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INTERNATIONAL MAIZE AND WHEAT IMPROVEMENT CENTER

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* Bekele Hundie Kotu is an agricultural economist at the Sinana Agricultural Research Center, Bale, Ethiopia. At the time this paper was drafted, Hugo Verkuijl was an associate scientist at the International Maize and Wheat Improvement Center (CIMMYT), Addis Ababa, Ethiopia. Wilfred Mwangi is a principal economist with CIMMYT and also Director of Agriculture, Ministry of Agriculture, Kenya. Douglas Tanner is an agronomist with CIMMYT, also based in Ethiopia. The views expressed in this paper are the authors' and do not necessarily reflect policies of their respective institutions.

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Abstract: This study assessed farmers' current wheat management practices, determined the technical and socioeconomic factors affecting the adoption of wheat technologies, and drew implications for research, extension, and policy. Adopters of improved varieties were younger, more educated, had larger families and farms, hired more labor, and owned more livestock. Farmers identified the following traits as important in wheat varieties: high yield, resistance to sprouting and lodging, seed color and size, and baking quality. The main constraint to adopting improved wheat varieties was the high price of seed. Both adopters and nonadopters preferred the wheat variety Pavon-76, suggesting that Pavon-76 has important traits that farmers appreciate and that should be considered in national and regional wheat breeding programs. In particular, farmers' perceptions of the disease and lodging resistance of improved wheats positively influenced their adoption. However, the perceived bread baking quality of the varieties negatively influenced adoption of improved wheats. This trait should be given higher priority by wheat breeding programs. The tobit analysis revealed that access to credit is an important factor in a farmer's decision to adopt improved wheat technologies (variety and fertilizer). Credit in kind not only relaxes the cash constraint currently existing in most farm communities, but also facilitates input availability for farmers. Hired labor is another determinant of a farmer's ability to adopt higher nitrogen fertilizer rates. This finding highlights the importance of developing labor-saving wheat production technologies to offset the cost of hired labor and expand the adoption of nitrogen fertilizer.

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ACRONYMS and ABBREVIATIONS

CIDA	Canadian International Development Agency
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo (International Maize and Wheat Improvement Center)
CSA	Central Statistical Authority
DA	Development agent
DAP	Diammonium phosphate
EACP	Eastern Africa Cereals Program
ESE	Ethiopian Seed Enterprise
IAR	Institute of Agricultural Research
masl	Meters above sea level
NGO	Non-governmental organization
OADB	Oromia Agricultural Development Bureau
PA	Peasant Association
SG-2000	Sasakawa Global-2000
SPSS	Statistical Package for Social Sciences
TLU	Tropical Livestock Unit
WADO	Woreda Agricultural Development Office

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EXECUTIVE SUMMARY

Wheat is one of the major cereal crops grown in Ethiopia. In sub-Saharan Africa, Ethiopia ranks second to South Africa in terms of total wheat area and production. In Ethiopia, wheat ranks fourth in total cultivated area and production. Despite the significant area of wheat production in the country, the mean national wheat yield (1.3 t/ha) is 24% below the mean yield for Africa and 48% below the global mean yield. This relatively low mean national yield may be partially attributed to the low level of adoption of improved wheat production technologies. Hence, the objectives of this study were to: assess farmers' current wheat management practices, determine the technical and socioeconomic factors affecting the adoption of wheat technologies, and draw implications for research, extension and policy.

Since its inception in 1966, the Institute of Agricultural Research (IAR, now renamed Ethiopian Agricultural Research Organization (EARO)) of Ethiopia has released a number of high yielding wheat varieties and recommended associated crop management practices. The wheat technologies promoted in Adaba and Dodola woredas included improved wheat varieties (ET-13, HAR-710, HAR-1685, and HAR-1709), fertilizer types and rates (100 kg/ha DAP and 100 kg/ha urea as a blanket recommendation), and weed control practices (hand weeding, 1.0 l/ha U-46 for control of broadleaf weeds).

Adopters of improved varieties were younger, more educated, and had larger families and farms. Also, adopters hired more labor and owned more livestock. Nonadopters appeared to have more off-farm income than adopters, but this difference was not significant. There were no significant differences between adopters and nonadopters in terms of the number of farm implements owned (e.g., hand hoes, ox-plows, or oxen carts).

During 1997, about 42% of farmers in the study area planted improved wheat varieties. About half of the adopters grew Kubsa (=HAR-1685) or Wabe (=HAR-710). For the adopters, about 65% of their total wheat area was allocated to improved wheat varieties. In Adaba, about 34% of farmers planted improved wheat varieties compared to 48% of farmers in Dodola. Moreover, the mean area under improved wheat varieties was significantly larger in Dodola (0.5 ha) than in Adaba (0.2 ha). Pavon-76 was the most popular variety, preferred by 35% of adopters and 43% of nonadopters. The next most popular variety was Kubsa, which was preferred by 28% and 20% of adopters and nonadopters, respectively. Farmers identified the following varietal traits as important: high yield, resistance to sprouting and lodging, seed color and size, and baking qualities. The main constraint to adopting improved wheat varieties was the high price of seed.

Most of the adopters (55%) began land preparation in March, while the nonadopters (48%) began preparation in February. More than 80% of farmers in both groups planted wheat in June. Average seed rates were 185 kg/ha and 178 kg/ha for adopters and nonadopters, respectively, which were higher than the recommended rate of 150-175 kg/ha. Farmers preferred a higher seed rate to compensate for low soil fertility and to compete with weed infestations.

Wheat and barley received priority for fertilizer application by 98% and 88% of adopters and 80% and 82% of the nonadopters, respectively. Significantly more adopters (95%) applied chemical fertilizer than nonadopters (75%). Adopters applied about 88 kg/ha of DAP and 81 kg/ha of urea, while nonadopters applied about 78 kg/ha of DAP and 60 kg/ha of urea; however, average fertilizer rates for both groups were below the recommended rate of 100 kg/ha DAP and 100 kg/ha urea. The main constraint to fertilizer use for both groups was its high price. Crop rotation and fallowing were two other important soil fertility management practices.

According to both farmer groups, broadleaf and grassy weeds were equally important in their wheat fields. Farmers controlled weeds by hand weeding or herbicide application. About 95% and 87% of adopters controlled weeds by hand weeding and herbicides, respectively, while 93% and 61% of nonadopters used hand weeding or herbicides, respectively. According to 75% of farmers, the most problematic weed that was not controlled by existing weed control measures in wheat fields was *Snowdenia polystachya*. The most important diseases were "leaf rust" (*Puccinia striiformis*) and "stem rust" (*P. graminis*), while cut worms, wild animals, and army worms were the most important pests. None of the farmers attempted to control diseases and only 9% of adopters and none of the nonadopters practiced pest control. The main reason for not controlling diseases and pests was a lack of knowledge of appropriate control measures.

Farmers obtained formal credit through the agricultural development offices of their respective woredas in the form of farm inputs (fertilizer, improved seed, and herbicides). About 85% of adopters and 60% of nonadopters had access to credit for the purchase of fertilizer, while 48% and 9% of adopters and nonadopters, respectively, had access to credit for the purchase of improved seed. The main credit constraints for both groups were high interest rates and a lack of cash for the required 25% down payment. All adopters and 99% of nonadopters had received an extension visit. Other sources of agricultural information were farmer field days, training courses, and broadcast radio messages.

The age of the farmer, the use of credit, and several varietal characteristics preferred by farmers (disease and lodging resistance and baking quality) significantly influenced the area allocated to improved wheat varieties. The marginal effect of the farmer's age on the area under improved wheat varieties was -0.01, and farmer's age decreased the probability of adoption among nonadopters by 1.5%. The marginal effect of the use of credit on improved wheat area was 0.59, and credit increased the probability of adoption among nonadopters by 84.3%. The marginal effect of disease preference on improved wheat area was 0.32, and the probability of adoption among nonadopters increased by 45.2% if the varieties were perceived to be more disease resistant. However, the marginal effect of baking quality on improved wheat area was -0.21, and the probability of adoption among nonadopters decreased by 29.9%. Lodging resistance was the third significant varietal characteristic preferred by farmers. The marginal effect of lodging resistance on improved wheat area was 0.31, while the probability of adoption among nonadopters increased by 44.2%.

The farmer's total wheat area, number of livestock, and the use of hired labor and credit significantly influenced the amount of fertilizer used. The marginal effect of a farmer's total wheat area on the mean amount of fertilizer used was -0.08, and wheat area decreased the probability of adoption among nonadopters by only 0.3%. The marginal effect of hired labor on the amount of fertilizer used was 0.25; the corresponding increase in the probability of adoption among nonadopters was 1.0%. The marginal effect of the number of livestock (TLU) owned on the amount of fertilizer used was 0.01, and TLU increased the probability of adoption among nonadopters by 0.04%. The marginal effect of credit on the amount of fertilizer used was 0.80, and credit increased the probability of adoption among nonadopters by only 3.2%.

Both adopters (50%) and nonadopters (53%) preferred Pavon-76, which suggests that it has traits important to farmers that should be considered in national and regional wheat breeding programs. In particular, the perceived resistance to disease and lodging of the improved wheat varieties were traits that positively influenced their adoption. However, the perceived bread baking quality negatively influenced the adoption of improved wheat seed. Hence, this trait should be given a higher priority by wheat breeding programs.

The tobit analysis revealed that access to credit is an important factor affecting a farmer's decision to adopt improved wheat technologies. Credit in kind not only relaxes the cash constraint currently existing in most farming communities, but also facilitates the availability of inputs to farmers. Therefore, credit in the form of improved seed and fertilizer should be made available to all wheat farmers. Hired labor was also found to positively influence the adoption of improved fertilizer practices. This highlights the importance of developing labor-saving wheat production technologies to offset the cost of hired labor and expand the adoption of N fertilizer.

Livestock ownership was an important factor which influenced the adoption of fertilizer. Livestock ownership is one means for farmers to minimize the risks associated with crop failure. Livestock represent the main cash source for financing crop production. Therefore, research and extension staff should give more attention to livestock production issues.

Adoption of Improved Wheat Technologies in Adaba and Dodola Woredas of the Bale Highlands, Ethiopia

Bekele Hundie Kotu, Hugo Verkuijl, Wilfred Mwangi, and Douglas Tanner

1.0 INTRODUCTION

1.1 Wheat Production in Ethiopia

Wheat is one of the major cereal crops grown in Ethiopia. In sub-Saharan Africa, Ethiopia ranks second to South Africa in terms of total wheat area and production. In Ethiopia, wheat ranks fourth in total crop area and production. It is grown in the highlands at altitudes ranging from 1500 to 3000 masl, situated between 6-16ºN and 35-42ºE; however, the most suitable agroecological zones for wheat production fall between 1900 and 2700 masl (Hailu Gebremariam 1991). Major wheat production areas are located in the Arsi, Bale, Shewa, Ilubabor, Western Harerghe, Sidamo, Tigray, Northern Gonder, and Gojam regions (Figure 1).

Export of Ethiopian wheat flour increased until the late 1940s. After this period, due to growing domestic demand for wheat, wheat exports declined. Between 1944 and 1952, Ethiopia exported 697,652 tons of cereals and pulses with a total value of 120.7 million Birr (7 Birr = 1 US$); however, since 1957, Ethiopia has become a net grain importer. Between 1961 and 1997, total wheat area increased from 364,000 to 1,450,000 ha, while total wheat production increased from 255,000 t to 1.980,000 t. Mean grain yield increased from 0.7 t/ha in 1961 to 1.4 t/ha in 1997 (Hailu Gebremariam 1991; CSA 1997a; Payne *et al.* 1996). Despite the growth in wheat area and total production, Ethiopia continues to be a net wheat importer.

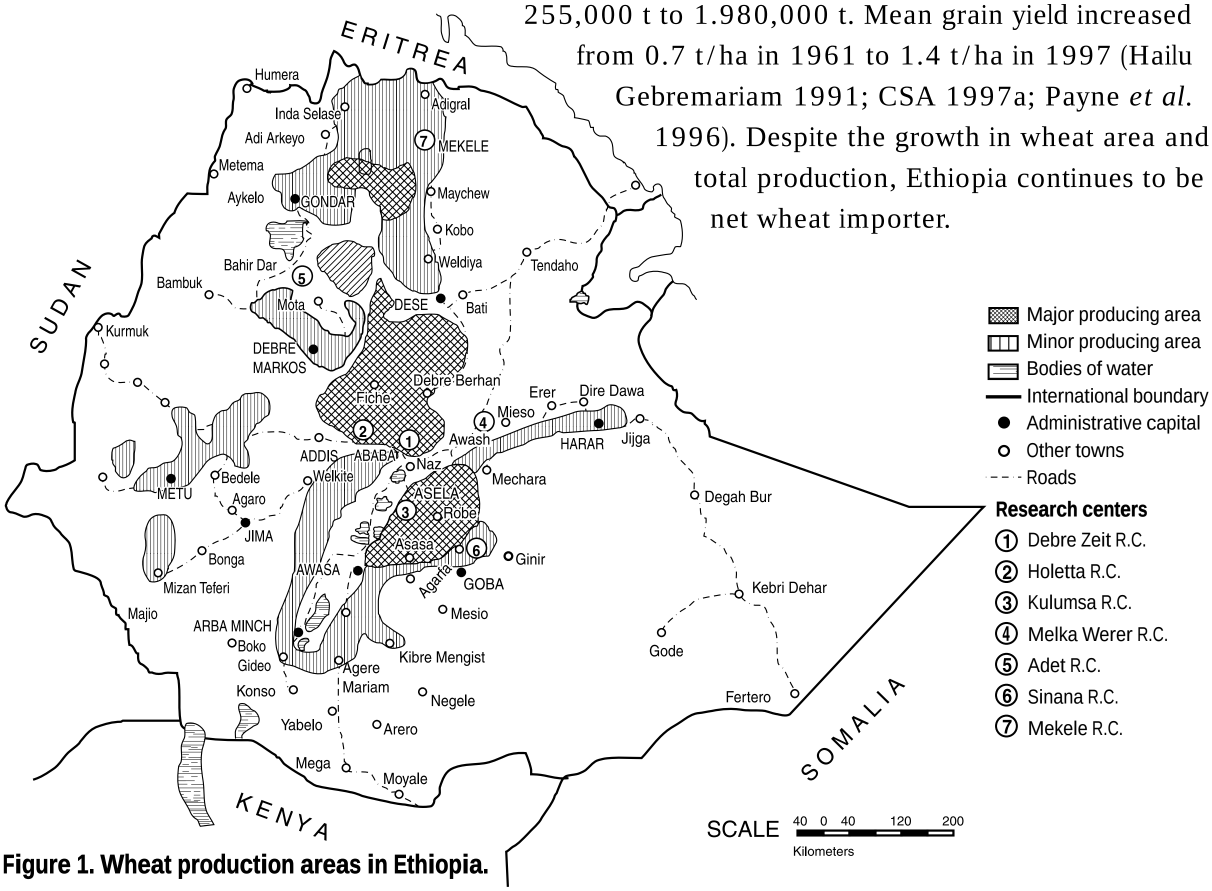

Figure 1. Wheat production areas in Ethiopia.

Throughout much of the Bale Highlands, wheat is produced in two seasons (*belg* and *meher*, being the short and long rainy season, respectively). In the study area, about 77% of total wheat production occurs during the meher season. The mean yield in the meher season (1.3 t/ha) exceeds that of the belg season (0.97 t/ha). During the meher season of 1998, wheat was the principal cereal crop, covering 41.6% of the area allotted to cereals, whereas in the belg season it covered 27.3%. Similarly, wheat accounted for 41.5% and 28.7% of total cereal production in the meher and belg seasons, respectively (CSA 1998a, b).

Three different categories of wheat producers have been identified in the Bale Highlands: small-scale farmers, state farms, and producer cooperatives. The small-scale farmers (i.e., private peasant holdings) contribute the largest wheat area, which has increased from 17,380 ha in 1985 to 103,390 ha in 1997. Similarly, small-scale wheat production increased from 13,482 t in 1985 to 121,736 t in 1997. Mechanized state farms were considered to be at the forefront of agricultural development during the tenure of the Marxist-oriented, previous government of Ethiopia. Thus, state farms were commercial wheat producers in the Bale Highlands prior to 1991. Nevertheless, after the fall of the previous regime, the current government has given more attention to small-scale farmers and private investors. Thus, the area of wheat managed by state farms has declined since 1991, falling from 29,550 ha in 1985 to 10,160 ha in 1990. Similarly, the total wheat production by state farms decreased from 43,133 t in 1985 to 9,273 t in 1997. Producer cooperatives were also more active before 1991, cultivating 4,620 ha of wheat in 1985 and 10,160 ha in 1990. However, most of the producer cooperatives collapsed after 1991 (CSA, various years).

Despite the significant area of wheat production in Ethiopia, the mean national wheat yield of 1.3 t/ha is 24% below the mean yield for Africa and 48% below the global mean yield (Gavian and Gemechu 1996). This relatively low figure may be partially attributed to the low level of adoption of improved wheat production technologies. Hence, the objectives of this study were to assess farmers' current wheat management practices, determine the technical and socioeconomic factors affecting the adoption of wheat technologies, and draw implications for research, extension, and policy.

1.2 The Study Area

The study area is situated in the southeastern highlands of Ethiopia—an area known for its high production potential for crops and livestock. More specifically, it encompasses Adaba and Dodola woredas in the northwestern region of the Bale Highlands. Adaba and Dodola woredas comprise 373,579 ha of land and are the major wheat producing areas in the Bale Highlands. Elevation ranges from 2300 to 2600 masl. The human population consists of about 223,310 people of which 87% depend on agriculture. The area is characterized by unimodal rainfall. Rainfall data received from four weather stations (Hunte, Herero-1, Herero-2, and Serofta) indicate that during 1990-1997 the study area received a mean rainfall of 728 mm per annum. The mean rainfall received during the cropping months (June-October) was 485 mm (Figure 2). Mean monthly maximum temperatures recorded at two weather stations (Hunte and Dodola) ranged from 19.6ºC in July to 23.3ºC in February, while the mean minimum temperatures ranged from 7.2ºC in February to 10.4ºC in July.

The soils in the study area are dominated by chromic and pellic vertisols, and dystric and humic cambisols. Chromic and pellic vertisols are heavy clay soils, found predominantly in flat areas. During the dry season, these soils shrink and exhibit deep cracks. During the wet season, the clay swells and exhibits low permeability. Pellic vertisols are dark and occur in the northern part of the study area. Dystric and humic cambisols mainly occur in steep sloping areas at high altitude where rainfall is high (Dereje Dejene and Mohammed Hassena 1994).

1.3 Improved Wheat Technology Recommendations

Since its inception in 1966, the Institute of Agricultural Research (IAR, renamed Ethiopian Agricultural Research Organization, or EARO) released a number of high yielding wheat varieties and recommended associated crop management practices. The Oromia Agricultural Development Bureau (OADB), Sasakawa-Global 2000 (SG-2000), and other organizations have extended these production technologies to selected contact farmers. Such technological packages have been delivered to farmers through the extension package program of the OADB, which is a continuation of the extension program started by SG-2000. Farmers host the demonstrations on half a hectare of land, and provide a down payment of 25% of the cost of inputs, the balance of which is settled at the time of harvesting. The number of farmers hosting demonstration trials in the Bale Highlands has increased dramatically since 1995, when the government increased the emphasis given to the extension of improved agricultural technologies as a means of achieving food self-sufficiency. The wheat technologies promoted in Adaba and Dodola woredas included improved wheat varieties ET-13, Wabe (=HAR-710), Kubsa (=HAR-1685), and Mitike (=HAR-1709); a blanket fertilizer recommendation of 100 kg/ha DAP and 100 kg/ha urea for wheat; and hand weeding and herbicides (1 l/ha of U-46) to control weeds

Other improved wheat varieties, such as Pavon-76 and Dashen, are still widely grown by farmers; however, these were introduced more than a decade ago and are not currently recommended. Thus, for the purposes of this study, these varieties are considered as local wheat varieties. Table 1 lists some of the agronomic characteristics of the wheat varieties grown in the Bale Highlands.

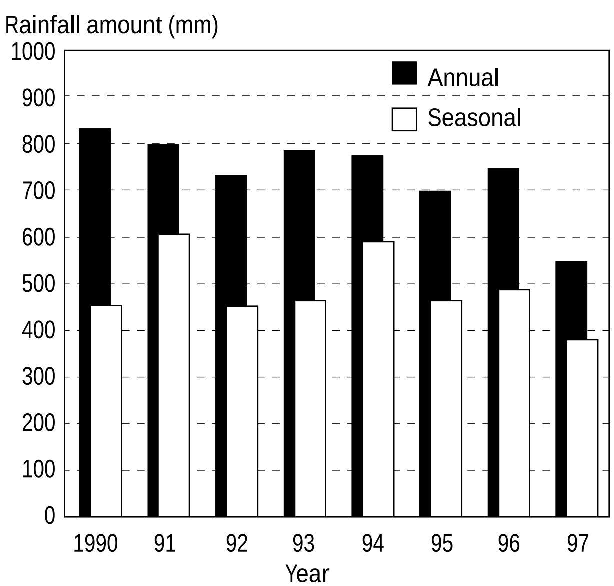

Figure 2. Mean annual and seasonal (June-October) rainfall, Adaba and Dodola, Ethiopia.

Table 1. Agronomic characteristics of wheat varieties grown in the Bale Highlands

Wheat variety	Year released	Maturity (days)	Height (cm)	Grain color	Yield (qt/ha)
Pavon-76	1982	120-135	90	White	30-60
Dashen	1984	130-149	94	White	30-60
Israel	NA (Local)	120-130	113	White	20-40
K6295-4A	1980	128-131	97	Red	30-60
Kubsa	1994	120-140	81	White	50-70
Wabe	1994	120-140	90	White	40-60
Mitike	1993	125-135	98	White	30-60
ET-13	1980	120-140	97	White	30-60

Source: Adapted from Asmare Yallew *et al.* (1997).

2.0 METHODOLOGY

2.1 Sampling Procedure

A multi-stage purposive sampling procedure with a stratified random sampling method was used to identify the sample units (i.e., the farmers). First, peasant associations (PAs) were purposively selected based on their potential for wheat production and accessibility to vehicles. Then, members of each PA were stratified in two groups based on the gender of the household head. A systematic random sampling technique was applied within each stratum to obtain a sample of 144 farmers, consisting of 108 male and 36 female heads of households. Primary data formed the core of the study and were obtained from farmers using a structured questionnaire. The questionnaire was developed through an informal farming system survey that provided qualitative data on farmers' practices and circumstances. Information obtained through the survey was supplemented by secondary data from Woreda Agricultural Development Offices (WADOs) and informal interactions with extension staff. The questionnaire was administered from October 1997 to January 1998.

2.2 Analytical Model

Factors influencing the adoption of new agricultural technologies can be divided into three major categories: 1) farm and farmers' associated attributes; 2) attributes associated with the technology (Adesina and Zinnah 1992; Misra *et al*. 1993); and 3) the farming objective (CIMMYT 1988). Factors in the first category include the farmer's education level, age, and family and farm size. The second category varies with the type of technology, e.g., the characteristics a farmer prefers in an improved wheat variety, such as high yield, disease resistance, quality of the grain for bread making, resistance to lodging, and maturity. The third category includes the influence of different farm strategies, such as commercial versus subsistence farming, on the adoption of technologies.

For this study, a tobit model was used to test the factors affecting the mean proportion of land allocated to improved wheat varieties or the amount of fertilizer (N kg/ha) used. A tobit model (McDonald and Moffitt 1980; Maddala 1983) that tests the factors affecting the incidence and intensity of adoption can be specified as follows:

$$
\begin{aligned}
Y_t &= X_t\beta + U_t && \text{if } X_t\beta + U_t > 0 \\
&= 0 && \text{if } X_t\beta + U_t \le 0 \\
& && t = 1, 2, \ldots, N
\end{aligned}
$$

where:

- Y_t = the proportion of land (ha) allocated to improved wheat varieties or the amount of fertilizer (N kg/ha) at a given stimulus level X_t;
- N = number of observations;
- X_t = vector of independent variables;
- β = vector of unknown coefficients;
- U_t = independently distributed error term assumed to be normal with zero mean and constant variance σ^2.

$X_t\beta$ is the index reflecting the combined effect of the independent X variables that inhibit or promote adoption. For the current study, the index level $X_t\beta$ was specified as follows:

$$X_t\beta \ = \ \beta_0 + \beta_1 X_1 + \ldots + \beta_{12} X_{12} + \varepsilon_i$$

where:

- β_0 = constant;
- X_1 = WHEAT (area under wheat, ha);
- X_2 = AGE (age of the household head, yr);
- X_3 = EDUC (education level of household head, dummy variable);
- X_4 = LABOR (family labor, number of adults per household);
- X_5 = HLABOR (hired labor, dummy variable);
- X_6 = CREDIT (credit obtained by farmer for improved varieties or fertilizer, dummy variable);
- X_7 = TLU: Tropical livestock units (index where livestock numbers are aggregated using the following weighting factors: oxen and cows = 1.0, goats = 0.08, sheep = 0.08);
- X_8 = EXTEN (farmer received extension visit, dummy variable);
- X_9 = GENDER (sex of the household head, dummy variable);
- X_{10} = DISEASE (farmer prefers the variety to be free of diseases, dummy variable);
- X_{11} = BREADTST (farmer prefers the baking quality of the grain in bread; dummy variable);
- X_{12} = LODGING (farmer prefers the variety to resist lodging; dummy variable);
- ε_i = error term.

Formation of the model was influenced by a number of working hypotheses. It was hypothesized that a farmer's decision to adopt or reject a new technology at any time is influenced by the combined (simultaneous) effect of a number of factors related to the farmer's objectives and constraints (CIMMYT 1993). The following variables were hypothesized to influence the allocation of land to improved wheat varieties or the amount of fertilizer used.

Farm size: The amount of wheat area (X_1) is an indicator of wealth and can perhaps serve as a proxy for social status and influence within a community. It is expected to be positively associated with the decision to adopt improved wheat technology. However, a small area allocated to wheat could conceivably encourage farmers to intensify their production practices. In this case, larger farm size would be negatively related to the adoption of improved wheat technology.

Farmer's age: Farmers' age (X_2) can either generate or erode confidence in new technology. In other words, with more experience, a farmer can become more or less risk-averse when judging new technology. This variable could thus have a positive or negative effect on a farmer's decision to adopt improved wheat technology.

Education: Education (X_3) could increase the farmer's ability to obtain, process and use information relevant to the adoption of improved wheat technology. Education is thus thought to increase the probability that a farmer will adopt improved wheat technology.

Household size: Large households will be able to provide the labor that might be required to implement improved wheat technologies. Thus, household size (X_4) is expected to increase the probability of the adoption of improved wheat technologies.

Hired labor: Similarly, access to hired labor (X_5) is expected to be positively related to the adoption of improved wheat technologies.

Credit: Farmers who have access to credit can minimize their financial constraints and therefore buy inputs more readily. Thus, it is expected that access to credit (X_6) increases the probability of adopting improved wheat technologies.

Livestock: Ownership of livestock (X_7) is expected to positively influence the adoption of improved wheat technologies.

Extension: Agricultural extension services provided by the OADB are the major source of agricultural information in the study area. It is hypothesized that contact with extension workers (X_8) will increase a farmer's likelihood of adopting improved wheat technologies.

Gender of household head: The gender of the household head (X_9) can positively or negatively influence the adoption of improved wheat technologies.

Disease resistance: Farmers are expected to prefer wheat varieties that are disease resistant (X_{10}).

Quality of grain for bread making: The perceived quality of the grain for bread making (X_{11}) is expected to affect the adoption of improved wheat varieties.

Resistance to lodging: Farmers are expected to prefer wheat varieties that are resistant to lodging (X_{12}). For example, the improved wheat varieties Kubsa and Wabe are relatively short-statured and are therefore more resistant to lodging; this is expected to have a positive effect on the adoption of these improved wheat varieties.

3.0 SOCIOECONOMIC AND DEMOGRAPHIC CHARACTERISTICS OF SAMPLE HOUSEHOLDS

3.1 Demographic and Socioeconomic Characteristics

The demographic and socioeconomic characteristics of the adopters and the nonadopters of improved wheat varieties are shown in Table 2. About 69% of the adopters live in Dodola, while 33% live in Adaba. Most adopters (85%) were male. These differences in location and gender were significant at $p<0.1$. Most adopters (73.3%) and nonadopters (65.4%) were Muslim, while about 27% of adopters and 33% of nonadopters were Orthodox Christian. About 75% of adopters were literate compared to 56% of nonadopters ($\chi^2 = 3.6$; $p<0.1$). The adopters (41.8 years) were significantly younger than the nonadopters (47.7 years) (t=2.2; p<0.05). Adopters had larger families (9 persons) than nonadopters (7.6 persons) (t=1.9; p<0.1). The average number of permanent workers did not differ between adopters (2.4) and nonadopters (2.3). There was also no difference between the average number of part-time workers hired by adopters (2.2) and nonadopters (2.4).

About 66% of adopters hired labor compared to 49% of nonadopters (p<0.1); however, nonadopters hired labor for 26 person-days/year compared to 24 person-days/year for adopters (NS). The average wage for hired labor was significantly higher for nonadopters (4.9 Birr/day) compared to adopters (4.4 Birr/day) (t=1.9; p<0.1). The majority of adopters and nonadopters hired labor for wheat and barley production (Table 2), most of which was used during harvesting and weeding. About 57% of adopters and 50% of nonadopters reported that hired labor was readily available. This difference was not significant.

Table 2. Demographic and socioeconomic characteristics of sample farmers, Bale Highlands, Ethiopia

	Adopters of improved wheat technologies		Nonadopters of improved wheat technologies		
	Mean	**Standard deviation**	**Mean**	**Standard deviation**	**t-test**
Farmer's age (yr)	41.8	15.3	47.7	16.2	2.2**
Family size (no.)	9.0	4.5	7.6	3.5	1.9*
Full-time workers (no.)	2.4	1.6	2.3	1.4	0.7 (NS)
Part-time workers (no.)	2.2	1.2	2.4	2.1	0.6 (NS)
Hired labor (person-days/yr)	23.7	22.3	26.1	30.3	0.4 (NS)
Wage rate hired labor (Birr/day)	4.4	1.1	4.9	1.3	1.9*
	Number of farmers	**Percent of farmers**	**Number of farmers**	**Percent of farmers**	χ^2
Woreda					2.9*
Adaba	19	33.1	37	45.1	
Dodola	42	68.9	45	54.9	
Gender					3.6*
Male	52	85.2	59	72.0	
Female	9	14.8	23	28.0	
Education					6.2*
None	15	24.6	36	43.9	
Basic education	18	29.5	21	25.6	
Primary education	20	32.8	19	23.2	
Secondary education	8	13.1	6	7.3	
Hired labor	40	65.6	40	49.4	3.7*
	Number of responses	**Percent of farmers**	**Number of responses**	**Percent of farmers**	χ^2
Crops that used hired labor					NC
Wheat	16	41.0	26	63.4	
Barley	14	35.9	20	48.8	
Linseed	6	15.4	7	17.1	
All crops	19	48.7	13	31.7	
Other	12	30.7	8	19.5	
Activities that used hired labor					NC
Weeding	12	30.8	20	48.8	
Harvesting	27	69.2	31	75.6	
Threshing	11	28.2	14	34.1	
Other	8	20.5	9	21.9	

Note: NS= not significant; * = significant at p<0.1; ** = significant at p<0.05; NC = not calculated.

For both groups, the main activities for men within the household were land preparation, planting, fertilizer application, and harvesting (Table 3). Women and children were mainly involved in weeding, threshing, and grain storage.

The main source of income for adopters (96.7%) and nonadopters (97.5%) was the sale of farm produce. Off-farm activities provided another important source of income for adopters (36.7%) and nonadopters (43.2%). Details of crops sold and off-farm activities are shown in Table 4. The most important cash crops for adopters were wheat (98.3%), faba beans (46.6%), and linseed (43.1%), while for nonadopters they were wheat (87.5%) and linseed (43.8%). Livestock sales (35%) were the third-most important generator of income for nonadopters. Most off-farm income was derived from trade for both adopters (32%) and nonadopters (29%). Other farm activities such as poultry and bee-keeping were also important sources of off-farm income for 41% and 29% of adopters and nonadopters, respectively. Casual labor provided the third-most important off-farm activity for 9% of adopters and 29% of nonadopters.

3.2 Land Holdings and Land Use Pattern

The total cultivated area for Adaba and Dodola was 25,732 ha and 25,825 ha, respectively. Table 5 shows the land holdings and land use pattern for farmers in the study area. About 98% and 93% of adopters and nonadopters, respectively, grew wheat (NS). Wheat area was significantly larger for adopters (1.5 ha) than nonadopters (1.1 ha) ($t=2.3$; $p<0.05$). Barley was grown by more adopters (92%) than nonadopters (81%) ($\chi^2 = 3.5$; $p<0.1$); however, the area under barley was almost equal for adopters (0.8 ha) and nonadopters (0.9 ha). Close to 50% of adopters and nonadopters grew linseed and the cultivated area was about 0.6 ha for both groups. About 44% of adopters and 34% of nonadopters grew teff (NS); however the cultivated area was significantly smaller for adopters (0.4 ha) than for nonadopters (0.5 ha) ($t=2.0$; $p<0.1$). Faba beans and field peas were grown by 38% and

Table 3. Allocation of labor to main cropping activities by sample farmers, Bale Highlands, Ethiopia

Type of activity	Adopters of improved wheat technologies (%)			Nonadopters of improved wheat technologies (%)		
	Men	Women	Children	Men	Women	Children
Land preparation	98.3	5.4	8.0	98.7	1.5	3.6
Planting	94.9	12.5	8.0	93.5	9.0	10.9
Fertilizer application	89.8	5.4	8.0	88.3	6.0	7.3
Weeding	39.0	94.6	90.0	32.5	82.1	81.8
Insecticide application	25.4	17.9	16.0	33.8	6.0	7.3
Harvesting	71.2	30.4	32.0	71.4	25.4	38.2
Threshing	54.2	57.1	56.0	53.2	55.2	69.1
Storage	47.5	73.2	76.0	40.3	80.6	85.5
Selling	47.5	30.4	14.0	52.5	52.2	32.7

Table 4. Farmers' sources of income, Bale Highlands, Ethiopia

Income source	Adopters of improved wheat technologies		Nonadopters of improved wheat technologies	
	Number of responses	Percent of farmers	Number of responses	Percent of farmers
Farm produce				
Wheat	57	98.3	70	87.5
Barley	13	22.4	22	27.5
Linseed	25	43.1	35	43.8
Teff	15	25.9	24	30.0
Faba bean	27	46.6	9	11.3
Field pea	9	15.5	3	3.8
Livestock	19	32.8	28	35.0
Other	8	13.8	10	12.5
Off-farm activities				
Poultry and bee-keeping	9	40.9	10	28.6
Trade	7	31.8	10	28.6
Casual work	2	9.1	10	28.6
Other	9	40.9	17	48.6

Table 5. Land holdings and land use pattern, Bale Highlands, Ethiopia

	Adopters of improved wheat technologies		Nonadopters of improved wheat technologies		
	Mean	Standard deviation	Mean	Standard deviation	t-test
Crops cultivated (ha)					
Wheat	1.48	1.00	1.14	0.70	2.3**
Barley	0.81	0.39	0.86	0.49	0.7 (NS)
Linseed	0.60	0.40	0.58	0.39	0.3 (NS)
Teff	0.37	0.24	0.53	0.37	2.0*
Faba beans	0.35	0.23	0.33	0.23	0.2 (NS)
Field peas	0.49	0.30	0.36	0.23	1.3 (NS)
Other crops	0.55	0.45	0.57	0.39	0.2 (NS)
Land holdings (ha)					
Total farm size	3.47	1.63	2.81	1.51	2.5**
Sharecropped land	1.46	0.77	1.80	1.23	0.9 (NS)
Cultivated area	3.27	1.44	2.63	1.42	2.6***
Fallow area	0.78	0.64	0.67	0.51	0.6 (NS)
Number of parcels	3.70	1.80	3.50	1.60	0.7 (NS)

Note: NS = not significant; * = significant at p<0.1; ** = significant at p<0.05; *** = significant at p<0.01.

31% of adopters, respectively, and about 22% and 16% of nonadopters, respectively ($p<0.05$). The area under faba beans was close to 0.35 ha for both groups, while the area under field peas was 0.5 ha for adopters and 0.4 ha for nonadopters (NS).

Total farm size was significantly larger for adopters (3.5 ha) than for nonadopters (2.8 ha) ($t=2.5$; $p<0.05$). Likewise, adopters (3.3 ha) had a significantly larger cultivated area than nonadopters (2.6 ha) ($t=2.6$; $p<0.01$). Fifteen percent of adopters and twelve percent of nonadopters sharecropped their land, and the two groups sharecropped similar amounts of land. The area under fallow was also similar for adopters (0.8 ha) and nonadopters (0.7). Both groups owned about four parcels of land. About 94% and 97% of adopters and nonadopters, respectively, received their land as an allocation from the local PA. About 8% of adopters rented or inherited their land, while 2% and 5% of nonadopters rented or inherited their land, respectively.

3.3 Livestock Ownership

The average number of tropical livestock units (TLU) was significantly higher for adopters (9.2) than for nonadopters (6.2) ($t=2.7$; $p<0.01$) (Table 6). About 92% and 95% of adopters and nonadopters, respectively, owned oxen. The average number of oxen owned appeared to be slightly higher for adopters (2.8) than nonadopters (2.4), but this difference was not significant. Eighty-one percent of the adopters owned cows compared to about 84% of the nonadopters. The average number of cows,

Table 6. Livestock owned by sample farmers, Bale Highlands, Ethiopia

	Adopters of improved wheat technologies		Nonadopters of improved wheat technologies		
Livestock	Mean	Standard deviation	Mean	Standard deviation	t-test
Tropical livestock units	9.2	7.7	6.2	5.5	2.7***
Oxen	2.8	1.6	2.4	10.4	1.4 (NS)
Cows	4.4	4.6	3.3	2.9	1.7*
Donkeys	1.8	1.0	1.7	1.0	0.3 (NS)
Equines	2.7	2.1	2.4	1.6	0.8 (NS)
Horses	2.1	1.4	1.5	1.1	1.7*
Sheep	4.7	3.7	4.5	2.5	0.3 (NS)
Goats	3.8	2.2	3.7	2.7	0.2 (NS)
Young bulls	3.0	1.6	1.7	0.8	1.8*
Calves	2.6	1.9	2.1	1.3	0.9 (NS)
Heifers	3.5	2.7	1.8	1.0	2.1*

Note: NS = not significant; * = significant at p<0.1; *** = significant at p<0.01.

however, was significantly higher for adopters (4.4) than nonadopters (3.3) ($t=1.7$; $p<0.1$). For adopters, about 58% and 77% owned donkeys and equines, respectively, while 63% of nonadopters owned both donkeys and equines. The average number of donkeys and equines did not differ significantly between groups. About 62% and 42% of the adopters owned sheep and goats, respectively, while 58% and 16% of nonadopters owned sheep and goats, respectively. The average number of sheep (4.6) and goats (3.8) was almost equal for both groups. About 46% of adopters and 47% of nonadopters owned horses. On average, adopters (2.1) owned more horses than nonadopters (1.5) ($t=1.7$; $p<0.1$). Thirty-nine percent of adopters and 26% of nonadopters owned other livestock (young bulls, heifers, and calves). The average number of young bulls (3.0) and heifers (3.5) owned by adopters was significantly higher than the average number of young bulls (1.7) and heifers (1.8) owned by nonadopters ($p<0.1$). The average number of calves did not differ significantly between adopters and nonadopters.

3.4 Farm Mechanization

Farmers used traditional and mechanized implements for different farm operations. The types of traditional implements used by sample farmers are shown in Table 7. The adopters appeared to own more hand hoes, ox plows, ox harrows, ox carts, and sickles than nonadopters; however, these differences were not significant. The most important constraint to farm mechanization for 68% of the adopters and 77% of the nonadopters was a lack of cash to purchase and/or hire farm implements. Other constraints included the unavailability of farm implements, land fragmentation, the nature of the terrain, and lack of knowledge. About 71% of adopters and 53% of nonadopters used mechanized farm implements ($p<0.05$). About 44% and 42% of adopters and nonadopters, respectively, used a tractor for land preparation, while 93% and 100% of adopters and nonadopters, respectively, used a combine harvester.

Table 7. Farm implements owned by sample farmers, Bale Highlands, Ethiopia

	Adopters of improved wheat technologies		Nonadopters of improved wheat technologies		
	Mean	**Standard deviation**	**Mean**	**Standard deviation**	**t-test**
Farm implement					
Hand hoe	1.6	0.8	1.3	0.5	1.4 (NS)
Ox plow (*maresha*)	1.8	1.1	1.6	0.7	1.5 (NS)
Ox harrow	1.7	1.0	1.0	0.0	1.6 (NS)
Ox cart (*gurtoo*)	1.2	0.5	1.1	0.2	1.1 (NS)
Sickle	2.0	1.0	1.8	0.9	0.9 (NS)
	Number of responses	**Percent of farmers**	**Number of responses**	**Percent of farmers**	
Farm mechanization constraint					NC
Lack of cash to buy/hire	41	68.3	63	76.8	
Unavailability	22	36.7	19	23.2	
Land fragmentation	17	28.3	28	34.1	
Nature of the terrain	13	21.7	20	24.4	
Lack of knowledge	2	3.3	7	8.5	
Other	12	20.0	13	15.9	

Note: NS = not significant; NC = not calculated.

4.0 ADOPTION OF RECOMMENDED WHEAT PRODUCTION PRACTICES

4.1 Wheat Varieties Grown and Sources of Seed

During 1997, about 42% of farmers planted improved wheat varieties, while 58% planted only local varieties. For the adopters, about 65% of their wheat area was allocated to improved wheat varieties. The adoption of improved wheat varied across woredas. In Adaba, about 34% of farmers planted improved varieties compared to 48% of farmers in Dodola ($\chi^2=2.9$; $p<0.1$). Moreover, the average area under improved wheat was significantly larger in Dodola (0.5 ha) compared to Adaba (0.2 ha) ($t=3.8$; $p<0.01$). About 51% of adopters planted Kubsa (HAR-1685), 49% planted Wabe (HAR-710), and 8% planted Mitike (HAR-1709). During 1997, 65% of the area farmed by adopters was planted to improved wheat varieties. About 41% of adopters planted Pavon-76, 10% planted Dashen, 12% planted Israel, 8% planted K6295–4A, 5% planted ET-13, and 3% planted other local wheat varieties. The most important varieties grown by nonadopters were Pavon-76 and Dashen. About 51% of nonadopters planted Pavon-76, 27% planted Dashen, 7% planted Israel, and 10% planted other local wheat varieties.

Figures 3 and 4 illustrate the total area planted to the most important wheat varieties for adopters and nonadopters from 1992 to 1997. The figures show that the area under Kubsa and Wabe increased for the adopters, while the area under Pavon-76 and Dashen increased for the nonadopters.

About 95% of adopters and 75% of nonadopters indicated that they had increased their total improved wheat area over time. The main reason given by adopters (90.9%) and nonadopters (78.3%) for increasing wheat area was the high market price of wheat compared to alternative crops.

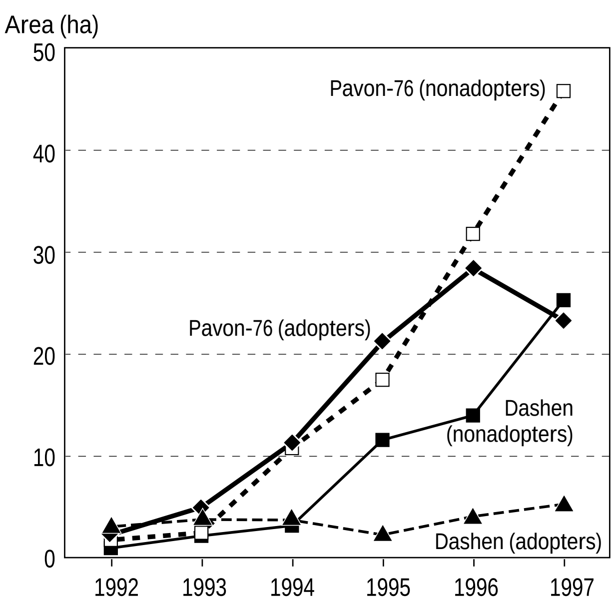

Figure 3. Area planted to the most important local wheat varieties, Bale Highlands, Ethiopia.

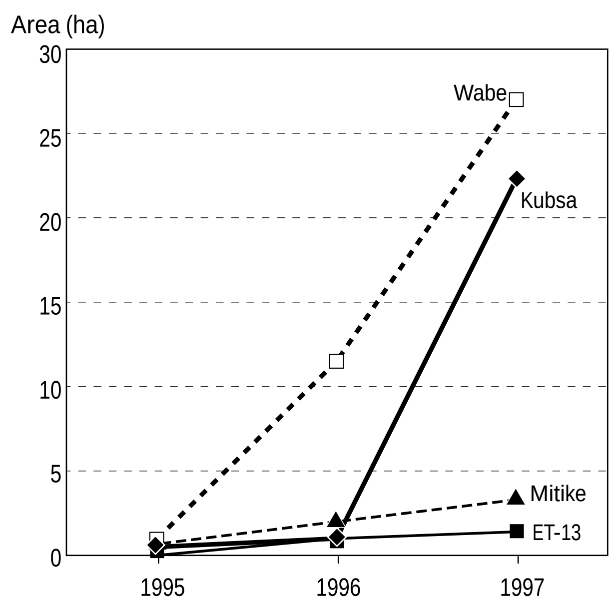

Figure 4. Area planted to the most important improved wheat varieties, Bale Highlands, Ethiopia.

A second important reason for both adopters (54.4%) and nonadopters (39.1%) was the availability of superior improved wheat seed compared to improved seed of other crops. About 36% and 39% of adopters and nonadopters, respectively, reported an increased requirement for home consumption as the reason for increasing their wheat area. Other reasons included the ease of mechanization of wheat production, and the low risk of wheat crop failure due to disease. Twenty-eight percent of adopters and 15% of nonadopters decreased the total area under local wheat varieties over time, while only 1% of both adopters and nonadopters decreased the area under improved wheat. The reasons for decreasing the total wheat area included poor quality of wheat seed, unsuitable soils for wheat production, unavailability of fertilizer, and the importance of other crops. About 5% of adopters and 17% of nonadopters did not change their amount of wheat area.

Table 8 shows the sources of wheat seed and the constraints on obtaining improved seed for farmers in the study area. For the adopters, about 51% obtained seed from the extension service of the OADB, 48% purchased their wheat seed, and 15% obtained their seed from other farmers. Most nonadopters (61.6%) purchased their seed, while 18% and 16% obtained their seed from the extension service or other farmers, respectively. Most of the adopters (61.3%) who purchased wheat seed bought it at the local market, while 23% bought it from other farmers. Three percent of the adopters purchased their wheat seed from local merchants or the Ethiopian Seed Enterprise (ESE). About 55% of nonadopters purchased wheat seed at the local market, while 31% bought it from other farmers. Five percent of the nonadopters purchased their wheat seed from local merchants or the ESE. During 1997, more adopters (64.3%) obtained seed of the wheat variety they wanted compared to nonadopters (36.4%). This difference was significant at $p<0.01$. The major constraint to using improved wheat seed was its high price, which was reported by about 68% of adopters and 73% of nonadopters. The second constraint to using improved wheat seed was unavailability, reported by 30% of adopters and 27% of nonadopters. The third most common constraint for adopters (26.3%) and nonadopters (31.1%) was lack of credit. Other constraints included an unfavorable climate, lack of information, and low farm-gate price of wheat.

Table 8. Wheat seed sources and constraints on growing improved wheat varieties for farmers in the Bale Highlands, Ethiopia

	Adopters of improved wheat technologies		Nonadopters of improved wheat technologies	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Obtained wheat variety in 1997				
No	20	35.7	42	63.6
Yes	36	64.3	24	36.4
	Number of responses	Percent of farmers	Number of responses	Percent of farmers
Wheat seed sources				
Purchased	29	47.5	45	61.6
Other farmers	9	14.8	12	16.4
Extension	31	50.8	13	17.8
Other	2	3.3	4	5.5
Constraints to improved wheat seed				
High price	39	68.4	54	73.0
Unavailable	17	29.8	20	27.0
Lack of credit	15	26.3	23	31.1
Unfavorable climate	11	19.3	4	5.4
Lack of information	3	5.3	15	20.3
Low wheat price	6	10.5	7	9.5
Other	20	35.1	26	35.1

4.2 Preferred Wheat Varieties

Fifty percent of adopters and 53% of nonadopters preferred Pavon-76 (Table 9). The second most preferred variety was Kubsa for 39% and 26% of adopters and nonadopters, respectively, followed by Wabe for 38% of adopters and 23% of nonadopters. The reasons why adopters preferred these varieties included

Table 9. Wheat variety preferences of farmers in the Bale Highlands, Ethiopia

	Adopters of improved wheat technologies		Nonadopters of improved wheat technologies	
	Number of responses	Percent of farmers	Number of responses	Percent of farmers
Preferred wheat varieties				
Pavon-76	28	50.0	32	52.5
Wabe	21	37.5	14	23.0
Kubsa	22	39.3	16	26.2
Mitike	3	5.4	2	3.3
ET-13	1	1.8	0	0.0
Others	5	8.9	15	24.6
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Discontinued use of improved wheat seed				
Yes	9	15.8	10	20.0
No	48	84.2	40	80.0

high yield (78.4%), resistance to sprouting (39.2%), quality of grain for bread (19.6%) or "injera" (19.6%), resistance to lodging (27.5%) or disease (19.6%), earliness (13.7%), seed size (17.6%), and seed color (13.7%). For nonadopters, the reasons for varietal preference included high yield (80.4%), quality of grain for bread making (39.3%) or injera (30.4%), resistance to sprouting (28.6%) or lodging (28.6%), seed color (26.8%), seed size (21.4%), earliness (17.9%), and disease resistance (7.1%).

About 16% of adopters and 20% of nonadopters stopped planting improved wheat varieties. For adopters, the main reasons for this were unfavorable climatic conditions (72.7%), unavailability of seed (18.2%), and crop damage by wild animals (9.1%). Similar reasons were given by nonadopters.

4.3 Wheat Management Practices

4.3.1 Land preparation, planting time, and seed rate

Table 10 lists the land preparation and planting practices of adopters and nonadopters in the study area. Most adopters (55%) started land preparation in March, while most nonadopters (48.1%) started in February. Only 7% and 12% of adopters and nonadopters, respectively, prepared land on

Table 10. Land preparation and planting practices of sample farmers, Bale Highlands, Ethiopia

	Adopters of improved wheat technologies		Nonadopters of improved wheat technologies	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Timing of land preparation				
February	16	26.7	37	48.1
March	33	55.0	23	29.9
April	9	15.0	13	16.9
May	2	3.3	4	5.1
Timing of planting				
June	52	85.2	68	82.9
July	9	14.8	14	17.1
Recommended seed rate used	13	21.3	15	18.1
	Number of responses	Percent of farmers	Number of responses	Percent of farmers
Method of land preparation				
Ox plow	59	100.0	78	100.0
Tractor	22	37.3	19	24.4
Hand hoe	4	6.8	3	3.8
Reasons for not using the recommended seed rate				
Traditional seed rate preferred	9	37.5	8	26.7
To compensate fo low fertility	5	20.8	7	23.3
Impure seed	2	8.3	2	6.7
Seed shortage	0	0.0	3	10.0
Other	9	37.5	10	33.3

the basis of recommendations from research stations or extension agents. More than 90% of farmers in both groups prepared their land at a specific time because it coincided with the beginning of the rains or for traditional reasons. All farmers used the local ox plow (*maresha*) for land preparation. Both groups plowed their land four times with the maresha. Sometimes farmers used the maresha in combination with a tractor. About 37% of adopters and 24% of nonadopters used a tractor for land preparation. Where the ox plow was used in conjunction with a tractor, both farmer groups plowed an average of three times. About 24% of adopters and 22% of nonadopters were informed of plowing frequency by an OADB extension agent, while more than 90% of farmers plowed in the traditional way.

More than 80% of farmers in both groups planted wheat in June, and about 90% of farmers reported that this decision was based on tradition or due to the beginning of the rains. Only 20% and 19% of the adopters and nonadopters, respectively, planted during June because of recommendations from OADB extension agents.

The average seed rate used was 185.0 kg/ha and 178.4 kg/ha for adopters and nonadopters, respectively (NS). Only 21% of adopters and 18% of nonadopters used the seed rate (150-175 kg/ha) recommended by OADB extension agents. The main reasons for not adopting the recommended seed rate were: 1) farmers perceived the traditional seed rate to be superior, and 2) farmers used a higher seed rate to compensate for low soil fertility.

4.3.2 Soil fertility management practices

Soil fertility practices of adopters and nonadopters are shown in Table 11. About 95% of adopters and 75% of nonadopters applied chemical fertilizer in 1996 and 1997 ($p<0.01$). During 1997, adopters used significantly more DAP (87.8 kg/ha) than nonadopters (77.6 kg/ha) ($t= 1.9$; $p<0.1$). Also, adopters used significantly more urea (80.6 kg/ha) than nonadopters (60.4 kg/ha) ($t=1.8$; $p<0.01$). More than 90% of both groups broadcasted their fertilizer. Fertilizer was applied to an average wheat area of 1.4 ha for adopters and 1.2 ha for nonadopters. Both groups used less than the recommended rate of 100 kg/ha of DAP and 100 kg/ha of urea, even though about 81% of adopters and 62% of nonadopters were aware of

Table 11. Soil fertility management practices of farmers in the Bale Highlands, Ethiopia

	Adopters of improved wheat technologies		Nonadopters of improved wheat technologies	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Used fertilizer in 1997	58	95.1	61	75.3
Fertilizer use started				
<1974	5	8.8	10	14.3
1974-1991	33	57.9	32	45.7
1991-1995	14	24.6	21	30.0
1996-1997	5	8.8	7	10.0
	Number of responses	Percent of farmers	Number of responses	Percent of farmers
Type of crops fertilized				
Wheat	55	98.2	61	80.3
Barley	49	87.5	62	81.6
Linseed	5	8.9	12	15.8
Teff	2	3.6	0	0.0
Fertilizer use constraints				
High price	46	78.0	60	88.2
Late delivery	33	55.9	38	55.9
Lack of credit	16	27.1	21	30.9
Lack of cash	19	32.2	24	35.3
Low output price	11	18.6	6	8.8
Inadequate supply	8	13.6	10	14.7
Not readily available	6	10.2	7	10.3
Other	14	18.6	10	14.7
Other soil fertility practices				
Green manure	7	12.1	3	3.8
Farm yard manure	9	15.5	5	6.3
Crop rotation	57	98.3	78	97.5
Fallowing	18	31.0	23	28.8

the recommended rates. The main reason that adopters (80%) and nonadopters (82.5%) did not follow the recommendations was a lack of cash for the required down payment. About 93% of adopters and 86% of nonadopters were satisfied with the fertilizer packaging size (NS).

Most farmers in Ethiopia have a long history of fertilizer use. In the study area, most adopters (57.9%) and nonadopters (45.7%) started using fertilizer during the Dergue regime (1974-1991), while about 9% of adopters and 14% of nonadopters started using fertilizer during the reign of Haile Selassie (prior to 1974). About 65% of adopters and 37% of nonadopters increased fertilizer use over time because they were convinced of the benefits and had perceived a decline in soil fertility. Fourteen percent of adopters and 12% of nonadopters decreased fertilizer use, mainly due to its high price. About 21% of adopters and 37% of nonadopters maintained a constant level of fertilizer usage.

About 98% of adopters and 80% of nonadopters used the purchased fertilizer on wheat, and 88% of adopters and 82% of nonadopters used it on barley. Few farmers used fertilizer on linseed or teff. Most adopters (96.2%) bought fertilizer from an OADB extension agent, while 6% bought it at the local market. The nonadopters (81.5%) mainly bought fertilizer from an extension agent, while about 15% and 6% bought it from the local market or a local merchant, respectively. High price was the major reason given for not using fertilizer by adopters (78%) and nonadopters (88.2%). Problems associated with fertilizer use were: late delivery, reported by 55.9% of adopters and 55.9% of nonadopters; lack of credit, reported by 31% of adopters and 27% of nonadopters; and a lack of cash, reported by 35% of adopters and 32% of nonadopters. Other constraints included inadequate supply or lack of availability of fertilizer, and low market price of wheat.

Crop rotation and fallowing were the most important alternative soil fertility management practices. About 72% of adopters and 63% of nonadopters practiced crop rotation. The adopters rotated wheat with barley (86.4%), linseed (55.9%), faba beans (32.2%), or field peas (25.4%), while the nonadopters rotated wheat with barley (81%), linseed (58.2%), faba beans (22.8%), and field peas (21.5%). About 53% of adopters rotated their crops once every two years, 23% rotated crops once every three years, and 23% rotated crops twice in three years. Sixty-two percent of nonadopters rotated their crops once every two years, 20% rotated crops once every three years, and 18% rotated crops twice in three years.

4.3.3 Weed management

Both adopters and nonadopters reported that broadleaf and grassy weeds were equally important in their wheat fields (Table 12). About 95% of adopters and 93% of nonadopters controlled weeds by hand, whereas 87% of adopters and 61% of nonadopters used herbicides. The average number of hand weedings was 1.7 and 1.8 for adopters and nonadopters, respectively (NS). While only 18% of adopters and 5% of nonadopters hand weeded on the basis of the OADB recommendation, 42% and 33%, respectively, were aware of the recommended weeding frequency. The main constraints to frequency of hand weeding for adopters were labor shortage (74.5%) and lack of cash to hire labor (59.6%). Similarly, the main constraints for nonadopters were labor shortage (68.2%) and lack of cash to hire labor (60.6%).

The most common herbicide used was U-46. The adopters (1.0 l/ha) used significantly more U-46 than nonadopters (0.8 l/ha) (t=2.0; p<0.1). About 61% and 52% of adopters and nonadopters, respectively, obtained herbicide from the agricultural development offices of the OADB, while about 30% and 47% of adopters and nonadopters, respectively, obtained herbicide from the local market. About 63% of adopters and 47% of nonadopters were aware of the recommended herbicide rate. Eighty-eight percent of adopters and 79% of nonadopters obtained information on herbicide use from an OADB extension agent. Other information sources included research staff at the Sinana Research Station (4% of adopters and 17.9% of nonadopters) and other farmers (4% for both groups). The main constraints to herbicide use for adopters included a lack of sprayers (58.0%), the high rental cost of sprayers (58.0%), and high price of herbicide (44.0%). The main constraints reported by nonadopters were a lack of sprayers (68.9%), high rental cost of sprayers (60%), and high price of herbicide (55.6%).

The most problematic weed that could not be adequately controlled by current weeding practices was *Snowdenia polystachya*, locally known as "muja" (reported by 75% of both adopters and nonadopters). Other problematic weeds included *Avena fatua*, locally known as "sinar" (21.2% of adopters and 26% of nonadopters), and "shabie" (5.8% of adopters and 13.7% of nonadopters).

Table 12. Weed management practices of farmers in the Bale Highlands, Ethiopia

	Adopters of improved wheat technologies		Nonadopters of improved wheat technologies	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Herbicide supplier				
OADB	42	60.9	30	51.7
Local market	21	30.0	27	46.6
NGO	2	2.9	0	0.0
Other	5	7.1	1	1.7
	Number of responses	Percent of farmers	Number of responses	Percent of farmers
Important weeds				
Broadleaf	54	88.5	74	90.2
Grass	54	88.5	73	89.0
Method of weed control				
Hand weeding	58	95.1	76	92.7
Herbicide	53	86.9	50	61.0
Frequent plowing	1	1.6	1	1.2
Constraints on herbicide use				
Lack of sprayers	29	58.0	31	68.9
High rental cost of Sprayers	29	58.0	27	60.0
High price of herbicide	22	44.0	25	55.6
Lack of herbicide	9	18.0	7	15.6
Other	13	26.0	11	24.4
Constraints to hand weeding				
Labor shortage	35	74.5	45	68.2
Lack of cash to hire labor	28	59.6	40	60.6
Other	15	31.9	21	31.8

4.3.4 Disease and pest management

Table 13 summarizes disease and pest management undertaken by farmers in the study area. The most important diseases were leaf rust

Table 13. Disease and pest management carried out by sample farmers, Bale Highlands, Ethiopia

	Adopters of improved wheat technologies		Nonadopters of improved wheat technologies	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Disease control used				
Yes	0	0.0	0	0.0
No	25	100.0	40	100.0
Pest control used				
Yes	2	9.1	0	0.0
No	20	90.9	27	100.0
	Number of responses	Percent of farmers	Number of responses	Percent of farmers
Diseases reported				
Leaf rust	44	93.6	55	94.8
Stem rust	25	53.2	28	48.3
Other	8	17.0	14	24.1
Pests reported				
No pests	14	27.5	20	29.4
Cut worms	7	13.7	24	35.3
Wild animals	7	13.7	4	5.9
Army worms	4	7.8	4	5.9
Aphids	2	3.9	6	8.8
Birds	1	2.0	1	1.5
Other	20	39.2	14	20.6

(*Puccinia recondita*), reported by 96.3% of adopters and 94.8% of nonadopters, and stem rust (*Puccinia graminis*), reported by 53.2% of adopters and 48.3% of nonadopters. Pavon-76, Dashen, and Wabe were the most affected wheat varieties reported by 51.2%, 27.9%, and 18.6% of adopters, respectively. For the nonadopters, Pavon-76 (56.1%) and Dashen (26.3%) were the most affected varieties. None of the farmers practiced disease control measures. A lack of knowledge of disease control was the main constraint cited by both adopters (73.9%) and nonadopters (87.5%). Also, adopters (10.9%) and nonadopters (5.4%) reported that there were no critical wheat diseases in the area. The lack of availability of chemicals was another reason for not practicing disease control, according to 15% and 11% of adopters and nonadopters, respectively.

About 28% of adopters and 29% of nonadopters reported that they had no pest problems. The most important pests for adopters were cut worms (13.7%), wild animals (13.7%), and army worms (7.8%). For nonadopters, cut worms (35.3%) and aphids (8.8%) were the most important pests. Nine percent of adopters and none of the nonadopters practiced pest control measures. A lack of knowledge on how to control pests was the main constraint cited by adopters (45.7%) and nonadopters (51.2%); however, 45.7% of adopters and 16.3% of nonadopters reported that pest control was not necessary. The unavailability of chemicals was cited as a constraint on pest control by 6% of adopters and 12% of nonadopters. Other minor problems reported were a lack of money, high price of chemicals, and the complexity of chemical application.

4.3.5 Post-harvest wheat management

Most adopters (77%) and nonadopters (53.8%) cleaned their wheat seed and stored it separately from their grain (Table 14). Most farmers in both groups (77%) stored their wheat seed in a traditional *gotera*—a local container made from bamboo plastered with mud. Twenty-four percent of farmers in both groups used fertilizer bags. Rodents (rats) were the most important storage problem reported by adopters (78.9%) and nonadopters (77%). About 56% and 19% of adopters and nonadopters, respectively, reported weevils as an important storage problem. Another impediment to storage was high grain moisture, reported by 8.8% of adopters and 6.8% of nonadopters.

Table 14. Post-harvest wheat management implemented by sample farmers, Bale Highlands, Ethiopia

	Adopters of improved wheat technologies		Nonadopters of improved wheat technologies	
	Number of responses	Percent of farmers	Number of responses	Percent of farmers
Method of seed storage				
Cleaned and stored separately from grain	47	77.0	43	53.8
Stored with grain	17	27.9	39	48.8
Type of storage				
Gotera	47	77.0	62	77.5
Fertilizer bag	15	24.6	19	23.8
Pots	3	4.9	3	3.8
Other	5	8.2	8	10.0

5.0 FARMERS' ACCESS TO SUPPORT SERVICES

5.1 Access to Credit

The types of credit that farmers have access to and the constraints they face in accessing formal credit are shown in Table 15. Farmers obtain formal credit through the agricultural development offices of their respective woredas in the form of farm inputs (fertilizer, improved seeds, and/or herbicides). About 85% of adopters and 60% of nonadopters received credit for fertilizer, while 48% of adopters and 9% of nonadopters received credit for improved wheat seed. Both differences were significant at p<0.01. The average amount of credit received was 660 Birr and 490 Birr for adopters and nonadopters, respectively (NS). For adopters, the decision to use credit was made jointly by the husband and wife (50.9%), or individually by the husband (41.5%) or the wife (5.7%). For nonadopters, the decision to use credit was made jointly (34%), or individually by the husband (31%) or the wife (19%). The adopters and nonadopters walked about 6.6 km and 7.1 km, respectively, to obtain formal credit (NS). A high interest rate was reported as the main constraint on using credit by 24% of adopters and 33% of nonadopters. Also, adopters (21.6%) and nonadopters (33.3%) reported insufficient cash for the obligatory 25% down payment. Other constraints included unfavorable repayment terms (18.9% of adopters and 22.2% of nonadopters), inadequate loans (16.2% of adopters and 22.2% of nonadopters), and inflexible loans (16.2% of adopters and 25.9% of nonadopters). Other credit problems included a lack of credit sources, late availability, and restrictive application procedures.

About 27% of adopters and 29% of nonadopters used informal credit (NS). The main sources of informal credit for adopters were relatives (58.3%), neighbors (16.7%), and money lenders (16.7%). Nonadopters obtained informal credit from relatives (36.8%), money lenders (26.3%), and neighbors (15.8%). The average amount of informal credit was about 205 Birr for adopters and 255 Birr for nonadopters (NS).

Table 15. Access to credit by farmers in the Bale Highlands, Ethiopia

	Adopters of improved wheat technologies		Nonadopters of improved wheat technologies		
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	χ^2
Credit for improved seed	28	47.5	57	9.0	26.2***
Credit for fertilizer	52	85.2	49	59.8	11.0***
Informal credit	16	26.7	21	28.8	0.1 (NS)
	Number of responses	Percent of farmers	Number of responses	Percent of farmers	
Constraints to using formal credit					
Lack of cash for down payment	8	21.6	18	33.3	
High interest rate	9	24.3	18	33.3	
Unfavorable repayment terms	7	18.9	12	22.2	
Inadequacy of OADB loan	6	16.2	12	22.2	
Inflexibility of OADB loan	6	16.2	14	25.9	
Lack of sources	4	10.8	8	14.8	
Late delivery	6	16.2	4	7.4	
Restrictive procedures	1	2.7	3	5.6	
Other	6	16.2	10	18.5	

Note: NS = not significant; *** = significant at p<0.01.

5.2 Access to Agricultural Information and Membership of Organizations

Both adopters (42.6%) and nonadopters (38.7%) commonly received one or two visits from extension agents per month (Table 16). The gender of the extension agent was usually male (74.1% for adopters and 65.7% for nonadopters). The majority of adopters (84.4%) and nonadopters (75.5%) did not express a preference for the gender of the extension agent. About 21% of adopters and 14% of nonadopters preferred a male extension agent.

The extension agent usually visited adopters (100%) and nonadopters (95.2%) as part of a group visit, while for 61% of adopters and 22% of nonadopters, the extension agent made individual visits. The extension agent contacted the male head of the household for 60.7% of adopters and 33.9% of nonadopters. For about 7% of adopters and 23% of nonadopters, the extension agent contacted the wife of the household. Extension staff contacted both spouses for 32% of adopters and 44% of nonadopters.

About 39% of adopters and 6% of nonadopters were contact farmers ($p<0.01$). Other sources of agricultural information reported by adopters were farmer field days (83%), farmer training courses (21.3%), and radio messages (48.9%). For nonadopters, other sources of agricultural information included farmer field days (80.6%), farmer training courses (22.2%), and radio messages (47.2%).

All farmers were members of a PA. The services commonly offered by a PA included handling credit in kind (seed and fertilizer) for farmers, and land allocation. About 24% of adopters and 11% of nonadopters were office bearers in their respective PA ($p<0.05$).

Table 16. Access to agricultural information by farmers in the Bale Highlands, Ethiopia

	Adopters of improved wheat technologies		Nonadopters of improved wheat technologies		
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	χ^2
Extension contact	55	91.7	62	76.5	5.6**
Frequency of contact					3.8 (NS)
< Once per month	16	29.6	28	45.2	
1-2 times per month	23	42.6	24	38.7	
>2 times per month	15	27.8	10	16.1	
Gender of extension agent					NC
Male	40	74.1	44	65.7	
Female	1	1.9	6	9.0	
Both	13	24.1	17	25.4	
Contact farmer					19.8***
Yes	22	38.6	4	6.0	
	Number of responses	**Percent of farmers**	**Number of responses**	**Percent of farmers**	
Source of agricultural information					NC
Farmer field day	39	83.0	29	80.6	
Farmer training course	10	21.3	8	22.2	
Radio	23	48.9	17	47.2	

Note: NS = not significant; ** = significant at p<0.05; *** = significant at p<0.01; NC = not calculated.

6.0 TOBIT ANALYSIS OF LAND ALLOCATION TO IMPROVED WHEAT VARIETIES AND FERTILIZER USE

Feder *et al.* (1985) defined adoption as the degree of use of a new technology in a long-run equilibrium when a farmer has all of the information about the new technology and its potential. Adoption at the farm level reflects the farmer's decision to incorporate a new technology into the production process. On the other hand, aggregate adoption is the process of spread or diffusion of a new technology within a region. Therefore, a distinction exists between adoption at the individual farm level and aggregate adoption within a targeted region. If an innovation is modified periodically, the adoption level may not reach equilibrium. This situation requires the use of econometric procedures that can capture both the rate and the process of adoption. The rate of adoption is defined as the proportion of farmers who have adopted a new technology over time. The incidence of adoption is the percentage of farmers using a technology at a specific point in time (e.g., the percentage of farmers using fertilizer). The intensity of adoption is defined as the aggregate level of adoption of a given technology (e.g., the number of hectares planted with improved seed or the amount of fertilizer applied).

The results of the tobit model on the mean proportion of land allocated to improved wheat varieties are presented in Table 17. The tobit model was used because the mean proportion of land allocated to improved wheat varieties is a continuous variable but truncated between zero and one. The use of ordinary least squares will result in biased estimates (McDonald and Moffitt 1980). In Table 17, $\delta EY/\delta X_i$ shows the marginal effect of an explanatory variable on the expected value (mean proportion) of the dependent variable, $\delta EY^*/\delta X_i$ shows changes in the intensity of adoption with respect to a unit change of an independent variable among adopters, and $\delta F(z)/\delta X_i$ is the probability of a change

Table 17. Tobit model estimates for land allocation to improved wheat varieties

Parameter	Coefficient	T-ratio	$\delta EY/\delta X_i$	$\delta EY^*/\delta X_i$	$\delta F(z)/\delta X_i$
Constant	-0.203280	0.31	-0.095264	-0.067713	-0.136218
Area under wheat (ha)	-0.052498	0.39	-0.024602	-0.017487	-0.035179
Farmer's age (yr)	-0.021741	2.51**	-0.010189	-0.007242	-0.014569
Education	0.204500	0.73	0.095836	0.068120	0.137035
Extension	0.181580	0.48	0.085095	0.060485	0.121677
Family size (no.)	0.055387	0.71	0.025956	0.018450	0.037150
Hired labor	0.197920	0.80	0.092752	0.065928	0.132626
Credit	1.258300	4.99***	0.589684	0.419144	0.843186
Livestock (no.)	0.013954	0.82	0.006539	0.004648	0.009351
Disease resistance	0.674130	2.18**	0.315921	0.224555	0.451734
Bread baking quality	-0.446270	1.78*	-0.209138	-0.148654	-0.299045
Lodging resistance	0.659760	2.21**	0.309187	0.219768	0.442105
Sigma			0.590360		
Number of samples			114		
Number of positive observations			51		
Proportion of positive observations (%)			47.71		
z-score			-0.13		
f(z)			0.3956		
Log of likelihood function			-77.96		
Wald chi-square (β_i=0)			41.87***		

Note: * = significant at p<0.1; ** = significant at p<0.05; *** = significant p<0.01.

among nonadopters (e.g., the probability of adopting improved wheat varieties) with a unit change in the independent variable (Roncek 1992). The Wald chi-square statistic was significant at $p<0.01$.

The farmer's age, use of credit, and several varietal characteristics preferred by farmers (disease and lodging resistance, bread baking quality) significantly influenced the mean proportion of land allocated to improved wheat varieties. The marginal effect of the farmer's age on the mean proportion of land allocated to improved wheat varieties was -0.01, and farmer's age decreased the probability of adoption among nonadopters by 1.5%. The marginal effect of credit on improved wheat area was 0.59, and credit increased the probability of adoption among nonadopters by 84.3%. The majority of adopters obtained credit in kind in the form of improved seed and fertilizer through the OADB extension package. These inputs are distributed to farmers who are willing to host a demonstration plot.

The varietal characteristics that were significant to farmers were the perceived resistance to disease and lodging, and baking quality. The marginal effect of disease resistance on the mean proportion of land allocated to improved wheat varieties was 0.32, and the probability of adoption among nonadopters increased by 45.2% if the varieties were perceived to be more resistant to disease. However, the marginal effect of baking quality on improved wheat area was -0.21, and the probability of adoption among nonadopters decreased by 29.9%. Lodging resistance was the third significant varietal characteristic that farmers preferred. The improved varieties Wabe and Kubsa are shorter and hence more resistant to lodging than some of the wheat varieties previously grown, such as Enkoy and Pavon-76. The preference for lodging resistance revealed that the marginal effect of lodging resistance on improved wheat area was 0.31, while the probability of adoption among nonadopters increased by 44.2%.

The coefficients of the tobit model used to investigate factors affecting the amount of N fertilizer used are shown in Table 18. The model is significant at the 1% level on the basis of the Wald chi-square statistic with 10 degrees of freedom. The farmer's total wheat area, the number of livestock, and the use of hired labor and credit significantly influenced the amount of fertilizer used. Wheat area decreased the probability of adoption among nonadopters by only 0.3%, and the marginal effect of a farmer's total wheat area on the mean amount of fertilizer used was -0.08.

The marginal effect of hired labor on the mean amount of fertilizer was 0.25; the corresponding increase in the probability of adoption among nonadopters was 1.0%. The improved wheat technologies are labor intensive, primarily due to the recommended increase in hand weeding. Farmers that can afford to hire labor are usually in a better position to adopt these technologies. Hicks and Johnston (1974) reported that a higher labor requirement explained the nonadoption of improved rice varieties in Taiwan and that a shortage of family labor explained the nonadoption of high yielding varieties in India.

The marginal effect of TLU on the mean amount of fertilizer used was 0.01, and TLU increased the probability of adoption among nonadopters by 0.04%. Livestock constitute accumulated wealth, a source of cash, and facilitate the 25% down payment required to obtain credit for inputs. Also,

Table 18. Tobit model estimates for fertilizer (N kg/ha)

Parameter	Coefficient	T-ratio	$\delta EY/\delta X_i$	$\delta EY^*/\delta X_i$	$\delta F(z)/\delta X_i$
Constant	-1.221200	2.32**	-0.5022480	-0.651109	-0.019785
Wheat area (ha.)	-0.207850	1.71*	-0.0854830	-0.110820	-0.003367
Farmer's age (yr)	0.000777	0.12	0.0003200	0.000414	0.000013
Education	0.063368	0.29	0.0260620	0.033786	0.001027
Extension	0.196020	0.74	0.0806180	0.104512	0.003176
Family size (no.)	-0.022934	0.34	-0.0094330	-0.012228	-0.000372
Hired labor	0.606170	3.03***	0.2493020	0.323193	0.009821
Credit	1.955600	7.84***	0.8042100	1.042570	0.031680
Livestock (no.)	0.025953	1.67*	0.0106730	0.013837	0.000420
Gender	0.101610	0.41	0.0417897	0.054176	0.001646
Sigma			19.671		
Number of samples			139		
Number of positive observations			104		
Proportion of positive observations (%)			74.82		
z-score			0.67		
f(z)			0.3187		
Log of likelihood function			-474.91		
Wald chi-square (β_i=0)			107.15***		

Note: * = significant at p<0.1; ** = significant at p<0.05; *** = significant at p<0.01.

farmers who buy inputs on credit carry the risk of crop failure and, therefore, the risk of being unable to repay their debts. Farmers who own more livestock may be more willing to take risks since they will still be able to settle their debts in the event of a calamity.

The marginal effect of credit on the mean amount of fertilizer used was 0.80, and credit increased the probability of adoption among nonadopters by only 3.2%. At the time of fertilizer application (June/July), most farmers face food shortages and use their available cash to buy food grain. Provision of credit to finance the purchase of inputs is therefore critical for successful adoption of fertilizer.

7.0 CONCLUSIONS AND IMPLICATIONS

7.1 Conclusions

Adopters of improved wheat technologies were younger, more educated, and had larger families and farms. Also, adopters hired more labor and owned more livestock. All of these differences were significant. Nonadopters tended to have more off-farm income than adopters, but this difference was not significant. There were no significant differences between adopters and nonadopters in terms of the number of farm implements owned (e.g., hand hoes, ox plows, and oxen carts).

During 1997, about 42% of farmers grew improved wheat varieties. Most adopters grew Kubsa (51%) or Wabe (49%). For the adopters, about 65% of their total wheat area was allocated to improved wheat varieties. In Adaba, about 34% of farmers grew improved wheat varieties compared to 48% of farmers in Dodola. Moreover, the average area under improved wheat varieties was significantly greater in Dodola (0.5 ha) than in Adaba (0.2 ha). Adopters (55%) and nonadopters (53%) preferred Pavon-76, followed by Kubsa, which was preferred by 39% and 26% of adopters and nonadopters, respectively. Varietal traits considered important by farmers included high yield, resistance to sprouting and lodging, seed color and size, and baking quality. High price was reported as the main constraint on using improved wheat seed.

Most adopters (55%) began land preparation in March, while nonadopters (48%) began in February. More than 80% of farmers in both groups planted wheat in June. The average seed rate was 185 kg/ha and 178 kg/ha for adopters and nonadopters, respectively, which are both higher than the recommended seed rate of 150-175 kg/ha. According to farmers, a higher seed rate was used to compensate for low soil fertility and to compete with weeds.

Fertilizer was mainly applied to wheat and barley crops by 98% and 88% of adopters, respectively, and 80% and 82% of nonadopters, respectively. Significantly more adopters (95%) applied chemical fertilizer than nonadopters (75%). Adopters applied 88 kg/ha of DAP and 81 kg/ha of urea while nonadopters applied 78 kg/ha of DAP and 60 kg/ha of urea. However, the average fertilizer application rate for both groups was below the recommended rate (100 kg/ha DAP and 100 kg/ha urea). The main constraint to fertilizer use for both groups was its high price. Crop rotation and fallowing were two other important soil fertility management practices.

According to both groups, broadleaf and grassy weeds were equally important in their wheat fields. Farmers controlled weeds by hand weeding or herbicide application. About 95% and 87% of adopters controlled weeds by hand weeding and herbicides, respectively, compared with 93% and 61% of the nonadopters, respectively. According to 75% of farmers, the most problematic weed that was not controlled by existing weed control measures was *Snowdenia polystachya.* The most important diseases were “leaf rust” (= *P. striiformis*) and “stem rust” (= *P. graminis*), while cut worms, wild animals, and army worms were the most important pests. None of the farmers practiced disease control and only 9% of adopters practiced pest control. The main reason that farmers did not attempt to control diseases and pests was a lack of knowledge of appropriate control practices.

Farmers obtained formal credit through the agricultural development offices of their respective woredas in the form of farm inputs (fertilizer, improved seeds, herbicides). About 85% of adopters and 60% of nonadopters had access to credit for fertilizer, while 48% and 9% of adopters and nonadopters, respectively, had access to credit for improved seed. The main credit constraints for both groups were high interest rates and a lack of cash for the required 25% down payment to purchase inputs. All of the adopters and 99% of nonadopters had received an extension visit. Other sources of agricultural information were farmer field days, farmer training courses, and radio broadcasts.

The farmer’s age, use of credit, and several varietal characteristics preferred by farmers (disease and lodging resistance, bread baking quality) significantly influenced the mean proportion of land allocated to improved wheat varieties. The marginal effect of the farmer’s age on the mean proportion of land allocated to improved wheat varieties was -0.01, and farmer’s age decreased the probability of adoption among nonadopters by 1.5%. The marginal effect of the use of credit on improved wheat area was 0.59, and credit increased the probability of adoption among nonadopters by 84.3%. The marginal effect of disease resistance on improved wheat area was 0.32, and the probability of adoption among nonadopters increased by 45.2% if the varieties were perceived to be more disease resistant. However, the marginal effect of baking quality on the amount of land allocated to improved wheat varieties was -0.21, and the probability of adoption among nonadopters decreased by 29.9%. Lodging resistance was the third significant varietal characteristic that was preferred by farmers. The marginal effect of lodging resistance on improved wheat area was 0.31, while the probability of adoption among nonadopters increased by 44.2%.

The farmer's total wheat area, the number of livestock, and the use of hired labor and credit significantly influenced the amount of fertilizer used. The marginal effect of a farmer's total wheat area on the mean amount of fertilizer used was -0.08, and wheat area decreased the probability of adoption among nonadopters by only 0.3%. The marginal effect of hired labor was 0.25; the corresponding increase in the probability of adoption among nonadopters was 1.0%. The marginal effect of TLU on the mean amount of fertilizer used was 0.01, and TLU increased the probability of adoption among nonadopters by 0.04%. The marginal effect of credit on the mean amount of fertilizer used was 0.80, and credit increased the probability of adoption among nonadopters by only 3.2%.

7.2 Implications for Research, Extension, and Policy

Pavon-76 was preferred by both adopters (50%) and nonadopters (53%). This suggests that this variety has important traits that farmers appreciate, and should be considered in the national and regional wheat breeding programs. In particular, the farmer's perception of the disease and lodging resistance of the improved wheat varieties positively influenced adoption. The perceived baking quality of the varieties negatively influenced adoption, however, and this trait should receive a higher priority in wheat breeding programs.

The tobit analysis revealed that access to credit is a determining factor in a farmer's decision to adopt improved wheat technologies, and credit for the purchase of improved seeds and fertilizer should be extended to all farmers. Credit in kind would not only relax the cash constraint currently existing in most farm communities, but also improve farmers' access to inputs.

Availability of hired labor is another determinant of a farmer's adoption of fertilizer, emphasizing the importance of developing labor-saving wheat technologies. This would offset the costs of hired labor and would expand the adoption of fertilizer by farmers who cannot afford hired labor.

Livestock ownership was an important factor in the adoption of fertilizer. Livestock represent the main cash source to finance crop production and livestock ownership is one means by which farmers can minimize the risks associated with crop failure. Therefore, research and extension staff should increase the attention given to livestock.

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