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Determinants of Adoption of Improved Varieties of Wheat (*Triticum aestivum*), Teff (*Eragrostis teff*), and Maize (*Zea mays L.*) in Central Ethiopia

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Abstract
This study determined factors of the adoption of improved varieties of certified maize, teff, and wheat seeds in central Ethiopia. The logit model was applied to estimate the likelihood of adoption decisions. The result showed that 29% of household respondents adopted improved seeds, while 71% relied on their local landraces. The findings also revealed that farmers' decisions to adopt wheat, teff, and maize varieties were significantly influenced by educational level, farm size, farming experience, income, credit access, extension contact, farm input, and distance to the market. Thus, the study recommends that the government should focus on strengthening extension services, improving access to improved seeds, expanding timely agricultural inputs supply, improving market opportunities, equipping knowledgeable farmers who increase the use of new varieties, and making the land more economical by sharing agronomic practices are areas that need policy attention enhancing the adoption of certified seeds of improved varieties.

Introduction

According to the World Fact Book (2020), agriculture is one of Ethiopia's key sectors accounting for 35% of the country's GDP, providing 75% of employment, and generating 80% of total exports. The CSA (2020) indicated that teff, maize, and wheat are the most important staple foods for crops that make up the majority of Ethiopia's agricultural outputs in terms of cultivated area, yield, and consumption. In 2020/21, out of the total acreage of grains, teff, maize, and wheat accounted for 23%, 20%, and 15%, respectively.

The adoption of enhanced agricultural technologies is a technique for boosting productivity in the agricultural sector, alleviating poverty, and ensuring food security. Farmers cannot easily adopt improved agricultural technology due to various factors, and many adoptions are not well understood if they are late. Solomon (2020) indicates some studies have reported multiple barriers to adoption including technology awareness, risk aversion, institutional restrictions, and lack of human and financial capital and infrastructure.

Among cereals, wheat is a strategic crop that generates farm revenue and improves food security. According to CSA (2020), wheat yield in Ethiopia was 1.83 tons/ha in 2009 and increased to 3.1 tons/ha in 2020. However, the primary rain-fed wheat yields for smallholder farmers in Ethiopia are still low and lagging behind other countries. During the 2020/21 harvest period, the nation produced 5.78 million tons of wheat on about 1.9 million hectares of land accounting for 19% of all cereals production and 17% of all grains production, and the yield was 3.1 tons/ha (CSA, 2020). Currently, Ethiopia is introducing 99 varieties of wheat to suit the population's expanding production needs (MoA, 2021). According to Wordofa et al. (2021); Karolina & Malgorzata (2020), improved agricultural technology increases yields and farm income, which has a significant positive impact on food security. Bedilu et al. (2021) indicate that farmers are not using improved wheat varieties due to a lack of information, accessibility, incentives, and unaffordable input prices.

Regarding teff, it is one of the cereal products cultivated in most of Ethiopia’s agroecological areas and primarily used for food consumption. Teff is gluten-free and rich in iron and fiber, and its demand has been flowing into the international market in recent years. It contributes 16% of the nation's overall grain production and 18% of the total cereal crops (CSA, 2020). Approximately 25 to 30 million people rely directly on teff production, and Ethiopia's productivity is still low. For instance, in the 2020/21 production year, the yields was 1.9 tons/ha, significantly lower than maize and wheat due to socio-economic issues, low utilization of modern ideas, outdated seeding approaches, post-harvest damage, and lack of high-yielding cultivars (Hailu et al., 2022). As a result, numerous better cultivars have been advanced and distributed with optimal administration techniques to increase productivity. To present, 54 enhanced teff varieties and farming methods have been made available to farming communities and many recommended technical packages have been developed by national and regional research centers (MoA, 2021). However, various region-specific pieces of evidence suggest low adoption of enhanced teff varieties in the nation. This low rate is usually driven by several issues may be the high price of seeds and desirable cultivars, lack of cognizance, and farm practices are often cited as limitations that contribute to the low uptake of improved teff varieties (Abate et al., 2019).

Maize is the most important commodity that is widely produced and consumed by smallholder farmers, who make up around 80% of the country's population. It is the main crop for food security, leading all other cereals in terms of production and productivity (Dawit et al., 2018). According to CSA (2020), maize is cultivated in a variety of agroecology, from the lowlands to the highlands of the country. In 2020/21, approximately 10.6 million tons of maize were produced, with yields of 4.2 tons/ha. Since the 1970s, about 77 improved maize production technologies have been introduced nationally (MoA, 2021). Understanding the factors which affect maize technology adoption is vital in promoting the use of certified seed to enhance its production across the country, especially in the study region.

The aim of this study was to determine the factors influencing the adoption of certified seeds of wheat, teff, and maize varieties as well as to assess the likelihood of adoption decisions. It specifically, analyzes factors affecting the adoption of improved seed varieties, identifies factors determining the adoption of improved seed technologies, and assesses the extent of adoption of improved technology at the household level.

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Methodology

Three districts: Ada'a, Bora (East Shewa zone in the Oromia region), and Moretina Jiru (North Shewa zone in the Amhara region) were selected because of their cereal-based farming systems. In the East Shewa Zone of Ethiopia, there are 14 districts, Ada'a is one of them and has 27 kebeles (the smallest administrative unit). It is adjacent to Dugda Bora to the south, Akaki to the northwest, Gimbichu to the northeast, and the Lume district to the east. The administrative center is Bishoftu, about 45 km from Addis Ababa, between latitudes 8° 37' 30" to 8° 46' 30" N and longitude 39° 0' 00" to 39° 9' 00" E. The district has 165,729 people, of whom 86,022 are men, 79,707 are women, and 161,354 are urban dwellers. The altitude is 1,500 to 2,000m above sea level. The mean annual rainfall was 839mm and the minimum and maximum temperatures were between 7.9°C and 28°C. It covers an area of 1,750 km^2, the farm is a mixed farming system. The most important crop components are cereals (teff, wheat, maize, and sorghum) and legumes (chickpeas, field peas, field beans, and lentils) grown at medium and high altitudes. Irrigated horticultural crops are emerging as a new opportunity for the district.

Bora is located in the Great Rift Valley of Ethiopia. It consists of 18 rural Kebeles, adjacent to Lake Ziway to the southeast, Adamitulu to the south, Southwest Shewa to the northwest, the Awash River to the north, Lake Koka to the northeast, and Arsi to the east. The administrative center is Bote (Alem Tena) and it is about 238 km from Addis Ababa, between latitudes 8° 10' 30" to 8° 30' 00" N and longitude 38° 50' 00" to 39° 3' 00" E. Based on CSA's (2013) national census projection, the district has 78,610 people, of whom 40,568 are male, 38,042 female, and 18,402 are urban residents. The lowest and highest temperatures are 22°C and 28°C, respectively, and the annual mean rainfall is bimodally distributed and ranges from 750 to 805 mm. The elevation ranges from 1,650 to 2,020 meters above sea level. 484.7 km^2 is the approximate total area. The farm is a mixed farming system, with major crops such as wheat, maize, teff, barley, chickpeas, haricot beans, fruits, and vegetables.

In the North Shewa zone of Ethiopia, there are 23 districts, Moretina Jiru is one of them and has 15 rural kebeles. It is adjacent to the Siyadebrina Wayu to the south, Ensaro to the southwest, Merhabiete to the northwest, Menz Keya Gabriel to the northeast, and Basona Werana to the east. The administrative center is Enewari, about 175km from Addis Ababa. It lies between latitudes 9° 52' 30" to 10° 1' 00" N and longitude 39° 1' 00" to 39° 18' 00" E. The district has 112,650 people, of whom 57,563 are male, 55,087 are female, and 15,723 are urban residents. The altitude varies from 1,350 to 1,850 meters above sea level. The annual rainfall ranges from 450mm to 761mm. It covers an area of 706.2 km^2. Its economy is centered on a crop and livestock production system. Cereals (teff, wheat, and sorghum) and pulses (faba bean, chickpea, and lentils) are mainly grown under rain-fed agriculture, while irrigation water is used to grow vegetables to generate income.

The sampled households were chosen using a multistage sampling technique. Two regions and three districts were purposely chosen for the initial stage based on their accessibility and agroecological suitability for wheat, teff, and maize production. The second step involved a random selection of six representatives of kebeles, the smallest administrative unit in the district. Step three, within targeted kebeles, farmers who adopted or did not adopt the technology were identified by stratified sampling techniques. A total of 299 interviewed samples (108, 68, and 123 samples from the districts of Ada'a, Bora, and Moretena Jiru respectively) were randomly selected. Twenty-five key informants were identified by using the key informant sampling technique, and all the key informants had an extensive understanding of the seed system and farm experience. Six focus group discussants were also organized and selected using a random sampling technique based on being socially respected within the society, each group was composed of 5-7 members.

Data were coded, organized, summarized, and analyzed using descriptive and econometric model analysis. Independent samples of chi-square and t-test were used to compare means, check for the existence of statistically significant differences in continuous variables (t-test), and show the interdependence between adoption categories for dummy variables (chi-square test). A logit model is utilized to decide the comparative impact of diverse explanatory variables at the based variable and has the advantage of showing the relative impact on the likelihood of technology adoption. In this scenario, the dependent variable is a dummy variable that accepts values of 1 for adopters and 0 for non-adopters.

The model is specified mathematically by:

$$P_i = E(Y = \frac{1}{Xi}) = \frac{1}{1+e^{-(\beta o+\beta iXi)}} \text{ --- } (1)$$

Where, Pi represents the probability of adoption of certified seeds for improved varieties, Yi = 1, and exp (Zi) is the odds ratio "e to the power Z_i". In the case of explanation, equation (1) is written as; of Z

$$P_i = \frac{1}{1+e^{-Zi}} \text{ -- } (2)$$

Where, $Z_i = \beta_0 + \beta_i X_i$.

The probability of a respondent choosing to perform these activities successfully is given by equation (2), and the probability of a respondent not performing the activity is given by equation (3).

$$P_i = \frac{1}{1+e^{Zi}} \text{ -- } (3)$$

$$P_i = \frac{1}{1+e^{-Zi}} = \frac{e^{Z}}{1+e^{Z}} \text{ -- } (4)$$

If P_i is the probability of an adopter, then the non-adopter is $(1 - P_i)$. So, $1 - P_i = \frac{1}{1+e^{Zi}}$ and

$$\frac{Pi}{1-Pi} = \frac{1+e^{Zi}}{1+e^{-Zi}} = e^{Zi} \text{ -- } (5)$$

$\frac{Pi}{1-Pi}$ is an odds ratio that favors adopters as a result. That is the probability that a particular farmer participates in the seed of improved varieties adoption and does not participate in adoption.

Then, $L_i = \ln\left(\frac{Pi}{1-Pi}\right) = Zi = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 ... + \beta_i X_i$ -- (6)

The logit model changes when the error term (Ui) is considered.

$L_i = Zi = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 ..... + \beta_i X_i + Ui$ -- (7)

Earlier runs of the model tested the explanatory variables for likely multicollinearity issues. The study used STATA version 14 to run a logistic model. The marginal effect (ME), is estimated with a logit model. ME = $\frac{\partial Ui}{\partial Xi}$

Based on the study, the subsequent explanatory variables were believed to have an impact on the adoption of wheat, teff, and maize technology (Table 1).

Table 1: Explanatory variables, measurement, and expected sign

Variables	Measurement	Type	Exp. sign
Sex	1 if male and 0 otherwise	Dummy	+/-
Age	household age in years	Continuous	-
Family size	Number	Continuous	+
Education	1) No formal education, 2) Gr. 1-4, 3) Gr. 5-8, 4) Gr. 9-10, 5) Gr. 11-12, 6) College and above	Categorical	+/-
Farm size/ land holding	Actual farm size in hectares	Continuous	+
Farm experience	Farming experience in years	Continuous	+
Livestock holding (TLU)	Number of livestock	Continuous	+
Sources of income	1) sales of the crop, 2) sales of livestock & products, 3) on-farm daily labor, 4- rented out oxen & land	Categorical	+
Off-farm income	1 if yes and 0 otherwise	Dummy	+
Credit	1 if accessed and 0 otherwise	Dummy	+
Farm input	1 if accessed and 0 otherwise	Dummy	+
Extension contact	Number of Visits by extension agent	Continuous	+
Market distance	Distance to the marketplace in minutes	Continuous	-

Results and Discussion

Adoption Characteristics

The descriptive statistics for the variables of the sample households examined in the study are offered in Table 2. It demonstrates that the *t value* was computed for all continuous variables and was found statistically significant for family size, land holding, farming experience, livestock holding, and extension contact at a 1% significance level. This suggests that there was a significant difference in all these factors between adopters and non-adopters.

Table 2: Adoption characteristics

Variable	Adopter (142)		Non-adopter (157)		Mean difference	Min	Max	T-value
	Mean	SD	Mean	SD				
Age	44.22	12.59	42.13	12.23	2.085	20	65	-1.452
Family size	5.92	2.32	5.24	1.96	0.687	1	13	-2.771***
Farm size/ land holding	2.51	1.74	1.54	0.83	0.968	0	11	-6.230***
Farming experience	25.05	10.56	15.67	7.78	9.381	0	52	8.802***
Livestock holding	7.47	5.77	5.53	4.97	1.950	0	43	-3.129***
Extension contact	2.51	1.97	1.62	2.12	0.896	0	8	-3.778***
Market distance	83.56	44.8	87.52	45.26	3.959	5	180	0.759

Source: Survey, 2021 ****Significant at P<0.01*

Association between adoption and socioeconomic characteristics

The findings revealed that the *Chi-square* test was figured for the categorical and dummy variables, and it was found that there was a statistical association between adoption decisions and significance for the sex of the household head, educational level, income, credit access, and availability of farm input at a 1%, and 10% significant level in these variables (Table 3). The percentage of female household heads was 12%; out of this about 9% were adopters, and only 23% of respondents from both groups had no formal education, while the majority (77%) of the respondents attend formal school in the study area. Concerning farm income, about 61% of the respondents had income from the sale of crops and crop products.

Table 3: Association between adoption decision and some socioeconomic characteristics

Variable	Category	Adopter (n=142)	Non-adopter (n=157)	Total value	Chi-square
		%	%	%	
Sex	Female	8.5	14.7	11.7	
	Male	91.5	85.4	88.3	0.096*
Education	No formal education	0.3	29.3	22.7	
	Gr. 1-4	0.4	44.6	39.1	
	Gr. 5-8	0.2	16.6	28.1	
	Gr. 9-10	0.1	5.7	6.7	
	Gr.11-12	0.0	1.9	1.7	
	College & above	0.0	1.9	1.7	0.000***
Income	Sales of crop	44.4	76.4	61.2	
	Sales of LS & products	45.8	8.9	26.4	
	Daily labor	0.7	1.9	1.3	
	Rented out oxen	8.5	12.7	10.7	
	Rented out land	0.7	0.0	0.3	0.000***
Off-farm	Sale of charcoal	13.4	18.5	16.1	
	Other (shops)	83.1	75.8	79.3	
	Salary	3.5	5.7	4.7	0.289
Credit	No	38.7	72.6	56.5	
	Yes	61.3	27.4	43.5	0.000***
Farm input	No	22.5	41.4	32.4	
	Yes	77.5	58.6	67.6	0.001***

Source: Survey, 2021 ****, * Significant at P<0.01and P<0.1 respectively*

Factors Influencing Choice to Adopt Wheat Varieties

Seven predictors (education level, land ownership, farming experience, total livestock unit, source of income, access to credit, and extension contacts) are statistically significant and prior expectations are revealed in Table 4. The coefficient of determination is approximately 0.4664. This indicates that a 47% chance that the household will adopt improved wheat varieties is clarified by all explanatory variables.

Table 4: Likelihood of adoption decisions of improved wheat varieties

Variables	Odds Ratio	dy/dx	Coef.	SE	z
Sex of the household head	1.4176	0.0405	0.3489	0.7093	0.49
Age of the household head	0.3858	-0.1106	-0.9525	0.7069	-1.35
Family size	1.1077	0.0119	0.1023	0.2055	0.50
Education level	2.4905	0.1059	0.9125	0.3176	2.87***
Farm size/ land holding	2.4339	0.1033	0.8895	0.4702	1.89*
Experience	1.2105	0.0222	0.1910	0.0466	4.10***
Livestock holding	0.6929	-0.0426	-0.3668	0.1671	-2.20**
Farm income	2.4919	0.1059	0.9131	0.4013	2.28**
Off-farm activities	1.4583	0.0438	0.3773	0.6009	0.63
Access to credit	5.8991	0.2060	1.7748	0.6002	2.96***
Access to farm input	1.7510	0.0650	0.5602	0.6263	0.89
Extension contact	1.4121	0.0401	0.3451	0.1478	2.33**
Market distance	0.9978	-0.0003	-0.0022	0.0129	-0.17
_cons	0.0005		-7.5562	2.3573	-3.21

Source: Survey, 2021

*Significant levels are indicated by ***, **, and *, which are P<0.01, P<0.05, and P<0.1, respectively; Sample (N) =299, LR chi^2 (13) = 79.49, Pseudo R^2 = 0.4664, Probability > chi^2= 0.000; Log likelihood = -45.4736*

The head's education level was statistically significant at 1% and positively correlated with the likelihood of adoption of wheat varieties. Other factors holding equal, odds ratio for adopting enhanced wheat varieties upsurges by a factor of 2.491 for farms where the householder is assumed to be literate than for those who are not. This is due to the fact that highly educated farmers have easier access to knowledge and are more aware of new technologies, which may drive technology adoption. The marginal effect shows that after a year of schooling, the head of household is more likely to adopt improved wheat varieties by 10.6%, while others remain constant. This outcome is similar to the conclusion of the study by Gezahegn (2021); Gishu et al. (2018).

The land holding positively and significantly influenced farm households' decision to adopt enhanced wheat varieties at a 10% level of significance. This indicates that the more farmers have larger farms, the more they adopt modern technology. Other things being equal, the odds ratio of 2.434 indicates favor of adopting wheat varieties as a land holding increased by one hectare. The marginal effect of farm size is also showing that an increase of farm by one hectare increases the probability of adopters than the non-adopters by 10.3%, keeping other variables at their means. This outcome was reinforced by the result of Aklilu et al. (2022) who obtained positive and significant results on farm size.

The farming experience of the head of household had a positive influence on the adoption of enhanced wheat varieties at the 1% significance level. As the farmer's farm experience increases by one unit, the odds ratio for adopting improved varieties increases by 1.211 times. This indicates that farmers with more agricultural expertise are more likely to adopt improved wheat varieties than farmers with less farming experience. The marginal effect demonstrates that one year of farming experience upsurges the likelihood of adopting enhanced wheat varieties by 2.2%. The results are consistent with Chandio & Jiang (2018); Dawit & Alemayehu, (2020).

Livestock holding is positively significant at a 5% level of significance and has a negative impact on the adoption of improved wheat technology. The odds ratio of using the enhanced wheat varieties is reduced by a factor of 0.693 for every unit increase in the livestock. This result demonstrates that farmers with high livestock are more likely to use improved wheat varieties than those with low livestock. Other conditions held constant, the marginal effect shows that with a one-unit increase in livestock the likelihood of households' adoption of improved wheat technology decreased by 4.3%. This result is consistent with the adoption study by Mengistu et al. (2021).

The result of farm income was positive and significant at the 5% level. The odds ratio increased in favor of using enhanced wheat varieties by a factor of 2.492, indicating that other variables were held equal as the farmer's income grew by one unit. The marginal effect shows, keeping other variables constant, that the probability of those households who had more income sources was higher than those who had fewer income sources adopting improved wheat technology by 10.6%. The result of this finding is in line with Dawit & Alemayehu (2020).

Credit access indicates that it is positively and significantly linked to the adoption of certified seed of enhanced wheat technology at a significance level of 1%. The odds ratio showed the decision to the adoption of improved wheat technology enhanced by a factor of 5.899, other things being constant. The marginal effects indicate that households with access to credit are 20.6% more likely than those without credit.

With respect to the household's choice to adopt enhanced wheat technology, the number of contacts with the extension was positive and statistically significant at the 5% level. This means that high-advice farmers are more likely to adopt improved wheat varieties than lowadvice farmers. Other than that, under certain conditions, the odds ratio increased 1.412 times concerning the increase in extension services. The marginal effect of this model demonstrates that a household's likelihood of adopting better wheat varieties increases by 4.0% for every additional extension contact that is made. The results are in line with Negussie et al. (2022); Susie & Bosena (2020) findings that an increase in the frequency of extension visits could increase the probability of adoption by 4.96 %.

Factors Determining Selection of Teff Varieties

The factors that would affect the choice to adopt the enhanced teff variety were estimated using a logit model. In this study, 13 independent variables were assumed to be factors affecting the household level of adoption, of which six (education level, land ownership, farming experience, income sources, credit access, and farm input access) were statistically significant, while the remaining variables did not significantly influence the adoption decisions (Table 5).

The overall model works, the pseudo-R-squared is 0.415, indicating that the explanatory factors in the model account for 42% of the likelihood that a household is using enhanced teff production technologies (Table 5). The effects of statistically significant explanatory variables on adoption are discussed below.

Table 5: Estimates for the adoption of improved teff varieties

Variables	Odds Ratio	dy/dx	Coef.	SE	z
Sex of the household head	2.7029	0.1308	0.9943	1.5119	0.66
Age of the household head	0.5512	-0.0783	-0.5956	0.7032	-0.85
Family size	0.8804	-0.0168	-0.1274	0.1851	-0.69
Education level	0.4472	0.1059	0.8049	0.3227	2.49**
Farm size/ land holding	2.2788	0.1083	0.8237	0.4151	1.98**
Experience	1.1402	0.0173	0.1312	0.0417	3.15***
Livestock holding	1.0609	0.0078	0.0591	0.0746	0.79
Farm income	0.5735	0.0731	0.5559	0.2880	1.93*
Off-farm activities	1.6642	0.0669	0.5093	0.7579	0.67
Access to credit	4.0649	0.1845	1.4024	0.6192	2.26**
Access to farm input	4.3524	0.1934	1.4707	0.6175	2.38**
Extension contact	1.0282	0.0037	0.0278	0.1511	0.18
Market distance	1.0011	0.0001	0.0011	0.0064	0.18
_cons	0.0396		-3.2293	3.1309	-1.03

Source: Survey, 2021

*Significant levels are indicated by ***, **, and *, which are P<0.01, P<0.05, and P<0.1, respectively; Sample (N) =299, LR chi^2 (13) = 62.05, Pseudo R^2 = 0.4146, Probability > chi^2= 0.000; Log likelihood = -43.8147*

The results show that the head of the household’s education level was evaluated as positive and significant, with a significance level of 5% concerning the likelihood of adopting teff varieties. The odds ratio using the improved teff varieties is increased by 0.4472 times and other factors remain constant. This means that well-informed farmers will have better access to information and become more conscious of new technologies, which encourages technology adoption. The marginal effect denotes that the literacy level of household heads increased by one year, and the likelihood of adoption of seeds of improved teff varieties increased by 10.6%, other conditions are constant.

Farm size or land holding owned by farmers was favorable and significantly influenced the adoption decision of improved teff variety at a 1% level of significance. The odds ratio of the model shows that the farm size increased by a hectare, the adoption of improved teff variety production increased by a factor of 2.2788, other things being held constant. The marginal effect is that an increase of one hectare in farm size increases the probability of a farmer making a decision to adopt by 10.8%. The result is in line with Chandio & Jiang (2018); Susie & Bosena (2020).

The farming experience of the household was favorable and significantly affected the adoption decision of improved teff variety at a 1% level of significance. The odds ratio results showed that as the farmer's farming experience increased by a year, the adoption of enhanced teff varieties increased by a factor of 1.1402, with other variables being constant. The marginal effect shows that with an increase in the farming experience by one year, the probability of adoption of improved teff varieties increased by 1.7%. This result is supported by Dawit & Alemayehu (2020)
The adoption of enhanced teff varieties was influenced by farm income, which was positive and statistically significant at the 10% level. The outcome reveals that for every increase in unit income, the odds ratio for the adoption of enhanced teff varieties increases by a factor of 0.5735. The marginal effects of this model show that an increase of one unit of income increases the likelihood of adopting improved teff by 7.3% and keeps the others constant. This result corresponds to the result of a study by Abatneh (2020).

The adoption of improved teff varieties was influenced by credit access and was positively significant at a 5% level. The odds ratio in favor of households adopting enhanced teff varieties increases by a factor of 4.0649, according to the model, whereas farmers with access to formal credit increase by one unit. Marginal effects indicate that other conditions are constant, the likelihood of farmers' adoption choice of enhanced teff increase by 18.5% when a household used credit. This outcome is in line with earlier research by Gezahegn (2021); Gishu et al. (2018); Chandio & Jiang (2018).

Model results show that access to farm inputs positively impacted on the likelihood of adopting improved teff cultivars at the 5% significance level. The odds ratio in favor of using the improved teff increased by 4.3524 times for each unit's access to the input. The marginal effect shows that increasing access to the utility by 1 unit increases the chances of adopting the improved teff by 19.3%. This outcome is in line with research by Dinku & Beyene (2019).

Determinants of Farmers' Adoption of Improved Maize Varieties

Among the 13 variables used in the model, the result indicates that five variables were significant for the adoption of improved maize technology at 5% and 10% probability levels. These variables comprise the household head's age, farming experience, availability of credit, interaction with extension agents, and distance to the market. The adjusted R^2 was 0.535, indicating that 54% of the variation in the dependent variable can be explained in the model (Table 6).

Table 6: Likelihood of the adoption decision of enhanced maize varieties

Variables	Odds Ratio	dy/dx	Coef.	SE	z
Sex of the household head	11.8923	0.2435	2.4759	2.9998	0.83
Age of the household head	0.0685	-0.2636	-2.6803	1.2784	-2.10**
Family size	1.4723	0.0380	0.3868	0.2901	1.33
Education level	1.2499	0.0219	0.2231	0.6713	0.33
Farm size/ land holding	1.9529	0.0658	0.6694	0.5294	1.26
Experience	1.1832	0.0165	0.1682	0.0742	2.27**
Livestock holding	1.0156	0.0015	0.0155	0.0551	0.28
Farm income	0.1641	-0.1777	-1.8072	1.3093	-1.38
Off-farm activities	7.6497	0.2001	2.0347	1.3892	1.46
Access to credit	10.2324	0.2287	2.3256	0.9130	2.55**
Access to farm input	0.2688	-0.1292	-1.3139	1.1416	-1.15
Extension contact	1.5824	0.0451	0.4589	0.2427	1.89*
Market distance	1.0241	0.0023	0.0238	0.0112	2.12**
_cons	0.0003		-8.0509	5.5746	-1.44

Source: Survey, 2021

*Significant levels are indicated by ** and *, which are P<0.05 and P<0.1, respectively; Sample (N) =299, LR*

chi^2 (13) = 49.63, Pseudo R^2 = 0.5348, Probability > chi^2= 0.000; Log likelihood = -21.5823

The household heads' age was significant at a 5% level of significance and has a negative impact on the adoption of improved maize technology. The results indicated that younger farmers are more likely to adopt maize technology than older farmers in the study area. The odds ratio implies that a unit increase in the age of a household head will reduce the probability of adopting improved maize technology by 6.9 percent. The marginal effect shows that all other factors remain constant, an increase in age by one year, will lead to the probability of adopting enhanced maize technologies by 26.4 percent. This finding is in line with previous studies by Aklilu et al. (2022); Luchia & Hadush (2018).

The farm experience of the household heads was positively related to the likelihood of adopting enhanced maize technologies at a significant level of 5%. This means that farmers who have more years of experience in agriculture are more likely to adopt the technologies than those who have less. Other things kept constant, as its operating experience increases by a year, the odds ratio increases by a factor of 1.1832. The marginal effect result indicates that, when the head of the household's farm experience increases by one year, the probability of adoption of enhanced maize seed upsurges by 1.7%. This result confirms the study done by Chandio & Jiang (2018).

Access to credit was also one of the key factors positively influencing the adoption of maize production technologies, with a significance level of 5%. The findings showed that when farmers receive credit, the odds ratio for choosing an enhanced maize variety increased by a factor of 10.2324, other things being equal. The marginal effect shows that when households used the credit, there was a 22.9% increase in the likelihood that farmers would select improved maize varieties. This finding is consistent with those of Gezahegn (2021); Chandio & Jiang (2018).

Extension contacts had a positive and significant impact on the adoption of maize varieties at a 10% level of significance. This means that farmers who frequently access and expose their advisory services have a higher likelihood of adopting improved varieties than farmers who do not. Otherwise, under certain conditions, the odds ratio will increase by a factor of 1.5824, accompanied by an increase in extension services with additional visits. The marginal effect shows that for every unit of extension contact, the likelihood of adopting improved maize varieties increases by 4.5%. This finding is in line with research by Dinku & Beyene (2019); Bedilu et al. (2021).

It was found that market distance was positively related to the likelihood of adopting enhanced maize production technologies at a significance level of 5%. Holding other conditions constant; the odds ratio increases by a factor of 1.0241 for each increase in market distance by one minute. Marginal effects indicate that as market distance increases by one minute, the likelihood of adopting the enhanced maize varieties improves by 0.2%, and other conditions are kept constant. This determination of the outcome is comparable to research by Dinku & Beyene (2019).

Utilization of Certified Seeds

Despite the release of several technologies, improved seeds were of limited use by many Ethiopian farmers. The lack of seeds combined with ineffective promotion schemes is the major factor, further contributing to lower agricultural productivity due to inefficiencies in the country's seed system.

According to CSA (2020), nationally, about 16 million smallholder farmers are engaging in to use of non-certified seeds and six million smallholder farmers are using certified seeds. The area covered by non-certified seeds was 79.7% and 20.3% covered by the certified seed of the total cereal crop area, whereas about 85.7% and 14.3% of the total seed area were covered by non-certified and certified seeds respectively. Regarding inputs, out of the total cereal, certified seeds of maize, wheat, and teff technology were utilized in amounts of 45.8%, 41.7%, and 3.5%, respectively (Table 7).

Table 7: Certified and non-certified seeds by area and quantity of inputs used in 2020/21

Crop	Non-certified seed		Certified seed		Total	
	(Ha.)	(T)	(Ha.)	(T)	(Ha.)	(T)
Wheat	1,543,710	310,755	353,695	47,406	1,897,405	358,161
Teff	2,738,114	162,334	190,092	3962	2,928,206	166,296
Maize	1,023,306	63,306	1,502,907	52,000	2,526,213	115,307
Total cereal	8,399,266	806,330	2,139,076	113,612	10,538,342	919,942
Total seed	13,379,273	1,043,516	2,228,604	116,951	15,607,877	1,160,467

Source: CSA, 2020

In the 2020/21 cropping season, certified seeds were supplied, and accessed to the smallholder farmers through cooperative unions, the bureau of agriculture, and seed enterprises. The crop types and varieties were wheat (Kekeba, Ogolcho, kingbird, Hidase, Denda'a, Mangudo, Utuba, and Wane), teff (Tsedey, Boset, Dega teff, and Dagim), and Maize (Limu, Shone, Damot, and Kortu).

Table 8 shows the crops and varieties released and introduced to farmers. The development of improved varieties of seeds should help increase the production and productivity of national crops. These varieties have been tested by breeders and rated by experts and the National Variety Release Committee (NVRC) as superior to existing cultivars. It works well in the evaluation and only the varieties approved by NVRC are released or registered in the plant variety registry with the main agronomic and morphological explanations and presented to the user (farmer). According to this, 14 new cereal crop varieties were released during the cropping season of 2020/21, and 487 varieties were released before 2020/21 (MoA, 2021).

Table 8: Cereal crops and varieties released and introduced to farmers in the year 2020/21

Crops	Varieties	Released		Released by (Organizations)
		In 2021	Before 2021	
Wheat	Abay, Shaki, and Laku	3	96	Kulumsa ARC/EIAR, Bako ARC/OARI
Tef	Takusa, Jarso, and Boni	3	51	Adet ARC/ARARI, Bako ARC/OARI, and Debere zeit ARC/EIAR
Maize	-	-	77	
Durum wheat	ETCROSS-21	1	41	Debere zeit ARC/EIAR
Triticale	-	-	10	
Emmer wheat	-	-	3	
Buckwheat	-	-	1	
Barley (Food & Malt)	Walashe, Jalqabne, Suba, MBF5P#26(Ras)	4	75	Sinana ARC/OARI, Bako ARC/OARI, Holeta ARC/EIAR, GonderARC/ARARI
Rice (upland, lowland, & irrigated)	-	-	40	
Sorghum	AYINAGE, Erer	2	60	Mechara ARC/OARI, Fedis ARC/OARI
Millet (Finger, Pear, & Foxtail)	Ikhulule	1	29	Mechara ARC/OARI,
Quinoa	-	-	1	
Food oat	-	-	3	
Total		14	487	

Source: MoA, 2021 (Crop variety register)

Adoption of Certified Seeds of Improved Varieties

The study shows that the most extensively produced crops in the study area were wheat, teff, and maize with 42%, 33%, and 12% of household respondents adopting improved seeds, respectively, and the majority (71%) of households respondents relying on their local landraces. In terms of input, improved wheat, teff, and maize seeds were used in amounts of 31 tons, 7 tons, and 2 tons, respectively (Table 9). Therefore, a lack of availability of improved seeds, a lack of awareness about improved cultivars, and a dearth of quality seeds at the appropriate time and place were the main causes of the low adoption rate. There are many reasons, farmers, use certified seeds of improved varieties as an alternative. Such as, the certified seed is a pure seed that has been grown and processed in accordance with rigid production standards, with rigorous restrictions on weeds and other crop types; maximizes the purity of varieties; provides quality assurance; access to new possibilities; allows for capitalization on traceability measures; improves traits such as better yield, pest resistance, and drought and herbicide tolerance; maximize other inputs; access to premium markets.

Table 9: Adoption of certified seed of improved varieties and input used

Crop Type	Districts				Improved seed (t)	Used (%)
	Ada'a	Bora	Moretina Jiru	Total		
	%	%	%	%		
Wheat	43	27	49	42	31	76
Teff	47	35	19	33	7	18
Maize	8	40	0	12	2	4

Source: Survey, 2021

The results of the study show that households gave several reasons for not adopting enhanced seeds. According to Table 10, the most common reason farmers cited was a lack of timely delivery of seeds 46% and incapable of paying prices 37%. Various studies have found that the main obstacles are the lack of the required amount of seeds at the right time and place and the lack of affordable seeds.

Table 10: The main reason for the non-adoption of certified seeds

Reasons	Ada'a	Bora	M. jiru	Total
	% (N)	% (N)	% (N)	% (N)
No supply of seed at the right time	52.3 (56)	41.2 (28)	43.9 (54)	46.3 (138)
Unaffordable price	25.9 (28)	44.1 (30)	43.1 (53)	37.1 (111)
Lack of source seed	8.4 (9)	2.9 (2)	2.4 (3)	4.7 (14)
No loan basis provision	5.6 (6)	4.4 (3)	1.6 (2)	3.7 (11)
No difference in productivity from the local one	7.5 (8)	7.4 (5)	8.1 (10)	7.7 (23)
A long way to obtain the seed	0.0 (0)	0.0 (0)	0.8 (1)	0.3 (1)
No exchange-based provision	0.9 (1)	0.0 (0)	0.0 (0)	0.3 (1)

Source: Survey, 2021

Conclusion and Recommendations

Adopters and non-adopters differed significantly on relevant characteristics. The adopted households have a relatively large family size and agricultural experience, own more land and livestock, and have more extension contacts than non-adopted. Low adoption rates were a result of limited availability of improved seeds, absence of awareness about enhanced varieties, a shortage of timely access to good-quality seeds, as well as expensive seed costs.
The household head's educational level, farm size, farming experience, income, credit access, extension contact, farm inputs, and distance from the market significantly determine the adoption of enhanced varieties, while adoption was significantly hampered by livestock holding and the age of the household head.

The adoption of improved varieties should be increased by providing investment and training to build educational capabilities; raising farmers' knowledge that makes them more rational when using improved technology; making land more economical by encouraging farmers to cultivate their potential land; improving income by promoting market opportunities; providing agricultural inputs based on credit, promoting timely delivery of agricultural inputs, and providing frequent extension visits by increasing the number of agents. Moreover, governments, non-governmental organizations, and advisors should be stimulated to facilitate extension services and knowledge sharing among farmers. In addition, appropriate seed policies need to be established to accelerate seed production and distribution through effective extension systems to facilitate, enhance and maintain the uptake of improved varieties.

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