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On-farm post-harvest physical grain losses of "*Kaiso*" rice variety in Eastern Uganda

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Abstract

Rice, *Oryza sativa* is one of the major crops through which people in eastern Uganda particularly Butaleja district earn their livelihoods. *Kaiso* is the main swamp rice variety grown and marketed in the region. The smallholder farmers who are the majority use rudimentary technologies to undertake post-harvest operations. Technocrats and policy makers have observed and noted with concern that high physical grain losses are occurring along the various post-harvest operations. The purpose of this study was, therefore, to generate post-harvest physical grain losses of rice during harvesting, threshing, drying and cleaning at farms of smallholder farmers in Doho rice irrigation scheme. Methodology involved experiments using quadrants and social interviews based on participatory research techniques. A total of 48 farmers and 5 extensions officers were involved in the various parts of the study. The results showed that highest grain losses occur during harvesting and threshing and the average quantities were 6.7% (285.1 kg ha^{-1} of paddy) and 4.7% (183 kg ha^{-1} of paddy). The total average physical grain loss during harvesting, threshing, drying and cleaning was 13.5% (578.8 kg ha^{-1} of paddy). The results generated correlate well with similar findings in the Asian countries reported by Food and Agricultural Organisation (FAO) of the United Nations.

Key words: Eeastern Uganda, grain losses, physical, post-harvest, rice

Introduction

The Ministry of Agriculture Animal Industry and Fisheries (MAAIF) estimates that the per capita rice consumption in Uganda has increased from 3.96 kg in 2006 to 10 kg in 2010, and the country only meets about 80% of the national demand (MAAIF, 2010). Due to this high demand, rice production has now been embraced by at least 81.25% of the districts (Candia *et al.*, 2008). Consequently MAAIF has considered rice to be the second most important cereal crop for investment after maize in Development Investment Sector Plan (DISP) 2009/10 -2013/14 for food security and poverty reduction in Uganda. Eastern Uganda is one of the major rice producing regions of the country. *Kaiso* is the main swamp rice variety grown by most of the smallholder farmers who use rudimentary technologies for various post-harvest operations. However, these farmers are facing several challenges. Among these challenges is the high physical grain loss that occurs along the post-harvest rice value chain. Unfortunately, there is no scientifically generated information on these loss levels. Policy makers and planners use arbitrary figures that are often misleading. The

purpose of this study was to generate physical grain losses in the rice post-harvest value chain at farms of smallholder farmers in Doho rice irrigation scheme as one of the ways to help guide decisions in the investments in the rice sector.

Materials and methods

Study area and scope

This study was conducted at Doho rice irrigation scheme in Butaleja district, eastern Uganda. Doho is one of the major rice growing areas of Uganda. It has a total farm area of 1000 ha and grows rice twice a year. The study covered determination of physical grain losses along the rice post-harvest value chain due to main technologies and methods used for rice harvesting, threshing, drying,and cleaning. Kaiso which is the most grown swamp rice variety in the region was used in the study. Only smallholder rice farmers were involved in the study. The study was conducted in second season of 2010.

Instruments used in the study

A digital electronic moisture meter model Riceter m 401 for grains made by Kettelectrics was used to measure the moisture content of paddy to determine grain maturity for harvesting. A triple beam balance 700/800 series made by OHAUS and spring balance Shalter make were used to measure the weights of paddy. The post-harvest physical losses were obtained at operations of harvesting, threshing, drying and cleaning.

Harvesting losses

The current studies have shown that 87.6% (Candia *et al.*, 2010) of farmers harvest their rice by cutting the paddy either at the base or in the middle of straw stem using mainly sickle. The harvesting loss determined was therefore due to this traditional method of harvesting. The physical grain loss due to this method occurs at three points: (1) cutting of the straws (2) intermediary piling of the harvested straws and (3) transportation of the straws to a central threshing point (Figure 1). During

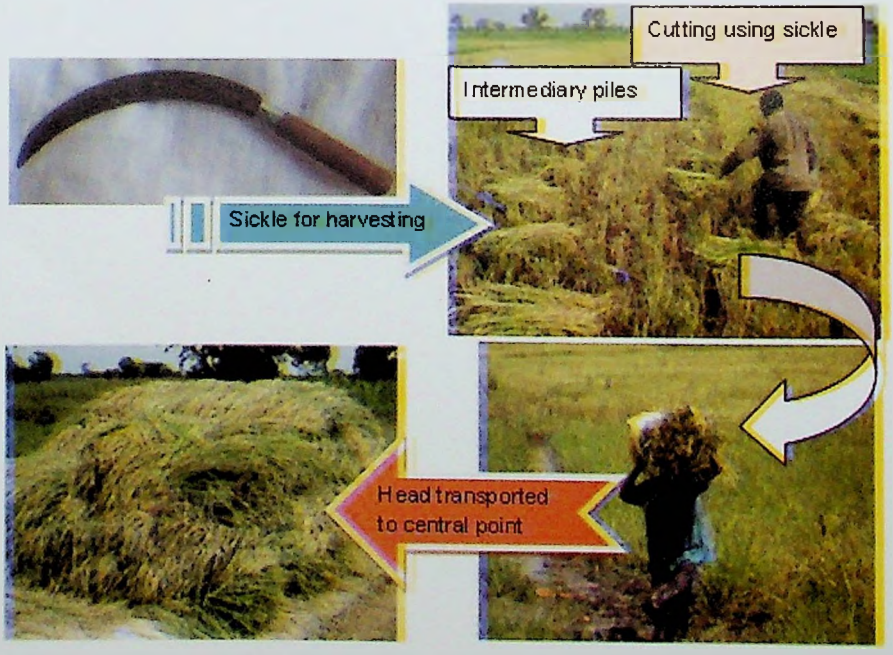


Figure 1. Traditional harvesting process of swamp rice using sickles.

cutting there is grain shattering and incomplete removal of the straws. Immediately after cutting farmers or farm labourers pile the straws in small mounts temporarily as harvesting continues. Rice grain dropping occurs at each of these small piles of straw. It is very difficult to recover such grains from the soiland farmers, therefore, abandon them.Grain loss also occurs during transportation process of the harvested straws to central point(s).

Total grain loss during harvesting is therefore given by the sum of all the grain losses that occur at the above three stages and is represented by equation 1.

$$H_G = H_S + H_C + H_H + H_t \quad \ldots\ldots (1)$$

Where:

H_G = Total grain loss at harvesting;
H_S = Harvesting loss due to grain shattering during cutting of straws (Shattering loss);
H_C = Harvesting loss due to incomplete cutting of mature straws;
H_H = Harvesting loss due to grain dropping during intermediary piling; and
H_t = Harvesting loss during transporting the straws to central threshing point(s).

Due to the muddy nature of the garden it is usually very difficult to determine the harvesting loss during transportation of the straws to a central threshing point. Experience through observations show that quantity of the grain that drop during transportation process is very insignificant and to simplify mathematical computations, this loss was not considered. The total grain loss during harvesting in this study was, therefore, given by equation 2.

$$H_G = H_S + H_C + H_H \quad \ldots\ldots (2)$$

Determination of Shattering losses (H_s)

A quadrant method was used to measure the level of grain loss due to shattering during cutting of the straws. A criterion was developed to identify rice gardens for the experiment. The criterion developed included the following:

1. Farmers who were willing to let research team use their rice gardens for the work;
2. Rice gardens which were easily accessible to the research team by road;
3. Gardens where the paddy had reached the correct harvesting time;
4. Gardens that had good yield of grain; and
5. Gardens that had healthy paddy.

Using the above criteria four rice farms were identified for the experiment. The gardens selected were each one plot (approximately half acre: 2,225 m^2). In each of the gardens six quadrants of one square meter were randomly set. Farm labourers harvested the entire paddy in each quadrant at the base using sickles. The harvested paddy was completely threshed, grain cleaned and weighed separately. Similarly, the grains that dropped in each of the above quadrants were all handpicked, cleaned, weighed separately. The weights of the dropped grains represent the shattering losses in each of those six quadrants.

Under ideal situations those grains should have not shattered and were going to be a part of the total yield in each of those quadrants. Consequently, every weight of shattered grain was added to the corresponding weight of the harvested grain to give the total yield of that quadrant. The shattering loss in each quadrant was, therefore, given by expressing weight of shattered grain as a percentage of the total yield of the quadrant.

The shattering loss in a particular garden (farm) was then given by the average of the shattering losses in the six quadrants. The representative shattering loss (H_s) during cutting of straws was then computed using equation 3. Sometimes grain droppings occur due to wind and other disturbances of the standing rice straw. The quantity of such grain is very insignificant and was consequently neglected.

H_S = Average of ($H_{f1} + H_{f2} + H_{f3} + H_{fi}$) ..... (3)

Where:

H_S = Shattering loss due to shattering of grain during cutting of straws; and

H_{f1}, H_{f2} ... H_{fn} = Average shattering loss in individual farms

Determination of harvesting loss due to incomplete cutting of mature straws (H_c)

A non-formal participatory research technique based on interactive face to face interview was used to collect this information. Farmers and extension officers were the respondents. Due to monogenicity of the respondents the research team interviewed only ten experienced farmers and five extension workers. The respondents were requested to estimate how much grain was usually lost due to incomplete harvesting per acre per season and the corresponding yield.

Determination of harvesting loss due to grain dropping during intermediary piling (H_{II})

A quadrant method was used to measure the grain loss levels during the intermediary piling of un-threshed straws. Using criterion described under determination of shattering loss method, five farms were identified and used for setting the required experiments. In each of the five farms three quadrants of 30 m^2 were set. Farm labourers harvested the entire paddy in each quadrant and placed the harvested straws on tarpaulin to trap the grains that would have dropped into the soil (Figure 2).

The piled straws in each quadrant were collected threshed, grain cleaned, weighed and recorded separately. The grains that dropped on the tarpaulin for each quadrant were collected, cleaned, weighed and also recorded separately. This quantity of grain gives the intermediary piling loss. The two weights (threshed and intermediary piling) were added to give the total yield of each quadrant. The intermediary piling loss in each quadrant was then given by expressing weight of grain in intermediary piles as a percentage of the total yield of the quadrant.

The intermediary piling loss in a particular garden (farm) was then given by the average of the intermediary piling losses in the three quadrants. The representative intermediary piling loss (H_{II}) during cutting of straws was then computed using equation 4.

H_{II} = Average of ($H_{II1} + H_{II2} + H_{II3} + H_{II4} + H_{II5}$) ..... (4)



Figure 2. Tarpaulins placed to trap the grains that drop during intermediary piling.

Where:

H_H = Harvesting loss due to intermediary heaping of straws; and

H_{H1}, H_{H2} ,..... H_{Hn} = Average grain loss during intermediary heaping in individual farms

Threshing losses

Threshing loss was measured in respect to beating method for rice threshing which is the technology used by 88.9% of farmers (Candia *et al.*, 2008). The paddy lost during this method occurs due to poor performing threshing technology and social behaviour of the farm labourers. The total grain loss during threshing is given by equation 5.

$$T_G = T_T + T_S \quad \ldots\ldots (5)$$

Where:

T_G = Total grain loss during threshing;
T_T = Grain loss during threshing due to poor performing beating sticks; and
T_S = Grain loss during threshing due to social behaviour of farm labourers.

Determination of grain loss during threshing due to beating sticks (T_T)

The physical grain loss due to beating sticks occurs at two points. The first is the grain loss due to incomplete removal of grains from the ears of the rice straw pinnacles and second is the scattering of grain due to the impact force from beating stick. Quadrant method was used to determine these grain losses. To improve on data validity, four small gardens of three different sizes (668, 912 and 1,716 m²) were selected and used in place of the usual small quadrants. All the rice straws in the garden were slowly and carefully harvested using the traditional method, collected and heaped on large tarpaulins.

Additional tarpaulins were placed all round the heap to collect all the grain that would have scattered and dropped into soil due to the impact force of the beating sticks. Experienced farmer workers that usually do the threshing business were hired to carry out the threshing of the heaped rice straws. All the unthreshed and incompletely threshed straws were sorted, threshed by hand stripping and cleaned separately from the main heap.

The grains that scattered on the tarpaulin placed round the heaped straws were collected separately. The grain obtained from unthreshed and incompletely threshed straws, and that scattered on the tarpaulin were weighed together and recorded as weight of grain loss due to the beating stick. The weight of the main grain was also taken and recorded. The total yield of the garden was obtained by adding weight of grain loss due to the beating stick and the weight of the grain harvest. The percentage loss due to beating stick was obtained by expressing weight of grain loss as a percentage of total yield of the garden. This was repeated for the other three farms.

Determination of grain loss during threshing due to social behaviour of farm labourers (T_S)

A non-formal participatory research technique based on interactive face to face interview was used to collect information on grain loss during threshing due to social behaviour of farmer labourers. Farmers and extension officers were the respondents. The research team interviewed ten farmers and five extension workers. The respondents were requested to estimate how much grain is usually lost due to incomplete threshing per acre per season and the corresponding yield.

Drying losses

The physical grain loss at the drying yards was determined by setting eight experiments of drying paddy from eight different farms. At the end of every drying day, the paddy from each experiment which remained in the drying yard including those that fell along the drying yard edge was collected, kept and dried separately to moisture content of 12%. The daily collected grains from each experiment were added together and weighed.

The weight obtained is the quantity of paddy lost during the drying process for that experiment. Weight of the main dried paddy was obtained and added to the weight of the paddy lost to give the total weight of paddy from that experiment. Percentage of grain lost for that experiment was obtained by dividing the weight of the paddy lost by the total weight of the grain. This was repeated for the other seven experiments. The representative physical grain loss during open sun drying was given by the average value of the drying losses from the eight experiments.

Paddy cleaning losses

Participatory research technique based on interactive face to face interview was used to collect information on paddy lost during cleaning. Farmers, women who do cleaning and extension officers were the respondents. The research team had discussions with eight farmers, eight women who do cleaning and three extension workers who are also farmers themselves. The respondents were requested to give how much grain was lost during cleaning 10 bags of paddy. The weight lost during cleaning from each respondent was then expressed as a percentage of total weight of the paddy in 10 bags. The average of the percentage lost was obtained to give representative grain lost during paddy cleaning by the traditional method of winnowing.

Data analysis

Descriptive statistics was used to analyse data.Microsoft Excel computer soft-ware was used to support the data analysis.

Results

Harvesting losses

Physical grain losses determined during harvesting were due to grain shattering, intermediary piling of harvested straws and incomplete harvesting. The results showed that farmers who grow "Kaiso variety lines were losing 1.56% of their paddy due to grain shattering and 3.96% due to intermediary piling of harvested straws (Table 1).

Table 1. Shattering and intermediary straw piling losses

Farm No	Average threshed grain in quadrant (kg of paddy)	Average shattering/ intermdiary piling grains quadrants(kg)	Average total yield of quadrant (kg of paddy)	Average shattering/ intermediary piling in the quadrant (%)
Shattering loss (H_s)				
Farm 1	2.60	0.058	2.658	2.2
Farm 2	3.10	0.021	3.121	0.7
Farm 3	1.60	0.031	1.631	1.9
Farm 4	3.50	0.050	3.55	1.4
Average				1.56
Harvesting loss due to intermediary piling of harvested straws (H_{ii})				
Farm 1	13.00	0.52	13.52	3.9
Farm 2	6.40	0.46	6.86	6.7
Farm 3	14.70	0.18	14.88	1.2
Farm 4	15.30	0.66	15.96	4.1
Average				3.96

Result of physical grain losses due to incomplete harvesting is shown in Table 2. There was a wide difference in the results of grain loss given by extension officers and farmers. The extension officers seem to have exaggerated the loss level due to incomplete harvesting. This is evidenced by the maximum level of 7.4% (Table 2) which appears unrealistic.

Threshing losses

The physical grain losses due to the traditional beating stick which accounts for 88.9% of the entire rice threshing method used in Uganda is shown in Table 3. Farmers experience grain loss due to this method of up to 2.6% of the total harvest.

Physical grain loss by farmers due to social issues during threshing is shown in Table 4. The value estimated by the extension officers was much higher than that given by farmers. Like harvesting, the extension officers seem to have exaggerated their quantities. This is evidenced by the maximum level of 7.0% (Table 4) which appears unrealistic. However they might have also seen and looked at it from a wider perspective and experience. For further discussions average values obtained from values of both farmers and extension officers were considered.The minimum and maximum values are 1.65% (60.8 kg ha^{-1}) and 5% (200 kg ha^{-1}), respectively.

Drying losses

The grain loss at the cemented drying yards was on average 0.4% during dry weather and 0.8% in the wet weather (Table 5). The loss during drying in wet season is almost twice that of dry season.

Grain cleaning losses

Grain losses due to traditional winnowing method under stream of air current are shown in Table 6. The information given by farmers and winnowing women correlate and while that from extension officers is much higher

Table 2. Harvesting loss due to incomplete cutting of straws (H_c)

Respondent	Quantity of grain lost (kg ha^{-1})		Average yield (kg ha^{-1})	Grain lost (%)	
	Minimum	Maximum		Minimum	Maximum
Extension agents	104	308	3,705	2.7	7.4
Farmers	41.2	102.1	3,705	1.1	1.4
Average				1.9	4.4

Table 3. Threshing loss due to beating stick (T_1)

Farm No.	Un-threshed and scattered grain collected (kg)	Yield of quadrant (kg)	Computed grain loss (kg/ha)	Grain loss (%)
Farm 1	9.5	709.5	52.6	1.3
Farm 2	10.5	410.5	98.9	2.6
Farm 3	2	252	29.9	0.8
Farm 4	3.5	453.5	29.9	0.8
Average	6.4		52.6	1.4

Table 4. Threshing loss due to social issues where workers use beating sticks (T_s)

Respondent	Grain recovered during re-threshing (kg ha^{-1})		Expected grain yield (kg ha^{-1})	Grain lost (%)	
	Minimum	Maximum		Minimum	Maximum
Farmers	35.6	115.6	3,705	1.0	3.0
Extensionofficers	86.0	284.5		2.3	7.0
Average	60.8	200		1.65	5.0

Table 5. Physical grain loss at the cemented drying yard

Parameter	Dry season	Wet season
Physical grain loss (kg ha^{-1})	13.1	29.6
Grain loss (%)	0.4	0.8

Table 6. Physical grain losses due to paddy cleaning by winnowing

Respondent	Physical grain lost (kg ha^{-1})		Grain lost (%)	
	Minimum	Maximum	Minimum	Maximum
Farmer	23.9	36.6	0.9	1.4
Extension	48.2	81.5	1.3	2.2
Winnowing women	31.6	48.6	0.9	1.3
Average	34.6	53.4	1.03	1.63

than the other two. The minimum average grain (paddy) loss was 1.03% and maximum average grain loss was 1.63%.

Discusson of the results

Harvesting losses

The harvesting physical grain losses consisted of shattering losses, losses due to intermediary piling of rice straws and incomplete harvesting losses. The results showed that farmers in Doho rice irrigation scheme who grow "Kaiso variety lines are losing 1.56% of their due to shattering. During the time of this study, the average yield per hectare in Doho was 3,705 kg. The average shattering loss of 1.56%, therefore, translates into 58.5 kg ha^{-1}. The minimum and maximum shattering losses were 0.7% (25.9 kg ha^{-1}) and 2.2% (81.5 kg ha^{-1}) respectively (Table 1). After cutting the mature straws, farmers initially pile the straws in small mounts (Figure 1). In these small mounts average physical grain loss was 3.96% (155 kg ha^{-1}). The high intermediary piling loss is being attributed to the high shattering properties of the Kaiso variety lines and poor harvesting technology.

Farmers' views on grain loss due to incomplete harvesting looked more realistic and were considered for further analysis.

Observations made for 3 years shows that the quantity of straws that are not cut during harvesting is very small. It is therefore difficult to obtain quantity of grain loss of 308 kg ha^{-1} (Table 2) due to incomplete cutting of straws that was reported by extension. Taking farmers' views, the minimum and maximum quantity of paddy farmers lose were 1.1% (41.2 kg ha^{-1}) and 1.4% (102.1 kg ha^{-1}), respectively.

Farmers and extension officers have attributed loss due to incomplete cutting of mature straws to poor harvesting technology and bad social behaviour of few farm labourers. Some of the hired farm labourers leave some straws deliberately with the purpose of coming back to carry out second harvesting of the remaining grain for their own benefit in the farmers' absence. However it was difficult to separate the straws which were genuinely not harvested due to poor harvesting technology from those which are deliberately left by some few unscrupulous labourers.

The total harvesting losses of Kaiso variety lines in Doho rice irrigation scheme ranged from minimum 6.62% (254.6 kg ha^{-1}) to a maximum value of 6.92% (315.6 kg ha^{-1}) with an average loss of 6.77% (285.1 kg ha^{-1}). These correlate very well to harvesting loss levels due to the same harvesting technology in some of the Asian countries. For instance the harvesting loss due to traditional method of sickle in Thailand is 9.2%. Harvesting losses due to ripper harvesting is 5.2 – 5.4% and combine harvester is 3.38% (FAO, 2002). The total harvesting losses due the same harvesting technologies also correlate very well with those obtained in Ghana which ranged between 4.07 and 12.05% (Appiah *et al.*, 2011) at farmers' fields.

Threshing losses

The total threshing grain losses composed of losses due to incomplete removal of grains from the ears of the rice straw pinnacles and scattering of grain because of the impact force from beating stick,and social behaviour of hired labourers. Based on the average yield of the rice in Doho during the study time, the results showed that the minimum and maximum threshing losses were 3.05% (113.4 kg ha^{-1}) and 6.4% (252.6 kg ha^{-1}), respectively with an average quantity of 4.7% (183.0 kg ha^{-1}). The average threshing loss in Asian countries is 3.38% (FAO, 2002). The average threshing loss of 4.7% and relates very closely to the values in Asian countries. Though the grain loss during threshing due to social behaviour is partially returned to the economy, the quantity is small and usually the quality of the grain recovered is poor with low market value. It can therefore still be considered as a lost grain.

Drying losses

The physical grain loss at the cemented drying yards was on average 0.4% (14.8 kg ha^{-1}) during dry weather and 0.8% (29.6 kg ha^{-1}) in the wet weather. The drying time in wet season is almost twice that of dry season. Usually, there is grain movement in and out of the store to the drying yards. In the process of spreading the paddy to dry and collecting it in bags for storage, grain loss occurs. The more this process is done, the more grain is lost at the drying yards. This, therefore, explains why there is more physical grain loss during drying in wet season than in dry season. Compared to direct physical grain losses from other post-harvest operations, the physical loss of grain during drying is small. However, the rapid drying has devastating effect on quality of paddy and hence milled rice and mill recovery.

Cleaning loss

The minimum average grain (paddy) loss was 1.03% (34.6 kg ha^{-1}) and maximum was 1.63% (53.4 kg ha^{-1}). The grain loss during cleaning was attributed to the use of rudimentary technology for cleaning and social behaviour of the hired farm labour force.

Total on-farm physical post-harvest grain losses excluding storage

"*Supa*" is one ofthe important swamp rice varieties grown in Uganda. Farmers and extension reported that *Supa*has close

shattering properties like "*Kaiso*" variety. The NERICA variety lines are the major upland varieties grown in the country but shatter slightly less than the "*Supa*"and "*Kaiso*" varieties. About 87.6% of the farmers in Uganda use the same post-harvesting methods (Candia *et al*., 2010). Though not accurate the total on-farm losses from harvesting to cleaning obtained in Doho could therefore beused to estimate approximate physical grain losses during post-harvest operations at national level. The study showed, that the average yield in Doho is 3,705 kg ha^{-1} and average national yield of 1,800 kg ha^{-1} of paddy (NaCRRI and Africarice, 2011).The total physical grain losses in the entire Doho rice irrigation scheme ranges from minimum 11.1% (462.6 kg ha^{-1}) to maximum 15.8% (695 kg ha^{-1}) with an average quantity of 13.5% (578.8 kg ha^{-1}). At national level the estimated loss levels range from minimum 11.1% (224.7 kg ha^{-1}) to maximum 15.8% (337.8 kg ha^{-1}).

Conclusion

The traditional method of harvesting rice using sickles and threshing using beating sticks causes high physical grain losses for farmers. The total average physical grain loss of 13.5% (578.8 kg ha^{-1} of paddy) during harvesting, threshing, drying and cleaning at Doho rice irrigation scheme is unacceptable level of financial loss to farmers. This is a setbackto food and income security of these farmers. Improvement of on-farm post-harvest technology, use of varieties that shatter less and farmer post-harvest knowledge enhancement will greatly reduce the high post-harvest physical losses as well as improve market competitiveness of the local rice industry.

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