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Adoption and intensity use of malt barley technology package by smallholder farmers in Ethiopia: A double hurdle model approach

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ABSTRACT

Ethiopia has an enormous production potential for malted barley due to its ideal agroecology, notably in the central and Bale highlands. However, local production cannot meet the demand for both new and old malt and brewing plants. Millions of dollars have been invested to import malt at the national level. The objective of this study was to investigate the factors that influence smallholder farmers' adoption and level of use of the malt barley technology package. A multi-stage sampling procedure was employed to choose representative kebeles and households. The study relied on actual data collected from 201 randomly selected barley-producing households. Descriptive statistics and Double Hurdle economic models were used to analyze the data. The descriptive findings show that malt barley varieties and the malt barley technology package were adopted at rates of 0.3 and 0.9, respectively. The Double Hurdle model results reveal that factors such as the household head's age, the total area under cultivation, the availability of information on malt barley production, distance from the main road, participation in the field day program, and membership in the agricultural cooperative all had an effect on smallholder farmers' decisions to adopt and use the malt barley technology package. The recommendation made by this research was to boost farmers' knowledge of malt barley production through training and field trip programs. Organizing smallholder farmers in nearby agricultural cooperatives, as well as ensuring access to roads and public transit for easy access to agricultural inputs and output markets.

1. Introduction

Barley was the first cereal to be domesticated by man, dating back to 7000 BCE, and its cultivation probably originated in the Abyssinia highlands and Southeast Asia in prehistoric times [1]. Barley is the fourth most important cereal crop in the world after maize, wheat, and rice and ranks fifth in area coverage [2]. Ethiopia is ranked 11th in the world and 1st in Africa in barley production, with a share of 1.47% of the world's total production [2]. In Ethiopia, barley is produced by more than 3.7 million smallholder farmers on around one million hectares of land, from which 2.3 million tons of grain are produced annually, with an average national yield of 2.5 tons per hectare [3]. The Amhara region is the second-largest producer in Ethiopia, covering 311,401.39 ha with a productivity of 2.3 tons per hectare. From these, North Shewa covers 47,656.36 ha (the second largest in the region) with an average productivity of

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2.6 tons per hectare. Out of this, the share of malt barley is insignificant and could not exceed 10%–15%, yet malt barley is among the priority commodities that have attracted the attention of malt factories, breweries, and policymakers in general [3]. Malt barley is becoming a major income source for smallholder farmers in the highland areas of Ethiopia, particularly where the agroecologies are not more productive than other cereal crops [4]. Even if malt barley production and productivity increased year over year, the supply does not meet the demand of the emergence of malt and brewery factories. The brewery factories demanded about 118,000 tons of malt per year, while the local malt source is 52,000 tons, which covers only about 50% of it [5–7]. This huge gap between malt barley demand and market supply with more farmland suitable for malt barley production indicates there is still an opportunity to expand the production, productivity, and local market supply of malt barley by smallholder farmers.

The government and other non-governmental organizations in developing countries focus on agricultural technology promotion and popularization and have invested huge amounts of capital recently. However, significant adoption and commercialization of emerging technologies have not been achieved, particularly in less-developed countries, due to a combination of cultural beliefs, ethical concerns, regulatory delays, and a lack of information and understanding of the science and technology being used [8]. The aggregate adoption of agricultural technology in developing countries remains low [9]. Despite the major emphasis on agricultural research for technology development and extension services, the uptake of modern technologies by smallholder farmers in Ethiopia fails to keep pace with the investment [10,11], as cited by Ref. [12]. The average adoption rate of improved barley varieties in three major barely growing regions, i.e., Oromia, Amhara, and SNNPR, accounted for 41.4% [13]. The largest proportion of adopters accounted for households in the Oromiya region (71%), followed by the SNNPR (27.3%) and the Amhara region (17.1%). Despite barley being largely grown in the Amhara region (this study area), the adoption rate of improved barley varieties was still very low [13].

Several works of literature point out a wide range of factors limiting agricultural technology adoption in Ethiopia. For example [14–17], find out that social participation, farm size, market distance, farmer's attitude, education level, family size, access to credit and training, membership in cooperatives, and total livestock units are the major determinants of malt and food barley technology adoption and intensity used in Ethiopia. But, in the North Shewa Zone of the Amhara Region, information on malt barley technology package adoption was scarce due to a lack of studies. On the other hand, most of the adoption studies focused on the adoption of malt barley varieties rather than the whole technology package (improved varieties, seed and fertilizer rates, planting methods and times, plowing and weeding frequency, proper chemical type, application rate, and time). Most of the time, agricultural technologies are introduced as a whole package, and the yield and other agronomic improvements gained from the synergy between the introduced production packages require an adoption study to assess the whole technology package. So that this study focused on the adoption of the malt barley technology package as a whole to assess the status of malt barley technology package usage and determinants of adoption and intensity use of malt barley varieties in the Central Highlands of Amhara Region, Ethiopia.

1.1. Theoretical and conceptual review

There are several paradigms or theories of the adoption of innovation that were developed by different scholars at different times. These are the theories of planned behavior [18], social cognitive theory [19], diffusion of innovation [20], technology acceptance model [21], innovation-decision process model [22], and social network theory [23]. However, the adoption of improved agricultural technologies has been guided and influenced by three paradigms or models, which include diffusion of innovation, perception of

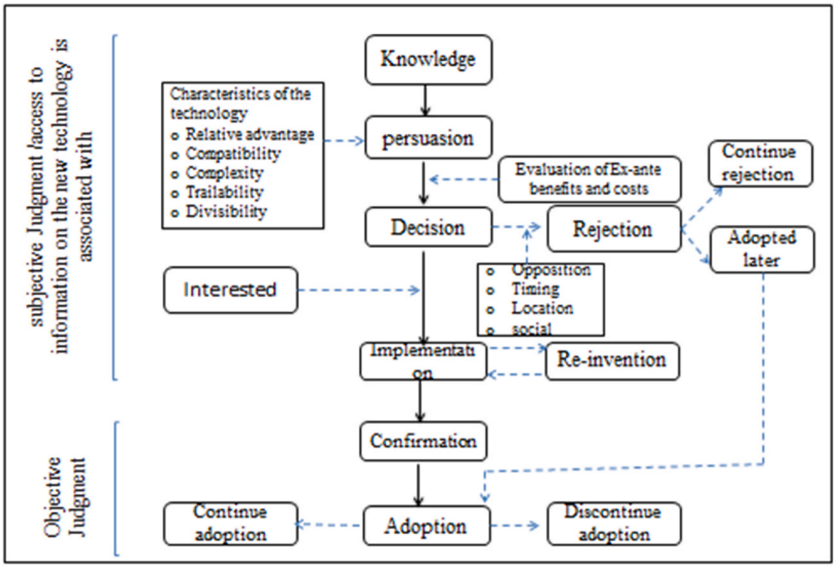

Fig. 1. Technology adoption by agricultural producers. Source: Adopted from Albert et al. (2018).

adopters, and economic constraint [24,25]. The first paradigm is the innovation diffusion paradigm, which deals with information dissemination [26] and Rogers [20]. The second paradigm is the economic constraint paradigm, which asserts or contends that technology adoption is influenced by utility maximization and economic constraints due to the existence of resource distribution asymmetry. It also asserted input fixity in the short run, such as credit, land, labor, and other inputs. Access limits, production flexibility, and conditions of technology adoption [25,27,28]. Third, the adopters‘ perceptions paradigm posits or theorizes that the adoption process starts with the problem of adopters‘ perceptions and the proposed technology [26]. In this study, the diffusion of innovation theory (information dissemination as the major factor of adoption) is used for understanding concepts and factors of adoption of agricultural technologies because, most of the time, low adoption of agricultural technologies in Ethiopia is due to limited access to information, technical knowledge, and agricultural technologies [29]. But also, most of the recent studies, like [30–32] and others, used diffusion of innovation theoretical models to study the adoption of agricultural technologies (Fig. 1).

1.2. Empirical studies on intensity use and adoption status of agricultural technologies

In most cases, according to Ref. [33], agricultural technologies are introduced in packages that include several components, such as high-yielding varieties (HYV), fertilizer, and corresponding land preparation practices. While the components of a package may complement each other, some of them can be adopted independently. In agricultural extension, in developing countries, there is a tendency to support whole-package adoption [34]. For multiple practices (packages), scholars used different methods to measure the adoption status of the agricultural technology package. Empirical studies by Ref. [15] used an adoption index to study the adoption status and intensity of the malted barley technology package in Melga woreda, southern Ethiopia. Whereas the study by Ref. [35] on technology adoption in Gram used a composite index. Scholars categorized the adoption status of smallholder farmers as non-adopters, partial adopters, and full adopters [15]. Other scholars also categorized smallholder farmers as low adopters, medium adopters, and high adopters [36]. The actual adoption index score ranges from 0 to 1. An index score of 0 implies non-adopters who have not used malt-barley technology. An index score of 1 indicates adopters who applied all practices according to scientific recommendations. Using the value of the index, the categories of adoption status are presented in percentages.

1.3. Empirical studies on determinants of malt barley adoption and intensity use

To understand the factors affecting the adoption and intensity of the use of malted barley, several studies have been undertaken in Ethiopia using different econometric models. The study by Ref. [14] was conducted on determinates of malt barley technology adoption and intensity used in Limuna Bilbilo, Shashemene, and Kofele districts of Oromia National Regional State using the Tobit model. The Tobit model result showed that social participation and total farm size affected malt barley technology adoption negatively and significantly, while operated plot size, profit level, market distance, and farmers’ attitudes towards malt barley technology influenced its adoption significantly and positively, among other variables. Another study was conducted by Ref. [15] on factors affecting the adoption and intensity of malt barley technology packages in Malga Woreda, southern Ethiopia, using the Tobit model. The results of the Tobit model indicated that factors influencing adoption and its intensity were education, family size, land size, access to credit, membership in a cooperative, access to training, access to demonstrations, total livestock units, and distance to the nearest market. These affected farmers’ adoption decisions and the intensity of adoption significantly in one way or another.

A study by Ref. [16] on determinants affecting the adoption of malt-barley technology in North Gondar, Ethiopia, using the Tobit econometric model The result explained that education and access to improved seed and training affected the adoption of malt-barley technology positively and significantly, while the social status of household heads influenced the technology significantly but negatively. The findings of [37] on the study of determinants of improved barley adoption and intensity used in Malga District of Sidama Zone, Ethiopia, indicated that age, farm experience, oxen, membership of the cooperative, distance to all-weather roads, and annual income significantly affect the intensity of barley adoption.

1.4. Empirical model review

Adoption survey analysis can include both an examination of farmers’ opinions and observations and a statistical comparison of adoption measures with characteristics of the farmer or the farming system [38]. There are several well-developed methods for looking at multivariate relationships. One of the most common is multiple regression analysis, but this is appropriate only if the dependent variable is continuous. As many adoption studies will deal with adoption as a categorical dependent variable (usually “yes” or “no”), other techniques are required. Two related multifactorial analytical techniques that are particularly useful for adoption studies are logit analysis and probit analysis. Both probit and logit models are techniques for estimating the probability of an event (such as adoption) that can take one of two values (adopt or don’t adopt) [24]. In some instances, one might want to analyze not only adoption but also the extent or intensity of adoption. For example, one might want to estimate both the probability that a farmer uses fertilizer and the rate of application as well. A commonly used model, in this case, is the Tobit model. Tobit, like probit, is based on the normal distribution. As in probit or logit, coefficients are estimated for the independent variables thought to be relevant. Tobit estimates also include the standard error of the regression, which is an estimate of the standard deviation of the error term in the regression model [39]. The logit and probit methods investigate the effects of regressors on the choice to use or not to use, but they do not measure the degree or intensity of adoption [24]. Therefore, an alternative static econometric procedure such as the Tobit [40] is used to analyze quantitative adoption decisions when information on the intensity of adoption is available. The Tobit model is superior to Probit and logit [40] when the dependent variable is truncated and thus continuous between a certain lower and upper limit. The advantage of this model compared to Probit and Logit models is that it reveals the probability of adoption and the intensity of use after its adoption. This inadequacy is overcome with the use of the Tobit model [40,41].

The Tobit model provides coefficients that can be further disaggregated to determine the effect of a change in the eighth variable or changes in the probability of adopting the new technology and the expected intensity of use of the technology. However, a study by Ref. [42] indicated that a Tobit model imposes restrictions because the variables and coefficients determining whether and how much to adopt decisions are identical. But, in theory, the estimation procedure could be improved by modeling the decisions that produce the zero observation rather than by using the tobit mechanically. Other alternatives to analyzing farmers' adoption decisions include the use of double hurdle models, which take into account zero observations [43,44]. The double-hurdle model was originally proposed by Ref. [43]. The model does not require the assumption that participation and intensity of participation are determined by the same process as in the Tobit model. It is worth noting that Cragg's Double Hurdle Model and Heckman's Model are similar in that both are two-stage econometric regression models. Heckman employs the Probit and Ordinary Least Square (OLS) models in the first and second stages, respectively, while Crag's Double-Hurdle model employs the Probit and then the Tobit, truncated normal regression, or lognormal regression models in the first and second stages, respectively. The Probit model employed in Heckman's model is not different from the one used in the Double Hurdle Model.

1.5. Conceptual frame work

A conceptual framework is an interconnected set of ideas regarding a particular phenomenon that shows how parts are functioning [45]. It lays out the key factors, constructs, or variables and the relationships among them. The conceptual framework contributes to better research and helps researchers clarify their thoughts [46]. Based on the theoretical, conceptual, and empirical review, the major independent variables that will be used in this study are broadly classified as demographic (sex, age, education status), socio-economic factors (farm size, family size/labor, income, and assets), institutional factors (extension contact, access to credit, market, inputs, and information, distance from main road and FTC, membership, and leadership position in local cooperatives), and technological factors (relative advantage, compatibility, complexity, trialability, and divisibility) (Fig. 2).

2. Materials and methods

2.1. Study area description

The research was carried out in the North Shewa Amhara of Basona Worana and Angolelana Tera woredas (Fig. 3). The woredas are located approximately 140 and 110 km northeast of Addis Ababa. Both woredas are defined by high land, midland, low land, and mixed farming methods. The annual temperature ranges from 6.1 to 19.67 °C with an average elevation of 2975 m, while the rainfall pattern in Bassona worana woreda is unimodal with an annual rainfall of 897.8 mm. The elevation of Angolelana tera woreda ranges from 1450 to 2800 masl, and its bimodal rainfall pattern covers an area of 930–1500 mm per year. The average annual temperature in

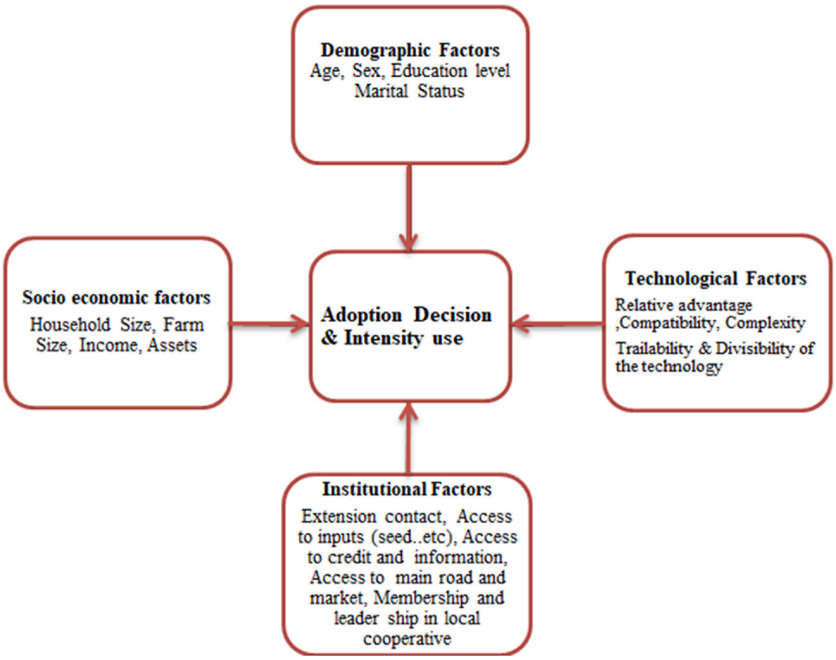

Fig. 2. Conceptual framework of the study. Source: Adapted from CIMMYT (1993) and Abera (2009).

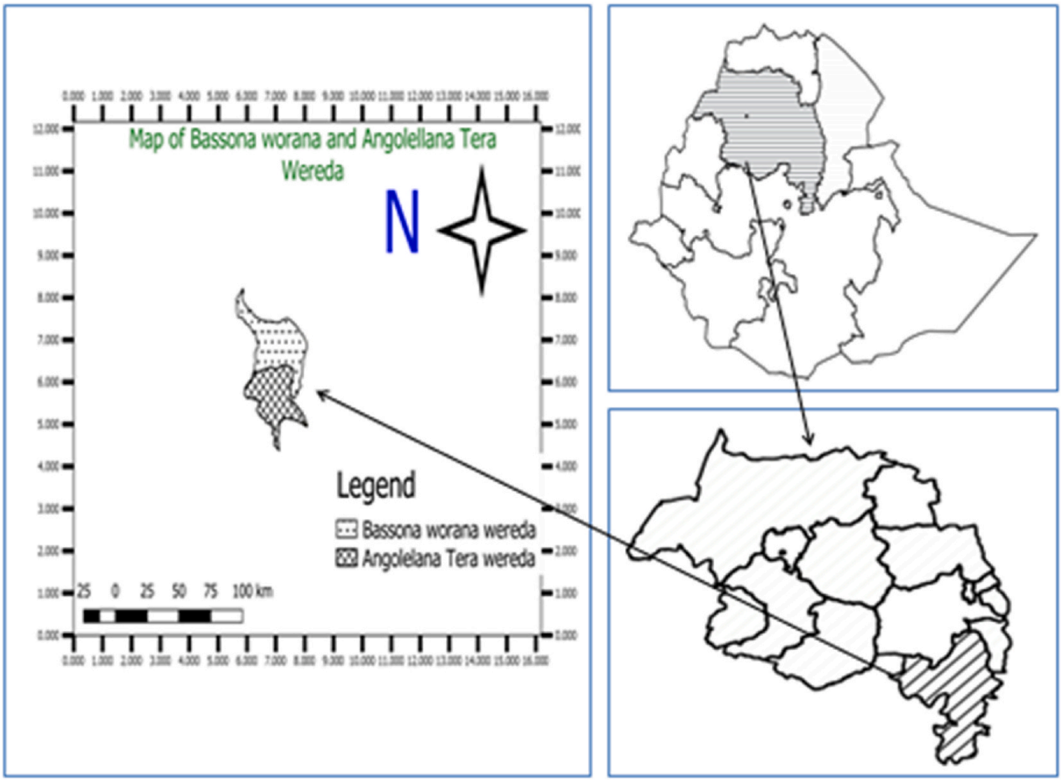

Fig. 3. Map of study areas.

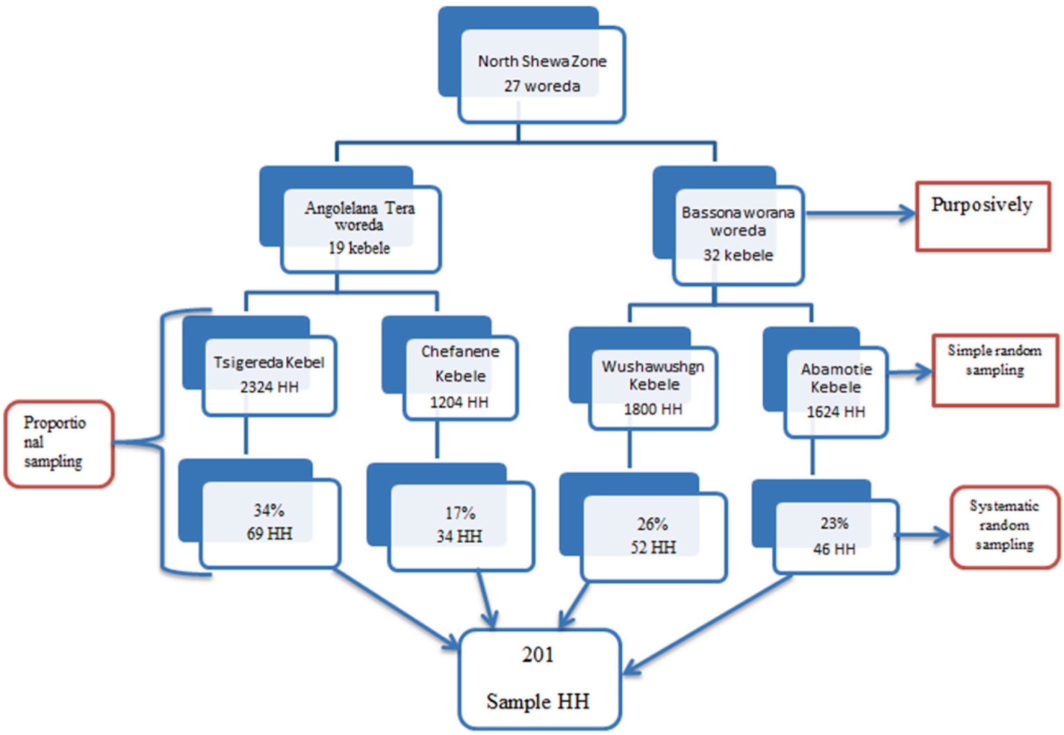

Fig. 4. Multistage sampling methods used for selecting study sample.

the woreda is 14 °C [47]. A mixed farming system supplies the population of the two woredas with their principal source of subsistence (both farming and livestock production). The two woredas' main field crops are barley, faba beans, and wheat [48].

2.2. Sampling method and sample size

Using multi-stage sampling approaches, the appropriate respondents were selected. Basona worana and Angolelana Tera woreda of the North Shewa administrative zone were specifically chosen in the first stage due to their capacity to produce malt and food barley. In the second step, two kebeles from each woreda that grow barley were chosen using simple random selection, taking into account cost, time, and labor. In the third stage, a sampling frame of 6952 smallholder farmers from four selected kebeles was used. Finally, sample respondents were drawn at random from both malt barley producers (adopters) and those who did not produce malt barley (non-adopters), proportional to the sample size of the chosen kebeles population (Fig. 4). A study sample of 201 respondents was determined using [49] as follows.

$$n = \frac{N}{1 + N(e)^2}$$

Where, N = the total size of barley (both food and malt barley) producers in the study area which is 6952, n = sample size which is 201 (10% add, e = the acceptable sampling error which is about 0.07 (Table 1).

According to Ref. [50], it is common to add up to 10% of the selected sample for compensating absentees of contact with respondents and rejected samples due to recording and other errors. The study sample respondents were calculated for each level.

2.3. Data collection technique

Focus group discussions and standardized questionnaires were used to gather the main data. Following orientation, the data collectors received training, and the questionnaire was pre-tested and revised for the intended application. Following that, over the course of six days in the second week of May 2021, the necessary primary data were gathered from randomly chosen barley producers (both food and malt). Four focus group discussions (one per kebele) were conducted with 7–10 selected barley farmers following the entry of the obtained data into the SPSS program.

2.4. Method of data analysis

Both SPSS (version 16) and STATA (version 14) software were used in the study. To analyze the gathered data and achieve the given objectives, descriptive statistics, inferential tests, and econometric models were used. To perform some comparison analysis, descriptive statistics like mean, frequency, and standard deviation, as well as inferential statistics from statistical testing like the *t*-test and chi-square (2), were utilized. The intensity of use of the technology packages was determined using the adoption index formula. The factors influencing the adoption decision and level of use of the malt barley varieties were estimated using the Double Hurdle econometric model.

2.5. Theoretical model used in this study

The Tobit model assumes that adoption decisions and intensity use decisions are related. Yet, studies by Ref. [43] on the desire for durable items and [51] on the use of fertilizer showed that such choices might not be closely related. Recently, most researchers [52–58] used the Double Hurdle mode for estimating the adoption decision and intensity of the use of agricultural technologies. As a result, the Double Hurdle model was used in this study. The Probit or Logit estimates may be used in the initial step of the model to assess the likelihood of adoption [59]. The intensity of adoption is estimated using a variety of estimation techniques in the second stage, including truncated regression [60,61]; lognormal regression [62] and OLS regression [40]. However, in this study, the binary Probit model was employed in the first stage for adoption decision and the Tobit model in the second stage for adoption intensity. As a result, the Double Hurdle model was used in this study which specified as:

$$Yi1^* = X1\beta1 + U1i \; U1i \sim N\left(0, \alpha1^2\right) \tag{1}$$

Table 1
Number of sample households and their proportion from each kebele.

Kebele	Total No Household		Sample Distribution	
	Male	Female	%	No
Tsigereda	2175	149	34	69
Abamotie	1222	402	23	46
Wushawushgn	1449	351	26	52
Chefanen	994	210	17	34
Total	5840	1112	100	201

Source: studied kebeles agriculture office households based data record.

$Y1 = 1$ if $Yi1^* > 0$, $Y1 = 0$ if $Yi1^* \leq 0$

$$Yi_2^* = X_2\beta_2 + U_{i2}\ Ui2 \sim N\left(0, \alpha 2^2\right) \tag{2}$$

$Y_2 \geq 1$ if $Yi2^* > 0$, and $y1 = 1$.

$Y_2 = 0$ if $Yi2^* \leq 0$ Where,

I refer to the ith household.

Y_{i1} * is the latent (unobservable) variable of Y_i

$_{Y1}$ is the observable discrete decision of whether or not to use Malt barley.

Yi_2* is a latent variable (desired areas allocated for malt barley production).

Y_2 is an observed variable (actual areas allocated for malt barley production).

X_1 and X_2 are vectors of explanatory variables

β_1 And β_2 are parameters to be estimated and U_1 and U_2 are random errors.

Producer farmers are frequently given a package of agricultural technologies to improve their farmin. How every, as a result of their ignorance of and fear of the freshly released technologies, farmers adopt the technology package at various rates and stages to lower farm risk. In this study, the adoption index formula was utilized to gauge how heavily respondents' farmers were utilizing the malt barley technology package. The evaluation of the malt barley technology package in this study took into account the amount of farmland set aside for malting barley, the seed rate, the rates of NPS and UREA fertilizers, the frequency of plows, the rates of weeding, and the rates of herbicide chemical applications [63].

$Ai = \sum_{i=1}^{n} \frac{\left(\frac{ATi}{RTi}\right)}{NP}$.

$$\sum_{i=1}^{n}\left(\frac{SA}{SR} + \frac{NPSA}{NPSR} + \frac{UREAA}{UREAR} + \frac{PFA}{PFR} + \frac{HCA}{HCR} + \frac{WA}{WR} + \frac{LAMB}{TCL}\right) \Big/ NP$$

Where, Ai = adoption index of the ith farmer i = 1, 2, 3 ….n; n is the total number of respondent farmers.

SA = seed rate applied per hectare, SR = seed rate recommended per hectare.

NPSA=NPS fertilizer rate applied per hectare, NPSR=NPS fertilizer rate recommended per hectare.

UREAA=UREA fertilizer rate applied per hectare, UREAR=UREA fertilizer recommended rate per hectare, PFA = plowing frequency applied, PFR = plowing frequency recommended.

HCA = herbicides chemical rate applied per hectare, HCR = herbicides chemical rate recommended per hectare, WA = weeding rate applied, WR = weeding rate recommended LAMB = land allocated for malt barley, TCL = total cultivated land NP = total number of the package for malt barley which is 7.

2.6. Hypothesis and definition of variables used in this study

In the literature, researchers used different proxies for the intensity use of malt barley such as area allocated for improved varieties, amount of improved seed used, amount of improved variety produced and adoption index of the technology package. In this study, the

Table 2

Explanatory Variables for Double Hurdle Model and their Expected Sign.

Variable	Description	Value	Expected sign for	
			adoption decision	intensity use
Age	Age of the household head (years)	Numbers	–	–
Sex	Sex of the household head (being male)	0 = F, 1 = M	+	+
Formal Education	Education level of HH head (years)	Number	+	+
Household Size	Number of individuals living in a house	Number	+	–
Cultivated Farm Size	The total size of cultivated farm (ha)	Number	+	–
Farming experience	Farming experience in general (years)	Number	+	
Access to MB productioninformation	HH information access on MB production	1 = Yes, 0 = No	+	+
Access to Credit	Household's access to credit	1 = yes, 0 = N0	+	+
Number of oxen	Number of oxen the HH had	Number	+	+
Livestock Holding	Number of livestock HH had (TLU)	Number	+	–
Contact with Das	HH contact with development agent	1 = yes, 0 = No	+	+
Market distance	HH distance from the nearest market (walking minutes)	Number	–	–
Cooperative distance	HH distance from cooperatives (walking minutes)	Number	–	–
Das office distance	HH distance from Das office (walking minutes)	Number	–	–
Main road distance	HH distance from the main road (walking minutes)	Number	–	–
Training participation	HH participation in the training program	1 = yes, 0 = No	+	+
Field day participation	HH Participation in the field day program	1 = yes, 0 = No	+	+
Demonstration participation	HH Participation in demonstration program	1 = yes, 0 = No	+	+
Membership in cooperative	Membership of household in local cooperatives	1 = yes, 0 = No	+	+
Household income	Total income of household (ETB)	Number	+	–
Adult equivalent	Adult Equivalent (AEU)	Number	+	+

adoption index of the malt barley technology package for adoption status and the area allocated for improved malt barley varieties for intensity use of malt barley were used as a proxy measure. There were two dependent variables used in the econometric models to achieve the objective of the study.

2.6.1. Malt barley adoption decision of smallholder farmers

The binary variable of the first stage of the Double Hurdle model (probit) valuing = 1 if the respondent grew malt barley during the 2021 main production season or = 0 otherwise (not use or produce malt barley).

2.6.2. Intensity use of malt barley by smallholder farmers

The continuous variable of the Double Hurdle model was the amount of farmland allocated for malt barley varieties during the 2021 main production season.

The explanatory variables that affect the adoption and intensity use of malt barley by smallholder farmers were collected based on different literature, adoption theory, economic theory and other documents. Then, the hypothesized variables were selected in different ways. Traditionally, factor variables were selected using a software package of stepwise selection, forward selection and backward elimination. But now, researchers used other modern variable selection strategies like penalized likelihood tests. Independent variable selection methods are based on the significance or information criteria, penalized likelihood, the change-in-estimate criterion, background knowledge, or combinations of them [64]. Modeling should start with defendable assumptions on the roles of independent variables that can be based on background knowledge that is from previous studies in the same field of research, expert knowledge, or common sense [64]. Hence, after contracting the full model using literature, the likelihood ratio test was used in this study to select the independent variables included in the final fitted model. The independent variables were described below (Table 2).

3. Results and Discussion

3.1. Demographic and socioeconomic characteristics of the sample households

A total of 201 smallholder farmers were included in the study. Out of it, 54.7% of the sample households grew different malt barley varieties with recommended production packages during the 2021 main production season, which are now called adopter households. Whereas, the remaining 45.3% of the sample households that did not grow malt barley in the study year were called non-adopter households. The independent *t*-test results (Table 3) show eight variables had statistically significant differences between adopter and non-adopter households. The mean age of the total sample households was 45.6 years. The *t*-test result shows the mean age of the sample household's head, who is assumed to be the main decision-maker of the household, was 44.1 and 47.4 years for adopters and non-adopters, respectively. The mean farming experience of the sample households was 27.5 years. The mean farming experience of the household head was 25.8 and 29.5 years for the adopter and non-adopter, respectively, with a statistically significant difference between them. The mean formal education level of the sample households was 2.5 years. The *t*-test result also shows the mean formal education level of the sample households heads was 2.9 and 2 years for adopters and non-adopters, respectively, with a statistically significant difference between them. The mean household size of the sample of respondent households was 4.9. The mean household size of adopters and non-adopters was 5 and 4.8, respectively. The mean adult equivalent values of adopters and non-adopters were 3.9 and 3.8, respectively (Table 3).

The *t*-test result shows the mean cultivated land of adopters and non-adopters was 1.9 and 1.3 ha, respectively, with a statistically significant difference between them. The mean number of oxen in adopters' and non-adopters' sample respondent households was 2 and 1.9, respectively. The mean livestock holding (TLU) of the adopter and non-adopter households was 5.3 and 4.8, respectively. The

Table 3
Respondent households' characteristics by continuous variables.

Variables	Total Sample		Adopters (110)		Non adopters (91)		t-value
	Mean	Stdvn	Mean	Stdvn	Mean	Stdvn	
Age of HH head	45.6	14.1	44.1	13.5	47.4	14.9	1.6
Formal Education level	2.5	3.3	2.9	3.3	2.0	3.1	−2.0**
Farming Experience	27.5	14.8	25.8	14.4	29.5	15.2	1.8*
Household Size	4.9	1.9	5.0	1.9	4.8	1.9	−0.7
Cultivated land (ha)	1.6	0.8	1.9	0.8	1.3	0.7	−5.9***
Number of oxen	1.9	0.9	2.0	0.9	1.9	1.0	−0.6
Livestock Holding (TLU)	5.1	2.2	5.3	2.2	4.8	2.1	−1.6
Distance cooperative	35.2	18.1	31.2	26.9	39.9	29.3	2.2**
Distance DAs office	32.1	31.1	28.7	30.3	36.9	34.4	1.8*
Distance to market	102.9	69.0	103.1	68.9	102.2	71.2	−0.1
Distance to the Main road	24.1	18.0	19.6.	15.1	29.4	19.9	3.9***
HH Income (ETB)	53,041	41,567	59,477	42,113	45,262	39,747	−2.5**
HH Assets (ETB)	272,883	200,192	308,943	213,943	229,294	173,536	−2.9***
Adult Equivalent	3.8	1.6	3.9	1.6	3.8	1.6	−0.5

The distance measured in walking minutes, ETB = Ethiopian birr.
***, **, * significant at 1%, 5% and 10% level respectively source: own survey result, 2021.

mean sample household distance from the local cooperative and development agent offices was 35.2 and 32.1 walking minutes, respectively. The *t*-test result shows the mean household residence distance from the local cooperative was 31.2 and 39.9 walking minutes for adopters and non-adopters, respectively, with a statistically significant difference between them. The mean sample household residence distance from the development agent's office was 28.7 and 36.9 walking minutes for adopters and non-adopters, respectively, with statistically significant differences between them. The *t*-test result indicates the mean sample household residence distance from the nearest market was 103.1 and 102.2 walking minutes for adopters and non-adopters, respectively. The mean sample household's residence distance from the main road was 19.6 and 29.4 walking minutes for adopters and non-adopters, respectively, with statistically significant differences between them. The mean sample household income and assets were 53040.95 and 272882.7 ETB, respectively. The *t*-test result confirmed that the average household income of adopter and non-adopter households was 59476.5 and 45261.7 ETB, respectively, with a statistically significant difference between them. The average household asset (estimated in Birr) of the adopter and non-adopter households was 308942.7 and 229293.7 ETB, respectively, with a statistically significant difference between them (Table 3).

3.2. Institutional characteristics of sample households

Only six factors had statistically significant variations between adopter and non-adopter households, according to the chi-square test result (Table 4). The chi-square test result reveals a statistically significant difference between adopter and non-adopter households, with access to information on malt barley production available to 99% and 67% of each, respectively. There were statistically significant differences between households that had contact with development agents in 91% and 90% of the adopter and non-adopter households, respectively. Households in the adopter and non-adopter samples had access to credit in roughly equal amounts (40% and 32%, respectively). Participation in field day activities on malt barley organized by development agents and others is 45% and 32% of adopter and non-adopter households, respectively.

According to the results of the chi-square test, there was a statistically significant difference in the participation of adopter and non-adopter households in the field day program for malt barley. Participation in training programs focused on malt barley is held by households that have adopted and have not adopted, respectively, at rates of 70% and 46%. The chi-square test result demonstrates that there is a statistically significant difference between households that participated in training and those that did not. Members of local agricultural cooperatives made up 82% of adopter households and 61% of non-adopter households, respectively. The chi-square test result also reveals that there were statistically significant variations in the membership of local agricultural cooperatives between adopter and non-adopter households.

3.3. Farmland allocation by sample households

Since land is the most valuable and rare resource for smallholder farmers in the highland areas of the North Shewa Zone, farm size and the allocation of land are the main issues influencing households' decisions on malt barley production. Between adopter and non-adopter sample households, there was a statistically significant difference in the amount of cultivated land, fallow land, land designated for malting, and food barley production (Table 5). However, there were no significant differences between adopters and non-adopter sample households in the amount of total owed land, the amount of grazing area, the amount of forest land, or the percentage of other major crops (wheat, faba bean, and field pea) (Table 5). The adopter farmers allocated an average of half a hectare for malt barley production, which was less than one-third of their total operated land.

Table 4
Respondent households' characteristics by dummy variables.

Variables	Categories	Adopters (110)		Non adopters (91)		Pearson x^2
		No	proportion	No	proportion	
Sex of household head	Male	107	53.2	87	43.3	0.4
	Female	3	1.5	4	2	
Access to information on Malt barley production	No	1	0.5	30	15	39.2***
	Yes	109	54.2	61	30.3	
Contact with Development Agents	No	1	53.2	9	4.5	8.5***
	Yes	109	1.5	82	40.8	
Access to credit	No	65	32.3	61	30.3	1.3
	Yes	45	22.4	30	15	
Field day program participation	No	60	29.9	62	30.8	3.9**
	Yes	50	24.9	29	14.4	
Training program participation	No	33	16.4	49	24.4	11.7***
	Yes	77	38.3	42	20.9	
Demonstration program participation	No	56	27.9	52	25.9	0.8
	Yes	54	26.8	39	19.4	
Membership in local agricultural cooperative	No	19	9.5	35	17.3	11.4***
	Yes	91	45.3	56	27.9	

***, **, * significant at 1%, 5% and 10% level respectively source: own survey result, 2021.

Table 5
Sample household landholdings and allocations during the 2021 main season (ha).

Land allocation (ha)	Total Sample (201)		Adopters (110)		Non adopters (91)		t-value
	Mean	Stdvn	Mean	Stdvn	Mean	Stdvn	
Total owned land	1.8	1.0	1.8	0.9	1.8	1.1	0.2
Cultivated land	1.6	0.8	1.9	0.8	1.3	0.7	−5.9***
Fallow land	0.1	0.3	0.2	0.3	0.1	0.2	−2.2**
Grazing land	0.3	0.3	0.3	0.3	0.3	0.4	1.5
Forest land	0.2	0.2	0.2	0.2	0.2	0.3	0.2
Malt barley land	0.3	0.3	0.5	0.3	0	0	−18.0***
Food barley land	0.7	0.6	0.6	0.5	0.9	0.7	3.0***
Other major crops (wheat, faba bean and field pea)	0.9	0.6	0.8	0.5	0.9	0.6	1.2

****, **, * significance level of 1%, 5% and 10% respectively, Source: own survey result, 2021.

3.4. Malt barley varieties used by sample households

Over the past ten years, many governmental and non-governmental groups have introduced various malt barley varieties in the chosen woredas of the North Shewa Zone through adaptation, demonstration, and wide promotion for both seed and grain purposes. The majority of the adopter farmers (58.2%) planted the Holker variety, followed by IBON 174/03 (25.5%), Bekoji-I (4.5%), and Traveller (3.6%), and 8.2% of them utilized both the Holker and Ibon 174/03 malt barley types (Fig. 5).

3.5. Malt barley seed source in the study areas

Since malt barley was a recently introduced cash crop in the study locations, the majority of the farmers (83%) obtained malt barley seed from local agricultural cooperatives during the main production season of 2021 b y cash and borrowing. Other adopter farmers obtained malt barley seed from their stores (4%) as well as from nearby farmers (8%) and local markets (5%) (Fig. 6). The local agricultural cooperatives obtained malt barley seed from Amhara Seed Enterprise, Dashen Malt Factory, Habsha Beer Factory, Global Malt Supply (GMS) Ethiopia, and Debre Birhan Agricultural Research Center during 2021's major production season based on secondary data gathered from each chosen kebele and focus group discussions.

3.6. Reasons for non-adoption of malt barley technology package

During the main production season of 2021, 45.3% of the sample's households—now referred to as non-adopters"—did not grow malt barley. Lack of farmland (32%), lack of seed (28%), lack of awareness (21%), low productivity of introduced malt barley varieties (8%), high input costs (6%), and being less tolerant to frost and waterlogging (5%) were the primary reasons for non-adopter households not growing malt barley during the main production season of 2021 (Fig. 7).

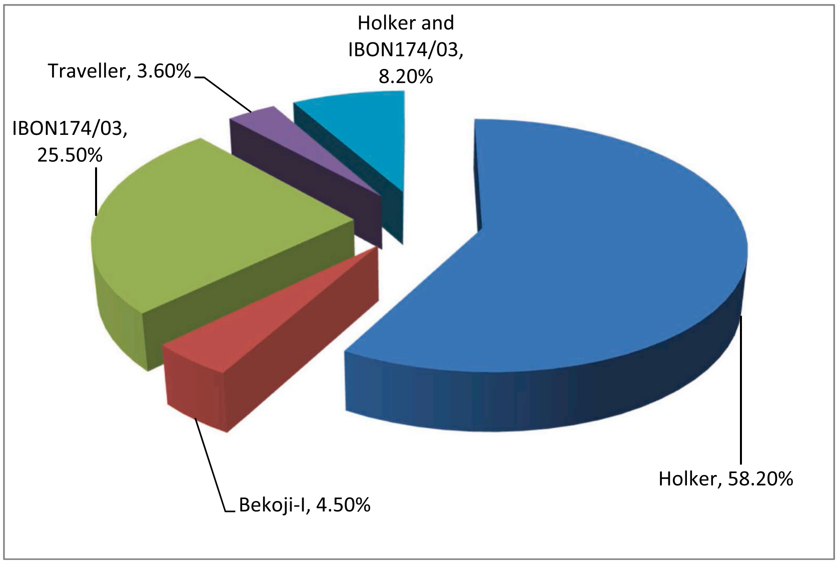

Fig. 5. Malt barley variety used by sample households.

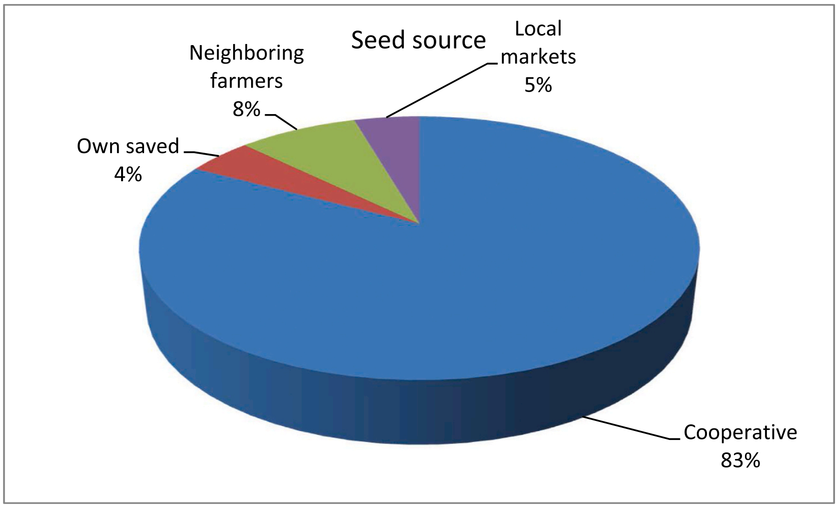

Fig. 6. Malt barley seed source during the 2021 main production season.

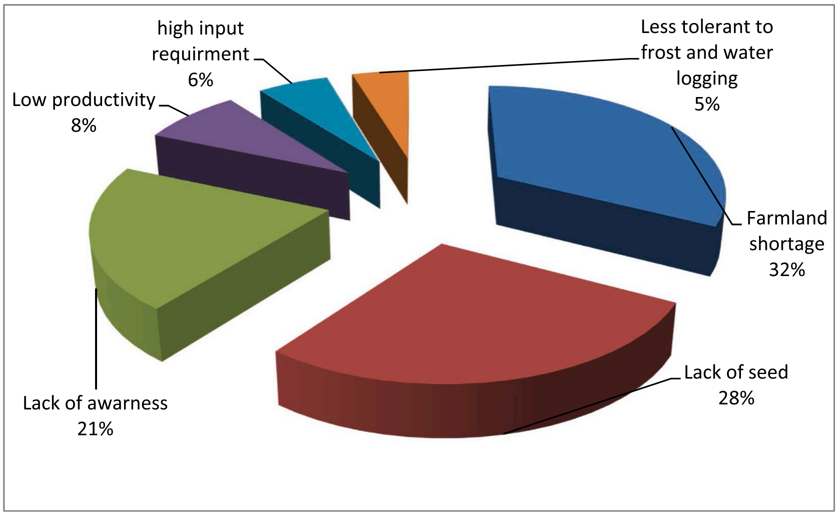

Fig. 7. Reason for non-adoption of malt barley technology package.

3.7. Intensity use of malt barley technology package by sample households

The intensity use of the malt barley technology package was calculated using the adoption index formula as follows:

$$Ai = \sum_{i=1}^{n} \left(\frac{SA}{SR} + \frac{NPSA}{NPSR} + \frac{UREAA}{UREAR} + \frac{PFA}{PFR} + \frac{HCA}{HCR} + \frac{WA}{WR} + \frac{LAMB}{TCL} \right) / NP.$$

$$Ai = \sum_{i=1}^{n} (1.38 + 1.7 + 0.7 + 1.1 + 0.99 + 0.32 + 0.3) / 7 = 0.9$$

The malt barley technology package was utilized with an average intensity of 0.9. However, the frequency of weeding and the intensity of malt barley use was also lower, at 0.32 and 0.3 respectively. The majority of farmers used NPS fertilizer, malt barley seeds, and plowing frequency more than the recommended rate, which increased the intensity of use of the malt barley technology package.

3.8. Determinants of adoption of malt barley varieties

The Tobit and Double hurdle models were compared using the [65] likelihood ratio test for the nested model. The likelihood ratio test result disqualifies the Tobit model and accepts the proposed double hurdle model (Table 6). The adoption and intensity of the use of malt barley varieties by smallholder farmers were analysed using the double hurdle model. First, 21 explanatory variables with both positive and negative influences on malt barley adoption and intensity use were proposed. However, the likelihood ratio test rejected the complete model in favor of the model with the chosen variables, keeping only thirteen variables in the final fitted model. Post-estimation tests were made for the fitted model of double hurdle regression. The results of the VIF (variance inflation factor) and

Table 6
Double hurdle model estimation of malt barley adoption and intensity use.

Double hurdle model	First hurdle		second hurdle	
Variables	Coef.	Std. Err.	Coef.	Std. Err.
Age of household head	−0.021**	0.009	−0.009**	0.002787
Formal education level	−0.026	0.042	−0.022	0.018
Location/Woreda	−0.365	0.246	−0.171	0.104
Cultivated Land	0.803***	0.190	0.341***	0.073
Number of oxen	−0.198	0.152	−0.068	0.064
Information on MB	2.215***	0.572	1.360***	0.283
Distance to cooperative	0.001	0.006	0.001	0.003
Distance to main road	−0.025**	0.009	−0.012***	0.004
Distance to Das office	0.006	0.005	0.002	0.002
Contact with Das	1.184	0.787	0.379	0.349
Participation in field day	0.258	0.289	0.237*	0.129
Participation in Demon.	−0.278	0.286	−0.108	0.128
Membership cooperative	0.758***	0.259	0.333**	0.121
_cons	−2.536**	1.027	−1.115**	0.473
/sigma			0.588	0.439
Number of obs	201		201s	
LR chi2 (13)	102.12		117.47	
Prob > chi2	0000		0000	
Log-likelihood	−87.361		−149.357	
Pseudo R^2	0.3689		0.2823	
LR test (Tobit Vs Double hurdle)	66.39***		Reject Tobit model	
The dependent variable for the first hurdle			Use or not use of malt barley	
The dependent variable for the second hurdle			Adoption index of malt barley technology package	

***, **, * significant at 1%, 5% and 10% level respectively source: own survey result, 2021.

pair-wise correlation test for continuous and dummy variables confirmed no multicollinearity problem (Appendices 1 and 2). The fitted model was robust for heteroscedasticity issues. Based on the estimation of the first stage of the double hurdle model, total cultivated land, information on malt barley production, household residence distance from the main road, and household membership in local cooperatives all significantly affect the likelihood that smallholder farmers will adopt a malt barley variety.

Age: At a level of significance less than 5%, the age of the household head had a negative effect on the likelihood of adoption of the malt-barley varieties. Older farmers were less exposed to information, which makes them more resistant to change, more risk-averse, and less informed about new technologies. This result was in line with the proposed hypothesis and earlier empirical results [31,66].

Cultivated farm size: The size of the household's farmed farm positively affects the probability that the malt barley varieties will be adopted, with a significance level of less than 1%. Due to their larger cultivated farmlands, farmers are using and allocating more farms for malt barley as a result. Even though the newly introduced malt barley variety may reduce yields, farmers were more prepared to handle larger areas of land for other food crops and were also less risky. The earlier empirical results [67,68] supported the proposed hypothesis and the result of this study.

Access to information on malt barley; At a significance level of less than 1%, access to malt barley production information positively influences the likelihood of adoption of the malt barley varieties. This is because farmers are aware of the recently developed agricultural technologies; they are familiar with the production techniques and advantages of the technologies, which helps them overcome their fear and form a favorable opinion of them. This result was consistent with the theoretical model of diffusion of innovation as well as earlier empirical research [53,69]. The diffusion of innovation suggested that information dissemination speeds up the adoption of agricultural technologies through the creation of awareness and knowledge among smallholder farmers.

Distance to main roads: At a less than 5% significance level, household dwelling residence distance from the main road has a negative effect on smallholder farmers' likelihood of adopting malt barley varieties. Due to transportation issues, farmers who lived far from major roads had less access to agricultural inputs like fertilizer and malted barley seed. This finding corroborated the proposed hypothesis and earlier empirical research by Ref. [70].

Membership in agricultural cooperatives: households' membership in local agricultural cooperatives affects the probability of adoption of malt barley varieties positively at less than a 1% significance level. This is because membership in the local agricultural cooperatives, which supply the majority of farmers in the study area with malted barley seed, is a necessity. Members of agricultural cooperatives had priority access to borrowing because most farmers obtained malted barley seed through this method. The result agreed with the proposed hypothesis and other previous findings [71,72].

3.9. Determinants of intensity use of malt barley varieties

The second stage of the double hurdle model showed that the household head's age, the amount of cultivated land, his or her access to information about malt barley production, the distance of their home from the main road, their participation in field days, and their membership in a local cooperative all had a significant effect on the intensity of use of malt barley varieties, with varying degrees of significance and both positive and negative effects (Table 6).

Age: The intensity of use of the malt barley varieties is negatively affected by the age of the household head at a less than 5% level of significance. This is because older farmers have less exposure to knowledge, are more risk-averse, and have a shallower understanding of the agronomic management of the introduced malt barley varieties. As a result, even though they used malt barley, older farmers allotted less farmland for the production of malt barley. This result was in line with the proposed hypothesis and earlier empirical results [73,74].

Cultivated farm size: At a less than 1% significance level, the size of the household's cultivated farm favorably influences the intensity of use of the malt barley varieties by smallholder farmers. This is because farmers tend to assign more farms to malt barley when their cultivated farms are larger. Even though the newly adopted malt barley varieties will result in a yield loss, farmers were better equipped to distribute land for other food crops and were also less risky when they had larger tracts of land. This result supported the proposed hypothesis and was in line with previous empirical findings [15,55].

Access to information on malt barley production; access to information on the production of malt barley significantly influences the intensity of use of the malt barley at less than a 1% significance level. This is so that farmers can feel less fear and have a good perception of trust in the varieties. Farmers are aware of the newly introduced agricultural technologies; they are aware of the production methods and benefits of the technologies. They assign additional cropland for the malt barley varieties as a result. This result supported the hypothesized hypothesis and was in line with earlier empirical research [75,76].

Distance to main roads: At a less than 1% significance level, household dwelling residence distance from the main road has a detrimental effect on smallholder farmers' intensity of use of the malt barley varieties. Due to transportation issues, farmers who lived far from major roads had less access to agricultural inputs like fertilizer and malted barley seed. In contrast to farmers who live closest to roadways, they were less likely to allocate more farmland for malt barley production even if they did. This finding supported the proposed hypothesis and earlier empirical research by Ref. [56].

Field day participation: malt barley variety intensity use is positively affected by household involvement in field day activities organized by development agents and other organizations at a level of significance of less than 10%. Farmer awareness and interest in malt barley grew, along with their willingness to set aside more farmland for its cultivation. They were also far more inclined to allocate more for malt barley production after taking part in the field day program for malt barley. The result was in line with the proposed theory and earlier findings by Ref. [77].

Membership in the agricultural cooperative: The intensity of use of the malt barley varieties was favorably affected by a household's membership in local agricultural cooperatives at a less-than-5% significance level. This is because membership in the local agricultural cooperatives, which are a common source of malt barley seed and other production inputs in the research area, was one of the prerequisites. Members of agricultural cooperatives had priority access to borrowing seed because most farmers obtained malt barley seed and fertilizer through borrowing. The findings of [37], as well as other earlier studies, supported the result of this study.

4. Conclusion and recommendation

The agroecology in the North Shewa Zone is ideal for the growth of malted barley. More than ten Woredas in this area produce barley, and just recently, two breweries and one malt factory were built to take advantage of the zone's potential for malt barley production. Despite coordinated efforts to support and increase malt barley production and market supply in the North Shewa Zone and throughout Ethiopia, local production was unable to meet the demand for the grain at home. As a result, millions of dollars are spent nationally to import malt, which has an impact on the nation in several ways. This study measures the extent to which smallholder farmers adopt malt barley technology packages. Additionally, it evaluated the factors that led to the adoption and level of use of the malt barley varieties in the North Shewa Zone's chosen woredas.

According to the descriptive results, adopter households allotted an average of 0.5 ha (27.8%) from their total cultivated lands. The malt barley variety Holker, which is an old variety, was utilized by most producer households (58%), and the primary source of seed was local cooperatives. Shortage of farmland, lack of malt barley seed, and lack of knowledge about malt barley production were the main barriers preventing sample smallholder farmers from adopting malt barley. Malt barley varieties and the intensity of usage of the malt barley technology package by smallholder farmers were 0.3 and 0.9, respectively. Even though the abuse of NPS fertilizer, seed rate, and plowing frequency resulted in a high intensity of usage of the malt barley technology package, the actual land allotted for the cultivation of malt barley varieties was less than previously predicted. The results of the econometric models demonstrated that the age of the household head, the total area under cultivation, the availability of information about malt barley, the distance of the household from the main road, and membership in agricultural cooperatives all affected the adoption of the malt barley varieties. Whereas, the household head's age, the amount of land that was cultivated, the availability of information about malt barley production, the distance of the household from the main road, participation in the field day program, and membership with agricultural cooperatives all affected how intensively smallholder farmers used the malt barley varieties in the study areas.

The following suggestions were made based on the study's findings to increase the production and productivity of the malt barley varieties and the whole technology package and to meet local demand for malt barley grain. Collaborative efforts from research institutions, universities, NGOs, local governments, the beer and malt industries, unions, and cooperatives are needed. Through various initiatives like training and field trips, the office of agriculture, regional NGOs, and other interested parties in malt barley production and marketing must trying to raise farmers' awareness of malt barley production and the proper use of the suggested production package. Enlisting nearby smallholder farmers in agricultural cooperatives to provide them with access to the market for agricultural inputs and finished products. Providing smallholder farmers with easy access to roads and transportation so they may quickly obtain agricultural inputs like seeds, fertilizer, and chemicals as well as market access. Increasing smallholder farmers' productivity and production of malt barley by using suggested technologies and high-yielding varieties. To enhance seed access and establish fair and motivating seed prices, seed enterprises, unions, and other seed production and marketing cooperatives must develop a well-functioning malt barley seed system.

This study was static (data collected at one time and across locations). This means that the influence of time for adoption of the malt barley technology package was not evaluated, and the sample size for this study was small owing to a lack of budget and other resources. So as a future direction, scholars must consider the influence of time on the adoption of agricultural technology by using time series and sufficient data.

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Author contribution statement

Dejene Mamo Workie: conceived and designed the experiments; performed the experiments; analysed and interpret the data; wrote the paper.

Workalemahu Tasew: contributed materials and analysis tools; analysed and interpret the data.

Data availability statement

Data included in article/supp. Material/referenced in article.

Additional information

Supplementary content related to this article has been publish online at [URL].

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e18477.

ANNEX

Appendix table 1
VIF test for Continuous Variables Used in Double hurdle Model

Variable	VIF	1/VIF
Distance from Das office	1.54	0.394205
Distance from the main road	2.21	0.452373
Distance from cooperative	1.94	0.514243
Formal education level of HH head	1.40	0.7119191
Cultivated land	1.29	0.778036
Age of household head	1.33	0.752987
Number of oxen	1.29	0.775673
Mean VIF	1.71	

Source: own survey result, 2021.

Appendix table 2
Pairwise correlation test for dummy variables of double hurdle model

Variables	InfoMB	Contact_Das	Dield day_P	Demo_P	M_to C
Access to MB information	1.0000				
Contact with Das	0.2824	1.0000			
Field day participation	0.0334	0.1373	1.0000		
Demonstration participation	0.0095	0.2123	0.6016	1.0000	
Membership to cooperative	0.0209	0.1710	0.2349	0.2473	1.0000

Source: own survey result, 2021.

Abbreviations

EIAR	Ethiopian Institute of Agricultural Research
SPSS	Statistical Package for Social Science
TLU	Tropical Livestock Unit
VIF	Variance Inflation Factor
CSA	Central Statistical Agency
DAs	Development Agents
FAO	Food and Agricultural Organization
MASL	Meter Above Sea Level
NGO	Non-Governmental Organization

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