Chapter VII

Adoption and Impact of Rust-resistant Wheat Varieties on Productivity and Household Food Security in Ethiopia

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7.1 Introduction

Wheat being a key source of livelihood in the cereal based mixed farming systems of the mid and high altitude areas of the country, a considerable increase in yield through the use of disease resistant and high yielding improved wheat varieties will have a major impact on household food and nutritional security, income generation and overall welfare of smallholder farmers dependent on crop agriculture. In view of this, the generation and transfer of improved agricultural technologies in general and that of disease resistant, widely adaptable and high yielding wheat varieties is one of the pillars in the national food security strategy adopted by the Government of Ethiopia.

As indicated in previous chapters, in mitigating the challenges of wheat rust multiple activities with interrelated objectives that include the following were implemented

- fast-tracking testing and release of rust-resistant bread wheat varieties and accelerating their seed production;
- demonstration and popularization of the rust resistance bread wheat varieties to create demand;

- promotion of large-scale certified seed multiplication for the selected rust-resistant bread wheat varieties;
- supporting emergency seed distribution;
- promotion of revolving seed fund small-pack seed distribution-cum-on-farm seed production; and
- development of early warning system for yellow and stem rust in the country through building the capacity building of NARS both in terms of enhancing skills of human resources and providing key equipment and facilities.

This article presents the adoption and diffusion of rust resistance varieties in terms of area with simultaneous reduction in the number of farmers and area under rust susceptible wheat varieties. Furthermore, factors influencing the adoption of disease resistant wheat varieties are examined, and the impacts of these technologies on wheat productivity, production, and household food security are shown. In addition, the study examined the mix and effectiveness of institutional innovations promoted in terms of variety releases, seed multiplication and delivery system.

7.2 Methodology

The impact of the initiative is assessed considering the role of the project in promoting the adoption of the rust-resistant bread wheat varieties; assessing the impact due to adoption of the rust-resistant bread wheat varieties; and the impact of the project in institutional innovation, which is key in creating a responsive system in cases of rust epidemics in the future. These three dimensions of project impact are assessed employing various approaches and methodology that are discussed below.

7.2.1 Sampling Procedure and survey implementation

Multiple data collection techniques including secondary data collection and analysis, review of project reports, focus discussions with key stakeholders and quantitative household survey were employed to assemble critical data required for assessing the effectiveness of project interventions in terms of meeting stated project objectives.

The household survey was based on a stratified multistage sampling scheme. First, two wheat growing regions, namely Amhara and Oromia regional sates were identified purposively to represent the diverse socio-economic and biophysical wheat growing environments of the country. Second, in consultation with the biophysical scientists involved in the design and implementation of the project, a total of seven districts, three from Amhara and four from Oromia, believed to be representative of the respective wheat growing environments in the two regions were selected. Then the kebeles within each of the identified district were classified into two strata namely intervention (direct beneficiary), and control (non-beneficiary) kebeles based on targeting. An intervention kebele is one which directly benefits from the project by hosting project activities such as on-farm trials, demonstrations and scaling up activities including on-farm seed production organized and implemented by the project. In contrast, a control kebele was identified as one where none of the planned project activities are deliberately promoted by the project. Despite the fact that most of the control kebeles are situated far from the intervention kebeles, households are likely to receive information through the regular government extension system and non-governmental organizations actively working in agricultural related activities. Finally, given a selected KA (Kebele Administration), using a household list solicited from each KA, 453 households were randomly selected and included in the household survey (Table 7.1).

A structured household questionnaire is used to collect relevant data. A total of 13 people involving 11 enumerators and 2 supervisors were recruited for conducting the survey. The enumerators were recruited by EIAR and had previous experience in household surveys. Three days of intensive training was given to the selected enumerators and supervisors. The training included briefings of the study objectives, a thorough review of the questionnaire, interviewing techniques, direction as to how to fill the structured questionnaire, and how to ensure quality data collection.

Field data collection was carried out by two teams. Besides the two survey teams, one person from the respective district agricultural office and two development agents stationed in the respective *kebeles* assisted the survey teams in locating households identified for the interview. Data collection took place from October to November 20I4.

Table 7.1 Distribution of sample households interviewed

Region	Zone	District	Sample households (No)
Amhara	West Gojam	Wenberema	72
	East Gojam	Debre Elias	69
	East Gojam	Gozamen	72
Oromia	East Shewa	Adea	60
	Arsi	Etossa	60
	Arsi	Gedeb Assasa	60
	Bale	Sinana	60
Total			453

7.2.2 Analytical models: household level adoption and impact

Ample literature exist explaining technology adoption decision behavior of smallholder farmers with respect to the adoption of high yielding crop varieties. In Ethiopia or elsewhere, several studies examined the determinants of technology adoption under smallholder contexts employing econometric techniques (Feder et al., 1985; Shiferaw and Holden, 1998; Bekele and Drake, 2003; Gebremedhin and Swinton, 2003; Yirga and Hassan, 2008). While assessment of determinants of adoption of a binary dependent variable such as the use of improved wheat varieties is straight forward, some complexities arise in assessing the impact of technology adoption on welfare employing observational studies like ours. Consequently, studies assessing the impact of adoption of agricultural technologies on productivity and welfare of farm households are infrequent.

Several impact assessment tools are available in the literature that would allow the proper measurement and quantification of program interventions on participants. The choice of any one tool, however, depends on the availability of a baseline data and information for estimating a counterfactual outcome. A counterfactual entails knowing what would have happed to an individual's welfare indicator or outcome of interest had the program not been in place. In a situation where a randomized experimental design is possible, the impact of a program can be estimated by a simple mean difference between treatment and control outcomes. In our case, the promotion efforts of disease resistant improved wheat varieties neither used such a design nor is a baseline data available. Hence, in this study, first, an adoption decision model assessing the factors affecting the adoption decision of rust-resistant wheat varieties is estimated. Then, using impact models, we estimated the influences of adoption decisions on farm productivity, production and household food security. The effectiveness of the institutional innovations was assessed by reviewing project documents and drawing on group discussions involving various stakeholders of the project. Results can assist producers in making adoption decisions and research and extension to devise better mechanisms for augmenting the spread of superior and disease resistant wheat varieties in place of the old and rust susceptible varieties.

a) Adoption decision model

In this study an adopter is defined as household using rust-resistant improved wheat varieties during the study year. Household could be considered as an adopter even if he/she cultivated rust susceptible improved varieties on some portion of his/her wheat field. Given the binary nature of the dependent variable represented by a dummy variable 1 if a household cultivated disease resistant wheat variety and zero otherwise, a probit model would appropriately capture the adoption decision behavior of farm households. Following Green (2008), the probit model could be specified as follows:

$$Y_i^* = \beta X + \mu_i \qquad (1)$$

Where,

Y^*= an underlying latent variable that indexes farmers use of rust-resistant wheat variety

i = 1, 2, 3… n (observations)

β_i =regression coefficients to be estimated

u_i = a disturbance term, and

X = covariates.

The coefficients generated from these regression models through maximum likelihood estimates are not straight forward. Hence, marginal effects, the effect of a small change in the explanatory variables on the probability of a particular outcome (adoption of rust-resistant wheat varieties), are commonly presented. Marginal effects are used to interpret the magnitude by which a one unit change in an independent variable will change the probability of the outcomes.

Variables often considered in modeling the adoption decision of farmers included household and farm characteristics, attributes of the technology and institutional factors such as land tenure, access to markets, information and credit (Feder et al., 1985; Shiferaw and Holden, 1998; Gebremedhin and Swinton, 2003; Bekele and Drake, 2003; Yirga and Hassan, 2008). In this study, based on review of the relevant literature a range of household, farm and plot characteristics, institutional factors and locational dummies are hypothesized to influence adoption of improved wheat varieties used by smallholder farmers in mixed crop-livestock based farming systems of the highlands of Ethiopia (Table 7.2).

Among household demographic characteristic age, education level of the household head, family size and wealth (livestock ownership and type of house) are believed to have differential impacts on the adoption decision behaviour of smallholder farmers. Farm characteristics hypothesized to influence adoption of disease resistant wheat varieties are distance of input markets and social capital. Institutional factors often considered to have differential impacts on technology adoption by smallholder farmers are access to information, institutional credit and off-farm employment (Table 7.2).

Table 7.2: Definition of variables hypothesized to condition adoption of rust-resistant improved wheat varieties by smallholder farmers in wheat based farming systems

Variable	Description	Values
HH characteristics		
Age	Age of the head of the farm HH	Years
Education	Illiterate, do not read and write	1= yes, 0=no
	Read and write/religious education	1= yes, 0=no
	Elementary (2-6 grades)	1= yes, 0=no
	Secondary (>6 grades)	1= yes, 0=no
Model farmer	If household head is designated as a model farmer	1= yes, 0=no
Livestock	Number of livestock owned by a HH	TLU
House type	Whether a HH owned corrugated iron roofed house or not	1= yes, 0=no
Family size	Number of family members of a HH	Number
Perception on incidence of rust	Whether a HH has faced rust incidence during the 2010 rust epidemics	1= yes, 0=no
Farm and plot characteristics		
Farm size	Total land owned in ha (crop, fallow, grazing)	Number in ha
Institutional factors		
Training	If HH has received training on improved wheat production technologies	1= yes, 0=no
Extension	Frequency of extension contact	Number of contacts in a year
Field days	Have not attended any field day during the year	1=yes, 0=no
	Attended at most two field days	1=yes, 0=no
	Attended three or more fielded	1=yes, 0=no
Credit	If a HH had access to institutional credit for the purchase of improved seeds	1=yes, 0=no
Off-farm	If a HH member participate in off-farm income generating activities	1=yes, 0=no
Plot operated	Number of plots cultivated	Number
Location (Zonal Dummies)	East Gojam, Amhara	1=yes, 0=no
	West Gojam, Amhara	1=yes, 0=no
	Arsi, Oromia	1=yes, 0=no
	Bale, Oromia	1=yes, 0=no
	East Shewa, Oromia	Comparison Group

b) Impact model

We used the propensity score matching (PSM) technique which is based on identifying assumption of un-confoundedness, or selection on observables for tracing and estimating causal treatment effects when program participants (adopters) and non-program participants (non-adopters) differ in characteristics that affect the outcome of interest (productivity of wheat) (Rosenbaum and Rubin, 1983). Assuming observable characteristics may account for all outcomes of relevant differences, matching techniques could be used. Once the distributions of observable characteristics are reweighed and are made identical between treatment and control, all other differences are assumed irrelevant for the outcome and a straight comparison of means is possible. Since we are interested in the productivity, production and food security effects of adopting rust-resistant improved wheat varieties, the average treatment effect (ATT) measuring the mean gain from adopting rust-resistant improved wheat for those who actually adopted was the main parameter.

The PSM is based on four critical steps including estimation of the propensity scores, choosing a matching algorithm, checking on common support condition and testing the matching quality (Caliendo and Kopeinig, 2005). The first step in the estimation of the PSM model is the construction of the propensity scores. This requires the selection of the observable variables or covariates that allow the estimation of the propensity score. It is worth noting that the covariates should not be affected by the treatment or intervention, but at the same time they need to influence simultaneously the participation decision and the outcome variable. In this study a host of covariates, including age, gender, education, family size, farm size, access to extension, livestock ownership including oxen and location dummies are used. The second step involved estimating the probability of getting the treatment as a function of observable characteristics. As is the case, we used the probit model. The third step is the use of the predicted values from the estimation to generate propensity score P(X) for all adopter and non-adopter group members. The fourth step involves the matching of treated unit with a sample of controls with similar P(X) based on several matching algorithms including the nearest neighbor, the kernel and caliper. Finally, ATT is estimated and test for the balancing of the most relevant variables conducted.

Outcome variables: The survey allows evaluating the impact of rust-resistant wheat variety use on four outcome variables wheat productivity, wheat production, income from wheat sales and household food security. While wheat productivity is basically yield per unit area measured in kilograms per hectare, wheat production pertains to total wheat harvest from all wheat plots operated by a household during the study year. Similarly income from wheat sales is measured as the amount of money the household earned from the sale of wheat grain and seeds from own production during the study year. Food security in our survey was a self-assessment captured as 1 if the household faces food shortages throughout the year, 2 if the households faces food shortages some months in a year, 3 if the household is self-sufficient (breakeven) and 4 if the households produces surplus. From this variable two food security dummy variables are generated for the impact analysis. The first food security dummy variable (fsecure 1) divides the households into two sub-groups, households facing food shortages with a value label of zero and households in the breakeven and surplus in the other sub-group with a vale label of 1. The second food security dummy variable (fsecure 2) as in the first one divides the sample into two with households producing surplus in one group with a value label of 1 and zero otherwise.

c) Contribution of the project for better adoption

The project started without a baseline survey that would have been used to compare the adoption and use patterns of improved rust-resistant bread wheat varieties in the target areas. Lack of baseline data paused serious difficulty to exactly document the contribution of the project in meeting project objectives. Nevertheless, we used data from a household survey conducted at a national level for measuring wheat technology adoption levels just before the launch of the program. Therefore, the impact of the project in enhancing the adoption rate of rust-resistant bread wheat varieties is assessed by comparing the varietal adoption levels of the present survey (see the detail in part 3.2) and the 2011 survey made at national level (Chilot et.al., 2013). The 2011 survey covered a sample of 2096 household from 125 *kebeles* from 60 wheat growing districts in Amhara, Oromia, Southern Nations, Nationalities and Peoples and Tigray Regions

d) Impact on institutional innovation

In addition to the direct impacts of the project through enhanced adoption of rust-resistant varieties and benefits gained due to use of rust-resistant varieties, several institutional innovations has played key role in addressing future wheat rust epidemics are identified. These are related with

- a new approach of fast-tracking variety testing and release;
- procedures of adequate seed multiplication for pre-released candidate varieties that would ensure adequate multiplication of basic and certified seed production;
- intensive demonstration and field days to popularize rust-resistant varieties to create awareness among farmers, stakeholders and policy makers;
- small-pack seed distribution-cum-on-farm seed production reaching 46 target districts;
- alignment of the various seed system actors (research, seed enterprises, commercial farms etc.) to timely respond in cases of rust epidemics; and developed rust epidemics early warning system linked with enhanced capacity in terms of human resources and physical capacities.

The impact of these institutional innovations of the project were assessed through narration of information generated through Key Informant Interviews (KIIs) and Focus Group Discussions (FGDs) with relevant stakeholders (farmers, expert of MoA, researchers) and with project implementers (EIAR, ICARDA). Various reports of the project mainly progress reports were used to augment the information generated from KIIs and FGDs.

7.3 Results and Discussion

7.3.1 Household level adoption of rust-resistant wheat varieties and its determinants

a) Farmers' awareness of rust-resistant wheat varieties

Farmers' awareness about the different types of rust resistance wheat varieties plays a key role in the adoption of the varieties. The mean levels of awareness for each of the improved wheat varieties in the sample are provided in Table 7.3. Awareness of disease resistant improved wheat varieties was higher among households in the intervention villages than in non-intervention villages. Among the disease resistant varieties promoted by the project three varieties namely, *Kakaba, Danda* and *Digelu* are widely known by farmers among sample farmers in the study areas but more so in intervention villages than non-intervention villages. For *Kakaba*, the level of awareness was about 94% in intervention villages and 75% in non-intervention villages. Mean awareness across all the disease resistant varieties, however, was low.

Table 7.3 Levels of awareness for improved wheat varieties by sample households in the sample

Variety	Member of intervention community (N=259)	Non-Member of intervention community (N=194)	All sample HHs (N=453)
Kakaba	93.8	75.3	72.4
Danda'a	58.8	26.8	36.6
Digalu (HAR 3116)	33.0	19.1	22.3
Kubsa (HAR 1685)	28.9	14.9	18.8
Galema (HAR 604)	4.6	7.2	5.1
Mada Walabu (HAR 1480)	3.6	8.2	5.1
Tusie (HAR 1407)	4.6	4.6	4.0
Simba (HAR 2536)	7.2	0.5	3.3
Shorima	4.6	3.1	3.3
Hulluka	1.0	6.7	3.3
Ogolcho	2.6	5.2	3.3
Sof-Oumar (HAR 1889)	5.2	2.1	3.1
Wetera (HAR 1920)	6.7	0.0	2.9
Hidase	4.6	1.5	2.6
Ude (CD 95294-2Y)	5.2	0.0	2.2
Other bread wheat varieties	1.5	3.1	2.0
Ejersa (CD 98206)	2.6	2.1	2.0
Werer (Mamouri I)	3.6	0.0	1.5
Shina (HAR 1868)	1.0	2.1	1.3
Hawii (HAR 2501)	1.0	1.5	1.1
Yerer (CD 94026-4Y)	2.1	0.0	0.9
Pavon 76	1.0	0.0	0.4
Abola (HAR 1522)	1.0	0.0	0.4
Dinknesh (HAR 3919)	0.0	0.5	0.2
Tossa (HAR 3123)	0.0	0.5	0.2
Other durum wheat varieties	0.0	0.5	0.2
Foka	0.5	0.0	0.2
Obsa (Altar 84)	0.5	0.0	0.2

Source: Own survey, 2014

b) Adoption of disease resistant wheat varieties

In this study, a farmer is considered as an adopter if he/she used disease resistant improved wheat variety on any one of her/his plots during the study year. Proportion of households growing rust-resistant wheat varieties disaggregated by intervention village is given in Table 7.4. Of the rust-resistant improved wheat varieties promoted by the project only three varieties namely *Kakaba, Digalu* and *Danda'a* have been found to be grown during the study year. Among the three rust-resistant varieties *Kakaba* appear to be the most widely grown by 49% of households followed by *Digalu* and *Danda'a* grown by 14% and 5% of households, respectively. Adoption levels, measured by proportion of households growing the varieties, however, did not differ significantly between intervention villages and non- intervention villages which may be due the intensive farmer to farmer seed and information exchange. Discussions with key informants and community leaders revealed that despite the fact that non-intervention villages were not directly targeted by the project, most community members in non-intervention villages benefited from farm to farm exchange of information and seeds of rust-resistant varieties. The distinction between intervention and non-intervention villages, therefore, is somewhat murky as information received by community members quickly diffuse to non-intervention villages. Hence, in subsequent sections, discussions on adoption levels of rust-resistant varieties and adoption decision behaviour of farm households are presented by district.

Table 7.4: Proportion of households using improved wheat by target group as of 2014

Type of variety	Variety	Target				Sample (N=453)	
		Intervention villages (N=259)		Non-intervention villages (N=194)			
		No	%	No	%	No	%
Rust-resistant	Kakaba	127	49.0	95	49.0	222	49.0
	Digalu	33	12.7	32	16.5	65	14.3
	Danda'a	14	5.4	9	4.6	23	5.1
Rust susceptible	Kubsa	105	40.5	70	36.1	175	38.6
	Sofumar	10	3.9	2	1.0	12	2.6
	Wetera	8	3.1	0	0.0	8	1.8
	Mada-Walabu	4	1.5	4	2.1	8	1.8
	Pavon	1	0.4	0	0.0	1	0.2
	Hidase	1	0.4	0	0.0	1	0.2
	Ude	1	0.4	0	0.0	1	0.2
	Hulluka	1	0.4	0	0.0	1	0.2
	ET-13	0	0.0	2	1.0	2	0.4
	Millennium	0	0.0	1	0.5	1	0.2
	Simba	0	0.0	1	0.5	1	0.2
	Hawii	0	0.0	1	0.5	1	0.2
	Other improved	3	1.2	1	0.5	4	0.9
	Other local	0	0.0	0	0.0	0	0.0

Source: Own survey, 2014

Table 7.5 presents, adoption rate estimates of rust-resistant wheat varieties aggregated by district. On the whole, the proportion of wheat farmers adopted rust-resistant varieties is fairly high estimated at about 69%. Adoption rates, however, differed considerably from one district to another. Within the project intervention districts, adoption of rust-resistant wheat varieties is highest in Wonebera district of the Amhara Region while adoption rates are the lowest in Ada'a district with only 3% of households growing. However, it should be noted that Ada'a is not a hot spot for yellow rust. At a region level, the proportion of households using rust-resistant varieties is much better in Amhara with 85% of sample farmers growing rust-resistant varieties on 91% of the wheat area compared to Oromia Region grown by about 43% of households on 54.6% of the wheat area. In terms of area, about 67% of the wheat area is under rust-resistant varieties, the bulk of which is covered by the variety *Kakaba*. Among the non-resistant wheat varieties, *Kubsa* appears to be dominating covering about 30% of the wheat area given the fact that is was one of the mega-variety grown across the country before 2010 yellow rust epidemics.

Table 7.5: Adoption rates of rust-resistant wheat varieties, 2014

Region	District	Sample size (N)	HH adopting (%)	Wheat area under rust-resistant varieties (%)
Amhara	Debre Eleni	69	84.9	97.1
	Gozamen	73	20.0	53.8
	Wonberema	72	100.0	100.0
Oromia	Etossa	60	45.0	53.9
	Gedeb Asassa	60	38.3	36.9
	Sinanna	60	85.0	89.3
	Ada'a	60	3.33	3.5
Whole sample		453	62.7	68.8

Source: Own survey, 2014

Table 7.6 shows effect of individual variables on adoption of rust-resistant wheat varieties comparing mean values of adopters and non-adopters. Among others household resource endowments (livestock), human capital (education level), access to information, participation in field days, access to credit for purchasing improved seeds have a significant effect on adoption of rust-resistant wheat varieties. Location representing a household's propensity to have access not only to improved seeds but also information is found to have a significant effect on varietal adoption. On the other hand demographic factors such as age and gender represented by the sex of the household head did not have a significant effect on rust-resistant varietal adoption.

Table 7.6 Socio-economic characteristics of sample households by adoption status

	Pooled data (N=453)	Adopters (N=283)	Non-Adopters (N=169)
Sex of the HH			
Male	91.8	94.4	87.6
Female	8.2	5.6	12.4
Age of the HH (Years)	44.2	44.7	43.4
Education (% households)			
dmy_educ1	32.45	24.65	45.56
dmy_educ2	22.08	26.41	14.79
dmy_educ3	30.46	33.45	25.44
dmy_educ4	15.01	15.49	14.20
Extension (number of contacts)			
dmy_ext1	7.95	3.87	14.79
dmy_ext2	34.22	36.27	30.77
dmy_ext3	57.84	59.86	54.44
Participation in field days (number)			
flday_dmy1	52.76	40.49	73.37
flday_dmy2	32.67	39.44	21.30
flday_dmy3	14.57	20.07	5.33
Credit Access	35.32	38.73	29.59
Social capital	10.98	11.93	9.40
Ownership of corrugated house (%)	85.21	89.79	77.51
Off-farm job (% households)	26.93	24.30	31.36
Family size (no)	6.18	6.24	6.07
Number of plots	5.59	6.02	4.86
Land per person (ha)	0.43	0.46	0.40
Livestock (TLU)	7.80	8.77	6.16
Distance to seed market (Km)	3.53	3.32	3.90
Distance to district d market (Km)	10.36	10.30	10.45
Perception on wheat rust (%)	64.59	62.19	68.67
Zone (% households)			
East Gojam, Amhara (Comparison)	29.14	26.06	34.32
West Gojam, Amhara	31.13	38.38	18.93
Arsi, Oromia	26.49	17.61	41.42
Bale, Oromia	13.25	17.96	5.33

Source: Own survey, 2014

c) Determinants of adoption of disease resistant varieties

The dependent variable for the probit model is binary representing 1 if the household adopted rust-resistant wheat varieties, zero otherwise. Table 7.7 presents both estimated coefficients and the marginal effects along with the level of significance. The likelihood ratio statistics as indicated by the χ^2 statistics is highly significant (P<0.0000) suggesting strong explanatory power of the model.

Among the hypothesized variables education level of the household head, extension contact, participation in field days, access to credit for the purchase of improved seeds and livestock ownership positively and significantly impacted the probability of using rust-resistant wheat varieties. Other hypothesized variables such as sex, age of the household head, social capital, participation in off-farm activities and past experience with rust incidence, however, are found to have no effects on likelihood of using rust-resistant wheat varietal adoption.

Of the considered household characteristics, education level of the head of the household is found to have a positive impact on the chances of using rust-resistant wheat varieties. The chances of using rust-resistant wheat varieties would be higher by 18 % for a household with elementary level of education compared to a household with no formal education. Similarly, the likelihood of using rust-resistant wheat varieties would be higher by about 20% for a household with secondary level of education. Hence, public interventions aimed at improving farmers' access to formal education are likely to improve the likelihood of using rust-resistant varieties among smallholder farmers in the study area.

The institutional variables considered in the study were access to extension services, participation in field days and access to institutional credit for the purchase of improved seeds. As expected, access to extension services was positively and significantly associated with the use of rust-resistant wheat varieties. Other things being equal, the chance of using rust-resistant varieties would be higher by 24% and 22% for households having less frequent and more frequent extension contacts compared to a household who do not have any extension contacts. These results suggest that extension messages emphasizing the importance of switching to newly released disease resistant varieties supported by field days had a higher chance of success. These results, therefore, suggest an important role of increased institutional support to promote knowledge regarding tackling rust epidemics through the use of resistant varieties.

Access to institutional credit for the purchase of seeds of improved varieties has a positive and significant impact on the likelihood of using rust-resistant wheat varieties. A possible explanation is that households who have access to credit for the purchase of seeds and complementary inputs are more likely to invest on improved seeds and allocate a higher proportion of their the land to rust-resistant varieties while households who do not have access to institutional credit depend on own saved seeds from previous harvest and use recycled seed. A recent adoption and seed system studies in Ethiopia indicated that seed recycling is a common practice in wheat growing areas of Ethiopia (Chilot et.al. 2013; Bishaw et al. 2010; Dawit and Bishaw 2015). The adoption study indicated that about 84% of the wheat growers depend on recycled seeds and the majority recycles wheat seeds at least for 6 years. This and other studies have shown the importance of improving smallholder farmers' access to credit in enhancing the adoption of improved seeds and complementary inputs such as inorganic fertilizers.

Number of livestock owned, measured in TLU showed a positive and significant influence on the use of rust-resistant wheat varieties. Livestock is a source of traction, manure, cash and cushion against crop failures and other misfortunes. Households who own livestock are thus more likely to adopt rust-resistant varieties as these households could purchase seeds of newly released rust-resistant varieties from income generated from livestock products. The greater likelihood of using rust-resistant varieties, therefore, could be due to the fact that respondents owning livestock are relatively better off, have got the resources and management skills, and are able to take the production and marketing risks associated with using new wheat varieties.

It is widely believed that individual perceptions of incidence of rust epidemics and past knowledge of site specific conditions influence the adoption decision of smallholder farmers in the study area. Contrary to expectations, however, experience of rust epidemics in 2010 did not have a significant influence on the adoption decision behaviour of wheat growers. Focus group discussion with wheat growers revealed that most farmers perceive rust incidence as a random event associated mainly with climatic variability. Consequently, farmers tend to keep high yielding and popular wheat varieties susceptible to rust for a longer period than necessary believing that such varieties are likely to do better in subsequent years.

Another interesting result worth noting is the differential effect of location on the adoption decision of rust-resistant wheat varieties. All else being the same, the chances of adopting rust-resistant wheat varieties in the West Gojam Zone of the Amhara Region and Bale Zone Zones of Oromia would be higher by about 17% and 35%, respectively compared to a typical households in the East Shewa Zone of the Oromia zone, the comparison group. Most of the research and development organizations are actively engaged in the promotion of agricultural technologies in Arsi and East Shewa Zones of the country for a long time. As a result, farm households in these zones are weary of the information provided by external agents. In the other less addressed zones of Bale and West Gojam zones, however, new information and knowledge on farming are eagerly accepted. Moreover, on-farm wheat varietal trials, demonstrations and scaling up efforts besides providing new knowledge and experience required for adopting rust-resistant varieties, provided the initial seeds critical for farmer testing of rust-resistant wheat varieties.

d) Contribution in enhancing adoption of rust-resistant wheat varieties

The project has contributed to the adoption of the different rust-resistant bread wheat varieties (Table 7.8). As indicated in the methodology part, due to lack of baseline survey for the project, the contribution in enhancing adoption of rust-resistant bread wheat varieties is assessed by comparing the national adoption level estimates of wheat varieties for 2010/11 production season with the 2013/14 production season estimates. Accordingly, there is a considerable difference in the level of adoption of the rust-resistant varieties, especially for the popular rust-resistant varieties (*Kakaba* and *Digalu*), where higher adoption rates are reported compared to the estimates in 2010/11 production season. Somewhat perplexing result is the high adoption level reported for *Kubsa* variety, which is susceptible to rust where the adoption level was estimated to be about 24% in 2010/11 and it was 39% in 2013/14 production season. It is worth noting that in some agro-ecologies such as the semi-arid mid highlands, tepid to cool (SA2) and moist lowlands, hot to warm (M1), the level of use for *Kubsa* in 2010/11 was 55% and 43%, respectively. Furthermore, the earlier survey was conducted right the year after the rust epidemic where farmers immediately dropped *Kubsa*, but later on readopt the variety in the absence of rust disease in subsequent years. Though, low level of adoption, older rust-resistant varieties was reported under use in the 2013/14 production season (Table 7.8).

Table 7.7: Parameter estimates of the determinants of rust-resistant wheat variety use: probit model estimates

Variable	Coefficient	SE	Z-value	P>|Z|	Marginal Effect
Sex of the HH	0.0953	0.2689	0.3500	0.7230	0.0348
Age of the HH (Years)	0.0025	0.0061	0.4000	0.6860	0.0009
Education of the HH					
dmy_educ2 (elementary)	0.5450	0.2042	2.6700	0.0080	0.1786
dmy_educ3 (Junior secondary)	0.5816	0.1942	3.0000	0.0030	0.1948
dmy_educ4 (Senior secondary)	0.2898	0.2627	1.1000	0.2700	0.0983
Extension (number of contacts)					
dmy_ext2	0.7272	0.3085	2.3600	0.0180	0.2420
dmy_ext3	0.6011	0.3017	1.9900	0.0460	0.2175
Participation in field days					
flday_dmy2	0.4210	0.1683	2.5000	0.0120	0.1447
flday_dmy3	0.8533	0.2552	3.3400	0.0010	0.2509
Credit Access	0.3689	0.1561	2.3600	0.0180	0.1282
Social capital	0.0100	0.0064	1.5700	0.1170	0.0036
Ownership of corrugated house	0.1827	0.2179	0.8400	0.4020	0.0672
Off-farm job	-0.2641	0.1655	-1.6000	0.1110	-0.0969
Family size	-0.0859	0.0421	-2.0400	0.0410	-0.0308
Number of plots	0.0543	0.0410	1.3200	0.1850	0.0195
Land per person	-0.7814	0.3746	-2.0900	0.0370	-0.2800
Livestock (TLU)	0.0807	0.0186	4.3500	0.0000	0.0289
Distance to seed market (km)	0.0050	0.0241	0.2100	0.8360	0.0018
Distance to district d market (km)	-0.0368	0.0138	-2.6600	0.0080	-0.0132
Perception on wheat rust	0.0757	0.1554	0.4900	0.6260	0.0273
Zone (dummies)					
West Gojam, Amhara	0.4930	0.2084	2.3700	0.0180	0.1674
Arsi, Oromia	-0.1468	0.2504	-0.5900	0.5580	-0.0534
Bale, Oromia	1.4812	0.3071	4.8200	0.0000	0.3540
Number	449				
LR chi2	150.98				
Prob > Chi2	0.00				
Log-Likelihood	-264.88				
Pseudo R-Square	0.2552				

Table 7.8. Adoption levels of wheat varieties

Rust resistance	Variety	2010/11 production season[1]	2013/14 production season[2]
Resistant varieties	Kakaba	-	49.0
	Digalu	2.2	14.3
	Danda'a	-	5.1
	Mada Walabu	5.1	1.8
	Pavon 76	4.7	0.2
	Hidase	-	0.2
	Ude	-	0.2
	Hulluka	-	0.2
	Tusie	3.7	-
Susceptible varieties	Kubsa	23.9	38.6
	Galema	10.3	-
	Dashen	8.2	-
	ET-13	3.3	0.4
	Enkoy	2.0	-
	Simba	1.5	0.2
	Hawii	-	0.2
	Sofumar	-	2.6
	Wetera	-	1.8
	Millennium	-	0.2

Source: [1] Chilot et al. (2013) and [2]own survey, 2014

7.3.2 Impact of adoption rust-resistant wheat varieties on productivity, production and household food security

a) Assessing the matching quality

As noted in the methodology section we estimated the probability of participating in adopting rust-resistant wheat varieties using a *probit* model to evaluate the impact of adopting rust-resistant wheat varieties on selected outcomes. We used three matching techniques namely Single Nearest Neighbor Matching, Kernel based matching with band width 0.25, and Caliper matching of 0.01.

Several tests are often used that would allow to gauge the matching quality (Sianesi, 2004). The first and basic method used to gauge quality of the match is covariate balancing tests before and after matching. This method basically compares the regression results before and after matching to identify whether there still are differences between both groups. As expected, the regression results revealed that statistical differences observed before matching disappeared after matching suggesting the matching strategy has worked. The second parameter used to assess matching quality is to compare the pseudo-R^2 after matching with the one obtained with all the observations (before matching). After matching there should be no systematic differences in the distribution of covariates between adopting and non-adopting households and for this reason the pseudo-R2 should be low. As shown in Table 7.9, the pseudo-R^2 for all the three matching algorithms used are significantly reduced from an average of about 8.6% before matching to about 1.5 % after matching. The third parameter considered in the assessment of matching quality is the comparison of bias before and after matching. Generally, the literature suggests that a mean bias less than 5% after matching is considered acceptable. In our case, of the three matching algorithms considered in the analysis, the Single Nearest Neighbor Matching and Kernel provided the best match with about 3.9% and 4.5 % mean bias after matching, respectively (Table 7.9). Overall, the low pseudo-R^2, low mean standardized bias, high total bias reduction, and the insignificant p-values of the likelihood ratio test after matching suggest that the proposed matching strategy has worked in terms of balancing the distribution of covariates between adopting and non-adopting households. Reported results, therefore, are based on the Single Nearest Matching and Kernel Matching algorithms that provided the best fit including only adopting and non-adopting households in the common support distribution.

b) Impact of using rust-resistant wheat varieties on wheat productivity and production

Table 7.10 provides the mean wheat productivity and production of adopters and non-adopters as well as the average treatment effect on the treated for Single NNM and Kernel matching algorithms that provided the best match. On average, adopters not only enjoyed higher productivity but also produced more wheat than non-adopters. The mean difference between adopters of rust-resistant varieties and non-adopters (used conventional varieties) ranges from 351 to 455 kg/ha and are statistically significant, suggesting the use of rust-resistant wheat varieties significantly improved wheat productivity and production. The results therefore unequivocally suggest that adoption of rust-resistant wheat varieties has a significant and positive effect on wheat productivity.

Table 7.9: Key statistics for assessing quality of the propensity score matching, impact of adopting rust-resistant wheat varieties on wheat productivity, production and food security

Outcome variable	Matching method	Ps R2 before matching	Ps R2 after matching	LR chi2 before matching (P-value)	LR chi2 after matching (P-value)	Mean bias before matching	Mean bias after matching	Total % (bias) reduction
Yield (kg/ha)	Single nearest neighbor matching	0.0887	0.008	52.45 (0.000)	3.7 (0.999)	21.3	3.8	82.159
	Kernel bwidth (0.25)	0.0851	0.017	50.37 (0.000)	13.09 (0.596)	30.9	4.4	85.760
	Caliper	0.0851	0.018	50.37 (0.000)	13.47 (0.566)	31.3	5.2	83.386
Production (kg/ha)	Single Nearest Neighbor Matching	0.0884	0.010	52.32 (0.000)	4.58 (0.995)	23.4	3.9	83.333
	Kernel bwidth (0.25)	0.0852	0.018	50.38 (0.000)	13.41 (0.571)	31.2	4.7	84.935
	Caliper	0.0852	0.018	50.38 (0.000)	13.12 (0.593)	30.9	6.2	79.935
Income from sale wheat seed and grain (Birr)	Single nearest neighbor matching	0.0887	0.010	52.45 (0.000)	4.83 (0.993)	24.1	4.1	82.987
	Kernel bwidth (0.25)	0.0851	0.018	50.37 (0.000)	13.56 (0.559)	31.4	4.6	85.350
	Caliper	0.0851	0.018	50.37 (0.000)	13.47 (0.566)	31.3	5.2	83.386
Binary food security (HH produce surplus)	Single nearest neighbor matching	0.0887	0.010	52.45 (0.000)	4.83 (0.993)	24.1	4.1	82.987
	Kernel bwidth (0.25)	0.0851	0.018	50.37 (0.000)	13.56 (0.559)	31.4	4.6	85.350
	Caliper	0.0851	0.018	50.37 (0.000)	13.47 (0.566)	31.3	5.2	83.386

Table 7.10 Mean treatment effect of adopting rust-resistant wheat varieties on wheat productivity and production

Outcome variable	Matching algorithms	Adopters	Non-adopters	ATT	t-stat
Wheat yield (kg/ha)	Single NNM	2975	2624	351	2.72
	Kernel band width (0.25)	3071	2650	421	3.47
	Caliper (0.01)	3066	2611	455	2.80
Wheat production (kg/ha)	Single NNM	3396	2811	585	1.52
	Kernel band width (0.25)	3761	2926	836	2.02
	Caliper (0.01)	3765	2359	1406	3.19

c) Impact of using rust-resistant wheat varieties on cash earnings

Smallholder farmers in the wheat- based farming systems of Ethiopia are generally cash constrained. Several studies indicated that lack of cash for the purchase of critical agricultural inputs such as improved seeds and fertilizer are identified among the major impediments to widespread adoption of improved technologies including improved wheat varieties (Feder et al, 1985). Hence, in this analysis, we assessed the impact of adopting rust-resistant wheat varieties on cash earnings using income from wheat and crop sales as a second set of outcome variables.

Our results show that the use of rust-resistant varieties has a positive impact on cash earnings of adopting households. This impact is reflected in an increase of the cash earnings from sales of wheat grain and seeds. The impact of adopting rust-resistant wheat varieties on crop income, however, although positive is not statistically significant (Table 7.11).

Table 7.11 Mean treatment effect of adopting rust-resistant wheat varieties on income form wheat and crop sales,

Outcome variable	Matching algorithms	Adopters	Non-adopters	ATT	t-stat
Income from wheat seed and grain sales (Birr)	Single NNM	9795	8391	1404	1.10
	Kernel band width (0.25)	11994	9292	2702	1.79
Income from crop sales (Birr)	Single NNM	13708	12459	1249	0.65
	Kernel band width (0.25)	16963	13967	2995	1.38

d) Impact of using rust-resistant wheat varieties on household food security

Table 7.12 presents the mean treatment effect of adopting rust-resistant varieties on self-reported household level food security obtained using the propensity matching. Two outcome variables based on self-assessment of households are constructed to capture food security at household level. The first food security dummy variable (fsecure 1) divides the households into two sub-groups, households facing food shortages with a value label of zero and households in the breakeven and surplus in the other sub-group with a vale label of 1. The second food security dummy variable (fsecure 2) as in the first one divides the sample into two with households producing surplus in one group with a value label of 1 and zero otherwise. As noted on Table 7.12, adoption of rust-resistant wheat varieties significantly increased the likelihood of food security as measured by fsecure 2. The impact of adopting rust-resistant varieties on perceived household food security measured by fsecure1, although, positive is not statistically significant. The results, therefore, suggest that the use of rust-resistant varieties have improved the wellbeing of smallholder farmers. Interventions amid at promoting the adoption and diffusion of rust-resistant varieties should be intensified to further consolidate the gains achieved thus far.

Table 7.12 Mean treatment effect of adopting rust-resistant wheat varieties on wheat productivity, production and food security based on several matching techniques

Outcome variable	Matching algorithms	Adopters	Non-adopters	ATT	t-stat
Binary food security = fsecure2 (1 if HH produces surplus)	Sngle NNM	0.199	0.120	0.078	0.040
	Kernel bwidth (0.25)	0.214	0.159	0.055	0.038
Binary food security = fsecure2 (1 if HH produces surplus)	Sngle NNM	0.765	0.747	0.018	0.047
	Kernel bwidth (0.25)	0.804	0.804	0.000	0.045

e) Impact on institutional innovation to address rust related epidemics

Results of the KII and FRG discussions revealed that the project have created institutional innovation in areas of fast-tracking variety testing and release, accelerated seed multiplication especially for pre-released candidate varieties, alignment of the various seed sector actors to ensure the seed demand from farmers' is fulfilled, and development of rust epidemics early warning system (Table 7.13).

Fast-track variety testing and release (FTVR): **Among the institutional innovations of the project is the introduction of fast track variety testing and release (FTVR) approach. This FTVR approach is a system where international and national research system actors collaborate to release varieties that are resistant to rust disease challenges. Through the project a partnership among ICARDA, CIMMYT and EIAR has been established to fast track variety testing and releases. Accordingly, 40 sets of 6523 wheat entries from ICARDA and CIMMYT international nurseries and 41 sets of 3504 wheat entries/lines from NARS were evaluated and five rust-resistant wheat promising lines were identified for verification and release in 2014 (Abebe, et al., 2014). This approach also gave priority for adaption of resistant varieties for abroad for quick release and also seed multiplication of candidate varieties for release (Table 7.13). A total of 10 stem rust and/or yellow rust resistant varieties were released through accelerated and/or regular approaches associated with the two projects from 2010 to 2014.**

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Table 7.13 Impact on institutional innovation to address wheat rust epidemics

Innovation	Conventional approach (before the project)	Project innovation (after the project)
Fast track variety testing and release	• Variety testing took formal and protracted procedure • Pre-release seed multiplication was not allowed	• Facilitated a 'crash' program for fast tracking variety testing and release for emergency situation • Created a system for pre-release seed multiplication procedure for selected candidate varieties • Aligning variety release with popularization and demonstration to create awareness and demand for seed
Accelerated seed multiplication of source seeds	• Early generation seed multiplication was made once a year • Early generation seed multiplication conducted only at research centers located in mid and highland environments	• Institutionalized a system to multiply early generation seed twice a year • Created a system where early generation seed multiplication is done in all potential areas including lowland irrigated environments • Alignment to fulfill demand was made by linking early generation seed production with certified seed production by public and private sector including public and private farms • Aligning of formal and informal seed systems using on-farm seed production with farmers through revolving seed system;
Alignment of the actors of wheat seed system	• Early generation seed was multiplied only considering multiplication capacity • Limited linkage between the formal and informal seed system	• Full engagement of regional, zonal and district BoA including the administration, extension experts, development agents, seed regulatory agencies in seed production and popularization • Full engagement of public and private seed sector as well as private and public commercial farms to ensure the multiplication of all seed classes (early generation and certified), • Work modalities of alignment became institutional culture in organizations involved
Early warning system of rust epidemics	• Ad hoc assessment of epidemics	• Institutionalized early warning system at MoA (Plant Health and Regulatory Directorate) in collaboration with NARS

Accelerated seed multiplication (ASM): Lack of seeds in sufficient quantities has been a major hurdle in promoting newly released improved varieties including rust-resistant varieties in Ethiopia. As a result the time lag between variety release, seed multiplication and farmer adoption of released varieties has been very high (Chilot et al. 2013). Unlike the conventional approach which takes several years to produce sufficient quantities of newly released wheat varieties, the project designed and implemented an accelerated source seed multiplication (ASM) approach.

The ASM approach involves both planning and implementation of enhanced micro-seed increase and maintenance breeding; accelerated pre-release and post-release seed multiplication of breeder, pre-basic and basic seed during the main and off-seasons using irrigation; and large-scale certified seed multiplication through both formal and informal. These activities were conducted through engaging relevant federal and regional research centers, and building their capacity in multiplication of source seed both during the main and off-season mainly through investments in irrigation facilities at research centers involved in wheat research.

Micro-seed increase and maintenance breeding in wheat seem to have been institutionalized at all wheat research centers including Kulumsa, Holetta, and Debre Zeit Research Centers of EIAR, Sinanna Research Center of OARI, Mekelle Research Center of TARI, Sirinka Research Center of ARARI, and Areka Research Center of SARI. Similarly, under the ASM approach, considerable amount of certified seed of rust-resistant bread wheat varieties were multiplied and supplied through the formal and informal channels.

The project purchased and provided farm machineries for research centers and mobile seed cleaning equipment for seed producers which proved to be critical for seed multiplication. Such capacities built by the project would allow actors to provide required service in a sustainable manner at least in the years to come.

Alignment of the actors of wheat seed system: The other critical institutional innovation introduced by the project is alignment of stakeholders for greater synergy. As a first step in the alignment process, institutions that have a stake along the seed value chain from the development of new wheat varieties to seed production, marketing and promotion activities were identified. Accordingly various actors in the seed system including research, seed producers, quality regulators, marketing agents specially cooperatives and BoA are identified as critical for moving seeds of newly released varieties form research centers to the final clients, smallholder farmers. The identified institutions were then brought together for clarifying mandates, expectations and roles. The discussions culminated in alignment of the various operations essential to fulfill the revealed demand by farmers and/or to create demand for new technologies.

Linked with strengthening the variety testing and release, source and certified seed multiplication, creation of a mechanism to align the different actors in the wheat seed system has been one of the impacts of the project. The project ensured the alignment through a mechanism where actors of the research system (EIAR and RARIs), seed producers (public seed enterprises and seed growers), extension system (MoA and BoA), and farmers themselves managed to work together. The project has created a system where seed multiplication was made not only in the mid and highland environments but also in lowland environments for which the country is well endowed with. This alignment is normally reflected in the multiplication of required type and amount of source seed (breeder, pre-basic and basic seed) for the production of the demanded type and quantity of certified seed. The linkage created between the formal and informal wheat seed system especially in the form of revolving wheat seed system, which run by local offices of agriculture, has contributed to process of fulfilling revealed demand. In addition, this alignment has helped timely distribution of the produced certified seed to farmers.

Developing rust early warning systems: Early warning systems for adverse effects play important role to reduce the impact of the events like drought, flood or disease epidemics. Early warning is about providing timely notice to elicit appropriate responses that will reduce or eliminate the impact of the adverse event (Davies, et al., 1991).

The wheat rust incidence in 2010 has affected considerable area in the major growing areas of Amhara, Oromia and SNNP Regional States covering an estimated total area of 591,590 ha in 289 districts. Consequently, fungicides were the only viable option at hand to control the rust epidemics. And yet, in the same year only 30% of the total affected wheat area was treated with fungicides costing the county about USD 3,273,810, which is about ETB 55 million. Experience from elsewhere in the world indicated that such costs could be reduced substantially or even avoided totally had the country instituted an early warning system capable of early detection of the epidemics. Accordingly, the project invested in building the capacity to predict rust epidemics through human capacity building, availing required facilities, and adequate sensitization of relevant stakeholders for early warning and establishment of working modalities.

The human capacity building included provision of practical training for model farmers, frontline extension workers, and SMS about identification of wheat rust incidence, reporting system, management options etc. The physical facilities provided to relevant stakeholders were provision of vehicles to enhance mobility in wheat production areas for surveillance. The created system is linked with the joint surveillance visits of researchers, experts of MoA and BoA, and fungicide reserve system in case of serious outbreak of wheat rust.

Plant health and regulatory directorate is responsible for the early warning system in close collaboration with regional BoA and the National Agricultural Research System.

7.4 Conclusion

The contribution of the project in enhancing the adoption of rust-resistant wheat varieties was very high especially for the recently released varieties like *Kakaba, Digelu,* and *Danda'a* varieties. The results indicate that there is clear evidence that the project has had a significant impact on wheat productivity, production, cash earnings and household food security. These results suggest that future project interventions aimed at promoting rust-resistant wheat varieties should focus in wheat growing areas that have not been addressed by the regular extension system. Furthermore, future programs should not only be limited to information provision but also consider credit provision that do not exclude the poorest farmers of the agricultural sector. Further research on this topic would require additional data and evaluation of impacts in other dimensions (e.g. environmental effects or costs of production).

In addition to the direct impacts of the project through enhanced adoption of rust resistance varieties and benefits gained due to use of those varieties, the project has contributed in putting in place institutional innovations indispensable for addressing current and future wheat rust epidemics. Among others, the institutional innovations established a fast-track variety testing and release approach; designed and implemented new procedure of adequate seed multiplication for pre-released varieties that can ensure adequate multiplication of basic and certified seed production; created a mechanism for alignment of the various seed system actors (research, seed enterprises, commercial farms etc.) to timely respond in cases of rust epidemics; and developed rust epidemics early warning system linked with built capacity in terms of human resources and physical capacities.

Wheat rusts remain major threats for wheat production in Ethiopia. Despite the impact of adoption of rust-resistant varieties on farmers' livelihoods, there is serious lack of varieties with stable and durable resistance where their longevity is very short lived. It is evident that recent experiences demonstrated that the conventional approach of development and deployment of rust-resistant varieties alone will not address the impeding risk of wheat production in the country. It is time to take stoke and make a concerted effort to develop an integrated strategy to tackle the rust threats. Developing a capacity for rust surveillance, use of chemical control and diversification of wheat-based production system are some of the measures need to be taken in addition to rust-resistant varieties. More importantly bringing together the wheat value chain actors particularly of durum wheat varieties by linking producers with markets is critical in the diversification efforts and to tackle the rust problems.

References

Alemu D and Z Bishaw. 2015. Commercial behaviours of small-holder farmers in wheat seed and its implication for seed demand assessment in Ethiopia. *Development in Practice, 25 (6):*798-814

Atilaw A, Z Tadesse, S Aliye, B Bekele, Z Bishaw, A Fikre, S Ahmed, and S Silim. 2014. Rapid Deployment of Rust-resistant Wheat Varieties for Achieving Food Security in Ethiopia. Fourth Quarterly Report (July – September 2014). October, 2014. Addis Ababa, Ethiopia

Augurzky B and C Schmidt. 2001. The propensity score: a means to an end. Discussion Paper No. 271, IZA.

Bekele W and L Drake. 2003. Soil and water conservation decision behavior of subsistence farmers in the Eastern Highlands of Ethiopia: a case study of the Hunde-Lafto area. *Ecological economics*, 46: 437 - 451.

Bishaw Z, PC Struik, and AJG van Gastel. 2010. Wheat seed system in Ethiopia: Farmers' varietal perception, seed sources and seed management. *Journal of New Seeds*: 11 (4): 281-327

Caliendo M and S Kopeinig. 2008. Some practical guidance for the implementation of propensity score matching. IZA Discussion Paper No. 1588, University of Cologne.

CSA (Central Statistical Agency). 2015. Report on Area and Production of Major Cereals (Private Peasant Holdings, Meher Season). Agricultural Sample Survey 2014/15 (2007 EC), Statistical Bulletin 578, Central Statistical Agency, Addis Ababa, Ethiopia.

Davies S, M Buchanan-Smith and R Lambert. 1991. Early Warning in the Sahel and Horn of Africa: The State of the Art: A Review of the Literature. IDS Research Report 20. Brighton: IDS

Feder G, EJ Richard and Z David. 1985. Adoption of agricultural innovations in developing countries: a survey. *Economic development and cultural change*, 33: 255-298.

Gebremedhin B and SM Swinton. 2003. Investment in soil conservation in northern Ethiopia: the role of land tenure security and public programs, *Agricultural Economics*, 29: 69-84.

Greene WH. 2008. Econometric analysis (6th Edition). Upper Saddle River, NJ: Prentice-Hall

Yirga C and RM Hassan. 2008. Multinomial logit analysis of farmers' choice between short and long-term soil fertility management practices in the Central Highlands of Ethiopia. Ethiopian Journal of Agricultural Economics, 7(1): 83-102.

Yirga C, M Jaleta, B Shiferaw, Hugo de Groote, M Kassie, T Mebratu, and A Mohammad. 2013. Analysis of Adoption and Diffusion of Improved Wheat Technologies in Ethiopia. Research Report 101. EIAR, Addis Ababa, Ethiopia.

Rosembaum PR and DB Rubin. 1983. The Central Role of the Propensity Score in Observational Studies for Causal effects, Biometrika, Vol.70, No.1, pp. 41–55.

Shiferaw B and S Holden. 1998. Resource degradation and adoption of land conservation technologies in the Ethiopian highlands: a case study in Andit Tid, North Shewa. *Agricultural Economics*, 18:233-247.

Sianesi B. 2004. An evaluation of the active labor market programs in Sweden. *The Review of Economics and Statistics*, 186(1):133-155.