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### Determinants in utilizing improved agricultural technologies for enhancing sorghum production in Tigray region, Northern Ethiopia

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#### Abstract

This paper examines the factors affecting in adoption of improved agricultural technologies in sorghum production in Tigray region, Ethiopia. A total of 284 farm households drawn from three districts of the region were included in the study. Both qualitative and quantitative data were collected using semi-structural questionnaires in 2019. A multivariate probit model and descriptive statistics were used to analyze the collected data. This study analyzes the factors that affect the adoption of improved agricultural technologies in sorghum production including, seeds of improved variety, inorganic fertilizer application, row planting, insecticide and pesticide chemicals and moisture conservation. The result indicates the probability to adopt the improved agricultural technologies in sorghum production were significantly influenced by factors such as; family size education status, participating in off-farm income, farm size, extension service, and distance to farmers training center. Though the smallholder farmers had better adoption indices, the technology wouldn't disseminate in large number of beneficiaries and areas. As a result, the adoption is foreseen to be low. Therefore, to improve the adoption of improved agricultural technologies in sorghum production giving more emphasize would be important to be offered the extension services like training, field days, experience sharing, technical support, and information on markets and pests & diseases control to the farmers.

**Keywords:** adoption, improved agricultural technologies, multivariate probit (MVP) model, sorghum production

#### Introduction

Increasing agricultural productivity through adoption and diffusion of modern agricultural technologies is one of the key pathways for economic growth and transformation in developing countries (Gollin, 2010) [25]. Adoption at the individual farmers' level is defined as the degree of use of new technology in long run equilibrium when the farmer has full information about the new technology and its potential in the context of aggregate adoption behavior within area (Feder *et al.* 1985) [21]. The adoption process is the change that takes place within individuals with regard to an innovation from the moment that they first become aware of the innovation to the final decision to either use it or not. The farmers require knowledge on the skills, techniques and the ability to use resources in the most efficient and effective ways, minimizing waste and loses so as to achieve the best.

Agricultural new technologies constitute the introduction and use of hybrid breeds, the greenhouse technology, genetically modified food, chemical fertilizers, insecticides and the application of other scientific knowledge (Matunhu, 2011) [33]. Adoption of improved technology has been identified as a key measure towards achieving food security

(Langyintuo *et al.*, 2008) [31]. Besides despite of the evidence the improvement of agricultural productivity among farmers is achieved through using of improved agricultural technologies (Moshi, 1997) [34].

Adoption of technological improvements is crucial to increasing agricultural productivity and reducing poverty, while sustaining the agro-ecosystems that support livelihoods (Kassie *et al.*, 2011; Asfaw *et al.*, 2012) [28] [6b].

Though introduction of the improved agricultural technologies has been practiced in many parts of Ethiopia for the last three decades, it is embarrassed with many challenges. The factors that influence the adoption of modern agricultural production technologies are broadly categorized into economic factors, social factors and institutional factors. The economic factors include farm size, cost of technology or modernization, expected benefits from the adoption of the technology, and off-farm activities. The social factors that influence probability of adoption of modern agricultural production technologies by farm households include age, level of education and gender. Institutional factors include access to information and extension services.

Sorghum (*Sorghum bicolor* (L.) Moench) is one of the most important cereal crops grown in arid and semi-arid parts of the world. It is the 5<sup>th</sup> most important cereal crop in the world (FAOSTAT, 2013) <sup>[19]</sup>, and the 2<sup>nd</sup> major crop (after maize) across all agro ecologies in Africa. FAO reported the United States of America was the top sorghum producer with a harvest of 9.7 million tonnes followed by India, Nigeria, Sudan, and Ethiopia (FAOSTAT, 2014) <sup>[20]</sup>.

Most East African sorghum is grown between the altitudes of 900m to 1500m. In Ethiopia, it is grown all over the country across various agro ecologies (that cover nearly 66%); from high altitude with sufficient amount of rainfall to low lands receiving low rainfall (Taye, 2013; Geremew *et al.*, 2004) <sup>[43]</sup> <sup>[24]</sup>. It is a staple food for more than 500 million people in the semi-arid tropics of Africa and Asia, and more than 80% of the world area of production is confined to these two continents (Masresha *et al.*, 2011) <sup>[32]</sup>. Ethiopia is the largest sorghum producing country in Eastern and Southern Africa next to Sudan. Ethiopian is often regarded as the center of domestication of sorghum because of the greatest genetic diversity in the country for both cultivated and wild forms (Masresha *et al.*, 2011) <sup>[32]</sup>. In Ethiopia sorghum ranked after tef, maize, and wheat, both in area coverage and production (CSA, 2017) <sup>[12]</sup>. Grain sorghum is a major cereal crop with multi-purposes in lower and mid altitude regions of Ethiopia. Sorghum is cultivated by nearly 5.4 million smallholders located in the eastern and northwest parts of the country shows Oromiya, Amhara and Tigray regions are the three major producers of sorghum (CSA, 2018) <sup>[14]</sup>. It is a staple food crop in the rural areas where it grows. Grain sorghum in Ethiopia is used primarily to prepare local foods such as '*Injera*', bread, thick porridge, 'kollo', boiled grains and ale (Rooney and Murty, 1982). Though sorghum is primarily a crop of resource poor small-scale farmers in Ethiopia, particularly in Tigray region, still the productivity of sorghum is very low.

The major problems for this low productivity might be attributed to a decline in the soil fertility, poor moisture conservation, diseases and insects, drought and low using of improved sorghum varieties. However, the factors that hinder or facilitate the adoption of improved agricultural technologies for sorghum production have not been well known and documented in Tigray region. Therefore this study focuses on assessing agricultural technology adoption for sorghum production specifically on improved seed varieties, row planting, chemical fertilizer, moisture conservation and chemical use.

## Objectives

- To describe the adoption status of sorghum technologies and its constraints
- To identify the factors affecting adoption of sorghum technologies

## Research Methodology

### Description of the study area

The study was conducted in southern, western and northwestern zones of Tigray regional state. The agro-ecological classification of the zones is lowland. Raya Azebo district is located at southern Tigray. It is found in the altitude of 1574 m.a.s.l. The district has a temperature (min/max) of 18°C and 25°C; and an annual rainfall of 300-750mm. Similar to this, Tahtay Adyabo is located at northwestern zone of Tigray, with the location of 14.05-14.89 °C Northing and 37.34-38.17 °C Easting. The district has 38-40 °C of temperature and 450mm-550mm annual rainfall. Agro ecologically 94.13% of the district is lowland and the remaining 5.87% is midland. While Kafta-Humera wereda is located in the western zone of Tigray Region and geographically it is located at 13.4 and 14.27 °C Northing and 36.27-37.32 °C Easting. In all of the districts a mixed farming production system is practiced, that comprises crop production and livestock rearing.

### Sampling and method of data collection

Multistage stage sampling technique was used. First three districts namely Kafta Humera, Tahtay Adyabo and Raya Azebo were selected, purposively for the study, based on their potential for sorghum growing. Then, a total of 9 Kebeles, three per each district, were randomly selected from the sorghum growing Kebeles. The survey was conducted during 2019 by selecting a total of 284 sample households which is 100 farmers from Kafta Humera, 98 farmers from Tahtay Adyabo and 86 farmers from Raya Azebo district. The farmers were selected from sorghum growing Kebeles using probability proportionate to the sample size (PPS). Finally, farmers from each Kebeles selected using systematic random sampling from the prepared farmers list. The survey was conducted using enumerators. Semi-structured questionnaire was used to collect primary data from 284 sorghum producer farmers and secondary data was collected from published and unpublished sources.

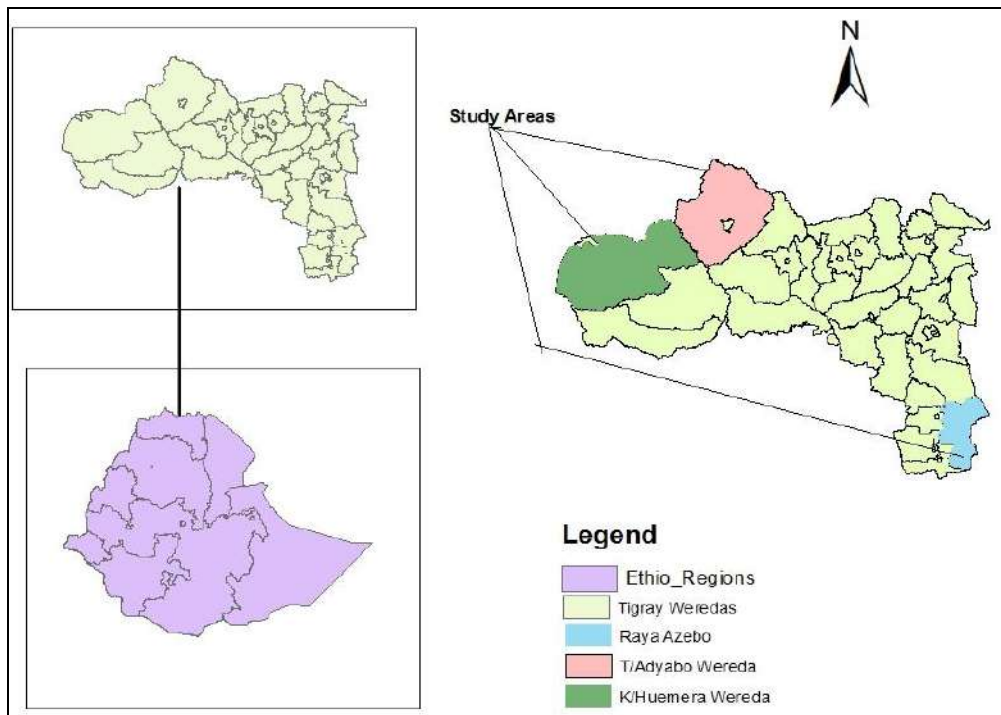


Fig 1: Map of the study area

**Data analysis method**

To analyze the collected data the study was used both descriptive statistics and econometric models. The descriptive statistics includes mean, frequency and percentage in describing the target households and identifying the main constraints in adoption of major agricultural technologies. In addition, Multivariate probit econometrics model were used in analyzing determinants of adoption of improved agricultural technologies in sorghum production.

**Multivariate probit**

Analysis of smallholder farmers technology adoption decision behavior, needs the use of a multivariate (instead of univariate) modeling framework to take into account the multiple improved agricultural practices, and the possibility using decision making process. The Multivariate probit approach simultaneously models the influence of the set of explanatory variables on each of the different practices, while allowing for the potential correlation between unobserved disturbances, as well as the relationship between the adoptions of different improved production practices. One source of correlation may be complementarity (positive correlation) or substitutability (negative correlation) between different practices (Belderbos *et al.*, 2004) [8]. Failure to capture unobserved factors and interrelationships among adoption decisions regarding different practices will lead to bias and inefficient estimates (Greene, 2008) [26]. Therefore, a multivariate probit model (MVP) regression was used to assessing the factors determining in adoption of improved agricultural technologies for sorghum production. As reported by Kassie *et al.* (2013) [29] and Mulwa *et al.* (2017) [35], a multi variate probit model with the five sets of binary dependent variables (i.e. using improved variety, inorganic fertilizer use, row planting, moisture conservation and use of chemicals), was formulated as indicated by

Equation 1:

$$Y_{ik} = \beta_k X_{ik} + \alpha_k A_{ik} + \epsilon_k \tag{1}$$

(k = improved variety (I), inorganic fertilizer (F), row planting (R), moisture conservation (M) and using chemicals (C). The following equation indicates the specification of the binary dependent variable.

$$Y_{ik} = 1 \text{ if } Y^*_{ik} > 0 \text{ and otherwise} \tag{2}$$

Where  $Y_{ik}$  is a latent variable which captures the observed and unobserved preferences associated with the  $k_{th}$  improved agricultural technology, and  $Y_{ik}$  represents the binary dependent variables.  $X_{ik}$  represents the observed household and farm specific characteristics, as well as institutional variables.  $A_{ik}$  represents plot characteristics to account unobserved heterogeneity.  $\beta_k$  and  $\alpha_k$  are parameters to be estimated.  $\epsilon_k$  represents the multivariate normally distributed stochastic error term (Wooldridge, 2003) [45]. In our multivariate probit framework, the error terms jointly follow a multivariate normal distribution with zero conditional mean.

The multivariate probit econometric model is dependent on latent variables  $Y^*_{ij}$  which is linearly related to a set of observed characteristics and an error term such that:

$$Y^*_{i,j} = X_{i,j} \beta_j + \mu_{i,j} \quad j = 1, 2, \dots \tag{3}$$

$$Y_{i,j} = \begin{cases} 1 & \text{if } Y^*_{i,j} > 0 \\ 0 & \text{if } Y^*_{i,j} \leq 0 \end{cases} \tag{4}$$

Where  $Y_{ij}^*$  is the latent variable measuring the propensity of adopting improved technologies;  $Y_{ij}^*$  is the observed binary outcomes;  $\beta_j$  are unknown parameters to be estimated and  $\mu_{ij}$  are the error terms which are independently and identically distributed with a standard normal distribution. The variance is normalized to unity, where  $(\mu_I, \mu_F, \mu_R, \mu_M, \mu_C) \approx MVN(0, \Omega)$  and the symmetric variance covariance matrix  $\Omega$  is specified  $\Omega$  by equation 5 such that:

$$\Omega = \begin{bmatrix} 1 & \rho_{IF} & \rho_{IC} \\ \rho_{FI} & 1 & \rho_{FC} \\ \rho_{CI} & \rho_{CF} & 1 \end{bmatrix} \pm \quad (5)$$

$\rho$  is the pairwise correlation coefficient of the error terms with regards to any two of the estimated adoption equations in the model.

**Terms**

- **Extension service index:** It is the summation of the six extension services divided to six. The extension services include demonstration, experience sharing, technical support, field days, training and receiving information on market, pest and disease control (yes/no).
- **Utilization Index:** It is the summation of the five technology package practices divided to five. The utilization of technologies/practices includes using of improved sorghum varieties, Utilization of fertilizer, row planting, use of pesticide, and moisture conservation for sorghum (yes/no).

**Dependent variables**

The Utilization and adoption of improved sorghum varieties, row planting, chemical fertilizer use, plant protection and moisture conservation for sorghum production could improve the small holders farmers income and food security. Debela (2011) [14] has revealed that, agricultural growth can be achieved through better farm management practices and increased adoption of improved agricultural technologies such as chemical fertilizers, improved seed varieties, pesticides, and organic minerals.

**Improved seed variety use**

Compared with indigenous seed, using improved seed varieties have higher value in rising productivity of the one crop. Using improved seed varieties able to increase production and to improve the household' income when farmers adopt it (Edosa, 2019) [16]. The consumption of improved seeds is very limited in Ethiopia due to limitation of development, multiplication, storage and distribution. The introduction of improved varieties could improve food security and income for a rapidly-growing population by improving productivity. The finding of Chilot and Hassan (2013) [10] indicates that the farmers believe yields of improved varieties increase dramatically when properly fertilized.

**Row planting**

Cultural control tactics such as narrowing of row spacing

and increasing seeding rates can provide some level of weed control. Altering row spacing and seeding rates have been considered as practical weed control methods in the past (Stahlman and Wicks 2000) [41]. It is reported that row planting method gives better output than most commonly practiced traditional method which is broadcasting (Attaullah *et al.*, 2007; and CAADP, 2012) [7] [9]. According to Negese *et al.* (2017) [37] adopters of row planting technology of wheat helped them to increase wheat crop yields, household food consumption expenditure, household agricultural input expenditure and income, and decrease amount seed rate.

**Moisture conservation**

Studies reported that soil moisture deficit for crop production in the semi-arid northern Ethiopia is not mainly associated with the amount of rainfall in the crop season but also influenced by type and time of soil and management practices applied (Gebreyesus *et al.*, 2006) [22]. For the situation of the semi-arid area appropriate moisture harvesting techniques such as tied-ridging is essential for increasing soil moisture for crop establishment and during grain filling (Gebreyesus, 2012) [23]. Moisture conservations like tied-ridging increased sorghum grain yield and soil water by more than 40 and 25%, respectively, as compared to the traditional tillage practice (*shilshalo*) in northern Ethiopia (Gebreyesus *et al.*, 2006) [22]. Studies also showed that lack of greater response to applied N and P fertilizer in Ethiopia was probably due to soil water deficit which is the major yield-limiting factor (Tewodros *et al.*, 2009) [44]. According to Tewodros *et al.* (2009) [44], profitable crop response to applied nutrients depends on soil water availability and moist.

**Chemical fertilizer use**

Fertilizer could increase productivity of the crop while the farmers adopt in the recommended rate and applied on the right time. Consumption of fertilizer is one of the vital inputs in crop production. Without utilization of fertilizer, world food production could be reduced from 40-60% annually (Hoyum, 2012) [27]. No one region in the world has increased crop production and adequately deal with food insecurity without enhancing fertilizer use (African Union, 2006) [2]. Expanding of fertilizer use is very critical not only for meeting of the food demand of the globe but also for sustaining soil fertility and ensure profitability of the farming system. Thus, the major means for increasing productivity is mostly reliant on chemical fertilizers.

**Pesticide /chemical use**

Pesticides are toxic chemicals used to kill pests (insects, weeds) and plant diseases, which have a long-term impact on the environment and human life (Sharma *et al.*, 2012) [40]. The awareness should be disseminated on pesticide misuse and the importance of personal protective equipment. The use of pesticide and herbicides is showing the increasing rate in the world for crop production. Herbicides are being rapidly adopted in developing countries that shortage of hand weeding labor and the need to an increase in crop production. Increased herbicide use promotes efficient fertilizer use, which leads to an increase in production (Rodenburg *et al.*, 2015) [38].

**Explanatory variables**

The inclusion of the explanatory variables in this analysis are mainly based on theoretical frameworks and past

empirical adoption literatures (Aryal and Holden, 2011; Erenstein and Farooq, 2009; Kassie *et al.*, 2013) <sup>[3][18][29]</sup>.

**Table 1:** Definitions of variables included in the multivariate probit model

Variable	Description	Values
<b>Dependent variables</b>		
Improved variety	Used improved sorghum variety	0) No 1) Yes
Row planting	Used row planting in sorghum production	0) No 1) Yes
Fertilizer	Used fertilizer in sorghum production	0) No 1) Yes
Pesticide	Used pesticides	0) No 1) Yes
Moisture	Practicing moisture conservation for sorghum production	0) No 1) Yes
<b>Independent variables</b>		
Age HH	Age of the household head	Continuous
SexHH	Sex of the household head	1) Female 0) Male
EduHH	Education level of the household head	0) Illiterate 1) Literate
Enga Off	Engaged in on/off activities	0) No 1) Yes
Manequivaent	Man equivalence of the family	Continuous
Farm size	Own land holding in ha	Continuous
TLU	Tropical Livestock Unit	Continuous
Farm distance	Average walking distance from residence to the farming plot in minute	Continuous
FTC Distance	Walking distance from farmers residence to FTC	Continuous
Extension service	Extension service in index	Continuous
Credit access	Credit access	0) No 1) Yes

**Results and Discussions****Descriptive statistics**

As depicted in Table 2, the variables of sex of the household, education status of the household, engagement of the household in off farm income and credit access are showing a significant difference in different level of significance among the three districts. This study shows that male dominance in using of improved technologies in

sorghum production which is 87.3% of male farmers. From the total participants 65.8% were literate. This could shows that literate farmers could have better access to information, which is important in adoption of the improved technology. The access of getting credit either from formal or informal sources and engagement of farmers in off-farm income plays a great role for adopting of improved agricultural technologies.

**Table 2:** Demographic characteristics for the dummy variables

S. N	Dummy Variables	K/Humera N (%)	T/Adyabo N (%)	R/Azebo N (%)	Difference N (%)	
1	SexHH	Female	15 (15)	6.1 (6)	17.4 (15)	chi2(1) = 6.05 P = 0.048
		Male	85 (85)	93.9 (92)	82.6 (71)	
2	EduHH	Illiterate	16 (16)	35.7 (35)	53.5 (46)	chi2(1) = 29.05 P= 0.000
		Literate	84 (84)	64.3 (63)	46.5 (40)	
3	Eng Off	No	61(61)	55.1 (54)	72.1 (62)	chi2(1) = 5.74 P = 0.057
		Yes	39 (39)	44.9 (44)	27.9 (24)	
4	Credit access	No	22 (22)	25.5 (25)	37.2 (32)	chi2(1) = 5.72 P = 0.057
		Yes	78 (78)	74.5 (73)	62.8 (54)	

As shown in Table 3, except the variable age, there is a significance difference among the three districts in the variables of family size, livestock holding, farm size, farm distance, extension service index and FTC distances in different level of significances.

The result of one way ANOVA test statistics indicates there is a significant difference in mean number of family size among the three districts. The districts were having an

average family size of 2.68, 3.44 and 2.94 respectively for K/Humera, T/Adyabo and R/Azebo. The availability of more labor force in the family is assumed as an indicator of performing more household activities in the household and this could help them to adopt improved technologies.

The average livestock holding in TLU were better at T/Adyabo followed by K/Humera district. The districts own an average TLU size of 6.66. There is a significant

difference in mean number of livestock ownership of the households among the three districts.

The farm households own an average land size of 3.4, 2.16 and 0.9 ha respectively at K/Humera, T/Adyabo and R/Azebo districts. The farmers traveled an average distance of 68.14, 37.09 and 31.56 minute from their residence to their farm at K/Humera, T/Adyabo and R/Azebo districts, respectively.

The institutional services includes demonstration, experience sharing, technical support, field days, training and receiving information on market, pest and disease

control were grouped under the extension service index. The index is the summation of the six institutional services given the value ranged from 0 to 1; i.e. 0, if the farmer not getting any of the services and 1 if the farmer receive all the six extension services. The household getting an extension service index of 0.49, 0.57 and 0.27 respectively at K/Humera, T/Adyabo and R/Azebo districts. The farmers were traveled an average distance of 20.66, 39.6 and 40.91 minutes, respectively from farmers training center at K/Humera, T/Adyabo and R/Azebo districts (Table 3).

**Table 3:** Summary for the continuous variables

Variables	K/Humera		T/Adyabo		R/Azebo		Total		F-test	Sig.
	Mean	Std.er	Mean	Std.er	Mean	Std.er	Mean	Std.er		
Age	45.14	1.033	47.06	1.136	44.73	1.202	45.67	0.647	1.233	0.293
Family Size	2.68	0.129	3.44	0.132	2.94	0.131	3.02	0.077	8.879	0.000
TLU	6.87	0.863	8.38	0.659	4.36	0.333	6.66	0.398	9.089	0.000
Land size	3.40	0.292	2.16	0.135	0.90	0.074	2.29	0.136	32.949	0.000
Extension Index	0.49	0.032	0.57	0.031	0.27	0.027	0.456	0.019	23.445	0.000
Distance to plot	68.14	6.923	37.09	3.179	31.56	2.664	46.41	2.957	16.805	0.000
Distance to FTC	20.66	1.382	39.60	2.531	40.91	3.468	33.37	1.551	20.635	0.000

**Adoption status of Improved Agricultural Technologies by Sorghum Farmers**

Based on the result shown in Table 4, about 45%, 28.5%, 55.9%, 51% and 59.85% of the sample farmers use improved sorghum variety, row planting, inorganic fertilizer, chemicals and moisture conservation practices,

respectively. Farmers at T/Adyabo were best on adopting of improved varieties, row planting and inorganic fertilizers by 66.3%, 52%, 83.7%, respectively as compared to the other Woreda’s. However farmers at K/Humera were good in using of chemicals (pesticide, herbicide) than the other Woreda’s.

**Table 4:** Improved agricultural technologies in sorghum production

Woreda	Farmers response									
	Improved variety use		Row planting		Fertilizer use		Chemical use		Moisture conservation	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
K/Humera	43	57	10	90	55	45	79	21	44	56
T/Adyabo	65	33	51	47	82	16	31	67	61	37
R/Azebo	20	66	20	66	22	64	35	51	65	21
Total	128	156	81	203	159	125	145	139	170	114

Source: Computed from own survey, 2019

In adoption of improved agricultural technologies for sorghum production: to know the level of adoption of each respondent the Adoption Index score was calculated. A total of five improved production packages on sorghum were used. These include using of improved sorghum varieties, row planting, inorganic fertilizer use, moisture conservation and chemical/pesticide use. The sample respondent adoption index scores were categorized in to four adopter groups namely non-adopter, low, medium and high adopter and the adoption index score ranges from 0 to 3. Adoption index score of 0, point implies non-adoption of the overall improved sorghum production technologies and 3 point indicates adoption of four or five out of the five improved agricultural technologies in sorghum production.

As shown in Table 5, both the non-adopter and low adopters accounts for 51.4%, and the remaining 23.9% and 24.6% respectively accounts for the medium and high adopters. Out of the 51.4% respondents 8.1% were non-adopter which was not practicing any of the improved agricultural technologies, while 43.3% of the farmers were practiced one or two improved agricultural practices and categorized under low adopters. From the high adopters groups 55.7%, 30% and 14.3% were from T/Adyabo, K/Humera and R/Azebo respectively. This study shows farmers were relatively good in adopting the improved technologies for the sorghum production at T/Adyabo followed by K/Humera districts.

**Table 5:** Adoption status of the farmers based on adoption to improved practices in sorghum production

Adoption category *		Woreda of the study area			Total
		K/Humera	T/Adyabo	R/Azebo	
None adopter	N	8	1	14	23
	%	8.0%	1.0%	16.3%	8.1%
Low adopter	N	53	29	41	123
	%	53.0%	29.6%	47.7%	43.3%
Medium adopter	N	18	29	21	68

	%	18.0%	29.6%	24.4%	23.9%
High adopter	N	21	39	10	70
	%	21.0%	39.8%	11.6%	24.6%
Total	N	100	98	86	284
	%	100.0%	100.0%	100.0%	100.0%

\*Adoption category: 0= Non Adopters of any practices, 1= low adopter (adopting 1 practice), 2= medium adopters (adopting 2-3 improved practices), and 3= High adopters (adopting of 4/5 technologies)

**Table 6:** Constraints for the low using improved agricultural technologies in sorghum production

SN	Row planting			Inorganic Fertilizer					Improved sorghum variety			
	Reasons			Reasons					Reasons			
	Shortage of labour	Knowledge & technical gap	Lack of row planter machine	High cost	Financial shortage and not allowed on credit	Rainfall uncertainty	Not available at the required time	Fertile soil	No favorable price	Drought tolerance problem	Lack of supply and lateness in delivering	Lack of knowledge/information
Frequency	39	29	4	15	7	4	5	3	6	3	12	10
%	54.2	40.3	5.5	44.1	20.6	11.8	14.7	8.8	19.3	9.7	38.7	32.3

Source: Computed from own survey, 2019

As indicated in Table 6, shortage of labour, knowledge and technical gap are the main identified challenges in adopting of row planting. Inline to this study Adunea and Fekadu (2019) [1]. reported that giving practical training on row planting could improve the indigenous farmer’s knowledge & technical skill which helps them in enhancing the adoption of row planning method. Costly of the inorganic fertilizer, financial shortage & not allowable in credit, not available in the required time and rainfall uncertainty were the reasons for not using the inorganic fertilizers by the respondents. Similar to this study, the finding by Elizabeth and Peter (2013) [19] indicates that unaffordability and inaccessibility are the main factors that distinguished for the low adoption of the inorganic fertilizer. On the other side, lack of seed supply and inaccessible on time, lack of knowledge/information about the varieties, and

unaffordability of its price were the prioritized constraints in adopting of the improved sorghum varieties. Solomon *et al.* (2011) [42]. was also revealed that farmer access to improved seed, supply of seed and farmers’ knowledge about the improved varieties, are the important factors for the adoption of the improved chickpea varieties.

**Determinant Factors for the Adoption of Improved Agricultural Technologies of sorghum Production**

The estimation show that the model fits the data as the Wald test (55) =133.04, P=0.000 with the likelihood of 652.29, in which the null hypothesis that all regression coefficients in each equation are jointly equal to zero. This shows the relevance of the model to account for the unobserved correlations in decisions to adopt multiple technology practices.

**Table 7:** Multivariate probit model result for sorghum technologies adoption

Variables	Improved sorghum		Row sorghum		Fertilizer use		Pesticide use		Moisture conservation	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
SexHH	0.275	0.287	-0.223	0.305	0.359	0.283	-0.026	0.281	0.079	0.281
AgeHH (in years)	-0.003	0.008	0.007	0.008	-0.004	0.008	-0.011	0.0084	0.0079	0.008
Edu status of the household	0.199	0.197	-0.026	0.204	0.233	0.193	0.414**	0.198	0.495**	0.200
Family size (Manequvlent)	0.062	0.067	0.228***	0.071	0.046	0.068	-0.056	0.067	-0.001	0.067
Farm Size (in ha)	-0.087*	0.049	-0.122*	0.068	-0.045	0.043	0.184***	0.062	-0.317***	0.072
TLU (total livestock holding)	0.020	0.014	0.013	0.016	0.007	0.014	-0.019	0.016	0.014	0.016
EngaOff	0.336*	0.184	0.069	0.191	-0.181	0.186	0.124	0.183	-0.202	0.185
Walking_dis to FTC (in minute)	-0.001	0.003	0.005	0.003	0.003	0.003	-0.011***	0.003	-0.0001	0.003
AVERAGEPLOT dis (in minute)	-0.000	0.001	-0.002	0.002	0.001	0.001	0.001	0.002	-0.002	0.002
EXTENSION Service (index)	1.155***	0.300	0.922***	0.314	1.390***	0.303	-0.303	0.296	-0.115	0.296
Credit access	0.044	0.202	-0.020	0.208	0.206	0.200	0.080	0.203	0.170	0.205
_cons	-1.043***	0.532	1.764***	0.556	1.026**	0.517	0.651	0.527	0.229	0.534

Source: Computed from own survey, 2019

**The significant determinant factors in adopting sorghum technologies**

**Education level of the household:** Education level of household heads is found to have a significant and positive relationship with the probability of adoption of moisture conservation and pesticide improved agricultural technologies in sorghum production at 5% level of significance. The multivariate model indicated that adoption of moisture conservation and pesticide use increased by 41.4% and 49.5% respectively on the literate household than the illiterate one. It is because of that the educated farmers

might be aware of more information and be more efficient in evaluating and interpreting information about innovations than those with no education. In line to this study Wuletaw and Daniel (2015) [47] have reported that education is probably positive and significantly influencing in adoption of new agricultural technologies.

**Family size (man equivalent):** Family size is an indication of labor availability. As expected it had a positive sign influence on adoption of improved agricultural technologies in sorghum production. The likelihood of practicing row

planting would be higher for a house hold having large family size by 22.8% than the others. This implies that as the household have more labour the tendency for planting of sorghum in row had increased. In consistent to this the study Musa *et al.* (2017) <sup>[36]</sup> had indicated that family size has a positive effect on the adoption of improved maize varieties.

**Off-farm income:** As expected, the variable participation to off-farm activities has significantly and positively influenced for adoption of improved sorghum variety at 5% level of significance. This shows that a household participated in off farm income have the probability to involve in improved agricultural technologies by purchasing the required inputs. Inline to this study Diro (2013) <sup>[15]</sup> has also reported that off-farm income is expected to provide farmers with capital for purchasing productivity enhancing inputs such as improved seed and fertilizers.

**Landholding (Farm size):** Farm size had a significant and negative relationship with adoption of improved sorghum variety and row planting at 10% significance level and moisture conservation at 10% level of significance and, on the contrary it is positively significant for adoption of pesticide use at 1% level of significance. A unit increase in area of the household would decrease the chance of adopting the improved sorghum varieties, row planting and moisture conservation. This implies that as farm size increased the probability of adopting improved sorghum varieties, row planting and moisture conservation decreases and vice-versa. On the other hand as land size increased by a unit the tendency of farmers to use pesticide and insecticide chemical application increased by 18.3%. This indicates that farmers who own smaller land sizes are more likely to adopt most improved agricultural technologies in sorghum production like using improved seed, row planting and moisture conservation, but the owners of large farm size have a higher probability of adopting pesticide. This shows that farmers who own large land size are giving less focus in using of improved agricultural technologies, this could be it is difficult to them to manage their large farm size and fearing the extra cost for using the practices of row planting, moisture conservation and improved seeds or fearing the additional costs. In line to this study farmers with bigger farm sizes had lower probability to adopt spacing, line planting and urea briquette among rice producing farmers in Ghana as reported by Samuel *et al.* (2019) <sup>[39]</sup>. The study of Kassie *et al.* (2015) <sup>[30]</sup> also revealed that having small land can induce agricultural intensification through the adoption of improved technologies. But the farmers that own large farm size are good in using of pesticides than those who have small land size. The reason could be it is the easiest option to manage their farm from weed and pests with little cost. So emphasize is need to make farmers aware in using of improved agricultural technologies for boosting their sorghum production.

**Extension service index:** As hypothesized extension service index had significant and positive in adopting of improved sorghum variety, row planting and fertilizer use in sorghum production at 1% level of significance. A unit increase in extension service index adoption of improved sorghum variety, row planting and inorganic fertilizer

increased by 115.5%, 92.2% and 139% respectively. This indicates access to participate in training, demonstration, technical support, field day and other extensions advisory services therefore creates the platform for acquisition of the relevant information that promotes the technology adoption. In consistent to this study access to extension services typically plays a crucial role in enhancing adoption of improved technologies and innovations (Chowdhury *et al.*, 2014) <sup>[11]</sup>.

**Distance to FTC:** The rural extension service is mostly delivered at farmers training center (FTC) by DAs and experts. The distance of the household residence from FTC were significantly and negatively affecting for pesticide use at 1% significance level. This could happened due to the fact that as farmers residence is near to FTC, the farmers have high probability to get more information and aware of what improved technology should use in their farming activities by getting advisory services from development agents. Inline to this study Assefa and Gezahegn (2010) <sup>[4]</sup>, and Asfaw *et al.* (2012) <sup>[5a]</sup> had reported that a negative influence of distance from FTC and demonstration centers on adoption of new technology.

On the other hand among the hypothesized variables used in the model; sex, age, TLU (total livestock holding), farm distance and credit access did not have a significant effect on the adoption of any of the improved agricultural technologies in sorghum production.

## Conclusion and Recommendations

### Conclusion

The paper analyzes the determinants in utilizing the improved agricultural practices for enhancing sorghum production on smallholder farmers in Tigray region, northern Ethiopia. The econometric models revealed that adoption of improved agricultural technologies by farmers in sorghum production was significantly affected by education status of the household head, family size of the household, farm size, engage in off farm income, extension service index and walking distance to FTC. Educational status, family size, off farm income and extension service index positively and significantly explained the adoption. While farm size and distance to FTC negatively and significantly influenced the adoption of the improved technology practices in sorghum production in the study area. However the variables of sex, age, TLU, average plot distance and credit access were showing insignificant difference in adopting of improved sorghum technologies. Based on the descriptive statistics about 45%, 28.5%, 55.9%, 51% and 59.85% of the sample farmers used improved sorghum variety, row planting, inorganic fertilizer, chemicals and moisture conservation practices, respectively in sorghum production. Shortage of labour, knowledge and technical gap are the main identified challenges in adopting of row planting. High price of the inorganic fertilizer, financial shortage & not allowable in credit, not available in the required time and rainfall uncertainty were the reasons for not using the inorganic fertilizers by the respondents. On the other hand, lack of seed supply and inaccessible on time, lack of knowledge/information about the varieties, and unaffordability of the price were the prioritized constraints



in adopting of the improved sorghum varieties.

### Recommendations

- Extension service like training, technical support, field day participation, experience sharing, involving in demonstration of new technologies and delivering information on market, pest and disease control has to give strong emphasize by Office of Agriculture and Rural Development of the respective districts, NGOs, and other governmental bodies.
- Such introducing row planter machine could solve for the low adopting of row planting
- Creating awareness and improve the farmers perception regarding importance of moisture conservation, improved sorghum varieties and row planting methods is very imperative.
- Government, development partners and the NGO sector should continuously work in developing the existing improved seed multiplying cooperatives and others to deliver the requested seed in continual manner to solve the seed supply limitations.
- More attempts need to address the reasons for the low adoption and the lagging behind in using the recommendations of the improved technologies in sorghum production.
- The Government, Regional and Woreda Office of Agriculture, NGOs and Research institutions are needed to further promote the improved agricultural technologies by addressing the farmer's problem and need.
- Research and other stakeholders should give focus on introducing more alternative improves sorghum varieties and the constraints faced to farmers regarding improved sorghum varieties.

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