organisations promoting BNF, access to credit, whether farmer applies nitrogenous fertiliser to legumes, perception of root nodules, region variables) + ε

Gross margin analysis was used to determine the profitability of BIOFIX® *Rhizobia* inoculants on soybean production. Gross margin is the difference between the total income and total variable costs of an enterprise, which measures what the enterprise is adding to the overall farm profit (Barnard and Nix, 1993; Mohammed *et al.*, 2011).

Gross margin was calculated as follows:

$$GM_i = TR_i - TVC_i, \; i = 1, ... n \quad (3)$$

Where:

GM_i= gross margin for the ith farmer per hectare
TR_i = total revenue from the sale of soybeans by the ith farmer per hectare.

Data collection and sampling. Farmers of soybean were stratified into two categories, namely; users and non-users of BIOFIX®. The first category was drawn from soybean farmers that had participated in N2Africa outreach activities and had, therefore, been exposed to BNF technology; while the second category was drawn from soybean farmers outside the programme (assumed not to have been exposed to the technology). A total of 210 farmers were interviewed. Farmers in the two groups were listed and the Online Research Randomiser software used to select farmers to be interviewed. The samples for both N2Africa member and non-member groups was drawn proportionally in each district.

Data were collected through personal interviews, using pretested questionnaires. Information collected included socio-economic data, information relating to the farm and use of *Rhizobia* inoculants. The prevailing market prices were used to estimate the cost of farm inputs and value of outputs.

The sizes of plots were converted into hectares. Farmers were asked to recall the amount of soybean harvested and this was in some cases cross-checked with records at local soybean collection points. The amount of soybean harvested was recorded in kilogrammes while labour was captured in man-days and valued based on opportunity cost. Descriptive statistical analysis and regression methods were used to analyse the data collected. Logit regression was used to model the factors that are likely to determine the use of *Rhizobia* inoculant and Tobit regression used to determine the factors that are likely to influence the intensity of inoculant use. Gross margin analysis was performed to examine the profitability of *Rhizobia* inoculants on soybean production. Comparison of gross margins of farmers who use inoculants to those who do not use was done by subjecting the gross margins to T-test.

RESULTS AND DISCUSSION

The general characteristic of the farmer population considered in this study is given in Table 1. The mean age of soybean farmer was 47 years, with 70% of the farmers interviewed being women. This suggests that women are more involved in growing of soybean than men. The mean household size was 5 members. The mean distance to the nearest market centre was 8.1 km.

The mean distance to the nearest soybean collection centre was 2.7 km; while mean

TABLE 1. Summary statistics of variables used in the empirical estimations

Variable definition	Mean	Std. Dev.
Dependent variables		
User of BIOFIX®	0.57	0.49
Area under inoculated soybean	0.10	0.18
Independent variables		
Natural log of age	3.80	0.30
Gender	0.30	0.46
Relationship to household head	0.57	0.50
Household size	5.41	2.73
Cropland	1.91	1.44
Distance to market	8.12	3.27
Application of N fertiliser	0.19	0.39
Perception of root nodules	0.57	0.50
Education level	6.83	3.56
Natural log of income	9.89	1.10
Contact with organisations promoting BNF	2.09	2.76
Membership in soybean producer group	0.72	0.45
Access to credit	0.45	0.50
Distance to soybean collection center	2.74	2.18

education level was 6.8 years, indicative of later primary schooling. The mean household income was US $406 per year. A total of 61% had contact with organisations promoting BNF technologies (cooperators in the N2Africa project), with an average of two contacts in a year. This indicates that these organisations play a big role in the use and adoption of *Rhizobia* inoculants. Credit (either cash or in form of inputs) was accessed by 45% of the respondents.

Characteristics of adopters and non-adopters of *Rhizobia* inoculants are presented in Table 2. Difference in household size was significant (P<0.05) indicating that users of inoculants had bigger household sizes than the non-users. They were also closer to the market centres (P<0.01). The other significant differences in the means between users and non-users of inoculants was in the perception of root nodules; with users having a more positive perception, mean income, contact with organisations promoting BNF, membership in soybean promoting group and distance to collection centres. Non-users were closer to the collection centres indicating the influence of the centres in growing soybeans by individual farmers who were not members of the soybean groups.

The results of the Logit regression model showed the factors hypothesized to affect the use of inoculants along with their marginal effects (Table 3). The results demonstrated that the area under crop, distance to the market, knowledge of root nodules, education, contact with organisations promoting BNF technologies, membership in soybean promoting group and location of the farmer conditions the use of *Rhizobia* inoculants with varying significance.

The area under crops (P<0.10) had positive effect with an expected 0.05 likelihood of using the inoculant with each increment in unit total crop area, holding other factors constant. Distance to the market (P<0.10) inversely influenced the use of inoculants. Marginal effect suggests that for farmers who were far from the market by one unit, the probability of using legume inoculant reduced by 0.02, holding other factors constant. This could be attributed to access to information by farmers near the market.

Knowledge of root nodules had a positive influence on the use of inoculants (P<0.01). This

TABLE 2. Characteristics of users *versus* non-users of BIOFIX® inoculants in western Kenya

Variable	Users	Non-users	P-value
Natural log of age	3.83	3.78	0.27
Gender	0.32	0.27	0.49
Relationship to household head	0.57	0.56	0.87
Household size	5.75	4.98	0.04
Cropland	1.94	1.87	0.74
Distance to market	7.08	9.48	<0.001
Application of N fertiliser	0.18	0.20	0.70
Perception of root nodules	0.81	0.25	<0.001
Education level	6.65	7.07	0.40
Natural log of income	9.63	10.22	<0.001
Contact with organisations promoting BNF	3.38	0.40	<0.001
Membership in soybean producer group	0.96	0.41	<0.001
Access to credit	0.54	0.33	0.002
Distance to soybean collection center	3.34	1.95	<0.001
Location variable			
Mumias	0.30	0.37	0.28
Bungoma	0.16	0.56	<0.001
Bondo	0.54	0.07	<0.001
Total number of farmers (N)	119	91	

implies that farmers who perceived root nodules on leguminous crops as beneficial were more likely to use inoculants. Similarly, number of contacts with organisations promoting BNF and membership in soybean producer group (P<0.01) positively influenced adoption of inoculants. Interestingly, education had an inverse influence on the use of inoculants (P<0.10), which may be attributed to involvement in other competing farming enterprises by farmers with higher education.

The location variables showed that other factors constant, farmers in Bondo were more likely to use inoculants than Mumias and Bungoma. This may be attributed to fewer cash crop enterprise choices in Bondo, which has drier climatic conditions than both Mumias and Bungoma.

The results of the Tobit regression model estimated to assess the factors determining the level of legume inoculants use are presented in Table 4. Perception of legume root nodules (P<0.05) and education (P<0.10) had a positive and significant influence on the land size planted with inoculated soybean. Being aware of the existence of root nodules in leguminous plants and perceiving that the nodules are beneficial enhanced the intensity of inoculant use. While

TABLE 3. Determinants of the use of BIOFIX® inoculants in western Kenya

Variable	Coefficient	p	Marginal effects	
			Coefficient	P
Awareness of nodules	2.75	<0.001	0.55	<0.001
Membership in producer group	3.31	<0.001	0.68	<0.001
Contact with BNF organisations	0.54	0.003	0.11	0.002
Cropland area	0.46	0.06	0.10	0.06
Education level	-0.19	0.090	-0.04	0.08
Distance to market	-0.18	0.10	-0.04	0.11
Location variables				
Mumias	-2.74	0.017	-0.58	0.003
Bungoma	-3.41	0.007	-0.68	<0.001
Constant	4.34	0.507		

TABLE 4. Determinants of the level of use of BIOFIX® use by Tobit regression in western Kenya

Variable	Coefficient	Standard Error	P-value
Cropland	0.03	0.02	0.12
Distance to market	-0.01	0.01	0.16
Perception of root nodules	0.11	0.05	0.04
Education level	0.04	0.02	0.09
Contact with BNF organisations	0.03	0.01	<0.001
Membership in producer group	0.40	0.09	<0.001
Distance to soybean collection center	-0.04	0.01	0.004
Location variables			
Mumias	-0.22	0.08	0.006
Bungoma	-0.41	0.10	<0.001
Constant	-0.37	0.37	0.321

Number of observations = 210 Prob> F = 0.0000
Log pseudolikelihood = -24.328 Pseudo R^2 = 0.760

holding other factors constant, each additional year in education contributed 0.04 units to the area under inoculated soybean.

Among the institutional variables, frequency of contacts with organisations promoting BNF technologies, group membership and the distance to collection centres had significant influence on the land size under inoculated soybean (P<0.01). Also, holding other factors constant, each unit increase in contact with organisations promoting BNF was likely to contribute 0.03 additional area under inoculated soybean. More contacts with these organisations enhanced sharing of information regarding the technology and accessibility. Contact was enhanced by attendance to group meetings where farmers interacted with extension agents. Farmers who failed to participate in such meetings often got little information, resulting in reduced adoption of legume inoculants. Soybean market access due to e.g. distance to soybean collection centres indicated that for each km a farmer was from a soybean collection centre, area under inoculant declined by 0.04 units, holding other factors constant. This shows that accessibility to soybean market is a key factor in the intensity of legume inoculants use.

According to FAO (2008), a national average yield of 840 kg $ha^{-1}$of soybean in Kenya was reported, including larger, commercial farms outside of the study area. This study found an overall average yield of 775 kg ha^{-1} for both users and non-users of BIOFIX® inoculants (Table 5). However, there was a significant difference in average yields (P<0.01) between farmers who inoculated and those who did not. This difference may be attributed not only to inoculation itself, but also to better management skills and quality inputs among those using inoculants due to their enhanced contact with extension service providers. Farmers who inoculated soybean harvested 864 kg ha^{-1}; while those who did not inoculate received 178 kg ha^{-1} less. Therefore, inoculation and other factors such as good management and quality inputs increased soybean yield by 26%. However, these yields were still low compared to 2.5 tonnes ha^{-1} achieved under best management in west Kenya. Despite these low yields, soybean cultivation is profitable (Table 5).

Gross margins for farmers who inoculated soybeans were significantly higher than that of non-users, i.e., \$278 and 175ha^{-1}; respectively (P=0.01). The difference in the cost of gunny bags

TABLE 5. Gross margin for users and non-users of BIOFIX® inoculant for soybean production in western Kenya

Variable	BIOFIX® Users		BIOFIX® non-users		t-value[a]	P-value
	Mean	Std. Dev.	Mean	Std. Dev.		
Output						
Yield kg ha^{-1}	864	348	686	207	4.61***	0.000
Returns Ksh ha^{-1}	43194	17401	34300	10347	4.61***	0.000
Variable costs (Ksh ha^{-1})						
Seeds	2826	695	2,934	632	-1.18	0.239
Fertiliser	1655	2598	923	2053	2.28**	0.024
Chemicals	218	817	165	686	0.51	0.608
BIOFIX®	225	251	0	0	9.81***	0.000
Labour	16137	2999	16256	2443	-0.32	0.753
Gunny bags	482	184	381	103	4.99***	0.000
Total Variable Cost ha^{-1}	21543	4396	20659	3390	1.65	0.101
Gross Margin Ksh ha^{-1} [b]	21652(US\$278)	17372	13641(US\$175)	11117	4.06***	0.000

Mean yield of soybean for both users and non-users of BIOFIX®= 775 kg ha^{-1}Number of observations (users of BIOFIX® = 119, non-users = 91)

[a]Significance of mean difference is ** = 5% and *** = 1%. [b]KSh 78 = US \$1

was also significant (P<0.01), certainly due to the requirement of more gunny bags to accommodate the extra yields.

CONCLUSION

Several factors influence the use of *Rhizobia* inoculants among the small-scale farmers. These factors include farmer and farm-specific characteristics such as knowledge of root nodules, level of education, area available for crop cultivation, distance to the market; contact with organisations promoting BNF technologies, membership in soybean promoting group, availability of output market and location of the farm. Use of legume inoculants, BIOFIX® in Kenya is profitable but with a high disparity in gross margins between farmers. The disparity is driven by difference in yields achieved.

There is need to strengthen local institutions and for greater involvement of commercial sector, particularly local agro-dealers, and agricultural extension to further promote inoculants. Markets are the drivers of adoption of this technology.

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