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Full Length Research Paper

Adoption of post harvest technologies used by small-holder farmers in Swaziland

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Post-harvest technology forms an important component of any agricultural system. It is vital in all circumstances, whether there is surplus or deficit. A lot has been done on the dissemination of post-harvest loss reduction technologies in Swaziland, but very little has been done to evaluate the adoption of such technologies. This study evaluated the adoption of post-harvest technologies by small-holder farmers. The objectives were to describe the existing post-harvest technologies in Swaziland and identify factors that influence adoption. Face-to-face interviews, using an interview schedule, were conducted targeting 70,850 small-holder farmers with a sample size of 382 selected from all ecological zones. The technologies identified were traditional in nature and those that were imported. Imported technologies were highly adopted (61.8%) as compared to traditional (38.2%) and this was due to the effort of the Ministry of Agriculture in promoting such technologies. Technology adoption was influenced by farmer oriented and technology based factors. Amongst the farmer oriented factors, females adopted more (57.3%) technologies than males (42.7%). Technology factors that were ranked highly in terms of adoption rates were; faster crop drying rate (46.1%), safety of crop (27.3%), and better crop protection (16.2%). Research should be conducted over time to determine crop losses within both traditional and imported technologies at farm level at all the ecological zones to come out with the best option.

Key words: Post-harvest technology, Swaziland, small-holder farmers.

INTRODUCTION

Storage facilities not only offer the opportunity to smooth hunger between staple crop harvests but farmers are possibly able to improve farm incomes by storing crops and selling at premium prices when demand outstrips supply later in the post-harvest period (Florkowski and Xi-Ling, 1990). As quality is an important determination of crop retail prices (Kohl and Uhl, 1998), effective storage is crucial to improve agricultural incomes, food nutrition and security for small scale farmers (Thamaga-Chitja et al., 2004).

It has been noted, that for many years, development efforts in agriculture especially in sub-Saharan Africa has been focused on the increase in food production by small-holder farmers (Wurdemann et al., 1998). This focus has led into policies which reflect such thrusts. In Swaziland, where most of the arable land is in the hands of small-holder farmers, such policies have been unable to eradicate hunger and malnutrition. The move towards improved post-harvest technologies has however proceeded without a corresponding evaluation of the rate of adoption among small-holder farmers located in the

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four agro-ecological zones of the country, which are characterized by distinct climate and socio-economic features.

In Swaziland, the concentration of efforts to improve food storage through loss reduction has been on the staple crop, maize. It is grown by approximately 90% of the farmers in a total land area of 70% (Government of Swaziland, 1987). Small-holder farmers on Swazi Nation Land produce maize and other crops primarily for home consumption and the surplus sold to other families and organized markets such as the National Maize Cooperation. This trend has been changing slowly over the years with small-holder farmers grouping together to diversify into high value crops such as sugarcane, as well as producing and selling as a group to minimize transport cost of inputs and produce.

In an attempt to overcome constraints in the post-harvest sector, the Government of Swaziland through the Ministry of Agriculture (MoA) established the Food Conservation and Crop Storage Section (FCCS). In doing so, MoA had assumed serious losses during storage, hence, developing improved grain storage technologies at both farm and cooperative levels. With the external assistance from the FCCS, the government developed an improved maize drying crib and concentrated on introducing these to farmers. The Food and Agricultural Organization (FAO) and its Special Action Programme for the prevention of food losses supported both these programmes and undertook detailed loss assessments of the preferred interventions (FAO, 1982).

Statement of the problem

A lot has been done on the dissemination of post-harvest loss reduction technologies in Swaziland, but very little has been done about the impact of such technologies in post-harvest food loss reduction and subsequently poverty alleviation. The dissemination of innovations or technologies to small-holder farmers has been a function primarily carried by the Ministry of Agriculture as manifested by its mission statement which states that, irrespective of gender, it will effectively and efficiently develop and disseminate appropriate technologies and workable extension messages that will promote household food security and increase agricultural productivity through the diversification and commercialization of agricultural activities, while ensuring community participation and sustainable development of the country’s natural resources (Government of Swaziland, 1998).

To form a conducive environment for this mission statement, Swaziland has for many years after independence in 1968 adopted an agricultural policy aimed towards self sufficiency, namely "to produce sufficient food to feed the entire population of Swaziland". Makhubu (1996) stated that food self sufficiency does not necessarily provide an insurance against famine, quite often, malnutrition and hunger co-exists with adequate supplies of food. Consequently, amongst the strategic actions recommended in this document to be undertaken to attain food security was to encourage food management, processing and storage technologies at national and household levels in order to optimize food availability. This then brings the question of technology transfer and adoption of the technologies that will address this goal from the source to the users. Small-holder farmers in Swaziland have the largest share of arable land area at their disposal, yet food production problems are more prevalent in their environments. As a direct result of this, the post-harvest loss reduction strategies that were identified by Delima’s (1979) were targeted at small-holder farmers in an effort to reduce the 16% post-harvest losses reported then. This work identified losses for a number of crops including maize and pulses where the pivotal percent mass losses were 2.25 and 1.25% respectively, while the protein mass losses were 9% for maize and 25% for pulses.

It is clear, therefore, that post-harvest losses are a serious problem in Swaziland as evident by the work of Schulten (1980) which compiled post-harvest losses in tropical Africa. In this document, Swaziland is shown to have 5% post-harvest losses in groundnuts, due to insects and moulds attack. Recently, FAO (2007) estimated post-harvest losses and seed use at 6% for maize. The question addressed by this study was to what extent have the post-harvest technologies transferred to small-holder farmers been adopted, hence, minimizing post-harvest losses and subsequently improving the well being of small-holder farmers in Swaziland.

Objectives

The primary goal of this study was to evaluate the adoption of post-harvest technologies by small- holder farmers in Swaziland with specific reference to:

1. Describe the existing post-harvest technologies that are used by small-holder farmers in Swaziland.
2. Identify the factors that influence the adoption of post-harvest technologies by small-holder farmers in Swaziland.

METHODOLOGY

Research design

A descriptive research utilizing schedule questionnaire survey procedures and personal interviews was used for collecting primary data, while secondary data was collected through desk search.

Sampling procedure and data analysis

The target population was the 70,850 small-holder farmers (Government of Swaziland, 1993) in the four agro-ecological zones

Table 1. Agro-ecological zones with the sample population on land area basis (Swaziland).

Agro -ecological zone	Area (km^2)	Altitude (m)	Rainfall (mm)	Geology	Farmers	
					Population (%)	Sample population
Highveld	5,680	900-1400	700-1200	Granite	33	125
Middleveld	4,840	400-800	550-850	Grainodio-rite, granite, gneiss	28	107
Lowveld	5,370	200-400	400-550	Sandstone/ claystone, basalt	31	118
Lubombo Plateau	1,480	250-600	550-850	Ignimbrite	8	32

Government of Swaziland (1993).

of Swaziland. These zones differ in altitude, rainfall and geology (Table 1). The sample size was 382 small-holder farmers determined from the technique developed by Krejcie and Morgan (1970).

The farmers were sampled at random and stratified according to the zones with each zone having a sample size depending on the population of farmers within it. The data collected was both qualitative and quantitative in nature. The quantitative data set were presented as percentages following analysis by Statistical Package for Social Sciences (SPSS) computer software, while qualitative data was described and summarized.

RESULTS AND DISCUSSION

The results were divided into two namely; the post-harvest technologies identified and used by the small-holder farmers as well as the adoption factors.

Post harvest technologies identified

Fourteen post-harvest technologies were described by farmers using the attributes; technology function and storage life (Table 2). They were broadly classified into traditional and improved or imported technologies. Traditional technologies included *in-situ* storage, house floor storage, grass silos, roof top drying, tree hanging, open fires and underground pits. The imported or improved technologies were metal and concrete tanks, maize crib, warehouse and bag/bale storage. The technologies identified were reflective of the average farm size of 0.5 ha on Swazi Nation Land, tenure system (Mabuza et al., 2009). The harvested produce from such farm sizes is small, hence, befitting technologies ought to have been adopted.

Traditional technologies

The traditional technologies were those that are local by nature and have evolved over time through transfer from one farmer generation to the other. They comprised *in-situ* storage, house floor storage, grass silos, roof top drying, tree hanging, open fires and underground pits (Table 3).

In-situ storage

This is a traditional storage technology where the crop is temporarily left standing in the field and is only harvested after drying or when the need for selling or home consumption arises. It is more common with perishable crops such as fruits and vegetables.

In cases of crops like groundnuts (*Arachis hypogea*), the crop is uprooted and turned upside down and then left to dry in the field, only to be collected later once it is dry. The results in Table 4 reflected that 1.9% of the small-holder farmers interviewed identified it as a drying method by function and only one farmer used it as a technology to prepare the crop for marketing. It is worth noting that the farmer was referring to perishables. While no farmer could estimate the capacity of *in-situ* storage, 2.7% farmers identified its crop storage life to be up to six months.

According to FAO (1982), in Swaziland, *in-situ* storage was found to have losses of 15%. This condition was made worse by the inavailability of labour to harvest the crop. In view of this, it was recommended that an adjustment of the school calendar be made to avail the labour necessary to harvest the maize, thus, minimizing the losses. It is for this reason that *in-situ* storage is not encouraged by the Ministry of Agriculture.

Metal bins

The advent of the automobile industry has availed containers that end up being used, among other things as post-harvest technologies. Metal bins may range in capacity between 20 or 25 L to 210 L. These are made of metal and they are a product of the petroleum industry. Bins usually have one opening at the top. The top part of the smaller capacity (20 to 25 L) bin is often removed by farmers. Bins are used primarily for storage (210 L) and marketing of dried cereals and grain legumes (20 to 25 L). The smaller metal bins are used as a unit measure during the marketing of dried crops such as maize (*Zea mays*), sorghum (*Sorghum bicolor*), beans (*Phaseolus vulgaris*), jugo beans (*Vigna subterranea*) and cow peas (*Vigna unguiculata*). In this study, the 210 and 20 L petroleum containers which are usually cylindrical

Table 2. Post-harvest technologies identified by farmers.

S/N	Technology	Function (N=382)								Storage life (Months) (N=382)					
		Drying		Storage		Crop protection and storage		Drying and storage		0 - 6		6 - 12		> 12	
		N	%	N	%	N	%	N	%	N	%	N	%	N	%
1	In-situ storage	07	1.8	-	-	-	-	-	-	10	2.6	-	-	-	-
2	Metal bins	-	-	20	5.2	-	-	-	-	19	5.0	20	5.2	02	0.5
3	House floor	-	-	08	2.1	-	-	02	0.5	21	5.2	-	-	-	-
4	Grass silos	-	-	06	1.6	-	-	-	-	02	0.5	-	-	-	-
5	Roof top	10	2.6	-	-	-	-	-	-	21	5.5	-	-	-	-
6	Hanging on trees	02	0.5	-	-	-	-	14	3.7	03	0.8	-	-	-	-
7	Open fires	03	0.8	-	-	08	2.1	32	8.4	04	1.0	03	0.8	01	0.3
8	Clay pots	-	-	07	1.8	-	-	-	-	03	0.8	01	0.3	-	-
9	Underground pits	-	-	10	2.6	13	3.4	-	-	06	1.6	20	5.2	10	2.6
10	Maize crib	11	2.9	04	1.0	-	-	119	31.2	47	12.3	11	2.9	06	1.6
11	Metal tank	-	-	39	10.2	6	1.6	-	-	20	5.2	43	11.4	10	2.6
12	Concrete tank	-	-	22	5.8	01	0.3	-	-	21	5.5	14	3.7	01	0.3
13	Warehouse	-	-	18	4.7	-	-	-	-	10	2.6	03	0.8	01	0.3
14	Bags/ bales	-	-	01	0.3	-	-	-	-	41	10.7	07	1.8	01	0.3
	Total	44	11.5	135	35.3	28	7.3	167	43.7	228	59.7	122	31.9	32	8.4

Technology description attributes. 1-9 Represent traditional technologies; 10-14 represents improved / imported technologies.

in shape were used for the storage of shelled maize and sorghum by 1.4 and 1.9% farmers, respectively (Table 4). Though not recommended by MoA, 5.2% farmers identified the function of metal bins as storage with low capacities and shelf lives of produce.

House floor

This is a traditional temporal storage technology which is not recommended by MoA due to the high losses associated with it. The crop is kept on the floor of a house which can either be concrete or earth lined or polished with wet cow dung (conferring some degree of pest control). This technology (Table 4) is used for maize (*Zea mays*) according to one farmer and cucurbits according to yet another farmer. This method may also be used for storing maize (*Zea mays*), sorghum (*S. bicolor*), groundnuts (*A. hypogea*), jugo beans (*V. subterranea*), beans (*P. vulgaris*), cowpeas (*V. unguiculata*), mung beans (*P. mungo*), melons (*Cucumis mel*) and pumpkins (*Cucurbita pepo*).

Grass silos

Grass silos are traditional technologies, usually crafted by women from natural grass species (Table 5). By function it was identified by 1.6% farmers as a storage technology with one farmer identifying it as a technology to hold the crop in preparation for the market. Both capacity and storage life were identified as low ranging from 0 to 40 bags and 0 to 6 months, respectively. The crops stored were identified as maize (*Zea mays*), grain legumes, cucurbits, tubers and root crops (Table 4).

Roof top

The crop is spread on top of the roof for purposes of both drying and safety from thieves, poultry and

Table 3. Post-harvest technologies used by small-holder farmers according to the crops stored (N = 382).

S/N	Technology	Crops stored																		Total	
		Maize (*Z. mays*)		Sorghum (*S. bicolor*)		Grain legumes		Tobacco (*N. tabacum*)		Cotton (*G. hirsitum*)		(*Sesamum alatum*)		Vegetables		Tubers/ root crops		Cucurbits			
		N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
1	*In-situ* storage	5	1.3	-	-	-	-	-	-	-	-	-	-	9	2.4	5	1.4	4	1.0	23	6.0
2	Metal bins	5	1.3	-	-	05	1.3	-	-	-	-	-	-	-	-	5	1.3	1	0.3	23	6.0
3	House floor	1	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	1.0	5	1.3
4	Grass silos	-	-	4	1.0	10	2.6	-	-	-	-	-	-	-	-	4	1.0	14	3.7	18	4.7
5	Roof top	7	1.8	-	-	11	2.9	-	-	-	-	-		-	-	-	-	-	-	32	8.4
6	Hanging on trees	3	0.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	0.8
7	Open fires	10	2.6	-	-	-	-	1	0.3	-	-	-	-	-	-	1	0.3	-	-	11	2.0
8	Clay pots	7	1.8	-	-	4	1.0	-	-	-	-	-	-	-	-	-	-	-	-	12	3.1
9	Underground pits	17	4.5	-	-	-	-	-	-	-	-	2	0.5	-	-	-	-	-	-	19	5.0
10	Maize crib	85	22.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	8.6	118	30.9
11	Metal tank	32	8.4	-	-	3	0.8	-	-	-	-	-	-	-	-	-	-	-	-	35	9.2
12	Concrete tank	5	1.3	7	1.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	1.3
13	Warehouse	18	4.7	-	-	12	3.1	-	-	1	0.3	-	-	-	-	-	-	14	3.7	45	11.8
14	Bags/ bales	1	0.3	-	-	13	3.4	-	-	15	3.9	-	-	4	1.0	-	-	-	-	33	8.6
	Total	196	51.3	11	2.9	58	15.2	01	0.3	16	4.2	02	0.5	13	3.4	15	3.9	70	18.3	382	100

1-9 Represent traditional technologies; 10-14 represents improved / imported technologies; bags -for maize and grain legumes were jute or plastic bags (75 kg), for cotton were jute bales and for tubers brown paper bags (10 kg); -, no data.

livestock. Maize and grain legumes are the crops that are usually dried in this technology. Ten farmers correctly identified it as a drying technology, while 2.9% farmers recognized the storage capacity of roof tops to be between 0 to 40 bags and only 5.5% of the farmers had crop storage lives in roof tops of 0 to 6 months (Table 5). It is worth noting that the storage capacities of roof top drying are very low due to the surface area available for storage and the imposed loads from the crop that these roofs can withstand.

Hanging on trees

These technologies were only found in the Lowveld, a region where the growing of maize under rain-fed conditions is not favourable due to low and erratic annual rainfall amounts. They were used for maize drying in cases where the crop was not de-husked, but hung in tree branches and where the crop was de-husked; the cobs were placed in wire baskets securely held between tree branches. Drying as well as drying and storage were the two functions identified by 0.5 and 3.7% of the farmers, respectively. The capacity was 0 to 40 bags with storage life being 0 to 6 months as identified by 0.8 and 0.8% of the small-holder farmers, respectively (Table 5). Once again the capacities of these technologies would not exceed two 70 kg bags of unshelled maize even though they are within the range 0 to 40 bags.

Open fires

In these traditional technologies, the crop is hung to dry using the husks inside a separate traditional hut. While the crop dries, it is simultaneously protected from pest attack by the smoke from open fires, a function that was identified by 2.1% farmers, while another 0.8% thought of it as a drying technology and 8.4% said it was a drying and storage technology. It is worth noting that this technology was used for drying traditional maize seed which explains the low storage capacities (0 to 40 bags) and crop storage life. Besides maize

Table 4. Post-harvest technology description attributes identified by farmers.

Technology	Technology description attributes																					
	Function (N=382)										Capacity (Bags) (N=382)						Storage life (Months) (N=382)					
	Drying		Storage		Protection and storage		Drying and storage		Marketing		0 - 40		40 - 80		80 - 120		0 - 6		6 - 12		> 12	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
In-situ storage	07	1.8	-	-	-	-	-	-	01	0.3	-	-	-	-	-	-	10	2.6	-	-	-	-
Metal bins	-	-	20	5.2	-	-	-	-	-	-	11	2.9	03	0.8	-	-	19	5.0	20	5.2	02	0.5
House floor	-	-	08	2.1	-	-	02	0.5	-	-	09	2.4	04	1.0	-	-	21	5.2	-	-	-	-
Grass silos	-	-	06	1.6	-	-	-	-	01	0.3	14	3.7	-	-	-	-	2	0.5	-	-	-	-
Roof top	10	2.6	-	-	-	-	-	-	-	-	11	2.9	-	-	-	-	21	5.5	-	-	-	-
Hanging on trees	02	0.5	-	-	-	-	14	3.7	-	-	03	0.8	-	-	-	-	3	0.8	-	-	-	-
Open fires	03	0.8	-	-	8	2.1	32	8.4	-	-	09	2.4	-	-	-	-	4	1.0	3	0.8	01	0.3
Clay pots	-	-	07	1.8	-	-	-	-	-	-	17	4.5	-	-	-	-	3	0.8	1	0.3	-	-
Underground pits	-	-	10	2.6	13	3.4	-	-	-	-	38	9.9	10	2.6	01	0.3	06	1.6	20	5.2	10	2.6
Maize crib	11	2.9	4	1.0	-	-	119	31.2	-	-	62	16.2	10	2.6	07	1.8	47	12.3	11	2.9	6	1.6
Metal tank	-	-	39	10.2	6	1.6	-	-	-	-	44	11.5	32	8.4	09	2.4	20	5.2	43	11.4	10	2.6
Concrete tank	-	-	22	5.8	1	0.3	-	-	-	-	17	4.5	21	5.5	01	0.3	21	5.5	14	3.7	1	0.3
Warehouse	-	-	18	4.7	-	-	-	-	03	0.8	03	0.8	7	1.8	10	2.6	10	2.6	3	0.8	1	0.3
Bags/ bales	-	-	1	0.3	-	-	-	-	-	-	04	1.0	25	6.5	-	-	41	10.7	7	1.8	1	0.3
Total	44	11.5	135	35.3	28	7.3	167	43.7	08	2.1	242	63.4	112	29.3	28	7.3	228	59.7	122	31.9	32	8.4

-, No data.

(*Zea mays*), tobacco (*Nicotiana tabacum*) curing and storage of tubers were the additional functions of this technology according to one farmer (Table 4).

Clay pots

Like grass silos, clay pots are traditional technologies crafted by women. They have multiple uses such as water storage containers and vessels for food cooking, though, the latter use is no longer common. They are oval in shape and made out of clay that is moulded and fired to acquire strength. Their function was identified in Table 5 by 1.8% small-holder farmers as storage, while 4.5% identified them as small capacity storage structures with 0 to 40 bag capacities. This trend was the same with the storage life. Clay pots were said to be used for storing shelled maize and grain legumes by 1.8 and 1.4% farmers respectively (Table 4). Their main problem is that once mishandled, they break without a chance of being mended again.

Underground pits

These are traditional crop protection and storage technologies. Though available in other parts of Africa, underground pits are unique in Swaziland in that they are located in cattle kraals, as well as being underground. It was identified as a crop protection and storage technology by 3.4% small-holder farmers, while 2.6% identified it as a storage structure (Table 4). In terms of capacity and storage life, the underground pits used by the farmers were on the lower sides. The entrance to the pit which is wide enough to allow a bag of maize or a human being to pass through is sealed with either concrete, metal cover or a flat stone and cow dung to prevent run-off and impurities during storage. Maize (*Zea mays*) is the crop that is mainly stored in underground pits, but other crops such as groundnuts (*Arachis hypogea*) can be stored for a short period of time to acquire resistance against pests and then taken out to be stored elsewhere. Their drawback is the odour that develops in the crop due to moisture and the loss of germination. The hot conditions within the pit acts as a deterrent against would be thieves.

Table 5. Post-harvest technology fabrication materials.

Technology	Fabrication materials																					
	Foundation (N = 382)						Wall (N = 382)										Roof (N = 382)					
	Concrete		Concrete blocks		Earth		Timber (untreated)		Timber posts and iron sheets		Timber posts and off-cuts		Wire mesh and timber posts		Other*		Corrugated iron sheets and timber		Grass and timber		None	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
In-situ storage	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Metal bins	-	-	44	11.5	-	-	-	-	-	-	-	-	-	-	21	5.5	-	-	-	-	-	-
House floor	10	2.6	-	-	14	3.7	-	-	-	-	-	-	-	-	-	-	40	10.5	7	1.8	21	5.5
Grass silos	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	0.5	-	-
Roof top	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22	5.8	-	-	-	-
Hanging on trees	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Open fires	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Clay pots	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	2.8	-	-	-	-	-	-
Underground pits	-	-	-	-	70	18.3	-	-	-	-	-	-	-	-	19	5.0	-	-	-	-	-	-
Maize crib	7	1.8	-	-	91	23.8	49	12.8	21	5.5	57	14.9	106	27.7	-	-	95	24.9	20	5.2	-	-
Metal tank	20	5.2	40	10.5	-	-	30	7.9	-	-	-	-	-	-	29	7.6	30	7.9	9	2.4	20	5.2
Concrete tank	40	10.5	-	-	-	-	-	-	-	-	-	-	-	-	10	2.6	-	-	-	-	-	-
Warehouse	18	4.7	17	4.5	11	2.0	-	-	-	-	29	7.6	-	-	-	-	39	10.2	17	4.5	60	15.7
Bags/ bales	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	95	24.9	101	26.4	186	48.7	79	20.6	21	5.5	86	22.5	106	27.7	90	23.6	226	59.2	55	14.4	101	26.4

* - Stick and mud, stone and concrete, earth, metal, grass, jute plastic and none; - No data.

Imported or improved technologies

The imported technologies comprised, metal tanks, concrete tanks, maize crib, warehouse storage and bag/bale storage amongst which the maize crib was the highly (30.9%) adopted technology followed by the warehouse.

Improved maize crib

The improved maize crib is one of the post-harvest technologies that are disseminated to small -holder farmers by the MoA. Most (22.3%) farmers correctly identified the maize crib as a technology primarily for the drying of maize (*Zea mays*), while 8.6% farmers used the maize crib for storing cucurbits. In terms of function, 31.2% of the farmers identified the improved maize crib as a drying and storage technology with only 2.9% using it as a drying technology. The majority of the improved maize cribs were of low capacities ranging from 0 to 40 bags and 40 to 80bags. This trend was true for the storage life as evident in Table 4.

According to Government of Swaziland (1982), the specifications or guidelines for reduced losses during crop drying and storage in the improved maize crib are dependent on siting, construction, maintaining a clean environment and protection from insect pests and diseases. In terms of siting, the crib should be sited on well drained soils to increase the life of the supporting timber and to reduce the amount of humid air entering the grain. The maize crib should be built away from other structures and over-hanging tree branches to prevent rats from gaining access to the crib from above. To ensure good air flow through the cobs, the crib should be built with its long axis at right angles to the prevailing wind.

The piers or vertical timber poles should be 15 cm in diameter. If not termite resistant, the piers should be treated with creosote alternatively to treat the soil around each pier with old engine oil or insecticides. All timber used should be stripped of the bark to avoid a hide-out of insect pests. While the width should not exceed 150 cm to avoid moulds due to un-dried cobs at the centre, the length can vary depending on the maize to be stored.

The maize demonstration cribs constructed at several sites (Chief's residences and polling stations) in the country are 300 cm in length × 135 cm in width × 120 cm in depth with a storage capacity of 40 bags of cobs or 15 to 20 bags of shelled maize. An increase in length of 150cm will increase the storage capacity by 20 bags of cobs. The roof may be corrugated sheets or thatch grass and should overhang walls of the crib by at least 75 cm all around to protect the crops against sunlight. A space of 75 to 100 cm between the apex of the roof and the upper cross bar of the crib ensures good air circulation when the crib is full.

The walls should be as open as possible to allow free air circulation. Chicken wire, vertical poles or loosely woven wattle fencing may be used provided that with the latter materials, enough spaces are left for the wind to enter the crib. The demonstration cribs have double doors on the walls. The small door at the top allows access when the crib is nearly full. The floor should be raised to at least 100 cm from the ground and it must be constructed out of strong treated timber to withstand the crop load. Rat baffles made out of flat iron sheets should be fixed on the piers (vertical members) at 100 cm from the ground.

The results in Table 6 shows the earth to be the highly (48.7%) used foundation materials, 23.8% of which is used for the improved maize crib and concrete is the following foundation material where the maize crib is featured forming 1.8% of the 24.9% farmers that used concrete. Wall fabrication material for the maize crib comprised wire mesh and timber piers, timber posts and off-cuts, untreated timber and timber posts and iron sheets each being used by 27.7, 14.9, 12.8 and 5.5% respectively.

The mostly (59.2%) used roofing material for the improved maize crib was corrugated iron sheets and timber, with grass and timber following as used by 14.4% of the small-holder farmers. A significant number (26.4%) of farmers indicated that their cribs have no roofs. This is not the only case where the specifications or rather recommendation from MoA was not taken by farmers. The orientation of the wall materials particularly wood, the ground clearance of 100 cm and the provision of rat guards as specified earlier have not been followed in some cases as observed during the study.

Metal tank or silo

These are corrugated metal storage tanks, usually cylindrical in design with a small diameter to height ratio. They have an inlet at the top with an outlet spout at the bottom end. Both these have to be closed tightly during storage to facilitate crop protection. Storage in metal tanks or silos is one of the technologies that were promoted by MoA. MoA recommends that the tanks should be well constructed with seams that are well riveted and soldered to allow effective crop fumigation, water proof and have a long life. The tanks should be sited in well drained soils and placed on an elevated platform 30 cm above ground. The platform could be made of concrete, concrete or cement blocks and should be wider than the tank diameter for effective anchorage, be damp-proof, and must prevent the tank from rusting (achieved by painting with bituseal or lining with old fertilizer bags). The tank should be well sealed. It is recommended that an open sided structure made out of pole piers with a roof at least 100 cm above the tank top with adequate room for removal of the tank for cleaning, inspection and repair should be built. The roof should project well beyond the tank to prevent heat from the sun from causing condensation in the tank which results in mould damage. Alternatively a “hat” or other form of shade directly resting on the roof of the tank is recommended. By function, metal silos were identified by 8.6% farmers as storage technologies with only 1.6% using it as a crop protection and storage technology. The storage capacities were within the ranges 0 to 40 bags, 40 to 80 bags and 80 to 120 bags according to 10.2, 8.1 and 1.0% of the farmers respectively. The storage life of the crops stored in metal tanks were 0 to 6 months, 6 to 12 months and more than 12 months according to 5.2, 9.9 and 2.6% of the small-holder farmers interviewed (Table 4). While Table 6 indicates a scenario where a structure was provided for metal tanks or silos, observations during the study reflected that a number of small-holder farmers did not provide the protective structure for the metal silos.

Concrete tank or silo

This is a concrete version of the metal tank, which means it is usually considered more durable, hence, more expensive. Moist concrete is moulded into a cylindrical shape and the top is provided with a lid to open and close whenever necessary. The concrete tank is usually made smaller than the metal tank in accordance with construction expenses. Unlike the metal tank which must be put in a shelter, the concrete tank may be kept in the open as long as the seal cover is secured. Extremes of heat and humidity may also be avoided in the concrete tank in comparison with metal tank technologies because of the nature of the construction material. Pest control is usually permissible. This technology may also have been adopted from South Africa.

Table 3 reflects that 1.8% of the farmers used concrete tanks to store sorghum (*S. bicolor*), while 1.3% used it for maize (*Z. mays*) storage. In terms of function, 5.8% of the farmers identified the concrete silo as a storage technology and only 0.3% correctly used it as a crop protection and storage technology (Table 4). Capacities of the concrete silo were on the higher side as the majority (5.5%) of farmers stored within the range 40 to to 80 bags and only 4.5% stored within the range 0 to 40 bags. The crop storage life was very low (0 to 6 months) as identified by 5.5% farmers and only 3.7% stored for a period within the range 6 to 12 months. Most (10.5%) of the farmers correctly used concrete to fabricate the concrete silo and 2.6% used concrete and stone (Table 6).

Table 6. Post-harvest technology fabrication materials.

Technology	Fabrication materials																				
	Foundation (N = 382)						Wall (N = 382)										Roof (N = 382)					
	Concrete		Concrete blocks		Earth		Timber (untreated)		Timber posts and iron sheets		Timber posts and off-cuts		Wire mesh and timber posts		Other[1]		Corrugated iron sheets and timber		Grass and timber		None	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
In-situ storage	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Metal bins	-	-	44	11.5	-	-	-	-	-	-	-	-	-	-	21	5.5	-	-	-	-	-	-
House floor	10	2.6	-	-	14	3.7	-	-	-	-	-	-	-	-	-	-	40	10.5	07	1.8	21	5.5
Grass silos	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	02	0.5	-	-
Roof top	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22	5.8	-	-	-	-
Hanging on trees	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Open fires	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Clay pots	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	2.8	-	-	-	-	-	-
Underground pits	-	-	-	-	70	18.3	-	-	-	-	-	-	-	-	19	5.0	-	-	-	-	-	-
Maize crib	07	1.8	-	-	91	23.8	49	12.8	21	5.5	57	14.9	106	27.7	-	-	95	24.9	20	5.2	-	-
Metal tank	20	5.2	40	10.5	-	-	30	7.9	-	-	-	-	-	-	29	7.6	30	7.9	09	2.4	20	5.2
Concrete tank	40	10.5	-	-	-	-	-	-	-	-	-	-	-	-	10	2.6	-	-	-	-	-	-
Warehouse	18	4.7	17	4.5	11	2.0	-	-	-	-	29	7.6	-	-	-	-	39	10.2	17	4.5	60	15.7
Bags/ bales	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	95	24.9	101	26.4	186	48.7	79	20.6	21	5.5	86	22.5	106	27.7	90	23.6	226	59.2	55	14.4	101	26.4

[1]–Stick and mud, stone and concrete, earth, metal, grass, jute plastic and none; - No data.

Warehouse

This is a structure where most often than not commodities are stored in bags or bales at cooperative level while awaiting transport to the market. There is no known small-holder bulk storage of crops in warehouses where operations like controlled drying and storage of crops could be performed. This a recommended structure by the Ministry of Agriculture. Farmers identified it as a technology where maize (*Z. mays*), grain legumes, cotton (*Gossypium hirsitum*) and cucurbits are stored (Table 3).

Warehouse storage is recommended together with the appropriate general repairs and hygiene to ensure that losses due to rodents, birds and pests are controlled. Bag storage in warehouses was recommended on pellets with clusters of three, five and six bags to prevent collapsing and allow air circulation. Periodical sampling using sampling spears was also recommended as a means of monitoring the condition of the grain in cases where prolonged storage prior to marketing is inevitable.

Bags / Bales

Bags were identified as technologies for storing maize, grain legumes and fruits and vegetables. The fruits and vegetable bags are usually small in size (10 kg), while the maize and grain legume bags usually ranges from 50 to 70 kg. The grain bags are stored in warehouses in clusters on top of timber pellets. The bales are used for cotton and are stored in warehouses or open ground covered with plastic sheets while awaiting transportation to markets. Bags are both available in plastic as well as jute, whereas bales are made out of jute (Table 3).

Factors affecting adoption level

The factors that affect the level of adoption were grouped into two categories (farmer oriented factors and technology based factors) as identified by the 382 small- holder farmers interviewed.

Farmer oriented factors

These factors were identified as gender, level of education, marital status and occupation.

Table 7. Distribution of farmers by gender according to technologies practiced (N= 382).

S/N	Technology	Gender				Total	
		Female		Male			
		N	%	N	%	N	%
1	*In-situ* storage	1	0.3	4	1.0	5	1.3
2	Metal bin	4	1.0	3	0.8	7	1.8
3	House floor	4	1.0	3	0.8	7	1.8
4	Grass silos	3	0.8	7	1.8	10	2.6
5	Roof top	27	7.1	19	5.0	46	12.0
6	Hanging on trees	-	-	1	0.3	1	0.3
7	Open fires	-	-	-	-	-	-
8	Clay pots	18	0.3	1	0.3	19	5.0
9	Underground pits	1	0.3	1	0.3	2	0.5
10	Maize crib	110	28.8	86	22.5	196	51.3
11	Metal tank	21	5.5	11	2.9	32	8.4
12	Concrete tank	4	1.0	9	2.3	13	3.4
13	Warehouse	18	4.7	9	2.3	27	7.1
14	Bags/ bales	8	2.1	9	2.3	17	4.5
	Total	219	57.3	163	42.7	382	100

-, No data.

Table 8. Relationship between gender and adoption of postharvest technology.

Technology	Gender				Total (R)	
	Male		Female			
	Observed	Expected	Observed	Expected	Observed	Expected
Traditional	39.0	41.4	58.0	55.6	97.0	97.0
Improved/imported	124.0	121.6	161.0	163.4	285.0	285.0
Total	163.0	163.0	219.0	219.0	382.0	382.0

χ^2 = 0.3254, df = 1, P = 3.84.

Gender

The distribution of the 382 small-holder farmers interviewed by gender according to the technologies practiced is detailed in Table 7. The improved maize crib was highly adopted by 51.3% of the small-holder farmers, most (28.8%) of which were females and 22.5% were males. This trend was true for roof-top drying technology, metal tanks, warehouse and clay pots, each being adopted by 12.0, 8.4, 7.1 and 5.0% respectively. Females as a whole appeared to be the highest practitioners of the technologies adopting 57.3% as compared to the 42.7% adopted by males.

A chi-square test of independence at both 5 and 1% levels showed that there is no relationship between the level of technology adoption and the gender of farmers (Table 8). This is in line with the findings of Bonabana-Wabbi (2009) who concluded that gender does not have any effect on technology adoption. Doss and Morris (2001) suggested that adoption is influenced by access to resources, 'rather than gender *per se'*. However, Kaliba et al. (2000), in their study in Tanzania found that gender does affect adoption and this was caused by the fact that women were usually poor as compared to their male counterparts.

Level of education

Table 9 shows the adoption pattern of technologies based on the level of education of the farmers studied. The results of this study showed that adoption of technologies in general was higher on the lower end of the education spectrum of the small-holder farmers than the high education spectrum.

Approximately, 33% of the farmers had primary education, while 24.1% had no formal education and another 0.5% had other forms of education forming a total of 57.6% farmers. On the other hand, the highest education spectrum manifested by the Form 1 to 5 or

Table 9. Distribution of farmers by level of education according to technologies used (N = 382).

S/N	Technology	Level of education: Non formal		Primary		Forms 1 - 5		Tertiary		Other		Total	
		N	%	N	%	N	%	N	%	N	%	N	%
1	*In-situ* storage	01	0.3	01	0.3	02	0.5	-	-	-	-	04	1.0
2	Metal bin	05	1.3	03	0.8	04	1.0	-	-	-	-	12	3.1
3	House floor	-	-	01	0.3	-	-	-	-	-	-	01	0.3
4	Grass silos	06	1.6	03	0.8	06	1.6	01	0.3	-	-	16	4.2
5	Roof top	14	3.7	11	2.9	23	6.0	03	0.8	-	-	51	13.4
6	Open fires	-	-	-	-	-	-	-	-	-	-	-	-
7	Hanging on trees	01	0.3	-	-	-	-	-	-	-	-	01	0.3
8	Clay pots	01	0.3	-	-	-	-	-	-	-	-	01	0.3
9	Underground pits	01	0.3	01	0.3	-	-	-	-	-	-	02	0.5
10	Maize crib	43	11.3	80	20.1	79	20.6	10	2.6	01	0.3	213	55.8
11	Metal tank	04	1.0	08	2.1	15	3.9	05	1.3	01	0.3	33	8.6
12	Concrete tank	02	0.5	04	1.0	02	0.5	01	0.3	-	-	09	2.3
13	Warehouse	10	2.6	09	2.4	10	2.6	-	-	-	-	29	7.6
14	Bags/ bales	04	1.1	03	0.8	02	0.5	01	0.3	-	-	10	2.6
	Total	92	24.1	124	32.5	143	37.4	21	5.5	02	0.5	382	100

-, No data.

Table 10. Relationship between level of education and post harvest technology.

Technology	Level of education: Non-formal		Primary		Forms 1-5		Tertiary		Other		Total	
	O	E	O	E	O	E	O	E	O	E	O	E
Traditional	29.0	21.2	20.0	28.6	35.0	32.9	4.0	4.8	0.0	0.5	88.0	88.0
Improved/Imported	63.0	70.8	104.0	95.4	108.0	110.1	17.0	16.2	2.0	1.5	294.0	294.0
Total	92.0	92.0	124.0	124.0	143.0	143.0	21.0	21.0	2.0	2.0	382.0	382.0

O, Observed; E, Expected; X^2= 8.00, df = 4, P= 9.49.

secondary education and tertiary education had adoption rates of 37.4 and 5.5% respectively forming a total of 42.4%.

More than half (55.8%) of the farmers interviewed adopted the improved maize crib where 20.6, 20.1 and 11.3% had an education level of form 1 to 5, primary education, and non formal education respectively. Only 2.6% of the farmers had tertiary education, while the remaining 0.3% had no education at all. Roof top drying was the second highly (13.4 %) adopted technology followed by metal tanks or silos (8.6%) and warehouse storage being adopted by 7.6%.

A chi-square test of independence at both 5 and 1% levels showed that there is no relationship between the level of education and the adoption of technology by the farmers studied (Table 10). However, Tabi et al. (2010), in Cameroon reported that education enhances farmers to think critically and use information efficiently. In the study of Alene et al. (2000) in Ethiopia, it was concluded that education has positive effects on adoption.

Marital status

Technology adoption was higher (71.7%) in the married group of farmers followed by 16.8% single farmers with another 11.3% widowed farmers as well as one divorced farmer (Table 11). Once again, the maize crib was the highly adopted technology as it was used by 47.6% small-holder farmers of which 39.3% were married, while the other 8.4% were single. This trend was similar with metal tank or silo storage which was second in popularity followed by drying of crops in roof tops and warehouse storage each being adopted by 14.4, 13.9 and 8.9% respectively.

Occupation

The major occupation which influenced adoption was full time farmers making up 43.2% and house wives who had an adoption rate of 34.8%. The part time practitioners of

Table 11. Distribution of farmers by marital status according to technologies practiced (N= 382).

Technology	Marital Status								Total	
	Single		Married		Divorced		Widowed			
	N	%	N	%	N	%	N	%	N	%
In-situ storage	1	0.3	3	0.8	-	-	-	-	4	1.0
Metal bin	2	0.5	6	1.6	-	-	-	-	8	2.1
House floor	-	-	1	0.3	-	-	-	-	1	0.3
Grass silo	-	-	9	2.4	-	-	1	0.3	10	2.6
Roof top	10	2.6	40	10.5	-	-	3	0.8	53	13.9
Hanging on trees	-	-	1	0.3	-	-	-	-	1	0.3
Open fires	-	-	-	-	-	-	-	-	-	-
Clay pots	-	-	1	0.3	-	-	-	-	1	0.3
Underground pits	1	0.3	1	0.3	-	-	-	-	2	0.5
Maize crib	32	8.4	150	39.3	-	-	-	-	182	47.6
Metal tank	1	0.3	22	5.8	1	0.3	31	8.1	55	14.4
Concrete tank	6	1.6	9	2.4	-	-	-	-	15	3.9
Warehouse	10	2.6	18	4.7	-	-	6	1.6	34	8.9
Bags/bales	1	0.3	13	3.4	-	-	2	0.5	16	4.2
Total	64	16.8	274	71.7	1	0.3	43	11.3	382	100

-, No data.

the technologies were the employed, the students, the unemployed and the retired workers who had the least adoption rates of 10.7, 5.8, 3.7 and 1.8% respectively. The technologies that were highly adopted and used were the improved maize crib, roof top crop drying, warehouse storage and metal tank storage each being used by 48.4, 17.0, 9.4 and 8.9% of the farmers respectively.

Technology factors

The small-holder farmers identified seven technology factors that affected their level of adoption. These were fast drying rate, better crop protection, economic technology, ease of marketing the crop, safety in terms of theft and livestock damage, technology being introduced by extension agent, and long crop storage life in technology (Table 12).

The factors that were mostly considered by farmers to greatly affect their technology adoption were, faster crop drying rate, safety from theft and livestock, and better crop protection within the technology each being recognized by 46.1, 27.3 and 16.2% of the farmers interviewed. The technologies with the least impact on the farmers were introduction of technology by the extension agent (6.8%), economic consideration of technology (5.2%), long crop storage life of the technology (4.7%), and ease of crop marketing (4.2%). These impacts were also identified by FAO (1994) as bottlenecks to be avoided for the success of post-harvest technologies and acceptance by local populations in Africa (Meridian Institute, Undated).

The ecological zones with the highest post-harvest technology influence on the adoption rates by farmers were the Middleveld (36.9%) and Lowveld (31.9%). Within the Middleveld, the factors that had the highest influence on the farmers' level of adoption were faster crop drying rates and the introduction of the technology by extension agents each influencing 17.5 and 5.5% farmers respectively. On the other hand, in the Lowveld better crop protection and crop safety during storage were the two most important factors respectively affecting 10.2 and 7.1% farmers. The Highveld and the Lubombo plateau were the least zones where technology had an impact on farmers and the trends were similar to those of the Middleveld.

Conclusions

The existing technologies adopted and used by small-holder farmers in Swaziland were identified as those that were traditional in nature and those which were imported. The traditional technologies included *in-situ* storage, house floor storage, grass silos, roof top drying, tree hanging, open fires and underground pits. The imported technologies were metal and concrete tanks, maize crib, warehouse storage and bag/bale storage.

The factors that influence the level of adoption by the small-holder farmers studied were grouped into farmer oriented factors and technology based factors. The farmer oriented factors were identified as gender, level of education, marital status and occupation as detailed. The seven technology factors that affected the level of adoption were fast drying rate, better crop protection,

Table 12. Technology based factors affecting levels of adoption by small- holder farmers (N = 382).

Ecological zone	Technology based adoption factors / reasons														Total	
	Faster drying rate		Better crop protection		Economic (Space and money)		Ease of marketing		Safety (Thieves & livestock)		Introduced by extension agent		Long storage life			
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Highveld	54	14.1	6	1.6	5	1.3	3	0.8	18	4.7	4	1.0	-	-	86	22.5
Middleveld	67	17.5	16	4.2	3	0.8	7	1.8	15	3.9	21	5.5	12	3.1	141	36.9
Lowveld	32	8.4	39	10.2	12	3.1	6	1.6	27	7.1	2	0.5	4	1.0	122	31.9
Lubombo plateau	23	6.0	1	0.3	-	-	-	-	6	1.6	2	0.5	1	0.3	33	8.6
Total	176	46.1	62	16.2	20	5.2	16	4.2	66	17.3	25	6.5	17	4.7	382	100

-, No data.

economic technology, ease of marketing the crop, safety in terms of theft and livestock damage, technology being introduced by extension agent, and long crop storage life of the technology.

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