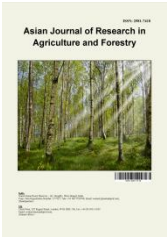

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Household Level Determinants of Wheat Packages Adoption in Tigray Region, Northern Ethiopia

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Wheat has been considered as one of the strategic food security crops in Ethiopia. A number of research efforts have been done by different research institutions to improve the production and productivity of the crop and as a result a number of wheat production packages has been released and promoted all across the country, including Tigray. Yet, in Tigray, there is no adequate evidence on the adoption status of wheat packages and their determinant factors. Hence, this adoption study was initiated with the objective to analyze the status of wheat packages adoption, and determinant factors for further adoption. A multistage sampling technique was employed to select 493 households from five wheat growing districts of the region. Data were collected through the administration of semi-structured questionnaires and analyzed using both descriptive statistics and Multivariate Probit (MVP) model. The descriptive results described that, the average wheat packages adoption status was 67%, of these only 17% of farmers adopted all five packages. The result of MVP model revealed that sex, age, livestock size, extension services, average plot distance, off-farm income source, farmer perception on his status and credit access were the determinant factors which facilitate/and/or hinder wheat packages adoption in Tigray. Thus, the policy and development interventions should focus on improving institutional support and wealth creation opportunities to improve production and productivity of wheat producer farmers in Tigray.

Keywords: Adoption index; multivariate probit; wheat packages.

1. INTRODUCTION

The government of Ethiopian has been promoting a package-driven extension that combines credit, fertilizers, improved seeds, and better management practices [1] and herbicides and conservation practices are among the contents of the packages on wheat commodity [2]. Wheat is the fourth largest cereal crop produced by close to 5 million smallholder farmers in Ethiopia [3]. Considering wheat as food security crop in the country in general, and Tigray in particular, a number of improved wheat varieties, and production packages has been released at national and regional level. However, despite of the efforts made to promote and introduce the improved technologies related to wheat by governmental and non-governmental organizations at different levels yet sustainable and essential technology adoption is not realized in the region. Consequently, the productivity of wheat in Tigray has remained very low, with an average of 2.1 t/ha, which is lower than the national average 3.04 t/ha under smallholder farmers [3].

Worldwide including Ethiopia, many investigations confirmed that agricultural technology adoption can contribute to improve productivity and raising income of farm households [4-9]. Specifically, adoption of improved wheat varieties [6,8-10], able to increase production and to improve the household' farm income. Adoption of row planting on wheat help to increase wheat crop yields 50 to 80% and decrease amount seed rate [11-13]. Adoption of inorganic fertilizer at recommended rate and applied at the critical time could increase productivity of the crop. Without utilization of fertilizer, world food production could be reduced from 40-60% annually [4]. Pesticides are also chemicals that are used to improve agricultural outputs by protecting against crop damages [14]. Increased herbicide use promotes efficient fertilizer use, which leads to an increase in production [1,5]. Furthermore, a recent finding confirmed that, the adoption of a combined fertilizer and improved seed provides higher productivity than the adoption of single technologies [15].

On contrary, many empirical evidences were documented related to adoption of improved agricultural technologies in Ethiopia in general and Tigray in particular, but the adoption studies were mainly focused on one package/ single technology/ adoption study at a time. Even though, there are very few exceptions, like [16,17], which considered the issues of simultaneity and sequences of technological options in their study. Practically the adoption decision involves choices among several technological options (simultaneity of choices) and interdependent decisions (e.g. the decision to use improved variety, row planting, inorganic fertilizer, chemicals and moisture conservation practices etc). Moreover, previous studies on adoption of wheat packages/technologies did not identify the determining factors for each package at the same time. Furthermore, if there are

studies they mainly focused at district level and zonal level with low coverage.

Hence, the initiation of this study was to know the adoption status and its determinants of the wheat in packages in the wheat growing area of Tigray. In this way, the findings will contribute to improve the wheat research interventions, and design better adoption programs so as to increase production and productivity of wheat at regional and national level in Ethiopia and beyond.

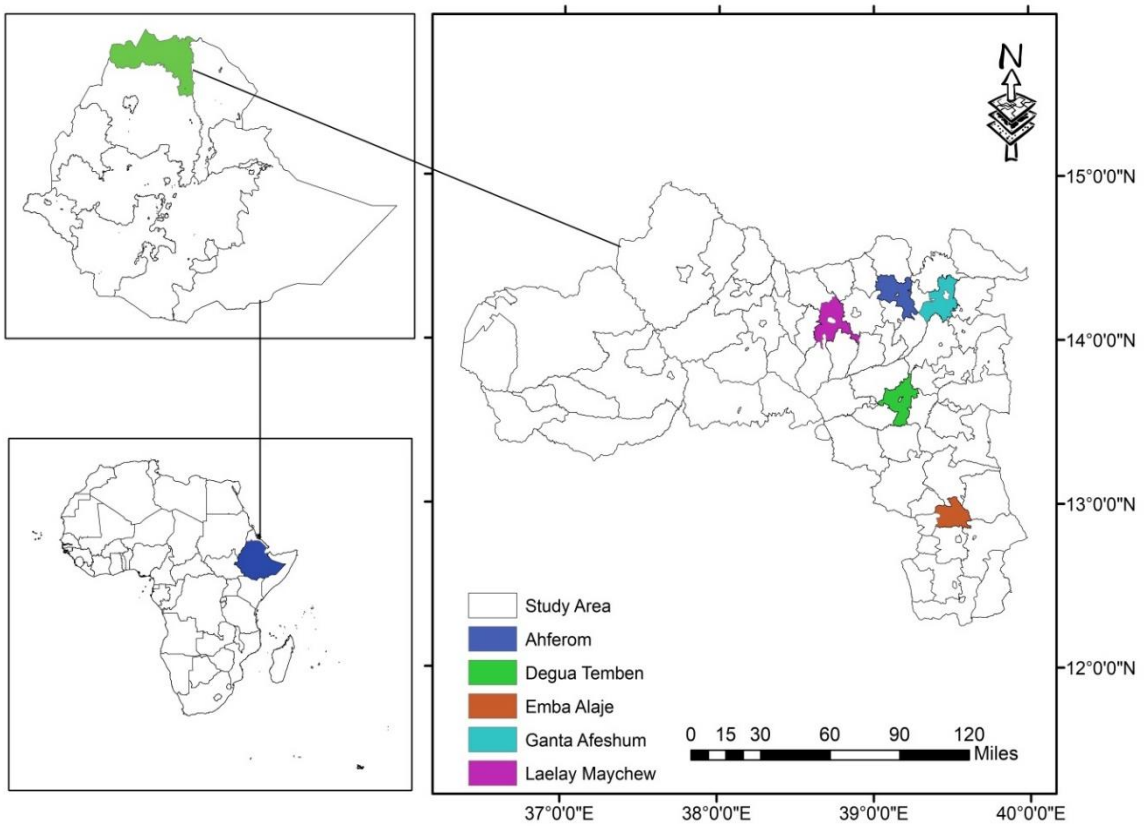
2. RESEARCH METHODOLOGY

2.1 Description of the Study Areas

The study was conducted in Tigray National Regional State of Ethiopia. The region is located between 12^0 -15^0 north latitude and $36^0$30'-$40^0$30' east longitude. The region has an area of 54,593 square kilometers [18]. It shares boundaries with Amhara and Afar regions, and with countries Eritrea and Sudan. In Tigray, a mixed farming production system is practiced, that comprises crop production and livestock rearing. The study mainly covers four wheat growing zones of Tigray (See Map).

2.2 Sample Size and Sampling Procedure

A multi-stage sampling technique was employed to select respondents for the study. First, the target districts were clustered according to their potential for wheat production. The cluster includes North western, Central, Eastern, South Eastern and Southern zones to embrace representativeness of commodity and agro-ecologies in each zones of the region. Secondly, Laelay Maychew, Ahferom, and Ganta Afeshum districts were selected from the mid land agro-ecologies; while the remaining Degua Temben and Alaje districts were also selected from highland agro-ecologies of the region purposively. From the selected five districts, three kebeles from each were selected. Finally, from 15 kebelles, a total of 493 respondents were included in the study using simple random sampling from the prepared wheat growing farmers list in the kebele.



Map. 1. Map of the study areas

2.3 Data Sources and Data Analysis Method

The study used both primary and secondary data sources. The primary data sources were collected through interview method (using semi-structured questionnaire) from Farmers. The secondary data sources were also collected from published journals and unpublished sources. To analyze and present the data the study was employed both descriptive and econometric models. The descriptive statistics includes mean, frequency, ranking and percentage for; describing and presenting the extension services and adoption status of wheat packages. In addition, multivariate probit econometrics model was used to identify the determinant factors for wheat packages adoption.

A multivariate probit model: In a single-equation statistical model, information on a farmer's adoption of one wheat package does not alter the likelihood of his adopting of other packages. However, the MVP 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 practices [19]. One source of correlation may be complementarities (positive correlation) and substitutabilities (negative correlation) between different practices (Ibid). Failure to capture unobserved factors and interrelationships among adoption decisions regarding different practices will lead to bias and inefficient estimates [20].

Multivariate probit model is appropriate for jointly predicting two or more choices of an individual. In this analysis, farmers have a choice to select one and or more than one/ not select one and or more than one from list of wheat packages. Currently, for Modeling farmers' adoption decisions of multiple crop technologies [16] to analyzed the determinants of the adoption of interrelated sustainable agricultural practices [21] to study the recommended agronomic practices adoption among wheat producer farmers [22] and Geda et al. [17] Determinants of adoption of climate smart agricultural technologies in wheat production were among the authors used multivariate probit model. The justification for their reasons were particular technologies is not independent of other technological selections-on the same farm plot of land. Hence, using multivariate probit model for this adoption study becomes reasonable. The definition and description of all the dependent and independent variables is summarized (Table 1).

Table 1. Definition of variables included in the model

Variables	Description	Value
Dependent variables		
Improved variety	Used improved wheat varieties	1=yes, 0=no
Row planting	Used row planting on wheat production	1=yes, 0=no
Fertilizer	Used fertilizer on what production	1=yes, 0=no
Pesticides/insecticide /herbicides/chemicals	Used pesticides/chemical on wheat production	1=yes, 0=no
Moisture conservation practices	Used moisture conservation practices on wheat production	1=yes, 0=no
Independent variables		
SEXHH	Sex of the household head	1=male, 0=female
AGEHH	Age of the household head	Number
EDULEVEL	Educational level of the household head	1= literate, 0= illiterate
FAMISIZE	Family size measured in man equivalent	Number
LANDSIZE	Land holding size of the household in (hectare)	Number
LIVESTOCK	Total livestock holding in Tropical Livestock Unit (TLU)	Number
ATTITUDE	The perception of the household head towards his status perceived as model	Not model=0 Semi model=1 Model=2
EXTENSION	Extension services index	Number in index
CREDITACC	Households access to credit	1=yes, 0= no
OFF-FARM	Household participation in off farm activities	1=yes, 0= no
AVERGE PLOT	Average Farm plot distance from household residence /in minutes/	Number

3. RESULTS AND DISCUSSION

3.1 Characteristics of the Sample Households

As indicated in Table 2, the proportion of female headed households in this study was found 14.8%. The highest percentage of female headed households was found at Alaje district whereas the lowest percentage was found at Ahforem district. The educational level of the majority household heads (63%) was literate, while the remaining are illiterate. The majority 61.7% of the respondents were not participated in off/non-farm income activities, whereas remaining 38.3% of the respondents were participated in off/non-farm income activities. Regarding to the participation in off/non-farm activities; the highest percentage of households, (50%) was in Laelay Maychew district, whereas the lowest percentage (31.4%) was found at Ganta Afeshum district. The majority (83%) of respondents had access to credit services during 2018 production season. The status of the households towards technology adoption low, which accounts 26.6% perceived as model and the remaining 49.5 and 23.9% respectively, was semi model and not model (Table 2). The descriptive analysis showed that, the mean age of sampled respondents was 46.97 years. This implies that the mean age of the respondents was at productive age. The average household size in man equivalent was 2.94 whereas; the average livestock holding was 3.77 TLU. The average landholding size of the respondents was about 0.77 hectare per household head. The land holding size of the respondents ranges from landless to 3.25 hectare owner (Table 2). The average plots distance of the households from their residence was about 34.8 minute walking on foot (Table 2).

NB: Wheat packages adoption index: It is the summation of the five packages/practices divided to five. The packages are using improved seed, inorganic fertilizer, row planting, pesticides use, and moisture conservation practices on wheat production (yes or no).

Extension services index: It is the summation of the six services divided to six. The services are; demonstration, experience sharing, technical support, participation on field days, participation in training and information on market, pest and disease control (yes or no).

3.2 Status of wheat packages adoption and associated problems in Tigray

The adoption of wheat packages in the wheat growing areas of Tigray is low. As indicated in Table 2, the average wheat packages adoption was 67% in the consecutive three years (Tables 2 and 3). The majority 401(81.3%) of the respondents used four and above wheat production packages, at the same time a small number of the households (5.9%) did not adopt any package in their wheat production activities (Fig. 1). More specifically as presented in the Table 3, the highest proportion of farmers (92.3%) participated on artificial fertilizer application while the remaining less than 40% of the farmers participated on wheat row planting package (Table 3).

3.3 Constraints Associated to the Wheat Packages Adoption

Wheat is one of the major commmodities in the selected districts for this study. Hence, the extension agenets and respective stakeholders are expected to caried out every components of the wheat pacakages for continuous adoption. However. as sumarized in Table 6, farmers still have mentioned their own reasons which hinders the continueus adoption for each packges. Lack of knowledge on use and application of the inputs, financial constraint to acquire the improved varieties and on time availability of the improved varieties were among the main reasons reported by farmers for using improved seed. Consistence to this study, lack of seed supply and inaccessible on time, lack of knowledge/information about the varieties, unaffordability of its price were the constraints on adopting improved sorghum varieties [23]. Besides, shortage of labor, lack of knowledge on use and application of the practice, and fear of risk on the practice implementation are among the main reasons for adoption of wheat row planting. Consistence to this study, previous findings reported that working labor and lack of awareness regarding to the benefits of row planting were among the main challenges on adopting row planting [12,23]. On the other side, high cost, unavailability on required time and shortage of supply are among the main constraint on fertilizer utilization. Similar to this study, previous findings reported that unaffordability and accessibility on the required time were the main reasons for not using the inorganic fertilizers [23,24]. Moreover,

unavailability, high cost and fear to damages for animals are also among the main reasons on pesticide application on wheat (Table 4).

3.4 Determinants of Wheat Packages Adoption in Tigray

As indicated in the Multivariate probit model output (Table 6), the chi-square is (chi^2 (10) = 136.516, Prob > chi2 = 0.000). This shows that variables included in the model are well explaining the adoption decision of wheat packages at less than 1% probability level. This implies that the joint null hypothesis of coefficients of all explanatory variables included in the model were zero should be rejected. Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0: this implies null hypothesis (Ho), that is, there is no correlation for each equations error terms. The alternative hypothesis (HA): there is correlation for each equations error terms. Except rho32 (fertilizer and row planting), all the nine rho were significant at 1 and 5% levels of significance. Hence, we reject the Ho and accept the HA, meaning there is error terms correlation among each equation which implies the acceptance of the model. The interaction between households' decision of choices in Table 5, rho21; rho31; rho41; rho51; rho42; rho52; rho43; rho53 and rho54 is positive and significant. This implies the households' decision to adopt one rho does not change the decision to adopt another rho and the reverse is true. Moreover, this positive interaction will have a positive effect on activities done to promote improved seed, row planting, fertilizer application, conservation practices and chemical application for wheat meaning they will take place at the same time by respondents. Hence, out of the eleven explanatory variable included in the Multivariate probit model eight variable were found the significance factors which determines the adoption of wheat packages (Table 6).

Sex of household head (SEXHH): Sex of household head has a positive influence on adoption of pesticides application for wheat production at 10% significance level. The model revealed that the probability of adopting pesticides on wheat increased by 35.8% as the sex of household head being male. This implies that the male headed households can simply applied pesticides than female headed on which spraying of pesticides need technical capabilities and protective measures, and then male headed households are more motivated to apply the pesticides. This result is consistent with the following authors, which were reported that sex of the household heads had a positive influence on pesticides use [25]; on the intensity of wheat package adoption [26]; on improved seeds, herbicides and row planting packages adoption for teff production [27].

Age of the household head (AGEHH): The variable is measured in years, and it has positive contribution for fertilizer and moisture conservation practices adoption for wheat at 1% and 10% probability level, respectively. This implies that as age of the household head increases by one year, adoption of chemical fertilizer increased by 2.4%, keeping others variables constant. Increasing age means there is high probability of learning from life experience and observes the importance of fertilizer application on wheat production practically. This result is consistent with the study of [28,29]. Similarly, the model shows that as age of the household increased by one year the probability of adopting moisture conservation practices increased by 1.2%, keeping other variables constant. This implies that the aged households have the probability to see the importance of conservation practices for wheat production than the younger once. The study is consistence with [30,31], which were reported that aged farmers have adequate knowhow their farming and solutions and, motivated to adopt the practices in their plot.

Off-farm income sources (Off-FARM): Engaging in various off/non-farm incomes activities has shown a negative contribution for adoption of improved wheat varieties at 1% probability level. The model revealed that the probability of adopting improved seed varieties decreased by 37.7% for household who have access to off/non-farm income activities as compared those households they did not have access. Even though, access to off/non-farm activity is believed to raise the households' financial position to acquire new technologies but they can interested to continue the non-farm activities, and farmers unlikely to allocate some amount of money for improved seed of wheat. Consistence with this study, [26], reported that households who had off/non-farm income access are motivated to shift to non-agricultural tasks than adopting wheat packages.

Table 2. Household characteristics of the sample households

Variables	Description	Laelay Maychew	Ahferom	Ganta Afeshum	Degua Temben	Alaje	Total	χ^2-value
		N (%	N (%)	N (%)	N ( )	N (%)	N (%)	
Sex of household head	Male	81(86.2)	80(93)	83(79)	97(90.7)	79(78.2)	420(85.2)	13.82***
	Female	13(13.8)	6(7)	22(21)	10(9.3)	22(21.8)	73(14.8)	
Educational level of household head	Illiterate	22(23.4)	26(30.2)	42(40)	45(42.1)	43(42.6)	178(36.1)	12.02**
	Literate	72(76.6)	60(69.8)	63(60)	62(57.9)	58(57.4)	315(63.9)	
Off-farm income sources	Yes	47(50)	36(41.9)	33(31.4)	38(35.5)	35(34.7)	198(38.3)	8.92*
	No	47(50)	50(58.1)	72(68.6)	69(64.5)	66(65.3)	304(61.7)	
Access to credit services	Yes	58(61.7)	63(73.3)	104(99)	98(98)	87(86.1)	410(83.2)	61.95***
	No	36(38)	23(26.7)	1(1)	9(9)	14(13.9)	83(16.8)	
Perceived as model/attitude towards his status	Not model	16(17)	9(10.5)	46(43.8)	33(30.8)	14(13.9)	118(23.9)	54.74***
	Semi model	41(43.6)	47(54.7)	42(40)	58(54.2)	56(55.4)	244(49.5)	
	Model	37(39.4)	30(34.9)	17(16.2)	16(15)	31(30.7)	131(26.6)	
Summary of the descriptive statistics of continuous variables								
Variables			Unit	N	Mini	Max	Mean	Sd
Age of the household head			Years	493	21	80	46.97	12.11
Family size			Man equivalent	493	0.4	9.30	2.94	1.29
Livestock holding			TLU	427	0.01	16.93	3.77	2.42
Average distance of plots from residence			Minute	448	0.15	240	34.82	31.81
Cultivable land size			Hectare	493	0	3.25	0.772	0.514
Extension services			Index	493	0	1	0.39	0.31
Wheat packages adoption			Index	493	0	1	0.67	0.26

Table 3. Status of households wheat packages adoption in the last three years (N=493)

Packages participated	Yes	%	No	%
Improved seed	422	85.6	71	14.4
Row planting	189	38.3	304	61.7
Artificial fertilizer	455	92.3	38	7.7
Chemicals application	221	44.8	272	55.2
Moister conservation practices	363	73.6	130	26.4
At least participated in one out of the five	464	94.21	29	5.89

Table 4. Constraints for wheat packages adoption

Reasons for not using seed	N	Rank
Lack of knowledge on use and application of the input	30	1st
Financial constraint to acquire the seed	15	2nd
Seed was not available on time	14	3rd
The production was unsatisfactory	13	4th
The price is expensive	7	5th
Reasons for not using row planting	N	Rank
Lack of knowledge on use and application of the practice	86	1st
Shortage of labor to perform the necessary agricultural activities	85	2nd
Fear of risk to implement the practice	32	3rd
Not better than the existing practices	12	4th
Lack of knowledge and shortage of labor	11	5th
Reasons for not using fertilizer	N	Rank
High cost/too expensive/	308	1st
Unavailability on required time	32	2nd
Shortage of supply	28	3rd
High cost and unavailability on required time	22	4th
Absence of credit facilities	18	5th
Reason for not using pesticides	N	Rank
Not available	59	1st
Too expensive	52	2nd
Causes damage on Livestock and other lives	32	3rd
Too expensive and not available	14	4th
Cash shortage/not credit access	13	5th

Table 5. Estimates of correlation coefficient for the error term from the five adoption equations for seed, row, fertilizer, chemical and moisture conservation practices

Parameter	Coefficient	St error	T value	P value
rho21 (Row and seed)	.2338778	.0942636	2.48	0.013
rho31 (Fertilizer and seed)	.8644996	.0505302	17.11	0.000
rho41 (Chemical and seed)	.1995203	.089701	2.22	0.026
rho51 (moisture conservation and seed)	.4826637	.0804233	6.00	0.000
rho32 (fertilizer and row)	-.2007677	.1286846	1.56	0.119
rho42 (chemical and row	.2251339	.0776602	2.90	0.004
rho52 (moisture conservation and row)	.3896512	0771265	5.05	0.000
rho43 (chemical and fertilizer)	.2583494	.0941723	2.74	0.006
rho53 (moisture conservation and fertilizer)	.5040529	.0883233	5.71	0.000
rho54 (moisture conservation and chemical)	.2168342	.0820067	2.64	0.008

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0: chi2 (10) = 136.516. Prob > chi2 = 0.0000

Table 6. Results of the multivariate probit model

Variables	Improved wheat variety		Wheat row planting		Fertilizer application		Pesticide/Chemical application		Moister conservation	
	Coef.	Sd.err	Coef	Std.err	Coef	Std.err	Coef	Std.err	Coef	Std.err
SEXHH .	0.3221	0.2514	-0.0008	0.2051	0.0174	0.3129	**0.3581***	0.2062	-0.0447	0.2204
AGEHH	0.0033	0.0088	-0.0045	0.0068	**0.0242*****	0.0116	0.0057	0.0067	**0.0118***	0.0071
EDULEVEL	-0.2415	0.2037	0.0028	0.1496	-0.1955	0.2637	0.1538	0.1495	-0.0639	0.1568
OFF-FARM	**-0.3737*****	0.1736	0.06629	0.1398	-0.0800	0.2091	-0.0254	0.1377	-0.1832	0.1425
FAMISIZE	0.0513	0.0769	0.04163	0.0554	-0.0004	0.1025	0.0020	0.0556	-0.0859	0.0587
ATTITUDE	**0.2711***	0.1394	**0.1970***	0.1070	0.1453	0.1650	**0.2101*****	0.1060	0.0058	0.1118
LANDSIZE	-0.1471	0.1990	0.0078	0.1504	0.2496	0.2848	0.2087	0.1485	0.1665	0.1624
LIVESTOCK	0.0390	0.0423	**0.0678*****	0.0312	-0.0245	0.04508	-0.0095	0.0323	-0.0150	0.0307
AVERAGEPLOT	-0.0001	0.0025	**-0.0045*****	0.0022	0.0034	0.0034	**0.0074*****	0.0022	**-0.0039***	0.0020
EXTENSION	0.15331	0.3020	**0.9859*****	0.2245	0.2333	0.3766	**0.7939*****	0.2238	-0.0184	0.2329
CREDITACC	**0.5822*****	0.2235	**0.4575*****	0.2013	**0.8662*****	0.2332	-0.0940	0.1901	**0.5262*****	0.1843
Cons	0.0830	0.4739	**-1.312*****	0.4174	-0.5277	0.5698	-1.6669***	0.4119	0.1899	0.4115
Log likelihood =							-889.48732			
Wald chi2 (55) =							149.45			
Prob > chi2 =							0.0000			

*Note: ***, **, and * represents significance at 1%, 5% and 10% probability levels, respectively.*
Source: Model output (2023)

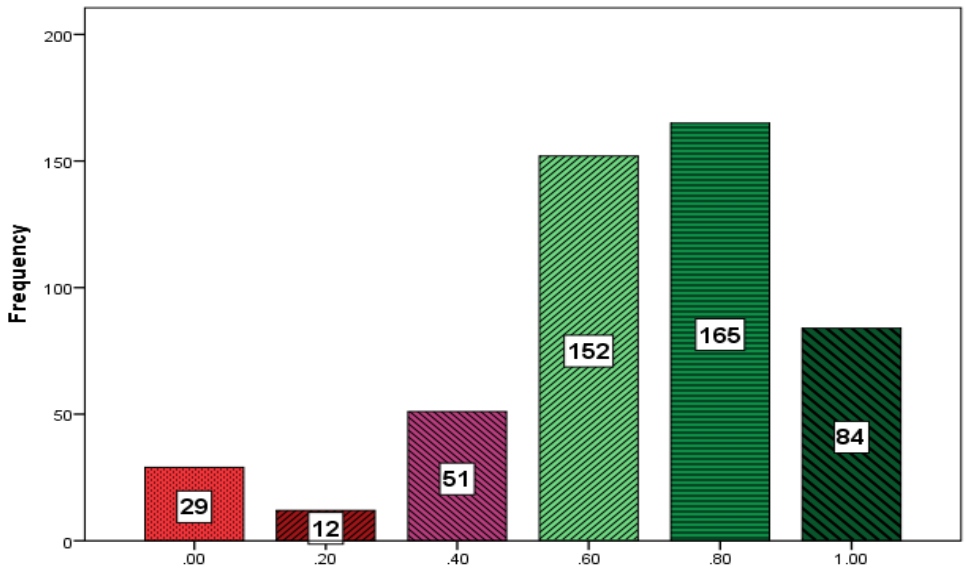


Fig. 1. Adoption index of wheat packages in Tigray

Attitude of household towards his status (ATTITUDE): This variable affects positively the adoption of improved seed varieties and wheat row planting at 10% probability level of significances, and pesticide/chemicals application on wheat at 1% probability level of significance. As the attitude of the household head on his status changed to semi model and model from not model, the household plan to adopt wheat packages like improved seed by 29%, wheat row planting by 19.7%, and pesticides application on wheat by 21%. This implies that households who perceived themselves as model they encourage to adopt improved wheat packages than the farmers perceived themselves as not-model farmers. The result is consistent with [22], who reported that as attitude changes from laggard to early adopters, the probability of using herbicides on wheat production increase by 54.3%. On the other hand, [32], reported that attitude of farmers was one of the major factors that determine their adoption decision towards improved wheat production technology.

Livestock size (TLU): The variable is measured by TLU (Tropical Livestock Unit), and it had a significant positive effect on adoption of wheat row planting at 1% significance level. The model revealed that as TLU of the household increases by one unit, probability of adoption wheat row planting increased by 6.8%, keeping others variables constant. The implication of this result is suggesting that, since row planting is labor intensive the more livestock owned households' have financial capacity to purchase and/or to hire additional labor on peak agricultural seasons like planting. The result is consistent with previous adoption studies on wheat packages [26], bread wheat technologies [33,34], wheat row planting [35] and teff row planting [27].

Average plot distance (AVERAGEPLOT): The variable is measured in minute and it has negative contribution for row planting and moister conservation practices adoption on wheat at 1% and 10% probability level, respectively. As the plot distance of the households increased by a unit the probability of adopting the row planting and moisture conservation practices decreased by 0.41% and 0.39% respectively. This implies that since the row planting and moisture conservation practices are labor intensive activities, it may challenging and less likely to implement the practices as the distance of the plot is being far away from the households' residence. In line to this study, many authors reported that as the distance of farmland from homesteads is large, farmers are not interested to adopt moisture conservation practices [30,34,36,37]. Similarly, as the distance of the farm plot becoming longer from the household residence, the farmers are less likely to involve his/her family members on row planting rather they might be sown the wheat through broadcasting to save labor. However, the study shows a positive contribution for pesticide application on wheat production at 1% significance level. As model revealed that the probability of adopting the pesticides/chemicals

use increased by 0.73% as the walking distance of the plot increased by one minute keeping other variables constant. This is because as the plot distance becomes far from the household residence the farmers will decrease the frequency of follow-up and practicing hand weeding rather they develop an interest to apply pesticides once at a time [38].

Extension services index (EXTENSION): Access to different extension services like field days, demonstrations, experience sharing, and attending training are expected to have positive influence on row planting and pesticides/chemical use on wheat at 1% probability level. The model revealed that, if the extension services index increase by a unit the probability of adopting row planting and pesticide/chemical use on wheat increase by 98.6%, keeping constant other variables. This implies that farmers that have the chance to receive extension services can fill their knowledge gap on practical application (like row planting and pesticides/chemicals application on wheat production), that are provided to the farm households by extension workers and other concerned bodies. In line with this finding access to different extension services affects positively smallholder farmers' adoption of row planting on wheat [12,27] and the probability of applying improved seed and row planting on teff production [27]. Furthermore, providing trainings and extension visit (like on farm demonstrations and field days) have a positive influence for adoption of improved bread wheat technologies [33]. Pesticides are one of the important inputs in agriculture in general and wheat production in particular to prevent loss of production. The model revealed that as the extension services index increase by a unit, the probability of adopting pesticide/chemical use on wheat increase 79.4%, keeping constant other variables. This implies that farmers who receive more extension services can acquire practical knowledge and skill to apply pesticides on wheat. Consistence with this study, it has a positive influence on adoption of improved production practices like the disease, and insect-pest control [39] on adoption decision of herbicides [40] and pesticide use [25].

Credit access (CREDITACC): Credit has a positive contribution for adoption of the four wheat packages (improved seed, row planting, fertilizer application and conservation practices) at 1% probability level. As access to credit increases the household head will plan to increase the productivity of wheat using the necessary packages as compared to the households they did have not credit access [41] . In line with this study, credit access have positive influence on the probability of wheat row planting adoption [35,42] adoption of improved wheat varieties [8,15,17,32,40,41] and adoption of improved seed and improved seeds + row planting technologies [27]. Moreover, the model revealed that access to credit increases the households' probability of adopting fertilizer by 86.6% as compared to the households they did have not credit access. Previous studies reported that access to credit service positively determines the probability households' decision to adopt fertilizer [15,28,43]. Furthermore, the model showed that access to credit increases the probability of adopting conservation practices by 52.62% as compared to the households they did have not credit access. Consistence to this study, there was positive influence for adoption of soil and water conservation practices [31].

4.CONCLUSION AND RECOMMENDA-TIONS

Even though, the government had a plan to provide the extension services and introduce the improved production packages for every households of the region. But, practically the agricultural extension services and its implication for wheat packages adoption is influenced by many factors. This study tried to investigate the main factors from the collected 493 rural households' data. The study employed both descriptive statistics and Multivariate probit model. The descriptive analysis revealed that; on average the adoption of wheat packages was about 67%, but only 17% of the farmers adopt all the five wheat packages. Based on the Multivariate probit model result, eight variables were found the significance factors which determine the adoption of wheat packages. The factors were personal (sex, age, farmer perception on his status), institutional factors (credit access, extension services, off-farm income sources), physical factors like average plot distance and economic factor like livestock size.

Therefore, this study suggest that to increase the adoption of wheat packages, it will important to understand each package during promotion and dissemination. The policy and development interventions should also focus on awareness creation, improving institutional support systems and economic wealth of farmers for high rates of

wheat packages adoption and their by leading to improve production and productivity of wheat producer farmers in Tigray and beyond in Ethiopia.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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