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Adoption of improved chickpea technologies for productivity enhancement in the North Western Ethiopian highlands

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ABSTRACT

Efforts have been made on promoting improved chickpea technologies. However, the result is not that much impressive. This study aimed to analyze drivers of technology adoption. 224 respondents were used for this study. Multivariate Probit (MVP) and Seemingly Unrelated Regression (SUR) models were employed. The results from MVP model, marginal success probability of adoption decision were 60%, 19%, and 17% for a variety, bio-inoculant, and chemical fertilizer, respectively. Distance from farmers' training center, farm income, livestock holding, and field day participation have significantly affected for adoption of chickpea varieties. A social network, market information, and field day participation have significantly influenced the adoption of bio-inoculant fertilizer. In addition, household size, asset owned, and field day participation has significantly influenced the adoption of chemical fertilizer. Field day participation was the most important variable for the adoption decision of chickpea technologies as a package. The results from SUR model, farmers' training center distance, farm income, livestock holding, social network and agricultural training have significantly influenced adoption intensity of improved varieties. Age, farming experience, livestock holding, social network, education status, and field day and training participation have significantly influenced the intensity of bio-inoculant adoption. In addition, Age, education status, radio owned, training participation, asset owned and farmer's perception have significantly influenced the intensity of chemical fertilizer adoption. Training participation is the most determinant factor for adoption intensity of improved technologies. Hence, government should emphasize on improving of extension services, provision of education, encouraging livestock rearing, strengthening credit access for farmers, strengthening rural infrastructure, and considering community social network for adoption of chickpea technologies.

1. Introduction

Chickpea is one of important pulse crops, cultivated in above 40 countries and around 11 million ha of land. Major producers are India, Pakistan, Turkey, Australia, Iran, Myanmar, Canada, Ethiopia, Mexico and Iraq cover 93% of the global production. In Africa, chickpea is widely grown in Ethiopia, Sudan, Eritrea, Kenya, Tanzania, and Malawi. It contributes around 46% of the total production in Africa [1]. Ethiopia is ranks first chickpea growing country in Africa, with a share of about 37% in area coverage and 63% in

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production and the seventh chickpea producer in the world. In Ethiopia, chickpea ranks third in area coverage among the pulses grown areas and proceeded by *Faba* bean and Field pea crops and second in volume of production only next to *Faba* bean. Amhara regional state has 61.5% in chickpea cultivated area and 60% in production share from the country. North Gondar zone also contributes around 25% chickpea cultivated area share of the region [1,2].

Different studies indicated that, adoption of improved technologies was very low. Among the total chickpea cultivated area (194,981 ha) only 0.69% was covered by improved chickpea varieties [3]. It has been recognized that the continuous use of local low yielding crop varieties is a major cause of low productivity. The main reasons indicated for low adoption rates are insufficient seed and marketing systems that limit the availability of quality-improved seeds, lack of credit, and late delivery of inputs [1]. Other studies also pointed out that the total quantity of improved seed supplied nationally has been increasing, however, the adoption of improved varieties was around 3%–5% of cropped area was under improved varieties [4]. The productivity of chickpea was low according to its potential i.e 1.85 ton per hectare [2]. In addition, the market share of the country from the world was low i.e about 4% by volume [5]. There is a need to identify the reason for low productivity of chickpea.

Technology adoption is the vehicle that allows most people to participate in a rapidly changing world where technology has become central to our lives [6]. In an attempt to increase agricultural productivity and improved food security at both national and household level, efforts have been underway by the government of Ethiopia to generate and disseminate improved agricultural technologies among smallholder farmers [7,8]. Individual farmers who cannot adopt will increasingly limit their ability to participate fully in the financial and convenience benefits associated with technology. Understanding the factors, influencing technology adoption helps us to arrange mechanisms for productivity enhancement [9].

Previous empirical studies on technology adoption were largely focused on dichotomous terms adoption versus non-adoption, though the actual decisions made by farmers are defined over a continuous range [10]. Their main purpose using choice models (such as Probit and the Logit) is to determine the probability of an individual with a given set of attributes will make one choice than an alternative [11]. Recent technology adoption studies [12,13] involve multiple stages and the decision may be independent or sequential for the determinants of technology adoption and intensity by farmers. These studies indicated that the magnitude and direction of influence of the factors hypothesized to condition technology adoption are area specific and their importance varied among regions, agro-ecologies and site specific [14]. Most of adoption studies [15–17] in Ethiopia focused on estimating of improved wheat and maize technologies and complementary inputs such as fertilizer and herbicides on smallholder farmers. Studies that analyzed technology package adoption are still very limited.

Many studies conducted so far emphasize on the adoption of a single technology rather than adoption decision of interdependence-improved technologies as a package for enhancement of productivity. Demographic, socioeconomic, institutional and infrastructure access factors, and communication condition of the household were significantly related to adoption and intensity of adoption of improved agricultural technologies [18,19].

Many efforts have been conducted to popularize improved chickpea technologies (improved chickpea variety, bio-inoculant fertilizer and chemical fertilizer), yet adoptions of improved technologies are not impressive. Thus, understanding adoption of recommended technologies are important concerns for the people dealing with agricultural development. The objective of the study was to identify factors affecting adoption of chickpea technologies in the Northern Western Ethiopian Highlands.

2. Methodology

2.1. Description of study area

Gondar zuria district is found in Amhara National Regional State. Based on traditional agro-ecological classification, *Gondar zuria* is described as 22% *Dega* and 78% *Woina Dega*. The annual average rainfall of the district ranges from 950 to 1035 mm. The yearly average temperature also ranges in between 24 and 33 C^0 and altitude of the district ranges from 1800 to 2700 m.a.s.l. The district had a human population of 224,460 with 113,702 (or 50.6%) males and 110,758 (or 49.4%) females based on CSA projection [2]. In addition, 87.2% of *Gondar zuria's* population lives in rural areas while the remaining lives in towns [2]. The total population density of *Gondar zuria* district was found to be about 203 persons per Km^2. This shows that there is high population, which should be seen from the high subsistence requirement and the limited sources of earnings. *Gondar zuria* district has estimated about 5228 ha of land for chickpea production potential (see Fig. 1).

Source: GIS shape file of Ethiopian administrate map.

2.2. Sampling and data Collection

Cross-sectional household survey was employed for this study. The sample size was determined by using [20] formula and 224 household heads was used for this study. A multi-stage sampling procedure was used to select district, *kebeles* and farmers. In the first stage of sample, procedure was purposive selection of *Gondar zuria* district. The district was selected purposively because of intensity of chickpea crop production, agro-ecological suitability and accessibility. In addition, improved chickpea technologies were promoted by Gondar Agricultural research center and office of agriculture in *Gondar zuria* district. At the second stage of sampling procedure, a total of four kebeles namely *Tsion-segaje, Bahiri-gimib,Zengaj* and *Degola-chinichaye* were selected randomly from chickpea growing potential kebeles. At the thrid stage respondets were selected using simple random sampling in the selected *kebeles*. The respondents from each selected *kebeles* were identified using probablity proportional to size random sampling technique. Survey instrument was prepared and data collected by using semi-structured interview questionnaire.

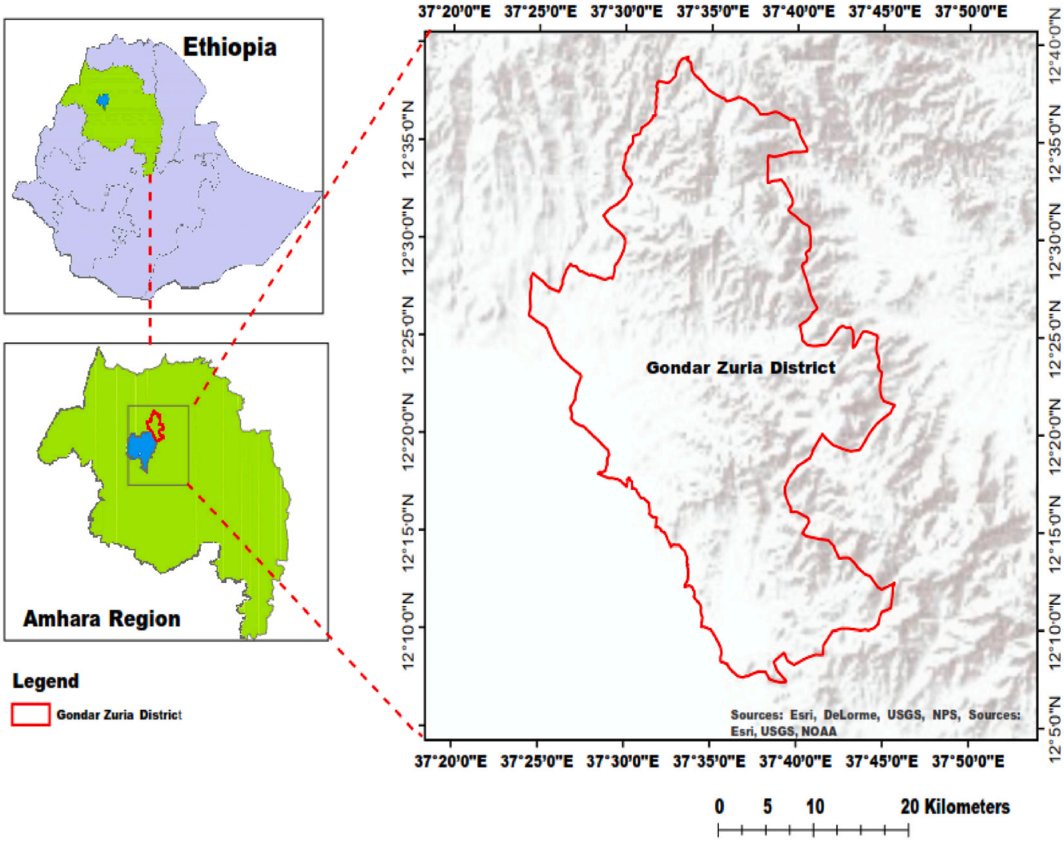

Fig. 1. Map of the study area.

2.3. Analytical models

Multivariate Probit (MVP) and Seemingly Unrelated Regression (SUR*)* models were applied for this study.

2.3.1. The multivariate probit (MVP) model

It is employed to analyze the drivers of adoption of chickpea technologies. Adoption status was improved chickpea technologies (Improved varieties, bio-inoculant fertilizer and chemical fertilizer). The MVP model would be appropriate for jointly predicting these three choices on an individual specific basis. The Probit model is used because its likelihood function is well behaved as it gives consistent Maximum Likelihood Estimates (MLE) coefficients (β) and standard error of the estimate (s) [21]. The Probit model estimates the probability of participating improved chickpea technologies for household level data and measures this likelihood after controlling the relevant variables in the model. The dependent variable in the first step is defined as dichotomous variable with the values 1 (one) for adopters and 0 (zero) for non-adopters.

The simplest and most straightforward estimation procedure would be to estimate each Probit equation separately. However, it is important to notice that the data for different technologies are collected from one individual at a given point in time. This may bring endogeneity with in the data set, that is, the error terms between the equations different technologies might be correlated since data is being collected from the same individual whose decision on a particular variety choice may affect the probability of selecting another technology. As such, we need to use a Multivariate Probit Model to address this problem. Following [22] the Multivariate Probit Model is structured as follows. Consider the M-equation Multivariate Probit (Equation (1)) and (Equation (3)).

Where:

$$Y_{im}{}^{*} = \beta_m{}' X_{im}{}^{*} + \varepsilon_{im} \quad m = 1, \ldots\ldots\ldots M \tag{1}$$

$$Y_{im}{}^{*} = 1 \ \text{if} \quad Y_{im}{}^{*} > 0 \quad \textit{and} \ \ 0 \ \textit{otherwise} \tag{2}$$

$$\begin{cases} \textit{Improved variety}_j = X_1{}'\beta_1 + \varepsilon^A \\ \textit{Bio}-\textit{inoculant fertilizer}_j = X_2{}'\beta_2 + \varepsilon^B \\ \textit{Chemical fertilizer}_j = X_3{}'\beta_3 + \varepsilon^C \end{cases} \tag{3}$$

Where:

$$\begin{pmatrix} \varepsilon^A \\ \varepsilon^B \\ \varepsilon^C \end{pmatrix} \ldots\ldots\ldots\ldots\ldots N \left[\begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix} \begin{pmatrix} 1 & \rho_{12}\rho_{13} & \\ \rho_{21} & 1 & \rho_{23} \\ & \rho_{31}\rho_{32} & 1 \end{pmatrix} \right] \quad 4$$

$$E(\varepsilon / X) = 0 \quad 5$$

$$Var(\varepsilon / X) = 1 \quad 6$$

$$Cov(\varepsilon / X) = \rho \quad 7$$

and $\varepsilon_{im}, m = 1, \ldots\ldots\ldots M$ are error terms distributed as multivariate normal, each with a means zero and variance-covariance matrix V, where V has value k of 1 on y the leading diagonal corrections $\rho_{jk} = \rho_{kj}$ as off diagonal elements. The multivariate probit model has structure like the Seemingly Unrelated Regression (SUR), except that the dependent variables are binary indicators. The Y_{im} might represent outcomes for M different choices at the same point time, for example, whether a farmer uses M technologies. The X_{im} is a vector of explanatory variables and β_m are unknown parameters to be estimated (Equation (1)).

2.3.2. *The seemingly unrelated regression (SUR) model*

This model used to estimate the adoption intensity of improved chickpea technologies. SUR model appears to be joint estimates from several regression models, each with its own error term [23]. It is used to analyze the factors that determine adoption intensity of improved chickpea technologies i.e varieties, bio-inoculant fertilizer and chemical fertilizer. The regressions are related because the (contemporaneous) errors associated with the dependent variables may be correlated. When we fit models with the same set of right-hand-side variables, the seemingly unrelated regression results (in terms of coefficients and standard errors) are the same as fitting the models separately. It is used to estimate models with $\rho > 1$ dependent variables that allow for different regressor matrices in each equation ($X_i \neq X_j$) and account for contemporaneous correlation, i.e E ($\varepsilon_{it}\varepsilon_{jt}$) $\neq 0$. In order to simplify notation, all equations are stacked in to a single equation: Matrix representation of the model (Equation (8)) and (Equation (9)).

$$\begin{array}{l} y_1 = x_1\beta_1 + \varepsilon_1 \\ \ldots \quad .. \quad .. \\ y_m = x_m\beta_m + \varepsilon_m \end{array} \quad 8$$

$$\begin{bmatrix} y_i \\ y_i \\ . \\ . \\ y_\rho \end{bmatrix} = \begin{bmatrix} x_1 & 0 & 0 & 0 \\ 0 & x_2 & 0 & 0 \\ & 0 & . & 0 \\ & 0 & . & 0 \\ & & 0x_\rho & \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \\ . \\ . \\ \beta_\rho \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ . \\ . \\ \varepsilon_\rho \end{bmatrix} \quad 9$$

$$(y = x\beta + \varepsilon) \quad 10$$

2.4. *Description and Measurements of Variables*

The description and measurement of the dependent and independent variables are shown in Tables 1 and 2, respectively.

Table 1
Description of dependent variables.

I. Adoption status of technologies	Measurement	Description
1. Improved chickpea varieties 2. Bio-inoculant fertilizer 3. Chemical fertilizer	Dummy	1 if a household applied each improved technology for chickpea production; 0 otherwise.
II. Intensity of technologies adoption	Measurement	Description
1. Improved chickpea varieties	Continuous	Proportion of land covered by improved chickpea varieties during production period [24]
2. Bio-inoculant fertilizer	Continuous	Proportion of actual and recommended bio-inoculant fertilizer package applied on plot of land for chickpea production during production period [24,25]
3. Chemical fertilizer	Continuous	Proportion of actual and recommended chemical fertilizer package applied on plot of land for chickpea production during production period [24,25]

Table 2
Description of independent variables.

Explanatory Variable	Variable Description	Unit	Expected sign
Sex	1 if sex is male; 0 otherwise	Dummy	+/−
Education	1 if literate; 0 otherwise	Dummy	+
Age	A household head age	Year	+/−
Family size	Number of family size	Number	+
Experience	Chickpea production experience	Year	+
Land size	Amount of land owned by a household	Hectare	+
Livestock (TLU)	Total Livestock own by a household	Number	+
Asset	Amount of asset own by a household	Birr	+
Farm income	Amount of farm income gain	Birr	+
Plot number	Number of plots of land own	Number	–
Cooperative	1 if member of cooperative; 0 otherwise.	Dummy	+
Social network	Relative and non-relative rely on	Number	+
Market distance	Nearest distance to main market	Minute	–
FTC distance	Distance home to farmer training center.	Minute	–
Credit	1 if access to credit; 0 otherwise	Dummy	+
Radio	1 if a household own radio; 0 otherwise	Dummy	+
Road distance	Distance of living house to main road	Minute	–
Field day	1 if participate in field days; 0 otherwise	Dummy	+
Training	1 if attended in training; 0 otherwise	Dummy	+
Market access	1 if access to market; 0 otherwise	Dummy	+
Perception	1 if a technology is superior; 0 otherwise	Dummy	+

Source: Based on authors' literature review

3. Results and discussions

3.1. Descriptive statistics

According to T-test and χ^2-test showed that the mean values or proportion values of the variables hypothesized to influence' the decision to adopt improved chickpea varieties. The result revealed that comparison between adopter and non-adopter improved chickpea technologies. The result showed that the proportion of male household head is significantly higher among adopters (58.04%) than non-adopters (30.80%) did. On the other hand, there is significant difference in age between non-adopter (46.7 years) and adopters (49.1 years) in the chickpea technology adoption status. Educational status of adopters (45.09%) was significantly higher than the non-adopters (22.32%). The mean of asset is also significantly higher in technology adopters (9745.73 birr) than the non-adopters (6538.74 birr) have.

Farm income also one of the determinant for technology adoption. In farm income, improved chickpea variety adopters (31,193.81 birr) have significantly higher than non-adopters (21,150.58 birr) have. Livestock holding size is significantly higher in adopters (6.72 TLU) than non-adopter (4.58 TLU). The *t*-test shows that adopters (1.82 ha) have significantly larger in farmland holding than non-adopters (1.48 ha). Adopters have also significantly longer chickpea farming experience (30.1 years) than non-adopters (26.8 years). However, adopters have significantly shorter main market distance (54.53 min) and farmers training center (18.47 min) than non-adopters in main market distance (65.29 min) and FTC (22.87 min). Improved chickpea variety users were significantly higher in credit access (41.9%) than non-adopters (21.88%). In addition, adopters have significantly higher in numbers of people rely on critical time (33%) than non-adopters (22%). Communication and market information are also affecting the technology adoption. Improved chickpea variety adopters (34.82%) were significantly higher in field day participation than non-adopters (7.14%) were. Training participation was also significantly higher in technology adopters (38.84%) than non-adopters (6.7%) were. Adopters (51.34%) have significantly higher in market information than non-adopters (25.89%). Household heads, who have better technology perception, adopt the technology early. Improved variety adopters (29.91%) were significantly higher on technology perception than non-adopters (16.96%) were.

Bio-inoculant fertilizer adopters have significantly higher in asset (11,548.72 birr) ownership than non-adopters' asset (7793.69 birr). Adopters have also significantly higher in livestock holding size (7.18 TLU) than non-adopters (5.59 TLU). They have also significantly larger land size (1.91 ha) than non-adopters' land holding size (1.64 ha). Technology adopters were significantly lesser in market distance (50.69 min) than non-adopters distance (60.55 min). Bio-inoculant fertilizers users on their chickpea land have significantly higher in average number people rely on in critical time (46) than non-users number of people (24). Field day and training participations, market information and technology perception were highly significant differences between technology adopters and non-adopters.

Chemical fertilizer influenced by asset own, farm income, field day participation, training participation, radio ownership and household heads' perception about the technology (see Table 3).

3.2. Econometrics model

3.2.1. Status of improved chickpea technologies adoption

Result of the analysis indicates that Table 3 Wald chi-square statistics is 114.49 and highly significant at 1% level of significance. This indicates that the model has good explanatory power. The likelihood ratio (LR) test result (Appendix 1) shows that interdependence among chickpea technologies adoption simultaneously related to the adoption of improved chickpea variety, bio-inoculant fertilizer, and chemical fertilizer at 1% level of significance in the production of chickpea crop. Appendix 2 also shows marginal success probability for an improved variety of 60%, bio-inoculant fertilizer 19%, and 17% for chemical fertilizer.

. The results on the above Table 3 show that, distance to farmers' training center, farm income, livestock holding and agricultural field days participation were important variables to significantly influence adoption of improved chickpea varieties. Farmer social network, market information and field day event participation significantly influence adoption of bio-inoculant fertilizer. Finally, family size, asset own and field day participation influence the adoption of chemical fertilizer significantly.

3.2.1.1. Socio-economic factors. Farm income positively and significantly influenced the adoption of improved varieties. This is because farmers are getting more income from farm crop. Previous studies also documented the positive and significant relationship of farm income on the adoption of technologies [26,27].

Livestock holding size, is the proxy of the wealth status of the household, positively and significantly influence the adoption improved varieties. This may mean that farmers with a larger livestock holding are more likely to adopt new technologies. This indicates that household can generate additional income from livestock and livestock products and purchase improved chickpea varieties for production purpose. Similar result had been documented by previous studies [16,19,27,28].

Family size: Have a negative and a significant effect on the adoption status of chemical fertilizer. Farmers who have less family size are more likely to use chemical fertilizer than other farmers. Possible explanation for this result is that less family size cannot prepare enough compost for their farmland to replace chemical fertilizer than larger family size. Large family size had low input purchasing power because of request high expenditure for children schooling, health, clothing and food services. Earlier studies [19,26,29,30] also found a similar research result. However, other studies [16,18,28] found different result in their studies.

3.2.1.2. Institutional and communication factors. Farmers' training center (FTC) distance negatively and significantly influences adoption of improved chickpea varieties. This might be due to the fact that farmers who are nearest to FTC can get enough information about improved technologies and able to observe and visit easily. This might encourage farmers to apply the new technology on their farm. Therefore, farmers are nearer to farmers' training center, they are more likely to adopt improved technology varieties for chickpea. This result is in line with previous studies who also obtained a similar result [26],[31],[32].

Field day participation has a positive and very significant influence on the adoption of improved chickpea varieties, bio-inoculant

Table 3
Multivariate Probit (MVP) model for adoption status of chickpea technologies.

Variable	Improved variety		Bio-inoculant fertilizer		Chemical fertilizer	
	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
Family size	0.015	0.061	0.036	0.068	−0.226***	0.071
Market distance	−0.002	0.003	−0.006	0.004	−0.003	0.004
FTC distance	−0.015**	0.007	−0.005	0.009	0.007	0.008
Asset own	0.295	0.196	0.064	0.193	0.512**	0.213
Farm income	0.387*	0.206	−0.159	0.254	0.304	0.231
Social network	0.001	0.004	0.008**	0.004	0.005	0.004
Credit access	0.302	0.203	−0.244	0.247	0.213	0.241
Livestock TLU	0.069*	0.039	0.054	0.043	−0.050	0.039
Market info. Access	0.360	0.233	0.676*	0.407	0.244	0.305
Off-farm income	0.000	0.000	0.000	0.000	0.000	0.000
Field day particip.	0.764***	0.211	1.374***	0.263	0.765***	0.244
Radio own	−0.148	0.212	−0.246	0.262	0.239	0.240
Constant	−7.075***	2.565	−1.495	2.893	−7.710**	2.907
/atrho21	3.39***					
/atrho31	2.68***					
/atrho32	1.68*					
rho21	10.19***					
rho31	3.25***					
rho32	1.76*					
Number of observation (N) 224						
Log likelihood - 252.14						
Wald chi2(36) 114.49***						

***, **and * indicate level of significance at 1, 5 and 10%, respectively.
Source: Computed from own survey data

fertilizer and chemical fertilizer at 1% level of significance. Field day event participation can give the chance for farmers to observe practically and understand improved technologies easily. This shows that more field day event participation on pulse crop production and marketing condition more likely to adopt new and improved chickpea varieties. This result is consistent with previous studies [13],[19],[27],[28],[32]. For bio-inoculant fertilizer case, the study might imply that farmers who participate on field day event organized by office of agriculture and agricultural research center have better information and knowledge about bio-inoculant fertilizer technology and hence more likely to adopt the technology than non-participant farmers in the study area [13],[32]. found a similar research result on their studies. The study also might imply that farmers who participate on field day event organized by office of agriculture and agricultural research center have better information and knowledge about chemical fertilizer and hence more likely to adopt the technology than non-participant farmers in the study area. Similar finding has been confirmed by the studies [13],[32].

Market information has a positive and significant influence on the adoption of bio-inoculant fertilizer at 10% level of significance. Therefore, people who have more market information are, more likely to adopt and use bio-inoculant fertilizer in the production of chickpea crop.

Social network has a positive and significant influence on the adoption of bio-inoculant fertilizer for production of chickpea crop in the study area. This indicates that more social capital and networking is helping to share information, resources and minimize risks of problems and thereby encouraging the adoption of new technologies. Therefore, people with more social networks are more likely adopting bio-inoculant fertilizer. This finding is consistent with the findings of [33] who also found the same result on their research finding.

3.2.2. *Intensity of adoption of improved chickpea technologies*

Breusch-Pagan test result (Appendix 4) shows that, the interdependence among the intensity of chickpea technologies (Improved chickpea variety, bio-inoculant fertilizer, and chemical fertilizer) adoption simultaneously related and highly significant at 1% level of significance. In other words, there are potential efficiency gains obtained by estimating these equations as a system.

As shown in Table 4, distance to farmers' training center, farm income, livestock holding, social network and agricultural training participation are important variables significantly influencing intensity of improved chickpea varieties adoption. Household head age, chickpea farming experience, livestock holding, social network, education, field day participation and agricultural training participation significantly influenced adoption of bio-inoculant fertilizer. Household head age, education, radio, agricultural training participation, asset and farmer perception is found significantly influence the adoption of chemical fertilizer. This means that different factors might differently influence the intensity of the technologies adoption.

3.2.2.1. Socio-economic factors. Farm income has positively and significantly affected the intensity of adoption of improved technology at 10% significance level. Farmers can take a risk and responsibility about a new technology. Studies [26,27] also reported that farm income was significant and positive related to the intensity of the adoption of technologies.

Livestock holding size is the proxy of the wealth status of the household. It was positively and significantly, influence intensity of adoption of improved chickpea varieties and bio-inoculant fertilizer. This shows that households with larger livestock holdings are more likely to adopt new technologies in terms of improved chickpea ad bio-inoculant fertilizer. This indicates that household can generate additional income from livestock and livestock product and purchase improved chickpea varieties and bio-inoculant fertilizer for production purpose. This indicates that farmers with large number of livestock are more likely to adopt bio-inoculant fertilizers

Table 4
Seemingly Unrelated Regression (SUR) model for intensity of technologies adoption.

Variable	Proportion of improved variety		Proportion of bio-inoculant fertilizer		Proportion of chemical fertilizer	
	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
Age	0.00002	0.004	−0.008[a]	0.003	−0.005**	0.003
Chickpea experience	0.001	0.004	0.008[a]	0.003	0.002	0.003
Market distance	0.001	0.001	0.000	0.001	0.000	0.001
FTC distance	−0.004[a]	0.002	−0.002	0.001	0.000	0.001
Farm income	0.079*	0.045	−0.051	0.033	0.021	0.034
Livestock TLU	0.017**	0.008	0.014[a]	0.005	−0.005	0.006
Social network	0.001*	0.001	0.002[a]	0.001	0.000	0.001
Education status	0.021	0.051	−0.061*	0.037	−0.130[a]	0.038
Radio own	−0.061	0.048	−0.033	0.035	0.060*	0.036
Field day part.	0.013	0.071	0.128**	0.051	0.085	0.053
Training part.	0.198[a]	0.071	0.085*	0.051	0.100*	0.053
Market info. Access	0.038	0.055	0.053	0.040	−0.013	0.041
Plot number	−0.010	0.016	−0.002	0.011	0.006	0.012
Asset own	−0.003	0.038	−0.004	0.027	0.055*	0.029
Perception	0.038	0.045	−0.010	0.032	0.075**	0.034
Constant	−0.654	0.500	0.631*	0.359	−0.388	0.374
Observation (N)	224		224		224	
Parms	15		15		15	
chi2	73.05[a]		91.79[a]		59.24[a]	

[a] , **and * indicate level of significance at 1, 5 and 10%, respectively.
Source: Computed from own survey data

than others. This revealed that relatively more livestock could generate more income from livestock and livestock products to purchase bio-inoculant fertilizer. Studies [16,19,27,28] also obtained similar result.

Age of household head has a negative and very significant influence on intensity of adoption of bio-inoculant and chemical fertilizers. This might be because younger farmers have better education status and more flexible on ideas and new things that would allow them adopting bio-inoculant and chemical fertilizers than older farmers. Therefore, younger farmers are more likely to adopt bio-inoculant fertilizer than older farmers. This is consistent to previous studies [18],[27],[32],[34].

Farming experience has a positive and highly significant influence on the intensity of adoption of bio-inoculant fertilizer at 1% significant level. This indicates that, more experienced farmers in chickpea production have better knowledge and information on the chickpea production and marketing condition. Therefore, more experienced farmers in the production chickpea crop are better to adopt and use recommended bio-inoculant fertilizer. This finding is in line with the findings of [18,29,35,36].

Education status has a negative and significant factor on intensity of adoption of bio-inoculant and chemical fertilizers. This implies that the likelihood of bio-inoculant and chemical fertilizers' adoption decreases with literate farmers. One possible explanation for this finding is the fact that relatively educated farmers can prepare and use livestock manure and compost for their land than bio-inoculant and chemical fertilizers. Similar to this, studies [16],[18],[27],[29],[31],[32] found a different result in their research findings.

Asset own has a positive and significant influence on the intensity of adoption of the chemical fertilizer. This might be the fact that asset indicate the proxy of wealth of the household which are the source of income and facilitate the production of chickpea crop. Therefore, the more the assets own by the household head are the more likely to adopt chemical fertilizer for the production of chickpea in the study locality. Study [31] also reported that household asset encourages technology adoption.

Farmers' perception matters the intensity of adoptions of the technology. Farmers who have good information and experiences about the chemical fertilizer their perception is also good. The result shows household heads good perception has a positive and significant factor on the adoption of chemical fertilizer for the production of chickpea crop. Studies [13,37] also found that farmers who have good perception easily adopt improved technologies.

3.2.2.2. Institutional and communication factors. Farmers' training center distance was negatively and significantly influenced the intensity of adoption of improved chickpea varieties at 1% level of significance. Farmers who live near to FTC can get enough information about improved technologies. Therefore, farmers who are nearer to farmers' training center, they are more likely to adopt improved technology. Previous studies [26],[31],[32] also obtained a similar result in their studies.

Training participation has a positive and very significant influence on the intensity of adoption of improved chickpea varieties, bio-inoculant fertilizer, and chemical fertilizer. This might be because training can improve capacity building and awareness creation of chickpea producers. This shows that more training participation on the pulse crop production and marketing, more likely to adopt new and improved chickpea varieties, bio-inoculant fertilizer, and chemical fertilizer. The same result was obtained [13],[19],[27],[28],[30],[32].

Radio own has a positive and significant influence on the intensity of adoption of chemical fertilizer. Farmers who have radio can get information and aware about technologies that enhance farmers' knowledge and skills decision-making ability. This is consistent with the findings [13],[32].

Field day participation has a positive and significant effect on intensity of adoption of bio-inoculant fertilizer. Farmers who participate on field day event have better information and knowledge about bio-inoculant fertilizer and hence more likely to adopt the technology than non-participant farmers [29].

Social network has a positive and significant influence on the intensity of adoption of improved varieties for production chickpea crop and bio-inoculant fertilizer for production chickpea crop. This indicates those people that have more social network can support to share information, resources and minimize risks of problems and thereby encourages the intensity of adoption of new technologies and the application of bio-inoculant fertilizer. Therefore, farmers who have more social network, the intensity of adoption of chickpea varieties and the application of bio-inoculant fertilizer is higher. A study by Ref. [33] found the same result.

4. Conclusions and recommendations

The performance of farmers using recommended improved agricultural technologies such as improved varieties, bio-inoculant fertilizer and chemical fertilizer has not been the expected level. Hence, strengthening the existing agricultural extension program, capacitate farmers' training centers, demonstrating improved technologies on farmers' field level, organizing field days and preparing practical oriented training to farmers, and improving existing credit service are important parameters to enhance the productivity of chickpea crop.

Distance from farmers' training center has negatively influence the adoption of improved chickpea technologies in the study area. Farm incomes positively influence the adoption of chickpea technologies. Farmers grow many diversified crops in the study area. These crops generate high income to farmers and assist the adoption improved chickpea technologies. The size of livestock owned had a significant positive impact on adoption of improved chickpea technology.

Participation on field days' event has positively influenced the adoption of improved chickpea technologies. Field practical observation had high opportunity to influence farmers' decision and get information concerning about the technologies. This facilitated more the adoption of the technologies in the study area. Research institutes and agricultural extensions should organize field days and participate more farmers to promote and create wider demand on the technologies.

Agricultural training participation had significant and positively influenced on the adoption status and its level of improved chickpea technologies. Training participation can improve farmers' skill, knowledge and perception about improved technologies. Social networking had significant and positively influenced on the status and level of adoption of improved chickpea technologies in the study area. Farmers who had high social network and rely on critical time more adopted the improved chickpea technology package.

The age of household head has a significant and negative impact on adoption of bio-fertilizer for the production chickpea crop in the study area. Younger farmers adopted bio-inoculant fertilizer faster than older farmers did. Related to the age factor is also the agricultural production experience, which is found to have a significant and positive factor on the adoption of improved technologies in the study area. Experienced farmers more adopted improved chickpea technology than less experienced farmers did. Finally, farmer's perception about the technologies had determined the adoption of improved chickpea technologies in the study area. However, still many farmers had less perception about improved chickpea technologies. The following recommendations are forwarded.

First, it is necessary to encourage and guide farmers to use improved agricultural technologies as package to boost production and productivity of crops. Agricultural extension wing, research institutes, universities should give effective, targeted and crop oriented trainings about production, management and marketing activities to farmers so that they can easily adopt improved technologies.

Second, new improved technologies should be demonstrated on farmers' training center (FTC) and on-farm site in wider locations; field evaluation and field days should be organized and participate many farmers at different chickpea growth stages in the study area. Related to this, farmers' training center should be strengthened with farm materials and serve to all farmers by demonstrating recommended improved chickpea technologies.

Third, livestock production should be encouraged through providing better livestock feed, improved health services and breed to increase income of farmers in the study area. This is because the higher livestock holding in terms of TLU has found positively and significantly influenced the technology adoption.

Fourth, the location of farmers' training centers needs to be located within a proximal distance for farmers. Farmers training center negatively influences the adoption of chickpea technologies.

Fifth, while aiming to enhance technology adoption among farmers, parallel efforts need to focus on enhancing the farm income of farmers. Higher farm income was positively and significantly influenced technology adoption.

Sixth, farmer's perception of the technologies influences the adoption of improved chickpea technologies. Adequate awareness about the technologies is vital before distributing it.

Author contribution statement

Mesfin Fenta Wale: Conceived and designed the experiments; Analyzed and interpreted the data; Performed the experiments; Wrote the paper.

Akalu Teshome Firew and Workneh Kassa Tessema: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Data availability statement

No data was used for the research described in the article.

Additional information

No additional information is available for this paper.

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

Appendix 1. Test of Interdependent among Chickpea adoption.

Likelihood ratio test of rho21 = rho31 = rho32 = 0:
chi2(3) = 32.4374*** Prob > chi2 = 0.0000

Appendix 2. Marginal Success Probability of Each Equation of Adoption Decision.

Variable	Obs	Mean	Std. Dev.	Min	Max
Improved variety	224	0.6085223	0.2612381	0.0160654	0.9932574
Bio-inoculant	224	0.1925844	0.219428	0.000237	0.9294146
Chemical fertilizer	224	0.1670767	0.1560698	0.0004698	0.7278564

Appendix 3. Joint Probabilities of Success or Failure of Adoption of Chickpea Technologies.

Variable	Obs	Mean	Std. Dev.	Min	Max
Success	224	0.0651532	0.0935901	2.00e-06	0.4486749
Failure	224	0.3729294	0.2546288	0.006596	0.9838693

Appendix 4. Test of Interdependent on Adoption Intensity by Correlation Matrix of Residuals.

	Variety Proportion	Bio-inoculant Proportion	Fertilizer Proportion
Variety proportion	1.0000		
Bio-inoculant proportion	0.1936	1.0000	
Fertilizer proportion	0.1162	0.2182	1.0000

Breusch-Pagan test of independence: chi2(3) = 22.083 ***, Pr = 0.0001.

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