ECONOMICS WORKING PAPER 03-01

Adoption of Maize and Wheat Technologies in Eastern Africa: A Synthesis of the Findings of 22 Case Studies

CHERYL DOSS, WILFRED MWANGI, HUGO VERKUIJL, AND HUGO DE GROOTE

CIMMYT

E C O N O M I C S

Working Paper 03-01

Adoption of Maize and Wheat Technologies in Eastern Africa: A Synthesis of the Findings of 22 Case Studies

Cheryl Doss, Wilfred Mwangi, Hugo Verkuijl, and Hugo de Groote*

* International Maize and Wheat Improvement Center (CIMMYT), Apartado Postal 6-641, 06600 Mexico, D.F., Mexico. The views expressed in this paper are the authors' and do not necessarily reflect the views of CIMMYT.

Correct citation: Doss, C., W. Mwangi, H. Verkuijl, and H. de Groote. 2003. *Adoption of Maize and Wheat Technologies in Eastern Africa: A Synthesis of the Findings of 22 Case Studies.* CIMMYT Economics Working Paper 03-01. Mexico, D.F.: CIMMYT.

Abstract: This paper synthesizes the findings of 22 micro-level studies on technology adoption carried out by the International Maize and Wheat Improvement Center (CIMMYT) with national agricultural research systems in Ethiopia, Kenya, Tanzania, and Uganda from 1996-1999. The authors found that technology adoption is taking place across Eastern Africa but considerable scope remains to improve the productivity of smallholder agriculture in higher potential regions with high levels of adoption. Extension was the variable most highly correlated with technology adoption, and extension services continue to play an important role in disseminating information on new varieties and how to manage them. Despite the usefulness of the micro-study results, especially for priority setting and impact assessment, future adoption studies can be improved by standardizing definitions across studies and using sampling techniques that allow results to be generalized across wider areas. Finally, the paper suggests that maize and wheat breeding research should be made more relevant to the preferences and circumstances of farmers, that the link between research and extension should be strengthened and include the private sector and non-governmental organizations, that policies should support the development and expansion of efficient markets for inputs and outputs, and that rural credit systems should be strengthened.

ISSN: 0258-8587
AGROVOC descriptors: Maize; Wheat; Innovation adoption; Technology transfer; Plant breeding; Small farms; Case studies; Fertilizers; Private sector; Nongovernmental organizations; Research institutions; International organizations; Ethiopia; Kenya; Tanzania; Uganda
AGRIS category codes: E14 Development Economics and Policies
F30 Plant Genetics and Breeding
Additional Keywords: Eastern Africa
Dewey decimal classification: 338.16

Printed in Mexico.

Contents

Tables

Page

Acknowledgment

The authors thank CIMMYT science writers Satwant Kaur and Mike Listman for their editorial assistance and designer Antonio Luna Avila for his help with layout.

Adoption of Maize and Wheat Technologies in Eastern Africa: A Synthesis of the Finding of 22 Case Studies

Cheryl Doss, Wilfred Mwangi, Hugo Verkuijl, and Hugo de Groote

Introduction

The adoption of improved technologies for staple crop production is an important means to increase the productivity of smallholder agriculture in Africa, thereby fostering economic growth and improved well being for millions of poor households. Yet, for much of Africa, basic descriptive data on the technologies used by farmers have not been available. In contrast to many other parts of the world, many African governments do not collect or report such data. Without basic, descriptive information about who is adopting technologies and who is not, it is difficult to formulate policies for increasing agricultural productivity.

To compile data and improve the capacity of local institutions to conduct technology adoption studies, the International Maize and Wheat Improvement Center (CIMMYT, by its Spanish abbreviation) collaborated with national agricultural research systems in 22 micro-level studies of technology adoption in four countries in Eastern Africa—Ethiopia, Kenya, Tanzania, and Uganda—during 1996-1999. The studies examined the adoption of improved wheat and maize varieties, as well as adoption of chemical fertilizers.

This paper synthesizes and analyzes the study results.[1] It is organized around four key questions: To what extent have farmers adopted improved technologies for maize and wheat in Eastern Africa? Which farmers are using the improved technologies? What are the main obstacles to farmers adopting improved technologies? Are improved seeds and fertilizer available? The final section discusses policy implications and offers recommendations.

Eastern African Adoption Studies

Table 1 provides a brief description of the micro-studies. All 22 studies involved collecting farm level data from households in survey areas. The data were representative of those collected for most adoption studies—farmers' characteristics, and descriptions of farms and technology use—and followed CIMMYT's manual for survey design (CIMMYT 1993). Researchers from the national agricultural research systems (henceforth: "national systems") in each country chose the study regions, which typically represented primary maize and wheat growing areas. The sample size for each study was fairly small, ranging from 36-353. In addition to recording descriptive data, most studies ran simple econometric models to analyze determinants of adoption of improved varieties and/or fertilizer.

---

[1] The research report for each of these studies is listed in Appendix 1.

Table 1. Description of adoption studies, Ethiopia, Kenya, Tanzania, Uganda, 1996-1999.

Country/region	Year	Crop	Improved varieties†	Fertilizer†	Market access††	Agricultural potential†††	Population / km2‡	Farm size/ha‡‡
ETHIOPIA								
Bale Highlands	1997	Wheat	Yes	Yes	Medium	High	60	3-4
Central Highlands	1997	Wheat	Yes	Yes	Medium	High	102-171	2-3
Chilalo Awraja		Wheat	Yes	No	High	High		4.0
Enebssie	1997	Wheat	Yes	No	Medium	High	131	
Northwestern Province	1999	Wheat	Yes	Yes	Medium	High	91	5-7
Sidamo and North Omo Zone	1997	Maize	Yes	Yes	Low	Medium	127-229	1.0
Western Oromia	1996	Maize	Yes	No	Medium	High		3-4
Wolmera Woreda		Wheat	Yes	No	High	High		2-3
KENYA								
Coastal Lowlands	1998	Maize	Yes	Yes	High	Low	60-114	4.30
Embu District	1998	Maize	Yes	Yes	High	Low	456	1.68
Kakamega and Vihiga Districts	1996	Maize	Yes	Yes	High	High	433-866	1.2
Kiambu District	1996	Maize	No	Yes	High	High	373	4-5
Narok, Nakuru, and Uasin Gishu Districts	1997	Wheat	Yes	No	High	Low	24-164- 187	100-780
TANZANIA								
Central	1995	Maize	Yes	Yes	Low	Low		8-25
Eastern	1995	Maize	Yes	Yes	Low	Low	35	7-10
Lake Zone	1995	Maize	Yes	Yes	Medium	Medium	49.4	
Northern	1995	Maize	Yes	Yes	High	High		2-4
Southern	1995	Maize	Yes	Yes	Low	Medium	19.3	2.6
Southern Highlands	1995	Maize	Yes	Yes	Medium	High	16.4	3.0
Western	1995	Maize	Yes	Yes	Low	Medium		10-11
Mbeya District (S. Highlands)	1997	Wheat	Yes	Yes	Medium	High		2-3
UGANDA								
Iganga District	1995	Maize	Yes	No		High	196	2.5

† Indicates whether the study examined the adoption of this technology.

†† Low access: seasonal markets are accessible but farmers have to travel at least one full day to get to large markets (>50,000 people) and the nearest tarmac roads are about 6 hours away by foot. Medium access: large markets are accessible and the nearest tarmac roads are about 1-2 hours on foot. Farmers have access to large markets (>50,000 people). High access: very large markets are accessible (>100,000 people) and tarmac road are less than 1 hour by foot.

††† Low: Unreliable unimodal rainfall, <600 mm per year, poor soils. Medium: 600-1,200 mm rainfall/yr, unimodal or bimodal. High: reliable bimodal rainfall distribution , >1,200 mm/yr. Soils are rich volcanic or alluvial.

‡ Population density is for the entire region. If a range is listed, it is for each of the two smaller units of area.

‡‡ Farm size is based on average farm size of sampled households.

It is important to note that the areas by concred these studies are not necessarily representative of Eastern Africa overall: they cover a wide range of areas, especially in Ethiopia and Tanzania, but most of the samples were purposively selected in major areas for production of the particular crop. Thus, the levels of adoption presented here are not representative of national adoption levels. Nor can adoption levels be directly compared across sites, since the definition of "adoption of improved varieties" varies. Nonetheless, the data show interesting patterns of adoption (Table 2).

To What Extent Have Farmers Adopted Improved Technologies for Maize and Wheat in Eastern Africa?

Maize and wheat are the two chief staple crops in Eastern Africa. In Ethiopia, maize is the most important crop in terms of production and yield, although teff is more widely cultivated. Maize is the most important crop in all three respects in the zones in Ethiopia where adoption of maize technologies were examined. Maize is a major crop cereal in Tanzania, providing 60% of dietary calories (FSD 1992; 1996). In some areas of Tanzania, maize is also an important cash crop, competing with cotton for land and labor. In Kenya, maize is a major staple and the main source of income and employment for most households. More than 70% of maize area in Kenya is cultivated by smallholder farmers (<20 ha; CBS 1990). In Uganda, maize is a major staple crop and has the potential to become a major export crop.

Overall, wheat is less important than maize in Eastern Africa but is important in some areas. In Ethiopia, wheat ranks fourth in total crop area and production. Ethiopia continues to be a net importer of wheat. Wheat is the second most important crop in Kenya and is the most important crop in some areas. Wheat is of minor importance in Tanzania (Ekboir 2002) and Uganda.

Maize

The data suggest that improved varieties of maize have been widely adopted in many maize-producing regions of Eastern Africa.

Ethiopia shows the lowest levels of adoption–0% to 56%–in the areas studied in 1996. However, adoption has increased dramatically since 1992 (when almost no farmers were growing improved maize varieties) due to the introduction of a new extension system supported by the Sasakawa Foundation of Japan.

Rates of adoption of improved maize varieties were relatively high in the three regions in Kenya and one region in Uganda examined. In Kakamega and Vihiga Districts, Western Kenya, 50% of farmers used certified maize seed in the first season, although in the second season all farmers grew only local varieties. In Embu District, 65% of the farmers surveyed sowed certified seed for two consecutive seasons. However, only 30% of farmers on the

Table 2. Percentage of sampled farmers adopting improved technologies, Ethiopia, Kenya, Tanzania, Uganda, 1996-1999.

Country/region	Seed adopters (%)	Fertilizer adopters (%)	Definition of adoption
ETHIOPIA			
Bale Highlands:			
Adaba	34	83	Recently released (<10 yrs) improved material
Dodola	48		
Central Highlands:			
Ada - MHH[†]	12 wheat 0 maize		Any improved material
Ada-FHH	5 wheat 0 maize		
Lume-MHH	39 wheat13 maize		
Lume-FHH	22 wheat11 maize		
Gimbichu-MHH	3 wheat 0 maize		
Gimbuchu-FHH	0 wheat 0 maize		
Chilalo Arwaja:	80% of harvested area		Variety released or introduced into study area between 1990-95.
Enebssie:			
Intermediate	32	70	Any improved material
High	36	27	
Northwestern Province:	72	60	Any improved material
Sidama and North Omo Zone:			Any improved material
Lowland	22	58	
Intermediate	25	70	
Western Oromia:			
Chaliya	46	78	Any improved material and
Bako-Tibe	49	97	fertilizer for maize production
Bila-Sayo	56	88	
Sibu Sire	39	79	
KENYA			
Coastal Lowlands:	30	4.5	Certified purchased seed on at least 1 acre
Embu District:	65	98	
Kakamega and Vihiga Districts:	51	35	Certified purchased seed on at least 1 acre
Kiambu District:		74	Any chemical fertilizer
Narok, Nakuru, and Uasin Gishu Districts:			Variety released in past 10 years
High potential	52		
Low potential	22		
TANZANIA			
Central:			
Lowlands	78 across all	17	Any improved material
Intermediate	3	77	
Highlands		17	
Eastern:			
Lowland	85	17	Any improved material
Intermediate	95	8	

[†] MHH = male-headed household. FHH = female-headed household.

Table 2. (cont'd)

Country/region	Seed adopters (%)	Fertilizer adopters (%)	Definition of adoption
Lake Zone:			
Low rain	45	50	Any improved material
Intermediate rain	62	48	
High rain	100	100	
Northern:			
Lowland	89	64	Any improved material
Intermediate	92	44	
Southern:		3	Any improved material
Southern Highlands:			
Intermediate	64	65	Any improved material
Highlands	44	79	
Western:			
High	55	66	Any improved material
Low	93	60	
Mbeya District (S. Highlands):	79	40	Any improved material
UGANDA			
Inganga District:	43	3	Recommended variety (grown on own initiative)

Kenyan coast grew improved maize seed. In the Iganga District in Uganda, 43% of the sample grew the recommended improved variety Longe-1, an open-pollinated variety (OPV) released in 1991. Most Ugandan farmers surveyed who were not growing this variety were growing Kawanda Composite A, a variety released in 1971. Composite A continues to be grown despite the lack of maintenance breeding and the collapse of the seed multiplication system in the early 1980s.

In Tanzania, most farmers surveyed were using improved materials. Two-thirds of the study regions reported at least a 75% adoption rate. Most farmers used recycled hybrid seed. Only in the Southern Highlands, a relatively high potential area, did most farmers report that they purchased new seed each year. The proportions are much lower in other zones. In the Central Zone, farmers in the lowlands reported that they recycled seed for 5-8 years; farmers in intermediate altitude and highland zones said they recycled seed for 8-10 years.

The number of farmers who purchased hybrid maize seed was very low. We do not know how frequently farmers replenish their seed in Uganda, where recommended varieties are OPVs rather than hybrids. Regardless of problems in interpreting or comparing data, it is noteworthy that farmers in all regions surveyed are using some improved materials.

Wheat

More sampled farmers were using improved varieties of wheat than was true for maize in Ethiopia. The figures range from 32% in Enebssie region to over 70% in the Northwestern region. Adoption of improved wheat varieties was over 90% in 1992 in the Central Highlands but was lower during 1997. Of those growing wheat, 70% of male-headed households and 86% of female-headed households grew local varieties. One explanation for the decline is that farmers who recycled improved seed considered it a local variety, once it had been recycled. This illustrates the difficulty of analyzing cross-country data when the definitions of terms are not harmonized beforehand. The report on Chilalo Awraja[2] noted that, although the majority of farmers grew improved wheat, only 2% used newly released varieties. The varietal replacement rate is very low in Ethiopia. For sites where it was calculated, the weighted average age of varieties was 11-13 years. This contrasts with averages of less than 4 years in the Yaqui Valley in Mexico to over 10 years in the Punjab of Pakistan, with a global average of 7 years. Still, it suggests a willingness to use new varieties and to adopt new technologies.

In the Mbeya District (Southern Highlands), the only wheat growing area studied in Tanzania, about 79% of the farmers sampled grew improved wheat varieties. The most commonly adopted variety was Juhudi, which was released in 1987. All five varieties recommended for the Southern Highlands were released in the 1980s.

In the only wheat growing are studied in Kenya—the Narok, Nukuru, and Uasin Gishu Districts—28% of the farmers sampled used "new" varieties, defined as varieties released within the previous 10 years.

Thus, a relatively large proportion of farmers, especially in high potential zones, have adopted improved varieties. However, these may be relatively old varieties and may have been recycled for many years.

Fertilizer

The proportion of farmers using fertilizer, specifically chemical fertilizer, varies tremendously across Eastern Africa. Fertilizer was more likely to be used in high potential zones.

Not all the Ethiopian studies looked at fertilizer use, especially in areas where fertilizer use was very low. Yet, high levels of adoption were found in areas where fertilizer adoption was studied. Fertilizer adoption rates were higher in wheat farming areas than among maize farmers. In the Bale Highlands, 95% of adopters of improved wheat and 75% of non-adopters used fertilizer. High levels of adoption of fertilizer—over 58%—were reported among the maize farmers surveyed in Ethiopia.

In Kenya, most farmers in high potential areas used inorganic fertilizer: 98% in Embu and 74% in Kiambu. This was substantially less in low potential areas: 35% in Kakamega and

[2] An "Awraja" is a sub-region in Ethiopia, and a "Woreda" is a district.

Vihiga Districts and only 4.5% on the Coast (Table 2). In Kiambu, 35% of farmers used both organic and inorganic fertilizer and 29% used only inorganic fertilizer.

In the highest potential area in Tanzania, the Southern Highlands, 65-79% of farmers used fertilizer.[3] In the Southern Zone, one of the lower potential areas of Tanzania, only 3% of farmers used inorganic fertilizer.

Fertilizer use was very low (3%) in the Iganga District in Uganda.

Thus, the range of fertilizer use is very wide. The proportion of sampled farmers using fertilizer was higher in Ethiopia than in Tanzania. Clearly, there are complementarities between fertilizer use and improved varieties. Although we typically expect that farmers adopt new varieties of seed first and then fertilizer, this was not the case in all areas. In Ethiopia especially, we saw areas where fertilizer adoption outstripped adoption of improved varieties.

Conclusion

Farmers have adopted improved varieties of wheat and maize and fertilizer, although it is important to be careful in interpreting the numbers, given that the definitions of adoption vary across sites and sites were not selected representatively for particular areas. Even with the limited data, we can draw a couple of conclusions.

First, farmers did not appear to be resistant to using improved varieties of wheat and maize. There did not seem to be strong cultural views against using these improved varieties. In a later section, we discuss which farmers adopted improved technologies and some of the reasons why some farmers did not adopt them. Similarly, farmers appeared to be willing to use fertilizer.

Second, although many farmers were using improved seed, much of the improved seed used was recycled and came from old varieties, especially in Ethiopia and Tanzania. Thus, not all of the benefits of hybrid maize were being realized. A recent survey of literature on recycled maize seed use concludes that "…while advanced-generation hybrids may not perform as well as crops grown from F_1 seed, in many cases they significantly outperform the variety that the farmer was growing previously" (Morris et al. 1999). This suggests that farmers obtain some but not all agronomic benefits from improved varieties. Using newly purchased seed would presumably increase output, but would also increase costs.

Many questions remain about the extent of adoption. We do not know how representative surveyed areas are. The surveyed areas were chosen because they were in the crop producing areas. Adoption rates were relatively high in many of these areas; researchers expected to find these technologies in use. We would expect that farmers in more remote and more marginal areas would be less likely to use improved technologies. Adoption studies could be improved by standardizing definitions across studies (or providing

---

3 The higher number is for the highlands areas, while the lower number is for the intermediate altitude zone.

information using more than one definition) and by using sampling techniques that allow results to be generalized. Despite their limitations, these studies indicate that even in higher potential regions with relatively high levels of adoption, there is still considerable scope to improve the productivity of smallholder agriculture in surveyed areas.

Which Farmers Use Improved Technologies?

Each micro-level adoption study provides descriptive data on farmer characteristics and most studies estimated the probabilities of a farmer adopting a technology. Like most adoption studies, these studies focused on a cross-section of the population and compared adopters to non-adopters. Because of this, it was not possible to glean anything from them about the characteristics of farmers at the time of adoption. Although regression results such as these are often interpreted as representing the probability that a farmer will adopt the technology, they are more appropriately interpreted as the probability that a farmer is using the technology. In other words, the information that we are using is current information on the farmer, not information on the farmer at the time of adoption. Interpreted in this manner, the estimations presented in these micro-studies do provide some information on the characteristics of farmers who were using the technology at the time of the studies. Summaries of the econometric findings are presented in Tables 3 and 4.[4]

Factors that affected technology use fell into three general categories: attributes associated with farmers and farms, characteristics of the technology, and objectives of the farmer. Institutional and policy factors that may have affected the use of technologies were rarely included in the analyses, usually because there was little or no variation across sampled households except for use of credit and extension services. Some local level institutional characteristics, including access to markets, were included only through a dummy variable indicating the district or ecological zone. Most of the econometric analyses focused on the effects of farmer and farm characteristics.

The CIMMYT/national system studies estimated the use of each technology separately, although some included a measure of the probability of using improved varieties in the estimation of the probability of using fertilizer.

The first technology considered was the use of improved maize and wheat varieties. Some of the estimations simply examined whether the farmer used improved varieties (again, the definitions of improved varieties vary across studies), while others examined the proportion of land a farmer planted with improved varieties. The second technology considered was the use of fertilizer. A few studies included analyses of fertilizer use. Again, in some farmers were simply asked whether they used any fertilizer, whereas others provide an actual figure for fertilizer application by area.

---

[4] Full details on estimations are available in individual reports (Appendix 1). Tables 3 and 4 list the variables that were included in each estimation and indicate which ones were significant. Since the definitions of variables and the units used vary across studies, these summary tables do not attempt to indicate the size of the effect.

Table 3. Summary of estimations of adoption of improved wheat and maize, Ethiopia, Kenya, Tanzania, Uganda, 1996-1999. (Variables listed are those included in the econometric estimations. Factors in bold are statistically significant at the 0.05 level or higher.)

ETHIOPIA

Bale Highlands (wheat)	**Central Highlands (wheat)**	**Enebssie (wheat)**	**Northwestern Province (wheat)**	**Sidama and North Omo Zone (maize)**	**Western Oromia (hybrid maize)**	**Wolmera Woreda (wheat)**
Wheat area **Age** Education Extension Family size Hired labor **Credit** Livestock **Disease resistance** Bread quality **Lodging resist.**	Livestock Coop member Household size **Extension** Education Km to market Farm size Age	Zone Credit Cultivated area **Extension** **Producer cooperative** **Oxen** **Experience** Education Labor Off-farm income	Chemical Fert. **Farm size** **Extension** **Participation in demo** Attend agricultural course Credit Illiterate Elementary Junior High	Age Education Family size Farm size **TLU** Off-farm income Hired labor **Zone** Extension **Credit** **Organization member** Contact farmer Hand hoe Ox plow	Experience **Education** **Extension** **Field day** Farm size Family size Hired labor Livestock **Off-farm income** **High yield** Lodging resistance Impurity Seed condition	Experience **Extension** Education Radio Family size Farm size **Zone**

KENYA

Chilalo Awraja	**Coastal lowlands (maize)**		**Embu District (maize)**	**Kakamega and Vihaga Districts (maize)**	**Narok, Nakuru and Uasin Gishun Districts**
Age Age squared **Near AADE farm** **Near ESE farm** **Near Res. stn.** Literacy Campaign Primary ed. Second. ed. Hosted demo plot Extension Farm size Contact farmer	Age Education Permanent employment **Use Credit** **Extension** Organization member **Hires labor** Female-headed household Farm size Off-farm income District	Mijikenda tribe Trees Cattle On-farm income Tractors Sells maize Maize acres Farmer training course **Listens to agricultural programs** Organization member	Age Education Use credit **Extension** Organization member **Hires labor** **Male** Farm size **Use fertilizer** Coffee area Zone	Age Primary Secondary **Cattle** Use credit **Extension** Organization member **Hires labor** Farm size Cash crop area Uses manure **Zone**	Seed source District Household size Seed selection Wheat price Age of head Education Zone Farm Size Seed retention **Years farming wheat**

Table 3. (cont'd)

ETHIOPIA						
Bale Highlands (wheat)	**Central Highlands (wheat)**	**Enebssie (wheat)**	**Northwestern Province (wheat)**	**Sidama and North Omo Zone (maize)**	**Western Oromia (hybrid maize)**	**Wolmera Woreda (wheat)**
TANZANIA						
Central (maize)	**Eastern (maize)**	**Lake Zone (maize)**	**Mbeya District (S. Highlands wheat)**	**Northern (maize)**	**Southern Highlands (maize)**	**Western (maize)**
Experience Labor Education Wealth index Extension **Zones** **Varieties**	Experience **Labor** Education Wealth index **Extension** Zones **Varieties**	Experience Education **Extension** **Farm size** Family labor Hired labor **Livestock** Hand hoe	Age Education Extension **Farm size** Family size Hired labor Livestock Off-farm income Credit	Farm size Experience Education Livestock units Family labor Hand hoe Ox-plow Tractor Nitrogen-fertilizer rate	**Zone** Farm size Hand hoe Ox-plow Extension Experience **Livestock units** Labor Hired labor Credit	Experience Labor Education Wealth Extension Varieties **Zone**
UGANDA						
Iganga District (maize)						
Age Household size Education Farm size Credit Livestock Hired labor Off-farm income Radio Organization member Gender						

Table 4. Summary of estimations of adoption of fertilizer, Ethiopia, Kenya, Tanzania, 1996-1999.[†]

ETHIOPIA:

Bale Highlands	**Northwestern Province**	**Sidama and North Omo Zone (maize)**
Wheat area	Farm size	Age
Age	TLU	Education
Education	Participation in demo	Family size
Extension	Field day	Farm size
Family size	**Agricultural training**	TLU
Hired labor Credit	**Radio**	**Off-farm income**
Livestock	**Coop member**	Hired labor
Gender	Credit	Zone
		Extension
		Credit
		Organization member
		Contact farmer
		Hand hoe
		Ox plow

KENYA

Coastal Lowlands	**Coastal Lowlands (continued)**	**Kakamega and Vihiga Districts**	**Kiambu District**
Age	**Maize**	Age	**Age**
Female-headed houseld	**Acreage**	Primary	**Extension**
Permanet	Extension	Secondary	**Organization member**
employment income	**Attend course**	**Cattle**	Farm size
Education	**Listens to agricultural program**	Use credit	Household size
Mijikenda tribe member	Credit	Extension	Hired labor
District	**Organization member**	Organization member	Livestock
Farm size		**Hires labor**	**Off-farm income**
Trees		Farm size	
Cattle		Crash crop area	
Hires labor		**Uses manure**	
On-farm income		**Zone**	
Off-farm income			
Tractors Hired			

Tanzania:

Central	**Eastern**	**Lake Zone**	**Northern**
Experience	Experience	Zones	Farm size
Labor	Labor	Farm size	Experience
Education	Education	Hand hoe	Education
Wealth index	Sealth index	Ox-plow	Livestock units
Extension	Extension	Extension	Family labor
Zones	Zones	Experience	Hand hoe
Varieties	Varieties	Livestock	Ox-plow
		Labor	Tractor
		Hired labor	Nitrogen- fertilizer

[†] Variables listed are those included in the econometric estimations. Variables in bold are statistically significant at the .05 level or higher.

Table 4. (cont'd)

TANZANIA:

Southern Highlands	**Western**	**Mbeya District (S. Highlands)**
Zone	Experience	Age
Farm size	Labor	Education
Hand hoe	Education	Extension
Ox-plow	Wealth	Farm size
Extension	Extension	Family size
Experience	Varieties	Hired labor
Livestock units	Zone	Livestock
Labor		Off-farm income
Hired labor		
Credit		Credit

Farmer Characteristics

Farmer characteristics that might be associated with the use of improved technologies include age or experience, education, wealth (including land), availability of cash or credit to purchase inputs, access to information, and access to labor.

The CIMMYT/national system studies hypothesized that experienced farmers were more likely to use improved technologies. We might also expect that younger, less experienced farmers are less set in their ways and are thus more likely to try improved technologies. The age of the farmer was often used as a measure of the farmer's experience, although sometimes the number of years the individual had been farming was used. None of these variables were statistically significant in any of the analyses on the use of improved maize varieties. Age (or experience) was positively associated with the use of improved wheat varieties in the Bale Highlands, Enebssie, and Chilalo Awraja in Ethiopia.

Years of farming experience related positively to fertilizer use in only the southern highlands of Tanzania. In Kiambu, Kenya, age was negatively related to inorganic fertilizer use but was not significant in determining combined use of inorganic and organic fertilizer. On the coast of Kenya, age was negatively associated and education positively associated with the fertilizer use.

Several measures of education were used. In the Tanzanian studies, it was the number of years of education of the household head. Only in the Lake Zone was this correlated with the use of improved varieties. A dummy variable was used in the Iganga District in Uganda to indicate whether the household head was literate but this was not statistically significantly related to the use of improved maize. In Ethiopia, the education variable was positive and significant only for the use of improved maize in Western Oromia.

At least one measure of wealth was included in most estimations of technology use. It is not obvious *a priori* what the relationship is between wealth and use of improved varieties, although it is often assumed that wealthier farmers have greater access to inputs, especially purchased seeds and fertilizer.[5] But many researchers have argued that seed technologies are scale neutral and thus available to farmers regardless of the size of their farms or levels of wealth. We might not expect to find much of a relationship between wealth and use of improved varieties, particularly in studies where the definition of an adopter of improved varieties does not necessarily indicate that the farmer purchased new seed. However, we might expect to see a stronger positive relationship with fertilizer use, given that fertilizer must be purchased. To the extent that the adoption of a technology increases a farmer's wealth, we might expect to see a positive relationship between current use and wealth. We might also expect to see a relationship between farmers' wealth and their willingness to try a new and unproven technology. Wealthier farmers may be more willing and able to take risks. Wealth may also be an indicator of a farmer's access to credit. For these reasons, we might expect a positive relationship between wealth and use of improved technologies.

A number of factors were used as a proxy for wealth. They vary, in part, because different measures are appropriate in different contexts. Some wealth indicators used in the analyses represent more than just measures of wealth and may be related to technology use in other ways.

One of the key measures of wealth used in the studies was farm size. In the maize adoption studies, farm size was only correlated with the use of improved varieties in the Lake Zone in Tanzania. A relationship between farm size and the use of improved variety was more frequent in wheat studies in Ethiopia—in two of the six wheat studies (Northwestern Province and Enebssie Region) a positive correlation was found. In areas where land is more abundant, farmers may increase productivity both by using fertilizer and by increasing farm size. In areas such as the Southern Highlands, where land is relatively scarce, farmers may increase productivity by using fertilizer. More intensive agriculture on smaller plots may be the appropriate strategy under these circumstances. Farm size was positively related to the use of fertilizer among maize farmers on the Kenyan Coast and wheat farmers in Mbeya District (Southern Highlands), Tanzania, but was negatively related to fertilizer use on maize in Tanzania's Southern Highlands.

Another frequently used measure of wealth is the number of livestock. Livestock ownership was positively related to the use of improved maize in the Southern Highlands and Lake Zone of Tanzania, and in Kakamega and Vihiga Districts, Kenya. Different definitions of livestock were used. In Kenya, only the number of cattle was included. In several Ethiopian studies, livestock were aggregated using tropical livestock units.[6] In the wheat studies, livestock were correlated only with use of improved varieties in the Enebssie region of Ethiopia, where the number of oxen was the livestock measure. Livestock may be a measure of wealth, but in the case of oxen particularly, they may also be used as an input in the

---

5 Many of the CIMMYT/national research system studies make this assumption.
6 They are usually aggregated as follows: Oxen and cows=1; goats and sheep =8; poultry =2.

production process, allowing for greater area to be cultivated. Animal manure may also substitute for purchased fertilizer.

Other wealth measures included assets that may be owned by farmers, either entered individually into the estimation or, as was done in three Tanzanian maize studies (Central, Eastern, and Western), aggregated into a wealth index. This wealth index combined the average number of livestock units, farm implements, and cultivated land for the past three years—each divided by the sample mean for the item. When assets were combined, the assumption was that they impacted similarly on decisions about technology use. When the assets were included separately in the equations, the assumption was that various forms of wealth affected input decisions differently. Since many forms of wealth are related to agricultural production, including land, tools, and livestock, each may have other effects than simply the wealth effect. Few of these variables were significant in explaining the use of improved technologies.

To the extent that agricultural inputs must be purchased, we would expect to find a relationship between the availability of cash or credit to a farmer and the use of improved technologies. One source of cash is off-farm income. Current income is not appropriate to examine initial adoption decisions because successful adoption of agricultural technologies may change farming households' incentives to supply off-farm labor. We may, however, be interested in the correlation between current off-farm income and current technology use, because off-farm income may be important for farmers who wish to purchase improved inputs. Off-farm income was correlated with the use of improved maize in Oromia, Ethiopia, and was positively related with both improved seed and fertilizer use in the Kenyan Coast. Off-farm income was not correlated to income in other studies that examined it. No measures of remittances were used in any of the studies. We might expect that remittances from family members who worked in the city would be used to finance agricultural inputs.[7]

For similar reasons, use of credit may also be correlated with the use of improved inputs. However, credit is only statistically significant in the estimation for two sites in Ethiopia–North Omo and Sidamo for maize and Bale Highlands for wheat–and for the Kenyan Coast. Credit is not available in many areas. Where it is available, the use of credit is often highly correlated with wealth or farm size. Although many of the studies referred to access to credit, the variable that is used is whether the farmer actually obtained credit.

Extension is the one variable that was statistically significant in many of the estimations. The definition of extension varies—it may include simply whether or not the farmer had any extension contact or it may be based on the number and frequency of visits. At most study sites, farmers who grew improved varieties were more likely to have extension contact than farmers who were not. Many extension offices also provided inputs, which increased the correlation between extension contact and use of improved technologies. Thus, extension effort is more than simply increasing knowledge. The provision of extension services may also be correlated with infrastructure and market access.

---

[7] For example, Francis and Hoddinott (1993) find this to be the case in Kenya.

When other information variables were included in the analysis, they were usually significant. For example, variables that were significant in explaining the use of improved seed included attending a field day in Western Oromia (for maize hybrids but not OPVs), participating in demonstrations in Northwestern Ethiopia, and being a contact farmer (but not hosting demonstration plots) in Chilalo Awraja. In addition, being near the Arsi Agricultural Development Enterprise, the Ethiopian Seed Enterprise, or the research station in Chilalo Awraja meant that a farmer was more likely to use improved wheat varieties. In Kenya, access to extension increased the likelihood of using improved seed in Embu, while on the Coast factors such as listening to extension programs on the radio, being a member of a group, or participating in training courses were also significant. Membership in an organization in Ethiopia and at the Kenyan Coast—usually a producer cooperative—was often associated with use of improved varieties. This may be due to both the information and access to resources that the organization provides. In addition, to the extent that farmers choose to participate in these organizations, we would expect a greater likelihood of their being adopters and innovators.

A final factor that may be correlated with the use of improved varieties is the availability of labor. Small-scale farms obtain labor from household members or by hiring labor. One measure used frequently in adoption studies to account for labor availability is household size. This may be the total number of individuals, the number of adults, or the number of adult equivalents (calculated by counting children as a fraction of an adult). Household composition may also be important in determining household labor availability, but no measure of this was included in any of the 22 studies.

We did not find a clear relationship between household size and use of improved varieties. Where household size is a significant explanatory factor, it is sometimes positively and other times negatively related to use of improved technology. When land and labor markets exist, we would not necessarily expect to find any relationship between technology use and household size.

The use of hired labor was related to the use of improved wheat varieties in Tanzania. In Uganda and Kenya, the use of hired labor was related to the use of improved maize varieties. Again, the use of hired labor is probably also correlated with the wealth of the farmer and the size of the farm.

None of the studies explicitly included variables to account for the agricultural potential of the land at the village or farm levels. Several included a dummy variable identifying an agricultural zone. In Ethiopia, farmers in intermediate areas in Sidamo and North Omo were more likely to allocate land to improved maize than farmers in the lowland areas. No zone effect was found for fertilizer use. In the Enebssie region, farmers in highland areas were more aware of improved varieties than farmers in intermediate areas, but this did not affect their use of the technologies. The location of Wolmera Goro, a peasant association in the Wolmera Woreda, was related to an increased probability of using improved bread wheat varieties, but the authors assert that this is because it is closer to the research center and thus has greater access to inputs, rather than due to a greater agricultural potential.

In Tanzania, four studies included measures of location. The location variable was significant in determining the amount of land allocated to improved varieties except in the Central Zone. In the Eastern Zone, lowland farmers were less likely to allocate land to improved maize varieties than farmers in intermediate or highland areas. In the Southern Highlands, farmers in intermediate areas were less likely to allocate land to improved varieties than farmers in the highlands. In the Western Zone, farmers in low rainfall areas were less likely to allocate land to improved maize. In general, farmers in the highlands were more likely to use fertilizer than those in the lowlands.

It is worth noting that most of the studies failed to include any measure of farmers' gender. The analyses of the Central Highlands of Ethiopia and the Kenyan Coast did disaggregate the data, especially adoption data, by gender of the household head. Male-headed households were found to be more likely to use improved wheat varieties than female-headed households. In Tanzania, researchers claimed that there are few female-headed households. The assumption is implicit in all studies that the male household head is the primary farmer and decision-maker. This may not be true if the male head of household is a migrant within the country, leaving his wife to manage the farm for much of the year. There is increasing evidence that many economic decisions made within households are dependent upon the characteristics of both men and women members, and that it is not sufficient simply to model farming decisions made solely by male heads of household.[8]

Technology Characteristics

The characteristics of the available technology also influences farmers' use of the technology. Again the results presented in this section tell us less about whether or not farmers will adopt new technologies than about which technologies farmers are using. Only a few of the studies included measures of technology characteristics in the econometric analyses.

Three of the Tanzanian studies—Western, Central, and Eastern—controlled for technologies' characteristics by including dummy variables for whether the farmer grew early- (3 months), intermediate- (3.5-4.0 months) or late-maturing (4.5-5.0 months) varieties. The dependent variable in the estimation was the proportion of land allocated to improved varieties. In all three regions, more land was allocated to improved varieties when early-maturing varieties were grown. In Eastern Tanzania, this was also true when intermediate-maturing varieties were grown. Thus, less land was allocated to improved varieties when late-maturing varieties were grown. Only in Eastern Tanzania was maturity type identified as significant in explaining the use of fertilizer.

In Western Oromia, Ethiopia, variables indicating farmers' preferences were included in estimations. It was assumed that farmers who were concerned about high yield, resistance to lodging, clean seed, and conditioned seed would allocate more land to improved varieties. The estimations found that this was the case when looking at the amount of land allocated to hybrid maize, but not for improved OPVs.

---

[8] See Doss (1999) for a detailed discussion of women and agricultural technology in Africa.

Wheat farmers in the Bale Highlands were asked about their preferences on three types of traits—disease resistance, bread baking qualities, and lodging resistance. Farmers' preferences for each positively influenced the amount of land allocated to improved varieties.

Farmer Objectives

We would certainly expect that farmers' objectives influence decisions on whether to use improved technologies. However, it is hard to sort out some of the relationships. Farmer objectives may also change as farmers become familiar with improved technologies and see options that not previously available.

A measure of the area planted to cash crops was included in the Kakamega and Vihiga District study in Kenya, but was not significantly correlated with use of improved inputs. In the Bale Highlands, Ethiopia, a measure of the area under wheat was included. This may capture the extent to which wheat is an important crop for the farm, but because no other measure of farm size was included, it may simply be capturing the effect of farm size. In the Central Highlands of Ethiopia, distance to the market was included as a measure. This provides a proxy for how easy it would be for the farmer to produce for the market. This variable, however, was not statistically significant in explaining the use of improved technologies.

Conclusion

Extension is clearly the variable most highly correlated with the use of improved technologies. It is not always clear, however, what the extension variable is actually capturing. It may be related to the provision of both inputs and information. The extent of extension services may also be picking up infrastructure issues: farmers in more accessible, less remote areas may receive more frequent extension visits. This provides further evidence of the need for great care in interpreting variables.[9]

What are the Main Obstacles to Farmers Adopting Improved Technologies?

Farmers cited several reasons for not adopting improved technologies. The first was simply being unaware of the technologies or that they could provide benefits; this may included misconceptions about the related costs and benefits. The second reason was that the technologies were not profitable, given the complex sets of decisions that farmers make about how to allocate land and labor across agricultural and non-agricultural activities. This may be due to the fact that appropriate varieties for farmers' agroecological conditions were not available or that farmers preferred characteristics found only in local varieties. It may also be due to institutional factors, such as the policy environment, which affect the availability of inputs (land, labor, seeds, fertilizer) and markets for credit and outputs.

[9] For further discussion on the interpretation of variables, see Doss 2002.

These institutional factors also affect input prices. It may also be that use of improved technologies may increase production risks: if crops fail, the financial losses will be higher. Finally, technologies were not adopted because they were simply not available. The availability of improved seeds and fertilizer will be discussed in the following section.

In a number of studies, farmers (both adopters and non-adopters) were asked to identify constraints to the adoption of improved technologies. Most of the Tanzanian studies did not list farmers' responses on this point, so the following section uses only data from the other three countries. Several Tanzanian studies, however, did report on farmers' explanations regarding constraints to fertilizer use.

Availability of Information

The first issue is whether lack of information is a constraint to the adoption of new technology. Overall farmers did not identify lack of information as a key constraint to adopting improved varieties or fertilizer, with the exception of the Kenyan Coast and a few other areas. However, additional information on extension services and farmers' awareness of extension recommendations suggests that many farmers were not aware of recommendations or technologies. If a farmer does not know about a technology, he or she will not say that the lack of information is the constraint! For example, the study on Chilalo Awraja, Ethiopia, reports that only 8% of the farmers interviewed were able to identify or had information about new varieties.

Farmers were asked to list constraints to adoption of improved technologies in their areas. For improved maize varieties, 28% of non-adopters in the Uganda sample said that lack of information was a constraint. At the Kenyan Coast, the proportion was 14%. In Ethiopia, lack of information was mentioned as a constraint by 12% of lowland and 2% of intermediate zone farmers in Sadamo and North Omo, and 5% of adopters and 20% of non-adopters in the Bale Highlands. In Mbeya District (Southern Highlands), Tanzania, 21% of non-adopters of improved wheat varieties said that lack of information was a constraint.

The range of opinion among farmers was wider for fertilizer. In the Uganda study, 39% of adopters of improved varieties and 64% of non-adopters reported lack of information as a constraint to fertilizer use. In two woredas in Western Oromia, Ethiopia, no one reported that lack of information was a constraint, but in the other two woredas, 13% and 50% of the farmers identified it as a constraint. In Sidamo and North Omo, Ethiopia, information was mentioned as a constraint by only 2-3% of sampled farmers. All areas that reported lack of information as a constraint to fertilizer use were maize farming zones.

A second way to look at this issue is to examine where farmers obtain their information. Table 5 presents data on the availability and sources of information on improved technologies. The Tanzanian studies asked farmers whether they received information on improved varieties and fertilizer and where they received it. Extension was clearly one of the key sources of information, except in the lowlands of the Northern Zone.

These results should not necessarily be viewed as saying that extension is effectively getting the message out about improved technologies. In studies broken down by adopters and non-adopters, more adopters received extension services. It may be surprising, however, to note the percentage of non-adopters who received extension services: 77% in the Bale Highlands, Ethiopia; 31% in Kakamega and Vihiga Districts, Kenya; 32% on the Kenyan Coast; 35% in Uganda; and 57% in Mbeya District (Southern Highlands), Tanzania.

These results should be interpreted as indicating that farmers do not generally view lack of information as an important constraint. Many farmers who adopted improved technologies did not follow recommended practices. It is not at all obvious from the data whether this is because they misunderstood recommendations, because other constraints prevented them from fully implementing recommended practices, or because the recommendations were inappropriate for their situation. In addition, farmers may not have realized that they lacked the information and thus may not have listed this as an important constraint.

Several studies reported additional information about extension services. In the Central Highlands of Ethiopia, information on extension was reported according to the gender of the household head. Similar numbers of male- and female-headed households were taught to use fertilizer in two of the three woredas surveyed (Ada and Lume), whereas the differences were more pronounced for the use of improved seeds. Considerably more farmers received information from extension services about fertilizer than about improved seeds, regardless of the gender of the household head.

Of the farmers in Kiambu, Kenya, 80% who used manure as fertilizer, 59% who used only inorganic fertilizer, and 40% who used both said there were various problems with extension services, including infrequent visits, unavailability, and unclear messages. Farmers' perceptions of the effectiveness of extension services were not reported in other Kenyan studies.

The results suggest a continued, important role for extension services to inform farmers about new varieties and how to manage them.

Profitability

The second set of reasons for non-use of improved technologies was that they were not profitable, given farmers' constraints. Profit for farmers is the value of the output minus the cost of production, including the opportunity cost of their time. Farmers rarely talk about their decisions in these terms. Instead, they focus on one aspect of the equation—the price of inputs. Most surveys, including the CIMMYT/national system studies from Eastern Africa, do not ask farmers specifically about profitability, although some do to allow researchers to calculate profitability.

The high price of improved seed was frequently listed as a constraint to adoption. Among maize farmers in Ethiopia, 62% of lowland farmers and 45% of intermediate altitude farmers in Sidamo and North Omo reported price as a constraint. Even adopters of

Table 5. Availability and sources of information on improved technologies, Ethiopia, Kenya, Tanzania, Uganda, 1996-1999.

Country/region	Received information –varieties		Received information –fertilizer	
ETHIOPIA	**Extension any**	**Contact 1-2 times/month**	**>2 times/month**	
Bale Highlands:				
Adopters	92	38	25	
Non-adopters	77	30	12	
Central Highlands:				
Ada-MHH		13		38
Ada-FHH		11		37
Lume-MHH		51		100
Lume-FHH		17		100
Gimbichu-MHH		30		88
Gimbuchu-FHH		15		52
Wolmera Woreda:				
Wolmera Goro	78	20		
Robe Gebeya	68	15		
KENYA	**Any extension visit**			
Kakamega and Vihiga Districts				
Adopters	41			
Non-adopters	31			
Kiambu District:	47			
Use manure				
Use fertilizer	92			
Use both	94			
Coast:				
Adopters	53.8			
Nonadopters	32.5			
TANZANIA	**All sources**	**Extension**	**All sources**	**Extension**
Central:				
Lowlands	100	62	64	53
Intermediate	91	78	75	45
Highlands	100	67	91	86
Eastern:				
Lowlands	91	86	65	56
Intermediate	94	86	67	89
Lake Zone:				
Low rain	87	60	95	71
Intermediate	77	60	82	67
Northern:				
Lowlands	100	44	100	29
Intermediate	85	56	80	55
Southern:	44		6	
Southern Highlands:				
Intermediate	98	73	96	74
Highlands	96	79	96	80
Western:				
High	77		98	60
Low	79		100	95
Mbeya District (S. Highlands):	**None**	**Rarely**	**Regularly**	
Adopters	41	28	31	
Non-adopters	57	18	24	
High rain	100	57	100	92
UGANDA				
Iganga District:				
Adopters	51			
Non-adopters	35			

MHH=male-headed households. FHH=female-headed households.

improved wheat seed (68%) in the Bale Highlands in Ethiopia claimed high seed prices as a constraint; the proportion of non-adopters reporting price as a constraint was even higher (73%). In Chilalo Awraja, 35% of surveyed farmers cited the high price of improved seed as a constraint.

Cost was also often mentioned as a constraint to fertilizer use, especially in Ethiopia. The cost of fertilizer was a constraint for 78% of adopters and 88% of non-adopters of improved wheat varieties in the Bale Highlands, 8% of intermediate altitude farmers, and 16% of highland farmers in the Enebssie region; between 40% and 67% of farmers sampled at the four study sites in Western Oromia, and 83% lowland farmers and 63% of upland farmers in Sidamo and North Omo. Related to the issue of cost is the low price of wheat, mentioned as a constraint by 10% of both adopters and non-adopters of improved wheat varieties in the Bale Highlands.

In the Iganga District in Uganda, 31% of adopters of improved maize varieties and 13% of non-adopters reported cost of fertilizer as a constraint (note that the lack of information was a key constraint for non-adopters). In Tanzania, the proportion of farmers who mentioned cost as a constraint varied tremendously: 10% of lowland farmers, 35% of intermediate farmers, and 5% of highland farmers in the Central Zone; 94% of farmers in intermediate and 90% of farmers in highland areas in the Southern Highlands, a high potential zone; 92% of highland farmers, 88% of lowland farmers, and 100% of intermediate zone farmers in the Eastern Zone. Only 21% of farmers in the Southern Zone mentioned price as a constraint. It should be noted again that a much higher proportion of farmers in the Southern Highlands than in the Southern Zone actually used chemical fertilizer, even though they reported high price as a constraint. Few farmers in the Eastern Zone (15%) used fertilizer, while the rates were higher in the Western Zone (63%). Thus, there does not seem to be a pattern in farmers in Tanzania reporting price as a constraint to fertilizer use and their actually *using* it. It may be that farmers who use some fertilizer are aware of its benefits and would like to use more but are constrained by price. Those not using fertilizer may or may not say that price is the reason.

Price may be a constraint because farmers cannot purchase the inputs due to limited credit markets or because the marginal levels of output from improved varieties do not justify the use of improved inputs. More information on whether prices vary across regions would also be useful in understanding these relationships. In particular, the cost of fertilizer varies due to transportation costs: not only do costs vary across villages; farmers may also face different transportation costs to get the materials to their fields.

Related to the issue of price is whether farmers have access to cash or credit to purchase inputs. If farmers report that lack of credit is a constraint, we can assume that the problem is not that the technologies are unprofitable, but that the lack of a credit market makes it impossible for them to take advantage of available opportunities. The cost of credit is not addressed in the statement that credit is not available. Thus, it may be that credit is simply not available at any cost or that it is available only at high cost.

Many farmers reported credit as a constraint to using improved seed. In Ethiopia, lack of credit was a constraint for 26% of adopters of improved wheat varieties and 31% of non-adopters in the Bale Highlands, and for 5% of lowland and 12% of intermediate farmers in Sidamo and North Omo. Many farmers in Sidamo and North Omo also noted that lack of cash was a constraint (6% of lowland farmers and 19% of intermediate zone farmers**).**

When asked about constraints to adopting fertilizer, farmers did not mention credit. In Enebssie region, Ethiopia, however, 51% of intermediate zone farmers and 34% of highland farmers said that shortage of cash was an important constraint to fertilizer adoption. Reports of lack of credit and cash shortage are related to each other and to the price of fertilizer.

Table 6 provides details on the use of credit where this information was reported.
The use of credit overall was much higher in Ethiopia than elsewhere. Credit is provided through the State in Ethiopia either through State-run banks or cooperatives. The proportion of people using credit to purchase fertilizer is especially high. It is clear that the majority of people who use fertilizer purchase it on credit. In Tanzania, however, the use of formal credit is much more limited, even in areas where fertilizer is heavily used. The Tanzania studies report rates by zone of 0-44% of farmers using credit. Within Tanzania, there are fairly wide differences in use of formal credit. Farmers in higher altitude and rainfall areas were more likely to use credit. It is not clear whether credit is more widely available in these areas or whether farmers there are more likely and able to take advantage of available credit.

Many farmers reported that improved seeds and fertilizer were either not available, or, in the case of fertilizer, that delivery was too late. These issues will be discussed further in the next section, but they imply that, among other reasons, farmers do not use these technologies because they are simply not available.

Conclusion

To the extent that lack of information is the binding constraint, there continues to be an important role for extension services. These services may be provided through the government or through non-governmental organizations (NGOs). It is clear that farmers are eager for more and better information.

To the extent that farmers do not adopt improved technologies because they are not profitable, given the state of the technology and their circumstances, there are two directions that policies can take. The first is to increase the productivity of improved varieties, thereby increasing output. The second is to reduce input costs for farmers. Subsidizing costs is not sustainable, and it is crucial to think about how to reduce input costs by changes in infrastructure, transportation, credit availability, and markets.

It is difficult to determine which factors are behind farmers' decisions not to use new technologies. Farmers often report that input prices are too high, but this means that prices are too high given their knowledge and expected returns. Seeds and fertilizer may be unavailable in a particular region in part because they cannot profitably be sold and used in that area. Inputs may not be available if transportation costs for inputs and outputs are too high.

Table 6. Percentage of farmers using formal credit, Ethiopia, Kenya, Tanzania, Uganda, 1996-1999.

Country/region	Formal credit	Credit for seed	Credit for fertilizer	Use of chemical fertilizer
ETHIOPIA				
Bale Highlands:				
Adopters		48	85	95
Non-adopters		9	60	75
Central Highlands:				
Ada-MHH	100			100
Ada-FHH	96			100
Lume-MHH	100			100
Lume-FHH	96			100
Gimbichu-MHH	100			100
Gimbuchu-FHH	100			100
Enebssie:				
Intermediate	30			70
Highlands	18			27
Northwestern Province†:				
Adopters		37††	55	70
Non-adopters		14	86	27
Sidomo and North Omo Zone:				
Lowland		21	26	58
Intermediate		26	34	70
KENYA				
Kiambu District				
Adopters	3			46
Non-adopters	9			23
TANZANIA				
Central:				
Lowlands	7			17
Intermediate	0			77
Highlands	13			17
Eastern:				
Lowlands	6			17
Intermediate	14			8
Lake Zone:				
Low rain	3			50
Intermediate	2			48
High rain	0			100
Northern:				
Lowlands	8			64
Intermediate	19	20	25	44
Southern:	0			3
Southern Highlands:				
Intermediate	22			65
Highlands	20			79
Western:				
High	44	0	16	66
Low	32			60
Mbeya District (S. Highlands):				
Adopters	11			40
Non-adopters	0			0
UGANDA				
Iganga District:				
Adopters	17			3
Non-adopters	16			3

MHH=male-headed household; FHH=female-headed household.

† Only credit received from the state is reported here. Credit may also be obtained from others.

†† The numbers reported are for credit for seed and fertilizer combined.

Are Improved Seeds and Fertilizer Available?

In addition to understanding constraints that farmers face, it is important to know whether improved technologies are actually available to farmers in their villages. In this section, we examine this by looking at the seed and fertilizer industries in each of the four countries and farmers' perceptions of whether the lack of availability of seed and fertilizer is a constraint to adoption. When seeds or fertilizer are unavailable, it is challenging to ascertain whether the issue is a problem with the distribution network or lack of effective demand.

In a few of the studies, farmers were asked directly to list constraints to adoption of improved varieties. Table 7 summarizes responses on whether seeds and fertilizer are available. In most areas of Tanzania, farmers did not report that either seeds or fertilizer were unavailable. The exceptions were in the low and intermediate rainfall areas of the Lake Zone, where relatively high numbers of farmers reported that improved seeds were unavailable. Non-adopters of improved wheat seed in Mbeya District (Southern Highlands) also reported that seed was unavailable.

Each of the four countries has a different system for research and development and for distributing seed and fertilizer. For each of the four countries, we will briefly discuss the seed sector and the seed and fertilizer distribution systems. These systems differ markedly across the four countries, although all are moving towards greater reliance on the market and increased privatization.

Ethiopia

The four main sources of seed for Ethiopian farmers are purchase, other farmers, extension, and recycling own seed. The distribution of these sources varies widely across study regions. In the Bale Highlands, 51% of the farmers reported purchasing new seed, while 31% obtained seed through extension and 15% from other farmers. Farmers did not mention obtaining seed from their own fields, although this was a primary source of seeds for farmers in other

Table 7. Percentage of surveyed farmers reporting unavailability of seed or fertilizer, Ethiopia, Kenya, Tanzania, Uganda, 1996-1999.

Country/ region	Seeds unavailable	Fertilizer unavailable
ETHIOPIA		
Bale Highlands:		
Adopters	30	10
Nonadopters	27	10
Chilalo Arwaja:	42	
Enebssie:		
Intermediate		
Highlands		
Sidamo and North Omo Zone:		
Low	9	3
Intermediate	11	4
West Oromia:		
Western Shewa-Challya	NA	11
Western Shewa-Bake		
Tibe	NA	0
Eastern Wellega Bila-Sayo	NA	40
Eastern Wellega-Sibu Sire	NA	0
TANZANIA		
Lake Zone:		
Low rainfall	63	0
Intermediate rainfall	94	0
High rainfall		0
Southern Highlands:		
Intermediate	0	15
Highlands	0	5
Mbeya District (S. Highlands):		
UGANDA		
Adopters	0	6
Non-adopters	76	5
Inganga District:		
KENYA		
Adopters	14	0
Non-adopters	47	0
Coast		7.6

The Uganda study did not look at fertilizer adoption None of the other information for this table was reported for Kenya.

areas. Seed purchases were much lower in areas that reported their seed source. Most obtained seed either from other farmers or from their own fields. Extension services provide as little as 5% to 34% of seed for sowing, depending on the area.

The Ethiopian seed industry continues to be dominated by the public sector. Improved varieties are developed by the national agricultural research system and development programs or introduced from outside. Public institutions are responsible for producing and distributing seed to farmers, although some private companies are now entering the seed industry and have begun research on hybrid seed production, marketing, and distribution. Seed supply has been constrained by inefficient public seed enterprises, poor seed promotion, poor transportation, and inappropriate agricultural and pricing policies. The limited availability of fertilizer further constrained the use of improved seed. Most seed in the smallholder sector is still produced by farmers (Hailu 1992).

Since its establishment in the 1950s, the Ethiopian national maize research program has been introducing germplasm from outside sources. Ethiopia began participating in the Eastern Africa Cooperative Maize Trials in 1967. Hybrids from Kenya and Zimbabwe had a 30% yield advantage over tested varieties, so State farms were encouraged to import Kenyan hybrids. In the early 1980s, Ethiopia began a national maize breeding program that developed a number of hybrids suitable for Ethiopian conditions.

The Ethiopian Seed Enterprise (ESE), which was incorporated in 1979, is run as an interministerial seed board with autonomous status to function as a profit making enterprise. It dominates the production, multiplication, processing, and distribution of seed. Since a policy reform in 1991, ESE has obtained seed from research centers and makes contractual arrangements with private investors, the Ethiopian Agricultural Research Organization, seed farms, and State farms for the production and multiplication of improved maize seed. The ESE has acknowledged that it is not meeting demand for maize seed.

Kenya

All three Kenyan studies on the use of improved varieties included information on where seed was purchased. (It is not reported how the rest of the seed was obtained). Seventeen percent of smallholder (<20 ha) wheat farmers in the Naruk, Nakuru, and Uasin Districts reported that they obtained seed from the Kenya Seed Company (KSC); 9% from the Kenya Farmer's Association, and the majority (56%) from other farmers. The patterns were similar with large-scale farmers: almost 50% reported obtaining seed from other farmers. On the Coast, 54% used their own recycled seed while 33% purchased seed. Sixty-five percent of purchased seed was certified seed.

The Kenya maize seed industry, especially the hybrid seed development of the 1960s and 1970s, has been hailed as one of the success stories of agricultural development in Africa. Yet, maize seed sales have stagnated for the past 15 years. An attempt was made recently to liberalize the sector in the hope that competition would improve the availability of quality seed and thereby increase adoption of improved varieties. Although it is too early to judge its impact, some changes can already be observed.

Maize research in Kenya started before independence in the 1950s. In 1955, the first maize breeder was posted in Kitale to develop hybrid varieties (Gerhart 1975). The seed industry started in 1956 when European settlers formed the KSC to produce seed, initially for pasture. In 1963, the Kenyan government contracted with KSC to produce new maize hybrid seed. Later, in the 1980s the Kitale program developed new varieties jointly with KSC and the government obtained a majority share in the company. Maize hybrids were very successful and seed sales increased from 235 tons in 1963 to more than 20,000 tons in 1985 (Ndambuki 1998). Hybrids showed a clear yield advantage over other varieties, but their deployment was also supported by extensive agronomic research (to combine hybrid seed with fertilizer and other management practices), extensive demonstration trials, and a large extension effort including radio dissemination and agricultural credit to purchase inputs. Distribution was organized through the Kenya Farmers' Association and other distributors.

After the initial success of improved varieties, sales have hovered around 20,000 tons per year since 1985, although they reached a low of 13,202 tons in 1996—the last year for which figures are available (Ndambuki 1998). Liberalization of the seed sector began the same year. The seed sector was split between government services and companies; new seed companies, both local and multinational, have proliferated along with new distribution outlets (stockists). Quality control was transferred from the Kenya Agricultural Research Institute (KARI) to a new regulatory agency, the Kenya Plant Health Inspectorate Service (KEPHIS). The Kenya Agricultural Research Institute's close link with KSC has also been severed and several disputes around property rights of old hybrids have soured the relationship. The KSC still has a quasi monopoly on late-maturing highland varieties, but new companies are moving in fast in intermediate-maturity varieties for the midaltitudes. The KSC has a strategy of a single price regardless of seed type or place of sale, whereas newcomers are much more flexible. With the arrival of new players, market information is much harder to come by. Despite the liberalization and delinking of quality control, seed regulations are still cumbersome and expensive.

The liberalization of the agricultural sector in general, which started in the late 1980s, also affected the demand for improved seed and other inputs. The number of distributors of agricultural inputs has mushroomed, making inputs widely available. However, subsidies have been abolished and the agricultural credit system has collapsed. Fertilizer subsidies as well as import taxes have also been abolished and competition to import and distribute is heavy (no fertilizers are produced in Eastern Africa). However, transport costs remain high and have increased the effective cost of fertilizers, although fertilizer has become more available. Since hybrids are less effective without fertilizer, this is assumed to decrease the demand for hybrid seed.

Tanzania

Four of the seven Tanzanian studies discussed how farmers obtained their seeds. In the high rainfall area of the Lake Zone, 85.7% of farmers reported purchasing seed regularly. The primary source for seed was NGOs. In the low rainfall zone, only 29% of farmers purchased seed regularly from the cooperative union or local market. No farmers in the intermediate zone reported purchasing seed regularly, but purchases, when made, were primarily from the cooperative union. The Southern Highlands again stands out as being different from other zones in Tanzania. Ninety percent of farmers in the highlands and 97% in intermediate areas purchased maize seeds regularly. The majority reported that their source of seeds were stockists. In Western Tanzania, only 14% of respondents reported purchasing new seed regularly. Forty-seven percent of wheat farmers in Mbeya District (Southern Highlands) obtained seed from other farmers and 31% from the market; the remainder was split between research, extension, NGOs, and retaining one's own seed.

The seed industry in Tanzania has been involved in maize breeding in Tanzania for more than 20 years. Open-pollinated varieties that were released in the 1960s are still widely used in some areas. In 1974, the National Maize Research Program was launched, which released two hybrids and six OPVs in the 1970s and 1980s.

The input market was liberalized in 1990 and the number of businesses engaged in selling inputs has increased dramatically. In many areas, inputs are available through village stockists and many shortages have been reduced. Inputs are available in a timely manner, but at a much higher price than previously. This corresponds to the fact that no farmers reported a lack of availability of seed or fertilizer.

The public sector seed source, Tanseed, markets locally bred hybrids. They have increasingly had competition from the private seed companies, Cargill and Pannar. By 2001, the public sector had released about 15 improved varieties and the private sector had released 12. Even though private companies produce purer, more uniform, and higher yielding seed, prices are also higher and grains have poorer storage, pounding, and taste qualities.

Uganda

Uganda suffered a near total collapse of the agricultural research system, seed multiplication capacity, output markets, input distribution networks, and extension services in 1986. The recommended variety Longe 1 was released in 1991 and was made available to farmers primarily though on-farm trials. Many farmers continue to grow Kawanda Compsite A, a variety released over 20 years ago and no longer distributed. Both of these varieties are OPVs.

The only study was in Iganga District, where there have been verification and demonstration trials for maize technologies since the 1980s, many conducted in farmers' fields. Thus, we would expect a high proportion of farmers in this District to have adopted the recommended variety. Most farmers who grew Longe 1 (51%) purchased or retained it from the previous harvest (46%). Seed for the other variety grown (not considered an "improved variety" since it was released in 1971) was saved from previous harvests.

The Ugandan Ministry of Agriculture multiplies breeder seed, certifies seed, and markets through private entrepreneurs and extension services. Associated agricultural inputs, such as fertilizer, are available mostly through private suppliers in urban areas. A large number of non-adopters (47%) reported that seeds were unavailable, although only 14% of adopters said that this was so.

Conclusion
The availability of seed and fertilizer varies from Kenya and Tanzania, where they are widely available locally through private shops, to Ethiopia, where seed is less readily available for purchase. Although the simple adoption numbers as reported in Table 2 do not necessarily reflect patterns of adoption by country or, thus, by availability of seed, it does seem that more farmers purchase seed in areas where seed is available. Causality should not necessarily be inferred—it may be simply that the private sector is more willing to supply seed in areas where farmers would choose to purchase it.

Implications for Policy and Research

One of the advantages of having a number of similar studies that vary across agroecological zones and also across countries is that it allows us to ask how institutional factors affect adoption of technology. These institutional factors include government policies, such as the privatization of input sectors discussed above and broader institutional factors, such as market access. Comparisons across areas with differing agricultural potential should also be possible.

The CIMMYT/national system micro-level studies provide some insights into these issues. Even though they are not detailed enough for formal hypothesis testing, they do provide some directions and suggestions for further research.

One interesting question is whether areas with higher agricultural potential are more likely to adopt improved technologies. The highest levels of adoption in Ethiopia were in Chilalo Awraja and Northwestern Province, areas with the highest altitude among those surveyed. High altitudes tend to get more rainfall, although not all studies report on rainfall. Yet in other areas with relatively high potential, especially the Central Highlands, there was low adoption of improved wheat and maize, although 100% of the farmers used fertilizer. Within survey areas, farmers at higher altitudes were more likely to adopt improved technologies than those at lower altitudes. A similar pattern seems to hold in Tanzania, where high potential areas included the Northern Zone and the Southern Highlands. The Northern Zone had high levels of adoption of improved maize varieties and the Southern Highlands had lower levels of adoption, but both are areas where farmers were most likely to purchase new seed. Thus, farmers in the South may have been taking better advantage of improved technologies than simple adoption proportions suggest. It is hard to see a pattern emerging from altitude and rainfall data alone, within study areas in Tanzania. This may be because other factors were more important or because other factors influencing agricultural productivity are not captured in the rainfall and altitude data.

A second question is whether market access plays a role in determining the level of adoption. Market access could affect adoption decisions in two ways. First, farmers would be more likely to produce for the market and it would be cheaper and easier to get goods to market. Second, market access reduces the costs—both in time and money—of obtaining inputs. In Ethiopia, the areas with the greatest market access were Chilalo Awraja and Wolmera Woreda. The former had a relatively high level of adoption of improved wheat.[10] In Tanzania, even areas with low market access had relatively high levels of adoption—in part because the term “adoption” in Tanzania includes all improved materials, not just recommended or recently released variety. The high market access Northern Zone had one of the highest levels of adoption of improved seed. There does not seem to be a direct link between market access defined across survey sites and level of adoption, possibly because of significant uncontrolled variation within surveyed zones.

A third question is whether intensification results in higher levels of adoption. All studies listed either the population density for the region as a whole, the average farm size of surveyed households, or both. Farm size is included in most regression analyses; however, we might expect that the average farm size for a region reflects the relative abundance or scarcity of land. There were no clear relationships between population density or farm size and adoption levels at aggregate levels for which data were available. The aggregate data may mask many relationships to be found in much more localized data.

The most important finding from these studies is that technology adoption is taking place across Eastern Africa. This is important, especially given that some researchers are skeptical about the willingness of farmers in the region to innovate and adopt new approaches. There was no evidence that farmers are failing to take advantage of these technologies where it is economically advantageous for them to do so.

There are no simple correlations across all studies that indicate one factor as key in the adoption process. Extension is the variable that is most statistically significant in explaining technology use. The lack of a clear correlation between individual indicators across sites may be that these relationships are difficult to pick up in the data, especially since many of the explanatory variables are highly correlated. It may also be that policies, institutions, and infrastructure are important determinants of adoption levels and micro-studies do not pick up these factors, even within regions.

The descriptive information available from these studies will be of use to policy makers within the region. These data have not previously been available. This basic information about the levels of adoption is critical for priority setting and impact assessment.

A number of lessons have been learned about how to carry out adoption studies across sites to allow us to address some bigger issues. It is crucial to standardize what we mean by an adopter. Clearly, the use of improved seed could be better defined in different categories such as: purchase of improved seed (in a certain period), use of recycled hybrids, and the use of recycled, improved open-pollinated varieties. Adding the number of cycles can further refine recycling. Moreover, adoption studies should cover clearly defined areas and the sampling procedure should result in a representative sample of the target area.

---

[10] Adoption levels are not available for Wolmera Woreda.

Regarding policy implications, although the econometric estimations do not necessarily yield clear conclusions on their own, they can be used in combination with the descriptive data and discussions with staff at national research centers who participated in the micro-studies, to arrive at certain clear inferences.

Research and extension are vital for the development and dissemination of new technologies and these services need to be strengthened. Research, especially maize and wheat breeding research, needs to be more relevant to farmers' circumstances and preferences. This suggests that there is a continuing need to link research and extension. Although governments should increase budgetary support for extension services, strengthening these services may also involve private sector and NGO participation.

Policies should also support the development and expansion of efficient markets for inputs and outputs. The recent liberalization of these markets in many Eastern African countries should be continued, with emphasis on finding ways to decrease input costs. Although the private sector clearly plays a role in this, the government also has a role by providing physical infrastructure. Finally, the rural credit system should be strengthened to improve availability and access to credit.

These studies have also opened up a number of bigger questions about technology adoption in Eastern Africa; specifically, relating to the role of policies, institutions, and infrastructure in the adoption process. The CIMMYT/national system studies suggest these may be important and encourage us to move beyond micro-level studies to answer these questions.

References

CBS. 1990. *Crops focus survey*. Nairobi, Kenya: Central Bureau of Statistics, Ministry of Planning and National Development, Kenya.

CIMMYT.1993. The *adoption of agricultural technology: A guide for survey design.* Mexico, D.F.: CIMMYT.

Doss, C.R. 1999. *Twenty-five years of research on women farmers in Africa: Lessons and implications for agricultural research institutions; with an annotated bibliography*. CIMMMYT Economics Program Paper No. 99-02. Mexico D.F.: CIMMYT.

Doss, C.R. 2002. Understanding farm level technology adoption: Lessons learned from micro surveys in Eastern Africa. CIMMYT Economics Program Working Paper No. 02-05. Mexico, D.F.: CIMMYT

Ekboir, J. (ed.). 2002. *CIMMYT 2000-2001 World Wheat Overview and Outlook: Developing No-Till Packages for Small-Scale Farmers*. Mexico, D.F.: CIMMYT.

Francis, E. and J.Hoddinott. 1993. Migration and differentiation in Western Kenya: A tale of two sub-locations. *Journal of Development Studies* 30(1):115-45.

FSD. 1992. *Comprehensive Food Security*. Dar-Es-Salaam, Tanzania; Food Security Department, Government of the United Republic of Tanzania, and the United Nations Food and Agriculture Organization (FAO).

FSD. 1996. *Tanzania food security bulletin* No. 2, April/May 1996. Dar-Es-Salaam, Tanzania: Food Security Department, Ministry of Agriculture.

Gerhart, J. 1975. *The diffusion of hybrid maize in Western Kenya*. Mexico, D.F.: CIMMYT.

Hailu, G. 1992. *Availability and use of seed in Ethiopia*. Addis Ababa, Ethiopia: Program support unit, Canadian International Development Agency.

Morris, M., J. Risopoulos, and D. Beck.1999. *Genetic change in farmer-recycled maize seed: A review of the evidence*. CIMMYT Economics Working Paper No. 99-07. Mexico, D.F.: CIMMYT.

Ndambuki, F. M. 1998. Kenya Seed Company: Activities and organization. In: Mwangi W. M. (comp.). *Seed production and supply policy: Teaching notes for the Training Workshop on Seed Production and Supply Policy*. Addis Ababa, Ethiopia: CIMMYT.

Appendix 1. CIMMYT/National System Eastern African Adoption Studies

Ethiopia

Tiruneh, A., T. Tesfaye, W. Mwangi, and H. Verkuijl. 2001. *Gender differentials in agricultural production and decision-making among smallholders in Ada, Lume, and Gimbichu Woredas of the Central Highlands of Ethiopia*. Mexico, D.F.: CIMMYT and Ethiopian Agricultural Research Organisation (EARO).

Getahun Degu, W.Mwangi, H. Verkuijl, and Abdishekur Wondimu. 2000. *An assessment of the adoption of seed and fertilizer packages and the role of credit in smallholder maize production in Sidamo and North Omo Zone, Ethiopia.* Mexico, D.F.: CIMMYT and Ethiopian Agricultural Research Organisation (EARO).

Abdissa G., G. Aboma, H. Verkuijl, and W. Mwangi. 2001. *Farmers' maize seed systems in Western Oromia, Ethiopia.* Mexico, D.F.: CIMMYT and Ethiopian Agricultural Research Organisation (EARO).

Tesfaye Zegeye, Girma Taye, D. Tanner, H. Verkuijl, Aklilu Agidie, and W. Mwangi. 2001. *Adoption of improved bread wheat varieties and inorganic fertilizer by small-scale farmers in Yelmana Densa and Farta Districts of Northwestern Ethiopia*. Mexico, D.F.: CIMMYT and Ethiopian Agricultural Research Organisation (EARO).

Bekele Hundie Kotu, H. Verkuijl, W. Mwangi, and D. Tanner. 2000. *Adoption of improved wheat technologies in Adaba and Dodola Woredas of the Bale Highlands, Ethiopia.* Mexico, D.F.: CIMMYT and Ethiopian Agricultural Research Organisation (EARO).

Alemu Hailye, H. Verkuijl, W. Mwangi, and Asmare Yalew. 1998. *Farmers' wheat seed sources and seed management in Enebssie area, Ethiopia*. Mexico, D.F.: CIMMYT and Institute of Agricultural Research (IAR now EARO).

Hailu Beyene, H. Verkuijl, and W. Mwangi. 1998. *Farmers' seed sources and management of bread wheat in Wolmera Woreda, Ethiopia*. Mexico, D.F.: CIMMYT and Institute of Agricultural Research (IAR now EARO)

Regassa Ensermu, W. Mwangi, H. Verkuijl, Mohammad Hassena, and Zewdie Alemayehu. 1998. *Farmers' wheat seed sources and seed management in Chilalo Awraja, Ethiopia*. Mexico, D.F.: CIMMYT and EARO.

Kenya

Makokha, S., S. Kimani, W. Mwangi, H. Verkuijl, and F. Musembi. 2001. *Determinants of fertilizer and manure use in maize production in Kiambu District, Kenya*. Mexico, D.F.: CIMMYT and KARI.

Salasya, B.D.S., W. Mwangi, H. Verkuijl, M.A. Odendo, and J.O. Odenya. 1998. *An assessment of adoption of seed and fertilizer packages and the role of credit in smallholder maize production in Kakamega and Vihiga Districts.* Mexico, D.F.: CIMMYT and KARI.

Ouma, J., F. Murithi, W. Mwangi, H. Verkuijl, M.Gethi, H. De Groote. 2002. *Adoption of seed and fertilizer technologies in Embu District, Kenya.* Mexico, D.F.: CIMMYT and KARI.

Gamba, P., C. Ngugi, H. Verkuijl, W. Mwangi, and F. Kiriswa. 2001. *Wheat farmer's seed management and varietal adoption in Tanzania*. Mexico, D.F.: CIMMYT and KARI

Wekesa E., W. Mwangi, H. Verkuijl, K. Danda, H. De Groote. 2002. *Adoption of maize production technologies in the Coastal Lowlands of Kenya.* Mexico, D.F.: CIMMYT and KARI.

Tanzania

Mussei, A., J. Mwanga, W. Mwangi, H. Verkuijl, R. Mongi, and A. Elanga. 2001. *Adoption of improved wheat technologies by small-scale farmers, Southern Highlands, Tanzania.* Mexico, D.F.: CIMMYT and the United Republic of Tanzania.

Kaliba, A.R.M., H. Verkuijl, W. Mwangi, A.J.T. Mwilawa, P. Anandajayasekeram, and A.J. Moshi. 1998. *Adoption of maize production technologies in Central Tanzania.* Mexico, D.F.: CIMMYT, United Republic of Tanzania, and Southern African Centre for Cooperation in Agricultural Research (SACCAR).

Bisanda, S., W. Mwangi, H. Verkuijl, A.J. Moshi, and P. Anadajayasekeram. 1998. *Adoption of maize production technologies in Southern Highlands of Tanzania.* Mexico, D.F.: CIMMYT, United Republic of Tanzania, and Southern African Centre for Cooperation in Agricultural Research (SACCAR).

Katinila, R., H. Verkuijl, W. Mwangi, P. Anadajayasekeram, and A.J. Moshi. 1998. *Adoption of maize production technologies in Southern Tanzania.* Mexico, D.F.: CIMMYT, United Republic of Tanzania, and Southern African Centre for Cooperation in Agricultural Research (SACCAR).

Nkonya, E., P. Xavery, H. Akonaay, W. Mwangi, P. Anandajayasekeram, H. Verkuijl, D. Martella, and A.J. Moshi. 1998. Adoption of maize production technologies in Northern Tanzania. Mexico, D.F.: CIMMYT, United Republic of Tanzania, and Southern African Centre for Cooperation in Agricultural Research (SACCAR).

Kaliba, A.R.M., H. Verkuijl, W. Mwangi, D.A. Byamungu, P. Anadajayasekeram, and A.J. Moshi. 1998. *Adoption of maize production technologies in Western Tanzania.* Mexico, D.F.: CIMMYT, United Republic of Tanzania, and Southern African Centre for Cooperation in Agricultural Research (SACCAR).

Kaliba, A.R.M., H. Verkuijl, W. Mwangi, A. Moshi, A. Chilangane, J.S. Kaswende, and P. Anadajayasekeram. 1998. *Adoption of maize production technologies in Eastern Tanzania*. Mexico, D.F.: CIMMYT, United Republic of Tanzania, and Southern African Centre for Cooperation in Agricultural Research (SACCAR)..

Mafuru, J., R. Kileo, H. Verkuijl, W. Mwangi, P. Anandajayasekeram, A. J. Moshi. 1999. *Adoption of maize production technologies in Lake zone of Tanzania*. Mexico. D.F.: CIMMYT, United Republic of Tanzania, and Southern African Center for Cooperation in Agricultural Research (SACCAR).

Uganda

Ntege-Nanyeenya, W.M. Mugisa-Mutetikka, W. Mwangi, and H. Verkuijl. 1997. *An assessment of factors affecting adoption of maize production technologies in Iganga District, Uganda.* Mexico, D.F.: CIMMYT and National Agricultural Research Organization (NARO).

ISSN: 0258-8587

CIMMYT
International Maize and Wheat Improvement Center
Apartado Postal 6-641, 06600 México, D.F., México
Worldwide Web site: www.cimmyt.org