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Adoption of Bio-Fertilizer Technology in Ethiopia's Central Highlands: The Case of the Rural Districts Surrounding the Capital City, Addis Ababa (Finfinne)

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Abstract

The objective of this study was to determine the key factors influencing small farm households' decisions to adopt bio-fertilizer technology in the central highlands of Ethiopia; the case of the rural districts surrounding the capital city, Addis Ababa (Finfinne). Bio-fertilizers are natural fertilizers used to increase the productivity of crops. The logit model was employed to examine the data collected from 384 smallholder farming households within the research area. The model results indicated that the household head's educational level, number of extension contacts, perception, training, and involvement in off/non-farm activities significantly and positively influenced the adoption of bio-fertilizer technology in the study area. However, the age of the household head significantly and negatively influenced the decision of farm households to adopt the technology. The results suggest that increasing the number of motivated development agents in each peasant association can also increase the frequency of extension contacts with individual farmers, which in turn helps them to develop a positive attitude toward the adoption of the technology, emphasizing the expansion and improvement of agricultural education and short-term training with special focuses on the aged farmers can increase the likelihood that farmers in the study area will adopt biofertilizer technology.

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INTRODUCTION

In countries like Ethiopia, where farming is the primary source of livelihood, improving agricultural productivity is essential for nourishing the swiftly expanding population. The use of chemical fertilizers is crucial for raising crop productivity and yield. However, applying these fertilizers is costly. The increased cost of chemical fertilizers is unaffordable to small holder farmers such as Ethiopian small holder farmers because of their limited economic resources. Moreover, chemical fertilizer has dangerous effects on *humans* if not properly used (Mishra *et al.,* 2022 and Kumar, *et al.,* 2017). Furthermore, applying these fertilizers excessively can harm the soil, increasing its acidity and pollution. Excessive amounts of chemical fertilizers (N, P, or K) are used to supply the plant nutrients needed to boost agricultural productivity globally. However, because of poor fertilizer use efficiency, only small portions (30–40%) of these nutrients are absorbed by the plants, and the remainder is lost to the soil, polluting the environment. Furthermore, chemical fertilizers contain radio-nuclides and heavy metals that are difficult to break down, making them persistent contaminants in the environment. Water source eutrophication is a significant problem associated with the overuse of chemical fertilizers. Because of these pollution issues that pose health risks to the general public, eco-friendly and sustainable methods that could lessen the use of synthetic fertilizers have to be developed (Santos *et al.,* 2012; Zhang *et al*., 2021).

As a result, specific supplements or replacements containing organic manures are required in addition to the chemical fertilizers. Increased agricultural productivity and soil protection are possible with the extensive application of sustainable management practices and restoration. In order to convert atmospheric nitrogen into ammonia (NH_3) in plant roots, symbiotic bacteria called legume-rhizobia can invade and induce root or stem nodules on leguminous plants. This symbiotic relationship is crucial to profitable and sustainable agriculture. In this instance, bio-fertilizers can significantly enhance crop productivity and soil quality (Jabasingh, 2018). Bio-fertilizers are natural fertilizes which are living microbial inoculants of bacteria, algae, fungi alone or in combination and they augment the availability of nutrients to the plants. Bio-fertilizers are eco-friendly technology for environmental sustainability. The role of bio-fertilizers in agriculture assumes special significance, particularly in the present context of increased cost of chemical fertilizers and their hazardous effects on soil health (Kumar *et al.,* 2017 and Kumar *et al.,* 2024).

Although biofertilizers have more benefits than chemical fertilizers, they are not without drawbacks. Kumar *et al*. (2024) noted three significant drawbacks of these natural fertilizers: First, non-reliable efficacy: despite a great deal of research in this area, the effectiveness of the majority of biofertilizers is questionable because their mechanism of action in promoting growth is not fully understood; Second, the impact of abiotic factors on the effectiveness of biofertilizers is unclear: the ways in which changes in soil type, management techniques, and weather impact the efficacy of biofertilizers are still unclear; Third, the performance of field trials is challenging: Testing inoculants in the field as part of standard experiments is still challenging.

According to research report by Jabasingh (2018), Rhizobia (Rhizobium leguminosarum L.), Pseudomonas (Pseudomonas putida), and Mycorrhiza (Glomus sp.) are three of the main types of biofertilizer strains that have been identified for the conditions of several East African countries. Rhizobial biofertilizer are used to improve the nutrient flow to pulse crops and are regarded to be among the greatest and most long-lasting techniques for managing soil fertility in the Ethiopian high lands. Rhizobium bacterial biofertilizers produce 20-30 kg of nitrogen per hectare every season. Hence, a lot of work has gone into identifying and describing the effective varieties of both local and exotic Rhizobial strains for pulse crops (Kumar *et al*; 2017).

Although studies have shown numerous viable paths for incorporating this technology into farming systems, not many farmers have adopted it (EIAR, 2019). Research report by Jabasingh (2018) shows that generally in Ethiopia, on average it is possible to increase the yield of pulse crops by at least 30% on farmer's field if bio-fertilizer is used. Particularly in Oromia regional state; the largest pulse producer in Ethiopia, it is recorded that with this technology the farmer can increase the yield of faba bean up to 64%. Reports from an agricultural office in the rural districts surrounding Addis Ababa, Ethiopia, demonstrate the potential of bio-fertilizer technology in enhancing faba bean yields beyond the regional average. In Walmera district, for instance, research conducted on-farmers' plots revealed a significant increase in faba bean yield when bio-fertilizer was utilized, with an average yield of 9.2 tone/ha compared to 4.5 tone/ha in fields without bio-fertilizer. Despite the promising results, the adoption of bio-fertilizer technology among faba bean producers in the study area remains low, and the factors influencing this low adoption are not well understood. Therefore, the major objective of this study was to identify and analyze the key factors that influence smallholder farming households' decisions to adopt bio-fertilizer technology in the rural districts surrounding the capital city of Ethiopia, Addis Ababa (Finfinne). It is designed to answer the key research question "What are the major factors that affect the adoption of bio-fertilizers technology in the study area?"

METHODOLGY

Description of the Study Area

For this study, six rural districts surrounding the capital city of Ethiopia, Addis Ababa (Finfinne), were chosen as potential faba bean producers in the country's central highlands. These districts were all under the former Special Zone of Oromia Surrounding Finfinne (SZOSF). The study area is located between 38°25′East and 39°07′East longitude and between 8°25′North and 9°25′North latitude. The average annual temperature of the area is 16^{o}c (Asfaw and Hailu, 2018). The administrative centre of this zone was Finfinne (Addis Ababa). The special zone had an estimated total area of 4,800 km^2. The six rural districts are: Akaki, Barak, Mulo, Sebeta – Hawas, Sululta, and Walmara (Figure 1).

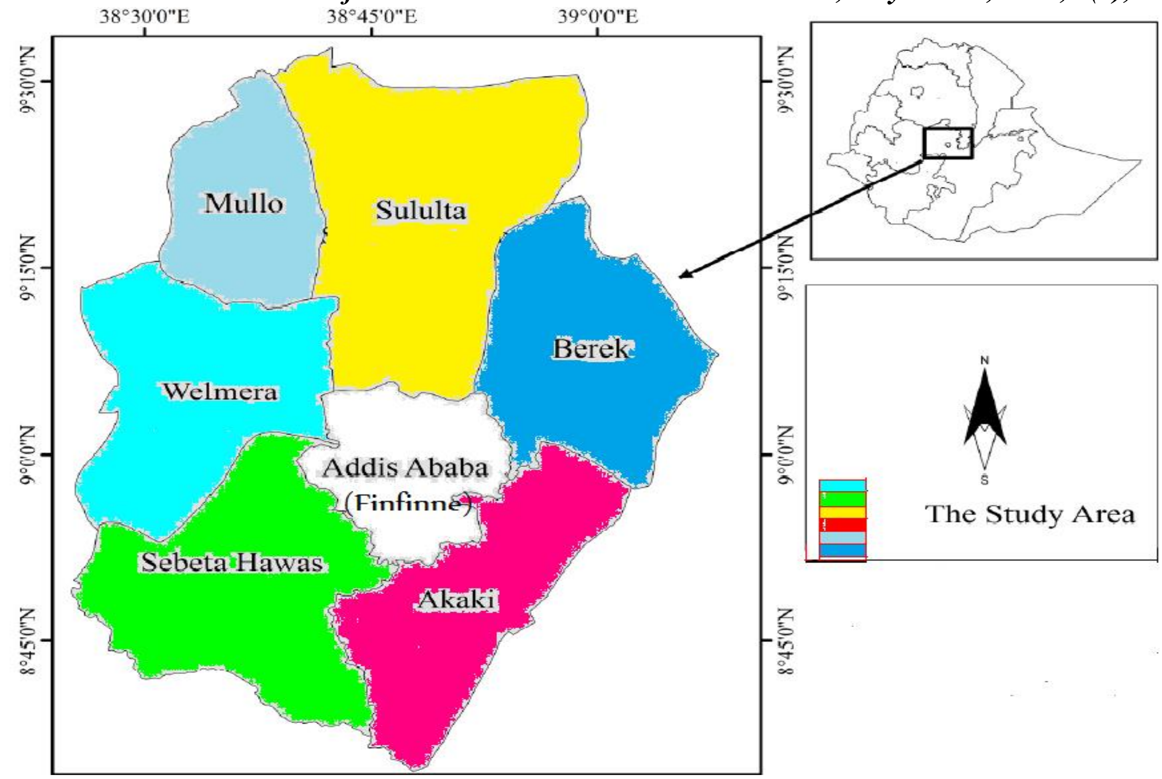

Figure 1: Map of the former Special Zone of Oromia Surrounding Finfinne (SZOSF)
Source: Asfaw and Hailu (2018)

The zone is now dismantled and the districts are restructured under the administration of four different zones and one city administration called 'Sheger City'.

Procedures of Choosing the Sample Respondents and Methods of Collecting Data

A multi-stage sampling procedure was used to choose the sample respondents. In the first stage, the central highlands of the Oromia regional state was selected due to the higher number of faba beans producers relative to other regions of the country. In the second stage, two rural districts, namely Wolmera and Sululta were randomly selected. In the third stage, 3 peasant association (PAs) from the lists of PAs in each district, a total of 6 PAs, were randomly selected. In the fourth and final stage, from the list of adopters and non-adopters obtained from the 6 selected PAs, a total of 384 farm households were randomly selected using probability proportional to size sampling (PPSS) techniques.

Key informant interviews, focus group discussions, and structured interview schedules were used to collect primary data. The questionnaire was applied after being translated from English into the native language of the study area, 'Afaan Oromoo' meaning Oromo Language. Trained enumerators who could converse in the local language used a structured questionnaire to get the quantitative data. Secondary data was gathered from unpublished and published sources.

Determining the Size of the Sample

The study used the sample size calculation formula provided by Bartlett *et al.* (2001) to determine the appropriate sample size when population size (N) is known for cross-sectional household survey:

$$n = \frac{z^{2} * pqN}{Ne^{2} + z^{2}\ pq} ----------------(3.1)$$

Where:

- n = sample size(the number of respondents needed)
- Z = confidence level,
- e = the desired level of precision and
- p and q are the estimated population variances.
- N = population size (in this study it refers to the total number of small holder farm households in the study area =74,295 farm households).

A survey study typically uses a 95% confidence level (Z = 1.96 in the Table). There is a 95% confidence level, if 95% of samples contain the true population value within the margin of error (e) = 0.05. Estimating the population's variance (P and q) is the second crucial element in a sample size formula. P = 0.5 is used in the method because to optimize variance and get the biggest sample size, Bartlett *et al*. (2001) advise researchers to choose 50% as their estimate of p (q = 1 –p = 1 – 0.5 = 0.5).

Thus:

$$n = \frac{(1.96 * 0.5)^{2} * 74{,}295}{74{,}295 * 0.05^{2} + (1.96 * 0.5)^{2}} \approx 384 ---------------------(3.2)$$

Techniques of Analyzing Data

The data for this study was analyzed using both descriptive statistics and econometric model. Among the descriptive statistics used are mean, frequency of occurrence, percentage, and standard deviation. The logit model was used to identify and analyze the major factors that influence smallholder farming households' decisions to adopt bio-fertilizer technology. The dependent variable is binary; it is equal to one for adopters of bio-fertilizer and zero otherwise. Thus from the deferent alternative econometric models suggested for such kind of data, Logit model was used in this study mainly because of its comparative mathematical simplicity. The model is specified as:

$$P_i = E(Y = 1 | X_i) = \frac{e^{Z_i}}{1 + e^{Z_i}} -------------------------(3.3)$$

Where*:*

- Pi, which goes from zero to one, is the farmer "i's" likelihood of adopting bio-fertilizer technology. Yi is an observed dummy variable with the following definition: Yi = 1 if the farmer 'i' is adopter, and 0 if not.
- *e* is the base of the natural logarithm;
- Z_i is a function of n independent variables X_i, which can be also expressed as

$$Z_i = B_O + \sum_{i=1}^{n} B_i X_i + U_i - (3.4)$$

Where:

- Z_i = is unobservable dependent variable for the farmer ' *i*',
- B_0= is constant term,
- U_i= is the error term,
- *Bi* = is an unknown parameter to be estimated;
- X_i= is an independent factors that are thought to have an impact on households' decisions to use bio-fertilizer and i = 1, 2, --- n are observations on variables for the adoption model; n is the number of independent variables (n=14).

From equation (3.3) it can be clearly seen that since the probability of adopting the technology, Pi has a non-linear relationship to Zi (to B'*s* and X's), it creates an estimation problem. So to solve this problem, we can take the odds ratio (OR) in favor of adopting bio-fertilizer technology ($\frac{P_i}{1-p_i}$) as:

$$OR = \frac{P_i}{1-p_i} = \frac{1+e^{z_i}}{1+e^{-z_i}} = e^{z_i} = e^{B_O + \sum_{i=1}^{n} B_i X_i + U_i} - (3.5)$$

By calculating the odds ratio's natural log, let's say L, using equation (3.5), we obtain,

$$L = \ln\left(\frac{P_i}{1-P_I}\right) = Z_i = \beta_o + \sum_{i=1}^{n} \beta_i X_i + U_i - - - - - - - - - - - - - - - - - - - (3.6)$$

That is the log of the odds ratio, which is linear in the parameters (B's) as well as the independent variables (X's). Rewriting equation 3.6

$$L = Z_i = \beta_o + \sum_{i=1}^{n} \beta_i X_i + U_i$$

$$\begin{aligned} L = Z_i = \beta_o &+ \beta_1 \text{EDLH} + \beta_2 \text{EDLAMH} + \beta_3 \text{GNDR} + /- \beta_4 \text{AGE} + \beta_5 \text{OXEN} + \beta_6 \text{INFN} \\ &+ \beta_7 \text{FRMS} + \beta_8 \text{CRDT} + + \beta_9 \text{PERC} + \beta_{10} \text{INCM} - \beta_{11} \text{LBRAV} + \beta_{12} \text{EXTNC} \\ &+ \beta_{13} \text{OFFRM} + \beta_{14} \text{TRNG}_i - (3.7) \end{aligned}$$

Where:

- B_0, B_1, B_2, B_{14} are unknown parameters to be estimated.
- EDLH = Educational level of household head, EDLAMH = Educational level of adult member of the household, GNDR = Gender of the household head, AGE = Age of the household head, OXEN = Number of oxen owned, INFN = Access to information, FRMS = Farm size, CRDT = Access to Credit, PERC = Perception of the HH to the technology, INCM =Income of the household, LBR = Labor availability, EXTNC = Extension contact, OFFRM = Involvement of the household head in the off-farm activity, TRNG = Training.

RESULTS AND DISCUSSION

This section reports the findings of descriptive and econometric analyses. In the first sub-section, the general socio-economic and demographic characteristics of respondents are presented. In the second sub-section, the econometric analysis using the Logit model is discussed.

Results of Descriptive Analysis

In this sub-section the major descriptive statistics such as the mean, standard deviation and the range of the continuous variables for the sample households is summarized first and then followed by the summary statistics (frequency and percentages) of dummy variables.

The study is based on cross-sectional data collected from a total of 384 farm-households. The mean education level of the sample household heads was 4.78 years of schooling with standard deviation of 3.948. The maximum educational achievement for the sample farmers was grade 12+2 while the lowest was 0. The average education level of adult household members was 7.70 years of schooling with a standard deviation of 3.549. The range of the educational level of adult members of the sample household is between 0 and 12+4 years of schooling. The age of the sample respondents ranges from 24 to 71 years with the average age of 45.17 years. The average farm size per sample household was 3.23, which ranges from 0.50 hectares to 6.89 hectares per household. All the sampled farm households prepare their farm land by oxen. On average they have about a pairs of oxen (2.26). Total number of oxen ownership ranges from 0 to a maximum of 3 pairs (6) of oxen (Table 1).

Table 1

Summary statistics of the sample households for continuous variables

Variables	Mean	Std. Dev.	Min	Max
Educational level of household head	4.78	3.948	0	12+2
Educational level of adult member of the household	7.70	3.549	0	12+4
Age of household head	45.17	9.404	24	71
Number of oxen owned	2.26	1.243	0	6
Farm size	3.23	1.360	0.5	6.89
Income of the household	328,737	159,543	58,566	840,898
Labor availability	3.01	1.059	0.8	6.3
Extension contact	4.684896	3.126	0	14
Training	3.679688	2.482	0	12

Source: Own survey (2023

The total income of household was estimated from the total value of crops produced during the survey year, the sales of livestock and their products, sale of honey and income from off/non-farm activities. The average income of sample household is 328,737 Birr/year. The sampled household income was recorded a minimum of 58,566 birr to a maximum of 840,898 birr during the survey year.

Economically active family labor force was calculated for the sample households. The average available labor was estimated to be 3.01ME with standard deviation of 1.059. The minimum available number of labor per household is 0.8 ME and the maximum number is 6.3 ME. Agricultural extension is of paramount importance to introduce better agricultural practices and improved technologies to smallholder farmers in a country like Ethiopia where traditional practices are dominant. In the study area, the districts (Woredas) agricultural offices provide technical assistance for farmers through their technical experts and development agents. The survey result indicated that the average number of contacts that the development agents made with farm households per year was 4.68 times. Although there are farm households who had no any contact with the development agents, a maximum contact made with farmer was 14 times during the survey year (Table 1).

Respondents were asked the number of training they participated in out of their local before and during the survey time. On average they participated in about four (3.7) different training programs such as how to use bio-fertilizer technology and other general agricultural technologies. There are respondents who did not participate in any agricultural training program during the specified period of time while others participated up to a maximum of 12 training programs.

As indicated in Table 2, from the gender category of the sample farm household heads, 88.3% were male-headed and the remaining 11.7% were female-headed. The result also revealed that 73.4% of the respondents had access to information services about agricultural technologies, agricultural production and marketing; whereas the remaining 26.6% had no access to information. Regarding access to credit, 70.8% of the sample farm household had access to different form and sources of credit.

Table 2
Summary statistics of sample household (dummy variables)

Variables	Category	Frequency (n = 384)	percent
Gender	Male	339	88.3
	Female	45	11.7
Access to Information	Has access	282	73.4
	Has no access	102	26.6
Access to Credit	Has access	272	70.8
	Has no access	112	29.2
Perception of the HHH to the technology	Positive	221	57.6
	Negative	163	42.4
Participation of the household head in off-farm activity	Participated	175	45.6
	Not-participated	209	54.4

Source: Own Survey (2024)

As displayed in Table 2, 57.6% of the sample farm household positively perceived the advantages of using bio-fertilizer technology in increasing the productivity of crops. But the remaining 42.4% of the house hold did not accept the importance of the technology under study in improving the productivity of crops. In addition 45.6% of the respondents participated in the off-farm activities. But the majority (54.4%) of the sample farm households was limited to only agricultural production.

The Results of Econometric Analysis

The results of econometric analyses are presented in this section. The relative effect of different independent factors on smallholder farmers' decisions to adopt bio-fertilizer technology was ascertained using a Logit model.

It was hypothesized that fourteen independent variables would have varying effects on farm households' adoption decisions. The existence of multicollinearity among these independent variables was examined prior to computing the model parameters. For continuous variables, the variance inflating factor (VIF) was used to find multicollinearity; for dummy variables, the contingency coefficient (CC) technique was used. The variance inflation factor (VIF) for the continuous independent variables is less than 8, indicating that there is no multicollinearity problem in the model (Table 3).

Table 3

The variance inflation factor (VIF) result for continuous independent variables

Variables	VIF
(Constant)	
Educational level of the head (EDLH)	1.624
Adult household members' educational level (EDLAM)	1.514
Age of HHH	1.313
Oxen owned	1.411
Farm size	1.509
Income	1.229
Labour availability	1.246
Extension Contact	2.224
Training	2.075

Source: Own Survey (2024)

In the same manner, the contingency coefficients (CC) were calculated using the correlation matrix for the dummy variables. All the values of the coefficients were found to be below 0.800, which indicated a weak degree of association among the variables considered (Table 4).

Table 4

Contingency Coefficients (CC) for the dummy independent variables

variables	Gender	Access to information	Access to credit	Perception	Off-farm
Gender	1				
Access to information	0.203	1			
Access to credit	0.073	0.088	1		
Perception	0.195	0.593	0.145	1	
Off-farm	0.122	0.290	0.115	0.363	1

Source: Own survey (2024)

Furthermore, a study by Cook (1977) revealed that in logistic regression, outliers have the potential to significantly affect the logit analysis's findings and cause false conclusions to be drawn. Therefore, the presence of outliers in the dataset for each continuous variable was checked, and an appropriate remedy was made to reduce their effect on the statistical analysis. After the multicollinearity and outlier tests, all the hypothesized nine continuous and five dummy variables, a total of fourteen independent variables were included in the estimation of the Logit model.

Table 5 displays the results of the Logit model estimate for factors affecting the decision of farm households to adopt bio-fertilizer technology. The model result indicated that 95.1% of the total variation in the adoption of bio-fertilizer technology was explained by the independent variables. A sample size of 95.3% for non-adopters and 94.8% for adopters was accurately predicted by the model.

Table 5

Logit results of factors influencing the decision of the farm household to adopt bio-fertilizer technology.

Variables	Coef.[a](S.E)	OR[b]
Educational level of the house hold head (EDLH)	0.237(0.091)*	1.267
Educational level of Adult member of the HH (EDLAMH)	-0.028 (0.098)	.973
Gender (GNDR)	0.560 (1.356)	1.750
Age of HHH (AGE)	-0.091(0.031)*	.913
Oxen Owned (OXEN)	-0.101(0.277)	.904
Information (INFN)	1.728 (1.312)	5.627
Farm size (FRMS)	-0.132 (0.250)	.876
Access to Credit (CRDT)	-0.644 (0.615)	.525
Perception (PRPN)	4.070 (0.875)*	58.555
Income (INCM)	0.000 (0.000)	1.000
Labour availability (LBR)	-0.383 (0.294)	.682
Extension Contact (EXNC)	0.659 (0.174)*	1.934
Off-farm (OFRM)	1.831 (0.707)*	6.240
Training (TRNG)	0.557 (0.203)*	1.745
Constant	-5.659 (2.381)	.003

Source: own Survey (2024)

- S.E = Standard Error, OR = Odds ratio, -2 Log likelihood 91.428;
- Predicted: Non-adopter 95.3%, Adopter 94.8%, and Overall Percentage 95.1%.
- a = Figures in column two are partial slope coefficients and measure the change in the estimated Logit for a unit change in the specified independent variable's value while keeping the other variables fixed.
- b = A more meaningful interpretation is in terms of odds-ratio (column three), which are obtained by taking the antilog of the partial slope coefficients (column two).

From the total of explanatory variables included in the logit model, the logit results of factors influencing the decision of the farm household to adopt bio-fertilizer technology showed that six variables were significant in affecting the decisions of households to adopt the technology under discussion. These variables included the educational level of the household head (EDLH), age of the household head (AGE), Perception of the household head on the technology (PERC), number of extension contacts (EXTNC), employment of the head in off-farm activities (OFRM), and access to training (TRNG). Below is a discussion of the explanatory factors that were significantly influencing the adoption of biofertilizer technology:

A. The head of the household's educational level ((EDLH). The level of education attained by farmers is positively correlated with their ability to acquire, evaluate, and use information. Education enables them to be more aware of the several advantages of new technology in enhancing farm productivity. So, as hypothesized, the head's educational level significantly and positively influenced the decision of small farm households to adopt bio-fertilizer technology at a 1% level of significance with an odds ratio of 1.267. This indicates that, while all other factors stay the same, the odds ratio in favor of adopting the technology increases by a factor of 1.267 as the household head's educational attainment rises by one grade level. This finding indicates that a household's probability of deciding to use bio-fertilizer technology is significantly influenced by the head's educational attainment. The result is supported by several previous adoption studies in Ethiopia and other developing countries: Mesele etal. (2022), Markew and Mesele (2022), and Kassa *et al*. (2021).

B. Age of the household head (AGE). The decision of the household to adopt the technology is expected to be affected by the head's age in either direction. The model result showed that the age of the household head had a negative and significant impact on farm families' decisions to adopt bio-fertilizer technology at 1% level of significance and with an odds ratio of 0.913. This shows that the odds ratio in favor of adopting the technology decreases by a factor of 0.913 as the age of the head increases by one year keeping other independent variables remain constant. This result is also supported by Workineh *et al*. (2019), Djibo and Maman (2019), and Kinuthia and Edward (2017),

C. Perception of the household head on the technology (PERC): This is a dummy variable equal to 1 for the respondents who positively perceived that bio-fertilizer technology has many advantages compared with other fertilizers such as chemical fertilizer in increasing the productivity of faba bean, improving the soil fertility for the next crop, cost-wise, etc., and 0 otherwise. Thus, as hypothesized perception of the household head on bio-fertilizer technology was positively affected the adoption of the technology at a 1% level of significance, with the odds ratio of 58.55. This shows that for the household head who positively viewed the technology keeping other things remain constant, the odds ratio in favor of using the technology rises by a factor of 58.55. This finding implies that the likelihood of a household deciding to adopt bio-fertilizer technology is raised for the head of the family has a positive view on the technology. The research results by Li *et al*. (2019) and Khan *et al*. (2008) are also in line with this result.

D. Number of Extension contact (EXTNC): The number of extension contacts positively and significantly influenced the decision of the farmer to use bio-fertilizer technology, as it was to be expected. With each additional extension contact with a farm household, there was a factor of 1.934 raises in the odds ratio in favor of adopting the technology. This suggests that frequent contact of the development agent with farmers play a vital role in educating and convincing them to adopt new technologies like bio-fertilizers. Previous studies by Lemma and Degefa (2023), Markew and Mesele (2022), and Mesele *et al*. (2022), are also in line with this result.

E. Involvement of the head of the household in the off/non-farm activities (OFFRM): There are different arguments on the effect of this variable on the farmers' adoption decision. On the one hand, having more money from off/non-farm sources increases the ability of the household to invest on new agricultural technologies, so assumed to have positive correlation. On the other hand there is an argument that the involvements of the farm household in off/non-farm activities negatively affect adoption decision that it decreases the labour availability of the farm and is expected to affect the adoption decision in opposite direction. However, in this study, this variable was hypothesized to positively impact the farmers' adoption decision of the technology since it increases the household's financial ability to invest in new agricultural technologies. As hypothesized, the household's participation in non/off-farm works positively and significantly influenced the decision of households to use the technology at 1% level of significance with an odds-ratio of 6.240. This suggests that, if all else stays the same, the odds-ratio increases by a factor of 6.240 for the head of the farm household who participates in off-farm activities. Previous research reports supported this result are Mesele *et al*. (2022), Workineh *et al*. (2019), Kinuthia and Edward (2017).

F. Household head participation in training (TRNG): This is the number of training in which the farm household head participated, outside of his/her locality. Training related to new agricultural technology such as the importance of agricultural technology, how to use the bio-fertilizer technology, and its negative and positive impact on the environment during the period of the last two years. As hypothesized, this variable had a positive and significant impact on the respondents' adoption decision at 1% significance level. For the farm household head who participated in one more training, the odds ratio in favor of adopters of bio-fertilizers increased by a factor of 1.745. This result is also supported by Kassa *et al*. (2021), Li *et al*. (2019), Kinuthia and Edward (2017).

CONCLUSIONAND RECOMMENDATIONS

Conclusion

To identify the major factors affecting smallholder farmers' decisions to adopt biofertilizer technology, a logit model was utilized. The results of the model showed that, of all the independent factors that were hypothesized to affect the adoption of the technology under discussion, the following six were statistically significant.

Educational level of the head, perception of head of the household, training, extension contact as well as family head participation in off/non–farm activities significantly and positively influenced the farmer’s decision to adopt bio-fertilizer technology in the study area; whereas age of the household head significantly and negatively influenced the decision of farm households to adopt the technology.

Recommendations

The results suggest the need for increased effort to the provision of basic educational programs in rural areas and designing appropriate ways in which the participation of farmers in this program could be increased, that means to enhance the adoption of biofertilizer technology, appropriate education related to the technology should be arranged for the small farm households. This finding also implies that the likelihood of using bio-fertilizer technology can be increased by emphasizing the expansion and improvement of important agricultural education at farmer training centers (FTC), which are presently located virtually everywhere in peasant associations, as well as encouraging the farmers’ participation in. To improve the extension services, special training programs out of their local and in their local such as trials on the farmer's own plot, preparing demonstration plots around the farmer's training center managed by development agents and agricultural shows need to be arranged for farmers with special attention to non-adopters of the technology and to the aged farm households to increase their participation in these training programs is particularly recommended.

Advice and persuading farmers to use the technology should be increased as the number of extension contacts with each of the individual farmers still appears to be a major factor significantly and positively influencing the adoption of the technology. Frequent contacts of the development agents (DA) with individual farmers help them to develop a positive attitude toward the advantages of the technology. Increasing the number of development agents in each peasant association and motivating them increases the frequency of extension contacts with individual farmers, so that each farmer gets adequate time and opportunity to learn and be clear about any distrust about the technology.

Finally it is recommended that further research will need to assess how biofertilizer technology would affect the incomes of smallholder farmers in the central highlands of Ethiopia.

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