Factors affecting adoption of improved haricot bean (*Phaseolus Vulagris* L) technology in West Hararghe zone of Oromia region, Ethiopia: A Heckman two-step approach

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Adoption of improved technology is one of the most promising ways to reduce food insecurity in Ethiopia. However, the adoption and dissemination of these technologies is constrained by various factors. The aim of this study was to determine intensity of adoption of improved haricot bean technology and identify factors affecting its adoption in the study area. The study was based on cross sectional data collected from 148 randomly selected improved haricot bean producing farmers. The Heckman selection model results showed that famers with large livestock size, members of primary agricultural cooperatives, participation in haricot bean technology demonstrations and having contact with an extension agent, are more likely to adopt and implement haricot bean production technology. Strengthening the existing livestock production system through providing improved health services and forage, expanding and capacitating primary agricultural cooperatives, and increasing the number of participants on technology demonstrations and field days are recommended to facilitate adoption of improved haricot bean technology.

Keywords: Decision to adopt, intensity of adoption, Heckman two-step procedure

Haricot bean (*Phaseolus Vulagris* L), locally known as 'Boleqe' also known as dry bean, common bean, kidney bean and field bean is a very important legume crop grown worldwide (Gebre-Egziabher et al. 2014). Haricot bean is an important pulse crop in Ethiopia and in the world. The crop ranks first globally while it stands second next to faba bean in the country (Worku 2015). It is increasingly becoming an important cash crop for the Ethiopian national economy (commodity and employment) and for the farmers as food and income generation (Rubyogo et al. 2011). White haricot bean accounted for 0.74% (about 95,000 ha) of the total grain crop and 0.52% (about 170,000 t) of the total grain production, is grown by 972,039 smallholder farmers (CSA 2020). Due to high demand in international and domestic markets, in Ethiopia between 2005 and 2012, the area cultivated with haricot bean increased from 169 to 359 hectares and production increased more than three-fold from 138,000 to 463,000 t. The contribution to national export earning was US$95.3 million in 2012 (FAO 2015). However, productivity was low over the same period, with an average of 1.2 t/ha (CSA 2012). The situation can be explained by supply side constraints, including low adoption of improved seeds, limited knowledge of smallholders on production practices and benefit of diversification, and by market-led constraints, particularly price instability in 2008 that led to diminished trust in the pulse sector for small producers after declining market returns. Additionally, there is insufficient seed in the country owing to an increasing demand from export markets, and therefore particular problems in accessing new white bean varieties (Dawit et al. 2010).

The government has increased extension efforts and prices have risen steadily since 2009 (FAO 2015). A haricot bean technology package, consisting of improved seed (Awash 1 and Awash Melka), seeding rate, fertilizer rate and spacing, has been introduced and scaled up in West Hararghe Zone by Mechara Agricultural Research Center since 2011. Different stakeholders (Goal, World Vision,

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Chercher and Oda Bultum Union, and Bureau of Agriculture of the Zone) also have been scaling up the technology in the study area.

But small-scale farmers decision to adopt or reject agricultural technologies depends on their objectives, constraints, costs and benefits. Farmers will adopt technologies that only suit their needs and no attempt has been made to study intensity and factors affecting adoption of improved haricot bean technology in the study area. Therefore, the study was attempted to identify factors affecting the adoption of the introduced technology and to determine the intensity of adoption of the technology.

Adoption is degree of use of new technology in long run equilibrium when the farmer has full information about new technology and its potential (Gershon et al. 1985). The intensity of adoption is the number of hectares planted with improved seed or the amount of input applied per hectare (Gershon et al. 1985; Nkonya et al. 1997). In our study, adopters are those who took improved (high yielder, early maturity and disease resistant as compared to locals) white haricot beans varieties. Intensity (degree) of adoption was measured in terms of the extent to which white haricot bean production package (fertilizer rate, seed rate and area allocated) have been implemented as compared to the recommended rate during the survey year.

Materials and methods

Description of the study area

The study was conducted in Habro and Daro Lebu districts of West Hararghe zone which have the potential for production of haricot bean.

Habro district is one of the 15 districts of West Hararghe zone of the Oromia National Regional State. It is located 404 km to the east of Addis Ababa, which is the capital city of Ethiopia and 75 km to the south of Chiro, zonal town. It is bordered by Guba Koricha district in the west, Boke district in the east, Daro Lebu in the south and Oda Bultum in the north. Gelamso town is the administrative seat of the district. The population of the district is 244,444, of which 118,268 (48.4%) are women and 126,176 (51.6%) are men. The altitude of the district ranges from 1600 –2400 masl. The annual average rainfall for the district is 1010 mm and the temperature ranges between 16 – 32 °C. There are two cropping seasons in the area, Belg (short rainy season) from March to June and Meher (main rainy season) from June to September. Belg rains are mainly used for land preparation and planting long cycle crops such as maize. The Meher rains are used for planting of cereal crops like barley, teff, wheat and vegetable crops. Meher rains are also the major source of moisture for the growth and development of perennial crops such as mango, coffee and khat. Haricot bean is grown in both cropping seasons.

Daro Lebu is one of the districts in the West Hararghe zone. The capital town of the district, Mechara is about 434 km south east of Addis Ababa. The latitude and longitude of the district are 08°35' north and 40°19' east. It has 42 kebeles of which, 37 are rural and five are urban. It is bordered by Boke district in the east, Arsi zone in the west, Habro district in the north, and Hawi Gudina district in the south. The agro-ecology of the district is 44% midland and 56% lowland. The district is characterized mostly by flat and undulating land features with altitude ranging from 1350 – 2450 masl. The ambient temperature of the district ranges from 14 – 26 °C, and it receives minimum and maximum annual rainfall of 900 and 1300 mm, respectively. The pattern of rain fall is bimodal and its distribution is mostly uneven. Generally, there are two rainy seasons: the short rainy season, Belg, lasts from mid-February to April whereas the long rainy season, Kiremt, is from June to September. The most commonly available soil type is sandy-loam-clay which is reddish in colour. The rainfall is erratic; onset is unpredictable, its distribution and amount are also quite irregular.

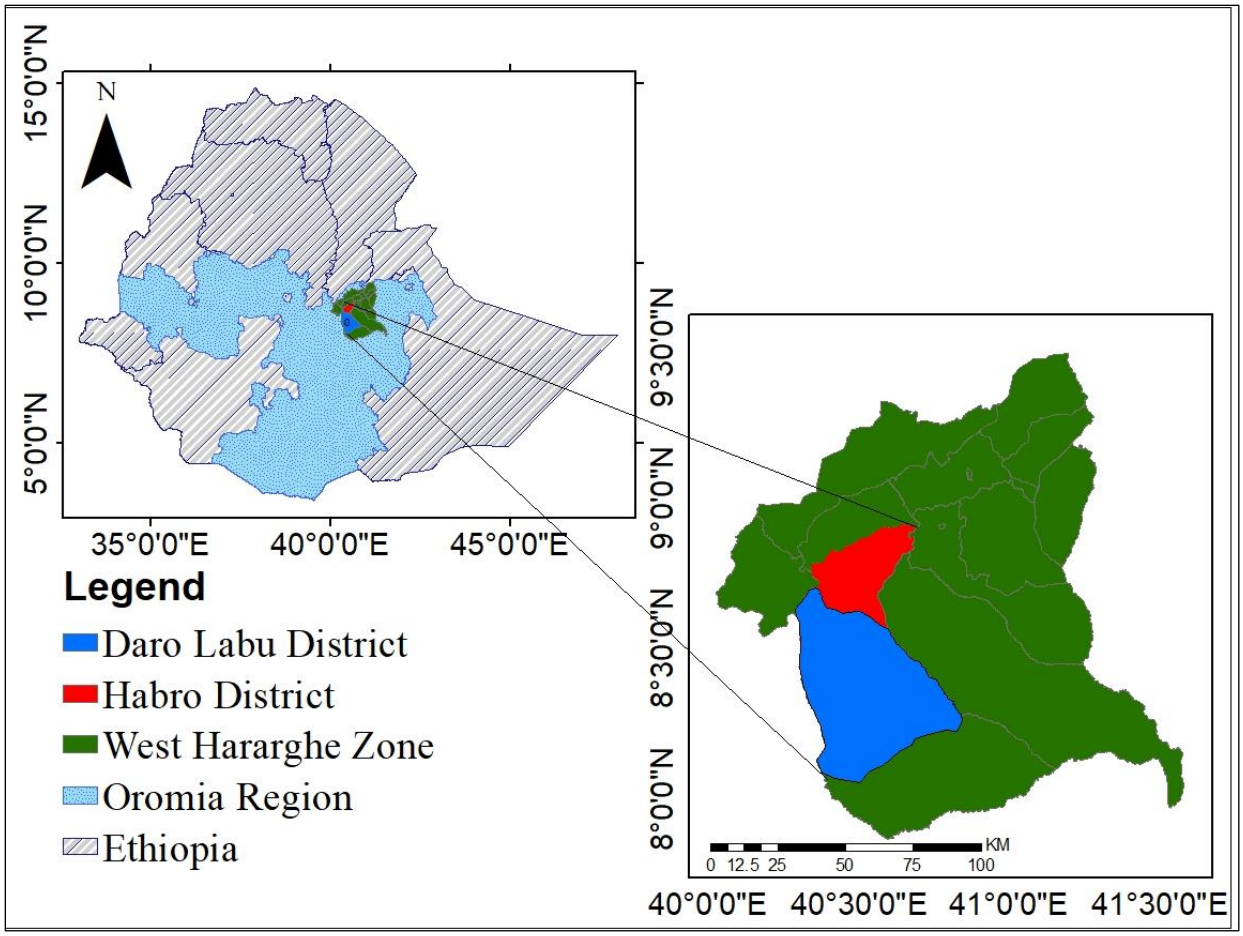

Figure 1: Map of the study area

Sampling procedure

In this study a multi-stage sampling technique was employed. Firstly, two districts were selected from the zone purposively based on their potential of using the technology. Secondly, two kebeles from each district were selected purposively based on their potential of using the improved haricot bean technology. Finally, a total of 148 representative households were selected in simple random sampling by considering probability proportional to population size (Table 1). The simplified formula provided by Taro (1967) was employed to determine the required sample size with level of precision (e) = 8%.

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

Where *n* is the sample size, N is the population size and e is the level of precision.

Table 1: Total number of households selected for the sample

Districts	**Kebeles**	**Number of sample households**
Daro Lebu	Sekina	38
	Kurfa-wachu	27
Habro	Haro-chercer	55
	Wachu-bedada	28
Total		**148**

Data source and method of data collection

Both primary and secondary sources were employed to collect qualitative and quantitative data. The secondary source data were collected from published and unpublished reports of district agricultural offices to support the data of primary sources. The primary source data were collected from the selected sample representative households through direct interviews and focus group discussions. Both qualitative and quantitative data were collected in the interviews and discussions. Prior to the administration of the questionnaire, enumerators were trained about the objectives of the study.

Method of data analysis

Both descriptive statistics (mean, standard deviation, frequency and percentage) and an econometric model (Heckman two-step procedure) were employed to meet the specific objectives of the study. Adoption index formula was also used to obtain the adoption level of farm households.

Heckman two-step procedure

Most adoption research has viewed the adoption decision in dichotomous terms (adoption and non-adoption). But for many types of innovations, the interesting question may be related to the intensity of use e.g., how much fertilizer is used per hectare or how much land is planted under improved varieties (Gershon et al. 1985). The farmer may adopt only some part of the recommended package and may also do this on anywhere between 1 to 100% of his/her farm (Alemitu 2011). The truncated regression model assumes that the decision to adopt and the intensity of adoption are independent; this is a potential restriction of the model (Cameron and Tivedi 2009). The Heckman selection model considers the possibility of such bias by allowing for possible dependence in the two parts of the model, decision to adopt and intensity of adoption (Cameron and Trivedi 2009; Dageye and Mengistu 2016). Following Cameron and Trivedi (2009), the two Heckman equations model can be specified as follows:

Let y_2^* denote intensity of adoption. In the standard tobit model, this outcome is observed if $y_2^* > 0.$ A Heckman selection model introduces a second latent variable, y_1^* (decision to adopt) and the outcome y_2^* (intensity of adoption) is observed if $y_1^* > 0,$ and $y_1^* \neq y_2^*.$ The two-equation model comprises a selection equation for y_1 where,

$$y_1 = \begin{cases} 1 \text{ if } y_1^* > 0 \\ 0 \text{ if } y_1^* \leq 0 \end{cases} \quad (2)$$

And a resultant outcome equation for $y_{2,}$

where, $y_2 = \begin{cases} y_2^* \text{ if } y_1^* > 0 \\ - \text{ if } y_1^* \leq 0 \end{cases} \quad (3)$

Here y_2 observed only when $y_1^* > 0,$ possibly taking a negative value, whereas y_2 does not take on any meaningful value when $y_1^* \leq 0.$ The classic version of the model is linear with additive errors, so $y_1^* = x_{1i}\beta_1 + u_i$ (4)

$$y_2^* = x_{2i}\beta_2 + v_i \quad (5)$$

With u_i and v_i possibly correlated. The tobit model is a special case where $y_1^* = y_2^*.$

Estimation of the adoption index

Before analysing the determinants of adoption, it is important to assess the level of the adoption for each farm household. Accordingly, farmers who were not growing an improved variety of haricot bean were considered as non-adopters, while farmers who were growing an improved variety with some of the recommended agronomic practices of haricot bean production for at least 1 years cropping season were considered as adopters. Among improved agronomic practices only three practices (improved variety, seed rate, and fertilizer application rate) are currently

practiced by haricot bean producer in the study area. The other two practices (spacing and chemical application) were excluded because of absence and difficulty in getting reliable information on them. The adoption index score was calculated by adding up the adoption quotient of each practice and dividing it by number of adopted practices of each respondent. The adoption quotient of each practice was calculated by taking the ratio of actual rate applied to the recommended rate. In this study, adoption index was used to measure the extent of adoption at the time of the survey for multiple practices (package), which shows to what extent the respondent farmer has adopted the package practices. The index for each respondent farmer was estimated as:

$$AI_i = \frac{\sum\left(\frac{AH_i}{AT_i} + \frac{SRA_i}{SRR_i} + \frac{FA_i}{FR_i}\right)}{NP} \qquad (6)$$

Where,

AI_i = Adoption index

AH_i = Area under improved variety of haricot bean of the i^{th} farmer

AT_i = Total area allocated for haricot bean production (improved variety+ local, if any) of the i^{th} farmer

SRA_i = Seeding rate applied per unit of area in the production of improved haricot bean of i^{th} farmer

SRR_i = Seeding rate recommended per unit of area

FA_i = Amount of fertilizer applied per unit of area in the cultivation of improved variety of Haricot bean by i^{th} farmer

FR_i = Amount of fertilizer recommended for application per unit of area in the cultivation of improved variety of Haricot bean

NP = Number of practices

Thus, the adoption index is a continuous dependent variable calculated using the formula presented above with a value ranging from 0 – 1. Zero indicates no adoption and 1 indicates full adoption; an adoption index score between 0 and 1 indicates partial adoption. Improved haricot bean production involves the use of different package practices. These include use of improved variety, seeding rate, fertilizer rate, spacing and so on. Significant improvement in production and productivity depends on the extent to which a household has practiced the recommended improved agronomic practices. The level of adoption of improved haricot bean production practices by farmers may vary depending on demographic and socioeconomic variables, institutional and environmental factors in which the household operates. The sample households' index scores were categorized into four adopter groupings namely non-adopter (0), low (0.01 – 0.33), medium (0.34 – 0.66) and high (0.67 – 1) adopter.

Results and discussion

Socio-economic characteristics of sample respondent for categorical variables

Participation in a social organization has an influence on adoption decision of household heads. It links the farmers to larger society and enhances access to new ideas and innovations. Table 2 indicates that 92.39% of adopters and 62.50% of non-adopters have participated in social organizations such as multi-purpose agricultural cooperatives, ikub, idir and kebele councils. The value of chi-square (χ^2) indicates whether there is a significant likelihood difference among adopters and non-adopters.

Males were the head of 115 (77.70%) of the sampled households while 323 (22.30%) were female headed. The higher number of male headed households is attributed to various reasons including the problem of economic position of female-headed households such as shortage of labour, limited

access to information and required inputs.

Participation in extension events such as demonstrations and field days can help the farmers to adopt a new technology. If the farmers participate in extension events, they are more likely to adopt seed production technologies than others. According to the result, 51.9% of the respondents have participated in field days, 29.6% have participated in demonstration and 18.5% have participated in both demonstrations and field days. Haramaya University, Mechara Agricultural Research Center and Capacity Building for Scaling up of Evidence-based Best Practices in Agricultural Production in Ethiopia (CASCAPE) were among the major organizations which prepared the demonstrations and field day on improved varieties of haricot bean in the study area. The survey revealed that there is statistically significant difference between participants and non-participants of extension events ($\chi^2 = 66.618$, $P \leq 0.001$).

Extension visits help to reinforce the message and enhance the accuracy of implementation of the technology packages (Walelign 2008). Agricultural extension is of paramount importance to introduce better agricultural practices and improved technologies to smallholder farmers in a country like Ethiopia where traditional practices are dominant. Mechara Agricultural Research Center, and with other stakeholders, have been carrying out research to increase the production and productivity of farmers in the study area. The survey result showed that 80 (86.96%) adopters and 14 (25.00%) non-adopters had extension contact. ($\chi^2 = 57.662$, $P \leq 0.01$)

The study also revealed that 41 (44.57%) adopters and seven (12.50%) non-adopters were trained regarding improved haricot bean varieties and agronomic practices, while 51 (55.43%) adopters and 49 (87.5%) non-adopters did not receive any training during the cropping year. In general, out of the sample households, only 32.43% of them had training related to improved haricot bean technology and about 67.57% of sample farmers did not receive training ($\chi^2 = 16.333$, $P \leq 0.01$) (Table 2).

Table 2: Socio-economic characteristics of sample respondent for categorical variables

		Non-adopter		Adopter		Total		
Variables		N	%	N	%	N	%	χ^2-value
Sex of the respondent	Female	18	32.14	15	16.30	33	22.30	5.040*
	Male	38	67.86	77	83.70	115	77.70	
Participation of social organization	No	21	37.50	7	7.61	28	18.92	20.276***
	Yes	35	62.50	85	92.39	120	81.08	
Participation of extension events	No	55	98.21	27	29.35	82	55.41	66.618***
	Yes	1	1.79	65	70.65	66	44.59	
Contacts with extension agents	No	42	75.00	12	13.04	54	36.49	57.662***
	Yes	14	25.00	80	86.96	94	63.51	
Access to training	No	49	87.50	51	55.43	100	67.57	16.333***
	Yes	7	12.50	41	44.57	48	32.43	

Note: ***, and * indicate significance at $P \leq 0.01$ and $P \leq 0.1$, respectively.

Socio-economic characteristics of sample respondent for continuous variables

The mean age of sample households was 36.51 years with standard deviation of 9.40. The maximum age for the sample farmers was 60 years while the minimum was 17 years. The t-test showed that there was no significant difference between adopters and non-adopters of haricot bean technology in terms of mean age of respondents in the study area (Table 3).

In the 2019/20 production year adopters received an average credit of US$20.77, while non-adopters received an average credit of only US$5.95 ($P \leq 0.05$). Of those who received credit, 71.0% took from Oromia Saving and Credit Institution, 19.4% from relatives, 6.5% from traders and 3.2% from agricultural cooperatives. Fear of debt and interest (38.8%), lack of collateral (35.9%) and no credit access (25.2%) were the reasons given by those who did not take credit.

Adopters of haricot bean technology owned 1.62 ha of land on average, while non-adopters owned 0.98 ha. The t-test indicated there is a mean difference between adopters and non-adopters regarding total farmland owned ($P \leq 0.01$). The total farmland owned has been allocated for both annual and perennial crops in the study area. The major annual crops grown in the area include maize, sorghum, teff, haricot bean, chickpea, groundnut, tomato, cabbage and hot pepper. Cereal crops are used mainly for food consumption and rarely for market purposes while pulses and horticultural crops are produced completely for market purposes. The major perennial crops produced in the area include khat, coffee and mango. These perennial crops are often used for market sale, as a result they are known as cash crops. On average, coffee is grown by 43.4% of sample households on about 0.60 ha of land. Khat is cultivated on 0.34 ha of land by 19.6% of sample households.

In addition to crops, livestock production is practised in the area. Livestock have an important role in the rural economy as a source of draught power, food, cash income, dung for organic fertilizer and fuel, and as a means of transport. The types of livestock found in the study area were cattle, equine, sheep, goat and poultry. On average adopters owned 3.51 total livestock (in tropical livestock units; Appendix 2) while non-adopters have 1.47 total livestock (in tropical livestock units). The t-test showed that there was a significant mean difference between adopters and non-adopters in terms of total livestock owned ($P \leq 0.01$).

Table 3: Socio-economic characteristics of sample respondents for continuous variables

	Non-adopter (N=56)		**Adopter (N=92)**		**Combined**			
Variable	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**t-value**	**P-value**
Age	37.43	9.61	35.96	9.28	36.51	9.40	0.92	0.3575
Amount of credit	5.95	26.86	20.77	47.57	15.17	41.51	-2.132	0.0347
Farm land	0.98	0.79	1.62	0.91	1.38	0.92	-4.33	0.0000
Educational level	2.38	0.94	2.41	0.82	4.39	2.72	-0.2	0.8388
Livestock size	1.47	1.94	3.51	2.16	2.74	2.30	-5.79	0.0000

Adoption status of sample households

The survey result showed that out of the total sample households 92 (62.2 %) were users (adopters) of improved haricot bean technology, while the rest 56 (37.8 %) were non-users (non-adopters); 3.26% of total adopters were low adopters, 73.91% were medium adopters and 22.83% were high adopters (Table 4). One way analysis of variance revealed that there is significant mean difference ($F=1351.1$, $P \leq 0.001$) among the adoption index score of the four adoption categories at 1% significance level.

Table 4: Frequency and percentage of adoption status

Adoption index category (value)	
Non adopters (0)	56
Low (0.01 - 0.33)	3
Medium (0.34 - 0.66)	68
High (0.67 - 1.00)	21
Total	148

$F = 1351.1$ $P \leq 0.001$

Cropping systems of improved haricot bean

As observed from the study main cropping systems practiced in the area are sole cropping and intercropping. Intercropping has immense importance for small-scale resource poor farmers who experience food shortages (Tolera et al. 2005). Cereal/legume intercropping could benefit smallholders through generating sustainable income, minimizing risk of crop failure and providing a source of diet protein (Fininsa 1997). In the study area, 76% grow haricot bean solely, 11% intercropped haricot bean with other crops and 13% practiced both intercropping and sole cropping (Figure 2). During group discussions, respondents mentioned that due to farmland shortage and to minimize the risk of crop failure, they employ intercropping. Haricot bean is mainly intercropped with the major crops such as: maize, sorghum, khat and coffee.

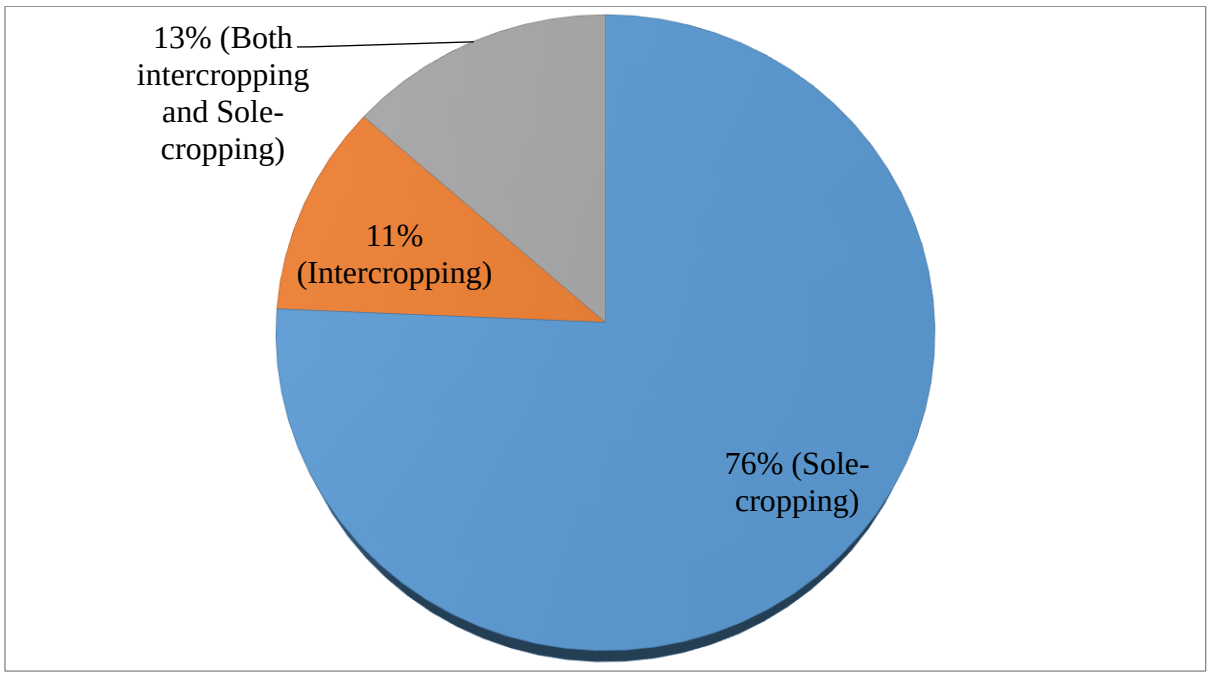

Figure 2: Percentage of respondents of improved haricot bean using various cropping systems

Agronomic practices of haricot bean production

Improved haricot bean varieties of Awash 1 and Awash Melka, and associated agronomic practices such as spacing, seed rate and fertilizer application have been disseminated to farmers by Mechara Agricultural Research Center and other stakeholders. The recommended spacing for haricot bean was 40 cm between rows and 10 cm between plants. Due to intercropping haricot bean with other crops, the space between rows and plants were not definitely known by farmers, only information on land allocated, seed rate and fertilizer rate are discussed below.

Seed rate

Seed rate is one of the important agronomic practices which need to be implemented at farm level. There was variation among the sample households in the amount of seed rate per unit area used. The recommended seed rate was 100 kg/ha but farmers used on average 29.40 kg/ha for the improved haricot bean varieties with a minimum and maximum of 5.33 and 35.00 kg/ha respectively. One-way ANOVA indicated the presence of significant mean difference in seeding rate applied between adoption categories ($F= 2102.6$, $P \leq 0.0001$) (Table 5).

Fertilizer application

Fertilizer application was one of the most important practices that need to be adopted by haricot bean growers. Farmers in the study area used fertilizer for haricot bean production. The mean fertilizer rate applied for haricot bean production by producers during the 2019/20 production year was 48.80 kg/ha of nitrogen (N) phosphorus (P) sulfur (S) fertilizer ranging between 5 – 50 kg/ha. The seed rate recommended by Mechara Agricultural Research Center is 100 kg/ha of NPS. Thus, farmers were applying below the recommended rate by 51.2%. In contrast, average quantity of NPS applied per hectare on haricot bean production at the national level reported by CSA (2020) was 177 kg/ha, which was more than the recommended level. There was significant mean difference between adoption categories ($F= 3946.2$, $P \leq 0.001$) in relation to fertilizer application rate.

Table 5: Agronomic practices of the study area

Agronomic practices	**Adoption category**	**Mean**	**Min**	**Max**	**F-value**	**P-value**
Seed rate applied (kg/ha)	Low adopter	4	5.33	10	2102.603	0.0000
	Medium adopter	25.70	5	35		
	High adopter	12.31	5.33	29		
	Combined	29.4	5.33	35		
Fertilizer applied (kg/ha)	Low adopter	3	5	8	3946.251	0.0000
	Medium adopter	4.83	7.25	50		
	High adopter	35.53	6	50		
	Combined	48.8	5	50		

Improved varieties

A lot of effort has been made by different organizations in developing, adapting and disseminating different types of improved varieties with appropriate agronomic practices to improve production and productivity of haricot bean. The released haricot bean varieties Awash 1 and Awash Melka were introduced to the farmers in the study area through different stakeholders such as Mechara Agricultural Research Center, district offices of agriculture, Melkassa Agricultural Research Center, Haramaya University and Chercher Oda-bultum Union (Table 6).

Table 6: Improved haricot bean varieties grown and number of production years

Variety	N	No of production years		
		Min	Max	Mean
Awash 1	70	1	15	4.08
Awash Melka	22	1	10	3.23

Econometric model analysis results

Factors affecting adoption decision and intensity of improved haricot bean technology

Results of the Heckman two-step procedure estimation of the determinants of adoption decision and intensity of adoption of haricot bean technology are given in Table 7. The table also contains marginal effects on probability of adoption. Marginal effect was computed by the syntax "*margins, dydx (independent variables list) expression(normal(xb(dependant variable list)))"* to estimate marginal effect of adoption decision. Since the second step of Heckman two-stage sample selection model is linear, intensity of adoption has been interpreted as it is.

The results from the Heckman two-step procedure suggest that there is sample selectivity bias because the coefficient of Mills Lamda (0.154 (0.0762) ($P \leq 0.05$) suggests that the adoption decision and intensity of adoption are interdependent and need to be simultaneously estimated. This confirms that the Heckman selection model used in this study is relevant.

Table 7: Heckman sample selection model estimates of factors affecting adoption decision and intensity of adoption of improved haricot bean technology

	Adoption decision			Intensity of adoption	
Variables	Coefficient	Std. Err.	Marginal effect	Coefficient	Std. Err.
Constant	-2.988***	1.038	-	0.368**	0.150
Age	-0.0260	0.0205	-0.0029	-0.00486***	0.00178
Sex	-0.493	0.511	-0.0548	-0.0479	0.0449
Extension events	2.873***	0.703	0.3194	0.113*	0.0594
Access to training	-0.0171	0.522	-0.0019	-0.0271	0.0380
Cooperative membership	1.880***	0.653	0.2090	-0.0127	0.0682
Total farm land	0.781***	0.262	0.0869	0.0638***	0.0225
Livestock size	0.277***	0.0886	0.0308	0.0246**	0.00956
Amount of credit	-0.000099	0.000152	-1.10E-05	1.26e-07	9.81e-06
Contact with extension agents	1.072**	0.493	0.1192	0.146**	0.0632
Observations = 148					
Selected = 92					
Non-selected = 56					
Wald $\chi^2(9) = 34.94$***					
Prob > χ^2 = 0.0001					
Mills lambda = 0.154** (0.0762), P>|z| = 0.044					
Rho = 1.000					
Sigma = .15362					

Note: ***, ** and * indicate significance at $P \leq 0.01$, $P \leq 0.05$ and $P \leq 0.1$

Age of the household heads

The finding of the study shows that age affected intensity of adoption of improved haricot bean technology of the smallholder farmers negatively at the 1% significance level. It indicated that a 1-year increase in adopter age will decrease the intensity of adoption of haricot bean production package by 0.49%, controlling for the other variables. This implies that younger farmers were more likely to allocate more land for an improved haricot bean variety and implement the recommended package than the older ones. This is probably because younger farmers are more energetic than older ones and able to implement the recommended fertilizer and seed rates. In contrast to current findings, Galmesa et al. (2019) reported that age positively and significantly influenced intensity of adoption of improved soya bean varieties in Buno Bedele and East Wollega districts of Oromia region.

Participation in extension events

Similar to prior expectation, participation in extension events such as field days and demonstrations were positively and significantly associated with adoption decision and intensity of adoption at $P \leq 0.01$ and $P \leq 0.1$, respectively. The result of the marginal effect implied the probability of adopting haricot bean variety increased by 31.94% and intensity of use of the haricot bean production package increased by 11.30%, for those who had participated in demonstrations and field days, other things kept constant. Similarly, Negash (2007) and Biniam et al. (2019) reported that participation in demonstrations and field days increased the probability of adoption and intensity of use of improved haricot bean production package.

Cooperative membership

Membership in cooperatives is among the explanatory variables which positively affected adoption of an improved haricot bean variety ($P \leq 0.01$). Membership of a cooperative increased the probability of adopting an improved haricot bean variety by 20.90%, other things remaining constant. Additionally, being a member of an association or cooperative influenced the decision of farmers to adopt new agricultural technologies. In the same way, the study conducted by Degnet and Mekbib (2013) suggested cooperatives can play an important role in accelerating the adoption of agricultural technologies by smallholder farmers in Ethiopia.

Total farm size

Total farm size had a significant and positive effect on the decision to adopt an improved haricot bean variety and the intensity of use of haricot bean production package ($P \leq 0.01$). The value of the marginal effect indicated that an increase in 1 ha of land increases the probability of adopting an improved haricot bean variety by 8.69% and intensity of use of haricot bean production package by 6.38%. Daniel et al. (2017) also indicated the size of land has a positive and significant effect on intensity of adoption.

Livestock size

It was hypothesized that livestock size was positively related to the adoption of agricultural technologies because it served as proxy for wealth status. The result showed that livestock size had a significant and positive impact on adoption of improved technology ($P \leq 0.01$). This was probably because households with large livestock holdings had good access for more credit and can purchase improved agricultural inputs by selling their livestock. The study also found that livestock size was positively and significantly associated with adoption of the improved haricot bean production package ($P \leq 0.05$). An increase in size of tropical livestock unit, increased the probability of adopting an improved haricot bean variety and intensity of haricot bean

production package usage by 3.08% and 2.46%, respectively. The result is consistent with Adam et al. (2005) and Fitsum (2016) who explained that farmers who have more livestock are more likely to adopt new technology and use it more.

Extension contact

Extension contact was positively and significantly related to adoption of improved haricot bean technology ($P \leq 0.05$). This is probably because contact with an extension agent is the crucial means through which farmers get information about improved haricot bean technology and it's agronomic practices. An increase in extension contact increases probability and intensity of use of improved haricot bean technology package by 11.92% and 14.60%, respectively. The findings of study is in line with Daniel et al. (2017), Fitsum (2016), and Assefa and Gezahegn (2010), who observed that contact with extension agents increased the probability and intensity of modern technology adoption.

Conclusion and recommendations

The study was conducted to identify factors influencing adoption and intensity of use of haricot bean production technology package by farmers in the study area. Improved haricot bean production package considered to estimate adoption index in this study includes use of improved variety, seeding rate and fertilizer rate.

The estimates of the selection model showed that younger farmers were more likely to implement the haricot bean production package than the older ones. Therefore, attention has to be given to younger household heads to increase their access to improved haricot bean technology, and to improve their knowledge and capacity in improved haricot bean production activities by delivering training and agricultural inputs to enhance the adoption of improved haricot bean varieties.

Adoption decision and intensity of implementing haricot bean production package were found to be influenced, among other things, by livestock size. A household with a large livestock holding can obtain more cash income from the sales of animal products. This income in turn helps smallholder farmers to purchase farm inputs. Strengthening the existing livestock production system through providing improved health services, better livestock feed (forage), targeted credit and adopting agro-ecologically based high-yielding breeds and disseminating artificial insemination are suggested to improve intensity of adoption of improved haricot bean technologies.

Those farmers who actively participated in social organizations such as cooperatives are more likely to adopt improved, haricot bean technology. Therefore, farmers' participation should be improved through intensive awareness creation regarding the benefits of rural social associations, such as primary agricultural cooperatives, ikub and idir.

Improved haricot bean production involves the use of different practices which require knowledge and skill of application and management. Extension services (participation in demonstrations and field days and contact with an extension agent) on improved haricot bean production were found to have a strong relation with adoption of the improved haricot bean production package as it enhances the ability to acquire and use information required for production. Hence, emphasis in field visits and demonstrations has, to be given towards strengthening farmers' knowledge in improved haricot bean production by arranging training on agronomic practices, such as fertilizer application, land preparation, sowing, spacing, weeding, and postharvest handling.

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Conflict of interests

The authors declare no conflict of interest.

Availability of data and materials

The datasets used for the study are available from the corresponding author upon request.

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Appendix

Appendix 1: Summary of hypothetical explanatory variables that affect probability of adoption and intensity use of haricot bean technology

Variables	Category	Measurement	Expected effect on adoption decision and intensity of adoption
Age	Continuous	Years	±
Sex	Dummy	1 if male, 0 otherwise	+
Extension events	Dummy	Hectare	+
Access to training	Dummy	1 if access, 0 otherwise	+
Cooperative membership	Dummy	Number of years	+
Total farmland	Continuous	Hectare	+
Livestock size	Continuous	Number in TLU	+
Amount of credit	Dummy	ETH BIRR	+
Contact with extension agents	Dummy	1 if contact, 0 otherwise	+

Appendix 2: Conversion factors used to calculate Tropical Livestock Units (TLU)

Animals	TLU-equivalent
Calf	0.25
Heifer and bull	0.75
Cows and oxen	1
Camel	1.6
Donkey young	0.35
Donkey adult	0.7
Sheep and goat	0.13
Chicken/poultry	0.013

Source: Storck et al. (1991)