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Research Article

Impacts of community Teff seed production technology adoption on the productivity and income of smallholder farmers in Northwestern Ethiopia

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Abstract: *To boost output and household livelihoods, improved crop technology must first be disseminated, which requires seed production and distribution. The government of Ethiopia recognizes three different kinds of community teff seed production systems: formal, intermediate, and informal. The formal and informal seed systems have been the subject of several investigations. There was, however, no empirical data on the impact of the intermediate seed system of communal teff seed production by organized groups of farmers. However, it is crucial that the community increase the supply and production of better teff seed. Thus, the objective of this study was to evaluate the impact of community teff seed production technology adoption on households' farm income and productivity. The study was carried out in the northwest Ethiopian districts of Enemay and Yilmana Densa in 2021–2022. 372 responders and six community teff seed producers Kebeles were chosen at random. Focus groups discussion, key informant interviews, and survey were used to gather both qualitative and quantitative data from primary and secondary sources. Descriptive and inferential statistics were used to analyze the data. The impact of community teff seed production technologies adoption on households' farm income and productivity was examined using an endogenous switching regression model. Accordingly, the model results demonstrated that education, farm clustering, extension contact, contract farming, and household credit utilization all had a substantial impact on the households' farm income and productivity. In addition, relative to their counterfactuals, the adopters' mean treatment effects increased their teff productivity by ha-1 and their average farm income by ETB (Ethiopian Birr) 12,425.31 (1 USD is equal to 124 ETB). Overall, the results demonstrated that community teff seed production improved household welfare and provided teff growers with seeds. The study concludes that the impact of community teff seed production technologies adoption on households' farm income and productivity is more effective. when the personal, socioeconomic, and institutional characteristics of farmers mentioned above are taken into consideration, as well as when policies and legal frameworks are in place to regulate community teff seed production and distribution. To increase the impacts of community Teff seed production technology adoption on the productivity and income of smallholder farmers, it is recommended that the Amhara National Regional State Bureau of Agriculture and pertinent seed sectors provide timely job training courses, make community teff seed production and distribution services accessible, ensure closed follow-up of supporting systems, and ensure farmer participation and field management of community teff seed production for agricultural seed sectors, farmers, Development Agents, and other similar stakeholders.*

Keywords: Community Seed Production, Endogenous Switching Regression model, Impacts, Northwestern Ethiopia, Seed Systems

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1. Introduction

Ethiopia has diverse agro-ecological zones that are appropriate for the production of crops and livestock, as well as a wide range of agricultural alternatives (UNCTAD, 2018). For Ethiopia's rural people, crop cultivation is the primary source of income and plays important social functions (MoA and ATA, 2015). The nation produced 335.1 million quintals of grain crops on 12.86 million hectares of cultivation in 2019–20 (CSA, 2020). Teff is a native staple cereal crop in Ethiopia that ranks first in terms of area (24.11%) at 3.1 million hectares and second in terms of output (57.36 million quintals, 17.11%), after maize (CSA, 2020). Amhara (37.28%) and Oromia (47.08%), which account for over 84% of the total teff acreage and production area, are the two main growing regions (CSA, 2020).

By encouraging teff production and export through the use of enhanced seeds and the use of teff technology, Ethiopia has a high potential to provide food security, economic growth, and poverty reduction (Melkamu et al., 2018). It is the mainstay of Ethiopian diets, grows in a variety of agro-ecological zones, and has a higher market price (Gurmis et al., 2019). To fully utilize the crop's genetic potential, the released teff varieties ought to be replicated and made available in adequate quantities and with the quality standards specified (Atilaw et al., 2017; Chandio and Jiang, 2018).

Seeds are a cost-effective and efficient way to increase agricultural yields per acre and farmers' incomes (Lence et al., 2016). Ethiopia acknowledged both formal and informal seed systems in the past few decades, but the formal seed system's share is lower and it cannot supply farmers with enough seeds because of low seed production and supply as well as weak stakeholder relationships. In order to increase the variety and replacement rate of improved seeds, the nation updated its seed policy in 2009 by including intermediate seed systems and utilizing community seed production with the involvement of organized groups of farmers who generate seeds (MoA and ATA, 2015). The produced seed is either sold to seed corporations, research centers, and seed producer unions or consumed for personal use (Bishaw and Atilaw, 2016).

Of the 15.6 million hectares under cultivation in 2020–2021, 2,228,604 (14.28%) were planted with improved seeds. Improved seeds were planted on 190,092 (6.49%) of the 2,928,206 hectares of land used for teff cultivation (CSA, 2021). In the Amhara region, 1,086,375 hectares of teff were covered, of which 82,817 (7.62%) hectares were covered with improved teff seed. Community seed producers provided 62% of the improved seeds distributed in the region (BoA, 2021), with public and private seed companies providing the remaining 38%. Additionally, roughly 37% of the total seed produced and distributed in the formal seed system was shared by community seed producers (FCA, 2017). This has led to the establishment of teff and other community seed productions around the country.

Numerous studies have been carried out to shed light on the various aspects of seed production in Ethiopia and other parts of the world. These include the factors that influence farmers' willingness to pay for improved seeds (Yaregal Tilahun & Benyam Tadesse, 2022), the impact of contracts on seed production on yield and profits (Mishra et al., 2018), the role of non-governmental organizations in informal seed production (Fekadu Beyene, 2010), the determinants of farmers' participation in seed production (Mesay Yami et al., 2013; Hunegnaw Amare, 2015; Hagos Kidane et al., 2018), and economic efficiency and profitability (Tebeka et al., 2017; Yazie Chanie, 2021). However, there is insufficient empirical data in the study areas regarding the intensity of technology packages, the factors influencing community teff seed production, and their impact on households' farm income and productivity. Thus, the objective of this study was to evaluate the impact of community teff seed production technology adoption on households' farm income and productivity.

2. Conceptual Framework of the Impact of Community Teff Seed Production

Adoption and dissemination of agricultural technologies which vary in location and time due to a complex set of farmer's adoption characteristics of demographic, socio-economic, institutional, and biophysical factors (Feder et al, 1985). Farmers' decision to adopt new technologies, to take risks and to maximize profits can be influenced by various factors related to their benefits and constraints. The level of technology adoption is not uniform; due to variations between households in access to resources, use of credit, access and use of information and participation in training, and behavior of the technology. Impacts on community livelihood improvement were depending on the type of technologies adopted and the conditions of the areas where the technology is to be introduced and disseminated (Legesse Dadi, 1998). This framework analysis consists of the determinant factors and levels of technology adoption and impact of community teff seed production technologies adoption on households' farm income and productivity. In general, the framework showed the pathway of the impact of community teff seed production technology adoption on the improvement of households' livelihood, which showed in Fig 1 as follows.

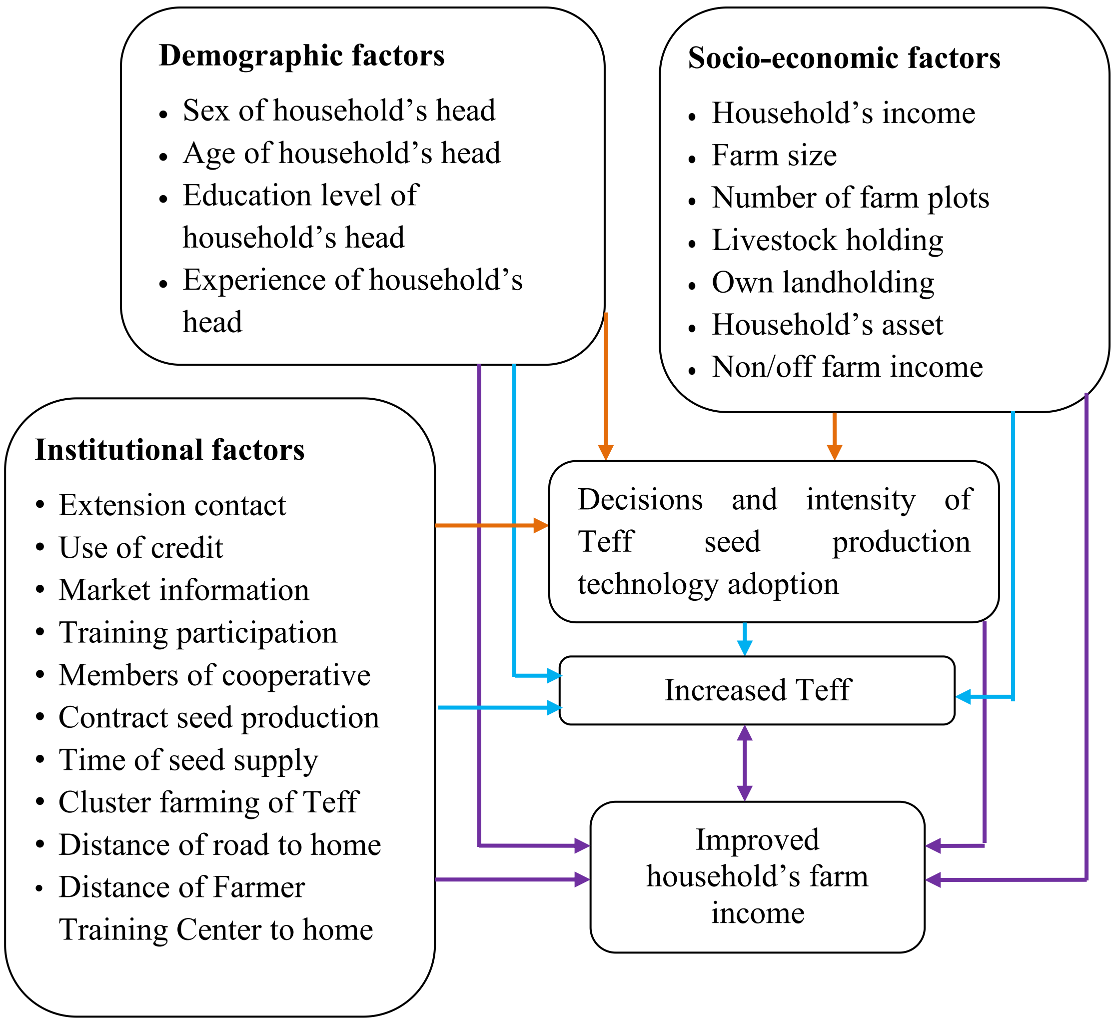

Figure 1: Conceptual framework of adoption and impacts of community Teff seed production

3. Materials and Methods

3.1. Description of the study area

The arrangement of leaves on the oats plant and the structure of its plant parts are typical of grasses. The leaves are solitary, alternate, two-ranked, and sessile (Fekede, 2004). A fully developed oats leaf consists of three main components: the terminal blade, the basal sheath, and a thin membranous ligule. The blade is elongated, flat, narrow, and linear, with an acute margin and pointed tip. The sheath forms an open cylinder that, in young plants, encloses the stem and younger leaves. At maturity, it surrounds the entire elongated internode above it. The ligule, a delicate membranous extension, connects the inner margin where the blade and sheath meet. It curves upward, clasping the stem. Lateral branches of the oats plant emerge from the axils of the foliage leaves. The leaves of tillers grow at a right angle to the parent axis. Before or during anthesis, the leaves exhibit a green to dark grayish-green hue (Fekede, 2004).

With a total area of 99,180 hectares, 42,273 dwellings, and an estimated 233,454 residents, 51.42% of whom are female, Yilmana Densa district is home to many people (YDWoA, 2022). Lowland (6.5%), temperate (72%) and highland (21.5%) make up the district's agro-ecology. Rainfall ranges from 1200 to 1600 mm, the temperature ranges from 12.7°C to 27.9°C, and the predominant soil types are nitisol (65%), vertisol (20%), and brown (15%) (Yitayih et al., 2021; EWoA, 2022). According to EWoA and YDWoA (2022), the majority of households in the Yilmana Densa district (32.4%) and Enemay (46%), respectively, were involved in teff production in 2021–2022. Teff, barley, grass pea, durum wheat, chickpea, maize, sorghum, and lentil are the main annual crops grown in Enemay (EWoA, 2022), whereas Yilmana Densa produces teff, maize, barley, bread wheat, potato, chickpea, and finger millet (YDWoA, 2022).

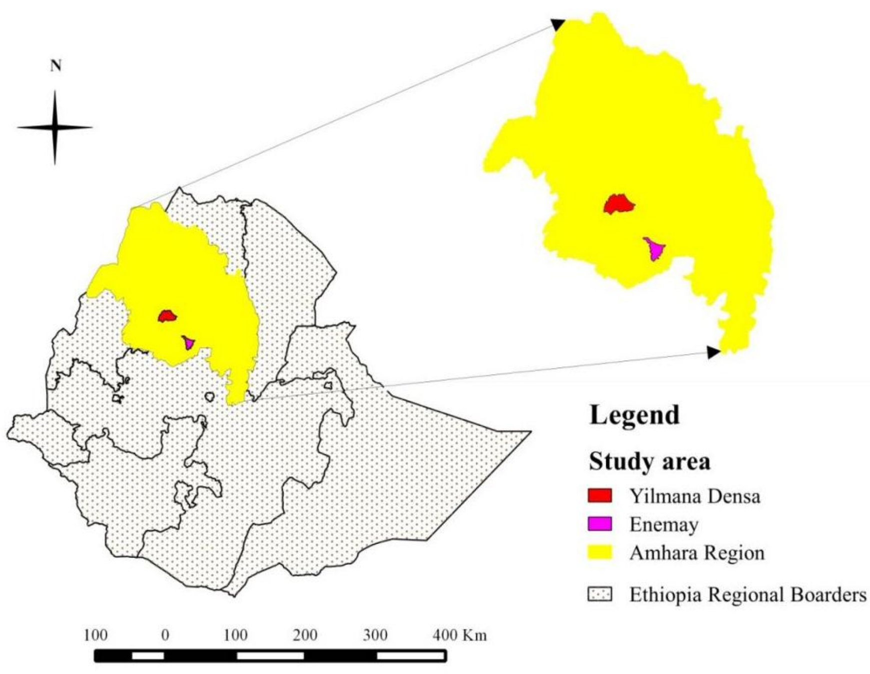

Figure 2. Location of the study area

Source: Own computation using Ethiopia's GIS map (2022)

3.2. Sampling procedure and sample size determination

A multistage sampling was used to choose households from the entire population. Because the bulk of the population farms teff and because of their experiences producing teff seeds in the community, the districts of Enemay and Yilmana Densa were purposefully chosen for the first stage. Yilmana

Densa has 35 kebeles (The lowest administrative unit in Ethiopia), while Enemay district has 27. All local producers of teff seeds were located and purposefully listed in the second step. Six kebeles were chosen at random from among the twelve community teff seed producers in the third stage.

Each Kebele household was divided into two groups in the fourth stage: those that produced teff seeds in the community (adopters) and those that did not (non-adopters). Finally, the numbers of interviewed samples were gathered from community teff seed producer and non-community teff seed producer using simple random sampling method. There are two groups (adopters and non-adopters), which is why random sampling is used. The other was that lists of adopters and non-adopters were part of a sample frame. In order to collect reliable and representative sample out of the target population, the sample size was determined by applying the scientific formula (Yemane, 1967) as shown below. The possible justification preferring this scientific formula was that the sampling frame of the study was 5348 which was below ten thousand.

$$n = \frac{N}{1+N(e)^2} = \frac{5348}{1 + 5348\,(0.05)^2} = 372$$

Where e is the 5% level of precision, n is the total sample size, and N is the size of the finite population. Based on the homogeneous of community teff seed producer characteristics within the population, sample size accuracy at 95% confidence is used; a more homogeneous population (less variability) necessitated fewer sample sizes than a big one. As indicated in Table 1, the number of sampled households was calculated as a percentage of all households each Kebele after the sample size was established.

Table 1: Sample size determination in the selected Kebeles

Districts	Kebeles	Number of households			Sampled households			
		Adopter	Non-adopter	Total	Adopters	Non-adopter	Total	%
Enemay	Mankorkoya	471	452	923	33	31	64	17.26
	Banja Sherer	323	265	588	23	18	41	11
	Bechena Debir	367	489	856	26	34	60	16
Yilmana Densa	Goshiye	708	384	1092	49	27	76	20.42
	Konch	491	372	863	34	26	60	16.14
	Adet Hana	472	554	1026	33	38	71	19.18
Total	6	2832	2516	5348	198	174	372	100

Note: Adopters: community teff seed producers and non-adopters: non-community teff seed producers.

3.3. Methods of data collection

Primary data were collected through household interviews, Focus Group Discussions (FGD) and Key Informant Interviews (KII). The household survey was carried out using an interviewed tool with closed and open questionnaire. The questionnaire was first prepared in English and then translated into the local Amharic language; for the easy understand of the questions. Eight interviewers were participated based on their skills, culture and data collection experiences from researchers and seed experts.

For the qualitative type of data collected, Key Informant Interviews (KIIs) and Focus Group Discussions (FGDs) were used to fill gaps observed during personal interviews, to crosscheck the data collected through formal surveys and to generate additional contextual data. Focus group discussions were conducted with a group of farmers using checklists (an FGD guide). It focused on impact of adoption of community seed production. In each district, two focus group discussions were formed considering members' involvement in community seed production. The discussions were held separately who participated in community teff seed production and who did not participate. Each focus group contained seven individuals with different composition in terms of sex, age and income to capture the possibility of getting different opinions.

With regard to key informants, interviews were made with six district seed production related experts, NGO seed production experts, four seed production department supervisors, two Development Agents and two heads of kebele office of agriculture. Level of education, working experience, competitiveness, and relevancy of specialization in seed production profession was among the criteria to select the experts.

3.4. Data analysis

The demographic, socioeconomic, and institutional characteristics of adopters and non-adopters were compared using descriptive and inferential statistics. The impact of community teff seed production technology adoption was also estimated using econometric models. Following data collection, STATA and R software were utilized for data analysis, while statistical software packages for social sciences (SPSS) were utilized for data entry and cleaning.

Quantitative data types were analyzed by adopter and non-adopter groups using basic descriptive statistics such as minimum, maximum, mean, standard deviation, frequency, and percentage. The mean difference between adopter groups of continuous variables was estimated using the t-test (Ndeke, 2021). Additionally, the association, goodness-of-fit, and homogeneity natures between the adopter categories in dummy and categorical variables were estimated using the chi-square ($\chi 2$) test (McHugh, 2013).

Endogenous Switching Regression (ESR) model

Prior research estimated the influence of agricultural innovations using the PSM (Propensity Score Matching) model. By avoiding functional form assumptions that deal with the systematic selection of observable variables, PSM overcomes the drawbacks of Ordinary Least Square (OLS) (Mendola, 2007).

Due to an issue with unobserved heterogeneity elements, such as farmers' motivation and skill levels, which are likely to affect their decisions to participate in the outcome equation, the PSM has certain limits when using this model (Wooldridge, 2010). Without accounting for unobserved factors, this could result in a deceptive treatment effect finding (Ebrahim, 2019). Given that the impact of technology adoption is influenced by both observable and unobservable elements (Belay and Mengiste, 2021), Consequently, the Endogenous Switching Regression (ESR) model was used since it used a Full Information Maximum Likelihood (FIML) to capture the shortcomings of both OLS and Propensity Score Matching (PSM), including insufficient counterfactual, endogeneity, and unobserved heterogeneity issues (Wodjao, 2020).

We used the first stage of the ESR model in the selection equation to display the elements of participation in community teff seed production for both outcomes in order to quantify the influence of technology adoption. For households' farm income and productivity, including adopters and non-adopters, the second stage's ESR model outcome equation should include the results of community teff seed production determinants. Valid instruments that are statistically and jointly significant in the selection equation but insignificant in the outcome equations were found prior to the study (Khonje et al., 2015).

Assuming that the participation options were binary, the first equation looked at farmers' adoption decisions. As a result, adopters' outcomes are higher than non-adopters', and non-adopters' results are represented by A*, so that A* > 0.

$$Ai* = \mathrm{Zi}\,\beta + Ui; \text{ where Ai } = \begin{Bmatrix} 1; if\ Ai*>0 \\ 0, otherwise \end{Bmatrix} \ldots\ldots(2)$$

where ui is an error term that captures the unobserved variables in the model, Zi is a vector of the observable characteristics of the set of explanatory variables influencing the adoption status, β is a vector of the parameters to be estimated, and Ai* is the latent dichotomous (binary) dependent variable, and Ai = the observable counterpart.

The ESR model's second stage assesses how community teff seed production outcome equations impact adopters' and non-adopters' farm income and productivity. Di-Falco et al. (2011) served as the basis for the calculation.

Regime- 1 (adopters): $Y_{1i} = \beta_1 X_{1i} + \varepsilon_{1i}$-----if A_i= 1…….....…………...………..…. (3)

Regime- 2 (non-adopters): $Y_{2i} = \beta_2 X_{2i} + \varepsilon_{2i}$---- if A_i = 0……..........................…….. (4)

Where β is a vector of parameters, X1i and X2i are vectors of explanatory variables that influence estimated outcome variables, and Y1i and Y2i are outcome variables for adopters and non-adopters, respectively. The error term in the equations is represented by εi.

To address selection bias in the case of a two-stage estimate procedure, the Inverse Mills Ratio (IMR) of adopters in community teff seed production was calculated as follows:

$$\lambda_{1i} = \frac{\phi\,(Z_i\alpha)}{\Phi\,(Z_i\alpha)} \text{ and } \lambda_{2i} = \frac{\phi\,(Z_i\alpha)}{1-\Phi\,(Z_i\alpha)} \text{------------------------ (5)}$$

Selection bias was demonstrated by non-zero correlation between the outcome equation and the selection error terms. Given the lack of selection bias, the null hypothesis may be disproved. The parameters to be estimated are β and σ, while η denoted an independently distributed error factor with constant variance and zero mean.

The actual and counterfactual household outcomes (farm income and productivity) are defined as follows, adhering to the two regimes of the outcome equations above:

$E\,[y_1/X, A_i = 1] = X_{1i}\,\beta_1 + \delta_{1\varepsilon}\lambda_{1i}$ (adopters)------- (6a)

$E\,[y_2/X, A_i = 0] = X_{2i}\,\beta_2 + \delta_{2\varepsilon}\lambda_{2i}$ (non-adopters) ------ (6b)

$E\,[y_2/X, A_i = 1] = X_{1i}\,\beta_2 + \delta_{2\varepsilon}\lambda_{1i}$ (adopters, they had been non-adopters) ------------ (6c)

$E\,[y_1/X, A_i = 0] = X_{2i}\,\beta_1 + \delta_{1\varepsilon}\lambda_{2i}$ (Non-adopters, they had been adopters) ------------ (6d)

The real expectations of the observed results were displayed in equations (6a) and (6b) above, whereas the counterfactual outcomes were displayed in equations (6c) and (6d). The difference between equations (6a) and (6c) was used to compute the average treatment effect on the treated (ATT), which represented the impact of community teff seed production.

$ATT = (a) – (c) = E\,[y_1/X, A_i = 1] - E\,[y_2/X, A_i = 1]$
$= X_{1i}\,(\beta_1 - \beta_2) + \lambda_{1i}\,(\delta_{1\varepsilon} - \delta_{2\varepsilon})$ ------- (7)

Additionally, we determined the average treatment effect on untreated (ATU), which is the difference between (d) and (b), by estimating the predicted farm income and productivity of households who had not engaged in community teff seed production.

$ATT = (d) – (b) = E\,[y_1/X, A_i = 0] - E\,[y_2/X, A_i = 0]$
$= X_{2i}\,(\beta_1 - \beta_2) + \lambda_{2i}\,(\delta_{1\varepsilon} - \delta_{2\varepsilon})$ ------------ (8)

Where β1 and β2 are the regression's estimated parameters, and X1 and X2 are sets of explanatory factors that influence outcome variables in regimes 1 and 2, respectively. The issue of unobserved variables is compensated for by the selection term (λ).

Table 2. Conditional expectations, Treatment, and Heterogeneity effects

Outcome variables	**Subsamples**	**Decisions stages**		
		Adopters (ATT)	Non-adopters (ATU)	Treatment Effect (ATE)
Households Farm income	Adopters	(a) $E\,[y_1/X, A_i = 1]$	(b) $E\,[y_2/X, A_i = 1]$	ATT
	Non-adopters	(c) $E\,[y_1/X, A_i = 0]$	(b) $E\,[y_2/X, A_i = 0]$	ATU
	Heterogeneous effects	BH1	BH2	TH
Productivity of teff	Adopters	(a) $E\,[y_1/X, A_i = 1]$	(b) $E\,[y_2/X, A_i =1]$	ATT
	Non-adopters	(c) $E\,[y_1/X, A_i = 0]$	(b) $E\,[y_2/X, A_i = 0]$	ATU
	Heterogeneous effects	BH1	BH2	TH

Note: (a) and (d) are observed outcomes; (b) and (c) are the hypothetical unobserved outcomes. Ai =1 if households participated; Ai = 2 if households did not participate.

The difference between Equations (6a) and (6d) for households that choose to participate in or did not choose to participate in communal teff seed production was used to compute the effect of base heterogeneity (BH1). The difference between Equations (6c) and (6b) was used to compute the base heterogeneity (BH2) (Carter and Milon, 2005). Lastly, the outcome variables, or transitional heterogeneity (TH) = (ATT-ATU), were either higher or lower than their counterfactual.

4. Results and Discussion

4.1. Relationship between groups of community teff seed production technology and continuous and categorical independent variables

4.1.1. Demographic characteristics of the respondents

Sex of the household's head (Sex): Based on the study, 81.72% of households were headed by a man, while the remaining 18.28% were headed by a woman, (Table 4). This suggested that males predominate in the community teff seed production.

Therefore, increasing female participation is crucial for community teff seed production. The sex of the adopter and non-adopter groups of community teff seed production technology did not statistically significantly correlate.

Age of the household's head (Age): The head of the household is between 24 and 68 years old. According to Table 3, the respondents' average age was 44.43 years, with an 8.92 standard deviation. Adopters are older on average (45.99) than non-adopters (42.64). This inference has demonstrated that adopter and non-adopter groups of community teff seed production technologies are present in the age ranges that are productive. At the 1% level of significance, there was a statistically significant mean difference between adopters and non-adopters. According to this finding, older farmers have greater agricultural experience than younger farmers when it comes to community teff seed production.

Education levels of the household's head (Education): Table 3 displays the average household head's educational attainment, which was 1.38 with a standard deviation of 1.33. At the 1% level of significance, the adopter groups' mean educational levels differed significantly.

Household family size (Famsize): The average responder family size was 5. Table 3 shows that the average family size for adopters was 5.48, whereas the average for non-adopters was 4.45. Households ranged in size from 2 to 9. At the 1% significance level, the statistical test revealed a significant mean difference between the two groups. This demonstrated that adopters had more family labor than non-adopters; community teff seed production uses more work than teff grain production, which is significant when it comes to the adoption of new technologies.

Experiences of community teff seed production (Exptefseedprod): The respondents have a wide range of teff production experience, with an average of 19.85 years and a range of 3 to 42 years. According to Table 3, community teff seed producers had an average of 20.27 years of experience, with a minimum of 5 and a maximum of 40 years.

4.1.2. Socio-economic characteristics

Farm size (Farmsize): The respondents' average farm size was 1.11 hectares. Adopters and non-adopters, on average, have 1.23 and 0.97 hectares, respectively. Given that farm size is crucial for teff seed production participation, this suggested that respondents engaged in community teff seed production had bigger farms than the non-adopters. At the 1% level of significance, the statistical test result indicated a significant mean difference in farm size between adopters and non-adopters.

Number of farm plots (Nfarmplot): Households had an average of 3.54 farm plots, with a range of 2 to 6. This inference demonstrated that respondents in both groups (adopters and non-adopters) had fragmented land. At the 1% significance level, the statistical test of the mean difference in the number of farm plots between the adopters and non-adopters' group was significant.

Tropical Livestock Unit (TLU): For analytical purposes, livestock were standardized into Tropical Livestock Units (TLU). Table 3 indicates that the Tropical Livestock Unit (TLU) score ranged from a minimum of 1.23 to a maximum of 6.99 units, with an average of 3.58. The majority of respondents owned animals as a source of income and food. At the 1% significance level, the Tropical Livestock Unit (TLU) statistical test result revealed a significant mean difference between adopters and non-adopters.

Distance of farm plot to main road (DisNfp_Mroad): The average walking time from the main road to the farming plot was 26.48 minutes, according to the results shown in Table 3. The adopter's average walking time was 19.97 minutes, whereas the counterparts were 33.88 minutes. This finding demonstrated a negative correlation between community teff seed production and distance. At the 1% significance level, there was a significant mean difference between adopters and non-adopters in the distance of the farm plot from the main road.

Table 3: An overview of the sampled households'-test findings (continuous variables)

Variables	Status	Freq.	Min	Max	Mean	St. Dev.	t-value
Age	Non-adopter	174	24	68	42.64	9.39	
	Adopter	198	27	68	45.99	8.18	-3.6771***
	Total	372	24	68	44.43	8.92	
Education level	Non-adopter	174	0	5	0.89	0.73	
	Adopter	198	0	8	1.82	1.56	7.2709***
	Total	372	0	8	1.38	1.33	
Family size	Non-adopter	174	2	8	4.45	1.23	
	Adopter	198	2	9	5.48	1.34	7.6847 ***
	Total	372	2	9	5.00	1.39	
Experiences	Non-adopter	174	3	42	19.38	8.58	
	Adopter	198	5	40	20.27	6.70	1.1191^{NS}
	Total	372	3	42	19.85	7.64	
Farm size	Non-adopter	174	0.5	2.5	0.97	0.26	
	Adopter	198	0.625	2.75	1.23	0.35	8.1660***
	Total	372	0.5	2.75	1.11	0.33	
Number of farm plot	Non-adopter	174	2	6	3.09	1.04	
	Adopter	198	2	6	3.93	0.94	8.2702***
	Total	372	2	6	3.54	1.07	
Asset ownership	Non-adopter	174	23,450	85,500	52,843.56	10,248.6	
	Adopter	198	27,930	87,800	54,518.06	11,335.3	1.4865*
	Total	372	23,450	87,800	53,734.83	10,858.4	
Tropical Livestock Unit (TLU)	Non-adopter	174	1.23	6.26	3.11	1.00	
	Adopter	198	1.26	6.99	3.99	1.27	7.4081***
	Total	372	1.23	6.99	3.58	1.23	
Distance of farm plot to the road	Non-adopter	174	15	60	33.88	9.29	
	Adopter	198	5	40	19.97	8.35	-15.1983***
	Total	372	5	60	26.48	11.21	

Where ***, ** and * indicated at 1%, 5% and 10% significance level, respectively

4.1.2. Institutional characteristics

Frequency of extension contact (Frq_Extcont): According to Table 4, on average, 17.74% of extension contacts occur once a week, 33.33% occur once every two weeks, 32.72% occur once every four weeks, 10.22% occur quarterly, and the remaining 5.91% occur annually (Table 4). According to the statistical test, there was a 1% significance level correlation between the adopter and non-adopter groups and extension contact. This consequence demonstrated that in order to receive technical assistance and market information, community teff seed production required regular communication and advise from the extension agent.

Access to market information (TMkt_Inform): The survey's findings indicate that 52.69% of households were informed about the market for community teff seeds grown, while the remaining dwellings were not. Cooperative unions provided 54.57% of the market information, followed by agricultural offices (18.82%), neighbours (23.66%), and primary cooperatives (2.99%). The results showed that 24.8% and 56.6% of respondents, respectively, owned a radio and a mobile phone. Having a radio and a mobile phone has made it easier for farmers to get market information.

Participation in Training (Traing_Seed): According to the results, 45.7% of households lacked training, whereas 54.3% of households received training in communal teff seed production and related technologies. The agricultural office provided 64.3%

of the training, followed by the agricultural research center (20.2%) and non-governmental organizations (6.5%). At the 1% significance level, the chi-square test result indicated a relationship between adopters and non-adopters.

Use of credit (Use_Credit): The results of the study show that during the 2021/22 agricultural season, 76.08% of the respondents utilized an average of 18,814 Ethiopian Birr (ETB), with 1 USD being equal to 124 ETB. This consequence demonstrated that having the money is crucial for buying supplies and inputs like better seeds, fertilizer, chemicals, and hired labor. Amhara Credit and Saving Institution (ACSI) accounted for roughly 96.8% of the credit received, with own saving and credit cooperatives accounting for 3.2%. Because community teff seed production required more funding for labor and inputs than grain production, adopters used more credit (81.82%) than their competitors (69.54%). At the 1% significance level, there was a correlation between adopters and non-adopters in terms of credit usage.

Members of seed collector cooperatives (Mem_SCcoop): According to Tsegaye et al. (2017), cooperatives are founded and run based on the members' shared interests. Multipurpose cooperatives gathered community-produced teff seed in the Enemay area, while seed producer cooperatives collected seed in Yilmana Densa. Consequently, 81.72% of households on average belong to cooperatives for seed collection. At the 1% level of significance, the test result indicated a relationship between the adopter and non-adopter groups.

Contract seed production (Contefseedprod): Farmers were provided assurances that they would produce and transport their goods in accordance with their contractual obligations. Over 88% of the teff seed produced was contracted by various organizations, as seen in Table 4. This demonstrated how crucial the system is to the development of sustainable communal teff seeds. Amhara Seed Enterprise (ASE) made 46.5% of the agreement, Ethiopian Seed Enterprise (ESE) made 11.5%, and the seed producer union made 42%. Teff, hybrid maize, chickpea, faba bean, and potato were among the seeds produced under contract in Yilmana Densa area, while teff, chickpea, and lentil were produced in Enemay. At the 1% significance level, the chi-square test revealed a link between the two groups of adopters and non-adopters.

Time of teff seed supply (Time_Seedsp): One of the most crucial aspects of crop productivity is the timing of seed distribution. According to the survey results, teff seed distribution was more punctual than teff grain production. According to Table 4, almost 53% of farmers who grow teff grains expressed dissatisfaction with the late and extremely late delivery methods of teff seeds, whereas 61.56% of community teff seed producers received their seed on time. At the 1% significance level, the chi-square test result indicated a relationship between the adopter and non-adopter groups.

Cluster farming of teff production (Tefp_Clustng): Table 4 shows that 30.46% of farmers who produced teff grain were placed in a cluster. In the meantime, 87.88% of the community producers of teff seeds introduced the cluster to other farmers. At the 1% significance level, the chi-square test result indicated a relationship between the adopter and non-adopter groups.

Table 4: An overview of the respondents' chi-square test findings (dummy/categorical variables)

Variables	**Categories**	**Percentage proportion of adoption status** Non-adopter (174)		Adopter (198)		Total (372)		**Pearson chi^2**
		N	%	N	%	N	%	
Sex	Female	37	21.26	31	15.66	68	18.28	1.9497^{NS}
	Male	137	78.74	167	84.34	304	81.72	
Extension contact	Never	4	2.30	0	0	4	1.08	117.3055***
	Once a week	5	2.87	61	30.81	66	17.74	
	once in two weeks	39	22.41	85	42.93	124	33.33	

	once in four weeks	70	40.23	48	24.24	118	32.72	
	Quarterly	34	19.54	4	2.02	38	10.22	
	Yearly	22	12.64	0	0	22	5.91	
Time of teff seed supply	Early	0	0	28	14.14	28	7.53	92.6080***
	On time	81	46.55	148	74.75	229	61.56	
	Late	79	45.40	22	11.11	101	27.15	
	Very late	14	8.05	0	0	14	3.75	
Market information	No	136	78.16	40	20.20	176	47.31	124.8041***
	Yes	38	21.84	158	79.80	196	52.69	
Participation in Training	No	123	70.69	47	23.74	170	45.7	82.2755***
	Yes	51	29.31	151	76.26	202	54.3	
Use of credit	No	53	30.46	36	18.18	89	23.92	7.6707***
	Yes	121	69.54	162	81.82	283	76.08	
Member of multipurpose coop	No	16	9.2	11	5.56	27	7.26	1.8228^{NS}
	Yes	158	90.8	187	94.44	345	92.74	
Members of seed collector coop.	No	51	29.31	17	8.59	68	18.28	26.6282***
	Yes	123	70.69	181	91.41	304	81.72	
Cluster farming	No	120	68.97	24	12.12	144	38.71	128.4842***
	Yes	53	30.46	174	87.88	227	61.02	
Contract seed production	No	130	74.71	23	11.62	153	41.13	152.2762***
	Yes	44	25.29	175	88.38	219	58.87	

Where ***, ** and * indicated significant at 1%, 5% and 10% significance level, respectively;

4.3. Community teff seed production's impact on household's farm productivity and income

Seven of the fourteen explanatory variables i.e., age, family size, frequency of extension contact, teff seed contract farming, use of credit, clustering of teff production, and seed delivery time were significant to the farmers' participation in households farm income, according to the results of the first stage of the ESR model for households farm income selection equation (column 2), (Table 5). Both adopters and non-adopters' farm income was impacted by the determinants, according to the results of the second stage estimation of the ESR model for the outcome equation (columns 3 and 4). Education level, family size, access to market information, farm size, Tropical Livestock Unit (TLU), and credit utilization were the factors that determined adopters' household farm income; on the other hand, non-adopter farmers' farm income was greatly impacted by education level, farm size, Tropical Livestock Unit (TLU), training participation, and frequency of extension contact.

Seven of the fourteen explanatory variables i.e., age, seed contract farming, use of credit, frequency of extension contact, clustering of teff production, access to market information, and seed delivery time significantly influenced farmers' participation in teff productivity, according to the results of the first stage of the ESR model for the selection equation of teff productivity (column 5), Table 5. Age, education level, family size, Tropical Livestock Unit (TLU), training participation, credit utilization, number of farm plots, and seed delivery time were the factors that impacted teff productivity for adopters' farmers, according to the results of the second stage estimation for the outcome equation (columns 6 and 7). In contrast, the productivity of the non-adopter farmers was significantly impacted by age, education level, Tropical Livestock Unit (TLU), clustering of teff production, and frequency of extension contact.

Table 5: Complete details for switching regression model maximum likelihood estimates

Variables	Participation	Households' farm income	Teff productivity

		Adopters	Non-adopters	Participation	Adopters	Non-adopters
Age	0.0319*	16.4218	112.0627	0.0278*	0.0640***	0.0607**
	(0.0173)	(107.8844)	(90.7279)	(0.0167)	(0.0203)	(0.0248)
Education	0.2263	2557.253***	2676.226**	0.1975	0.3049***	0.9224***
	(0.1395)	(566.9999)	(1131.259)	(0.1359)	(0.1074)	(0.3107)
Famsize	0.2049*	2435***	513.7625	0.1325	0.3509***	0.1041
	(0.1229)	(693.5323)	(710.264)	(0.1195)	(0.1312)	(0.1962)
Nfarmplot	0.1214	-876.2971	-860.9883	0.1431	-0.3431**	0.0195
	(0.1333)	(912.804)	(862.7995)	(0.1316)	(0.1709)	(0.2368)
Farmsize	0.2207	16465.99***	11360.8***	0.5049	0.8377	0.9222
	(0.5186)	(2819.392)	(3318.541)	(0.5318)	(0.5317)	(0.9120)
Tropical	0.1005	1608.062**	1883.611**	0.1714	0.4109***	0.7502***
Livestock Unit (TLU)	(0.1196)	(677.1551)	(820.9741)	(0.1199)	(0.1275)	(0.2268)
Frq_Extcont	0.3458***	101.4658	1454.403**	0.4212***	0.2492	0.3755**
	(0.1282)	(1167.681)	(647.5655)	(0.1412)	(0.2192)	(0.1778)
SContrtfarmn	0.5988**	1956.215	295.357	0.8075***	0.2190	0.2687
	(0.2794)	(2738.255)	(2149.639)	(0.2753)	(0.5093)	(0.5995)
Traing_Seed	0.2209	1087.209	5330.69***	0.2550	0.9449**	0.3832
	(0.2831)	(2304.796)	(1837.62)	(0.2924)	(0.4318)	(0.5060)
Tefp_Clusern	0.9837***	386.7454	2584.801	0.9594***	0.5605	0.9239*
	(0.2905)	(2594.837)	(1963.188)	(0.2923)	(0.5005)	(0.5359)
Use_Credit	0.7127**	5368.458**	1510.888	0.9531***	0.8367**	0.4172
	(0.2927)	(2134.673)	(1807.448)	(0.3054)	(0.4025)	(0.4906)
SMkt_Inform	0.3748	5742.466***	501.1135	0.6716**	0.1559	0.4992
	(0.2551)	(2202.782)	(2160.241)	(0.2757)	(0.4108)	(0.6003)
Mem_SCcoop	0.0092	3610.12	2485.617	0.2536	0.3500	0.6132
	(0.4069)	(2960.331)	(1939.326)	(0.4212)	(0.5559)	(0.5307)
Time_Seedsp	-0.8522***	-72.7517	1520.988	-0.9919***	-0.6581**	0.3209
	(0.2511)	(1750.345)	(1267.089)	(0.2673)	(0.3289)	(0.3480)
DiNfp_Mroad	-0.0688***			-0.0741***		
	(0.0149)			(0.0151)		
Souc_MInfor	0.2759***			0.2423***		
	(0.0528)			(0.0574)		
Cons.	-3.7474***	10022.84	25814.9***	-4.1775***	14.575***	12.517***
	(1.4545)	(10844.82)	(6374.475)	(1.6049)	(2.0499)	(1.7544)
/ r1	0.4839**			0.6991**		
	(0.2367)			(0.2997)		
/ r2	0.5837**			0.3455		
	(0.2927)			(0.2836)		
Sigma(σ)		11,264.15	9,823.291		2.1357	2.6739
		(584.9334)	(558.6699)		(0.1159)	(0.1471)
Rho (δ)		0.4494	0.5253		0.6038	0.3324
		(0.1889)	(0.2119)		(0.1904)	(0.2523)
Log likelihood	-4033.1888				-907.41489	
Wald chi2 (15)	202.20				114.11	
Prob > chi^2	0.0000				0.0000	
Observation	372				372	

LR test of independent equations. χ 2 (1) = 7.07*** 7.36***

Note ***, ** and * indicated 1%, 5% and 10% significance levels, respectively

Indicating that the explanatory variables in the models together explained the fluctuation of community teff seed output on households' farm income and productivity, the Wald chi-square values (202.2 and 114.11) were statistically significant at the 1% level. Additionally, households' farm income and teff productivity demonstrate statistical significance at the 1% level according to the likelihood ratio (LR) tests of the independent equations (7.07*** and 7.36***). This test demonstrated that the outcome equations and the selection equations jointly estimate the model parameters. Thus, it is appropriate and warranted to employ the full information maximum likelihood (FIML) in this investigation (Donkor et al., 2019).

The correlation coefficient between the outcome equations and the selection equation's error term was displayed by Rho1 and Rho2 estimation (Poetschki et al., 2021). Both correlation coefficient results are positive, suggesting that farmers who produce teff seeds in the community earn more money and produce more teff than farmers who are chosen at random. Furthermore, $\rho 1$ and $\rho 2$ share the same positive sign, suggesting that adopters are better suited for adoption than non-adopters due to their higher farm income and teff productivity (Adjin et al., 2020).

The ESR model revealed base heterogeneity, average treatment effects relative to the treated (ATT), and counterfactual outcomes (Table 6). Since adopters might have had higher farm income and teff productivity than non-adopters despite not adopting in the community teff seed production for unobserved reasons, the heterogeneity effects (HE) on households' farm income and productivity were computed (Kumar et al., 2018; Li et al., 2020). As a result, the impacts of heterogeneity between adopters and non-adopters were investigated. Lastly, the transition heterogeneity (TH) difference between the groups' HE1 and HE2 was used to compute the results (Adjin et al., 2020).

Table 6: Average Treatment Effects (ATE) of community teff seed production on household's farm income and productivity

Outcome variables	Categories	Decisions stage		Treatment Effect (ATE)	% of changes
		Seed producers	Non- producers		
Households farm income	ATT	(a11) 68,420.5	(c10) 55,995.19	12,425.31***	22.19
	ATU	(d01) 64,930.13	(b00) 53,575.62	11,354.51***	21.19
	HE	EH1 3,490.37	EH2 2,419.57	1,070.8	
Productivity of teff	ATT	(a11) 23.80	(c10) 21.23	2.57***	12.11
	ATU	(d01) 23.24	(b00) 20.83	2.41***	11.56
	HE	EH1 0.56	EH2 0.40	0.16	

Note *** indicated significant at 1% significance level

The observed difference (a-b) in household farm income and teff productivity between adopters and non-adopters was 14,844.88 ETB and 3.03 quintal ha-1, respectively (Table 6). This indicates that households' farm income is raised by 27.71% and teff productivity is raised by 14.55% when adopters participate in communal teff seed production. However, this result did not take into consideration elements that were not detected during the investigation. As a result, a counterfactual condition was computed for both the treated and control groups. In comparison to their counterfactuals, the average treatment effects (ATT) score of adopters raised household farm income by 12,425.31 ETB and teff production by 2.57 quintal ha-1.

According to the findings, households' farm income and teff productivity improved by 22.19% and 12.11%, respectively, when they adopted communal teff seed production. In a similar vein, non-adopters (control groups) would have seen increases in average household farm income and teff productivity of 21.19% and 11.56%, respectively, if they had taken part in communal teff seed production. The results aligned with those of Natnael (2019), who discovered that adopting improved teff varieties increased household income by 23.9%. Adjin et al.

(2020) found that cooperatives increased household income by 14.1% and productivity by 20%, while Bahta et al. (2018) found that land ownership increased net returns by 22.07% and productivity by 43.37% of maize production.

Both household farm income and production have a positive and significant transitional heterogeneity effect, indicating that adopters had a greater impact on community teff seed producers than non-adopters (Di-Falco et al., 2011). This result was in line with the findings of Kumar et al. (2018), Adjin et al. (2020), and Mossie et al. (2022), who discovered the impacts of agricultural cooperatives in Senegal. For seed producer farmers in the research areas, community teff seed production therefore significantly impacts household farm income and productivity.

5. Conclusion and Recommendations

Overall, the results demonstrated that community teff seed production improved household welfare and provided teff growers with seeds. The study concludes that the impact of community teff seed production technologies adoption on households' farm income and productivity is more effective when the personal, socioeconomic, and institutional characteristics of farmers are taken into consideration, as well as when policies and legal frameworks are in place to regulate community teff seed production and distribution. The model's findings showed that, in comparison to their counterfactuals, adopters had an average yearly household farm income of roughly ETB 12,425.31 and teff productivity of 2.57 quintal ha-1. Community teff seed production generally improves household livelihoods and increases food security. Therefore, it is possible to conclude that Community teff seed production technology adoption has a significant relationship with household income and productivity.

Based on the finding results of the study and discussion with FGD and KII participants, the following recommendations were suggested. The agricultural extension system and seed producer organizations should begin by concentrating on and giving priority to households with access to credit, higher levels of education, larger families, cosmopolite or informative households, larger farms, and higher Tropical Livestock Unit (TLU) in order to maximize the impact of community teff seed production technology adoption on household income. Similar to this, it was suggested that the agricultural extension system and seed producer organizations should begin by concentrating on and giving priority to households with accessible and timely (by simplifying the structure and pointless procedures of seed supply and distribution networks), access to training who generate their own seeds, access to closed follow-up of supporting systems, higher household head age, higher education level, larger family size, more cosmopolites, larger farm size, and higher Tropical Livestock Unit (TLU) in order to maximize the impact of community teff seed production technology adoption on productivity to increase the productivity impact of adopting community seed production technology".

Data availability statement

Upon a reasonable request, the corresponding author will provide the data supporting the study's findings.

Conflicts of interest

The authors declared that there is no conflict of interest among them.

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