Determinants of Smallholder Farmers' Adoption and Willingness to Pay for Improved Legume Technologies in Tanzania

Lugamara, C.B.[1]*, J.K. Urassa[2], P.M. Dontsop Nguezet[3] and C. Masso[4]

[1]Department of Development Studies, Sokoine University of Agriculture (SUA), Morogoro, Tanzania
[2]Department of Policy, Planning and Management, Sokoine University of Agriculture (SUA), Morogoro, Tanzania
[3]International Institute of Tropical Agriculture (IITA), Birava Road, Bukavu, Democratic Republic of Congo
[4]International Institute of Tropical Agriculture (IITA), Nairobi, Kenya.

*Corresponding author e-mail: charleslugamara@gmail.com

Abstract

Generally, legumes are critical in improving nutritional status, enhancement of ecosystem resilience and reduction of poverty for rural households. However, limited information is available concerning smallholder farmers' adoption and their willingness to pay for improved legume technologies in Tanzania. Therefore, this paper assesses the determinants of smallholder farmers' adoption of improved common bean seeds (Uyole Njano, Lyamungo 90 and Rose-coco/Red bean) and willingness to pay for improved common bean seeds, Basal fertilizers (NPK; DAP), Boosting fertilizers (UREA), Pesticides, Herbicides and Anti-fungal). The study adopted a cross-sectional research design whereby data from 400 respondents were collected once from Gairo and Mvomero districts, Tanzania through a questionnaire, key informant interviews and focus group discussions. A third of the respondents were from the non-intervention area. Data were analysed using SPSS and STATA whereby descriptive and inferential statistics were determined. The results show that there were statistically significant associations between the adoption of improved common bean seeds and availability of legume technology intervention ($p<0.05$), the total area cultivated ($p<0.01$) and size of the household ($p<0.05$). In addition, being a member of a farmers' association ($p<0.05$) and visits by extension officers ($p<0.01$) were statistically and significantly associated with willingness to pay for improved legume technologies available in the study area. It can be concluded that, availability of legume technology intervention, the total area cultivated and size of the household determines adoption of improved legume technology, being a member of a farmers' association and visits by extension officers determines willingness to pay for improved legume technologies. Therefore, the government and other stakeholders need to further promote improved legume technologies' intervention, formation of farmers association as well as extension services to enhance adoption and willingness to pay for improved legume technologies.

Keywords: Smallholder farmers, adoption, willingness to pay, improved legume technologies, Tanzania

Introduction

Legume crops play great roles in improving people's livelihood in Tanzania. Legumes act as a good source of food and income of the smallholder farmers (Venance *et al.,* 2016; Nassary *et al.,* 2020), improve soil fertility (Latati *et al.,* 2016) and foreign currency earning through export (Birachi, 2012). Based on their importance various initiatives have been in place to scale up its production and productivity. For example the Agriculture Sector Development Strategy I (ASDS I) aims to facilitate growth of agriculture sector to ensure food security and increased income of smallholder farmers and the nation income (URT, 2001). Similarly, the Agriculture Sector Development Programme phase two (ASDP II) aims to achieve sustainable increase in production, productivity, profitability and competitive value chain of the agricultural sector driven by smallholders (URT, 2016). Despite the above efforts, the legume production rate is 0.19-0.85ton/ha (URT, 2012), 0.7ton/ha (Mutengi and Zingore, 2014) or 0.2-2.5ton/ha (Nassary *et al.,* 2020) which is quite low compared to reported production potential of 1.5-3.5ton/ha (Mutengi and Zingore, 2014; Nassary *et al.,* 2020). Therefore, various reasons contribute to the low productivity of legume crops including the use of poor quality seeds (Gyan, 2018). Other researchers reported poor adoption of the technology due to low level of education of the farmer, small size of land cultivated, costs associated on accessing the technology and the farmer if doesn't see the importance of the technology (Niassy *et al.,* 2020).

In order to increase legume production and productivity in Tanzania, the Scale-up Improved Legume Technologies (SILT) project in the year 2015/16 used multi-media approaches and other extension methods to scale up the use of improved legume technologies (MLE, 2016). The approaches involved farm visit/field days whereby 461 farmers participated on preparations of demonstration plots in Ndole village, Mvomero District and Ikenge village, Gairo District, Tanzania. In addition, 164 farmers out of 461 who participate on the preparation of demonstration plots during farmer field days received technological briefs (leaflets and brochures). Further, during the implementation of the SILT project cultivation of improved common bean variety (Uyole Njano) was demonstrated and farmers were allowed to participate in all procedures/practices step by step. The procedures involved site selection, land preparation, planting, weeding, herbicide application, fertilizer application, pesticide application, anti-fungal application, harvesting and common bean storage. Further to the above, the distributed technological briefs (leaflets and brochures) contained bean seed varieties with all agronomic directives/practices.

After getting exposed to various agronomic practices and improved legume technologies during SILT project implementation, farmers were advised to apply the same in their farms in order to increase legume production and productivity. The market price for the legume technologies in the area of study during 2015/16 cropping season were 4000 Tanzanian shilling per kg of improved common bean seeds (Uyole Njano, Lyamungo 90 and rose coco/red bean); 2000 Tzs/kg of basal fertilizers (NPK; DAP); 1500 Tzs/kg of boosting fertilizers (UREA); 20 000 Tzs/litre of pesticides (dudubar); 10 000 Tzs/litre of herbicides (round up) and 12 000 Tzs/kg of anti-fungal (Linkomil). However, the adoption and willingness of smallholder farmers to pay for improved legume technologies are yet to be determined or understood. Therefore, the study measured adoption by considering farmers who planted the improved bean varieties available in their environment or nearby agro-dealers after getting exposure to demonstration plots through farm visits and receiving leaflets and brochures. Furthermore, the study assessed the determinants of willingness to pay by considering the responses of farmers who were willing to purchase the technologies (improved common bean seeds, herbicides, fertilizers, pesticides and anti-fungal) at the market price of the particular technology. The study was guided by two hypotheses, the first states "smallholder farmers' adoption of improved legume technologies does not differ between areas with and without intervention" and the second states that "smallholder farmers' willingness to pay for improved legume technologies does not differ between areas with and without intervention".

According to Rogers (2003) cited in Sahin (2006) adoption refers to the decision of full use of an innovation whereas rejection is a decision of not to adopt an innovation. Generally, the adoption process has five stages; (a) Awareness stage, whereby the farmer or potential innovator hears about the technology for the first time (b) Interest building stage in which the farmer seeks more information about the technology (c) Evaluation stage in which the farmer weighs the advantage and disadvantage of using the technology (d) Trial stage which the farmer tests the technology on a small-scale to avoid the risk associated with using the technology (e) Adoption stage in which the farmer applies the technology on a large-scale in preference to the old technologies (Sahin, 2006). In addition, adoption of technologies is influenced by many factors i.e. farm size, expected output, access to credit and extension services (Akudugu *et al.,* 2012), farmers' education level and land size (Niassy *et al.,* 2020).

Furthermore, in measuring willingness to pay the study adopted the concept of Contingent Valuation, a method of estimating the value that a human being commits on accessing or achieving certain products/commodities. Willingness to Pay (WTP) as defined by Hanemann *et al.* (1991) and Kanninen (1993) is the maximum amount that an individual is willing to pay for a good or service. The method gives one room to specify/report his/her WTP to acquire/get certain goods of a certain quality (Lusk, 2003; Shee *et al.,* 2020) (more details in section 2.3 below). This means the technologies with high access cost are most likely to be less accepted and vice versa. Other reported factors that influence willingness of the farmers to pay for the technologies include gender, age, education, farm size, access to credit, being member of farmer based organisations (FBO), income, livestock ownership of household head (Banka *et al.,* 2018) and access to extension services (Shee *et al.,* 2020).

Materials and method

The study was conducted between February and March 2017 in Gairo and Mvomero districts in Morogoro Region, Tanzania. In addition, the above districts were purposively selected because, technological briefs (leaflets and brochures), as well as participation of the farmers in all procedures of preparation of demonstration plots during farmer field days were used on the efforts of scaling up legume technologies during the cropping season in the year 2015/16 (MLE, 2016).

Research design

A cross-sectional research design was used in this study because it allows data to be collected at a single point in time in a given population (Gray, 2014; Kothari and Garg, 2014). In addition, the design allows the determination of relationships between variables; it saves time and provides room for a big sample to be used (Gray, 2014; Kothari and Garg, 2014).

Sampling technique and sample size

Two wards (Kinda Ward in Mvomero District and Rubeho Ward in Gairo District) were purposefully selected due to their involvement in the SILT project implementation during the cropping season in the year 2015/16. Two villages in each ward (one from the area with intervention and the other from the area with no intervention as control group) were purposively selected for the study. A total of 400 respondents were interviewed by using a pre-structured questionnaire of which, 265 were randomly selected from the list of respondents received intervention while 135 were randomly selected from the non-intervention area (Table 1). The sampling unit was the household within the area that received intervention and areas with no intervention. In addition, twelve focus group discussions (FGDs) (3 per each village of study) with a range of 6 – 12 participants per FGD were conducted to gather qualitative information. Further, key informants (KI) (District Agricultural, Irrigation and Cooperative Officers and Ward Extension Officers) in the area of study were interviewed to explore more information about the study.

A random sample size calculation formula developed by Cochran (1977) was used to calculate a representative sample size of smallholder farmers as shown in eq. 1:

$$n = Z^2{}_{\alpha/2} P(1-P)/e^2 \quad (1)$$

Whereby: n=sample size; Z(α/2) = is the probability distribution with the level of significance α=5 per cent; "P" = Proportion of respondents willing to adopt/pay for legume technologies; (1-P) = proportion of smallholder farmers not willing to adopt/pay for legume technologies; and "e" = the level of marginal error.

Then the calculation of the representative sample of the population of smallholders farmers was estimated considering the proportion of smallholder farmers in both control and intervention arms who are willing to adopt/pay for legume technologies =50 per cent, a 95 per cent confidence level or ά =0.05 and acceptable margin of error =0.049. Then, the required sample size is 400.

n = (1.96x1.96x0.5x0.5)/0.0024 = 400).

Table1: Number of respondents selected in Gairo and Mvomero districts

District	Ward	Village	Intervention	People receiving intervention	Sample
Mvomero	Kinda	Ndole	Farmer field days	82	47
			Farmer field days +Technological briefs	44	30
		Makate	No intervention (control village)	00	69
Gairo	Rubeho	Ikenge			
			Farmer field days	215	120
			Farmer field days +Technological briefs	120	68
		Rubeho	No intervention (control village)	00	66
Total				**461**	**400**

Source: Field data, 2017.

Data analysis

The primary data collected through the questionnaire was coded and entered into SPSS software (version 20) and STATA version 16 for analysis. The data was checked for accuracy and the anomalies found were corrected accordingly. Descriptive statistics such as frequencies and percentages were computed. Furthermore, inferential statistics (binary logistic regression model) as given by Agresti (2002) was used to determine the factors influencing adoption of improved legume technologies among smallholder farmers. In addition, Contingent Valuation Method was used to ascertain factors predicting willingness to pay for improved legume technologies among smallholder farmers. The differences/associations were considered statistically significant if the p-value is ≤ 0.05.

The binary logistic regression model was as specified below:

$$Logit\left(Pi\right)=\log\left(Pi/1-Pi\right)=b_0+b_1x_1+b_2x_2+b_1x_1+...b_kx_k \quad .....(2)$$

Logit (Pi) = in odds (event) that is the natural log of the odds of an event (adoption) occurring

Pi = Prob (event), that is the probability that the event will occur

1-Pi = Prob (no-event), that is the probability that the event will not occur

b0 = Equation's constant

b1-bk = Coefficient of the independent variables

k = Number of the independent variable

x1 to xk = Independent variables entered in the model

x1 = Number of people in a household (household size)

x2 = Sex of the respondent dummy which takes value '1' if is a male and value '0' otherwise

x3 = Age of the household head in years

x4 = Marital status of the respondent dummy which takes value '1' if married and value '0' otherwise

x5 = Education level of the respondent dummy which takes value '1' for primary, '0' otherwise

x6 = Type of intervention dummy which takes value '1' if received intervention and value '0' otherwise

x7 = Revenue accrued from other income-generating activities (IGA)

x8 = Actual land cultivated (acres)

x9 = Membership to farmers association dummy which takes value '1' if member and value '0' otherwise

x10 = Access to extension service dummy which takes value '1' if accessed and value '0' otherwise

x11 = Borrowing money for farming dummy (value '1' if ever received credit and value '0' otherwise)

Analytical framework for willingness to pay

During the study in February to March 2017 a structured questionnaire was designed to collect information for accuracy economic valuation of the underlying legume technologies. Four initial bid prices prevailing market price (for example 25, 50, 75 and 100% above and below the market price) were randomly assigned to each participating respondent across all evaluated six legume technologies. Therefore, the initial bid price response was coded as "Yes", "No" and when the response was "Yes" or "No" the respondent was supposed to answer the follow-up question with a higher or lower bid price than the initial bid prices. After having all responses, three group prices were considered for more realistic analysis (market price, 50% above market price and 50% below the market price for all technologies) (Table 2).

Table 2: Proposed bid prices for the selected legume technologies

Type of technology	Bid 1	Higher bid (h)	Lower bid (l)
Improved Common bean seeds (Uyole Njano, Lyamungo 90, Rose coco/red bead) - Tzs/kg	4000	6000	2000
Basal fertilizers (NPK; DAP) - Tzs/kg	2000	3000	1000
Boosting fertilizers (UREA) - Tzs/kg	1500	2250	750
Pesticides (dudubar) Tzs/litre	20 000	30 000	10 000
Herbicides (round up) - Tzs/litre	10 000	15 000	5000
Anti-fungal (Linkomil)- Tzs/kg	12 000	18 000	6000

Source: Field data, 2017

Therefore, the evaluation of farmers' willingness to pay for the mentioned legume technologies was conducted using contingent valuation (CV) approach because it has been recommended the best in valuing goods introduced on the markets (Donfouet and Makauddze, 2011; Hanemann *et al.,* 1991; Banka *et al.,* 2018; Shee *et al.,* 2020). Dichotomous CV with follow up questions or a double-bounded (DB) CV model was suggested by Hanemann *et al.* (1991) to be used in order to improve efficiency of estimation.

Therefore it was assumed, the true WTP for the improved legume technologies or an input could be modelled using the linear function in Equation (3):

$$WTP_i(z_i u_i) = z_{i(j)}\beta +_{Ui} \quad ....(3)$$

Where $z_{i(j)}$ is a vector of explanatory variables for respondent i or household j level socio-economic and demographic characteristics, β is the conformable vector of parameters, and Ui is an independently and identically distributed normal error term with mean zero and variance σ2. WTP was not directly observed, but a range of WTP could be identified by using survey responses. Because of the answer to the initial bid, a second bid was given, which was higher than the initial bid for a "Yes" response, and lower for a "No" response. According to Hanemann *et al.* (1991) the initial bid amount is called t_i^1 and the second t_i^2. The WTP for each household would then be in one of the four groups (G) as follows:

(G1) $t_i^1, \leq WTP_i < t_i^2$, if the individual answers yes to the first question and no to the second;

(G2) $t_i^1, \leq WTP_i <$ □, if the individual answers yes both to the first and second questions;

(G3) $t_i^2, \leq WTP_i < t_i^1$, if the individual answers no to the first question and yes to the second;

(G4) $0, \leq WTP_i < t_i^2$, if the individual answers no both to the first and second questions.

The log-likelihood function of the WTP model specified as:

$$\ln L=\sum_{G1}\ln\left[\Phi\left(\frac{t^2-z^{'}\beta}{\sigma}\right)-\Phi\left(\frac{t^1-z^{'}\beta}{\sigma}\right)\right]+\sum_{G2}\ln\left[1-\Phi\left(\frac{t^2-z^{'}\beta}{\sigma}\right)\right]..(4)$$

$$\sum_{G3}\ln\left[\Phi\left(\frac{t^1-z^{'}\beta}{\sigma}\right)-\Phi\left(\frac{t^2-z^{'}\beta}{\sigma}\right)\right]+\sum_{G4}\ln\left[\Phi\left(\frac{t^2-z^{'}\beta}{\sigma}\right)\right]$$

Where Φ is the standard normal cumulative distribution function. Using maximum likelihood estimation, the separate interval-censored models for legume technologies were estimated (Lopez-Feldman, 2012; Shee, *et al.,* 2020). β ̂ and σ ̂ were directly estimated from which WTP could be indirectly estimated. Therefore, average WTP can be obtained by E(WTP) = z'(β,) ̂ where β ̂ is the vector of parameter estimates.

Result and discussion

Distribution of smallholder farmers who adopted improved legume technology

The study results (Fig.1) show that about a quarter of the respondents adopted at least one out of three types of improved common bean seeds available in the study area. Again, the study found that the level of adoption differs across the respondent types. The adoption was high in group with demo/farmer field days and technological briefs intervention (35.7%) and low in non-intervention area (7.5%). The study results (Fig. 1) further show that the most adopted bean seeds were Lyamungo 90 (11.2%) followed by Rose-coco/Red bean (10.5%) and Uyole Njano (3%). Generally, the overall percent

Table 3: Descriptive statistics of the variables in the model (n=400)

Variable	Description	Values	Expectations	Mean	Std. Dev.	Min	Max
V1_HHS	Household size	Continuous variable (count)	+	4.75	1.742	1	14
V2_Sex	Sex of respondent	‘1’ if is a male, ‘0’ otherwise	+	0.88	0.328	0	1
V3_Age	Age of respondent (yrs)	Continuous variable (count)	-	39.79	12.165	18	79
V4_MST	Marital status of respondent	‘1’ if married, ‘0’ otherwise	-	0.84	0.372	0	1
V5_EDU	Education of respondent	‘1’ primary and above, ‘0’ otherwise	+	0.83	0.376	0	1
V6_Intvn	Technology intervention	'1' if received intervention, '0' otherwise	+	0.67	0.473	0	1
V7_TIGA	Total income accrued from IGA (Tzs)	Continuous variable (count)	+	788002	545115.5	0	4710000
V8_ TARCULT	Total area cultivated (acres)	Continuous variable (count)	+	1.2	1.1	0.2	10.0
V9_ FMASSOC	Member of farmers' association	‘1’ member, ‘0’ otherwise	+	0.1	0.294	0	1
V10_ EXTVISIT	Extension Officer visit	‘1’ accessed, ‘0’ otherwise	+	0.07	0.26	0	1
V11_ BORROW	Borrowing money for farming	‘1’ ever received credit, '0' otherwise	+	0.23	0.418	0	1

Source: Field data 2017

of adoption was less than a quarter (23.8%) though this seems to be low; it could be seen as high based on the fact that the intervention was in the first year of implementation (initial stage). Therefore, it is hoped that as time passes many more farmers may adopt. Another study (Abebe and Bekele, 2015) argued that the rate of adoption can be understood concerning the duration of technology intervention.

negative association with adoption of improved common bean technologies. The above results is contrary to what reported by Akudugu *et al.* (2012) that access to credit for farming enhances adoption of the technology.

Generally, the results imply that, total area cultivated and household size influencing smallholder farmers' adoption of improved common bean technologies in line with the intervention. Therefore, the project intervention has played a great role in changing smallholder farmers' behaviour/attitude towards the adoption of improved common bean seeds because it is the first significant factor with a high Wald statistic value, followed by the total area cultivated. The observation is also supported by other studies (Akudugu *et al.,* 2012; Challa and Tilahun, 2014; Tegegne *et al.,* 2017) whereby it has been reported that farm size (total area cultivated) have a significant impact on the adoption of agricultural technologies. The study results contrast with Uaiene *et al.* (2009) who reported that borrowing money from credit financial institutions is a major determinant of the adoption of agricultural technologies. Based on the study results, the null hypothesis which states that "Smallholder farmers' adoption of improved legume technologies does not differ between the area with and without intervention" is rejected.

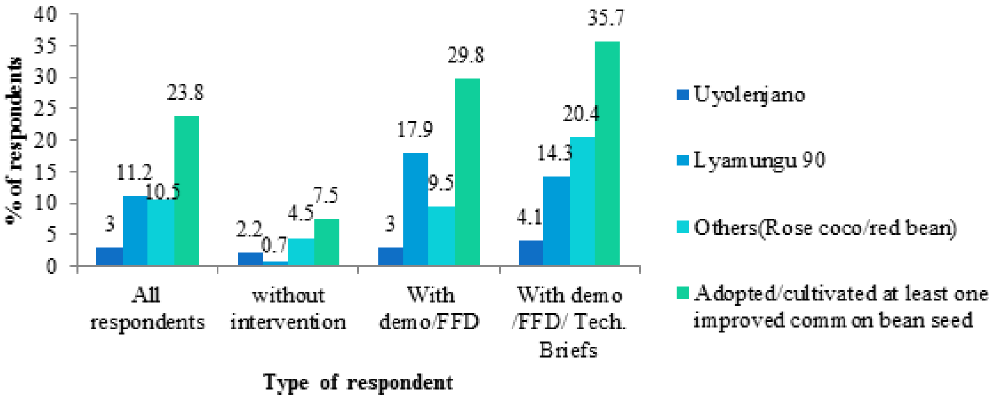

Figure 1: Distribution of smallholder farmers by their adoption of improved common bean seeds in 2015/16 (n=400)
Source: Field data 2017

Determinants of adoption of common bean seeds

Study findings (Table 4) show that there was a significant association ($p<0.01$) between the availability of legume technology intervention, the total area cultivated ($p<0.05$), household size ($p<0.05$) and adoption of improved common bean technologies. Study results by Nguezet *et al.* (2011) also reported that household size and area cultivated (farm size) influence the adoption of agricultural technologies. Furthermore, Abate *et al.* (2011) and FAO (2015) argue that the availability of relevant technologies intervention is the foundation for smallholder farmers' adoption of agricultural technologies. In addition, the Logistic regression results (Table 4) show that total revenue from other sources of income ($p<0.01$) have zero influence on adoption of improved common bean technologies while borrowing money for farming ($p<0.05$) was

Table 4: Determinants for adopting improved common bean seeds by surveyed households

Factors	B	Std. Err.	Wald	Df	Sig.	Exp(B)	95% CI	
							Lower	Upper
Household size (X1)	0.186	0.081	5.247	1	0.022**	1.205	1.027	1.413
Sex of respondent dummy (X2)	-0.547	0.784	0.488	1	0.485	0.578	0.124	2.689
Age of respondent (X3)	-0.002	0.012	0.021	1	0.884	0.998	0.974	1.023
Marital status of respondent dummy (X4)	0.822	0.729	1.270	1	0.260	2.274	0.545	9.489
Education of respondent dummy (X5)	0.172	0.358	0.231	1	0.631	1.188	0.589	2.393
Technology intervention dummy (X6)	1.667	0.375	19.792	1	0.000***	5.297	2.541	11.042
Total income accrued from IGA (X7)	0.000	0.000	7.945	1	0.005***	1.000	1.000	1.000
Total area cultivated (acres) (X8)	0.527	0.139	14.402	1	0.000***	1.693	1.290	2.223
Member of an association dummy (X9)	0.122	0.474	0.066	1	0.797	1.129	0.446	2.861
Extension Officer visit dummy (X10)	0.099	0.498	0.040	1	0.842	1.104	0.416	2.929
Borrowing money for farming (X11)	-0.857	0.379	5.123	1	0.024**	0.424	0.202	0.891
Constant	-3.482	0.819	18.095	1	0.000***	0.031		

MODEL SUMMARY: Cox & Snell R^2= 0.171, Nagelkerke R^2= 0.257, Hosmer and Lemeshow Test 0.389, p= 0.000, -2 Log likelihood = 363.581. Overall percentage (%) of correctness of the model = 78.5
Source: Field data 2017

Determinants for willingness to pay for improved legume technologies

Distribution of farmers willing to pay (WTP) bid prices and responses

The results (Table 5) show that less than half of respondents interviewed were willing to pay for boosting fertilizers (UREA) at the initial market price and about a quarter were willing to pay improved common bean seeds. Generally, the results in table 5 show a high percentage that farmers were willing to pay for improved legume technologies at the second bid price. This means, respondents answered "No" to the first bid but also answered "Yes" to the second bid which was set 50% below the market price. Therefore, respondents' willingness to pay for the legume technologies increase as the value of goods decreases. The results in Table 5 shows, technologies that had a higher per cent of acceptance were herbicides with mean 8850Tzs/litre (12% below prevailing market price); basal fertilizers (NPK; DAP) at 1540Tzs/kg (23% below the prevailing market price) and improved common bean seeds with mean 3320 (17% below the prevailing market price).

Determinants of smallholder farmers' willingness to pay (n=400)

The study findings (Table 6) show that there was a significant association between revenues accrued from other income generating activities (IGA) being a member of farmers association and willingness to pay for improved legume technologies. The above conform to what Banka

Table 5: Distribution of farmers willing to pay (WTP) bid prices and responses (n=400)

Improved common bean technologies	n(%)	Mean	Std. Dev.
Bid for the first WTP question (WTP_1st) (TZS) 4000Tzs/kg	-	4000	0.0
Response to WTP_1st is YES (%)	132(33)	0.33	0.471
Bid for the second WTP question (WTP_2nd) (TZS) h(6000); l(2000)/kg	-	3320	1883.21
Response to WTP_2nd is YES (%)	202(50.5)	0.51	0.501
Basal fertilizers (NPK; DAP)		**Mean**	**Std. Dev.**
Bid for the first WTP question (WTP_1st) (TZS) 2000/kg	-	2000	0.0
Response to WTP_1st is YES (%)	108(27)	0.27	0.445
Bid for the second WTP question (WTP_2nd) (TZS) h(3000); l(1000)/kg	-	1540	889.031
Response to WTP_2nd is YES (%)	206(55.5)	0.52	0.5
Boosting fertilizers (UREA)		**Mean**	**Std. Dev.**
Bid for the first WTP question (WTP_1st) (TZS) 1500/kg	-	1500	0.0
Response to WTP_1st is YES (%)	170(42.5)	0.43	0.50
Bid for the second WTP question (WTP_2nd) (TZS) h(2250); l(750)/kg	-	1387.5	742.44
Response to WTP_2nd is YES (%)	155(38.8)		
Pesticides		**Mean**	**Std. Dev.**
Bid for the first WTP question (WTP_1st) (TZS) 20000/litre	-	20000	0.0
Response to WTP_1st is YES (%)	52(13)	0.13	0.34
Bid for the second WTP question (WTP_2nd) (TZS) h(30000); l(10000)/litre	12600	6734.49	
Response to WTP_2nd is YES (%)	138(34.5)	0.35	0.48
Herbicides		**Mean**	**Std. Dev.**
Bid for the first WTP question (WTP_1st) (TZS) 10000Tzs/litre	-	10000	0.0
Response to WTP_1st is YES (%)	154(38.5)	0.39	0.49
Bid for the second WTP question (WTP_2nd) (TZS) h(15000); (5000)/litre	-	8850	4872.05
Response to WTP_2nd is YES (%)	241(60.3)	0.6	0.49
Anti-fungal		**Mean**	**Std. Dev.**
Bid for the first WTP question (WTP_1st) (TZS) 12000Tzs/kg	-	12000	0.0
Response to WTP_1st is YES (%)	44(11)	0.11	0.31
Bid for the second WTP question (WTP_2nd) (TZS) h(18000); l(6000)/kg	-	7320	3759.38
Response to WTP_2nd is YES (%)	138(34.5)	0.35	0.476.0

Source: Field data 2017

et al. (2018) reported that being a member of farmer based organisations increases the willingness to pay for agricultural technologies. In addition, there was a significant association between availability of legume technology intervention ($p<0.01$) and smallholder farmers' willingness to pay for boosting fertilizers (UREA). Furthermore, the study results show that there was a significant association between being a member of farmers' association ($p<0.05$), visits by an extension officer ($p<0.05$) and smallholder farmers' willingness to pay for pesticides. The findings further show that there was a significant association between marital status of respondents ($p<0.05$), visits by an extension $p<0.01$ and smallholder farmers' willingness to pay for herbicides. The results conform to Chuma *et al.* (2019) results that married farmers (marital status) were willing to pay for the agricultural technology. The study findings (Table 6) show that there was a significant association between being a member

Table 6: Factors associated with willingness to pay for improved legume technologies (n=400)

Factors	Improved Common bean seeds	Basal fertilizers (NPK; DAP)	Boosting fertilizers (UREA)	Pesticides	Herbicides	Anti-fungal
Household size (number of member in a HH)	18.882 (71.321)	28.255 (28.493)	1.825 (24.954)	-325.937 (324.346)	-77.48 (188.673)	2.88 (184.124)
Sex of respondent dummy	602.696 (549.191)	-81.987 (223.463)	-79.253 (195.48)	3412.444 (2670.201)	-1344.401 (1487.815)	-810.392 (1436.813)
Age of respondent (years)	-10.056 (10.298)	-3.31 (4.037)	0.643 (3.621)	-	-18.995 (27.426)	10.137 (26.719)
Marital status of respondent dummy	-98.353 (486.803)	222.112 (198.885)	156.19 (174.403)	814.668 (2315.487)	2731.6** (1317.542)	979.739 (1281.669)
Education of respondent dummy	309.775 (313.903)	-	19.49 (109.41)	443.936 (1496.209)	409.907 (834.506)	317.616 (814.06)
Technology intervention dummy	-758.85*** (244.09)	173.53* (98.256)	224.763*** (86.278)	-947.787 (1172.875)	577.067 (654.251)	65.3 (630.5)
Total income accrued from IGA (Tzs)	0.001** (0)	-0.0001**(0)	-0.0001*** (0)	-0.0001 (0.001)	-0.001 (0.001)	-0.0001 (0.001)
Total area cultivated (acres)	-3.907 (109.365)	50.119 (42.488)	38.755 (37.691)	441.721 (506.137)	-138.16 (292.20)	297.097 (269.596)
Member of farmers' association dummy	779.78** (398.17)	154.171 (158.986)	203.53 (138.567)	3845.985** (1804.749)	1822.401* (1074.448)	2003.247** (975.706)
Extension Officer visit dummy	128.666 (435.404)	203.329 (174.888)	198.156 (153.096)	4446.012** (2015.577)	3290.651*** (1207.06)	3186.948*** (1076.673)
Borrowing money for farming dummy	-306.521 (435.404)	95.52 (111.777)	-28.16 (97.916)	1953.74 (1313.183)	857.405 (750.35)	716.085 (708.186)
Constant	3233.371***	1326.932***	1111.81***	5285.323*	8825.005***	3933.526**
Sigma	2092.745***	825.852***	729.066***	9338.149***	5591.443***	4962.177***
Number of observations	400	400	400	400	400	400
Log likelihood	-519.64378	-465.95174	-504.33661	-392.83452	-530.8034	-372.03009
chi2	28.45	18.34	24.73	22.14	23.59	19.81
p	0.0028	0.0494	0.0100	0.0144	0.0146	0.0481

NB: Number outside the bracket refers to coefficient while the number in bracket indicate Standard error
****, **, * are significance levels at 1%, 5%, and 10%, respectively.*
Source: Field data 2017

of farmers' association ($p<0.05$), visits by an extension officer ($p<0.01$) and smallholder farmers' willingness to pay for anti-fungal. The findings conform to what Alhassan *et al.* (2016) and Shee *et al.* (2020) reported that contact between farmers and extension workers enhance willingness to pay for the technology. Further to the above, the study results (Table 6) show a negative influence between availability of legume technology intervention ($p<0.01$) and willingness to pay for improved common bean seeds, though the variable was expected to have positive influence. In addition, the results show negative influence between total income from IGA ($p<0.05$) and willingness to pay for the basal and boosting fertilizers. Based on the negative influences of technology intervention on the willingness to pay for improved common been seeds the study failed to reject the null hypothesis which states that "smallholder farmers' willingness to pay for improved legume technologies does not differ between the area with and without intervention".

Conclusions and recommendations

This manuscript has assessed the determinants of smallholder farmers' adoption and willingness to pay for improved legume technologies in Tanzania. Six technologies were evaluated during the study such as improved common bean seeds (Uyole Njano, Lyamungo 90 and rose coco/red bean); basal fertilizers (NPK; DAP); boosting fertilizers (UREA); pesticides (dudubar); herbicides (round up) and anti-fungal (Linkomil). The results show that availability of legume technology intervention, the total area cultivated and size of the household determines adoption of improved legume technology. In addition, less than half of respondents interviewed were willing to pay for boosting fertilizers (UREA) at the initial market price while about a quarter were willing to pay for herbicides and improved common beans seeds at the initial market price. In general a high acceptance of more than 50% of the farmers willing to pay for improved legume technologies were observed at second bid price for herbicides, basal fertilizers and improved common bean technology with their mean bid price below the prevailing market price. This implies that, respondents' willingness to pay for the legume technologies increase as the value of goods decreases. In addition, the study revealed a significant association between availability of legume technology intervention, marital status of household head, being a member of a farmers' association and visits by extension officers as determinants of willingness to pay for improved legume technologies.

Generally the study recommends that, the government and other stakeholders should insist more on improving extension services in order to increase the rate of adoption and willingness to pay for agricultural technologies. Various stakeholders (public and private organisations included) should continue to promote improved legume technologies and the formation of farmers association to enhance willingness to pay for improved legume technologies. Smallholder farmers should be sensitised to look on the alternative sources of income because doing so can help them to get extra income which can be used to access improved common bean seeds to increase adoption. The government and other stakeholders should insist more on input subsidising in order to minimise the costs associated on accessing agricultural inputs.

Acknowledgements

The authors would like to acknowledge the participation of smallholder farmers in Mvomero and Gairo districts, Tanzania by providing useful information. Authors also acknowledge the financial support from the International Development Research Centre (IDRC) and the Canadian International Food Security Research Fund (CIFSRF), field and technical assistance obtained from the International Institute of Tropical Agriculture (IITA) and the Sokoine University of Agriculture (SUA).

References

Abate, T., Shiferaw, B., Gebeyehu, S., Amsalu, B., Negash, K., Assefa, K., Eshete, M., Aliye, S. and Hagmann, J. (2011). A systems and partnership approach to agricultural research for development Lessons from Ethiopia. Outlook on Agriculture, 40(3): 213–220.

Abebe, Y. and Bekele, A. (2015). Analysis of adoption spell of improved common bean varieties in the central rift valley of Ethiopia: A duration model approach. *Journal of Agricultural Economics Development,* 4(3): 37–43.

Agresti, A. (2002). Categorical data analysis, 2nd edn.Wiley, Hoboken.

Akudugu, M.A., Guo, E. and Dadzie, S.K. (2012). Adoption of Modern Agricultural Production Technologies by Farm Households in Ghana: What Factors Influence their Decisions? *Journal of Biology, Agriculture and Healthcare,* 2(3): 1-13.

Alhassan, N.J., Samuel, A.D., Franklin, N.M. and Isaac, G.K.A. (2016). Commercializing innovations from agricultural research in Northern Ghana and farmers' willingness to pay. *African Journal of Business Management,* 10(7):140–150.

Banka, M., Aidoo, R., Abaidoo, R.C., Fialor, S.C. and Masso, C. (2018). Willingness to Pay for Biofertilizers among Grain Legume Farmers in Northern Ghana. *Journal of Scientific Research and Reports,* 19(1): 1-13.

Birachi, E. (2012). Value chain analysis of beans in eastern and southern Africa: Building partnerships for impact through research on sustainable intensification of farming systems. International Institute of Tropical Agriculture. 21pp.

Challa, M. and Tilahun, U. (2014). Determinants and impacts of Modern Agricultural Technology Adoption in West Wollega: The Case of Gulliso District. *Journal of Biology, Agriculture and Healthcare,* 4(20): 63-78.

Chuma, T., Mudhara, M. and Govereh, J. (2019). Factors determining smallholder farmers' willingness to pay for a metal silo in Zimbabwe. Agricultural Economics Association of South Africa. 16pp

Cochran, W.G. (1977). Sampling Techniques (3rded.). New York: Wiley. [http://hbanaszak.mjr.uw.edu.pl/StatRozw/Books/Cochran_1977_Sampling%20Techniques.pdf] site visited on 30/9/2016.

Donfouet, H.P.P, Makauddze, E.M. (2011). The economic value of the willingness to pay for a community-based prepayment scheme in rural Cameroon. Research Paper No.3 of 2021.

FAO (Food and Agriculture Organization of the United Nations) (2015). Food Security Impact of Agricultural Technology Adoption under Climate Change: Micro-Evidence from Niger. Rome. 139pp.

Gray, D.E. (2014). Doing Research in the Real World. Third Edition. SAGE Publications Ltd, London. 729pp.

Gyan, K. (2018) Farmers' Willingness to Pay for Soya Bean Production Inputs in Northern Ghana: A Thesis Submitted In Partial Fulfilment of the Requirements for The Award Of Master Of Philosophy In Innovations Communication. The Department of Agricultural Extension Rural Development and Gender Studies, Faculty of Agribusiness and Communication Sciences. 144pp.

Hanemann, M., Loomis, J. and Kanninen, B. (1991). Statistical efficiency of double-bounded dichotomous choice contingent valuation. *American Journal of Agricultural Economics,* 73(4):1255–1263

Kothari, C.R. and Garg, G. (2014). Research Methodology, Methods and Techniques. Third edition (In two colour). New Age International Publishers, New Delhi. 449pp.

Latati, M., Bargaz, A., Belarbi, B., Lazali, M., Benlahrech, S., Tellah, S., Kaci, G., Drevon, J.J. and Ounane, S.M. (2016). The intercropping common bean with maize improves the rhizobial efficiency, resource use and grain yield under low phosphorus availability. *European Journal of Agronomy,* 72, 80–90. [https://doi.org/10.1016/j.eja.2015.09.015].

Lopez-Feldman, A. (2012). Introduction to Contingent Valuation using Stata. MPRA Paper No. 41018. [https://mpra.ub.uni-muenchen.de/41018/ MPRA Paper No. 41018] site visited on 5 December 2021)

Lusk, J.L. (2003). Effects of cheap talk on consumer willingness-to-pay for golden rice. *American Journal of Agricultural Economics,* 85(4): 840-856.

MLE (Monitoring Learning and Evaluation Strategy) (2016). Scale-up of Improved

Legume Technologies through Sustainable Input Supply and Information Systems in Tanzania (SILT). MLE working Group.19pp.

Mutegi, B.J. and Zingore, S. (2014). Closing yield gaps in sub-Saharan Africa through Integrated Soil Fertility Management. IPNI-Sub-Saharan Africa Program. 7pp.

Nassary, Eliakira Kisetu; Baijukya, Frederick; Ndakidemi, Patrick Alois (2020). Productivity of intercropping with maize and common bean over five cropping seasons on smallholder farms of Tanzania. *European Journal of Agronomy,* 113(2020) 125964. [https://doi.org/10.1016/j.eja.2019.125964]

Nguezet, P.M.D., Diagne, A., Okoruwa, V.O. and Ojehomon, V. (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,* 50(3): 267-291.

Niassy, S., Kidoido, M., Mbeche, N.I., Pittchar, J., Hailu, G., Owino, R., Amudavi, D. and Khan, Z. (2020). Adoption and willingness to pay for the push-pull technology among smallholder maize farmers in Rwanda. *International Journal of Agricultural Extension and Rural Development,* 8(3): 001-015.

Rogers, E.M. (1983). Diffusion of Innovation. Third edition. The Free Press. New York. 453pp.

Sahin, I. (2006). A detailed review of Rogers' diffusion of innovations theory and educational technology-related studies based on Rogers' theory. TOJET: *The Turkish Online Journal of Educational Technology,*5(2): 14-23.

Shee, A., Azzarri, C. and Haile, B. (2020). Farmers' Willingness to Pay for Improved Agricultural Technologies: Evidence from a Field Experiment in Tanzania. Sustainability, 12 (216): 1-13

Tegegne, Y., Kassa, W. and Tegegne, B. (2017). Factors Affecting Adoption of Legume Technologies and its Impact on Income of Farmers: The Case of Sinana and Ginir Woredas of Bale Zone. A Thesis for an award of MSc. Degree at Haramaya University. 97pp.

Uaiene, R.N., Arndt, C. and Masters, W.A. (2009). Determinants of agricultural technology adoption in Mozambique. Discussion papers No. 67E. Mozambique. 29pp.

URT (United Republic of Tanzania) (2001). Agricultural Sector Development Strategy. Dar es Salaam, Tanzania. 73pp.

URT (United Republic of Tanzania) (2013). 2012 Population and Housing Census: Population Distribution by Administrative Areas. Dar es Salaam, Tanzania. 244pp.

URT (United Republic of Tanzania) (2016). Agricultural Sector Development Programme Phase Two (ASDP II) – 2016/17 - 2025/26. Dar es Salaam, Tanzania. 205pp.

Venance, S.K., Mshenga, P. and Birachi, E.A. (2016). Factors Influencing on-Farm Common Bean rofitability: The Case of Smallholder Bean Farmers in Babati District, Tanzania. *Journal of Economics and Sustainable Development,* 7(22): 196-201.

Appendices

Appendix I: Factors associated with willingness to pay for improved common bean seeds

	Coef.	**Std. Err.**	**z**	**P>z**	**[95%Conf.**	**Interval]**
Household size	18.882	71.321	0.260	0.791	-120.906	158.669
Sex of respondent dummy	602.696	549.191	1.100	0.272	-473.697	1679.090
Age of respondent (years)	-10.056	10.298	-0.980	0.329	-30.239	10.127
Marital status of respondent dummy	-98.353	486.803	-0.200	0.840	-1052.470	855.764
Education of respondent dummy	309.775	313.903	0.990	0.324	-305.465	925.014
Technology intervention dummy	-758.850	244.090	-3.110	0.002	-1237.258	-280.442
Total income accrued from IGA (Tzs)	0.001	0.000	2.380	0.017	0.000	0.001
Total area cultivated (acres)	-3.907	109.365	-0.040	0.972	-218.259	210.445
Member of farmers' association dummy	779.780	398.170	1.960	0.050	-0.618	1560.178
Extension Officer visit dummy	128.666	435.404	0.300	0.768	-724.710	982.041
Borrowing money for farming dummy	-306.521	280.498	-1.090	0.274	-856.286	243.245
Constant	3233.371	633.085	5.110	0.000	1992.548	4474.194
Sigma	2092.745	105.996	19.740	0.000	1884.996	2300.494

doubleb BID1_BasalF BID2_BasalF Answer1Ba Answer2Ba V1_HHS V2_Sex V3_Age V4_MST V6_Intvn V7_TIGA V8_TARCULT V9_FMASSOC V10_EXTVISIT V11_BORROW

Appendix II: Factors associated with willingness to pay for basal fertilizers

	Coef.	Std. Err.	Z	P>z	[95%Conf.	Interval]
Household size	28.255	28.493	0.990	0.321	-27.591	84.100
Sex of respondent dummy	-81.987	223.463	-0.370	0.714	-519.967	355.993
Age of respondent (years)	-3.310	4.037	-0.820	0.412	-11.222	4.602
Marital status of respondent dummy	222.112	198.885	1.120	0.264	-167.695	611.919
Technology intervention dummy	173.530	98.256	1.770	0.077	-19.049	366.109
Total income accrued from IGA (Tzs)	-0.000	0.000	-2.230	0.026	-0.000	-0.000
Total area cultivated (acres)	50.119	42.488	1.180	0.238	-33.156	133.393
Member of farmers' association dummy	154.171	158.986	0.970	0.332	-157.435	465.777
Extension Officer visit dummy	203.329	174.888	1.160	0.245	-139.446	546.103
Borrowing money for farming dummy	95.520	111.777	0.850	0.393	-123.559	314.599
Constant	1326.932	222.285	5.970	0.000	891.262	1762.602
Sigma	825.852	40.113	20.590	0.000	747.232	904.472

doubleb BID1_BasalF BID2_BasalF Answer1Ba Answer2Ba V1_HHS V2_Sex V3_Age V4_MST V6_Intvn V7_TIGA V8_TARCULT V9_FMASSOC V10_EXTVISIT V11_BORROW

Appendix III: Factors associated with willingness to pay for boosting fertilizers (UREA)

	Coef.	Std. Err.	Z	P>z	[95%Conf.	Interval]
Household size	1.825	24.954	0.070	0.942	-47.083	50.734
Sex of respondent dummy	-79.253	195.480	-0.410	0.685	-462.387	303.882
Age of respondent (years)	0.643	3.621	0.180	0.859	-6.455	7.741
Marital status of respondent dummy	156.190	174.403	0.900	0.370	-185.633	498.013
Education of respondent dummy	19.490	109.410	0.180	0.859	-194.950	233.930
Technology intervention dummy	224.763	86.278	2.610	0.009	55.661	393.865
Total income accrued from IGA (Tzs)	-0.000	0.000	-2.960	0.003	-0.000	-0.000
Total area cultivated (acres)	38.755	37.691	1.030	0.304	-35.118	112.629
Member of farmers' association dummy	203.530	138.567	1.470	0.142	-68.055	475.116
Extension Officer visit dummy	198.156	153.096	1.290	0.196	-101.907	498.219
Borrowing money for farming dummy	-28.160	97.916	-0.290	0.774	-220.072	163.751
Constant	1111.810	221.008	5.030	0.000	678.642	1544.978
Sigma	729.066	36.000	20.250	0.000	658.508	799.625

doubleb BID1_UREA BID2_UREA Answer1UREA Answer2UREA V1_HHS V2_Sex V3_Age V4_MST V5_EDU V6_Intvn V7_TIGA V8_TARCU LT V9_FMASSOC V10_EXTVISIT V11_BORROW

Appendix IV: Factors associated with willingness to pay for pesticides

	Coef.	Std. Err.	Z	P>z	[95%Conf.	Interval]
Household size	-325.937	324.346	-1.000	0.315	-961.644	309.769
Sex of respondent dummy	3412.444	2670.201	1.280	0.201	-1821.053	8645.942
Marital status of respondent dummy	814.668	2315.487	0.350	0.725	-3723.603	5352.939
Education of respondent dummy	443.936	1496.209	0.300	0.767	-2488.581	3376.452
Technology intervention dummy	-947.787	1172.875	-0.810	0.419	-3246.580	1351.006
Total income accrued from IGA (Tzs)	0.000	0.001	0.280	0.780	-0.002	0.002
Total area cultivated (acres)	441.721	506.137	0.870	0.383	-550.289	1433.732
Member of farmers' association dummy	3845.985	1804.749	2.130	0.033	308.742	7383.228
Extension Officer visit dummy	4446.012	2015.577	2.210	0.027	495.553	8396.471
Borrowing money for farming dummy	1953.740	1313.183	1.490	0.137	-620.051	4527.530
Constant	5285.323	2734.589	1.930	0.053	-74.372	10645.020
Sigma	9338.149	596.453	15.660	0.000	8169.122	10507.180

doubleb BID1_PES BID2_PES Answer1Pes Answer2Pes V1_HHS V2_Sex V4_MST V5_EDU V6_Intvn V7_TIGA V8_TARCULT V9_FMASSOC V10_EXTVISIT V11_BORROW
V7_TIGA V8_TARCULT V9_FMASSOC V10_EXTVISIT V11_BORROW

Appendix V: Factors associated with willingness to pay for herbicides

	Coef.	Std. Err.	Z	P>z	[95%Conf.	Interval]
Household size	-77.480	188.673	-0.410	0.681	-447.272	292.312
Sex of respondent dummy	-1344.401	1487.815	-0.900	0.366	-4260.465	1571.663
Age of respondent (years)	-18.995	27.426	-0.690	0.489	-72.748	34.758
Marital status of respondent dummy	2731.600	1317.542	2.070	0.038	149.265	5313.935
Education of respondent dummy	409.907	834.506	0.490	0.623	-1225.695	2045.509
Technology intervention dummy	577.067	654.251	0.880	0.378	-705.241	1859.376
Total income accrued from IGA (Tzs)	-0.001	0.001	-1.430	0.153	-0.002	0.000
Total area cultivated (acres)	-138.160	292.202	-0.470	0.636	-710.865	434.545
Member of farmers' association dummy	1822.401	1074.448	1.700	0.090	-283.479	3928.281
Extension Officer visit dummy	3290.651	1207.060	2.730	0.006	924.857	5656.444
Borrowing money for farming dummy	857.405	750.350	1.140	0.253	-613.253	2328.064
Constant	8825.005	1688.451	5.230	0.000	5515.703	12134.310
Sigma	5591.443	288.417	19.390	0.000	5026.155	6156.730

doubleb BID1_Herb BID2_Herb Answer1Herb Answer2Herb V1_HHS V2_Sex V3_Age V4_MST V5_EDU V6_Intvn V7_TIGA V8_TARCULT V9_FMASSOC V10_EXTVISIT V11_BORROW

Appendix VI: Factors associated with willingness to pay for anti-fungal

	Coef.	**Std. Err.**	**Z**	**P>z**	**[95%Conf.**	**Interval]**
Household size	2.880	184.124	0.020	0.988	-357.997	363.756
Sex of respondent dummy	-810.392	1436.813	-0.560	0.573	-3626.493	2005.709
Age of respondent (years)	10.137	26.719	0.380	0.704	-42.231	62.504
Marital status of respondent dummy	979.739	1281.669	0.760	0.445	-1532.287	3491.764
Education of respondent dummy	317.616	814.065	0.390	0.696	-1277.922	1913.153
Technology intervention dummy	65.300	630.574	0.100	0.918	-1170.603	1301.202
Total income accrued from IGA (Tzs)	-0.000	0.001	-0.610	0.544	-0.001	0.001
Total area cultivated (acres)	297.097	269.596	1.100	0.270	-231.302	825.496
Member of farmers' association dummy	2003.247	975.706	2.050	0.040	90.899	3915.595
Extension Officer visit dummy	3186.948	1076.673	2.960	0.003	1076.708	5297.188
Borrowing money for farming dummy	716.085	708.186	1.010	0.312	-671.934	2104.103
Constant	3933.526	1640.038	2.400	0.016	719.109	7147.942
Sigma	4962.177	324.227	15.300	0.000	4326.703	5597.651

doubleb BID1_AFU BID2_AFU Answer1AFU Answer2AFU V1_HHS V2_Sex V3_Age V4_MST V5_EDU V6_Intvn V7_TIGA V8_TARCULT V9_FMASSOC V10_EXTVISIT V11_BORROW