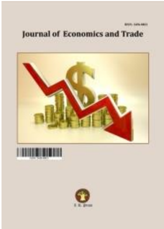

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Adoption of Agricultural Technologies of the Barley-Based Farming System in Ethiopia

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Authors' contributions

This work was carried out in collaboration between both authors. Authors EG, SD contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

Background: Improving the well-being of small holder farmers through the promotion of improved technologies has gained increased attention in recent times. Despite the high production potential and the crop's economic importance, adoption and diffusion of barley technologies are constrained by various factors. The purpose of the study is to identify determinants of adoption of agricultural technologies in the barley-based farming system of Ethiopia, with the specific objectives of identifying factors affecting Agricultural technology package choice and assessing the inter-dependency between the technologies.
Methods: The study was carried out in highland areas of Ethiopia. The study used data from the Ethiopian socio-economic survey of 693 sample households. The descriptive and econometric analytical tools were applied. The research employed the Multivariate probit model to estimate the factors that influenced the adoption of agricultural technologies choice for barley production.

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Results: The descriptive result of the study identified that variables, like education, family size, credit access, farm size, farm income, and farmer's age play significant roles across barley technologies. The results showed that about 66.96%, 58.59%, 75.18%, 65.17%, and 75.99% of sample house hold adopted an improved variety of barley, by using urea, DAP, chemical, manure, and crop rotation, respectively. Multivariate probit model results showed that the age of the house hold head, soil fertility, farm size, training, and transportation cost affect the adoption of barley technologies negatively and significantly. Sex of the household head, education level of the house hold head, farm income, tropical livestock unit, and access to credit affect the adoption of barley technologies positively and significantly.

Conclusion: Small holder farmers were more likely to succeed than fail in jointly adopting barley technologies. Consequently, government policy and other concerned parties should emphasize on the improvement of the institutional support system and decrease gender disparities in access to such institutions.

Keywords: Adoption; barley; agricultural technologies; multi variate probit model.

ACRONYMS AND ABBREVIATIONS

AgSS : Annual Agricultural Sample Survey
CGIAR : Consultative Group for International Agricultural Research
CSA : Central Statistical Agency
DAP : Di Ammonium Phosphate
EAs : Enumeration Areas
ESS : Ethiopian Socio-Economic Survey
GDP : Gross Domestic Product
ISA : Integrated Survey on Agriculture
LSMS : Living Standard Measurement Study
MoARD : Ministry of Agriculture and Rural Development
MVP : Multi Variate Probit
SPIA : Standing Panel on Impact Assessment

1. INTRODUCTION

Agriculture is the base for the whole socio-economic structure and has the main effect on all other economic sectors of Ethiopia [1] The sound performance of agriculture permits the availability of food crops. This achievement in agriculture does not only signify the adequate acquirement of food crops to attain food security but also heralds a positive aspect of the economy. Regarding this, collective efforts are being geared to securing agricultural outputs of the desired level so that self-reliance in food supply can be achieved and disaster-caused food shortages are contained in the shortest possible time in Ethiopia [2].

Agriculture is a leading sector of the Ethiopian economy which had a higher contribution to the Gross Domestic Product, foreign exchange earnings, and employment. Agriculture is quite supposed to remain a sector that plays a key role in encouraging the overall economic development of the country. This would be comprehended if and only if obstinate efforts are made by the government and other concerned bodies, including farmers to boost agricultural production and productivity [3].

Ethiopian agriculture is dominated by subsistence, low output; low input, and rain-fed farming systems. The use of chemical fertilizer and improved seed is relatively limited despite the government efforts to encourage the adoption of modern, intensive agricultural practices. Low agricultural productivity can be attributed to limited access by small holder farmers to agricultural inputs, financial services, improved production technologies, irrigation and agricultural markets, and more importantly poor land management practices that have led to severe land degradation [4].

Barley is one of the essential food and survival crop in the country; it is an annual crop that is produced in more than 800,000 hectare. Barley is categorized into malt barley and food barley. Malt barley is a vital cash crop for resource-poor households in Ethiopia [5]. Ethiopia commonly produces food barley, with its share estimated to be 90% while that of malt barley has a share of 10% [6].

However, a long history of cultivation and livelihood importance of barley, its productivity has never increased above 2.2 t ha−1, which is about one-third of the potential yield of 6.0 t ha−1 obtained in experimental plots. The declines in soil fertility driven by high rates of soil erosion, sub-optimal fertilizer application rate, nutrient imbalance, and limited access to improved varieties are among the major limiting factors claimed for low food barley productivity in Ethiopia [7].

Adoption of agricultural technologies in developing countries appeals to substantial consideration since it can offer the basis for rising production and income. The farmers' decision can adopt or reject agricultural technologies based on their purposes and limitations as well as costs and benefits adding to it [8]. Consequently, farmers will adopt only technologies that suit their needs. Numerous factors affect the adoption of agricultural technologies. Among these factors - social, economic, and institutional, are the main variables that affect adoption. Accordingly, recent studies have been made on the determinants of adoption of barley and other crops both in Ethiopia and other countries Ashenafi et al, [9]. Samuel et al, [10] Galmesa, [11] Abiro et al, 2017; Merkineh, [12] Audrey A, [13] Ermias T, [14].

Furthermore, previous studies have focused mainly on factors affecting the adoption of improved variety alone. Barley technology package consisting of improved seed, urea, DAP, fertilizer rate, and crop rotation was introduced to the study area to improve the food security status. Despite such intervention adoption of an improved barley production package is still very low. Besides, there is also variation among farmers in their intensity of adoption of an improved barley production package. However, there is no empirical information about the extent of adoption, various factors influencing adoption, and intensity of use of the package. Therefore, this study was proposed to analyze determinants of adoption and intensity of use of barley production technology package to fill the existing knowledge gap. It assisted in providing policy recommendations on technologies supply based on farmers' input expenditure patterns.It is also possible to drive a demand system for agricultural technologies.

1.1 Objectives of the Study

1. To identify factors affecting agricultural technology package choices.
2. To assess the inter-dependence of barley production technologies.

2. METHODOLOGY

A brief description of the study area, research approach, research design, sampling methods, sources and types of data, methods of data analysis, are presented.

2.1 Description of the Study Area

Ethiopia is the second-most populous country in Africa with an estimated population of more than 100 million. Ethiopia is located in the horn of the continent covering the land with an area of 112.3 million hectares. Agriculture is the main-stay of its economy, accounting for 46.3% of Gross Domestic Product (GDP). Out of the total land area, 16.4 million hectares are allotted for the production of perennial and annual crops [15]. According to Dorosh and Gemessa, 2013, barley, wheat, teff, maize, and sorghum production constitutes the major food crops in the country, accounting for three-fourths of the total area of land under cultivation and 14% of GDP. Coffee, pulses, hides, skins, oil seeds, tea, honey, and bees wax are the major agricultural exports of the country.

2.2 Data Sources, Type, and Methods of Collection

The study was used Ethiopian Socio-economic Survey (ESS) data conducted by the CGIAR Standing Panel on Impact Assessment (SPIA) in collaboration with the LSMS-ISA project and the Central Statistical Agency of Ethiopia in 2015 / 2016 by extracting barley producers. The comprehensive survey was undertaken in four major regions of the country as Amhara, Oromiya, SNNP, and Tigray and also Addis Ababa; quotas were set for the number of EAs in each region. The sample is not representative of each of the small regions, including Somalie, Benshangul Gumuz, Afar, Harari, Gambella, Dire Dawa, and other regions of the country. Moreover, regular statistical reports from sources, like the Ministry of Agriculture and CSA have been reviewed.

2.3 Research Design

The research design of the study was a cross-sectional research design. The survey conducted by ESS was designed to be implemented in two visits following the AgSS field schedule. The qualitative and quantitative data were conducted from sample respondents in all selected areas. In this visit, the post-planting agriculture and livestock questionnaires were administered.

2.4 Sampling Design

The sample was designed in a two-stage probability sample. The first stage of sampling entailed selecting primary sampling units, or CSA Enumeration Areas (EAs). A total of 433 EAs were selected based on probability proportional to the size of the total EAs in each region. For the rural sample, 290 EAs were selected from the AgSS EAs. A total of 43 and 100 EAs were selected for small towns and urban areas, respectively. However, the study was used 693 households by extracting barley producers.

2.5 Method of Data Analysis

In this study, both descriptive statistics and an econometric model were used to analyse the data.

2.6 Descriptive Statistics

Descriptive statistics such as mean, frequencies, percentages, and standard deviation were used to have a clear depiction of the characteristics of sample units. A correlation matrix is also used to check technological complementarities or substitutability's in terms of dependent variables.

2.7 Econometric Model

Different econometric models were applied in the literature to measure determinants of agricultural technology adoption with advantages and short-comings. Linear probability is easiest for binary but difficult disturbance terms. Univariate model has a problem to measure the potential correlation among the unobserved disturbance and relationship between different choices (Lin et al, 2005).

Multinomial logit model needs the choice variables to be mutually exclusive and assumes independence across outcomes [16]. Multinomial probit models require multivariate normal integration to predict unknown parameters (Temesgen et al, 2009) MVP Model is the binary response regression model used to estimate both observed and un-observed influences on dependent variables by several independent variables simultaneously Kariuki & Loy, [17] Koo et al, 2014; Milioti, 2015).

Multivariate probit (MVP) regression was used to estimate the factors that influenced the adoption of agricultural technologies choice for barley production. Statisticians and econometricians view the multivariate probit model used to estimate different correlated binary outcomes simultaneously [18]. Generally, a multivariate model extends to more than two outcome variables just by adding equations. Adoption of specific technologies depends on other technological choices on a similar farm. The MVP simultaneously models the relationship between a set of covariates and each of the different technologies, while allowing un-observed and un-measured factors to be correlated. Correlation among the different adoption decisions may be due to technological complementarities or substitutability. When such correlation occurs, estimates of simple probit models would be in-efficient and biased [19]. In this study, six different agricultural technologies were identified for barley production viz., Improved Seed, Chemical Fertilizer, Urea, DAP, Manure, and Crop Rotation (CR). Therefore the study has six dependent binary variables *yij* for household *i* and plot *j*.

$$y^*ijm = Xijm\,\beta m + \varepsilon ijm \quad m = 1, 2 \ldots 6 \quad (1)$$

$$yijm = 1 \text{ if } y^*_{ijm} > 0 \quad (2)$$

0 if otherwise

Where *y*ijm* is a latent variable that captures the degree to which a farmer views technology *m* as beneficial. This latent variable is assumed to be a linear combination of observed plot and household characteristics, *X ijm*, and un-observed characteristics captured by the stochastic error term, *εijm*. The vector of parameters to be estimated is denoted by *βm*. Given the latent nature of *y*ijm,* estimation is based on observable binary variables *yijm*, which indicates whether or not a farmer used a particular technology in the reference year [19]. A few previous technology adoption studies also used a multivariate probit model, such as Samuel and Shaibu, [10] who analyzed the adoption of improved agricultural technologies among rice farmers in Ghana - A Multivariate Probit Approach. The error terms *εijm* (m = 1, 2 . . . 6) is distributed multivariate normal each with mean 0 and a variance-covariance matrix V, where V has 1 on the leading diagonal, and correlations *pjk* = *pkj* as off-diagonal elements.

$$V = \begin{Bmatrix} 1 & p_{12} & p_{13} & . & . & p_{1k} \\ p_{21} & 1 & p_{23} & . & . & p_{2k} \\ p_{31} & p_{32} & 1 & . & . & p_{3k} \\ . & . & . & 1 & . & p_{4k} \\ . & . & . & . & 1 & p_{5k} \\ p_{j1} & p_{j2} & p_{j3} & p_{j4} & p_{j5} & 1 \end{Bmatrix}$$

P is the pair-wise correlation coefficient of the error terms with regards to any two of the estimated adoption equations in the model. The correlation between the stochastic components of different improved technologies adopted is represented by the off-diagonal elements, e.g. $\rho_{jk,\ and}$ p_{kj} in the variance-covariance matrix [19].

The correlation is based on the principle that adoption of a particular improved practice may depend on another (complementarity or positive correlation) or may be influenced by an available set of substitutes, i.e. negative correlation [20].

Before running the econometric model, the data were tested against econometric problems. Accordingly, the data were checked for multi-collinearity test for all variables was done using Variance Inflation Factor (VIF). However, the value of VIF was low and below 10, which indicates the absence of severe multi-collinearity problem among the explanatory variables.

Moreover, the Breusch-Pagan test [21] was also used to detect the presence of hetero-skedasticity. The test results indicated that there was no problem of hetero-scedasticity in the model.

2.8 Variables Description and Measurements

2.8.1 Dependent variables

The dependent variables consist of dummy variables indicating the adoption of particular technologies (from 1 to 6**),** such as improved seed, chemical fertilizer, urea, DAP, manure, and crop rotation. The multivariate probit model takes binary variables y_{ijm}, which indicate whether or not a farmer used a particular technology.

3. RESULTS AND DISCUSSION

3.1 Descriptive Statistics Results

3.1.1 Demographic characteristics of house holds

The study required to find out the gender and age distribution among the respondents in Ethiopia. The respondents were asked to indicate their gender and age. This was done to assess if demographic characteristics of the respondents had any influence in the adoption of agricultural technology in barley production.

The result presented in Table 1 indicated that 83.98% of the respondents were male-headed, and the rest 16.02% were female-headed. This implies that male-household heads have access of adopting barley technology packages than females who are in most cases restricted to home chores. Therefore, gender equity among the respondents who participated in this study was not achieved. This could also point out the low participation of women in agricultural activities in Ethiopia.

The results show in Table 2 indicated that the mean age of house hold heads was 43 years. This meant that majority of the respondents were mature middle-aged people, which implies most of the barley producers had more experience in adoption of barley production packages.

3.1.2 Socio-economic characteristics

Table 3 provides a summary of socio-economic characteristics status of the households in this study. Household size is a key variable that characterizes farm households. The mean family size and land size of households were 6.94 in man day equivalent and 4.3 ha, respectively. This indicates, the average land holding for barley production was high in the area. Education can affect the productivity of barley farmers and the adoption of agricultural technology packages. Therefore, literate barley producers are estimated to be in a better knowledge and use information which used to develop their adoption of agricultural technologies. According to the survey results, the overall average year of formal schooling of the total sampled household heads had up to only 5 years of formal education. This indicates a low level of formal education among barley farmers in Ethiopia. Findings are shown in Table 3.

Table 1. Sex characteristics of respondents

Sex of Household Head	Frequency	Percent
Male	582	83.98
Female	11	16.02

Source: Own Computation, 2021

Table 2. Age of sample households

Variable	Mean	Standard Deviation	Minimum	Maximum
Age	43.47042	11.72411	21	80

Source: Own Computation, 2021

Table 3. Socio-economic characteristics of sample households

Variables	Mean	Standard Deviation
Family Size	6.943723	3.9795
Education Level	5.005772	2.692845
Farm Size	4.379509	2.532788
Oxen Power	1.379161	1.460921
Land Fragmentation	13.61216	7.470333
TLU	4.440147	3.843299
Total Farm Income	1572.07	3220.39
Transportation Cost	39.41477	100.6367

Source: Own Computation, 2021

On average, a farmer had up to 1.34 oxen in a number, indicates a farmer had a small number of oxen to enrich agricultural activities in the area. Consequently, farmers enforced to rent oxen as require as the size of a farm. Additionally, farmers have 13 numbers of plots, which indicates there is a higher land fragmentation in Ethiopia, having of larger fragmented land it might be difficult to manage a farm and unable to produce quality standard barley grain.

Farm animals are a source of draught power, food, animal dung for organic fertilizer, cash, and used as means of transportation. To help with the analysis, the livestock number was converted to a tropical livestock unit (TLU). The average number of livestock owned by sampled households which were measured by tropical livestock unit (TLU) is 5.4 tropical livestock units. The number of livestock owned accounted for all types of livestock possessed by the household. This indicates the farmers had high livestock units which are important for the source of income of agricultural activities in the area. Hence, a household with large livestock holding can have good access to more draught and it is one of the main cash sources to purchase inputs [22].

Farm income is believed to be the main source of capital for purchasing agricultural technology packages. Thus, those farmers with a relatively higher degree of farm income are more likely to purchase agricultural technologies for barley production. Therefore, a mean of annual income for sample households was 1572.07 birr from crop and livestock sales. This indicates farmers had a lower level of farm income to purchase improved seeds, fertilizers, chemicals, or other agricultural inputs in Ethiopia. Findings are shown in Table 3.

3.1.3 Adoption of agricultural technologies by barley farmer

Table 4 presents different agricultural technologies and levels of adoption practice among barley farmers in Ethiopia. The results reveal that about 58.59% of the respondents practiced urea on barley farm plots. Accordingly, about 75.18% of the samples respondents adopt DAP. Only 19.62% of the farmers practiced chemical on barley production. Moreover, the Table 4 shows that the respondents adopt manure, improved variety, and crop rotation with the adoption rate of 65.37%, 66.96%, and 75.99% respectively. The findings are shown in Table 4.

3.1.4 Adoption and intensity of adoption of barley production package seeding rate

The practice of appropriate seeding rate is one of the most important uses in agricultural production. Excessive or underutilization of seed will result in poor production performance. Generally, research recommends a specified level of seeding rate for a given variety or crop with a given range of seed feasibility [22]. The extension also advises farmers based on this research recommendation. The recommended seeding rate of barley variety is 100 to125 kg per ha vary from region to region [23]. Farmers' adoption of the recommended seeding rate however based on among numerous things on the relevance of the recommended rate itself, availability of quality seeds, uncertainty in its germination percentage, and other household-related socio-economic problems (knowledge / awareness level). The result of the average seeding rate across adoption categories as indicated in Table 5.

Farmers in Ethiopia were found to use varying seeding rates of improved barley variety. There is the variability in the amount of seed-applied per hectare of land among sample respondents. On average, farmers applied 93.31 kg of seed per hectare of land, which is close to barley production recommendation rate.

3.1.5 Fertilizer application package

Barley production, like any other crop, requires the use of different inputs. Urea and DAP are the most important fertilizers used for various crops, to boost the production and productivity of crops. Fertilizer application is one of the most important practices that need to be adopted by barley growers [19]. Moreover, proper application of the recommended rate of urea (50 to 100 kg/ha) depending on N stress level is important to obtain the required yield, while the proper application rate of DAP is 100kg/ha [23]. As far as urea and DAP fertilizers use is concerned, farmers in the area use varying fertilizer rate, which is below the recommendation. The average fertilizer application rate is shown in Table 6.

The average rates of urea application for barley production by sample respondents during the production year was 49.78 kg herewith the standard deviation of 68.99. The mean of DAP applied rates of barley production by sample respondents was 67.07kg/ha. The farmers had used a low level of fertilizer rather as recommended as per hectare as shown in Table 6.

Sample respondents have mentioned different reasons for their use of such low fertilizer rates. In the first place, they were claiming lack of financial capacity and unavailability of fertilizer at the right time was mentioned in the second place. In their view, the amount of fertilizer to be applied per hectare of land depends on attention paid to land preparation and the fertility status of the land. Lack of soil moisture and lack of irrigation facilities may also result in low fertilizer use [19]. It is a consequence for research indicating the need to restudy the previous research recommendation by conducting additional site-specific fertilizer trials.

3.1.6 The relationship between the agricultural technologies – correlations matrix residuals

Table 7 presents the results of the correlation matrix from the multivariate regression. The results indicate that all pairwise coefficients were positively correlated, positive correlation indicating complementarity among the barley production technologies. The relationships amongst all the technologies were significant except for chemical and urea, manure and chemical, improved variety, and chemicals.

Table 4. Agricultural technologies used

Technology	Frequency (No. of Farmers Practicing)	%
Urea	406	58.59
DAP	521	75.18
Chemical	136	19.62
Manure	453	65.37
Improved Variety	464	66.96
Crop Rotation	497	75.99
N=693	--	--

Source: Own Computation, 2021

Table 5. Improved variety rate of application

Variable	Mean	Standard Deviation
Seed Quantity	93.31009	92.47105

Source: Own Computation, 2021

Table 6. Fertilizer rate application

Variable	Mean	Standard Deviation
Urea Quantity	49.7875	68.99082
DAP quantity	51.48904	69.43529

Source: Own Computation, 2021

Table 7. Correlation matrix of the technologies from the multivariate probit model

	Urea	DAP	Chemical	Manure	Improved Variety	Crop Rotation
Urea	1.0000	-	-	-	-	-
DAP	0.5581*	1.0000	-	-	-	-
Chemical F	0.0300	0.1656**	1.0000	-	-	-
Manure	0.8611*	0.6418*	0.1401	1.0000	-	-
Improved V	0.8206*	0.6192*	0.1267	0.9570*	1.0000	-
Crop Rotation	0.6881*	0.8331*	0.1523**	0.8132*	0.7958*	1.000

Source: Own Computation, 2021

There are several positive correlations in Table 7, indicating technological complementarities. The adoption of DAP is positively correlated with the adoption of urea. The adoption of chemicals is positively correlated with the adoption of DAP at a 5% significance level. The adoption of manure is positively correlated with the adoption of urea; DAP, at a 1% level of significance. The adoption of improved variety is positively correlated with the adoption of urea, DAP, and manure, at a 1% level of significance. The adoption of crop rotation is positively correlated with the adoption of urea, DAP, manure, and improved variety, at a 1% significance level. The adoption of crop rotation is positively correlated with the adoption of chemicals, at a 5% significance level. The highest correlation was between the adoption of improved variety and manure (95.70%). Findings are shown in Table 7.

3.2 Results of the Econometric Model

This section presents the econometric results of the study. In this sub-chapter, the results of the multivariate probit model were presented and discussed. Several factors can affect barley farmers' decision to adopt one particular technology or the other. Numerous variables are significant across several places and overtime in amplifying the adoption of technologies by farmers. Many factors are expected to affect the adoption of agricultural technologies based on theoretical models and empirical evidence. Moreover, this section identifies the variables which determine the adoption of agricultural technologies by barley farmers using a multivariate probit model. The findings are shown in Table 8.

Sex of Household Head: As the results indicate the sex of the household head had a positive and significant influence on the adoption of urea at a 1% level of significance, the findings are shown in Table 8. This revealed that being male-headed households have better access to information on barley production technologies and are more likely to adopt urea than female-headed households. Galmesa [11]. probit regression model results revealed that the adoption of improved soya bean production technologies is biased by gender, where male-headed households are more likely to adopt soya bean varieties than their counterpart.

Age of Household Head: Age was negatively related to the adoption of improved variety and adoption of urea at a 5% level of significance, the findings are shown in Table 8. The result of the multivariate probit model indicates that younger households are more likely to give a higher amount of land to improved varieties and more likely to use urea than old-age households**. T**he impact of this result is that younger farmers had a higher probability of adopting new technologies than older barley farmers. Moreover, Samuel et al [10] found a negative effect of age on the adoption of harrowing, irrigation, and bunding. The findings are shown in Table 8.

Education: Education was found to have a positive and significant relationship with the adoption of urea, manure, and improved varieties at 5%, 1%, and 1% level of significance respectively, the results are shown in Table 8. In other words, the result means that higher educational status increases farmers' awareness about the benefits of adopting urea, manure, and improved varieties. A better-educated farmer has more lucrative income sources and thus fewer capital constraints to invest in external inputs. While education had a negative and significant relationship with the adoption of chemicals at a 5% significance level but failed to explain the adoption decision of DAP and crop rotation. Samuel et al [10] using the multivariate probit model to study the adoption of Improved Agricultural Technologies among rice farmers in Ghana concluded that education increases farmers' awareness of improved technologies.

Table 8. Result of multi variate probit model

Variable	Urea		DAP		Chemical		Improved Variety		Manure		Crop Rotation	
	Coefficient	**Standard Error**	**Coefficient**	**Standard Error**	**Coefficient**	**Standard Error**	**Coefficient**	**Standard Error**	**Coefficient**	**Standard Error**	**Coefficient**	**Standard Error**
Age	-0.004**	0.002	-0.001	0.002	0.001	0.001	-0.004**	0.002	-0.003	0.002	-0.004	0.002
Sex	0.341*	0.115	0.206***	0.110	0.156***	0.091	0.261**	0.112	0.245**	0.113	0.232**	0.106
Education	0.030**	0.012	0.003	0.011	-0.024**	0.009	0.039*	0.012	0.037*	0.012	0.004	0.011
Family Size	-0.012***	0.006	-0.009	0.006	0.006	0.005	-0.014**	0.006	-0.013**	0.006	-0.009	0.006
Farm Size	-0.021	0.012	0.007	0.012	0.012	0.010	-0.025**	0.012	-0.025**	0.013	0.001	0.012
Soil Quality	-0.139*	0.041	-0.004	0.039	0.012	0.032	-0.101**	0.039	-0.105*	0.040	-0.029	0.038
Irrigation	-0.097	0.119	-0.125	0.113	0.173***	0.093	-0.056	0.114	-0.002	0.123	-0.105	0.11
Extension Contact	0.207***	0.116	0.171	0.110	-0.258*	0.091	0.090	0.112	0.066	0.114	0.205***	0.107
Credit	0.488*	0.164	0.509*	0.157	0.122	0.129	0.536*	0.158	.0523*	0.162	0.519*	0.152
Training	-0.599*	0.183	-0.539*	0.174	-0.115	0.144	-0.547*	0.176	-0.552*	0.181	-0.610*	0.169
Oxen Power	-0.022	0.021	-0.035***	0.020	0.023	0.016	-0.026	0.020	-0.026	0.020	-0.018	0.019
Land Fragmentation	0.003	0.004	0.0062	0.003	0.005***	0.003	0.002	0.003	0.003	0.003	0.004	0.003
Crop Insurance	0.093	0.090	0.088	0.086	0.071	0.009	0.053	0.087	0.031	0.089	0.059	0.084
Erosion	0.083	0.053	0.060	0.051	0.042**	0.083	0.082	0.051	0.095	0.053	0.041	0.049
TLU	0.011	0.008	0.016**	0.007	0.006	-0.002	0.017**	0.007	0.016**	0.008	0.008	0.007
Income	0.001**	0.000	0.000**	0.000	7.8-06	7.8-06	0.000*	0.006	0.001	0.016	0.003*	0.000
Transportation Cost	-0.000*	0.000	-0.006**	0.000	0.002	0.006	-0.000**	0.005	-0.004**	0.0002	-0.000**	0.000
_cons	1.075	0.276	0.747	0.263	0.217	1.492	1.065	0.266	1.099	0.272	0.787	0.256

Source: Own Computation, 2021

Notes: N = 693; log likelihood = -1892.60239; Wald chi2 (102) = 787.98; likelihood ratio test of rho chi2 (15) = 701.843. ***, ****and ******* represent 1%, 5%, and 10% level of significance respectively

Family Size: Family size was hypothesized to have a positive effect on the adoption of improved variety and manure technologies since the family is the major source of labor for agricultural activities. However, contrary to the prior expectation, it has turned out to influence the adoption of improved variety and manure negatively and significantly at a 5% level of significance, the results are shown in Table 8. Hence, given the higher opportunity cost of labor in Ethiopia, the application of more labor for other jobs will affect the adoption of agricultural technologies for barley production negatively. This finding contradicts the work of Samuel et al [10] who found that household size was significant and correlated positively with the adoption of bunding.

Soil Fertility: The result revealed that soil fertility was negatively and significantly related to the adoption of urea, improved barley variety, and manure at 1%, 5%, and 1% level of significance respectively, the findings are shown in Table 8. The result of the multivariate probit model revealed that the farmers whose farmland was infertile more likely to adopt urea, manure and improved variety than those have fertile soil. Hence, the application of animal manure is used for the restoration of soil fertility and the improvement of crop production. Generally, the application of improved variety, urea, and manure increases the supply of nutrients to the crop and increases the organic matter content of the soil [24].

Farm Size: Farm size was significant and had a negative relationship with the adoption of improved barley variety and manure at a 5% level of significance. Findings are shown in Table 8. Meaning, farmers with bigger farm sizes had a lower probability to adopt improved barley variety and manure compared with those who had smaller farm sizes. The negative correlation between farm size and the probability of adopting improved barley variety and manure is due to the labor-demanding and capital-demanding nature of package approaches and resulting difficulty for poor farmers regardless of their farm sizes (Lucia and Hadush, 2018). This could be so because adopting these technologies would come with extra costs aside cost of seed and labor for manure application [10].

Extension Contact: Household extension contact was only significant and negatively related to the decision to adopt, chemical at 5% level of significance, redundant in explaining the adoption of the other technologies, the findings are shown in Table 8. This finding did not meet the a priori expectation since the agricultural extension is meant to influence technology uptake by farmers. However, Samuel et al [10] posit that the household extension method does not promote cross-learning and experience sharing among farmers from different homes and backgrounds since it is carried out only within the household of the person transmitting the information.

Access to Credit: As the multivariate probit model result indicates it had a positive and significant influence on the adoption of urea, DAP, manure, improved variety, and crop rotation at a 1% significance level. The results are shown in Table 8. The results of multivariate probit indicate that those households who have access to credit are more likely to adopt barley technologies than those who have no access to formal credit. Hence, accessibility of credit from appropriate sources helps farmers to purchase essential agricultural inputs. Rahmeto [22] using the Tobit model to study determinants of adoption of improved haricot bean production package concluded that farmers who have access to credit, are more likely to adopt improved haricot bean technology.

Training: Training was significant and negatively related to the adoption of urea, DAP, improved variety, manure, and crop rotation at a 1% level of significance, the results are shown in Table 8. This implies there is a promotion of inappropriate technology, insufficient adaptive research in the barley-based training section, which might be due to the range of (class, gender, literacy, and location). The weakness in the state-led agricultural training systems has also led to the assumption of responsibility of investigating and disseminating information to farmers in Ethiopia. Contrary to *a priori* expectation, however, access to training access had a significant but negative relationship with the adoption of barley technologies, contradicting the findings of Samuel et al. [10] indicates that farmers' access to agricultural training significantly and positively influenced their adoption of nursery, spacing, line planting, urea briquette, irrigation and bunding.

Tropical Livestock Unit (TLU): Number of livestock owned as measured by tropical livestock unit. TLU has a significant and positive influence on the adoption of DAP, manure, and improved variety at a 5% level of significance, the findings are shown in Table 8. A larger number of livestock units on the farm are associated with a higher probability of manure use and with a lower probability of retaining crop residues in the field. The result revealed that high livestock leads to exhaustive farming practices as these smooth financial constraints to purchase the agricultural technology packages and hire extra labor for the duration of peak agricultural seasons (Luchia and Hadush, 2018).

Farm Income: Farm income was positive and significantly related to the adoption of DAP and urea at a 5% level of significance. Farm income was also positively and significantly related to the adoption of manure, improved variety, and crop rotation at a 1% level of significance, the findings are shown in Table 8. The multivariate probit model result indicated that those barley farmers with a relatively higher degree of farm income are more probable to purchase urea, DAP, and other agricultural inputs [25,26].

Transportation Cost: Transportation cost was negatively and significantly related to the adoption of urea at a 1% significance level. Additionally, it was negatively and significantly related to the adoption of DAP, improved variety, manure, crop rotation at a 5% level of significance, the results are shown in Table 8. The multivariate probit model indicates that those farmers who have fewer transportation costs are more likely to adopt barley technologies than those who have high transportation costs. The possible explanation for this is that farmers who have higher transport costs might face far away from market centers and lack of information on the availability of the newly released technology provided by the extension system [27,28].

4. CONCLUSION AND RECOMMENDATION

4.1 Conclusion

The role of barley in income generation and food security for smallholder farmers is very high in highland areas of Ethiopia. Adoption of agricultural technologies in Ethiopia appeals to substantial consideration since it can offer the basis for rising production and income.

The finding shows that the relationships among all barley technologies were positive and significant. There is complementarity among improved barley production technologies (Urea, DAP, Chemical, Improved Variety, Manure, and Crop Rotation), meaning that the adoption of a given barley technology was conditional on the adoption of the others. Furthermore, higher proportions of adopters (75.99%) were practiced crop rotation; while lower proportions of farmers (58%) adopted urea. The results of a study showed that adopters of barley technologies as compared with non-adopters were characterized by better educational status, higher livestock assets ownership, and higher farm income.

A multivariate probit model result has suggested that ten variables were found to significantly affect adoption of barley technologies. Age of the household head was negative and significantly related to urea and improved variety. The sex of the household head was positive and significantly related to urea, improved variety, manure, and crop rotation. Being a male household head had a higher probability to adopt barley technologies. Education was found to have a positive and significant relationship with the adoption of urea, manure, and improved variety. Therefore, educated barley farmers are expected to be in a good position to get and use agricultural technology availability which contributes to improving their barley production practices. Family size was found to be negatively and significantly affect the adoption of the use of urea improved varieties, manure. This implies the application of more labor for other jobs will affect the adoption of agricultural technologies for barley production negatively.

Farm income was found to positively and significantly related adoption of the use of improved varieties, manure. This implies income is the main source of capital for purchasing agricultural inputs. Transportation cost was negatively and significantly related to the adoption of barley technologies. This implies the rising cost of transportation farmers' consequence of being far away from market centers which might face a lack of information on the availability of the newly released barley technology provided by the extension system.

4.2 Recommendation

Based on the results of a study, the following recommendations are suggested to be considered in future intervention policies.

The government should make a policy that empowers female-headed households to participate in different institutions and agents of change by considering a widespread and comprehensive development of the country where their involvement is important in all overall country's development.

Younger household heads are more likely to adopt barley technologies. Hence, the introduction of new agricultural technology in the areas may be effective if it emphasizes more on young farmers. **T**his study provides evidence on the role of credit use in improving the adoption of barley technologies positively; therefore, efforts towards establishing and strengthening micro-finance institutions seem crucial. Supporting adequate and effective basic educational opportunities for the rural farmers in Ethiopia is more crucial.

Enhancing the current livestock production system through supplying improved livestock feed, health services, targeted credit, and adopting high-yielding breeds in the areas to improve adoption packages of barley technologies. The government needs to launch a market center for the producers around their home which boosts the livelihood of adoption of barley technologies.

AVAILABILITY OF DATA AND MATERIALS

The datasets used and analyzed data during the current study are available from the corresponding author on reasonable request.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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