RESEARCH PROGRAM ON Roots, Tubers and Bananas

CGIAR

Technical report:
Improved Potato Harvesting Techniques

Expanding Utilization of Roots, Tubers and Bananas and Reducing Their Postharvest Losses

RTB ENDURE

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IFAD
Enabling poor rural people to overcome poverty

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The CGIAR Research Program on Roots, Tubers and Bananas (RTB) is a broad alliance led by the International Potato Center (CIP) jointly with Bioversity International, the International Center for Tropical Agriculture (CIAT), the International Institute for Tropical Agriculture (IITA), and CIRAD in collaboration with research and development partners. Our shared purpose is to tap the underutilized potential of root, tuber and banana crops for improving nutrition and food security, increasing incomes and fostering greater gender equity, especially among the world's poorest and most vulnerable populations.

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List of Acronyms

AETREC	Agricultural Engineering and Appropriate Research Centre
BugiZARDI	Buginyanya Zonal Agricultural Research and Development Institute
CIP	International Potato Center
KIPA	Kacofa-Irish Potato Association
MIFA	Mengya Integrated Farmers Association
NARL	National Agricultural Research Laboratories
NARO	National Agricultural Research Organization

Executive Summary

Potato is considered both a staple food and main source of income on the slopes of Mt. Elgon and south-western highlands in Uganda. The districts of Kapchorwa, Kween, Mbale and Bukwo in eastern Uganda are estimated to produce over 40% of the national crop. The crop is mainly produced on areas ranging from 0.5ha to 5ha of land using manual methods both at planting and harvesting. Such methods lead to increased losses especially at harvest where hand hoes are used to dig out/lift the potato tubers. Four lifting methods were compared for their efficiency in lifting potato in plots of 12.5 by 10m with 4 replications. The lifting method included: i) hand hoe; ii) ordinary ox-drawn lifter modified from groundnut lifter; iii) ox-drawn lifter modified from Cossul plough based on farmers' recommendations; and iv) tractor-drawn single sieve single row potato lifter. The quantity of potato by harvesting technique were recorded after grading into marketable (medium to large-size), small and damaged tubers. The total acreage of potato field used was 0.204ha with an average plant spacing of 0.65m by 0.45m. The total recovery of all tubers both marketable and small was 2.63t giving a yield of 12.89t/ha.

The findings confirmed that a high proportion of tubers are left unharvested in the ground (38%) or are damaged during harvesting (e.g., 19% of harvested tubers when using hand hoes). This calls for an urgent need to develop more effective harvesting equipment. The tested lifters substantially reduced the proportion of tubers presenting cuts and bruises, and therefore unmarketable (7% to 9%). Farmers indicated that the required time and drudgery were also reduced although these were not assessed. Farmers also appreciated that the lifters ease subsequent land preparation thus shortening the period between harvesting and the planting of next crop.

These techniques require further evaluation with more uniform fields preferably after planting using oxen and in straight lines.

I. Introduction

Potato is an herbaceous starchy, tuberous crop and it is locally known as Irish potato in Uganda. Globally the Irish potatoes are the fourth largest food crop following rice, wheat and maize. In Uganda Irish potato is both a staple food and main source of income. The districts of Kapchorwa, Kween and Mbale in eastern Uganda are estimated to produce over 40% of the national crop. As a result of increased demand, especially in urban areas, production has been intensified in the traditional zones and it is spreading into central Uganda and other areas.

Potato is mainly produced twice a year by smallholder farmers on rain fed conditions. Land size typically ranges from 0.2ha to 5ha. Farmers mainly use farm saved seed, manual labor and limited input. Common varieties in Uganda include: Victoria, Rwangume, Kabaale, Rutuku, Kinigi and NAKPoT (1, 2, 3, 4, and 5). Other local varieties include Cruza and Wanale mainly used boiled or steamed. In eastern Uganda the crop is cultivated on steep slopes of Mt Elgon and therefore difficult to mechanize. Land is prepared mainly using manual methods with 85% of farmers using hand hoes and only 15% using oxen. Luckily some areas of Kween and Kapchorwa are flat enough for mechanization. Planting is done manually and ridges are usually created with hand hoes at first weeding. In Kapchorwa and Kween, several potato producers have modified the planting technique by opening ridges using oxen, placing seed by hand and covering the seed using a log pulled by oxen. Harvesting however is still manual using hand hoes. Harvesting is mainly carried out women and children with youth participating at the loading. From the fields the tubers are loaded into bags and carried on donkeys to the roadside, where they are poured directly onto the bare frame of waiting trucks and the rest parked in 120Kg bags on the truck frame. Potato is then immediately transported and sold to local middlemen or transported to rural markets for bulking. There is no form of storage or curing done whatsoever.

II. Challenges facing potato production

There are several challenges faced by the actors along the potato value chain. Most significant is the high perishability of the crop and the lack of suitable storage facilities to extend the shelf life of the potato. Producers lack appropriate harvesting techniques like potato lifters and thus use rudimentary tools like hand hoes and sticks for harvesting. Poor access to quality seed and incidence of disease such as potato blight are reported as major challenges. Furthermore, stakeholders lack understanding of market opportunities and enjoy limited access to market information and poorly structured markets which forces them to harvest and sell off immediately at low price. Finally, farmers are poorly organized in groups to enjoy advantages of large scale production and marketing.

III. Objectives

Hand digging is said to cause mechanical damages to about 40% of tubers and it is estimated that up to 20% of the crop is left underground. It is estimated that almost 100% of tubers can be harvested if appropriate tools are used. This report presents the findings of a research aiming at evaluating mechanized potato harvesting/lifting equipment suitable for the slopes of Mt. Elgon.

IV. Methodology

Potato digging is a cumbersome process and requires several man-hours per hectare if done manually. Potatoes are generally lifted with spades, digging hoes, digging forks as used for manual tillage or with animal drawn potato ploughs. A number of animal drawn and tractor mounted tools and equipment have been developed for lifting or harvesting operations.

NARO ox-drawn potato lifter

Ox-drawn potato lifter (OPL) have been developed and used in India for centuries, while in Italy they have been modified for use on tractors. An OPL was designed on the basis of the groundnut digger and the ordinary ox-plough. The digger is similar to a mouldboard plough. It consists of mild steel box frame, a bent tine for attaching mouldboard with the frame, mouldboard plough shaped part and a flat piece attached to the tip of the share, hitch assembly and handle. All the components are made of mild steel. For operation, a pair of bullocks pulls the implement; the flat piece attached to the share tip penetrates in the soil and harvested crops along with the soil lumps slide over the mouldboard.

The engineers at National Agricultural Research Laboratories (NARL) through the Agricultural Engineering and Appropriate Technology Research Centre (AEATREC) at Namalere, converted the mouldboard plough into an animal drawn single row implement suitable for lifting out potato tubers (Figure 1). A V-shaped ridger type share was provided to dig out the tubers. The lifter rods are attached behind the share. These lifter rods are spaced to allow the clods and residual material/tubers to drop while operating the implement (Figure 4). The tubers along the ridge are then collected manually.

Specification for animal drawn potato digger

Based on IS: 11033 – 1984 (Revised 2001) of the Indian Standards. This standard specifies material, constructional performance and other requirements for ridger type animal drawn potato digger (Figure 2 and 3).

Material: The material of construction of share body, share and land side shall be chilled cast iron or steel conforming to Grade 75 C6 or any other material having characteristics equivalent to or better than this may also be used. The material of construction for components other than those specified earlier shall be of cast iron or mild steel. These can be used for beam, handle, handle grip, share body, share and land side.

Figure 1: NARO ox-drawn potato lifter, with a mouldboard replaced by pronged fork

Dimensions

The working width of the digger should be adjustable between 450 to 600 mm. The adjustment of the diverging wings or curved bars attached to the mouldboard far separation and exposure of potatoes may be varied as per requirement.

The digger should be set at its working position and the throat clearance should be in the range of 250 to 500 mm. The vertical distance between the ground and the centre of the grip can be adjustable. The distance should lie between 900 and 1,100 mm.

The handle grip should be circular or oval in cross section. The diameter should be between 25 and 30 mm. The length of the grip should be not less than 125 mm. The angle between the grip and the handle should be between 100° and 105°.

The cutting edge of the share will be beveled (slanted) to a distance between 5 and 10 mm. The thickness of the cutting edge should be from 0,5 to 2 mm. The variation in edge thickness in a share shall be not more than 0.05 mm.

The angle of cut and angle of penetration is 5° to 15° and 15° to 30° respectively. The variation from the declared angle should be not more than 3° subject to the angle remaining within the specified limit.

All the components should preferably be detachable for ease of replacement. The fasteners coming in contact with soil should have coarse thread. The head of the fasteners, coming in contact with soil, should be flush with the working surface. As far as possible bolt of 10 mm size should be used for all fastenings to facilitate the use of minimum number of tools. Each bolt should have spring or flat washer of appropriate size for better contact. The digger should be symmetrical on both sides along the longitudinal central axis of the digger bottom. The mass of the digger including the beam is about 20 kg.

When the digger is set at its working position and is placed on a plane surface, its bearing points (point of share and wing of share and heel of land side) should touch the ground and the digger to keep the digger well-balanced.

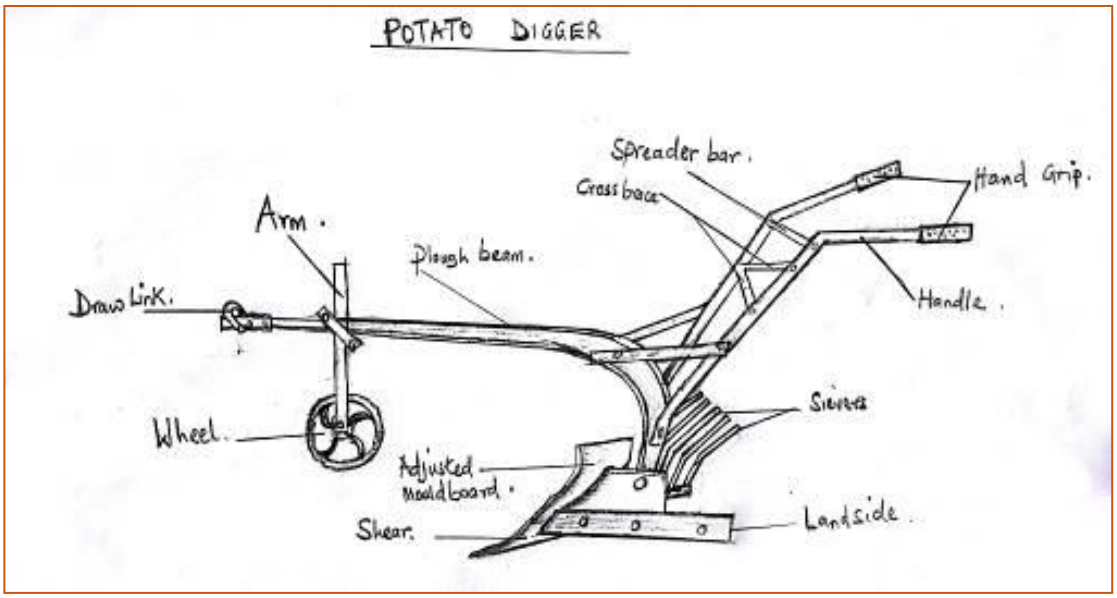

Figure 2: Sketch of Ox-potato lifter showing the different components

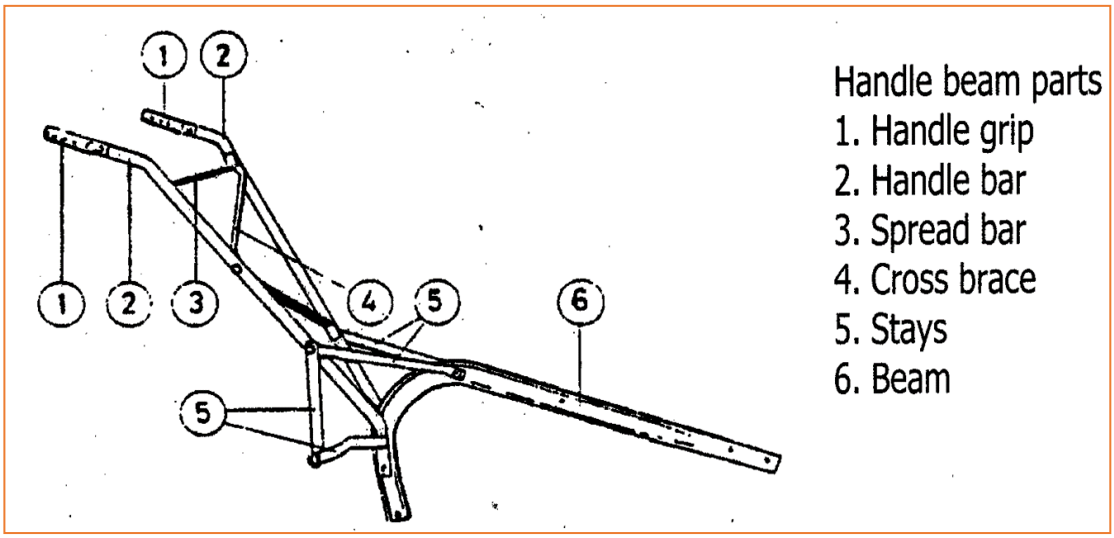

Figure 3: Main parts of animal drawn potato lifter

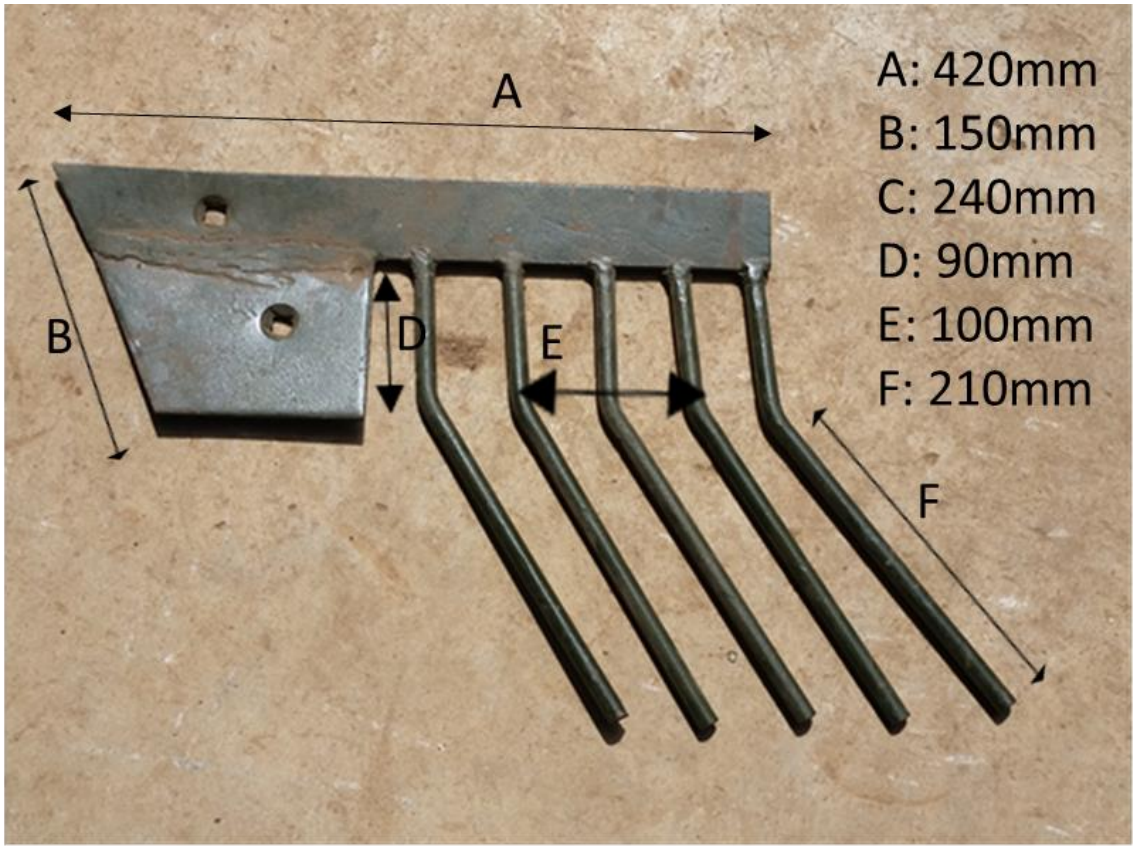

Figure 4: Pronged plate to replace mouldboard on potato lifter

Farmers' modified ox-drawn potato lifter

A member of the farmers' association (Mr. Kiptala Moses) noted that the original lifter was designed based on an ordinary frame used in the lower plains for maize cultivation. The farmer and the engineers teamed up to modify the digger by removing the mouldboard end of the ordinary Sebei plough and replacing it with pronged plate (Figure 5). This particular type has a shorter beam and the share is shorter and narrow (see figure). This particular frame is based on the Cossul plough design commonly used in Kenya and Tanzania. The effectiveness of an animal drawn implement depends on the frog and pitch range. The farmers' design has a frog width of 200 mm and a pitch of 50° compared to 180mm and 25° of the NARO lifter. The higher pitch gives the lifter ability to dig deeper in heavier soils such as those found in Mt. Elgon.

Figure 5: Innovative farmer transferring forked/pronged attachment onto Sebei frame which has a much shorter beam and share than ordinary plough frame (brown frame) with pronged end (green) replacing the mouldboard

Tractor-drawn potato lifter

Tractor drawn potato harvesters are small and simple, capable of harvesting potatoes, onions and beetroot. The harvester gently lifts the product which is then vibrated to separate the crop from the soil. The crop is laid gently on the griund to facilitate easy bagging thus ensuring 100% of the crop grown is saleable. A tractor drawn potato lifter was sourced from Kenya through a Ugandan input dealer (El-Shadai International).

The Italian manufactured SP50V single row-single sieve potato lifter (Figure 6) was acquired for evaluation alongside the other harvesting techniques. It is has a reduced size making it ideal for digging potatoes and other tubers also in small plots, and it is especially efficient on sandy soils.

The SP50V potato lifter is equipped with discs and a vibrating share facilitates the penetration into the soil. It must be applied to three point linkage of tractors. The lifter is fitted with an off center and rear discharge port. It has a working width of 54cm, weighs 160Kg, length 160cm, width 75cm, height 85cm and working depth of 54cm. it has two grass cutter discs attached at the 3 point linkage end, 1 swing plow and an oscillating grid.

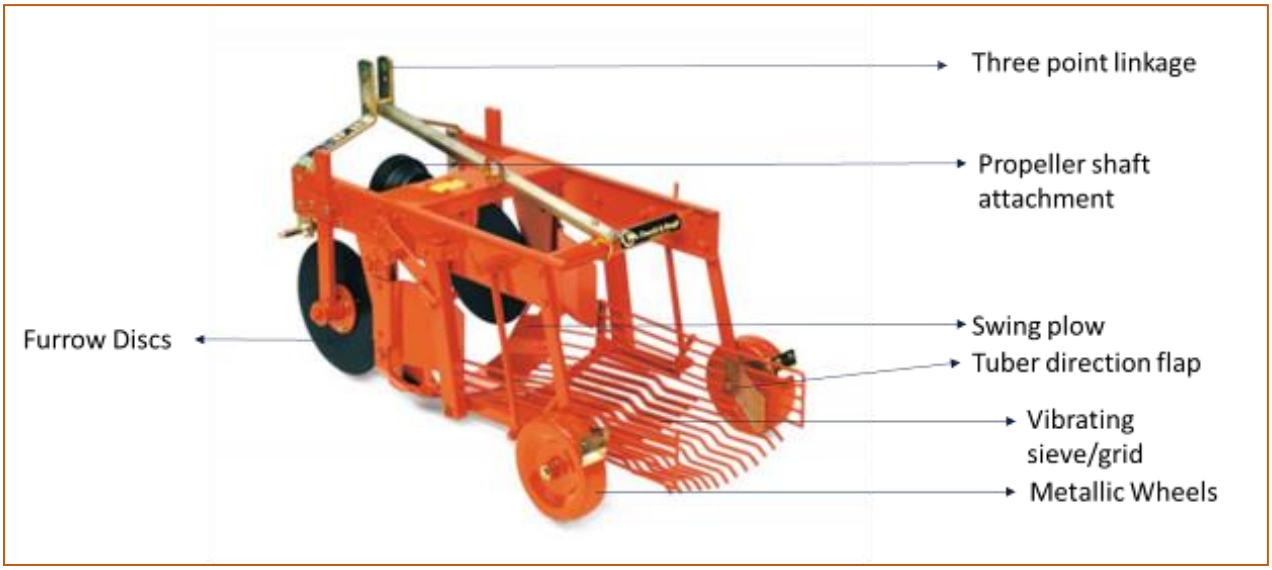

Figure 6: Parts of a tractor powered single row single sieve potato lifter

Specifications for the tractor drawn potato digger

It comprises of a frame, V type edge/trapezoidal type digging blade, endless rod chain conveyer attached behind the blade, gearbox, two gauge wheels, idlers and driving sprockets. Two oval agitator sprockets oscillate the conveyer chain rod, which helps to separate the soil.

Power Source: Tractor of 35 HP or above

Hitch: Rear 3 point linkage, CAT-I/CAT-II

Frame: Should be good quality (MS Channel/ Box welded frame)

Digging blade: V type edge/Trapezoidal plate type 42-45cm width

Gauge wheels: Two

Depth Adjustment: Through 2 coulter discs at both end of blades

Conveyer: Endless rod chain conveyer made of MS rods of 13 mm (min.), length of conveyer 150-250cm, 18-20 degree angle with the horizontal, spacing between conveyor rods 25 mm (min.), and peripheral speed of conveyor 2-2.2 m/sec

The workmanship should be of high quality. It should not have sharp projections. All the moving parts should be properly protected. The machine should be painted with high quality paint after applying proper primer. The machine should be warranted for two years for any manufacturing defects. The machine should be easily serviceable with good availability of spare parts.

Figure 7: Potato lifter mounted on 3 point of a tractor in field after harvesting

Field evaluations

A field in Kapkoch, Kween district ready for harvesting potatoes was identified and selected for the study.

The field was divided into plots of 12.5 by 10m with 1m between the plots. 4 replicates were randomly assigned for the hand hoe harvesting while two adjacent plots were used for the 2 ox-drawn potato lifters and a whole strip of 4 plots used for the tractor harvester (Figure 8).

Hand hoe	HHL
NARO ox-drawn potato lifter	OPL_NARO
Farmers ox-drawn potato lifter	OPL_Farmer
Tractor Drawn potato lifter	TPL

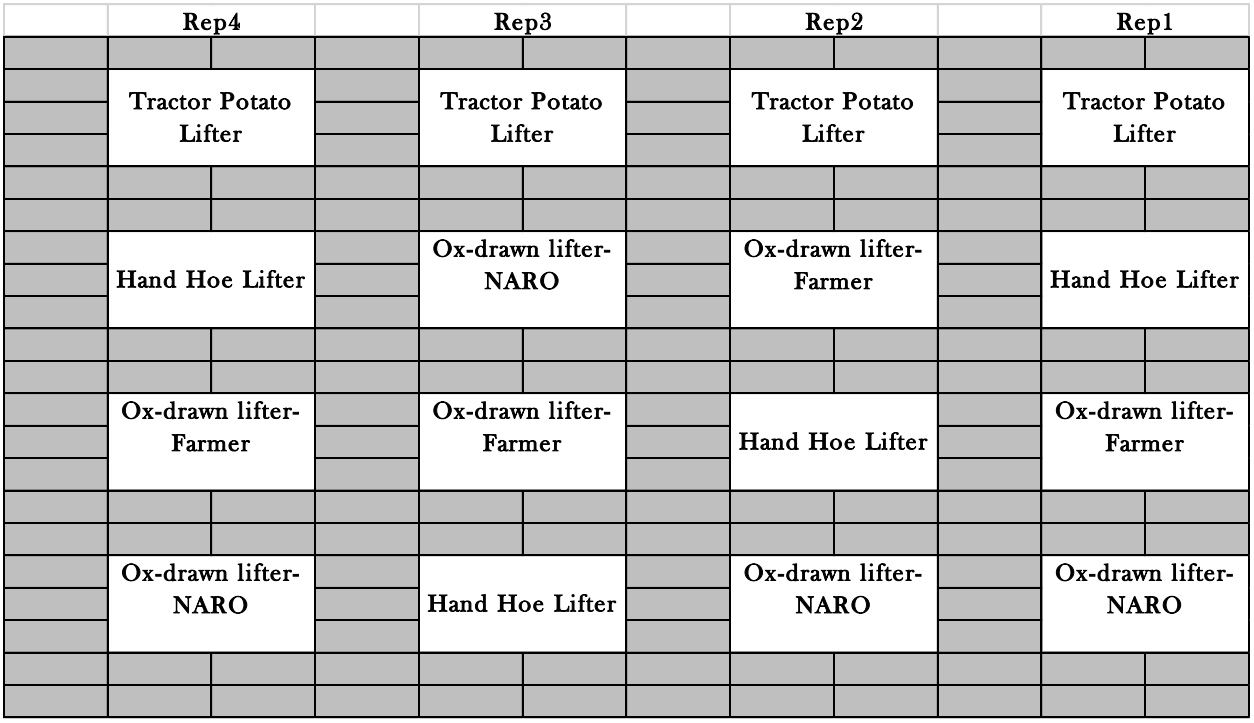

Figure 8: Ground layout of the mechanised harvesting experiment

Fifteen persons (8M:7F) were selected to conduct the common hand hoe harvesting in each of the relevant plots (Figure 9).

Figure 9: Hand hoe harvesting of potato in Kween district, exposed tubers are thrown in a heap ahead of the harvesters

The ox-drawn potato lifters were hitched to a pair of oxen. The ox-potato lifters were handled by one person, while another was driving the pair of animals through the plots (Figure 10). At end of each plot the handler would lift up the digger until the whole plot is harvested.

Figure 10: Potato harvesting using oxen with tubers shown in adjacent rows and tuber collection as they are lifted on top of ridges

Data collection

The following data were collected:

a) Potatoes lifted from the soil by harvesting technique (collected by picking lifted potatoes)

b) Total potatoes (by summing all weights of lifted potatoes)

c) Damaged potatoes from each trial plot (cut or bruised potatoes)

d) Total remaining unharvested potatoes collected after running through with the tractor lifter

The following was then calculated:

Exposure percentage by mass

$$\text{Exposure percentage by mass} \rightarrow \left[\frac{\text{mass of potatoes exposed (collected from all rows)}}{\text{mass of total potatoes (collected from all rows)}} \right] \text{X100}$$

Damaged percentage by mass

$$\text{Percentage of damaged tubers} \rightarrow \left[\frac{\text{mass of damaged exposed tubers per treatment}}{\text{mass of total potatoes per treatment}} \right] \text{X100}$$

V. Results

The experimental field utilized was not established by researchers and therefore plant population may vary for each plot. The crop planted was of variety Kabale with seed acquired from the ordinary market. The farmer used 0.24t of seed on an area of 0.204ha with an average plant spacing of 0.65m by 0.45m.

The plot sizes were 12.5 by 10m with a 1m path on all sides consisting of 60 rows. The total recovery of all tubers both marketable (big and medium size) and small was 2,627Kg or 2.63t giving a yield of 12.89t/ha.

Harvested tubers by harvesting technique

The total quantity of harvested tubers was not even across plots, with substantial variation in harvested yield ranging from 5.35 to 10.51 t/ha. In fact, farmers used oxen to open the land and manual labor to plant which may have affected the seed distribution, establishment and therefore plant population. About 56% of harvested tubers were of medium to large size, while 33% were small with the remaining tubers being damaged and presenting severe cuts and bruises (11%). About 38% of potatoes in the field remained unharvested and were then recovered by the tractor lifter. About 83% of recovered potatoes were undamaged.

Table 1: Parameters measured for different methods of potato harvesting

Harvesting technique	**Parameter**	**Yield (t/ha)**
Hand hoe	Quantity of marketable-size tubers	4.74
	Quantity of small-size tubers	3.80
	Quantity of damaged tubers	1.97
	Total quantity of tubers harvested	10.51
Farmers' ox-drawn lifter	Quantity of marketable-size tubers	6.08
	Quantity of small-size tubers	3.44
	Quantity of damaged tubers	0.66
	Total quantity of tubers harvested	10.18
NARO ox-drawn lifter	Quantity of marketable-size tubers	4.58
	Quantity of small-size tubers	2.24
	Quantity of damaged tubers	0.70
	Total quantity of tubers harvested	7.52
Tractor-drawn lifter	Quantity of marketable tubers	3.30
	Quantity of small-size tubers	1.68
	Quantity of damaged tubers	0.37
	Total quantity of tubers harvested	5.35
Recovered by tractor lifter from the whole field after harvesting using hand hoe and ox-drawn lifters	Quantity of marketable-size tubers	12.80
	Quantity of small-size tubers	4.40
	Quantity of damaged tubers	3.60
	Total quantity of tubers harvested	20.80

Damaged tubers by harvesting technique

The proportion of harvested tubers (both marketable and small-size) with cuts and bruises was substantially higher with hand hoe harvesting than with either ox-drawn lifters or tractor-drawn lifter. A lower percentage of harvested tubers presented damages when potatoes were harvested with the farmers' ox-drawn lifter and tractor-drawn lifter (7% for both) than with the NARO ox-drawn lifter (9%) and hand hoe (19%), as presented in Table 1 and Figure 11.

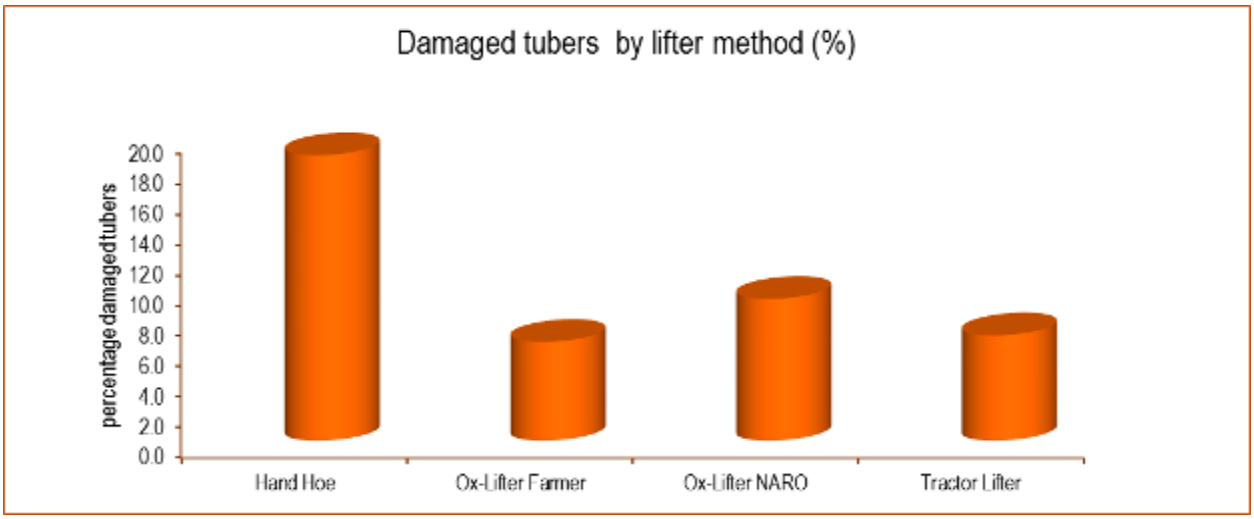

Figure 11: Proportion of damaged tubers by harvesting method

VI. Discussion and conclusions

The findings confirmed that a high proportion of tubers are left unharvested in the ground (38%) or are damaged during harvesting (e.g., 19% of harvested tubers when using hand hoes). This calls for an urgent need to develop more effective harvesting equipment. The evaluation of four different potato harvesting techniques has introduced the potato associations to more efficient harvesting options than the conventional manual methods. The participants were unsure about the effectiveness of using the ox-drawn potato lifters at the beginning of the experiment but they were appreciative at the end of it. The tested lifters substantially reduced the proportion of tubers presenting cuts and bruises, and therefore unmarketable (7% to 9%). Farmers indicated that the required time and drudgery were also reduced although these were not assessed. Farmers also appreciated that the lifters ease subsequent land preparation thus shortening the period between harvesting and the planting of next crop.

In reference to gender aspects, it was observed that children, youth and elderly could all get involved when the lifters are used. The main challenge however relates to the planting method that needs to be adjusted to straight lines to ease harvesting. Furthermore, removal of stones and bolder from the fields is required.

The ease of use of all the equipment was also appreciated with participants particularly interested in adopting the ox-drawn lifter technology. The fuel consumption of the tractor can potentially hinder the adoption and it was suggested to introduce smaller tractors than the one used in the evaluation.

Overall the participants were happy to have been involved in the evaluation and some offered to try out the equipment, especially the ox-drawn lifter in the farms. They also advised each other to train oxen handlers in the proper use of the equipment because we observed that poor placement of the shear can result into significant damage of tubers.

The results are promising and more evaluations are recommended on more uniform fields and different potato varieties. Ideally these experiments should be carried out where planting is done with harvesting experimentation in mind.