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Determinants of Adoption of Improved Maize Varieties and Chemical Fertilizers in Mozambique

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Abstract

In Mozambique, adoption of improved maize seed and chemical fertilizers is still limited. This study assessed farmers' attitudes towards hybrid maize SC513, Nitrogenous (N) Phosphorous (P) Potassium (K), (NPK 12-24-12) and urea fertilizers in highlands and lowlands of the Manica District. The study determined the influence of farmers' characteristics, attitudes, sources of information, and agro-ecological conditions on adoption of these technologies during 1995 through 2005. A questionnaire was administered during April and May 2006 with a randomly selected sample of 293 households. In general, farmers held positive attitudes towards improved maize varieties and chemical fertilizers, but the strength of attitudes towards fertilizers, in particular, varied by source of information. Farmers who learned about fertilizers from extension had stronger positive attitudes than farmers who learned about fertilizers from neighbors, although with hybrid seeds adoption, there was no significant difference between key sources. Overall, the number of farmers using SC513 was higher than the number of farmers using NPK and urea. Farmers' decision to adopt SC513 was positively associated with agro-ecological conditions, knowledge, production traits and marketability of the maize. Agro-ecological conditions, knowledge of fertilizer application, and extension contact influenced adoption of chemical fertilizers. The results differentiate a simpler process of adoption of new seed from a more complex process of adoption of fertilizers which demands greater knowledge of timing and soils as well as basic computational skills. Factors determining adoption of hybrid maize varieties and chemical fertilizers should be considered when designing extension programs for these technologies.

Keywords: Adoption, attitudes, chemical fertilizer, extension, improved maize varieties

Introduction

Improving maize production is one of the most important strategies for food security in Mozambique. However, chemical fertilizers and improved maize varieties are not yet widely adopted in Mozambique. In 2008 less than 5 percent of approximately three million farmers used chemical fertilizers and about 10 percent used improved maize varieties (Ministry of Agriculture [MINAG], 2009). Hence a widespread adoption of improved seed varieties and chemical fertilizers is a challenge for agricultural development policy in Mozambique.

Improved maize varieties include hybrids and open pollinated varieties (OPVs) whose traits have been improved for selected characteristics such as drought tolerance, disease resistance, short maturity rate, increased yield per unit of land, and quality protein (Byerlee, 1994). Adoption of improved maize varieties can help farmers face labor constraints, food insecurity and lack of income. Research in Southern Africa (Byerlee, 1994; Kaliba et al., 2000) indicated that farmers prefer early maturing maize to better deal with labor constraints, risk considerations and crop rotations. Sometimes farm households would improve food security by planting an early maturing variety that can be consumed in the "hungry season," before the main harvest. In areas with small scale irrigation and near market places for fresh maize, early maturing varieties provide sources of income for farmers (Rotter and Keulen, 1996).

Expanded use of fertilizer in Sub-Saharan Africa has been stressed as one of the solutions to alleviate production shortfalls and land degradation in the region (Pinstrup-Andersen, Pandya-Lorch, & Rosegrant, 1997). Farmers can benefit from applying chemical fertilizer to maize. When used in optimal amounts, chemical fertilizers increase production and farm efficiency. Optimal applications of commercial fertilizers replenish the nutrients removed by the crop and in some cases exceed levels of nutrients found in the soils before they were farmed. In Kenya, Rotter and Keulen (1996) found that there was a tremendous potential for increasing maize yields, and hence national production, by applying moderate amounts of nitrogen (N) and phosphorous (P) fertilizers in the lowlands and midlands.

For widespread adoption of improved varieties and chemical fertilizer by farmers, extension educators need to understand the factors affecting technology adoption (Abebaw & Belay, 2001). Adoption of technology is influenced by physical, socio-economic, and mental factors including agro-ecological conditions, age of farmer, family size, education of farmer, how-to-knowledge, source of information, and farmer's attitudes towards the technology (Feder et al., 1985; Byerlee & Polanco, 1986; Neupane et al., 2002; Rogers, 2003). High levels of adoption of improved maize varieties and chemical fertilizers are more likely to be found among farmers located in agro-ecological regions with high rainfall (Kaliba et al., 2000; Hintze et al., 2003). Young farmers are more likely to adopt a new technology because they have had more schooling and are more open to attitude change than older farmers (International Maize and Wheat Improvement Center [CIMMYT], 1993; Visser & Krosnick, 1998). Education is expected to enhance the decision making and the adoption of agricultural technologies. Family size plays a role on labor provision. Adoption of new varieties often requires more labor inputs (Feder et al., 1985). It is assumed that large families provide the labor required for improved maize production practices. Access to sources of information, such as extension, market, and neighbors, enhances the adoption of technology (Abebaw & Belay, 2001). Knowledge influences adoption. Farmers who have adequate knowledge of technology use are more likely to adopt it (Abebaw & Belay, 2001; Rogers, 2003).

Knowledge of technology application acts as an intervening variable between "attitudes towards the technology" and "use of the technology" (Rogers & Havens, 1961). Farmers' attitudes are important in determining adoption of improved technology. Attitudes are evaluative responses towards the technology, and are formed as farmers gain information about it. Adopters tend to hold positive attitudes towards the technology (Chilonda & Van Huylenbroeck, 2001). The literature suggests that attitudes towards improved maize varieties place great emphasis on two factors: *production characteristics* and *income factors*. Similarly, for chemical fertilizers, the literature suggests two factors: *effect of fertilizer* and *costs factors* (Enyong et al., 1999; Thompson, 1992).

The objectives of this study were twofold: firstly, to assess farmers' attitudes towards adoption of hybrid maize SC513, NPK, and urea fertilizers in highlands and lowlands of the Manica District; and secondly, to determine the influence of farmers' characteristics, attitudes, source of information, and agro-ecological conditions on adoption of hybrid maize SC513, NPK, and urea fertilizers.

Materials and Methods

This study involved a cross-sectional survey with 293 randomly selected households growing maize in the highlands of Machipanda and lowlands of Vanduzi in the Manica District, central region of Mozambique. Machipanda and Vanduzi were selected purposely because of the importance of maize in the farming systems and the availability of maize technology dissemination programs in the two areas. Vanduzi and Machipanda represent two distinct agro-ecological zones, R4 and R10 respectively. Machipanda is located at higher altitude (900-1500 m), and gets higher annual rainfall (900-1500 mm) than Vanduzi which is located at 200-1000 m above sea level with annual rainfall of about 900-1000 mm.

Data were collected between April and May, 2006, using personal interviews with 120 farmer household heads from Machipanda, and 173 fromVanduzi. The explanatory variables measured in the questionnaire are presented in Table 1.

The Logistic Model

In the field of agriculture, adoption of technologies is measured as a dichotomous response variable (0 = non - adoption of innovation and 1= adoption of innovation). The logistic model is the standard method of analysis, when the outcome variable is dichotomous (Hosmer & Lemeshow, 2000). The logistic regression model characterizing adoption of SC513, NPK or urea by the sample of households is specified as follows:

$$\pi = \frac{e^{\alpha+\beta1x1+\beta2x2+\cdots+\beta pXp+\varepsilon}}{1+e^{\alpha+\beta1x1+\beta2x2+\cdots+\beta pXp+\varepsilon}} \quad (1.0)$$

Where:

π, is the actual proportion of farmers adopting the technology for particular values of independent variables $X_1, X_2, \ldots, X_p$, that influence adoption of SC513, NPK or urea. $\beta_1, \beta_2, \ldots, \beta_p$ denote the regression coefficients associated with independent variables $X_1, X_2, \ldots, X_p$. ε is the error term. From the equation (1.0), we arrive at a simple linear regression equation through *logit transformation* (Chatterjee et al., 2000; Hosmer and Lemeshow, 2000):

$$\log[\pi/(1-\pi)] = \alpha + \beta1x1 + \beta2x2 + \cdots + \beta pXp + \varepsilon \quad (2.0)$$

Table 1
Description of Explanatory Variables Measured in the Questionnaire

Variable name	Variable type	Description
Agro ecological region (X_1)	Dichotomous	0 = Lowlands (Vanduzi), 1 = Highlands (Machipanda)
Age (X_2)	Continuous	Farmer's age (years)
Family size (X_3)	Continuous	Number of members in the family
Level of education (X_4)	Dichotomous	0 = illiterate, 1 = some schooling
Knowledge of advantages and disadvantages of improved maize and knowledge of fertilizer application(X_5)	Dichotomous	0 = not knowledgeable, 1 = knowledgeable
Source of information (X_6)	Multiple category variable	*For improved maize SC513:* 1 = neighbors, 2 = market, 3 = extension *For chemical fertilizers:* 1= market, 2 = extension, 3 = neighbors
Attitude (X_7)	Interval	Factor scores for attitude toward marketability of grain of improved maize SC513 Factor scores for attitude toward production traits of improved maize SC513 Factor scores for attitude toward NPK Factor scores for attitude toward urea

Data Analysis

Data were analyzed using the Statistical Package for Social Sciences SPSS version 15 **(**SPSS Inc. 2006). Attitude statements were measured using a 5-point Likert scale with *1 = Strongly Agree, 2 = Agree, 3 = Neutral, 4 = Disagree, and 5 = Strongly Disagree.* Exploratory and confirmatory factor analyses were used to create summated scales of attitudes towards SC513, NPK and urea. A two-factor model for improved maize variety SC513 had an excellent fit, $X^2 = 7.550$, $p > 0.05$. Comparative index (CFI) was greater than 0.90 and the root mean square error of approximation (RMSEA) was lower than 0.05. A one-factor model for NPK had also a good fit, $X^2 = 7.285$, $p > 0.01$. Comparative index (CFI) was greater than 0.90. Although the RMSEA was greater than 0.05, the 90% confidence interval for RMSEA was 0.030 to 0.184. This interval includes 0.05 criteria which indicate "reasonable" errors of approximation in the population. A one-factor model for urea had a reasonable fit. Comparative index (CFI) was slightly greater than 0.90. This means that although X^2 and RMSEA had values of 31.267 and 0.237 respectively, which suggest a poor fit, the one-factor model is still better than the complete or baseline model for urea.

Each of the two factors of the scale on attitudes towards maize variety SC513 had three items. Hence, for each factor the summed score across items for a given respondent ranged from 3 to 15, with scores lower than 9 indicating favorable attitudes, and scores greater than 9 indicating unfavorable attitudes. The scale of attitudes towards NPK /Urea had four items. The summed score across items for a given respondent ranged from 4 to 20, with scores lower than 12 indicating favorable attitudes, and scores greater than 12 indicating unfavorable attitudes. One-Way ANOVA was used to compare mean attitude scores for the three groups of sources of information on the technology, neighbors, market, and extension.

To create attitude scores for subsequent use in logistic regression, factor scores were estimated through principal component and varimax procedure (Hair et al., 2005). Two-factor solutions for the attitude scale on SC513, explained about 59.3 percent of the variance in attitudes toward SC513. One factor solution for the attitude scale on NPK explained about 48 percent of the variance in attitude toward it. One factor solution for the attitude scale on urea explained about 56.4 percent of the variance in attitudes toward urea. Variance Inflation Factor (VIF) estimates were examined for collinearity diagnostic in Multiple Logistic Regression. Most of VIF estimates had values less than 2, which indicate no serious problems of collinearity.

Results and Discussion

Characteristics of farmers

The last section of the questionnaire measured the general characteristics of the farmers. The results are presented in Table 2.

Table 2
Characteristics of Farmers in Machipanda and Vanduzi in the Manica District

Characteristics	Study Location			
	Machipanda		Vanduzi	
	Frequency	Percent	Frequency	Percent
Age (Years)	(n = 120)		(n = 173)	
Less than 44	65	54.2	89	51.4
45 to 60	38	31.7	59	34.1
61 to 76	12	10.0	21	12.1
More than 76	5	4.2	4	2.3
Level of education	(n = 120)		(n = 173)	
Illiterate	17	14.2	53	30.6
Primary School	95	79.2	109	63.0
Secondary/High School	8	6.7	11	6.4
Family size	(n = 120)		(n = 173)	
Less than 8	79	65.8	112	64.7
9 to 12	30	25.0	44	25.4
More than 13	11	9.2	17	9.8

Farmers were similar regarding age and family size. In both study locations the majority of farmers had an age < 44 years and family size < 8 members. However, for level of education the respondents showed differences. Vanduzi had a larger number (30.6 %) of illiterate farmers than Machipanda (14.2 %). It is possible that farmers in Machipanda had more access to school due to proximity to Zimbabwe, than farmers in Vanduzi.

The results on family size indicate that about 25 percent of households in both study areas have between 9 and 12 members. These numbers are higher than the average family size in rural areas of Mozambique which is approximately six members. Assuming that adoption of new varieties requires more labor inputs (Feder et al., 1985), we would think that 25 percent of the rural households in Machipanda and Vanduzi, have relatively large families to rely upon for labor demands. However, the total number of family members does not always mean availability of labor, because some families may have higher dependency rates than others. Thus while the relatively large family size may suggest more labor for cultivation, more precise results on labor availability would need to be provided by information on dependency ratios.

Farmers' Attitudes Towards Improved Maize SC513, NPK and Urea Fertilizers

To capture farmers' attitudes, farmers were asked the extent of their agreement with six statements on characteristics and marketability of improved maize variety SC513, four statements on chemical fertilizer NPK, and four statements on chemical fertilizer urea. Tables 3, 4 and 5 present farmers' attitudes towards improved maize SC513, NPK and urea fertilizers. Mean score was based on a 5-point interval scale where *1 equals Strongly Agree, 2 equals Agree, 3 equals Neutral, 4 equals Disagree, and 5 equals Strongly Disagree*. The scale was reversed for negative statements.

Table 3
Farmers' Attitudes Towards Improved Maize Variety SC513

	Percent of Response Categories in Machipanda (n = 115)							Percent of Response Categories in Vanduzi (n = 91)						
	SA %	A %	N %	D %	SD %	*M*	*SD*	SA %	A %	N %	D %	SD %	*M*	*SD*
Attitude toward marketability of improved maize variety SC513.														
Grain from SC 513 is easy to sell.	7.8	66.1	19.1	6.1	.9	2.3	.7	7.7	62.6	29.7	-	-	2.2	.6
Fresh maize (roasting cobs) of SC 513 is easy to sell.	7.0	51.3	38.3	2.6	.9	2.4	.7	2.2	50.5	41.8	4.4	1.1	2.5	.7
Planting SC 513 is a waste of time and money.	4.3	77.4	5.2	11.3	1.7	2.3	.8	3.3	67.0	24.2	4.4	1.1	2.3	.7
Attitude toward production characteristics of SC513.														
Seed from SC 513 has good germination.	12.2	78.3	7.0	1.7	.9	2.0	.6	20.9	46.2	33.0	-	-	2.1	.7
Grain from SC 513 is good for milling.	28.7	65.2	3.5	2.6	-	1.8	.6	26.4	42.9	28.6	1.1	1.1	2.1	.8
When rainfall is low, Chimanhica has better production than SC 513.	7.0	73.9	7.0	12.2	-	2.2	.8	5.5	53.8	27.5	13.2	-	2.5	.8

Table 4
Farmers' Attitudes Towards NPK

	Percent of Response Categories in Machipanda (n = 117)							Percent of Response Categories in Vanduzi (n = 145)						
	SA %	A %	N %	D %	SD %	*M*	*SD*	SA %	A %	N %	D %	SD %	*M*	*SD*
NPK is good for maize.	5.1	80.3	6.8	6.8	.9	2.2	.7	4.8	78.6	15.2	1.4	-	2.1	.5
NPK increases maize yield.	6.0	78.6	10.3	5.1	-	2.1	.6	6.2	79.3	14.5	-	-	2.1	.4
NPK is not good for the soil.	2.6	16.2	11.1	59.0	11.1	3.6	1.0	2.8	24.8	34.5	34.5	3.4	3.1	.9
NPK is a waste of time and money.	1.7	61.5	6.0	29.1	1.7	2.7	1.0	4.1	56.6	25.5	12.4	1.4	2.5	.8

Table 5
Farmers' Attitudes Towards Urea

	Percent of Response Categories in Machipanda (n = 118)							Percent of Response Categories in Vanduzi (n = 144)						
	SA %	A %	N %	D %	SD %	*M*	*SD*	SA %	A %	N %	D %	SD %	*M*	*SD*
Urea is good for maize	15.3	82.2	1.7	.8	-	1.9	.4	6.3	74.3	17.4	1.4	.7	2.2	.6
Urea increases maize yield.	17.8	78.0	3.4	.8	-	1.9	.5	9.0	74.3	15.3	.7	.7	2.1	.6
Urea is not good for the soil.	7.6	64.4	10.2	17.8	-	2.4	.9	3.5	31.9	33.3	30.6	.7	2.9	.9
Urea is a waste of time and money.	7.6	78.0	2.5	11.9	-	2.2	.7	7.6	59.7	18.8	12.5	1.4	2.4	.9

Farmers' attitudes towards SC513 consisted mostly of cognitive responses, expressed as beliefs by farmers about the relationship between the seed and the production and marketability characteristics that describe the seed. In general, respondents from Machipanda and Vanduzi held positive attitudes towards the marketability of improved maize variety SC513, production characteristics of SC513, and use of NPK and urea for maize production. For improved maize variety SC513, most farmers in Machipanda (93.9%) and Vanduzi (63.3%) appreciated the quality of the seed and maize meal obtained with maize variety SC513. Other studies found that farmers are favorable toward production characteristics of improved maize varieties (Hintze et al., 2003).

For chemical fertilizers most farmers (>80%) in Machipanda and Vanduzi appreciated the effect of NPK and urea on increasing maize yield. Farmers agreed that NPK and urea were good for increasing maize yield. Farmers' attitudes towards use of chemical fertilizer on maize consisted of both cognitive and affective responses. The cognitive responses were expressed as beliefs farmers have about the relationship between the fertilizer and its capacity of increasing maize yield as well as the relationship between the fertilizer and its value for maize production.

The affective response was expressed as a good or bad feeling experienced by farmers when fertilizers are paired with their effect on the crop and soil. For example, farmers, particularly in Machipanda, expressed a negative attitude towards the effect of NPK on the soil. These farmers might have learned the affective response "Chemical fertilizer is not good for the soil" through direct emotional experiences offered by those instances when farmers stopped applying fertilizer and obtained low yields. As farmers explained when asked why they thought chemical fertilizer was not good for the soil, "NPK kills the soil. Once you use it, you should keep using it. The soil becomes dependent on it. If you stop using NPK your soil will not produce as much as before" (Farmers in Machipanda, 2006). This suggests that some farmers in Machipanda view the application of NPK as an intrusion of plant nutrients into a balanced environment. Another aspect explicit in farmers' explanations is a fear of their maize production becoming dependent on an input (NPK) which they feel cannot afford buying it regularly. These results highlight the need of increasing farmers' knowledge of optimal fertilizer use, and improving access to fertilizer.

Influence of Source of Information on Farmers' Attitudes Towards Improved Maize SC513, NPK and Urea Fertilizers

This study also performed comparisons between mean attitude scores and sources of information within each study location. The results, of ANOVA and Scheffe's post hoc multiple comparison method, are presented in Table 6.

Table 6
Sample ANOVA Table for Mean Attitude by Sources of Information

		Machipanda				Vanduzi			
	Source Information	*N*	Mean	*F*	Sig	*N*	Mean	*F*	Sig
Attitude toward marketability of improved maize variety SC513.	Neighbors	72	6.81			28	7.43		
	Market	35	7.37	2.02	.138	26	7.15	2.05	.135
	Extension	8	6.25			37	6.73		
Attitude toward production characteristics of SC513.	Neighbors	72	5.99			28	7.04		
	Market	35	6.26	.661	.518	26	7.08	2.79	.067
	Extension	8	5.75			37	6.14		
Attitude toward NPK.	Market	41	10.7			25	9.52		
	Extension*	19	10.2	.512	.600	32	9.03	5.76	.004
	Neighbors*	57	10.6			88	10.2		
Attitude toward urea.	Market	41	8.63			26	9.46		
	Extension**	19	8.47	1.34	.265	30	8.33	8.53	.000
	Neighbors**	58	8.05			88	10.06		

In the lowlands, the strength of positive attitudes towards fertilizers differed significantly (P<.01 and P<.001) between farmers who learned about fertilizers from extension and those who learned from neighbors. Farmers who learned about fertilizers from extension had stronger positive attitudes than farmers who learned about fertilizers from neighbors. Personal contacts between extension agents and farmers are more effective for delivering specific information to farmers and eventually persuade farmers to use fertilizers. The results show that while all three sources of information, neighbors, market and extension can be used by farmers to learn and raise awareness about fertilizers, particular attention should be given to public extension to strengthen farmers' attitudes towards fertilizers.

Pattern of Adoption of Improved Maize Variety SC513 and Chemical Fertilizers NPK and Urea in Machipanda and Vanduzi

The results on patterns of adoption of SC513, NPK and urea in Machipanda and Vanduzi are presented in Figures 1, 2, and 3. The curves are based on respondents' recall of the year in which they first used the technology.

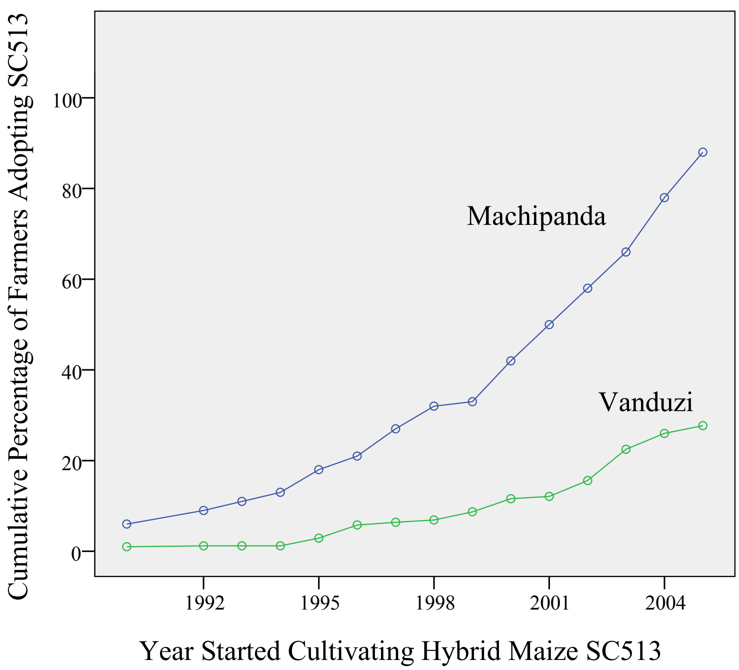

Figure 1. Pattern of Adoption of Hybrid Maize SC513 in Machipanda and Vanduzi from 1990 – 2005.

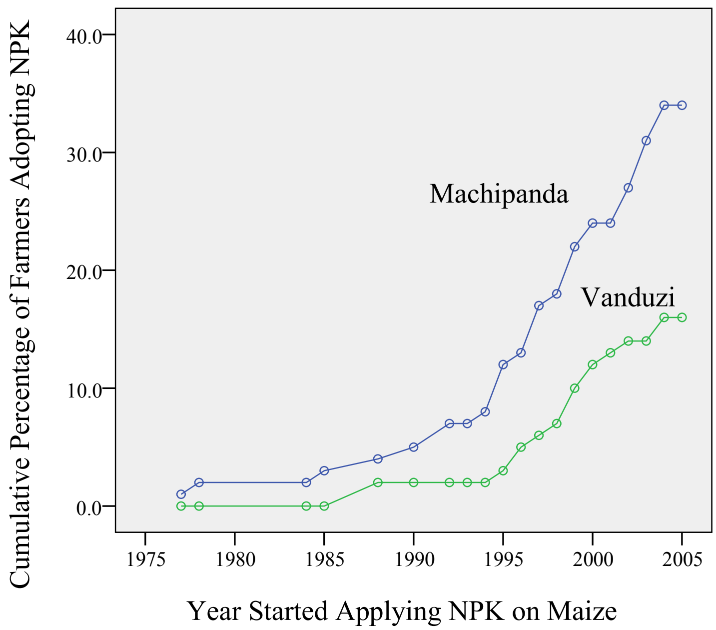

Figure 2. Pattern of Adoption of Fertilizer NPK in Machipanda and Vanduzi from 1970 – 2005.

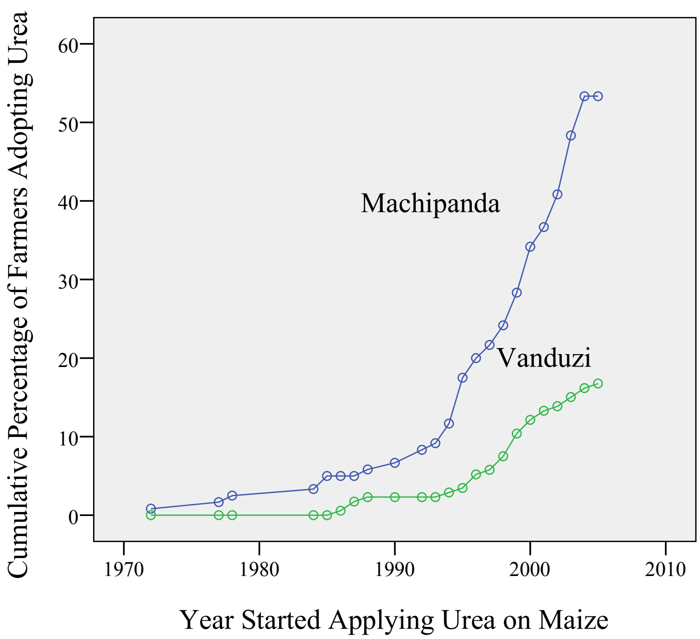

Figure 3. Pattern of Adoption of Fertilizer urea in Machipanda and Vanduzi from 1970 – 2005.

Farmers in Machipanda and Vanduzi, have been using improved maize variety SC513 since early 1990, while chemical fertilizers for maize production started much earlier, before 1990. Improved maize variety SC513 and chemical fertilizers NPK and urea were formally introduced in the study area in 1995. Since then new farmers joined each year increasing the percentage of usage (i.e. the number of farmers who have used the technology). This increase was more rapid in highlands of Machipanda than in lowlands of Vanduzi. A possible explanation is that hybrid maize seeds do better than local varieties in high rainfall regions and in these regions higher incidence of fertilizer use are also expected than in the lowland regions (Kaliba et al., 2000). In addition, Machipanda is much closer to Zimbabwe and farmers had access to inputs there. Since the increase of percentage of usage was different between the two agro ecological regions, these findings call attention to the evaluation of the suitability and accessibility of improved maize technology in a particular agro-ecological zone.

Discontinuance of SC513, NPK and Urea

The pattern of adoption provides a positive picture in the sense that it expresses that through the years the number of farmers who had used the technologies was accumulating. Nevertheless, the current adoption was not high. For example, in both study areas the percentage of farmers cultivating improved maize variety SC513 and applying chemical fertilizer on maize during the growing season 2004 – 05 was lower than the cumulative percentage (Table 7). The current adoption (i.e. adoption in years 2004 and 2005) indicates that discontinuance occurred throughout the time since the first year farmers started using the technologies. One obvious reason for reduced adoption is discontinuance. After farmers had adopted the technologies, they may discontinue their use for various reasons including replacement, dissatisfaction, and misuse of the technology (Rogers, 2003).

Table 7
Percentage of Farmers Ever Used and Currently Using the Technology

Technologies	Study location			
	Machipanda		Vanduzi	
	Ever used	Using 2004-05	Ever used	Using 2004-05
Hybrid maize SC 513	88% (105)	37.7% (45)	28% (48)	5.8% (10)
Fertilizers (NPK/urea)	87% (102)	33.3% (39)	33% (48)	2.8% (4)

Reasons for Discontinuance of SC513, NPK and urea

The reasons for discontinuance of SC513, NPK and urea, were also explored. The discontinuance of improved maize SC513 was mainly due to dissatisfaction with husk cover, susceptibility to storage insects, and replacement of hybrid variety SC513 with OPV and local maize varieties. The discontinuance of fertilizers was, mainly, due to lack of money to purchase NPK and urea.

The reasons for discontinuance have important implications for maize breeders and social scientists. Breeders need to improve the husk cover and enhance resistance to storage insects to make the hybrid variety SC513 attractive to farmers. Social researchers need to investigate ways by which farmers can be provided with fertilizers at accessible costs including provision of fertilizer on credit basis.

Factors associated with adoption of improved maize SC513, NPK and urea fertilizers

Tables 8, 9 and 10 present the maximum likelihood estimates of the logistic models for factors associated with adoption of SC513, NPK and urea.

Table 8
Maximum Likelihood Estimates of Logistic Model for Factors Affecting Adoption of SC513

Variables	β	S.E.	Wald	Sig.	Exp(β)
Agro-ecological zone	2.51	.512	24.0	.000	12.2
Knowledge of advantages and disadvantages of SC513	1.99	.732	7.40	.007	7.32
Attitude toward marketability of produce from SC513	-.497	.234	4.50	.034	.608
Attitude toward traits of SC513	-.812	.228	12.6	.000	.444
Constant	-.704	1.33	.279	.598	.495
Likelihood ratio chi-square df(10)	*87.03*			*.000*	

Table 9
Maximum Likelihood Estimates of Logistic Model for Factors Affecting Adoption of NPK

Variables	β	S.E.	Wald	Sig.	Exp(β)
Agro-ecological zone	.794	.392	4.10	.043	2.21
Knowledge of application methods for NPK	2.61	.753	12.0	.001	13.6
Information sources on NPK			14.5	.001	
Market (1)	.154	.442	.122	.727	1.17
Extension (2)	1.57	.430	13.3	.000	4.81
Constant	-4.32	1.11	15.1	.000	.013
Likelihood ratio chi-square df(8)	*64.3*			*.000*	

Table 10
Maximum Likelihood Estimates of Logistic Model for Factors Affecting Adoption of Urea

Variables	β	S.E.	Wald	Sig.	Exp(β)
Agro-ecological zone	1.43	.369	14.9	.000	4.16
Knowledge of application methods for urea	2.05	.521	15.5	.000	7.74
Information sources on urea			9.99	.007	
Market (1)	-.211	.418	.256	.613	.810
Extension (2)	1.23	.434	8.01	.005	3.41
Constant	-2.86	.964	8.81	.003	.057
Likelihood ratio chi-square df(8)	*81.6*			*.000*	

The fit of the models was satisfactory. The estimated coefficients for the likelihood ratio chi-square were significant ($P<.001$), with chi-square values of 87.0, 64.3, and 81.6. The models accounted (R^2_{Logistic}.) for 39, 24 and 27 percent of the variation between adopters and non-adopters of SC513, NPK, and Urea respectively.

As expected, the agro - ecological zone and how-to knowledge were positively ($P<.05$) associated with the adoption of improved maize variety SC513, NPK, and urea fertilizers. Being in the highlands increased the probability of adoption of the three technologies, by a factor of 12, 2 and 4 respectively. These results can be related to the effect of high annual rainfall in the highlands of Machipanda. This argument is supported by other studies (Kaliba et al., 2000; Hintze et al., 2003). Hybrid maize might be more adaptable to the highlands of Machipanda than to the lowlands of Vanduzi. Likewise, fertilizer use is expected to be higher in highlands where rainfall is relatively higher than lowlands.

Feeling knowledgeable about advantages and disadvantages of improved maize and about application of chemical fertilizers increased the probability of adoption of the three technologies, by a factor of 7, 14, and 8. Positive association between knowledge of fertilizer application and adoption of fertilizer was also mentioned by Rogers and Havens (1961). These researchers found that knowledge of fertilizer (i.e. how to use fertilizer, and what nutrients the crop needs) acted as an intervening variable, between "attitude toward fertilizer" and the "use of fertilizer." CIMMYT (1993) also highlights the importance of basic computation skills for proper use of fertilizers.

Extension was a significant factor ($P<.05$) for adoption of fertilizers. The probability of adoption of NPK and urea, for farmers who learned about these technologies from extension services, increased 5 and 3 times more than the probability of adoption by farmers who learned from neighbors. Other studies had found positive relationships between extension and chemical fertilizers (Abebaw and Belay, 2001; Kaliba et al., 2000). The results indicate that strengthening the provision of information on the use of fertilizers through extension (i.e. results from demonstration plots, individual or group meetings) may improve the levels of adoption of chemical fertilizers in Machipanda and Vanduzi. Moreover, given the relevant role played by extension in the adoption of chemical fertilizers, one option would be to concentrate extension resources to train farmers in the optimal use of fertilizers. Another option would be to promote vocational training on improved maize varieties technology, including chemical fertilizers, in the rural schools. For improved maize variety, contrary to what was expected, extension had no significant effect on adoption of SC513. As a source of information, extension had a positive but insignificant impact on the adoption decisions of SC513. It is plausible that all sources of information (market, neighbors, extension, and market) provide farmers with useful information.

Farmers' attitudes were significant factors of adoption of improved maize. As expected, holding negative attitudes toward traits of SC513 and negative attitudes toward the marketability of produce from SC513 had a significant ($P<.05$) negative effect on the logarithm of the odds of adoption. Other studies found that farmers' perceptions of production characteristics (yield, maturity rate, drought resistance, insect resistance lodging resistance, grain weight) determine variety selection and adoption (Hintze et al., 2003). These results imply that researchers should continue and strengthen research on production characteristics of improved maize varieties, and public extension services as well as the private sector (seed companies, wholesalers and retailers) should emphasize messages on the production characteristics of the improved maize varieties, including seed quality, drought tolerance and maize meal quality. Positive attitudes toward selling grain and fresh maize of SC513 were also a significant factor of adoption. This association indicates that farmers obtain some surplus from SC513 that can be used for household income. Thus, in addition to production characteristics, and benefits associated with improved maize varieties, extension messages should provide information on prices and demand for it. Breeders should develop maize varieties for which output is marketable. The private sector should provide farmers with marketing information.

Overall the three most important factors associated with adoption of improved maize SC513, in decreasing order were: agro ecological region, attitude toward production traits of improved maize SC513, and knowledge about advantages and disadvantages of improved maize varieties. Extension on NPK and urea, knowledge about fertilizer application, and agro-ecological conditions had significant influence on adoption of chemical fertilizers.

Conclusion

This study showed that, in general, farmers in Machipanda and Vanduzi do support the use of improved maize varieties and chemical fertilizers, but attitude strength varied according to sources of information. In the lowlands farmers who learned about fertilizers from extension had stronger positive attitudes than farmers who learned about fertilizers from neighbors. Different patterns of adoption were found in this study. The number of farmers using improved maize SC513 was higher than the number of farmers using NPK and urea for maize production. For each of the three technologies the rate of usage differed between the highlands and lowlands. The increase was more rapid in highlands than in lowlands. Hence these findings call attention to the evaluation of the suitability and accessibility of improved maize production technology in a particular agro-ecological zone.

Regarding factors of adoption, this study has confirmed earlier research which showed that adoption of improved maize varieties and chemical fertilizers technologies, is influenced by agro ecological conditions, attitude toward production traits and marketability of improved maize, how-to-knowledge to apply the technology, and the role of extension in dissemination of improved technology. Therefore, these factors should be considered when planning, implementing and evaluating extension programs for dissemination of improved maize varieties and chemical fertilizers. Farmers' characteristics such as age, level of formal education, and family size did not influence significantly the adoption of improved maize variety SC513 and chemical fertilizers NPK and urea, in the highlands of Machipanda and lowlands of Vanduzi in the Manica District.

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