International Journal Of Engineering Research And Development
e- ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 20, Issue 5 (May. 2024), PP. 253-263

A Review On Cassava Harvesting Equipments

Mbarga Awoumou clovis[1] and Doua Philémon[1]
[1]*National School of Agro-industrial Sciences, University of Ngaoundere, Cameroon, B.P 454 Ngaoundere*

ABSTRACT
Harvesting is a bottleneck in the cassava production value chain. When done manually and semi-manually, it is tedious. Drudgery is observed through the serial repetition of harvesting operations rather than parallel harvesting approach. This state of things causes loss of time, energy and attacks on the health of farmers like hand blisters; cought due to dust, wind and or rain; and body fatigue. It also leads to low productivity. Transporting the harvesting tool and the harvested products requires supplementary efforts from the farmer. Semi-mechanized and fully mechanized cassava harvesting equipments need less or no human labour force, save time and increase the productivity but in semi-mechanized equipments only the root digging process is mechanized and is not interested in harvesting other parts which still needs human labor to separate roots from the stem and for the harvesting of leaves. Also, it is more expensive due to purchasing price and the use of fuel. On the other hand, fully mechanized cassava harvesting equipments also have the advantage of leaving the field ploughed after harvesting. This saves fuel, facilitates soil preparation and planting for the next season but the disadvantages of these equipments are that only digging, lifting and transport of roots are concerned and are more expensive due to higher purchasing prices and the use of more fuel. Since the efficiency of these harvesters is not 100%, there are still possibilities to improve on the quality of harvesters. It is thus necessary to have an overview on the existing cassava equipments.
Keywords: *cassava, harvesting, equipments, labor intensive, mechanization.*

Date of Submission: 20-05-2024 Date of Acceptance: 03-06-2024

I. Introduction

Cassava has become an important food security and the world's third most important crop. The crop is an essential source of food and income throughout the tropics providing livelihood for countless farmers, processors and traders worldwide (FAOSTAT, 2016). In Africa, cassava is the single most important source of dietary energy for a large proportion of the population living in the tropical areas (Cock, 2011). No other continent depends on cassava to feed as many people as does Africa, where over 500 million people consume it daily. The main bottleneck to cassava harvesting which mainly consist of uprooting the plant is that it is very tedious because the plant must be held, pulled out of the ground and the harvester found out of the circumscribe sphere where the roots are found. Also, the plant should be harvested at the right time and in the proper manner to avoid deterioration as early as 1 to 3 days after harvesting (Agbetoye *et al.,* 2003). To solve this problem, many methods and the corresponding equipments are currently used across the world. The manual method is adapted for family consumption and involves the use of bare hands with or without the use of indigenous tools such as cutlass, hoe, mattock, and others. This method is very tedious and is labour intensive when harvesting hectares of land using about 23 to 51 man hour per hectar (man-h/ha). It also exposes the farmer to attacks from the environment like the climate, insects and plants. It is also time and energy consuming. The semi-manual method involves the used of effort multiplying equipments having an output range of 16 to 45 man-h/ha and is adapted for cash crop farming on a medium surface area cultivated. Here, human intervention is still highly needed. In semi-mechanized harvesting method equipments, only the root digging process is mechanised having a high output falling in the range of 1 to 4 man-h/ha. Equipments used are usually tractors on which implements are hitched and manual effort may be needed after cassava uprooting to collect and detch the cassava root tubers (Amponsah *et al.*,2018). In fully mechanized method, all processes from digging of roots, lifting of uprooted roots onto the soil surface to transport are mechanically done. But the financial cost of purchasing and for the maintenance of these two last type of equipment is not affordable to local farmers. It also needs very large surface area to be profitable. It is thus very important to choose the equipment that matches with specific situations among the set existing ones. The aim of this work is to present existing manual, semi-manual, semi-mechanized and mechanized equipments. All these methods and their corresponding equipments should be evaluated on many factors such as their ability to: increase the quality of the harvested products by reducing the percentage of root breakage, leaves losses and by properly cutting the stems so as to have buds adequately placed for future use; increase the quantity of cassava roots, leaves and stem harvested as well as the quantity transported per work cycle to ware houses; affordability to farmers in terms of price and cost of usage;

reduction of drudgery related to harvesting operations; reduction of loss of time, energy and matter; reduction of attacks on the operator so as to preserve his health; ability to increase the availability of cassava roots, leaves and stem in different local markets.Cassava harvesting is done using the following processes.Firstly,cassava is harvested by digging.This is done by removing the soil that surrounds the plant partially or completely. Usually, these tools are used to dig round the standing stem to facilitate the pulling of the roots from the soil before detaching the uprooted roots from the base of the plant (Amponsah *et al.*, 2018). In some communities in Cameroon, the soil is removed partially and some roots are detached from the main plant and then the dug hole is filled back with the soil and the rest of the roots can be harvested latter. Here the equipment has to come against frictional forces.Secondly,the pulling process is often used.Here, the cutting and selection of animal fodder (cassava leaves and other aerial parts) and planting materials can be done before pulling or after. When the cutting is done before pulling, the cassava stem left is usually of height between 20 to 40 cm above the soil level and is mostly harvested by hand, lifting the lower part of the stem and pulling vertically upwards the roots out of the ground and then detaching them from the base of the stem (Shadrack kwadwo *et al.,* 2014).The last process is a combination of the two previous processes that is digging and pulling. Prior to the application of this process, the cutting and selection of animal fodder (cassava leaves and other aerial parts) and planting materials is done. Only 20 to 40 cm lengths of the stems are left still attached to the roots underground, so that these may be more easily extracted or pulled out of the soil. Here, a machine goes under the cluster of roots, raises them up and lays them down on the surface (Peipp et al. 1994).

II. Cassava harvesting equipments

2.1 Manual harvesting equipments

This is the traditional method of harvesting cassava manually with bare hands and with the help of rudimentary tools such as a hoe, cutlass or mattock and other types of locally developed tools to dig round the standing stem to pull out the root before detaching them from the whole plant. Bare hands permit to harvest the leaves, the stem, the roots and to collect them for transport. The root breakage percentage ranges between 8% and 10% with an average uprooting force falling between 600N and 1KN per plant. It is cost free and requires no fuel consumption. Labor demande ranges between 11 to 29.9 man-day/ hectar. The work cycle depends on the farmer and usually the maximum quantity of harvested cassava daily is 500Kg (Ospino *et al.,* 2007) but this causes usually body illnesses.The purchasing price of a hoes is affordable to local farmers and the labor demande is in the range 42 to 51 man-day/ hectar (Shadrack kwadwo *et al.*, 2014).The cutlass permit to harvest the leaves, the stem, the roots. The root breakage percentage is 8.9% with a labor demande of 18.5man-day/ hectar.The purchasing price of a hoe is affordable to local farmers (Shadrack kwadwo *et al.*, 2011).

2.2 Semi-manual equipments

This involves the use of systems that multiply the input effort to ease harvesting. These systems either use the principle of moment of forces which maximizes the mechanical advantage or Pascal principle in which the input force is been magnified due to an increase in the surface of the applied force. Some systems combine these two principles.

2.2.1 Semi-manual cassava harvesters using the principle of moment

The Council for Scientific and Industrial Research, Crop Research Institute (CSIR-CRI) Ghana, and the National Centre for Agricultural Mechanization (NCAM) Nigeria, designed a simple harvester based on the principle of moment as shown in Figures 1. With the advancement in technology, many of these harvesters are improvised around the world (Amponsah *et al.,* 2018).

Figure 1:Cassava harvester designed by CRI(left) by NCAM(right)(Amponsah et al.,2018)

Another semi-mechanised equipment was developed by the department of mechanical engineering of the federal university of Petroleum Resources, Effurun, Nigeria as shown in figure 2 below.

Figure 2:Field trial to showcase the operation of the semi-manual cassava harvester(Otonocha et al.,2021).

A semi-mechanised cassava stem cutter and harvester was developed in the Department of Agricultural and Bio-resources of Federal University of Technology, Minna, Niger State. The first-class principle of levers was applied in the design and fabrication of the uprooting mechanism, the scraper and secateurs. While the second-class lever principle was adopted in the fabrication of the machine frame (Gbabo *et al.*, 2020).

Figure 3:The Cassava harvester and stem cutter(Gbabo et al.,2020)

A semi-mechanized cassava harvester was fabricated in Kanjirapally municipality, Southern region, India in January 2018.

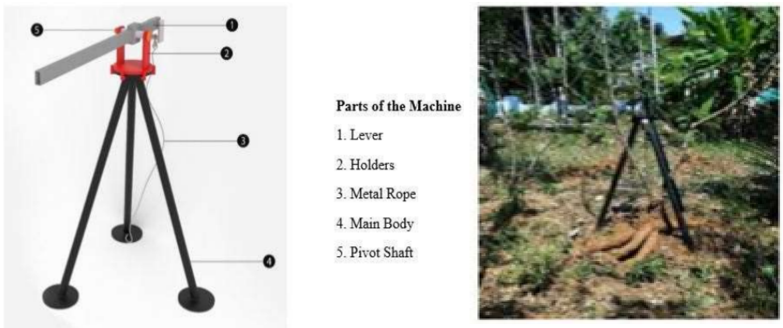

Figure 4:Catia design of the product and field testing(Aby Cherian,2018)

2.2.2 Semi-mechanized cassava harvesters using Pascal's principle

A semi-mechanized cassava harvester was constructed and tested in the Olabisi Onabanjo University in Nigeria. It uses a hydraulic system based on pascal principle to magnify the input force

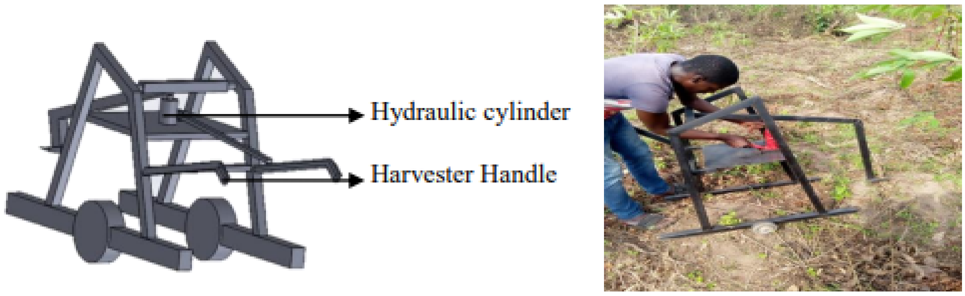

Figure 5:3D model and field test of the constructed harvester(Babalola et al.,2018)

2.2.3 Semi-mechanized cassava harvesters combining the principle of moment of force and Pascal's principle
The department of agriculture and bio-resources engineering of the federal university of agriculture Abeokuta, Nigeria constructed three cassava harvesters based on Pascal's principle coupled to the principle of moment to actuate the cassava root uprooting process of the stem attached to the gripping arm through the lever hydraulic arm (Ola *et al.* 2019).

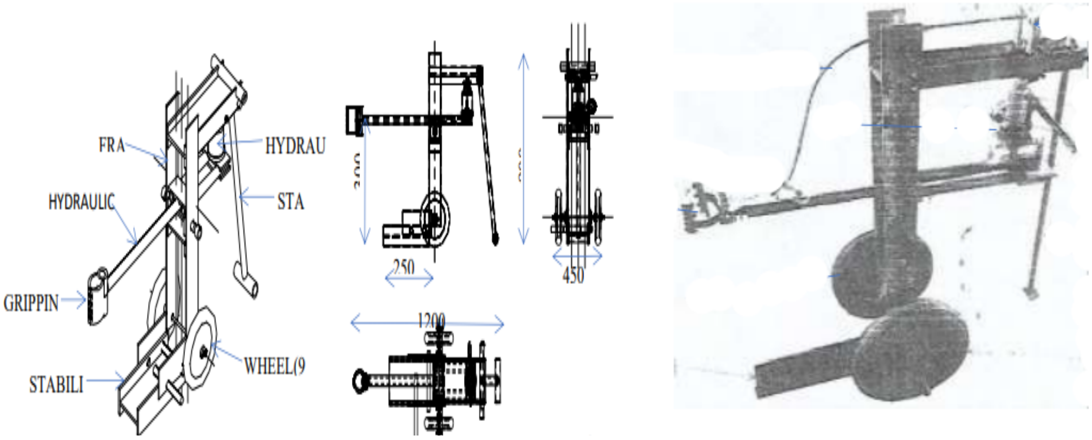

Figure 6:Hydraulique arm cassava root uprooting(Ola et al.,2019)

The second design is an amelioration of the hydraulic arm cassava uprooting device. Here, the frame of the machine was changed into pillar form to reduce the overall weight of the device and energy expended in using the unit on the field.Two metric tons bottled hydraulic jack was also used to develop the required uprooting force.

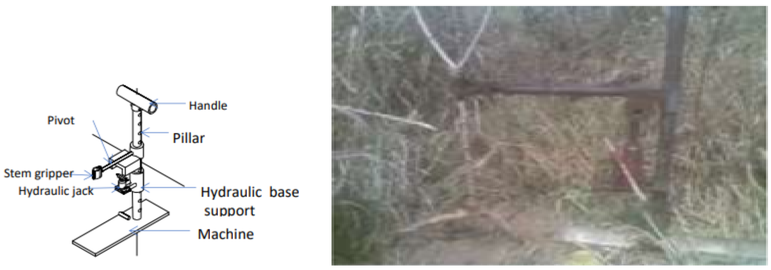

Figure 7:Pillar frame hydraulic and field evaluation of the harvester(Ola et al.,2019)

The third design is a refinement over the other two. This made it lighter in weight to reduce the overall energy inputted in operating the unit. It is made up of four component parts as shown in figure number.

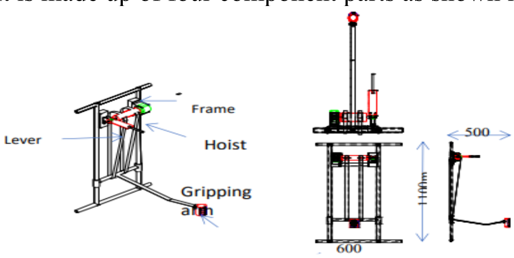

Figure 8:Lever hoist cassava root uprooting devices and field operation of the harvester(Ola et al.,2019)

2.3 Semi-mechanized harvesting method equipments
In semi-mechanized harvesting method equipments, only the root digging process is mechanised and have a labor demande falling in the range of 1–4 man-hha principally to detach the roots from the stem. Equipments used are usually tractors on which implements are hitched and manual effort may be needed after cassava uprooting to collect and detach the cassava root tubers (Amponsah *et al.*, 2018).

CLAYUCA Cassava Harvester Model P600

The Latin American and Caribbean Consortium to Support Cassava Research and Development (CLAYUCA) conducted some research on the adaptation and evaluation of semi-mechanized harvesting systems for cassava in Columbia. Two semi-mechanised cassava harvester prototypes developed in Brazil were imported and their performance was evaluated under specific conditions in the main cassava growing regions of Columbia. The prototype had a front cutting disk that facilitated the harvesting process and was able to work even on dry soils where manual harvesting was not possible. Also, the implement needs to be hitched on a tractor of more than 90 horse power, has a daily output of 5 to 8 ha/8-h day**,** weights 200 kg, harvests two furrows at the same time and between distances of 80 to 100 cm and works at depths of 40 to 60 cm, depending on tractor type being used. For a smooth operation, however, it required the cutting of cassava stems prior to harvesting to a height of 20-40 cm. Figure 9 shows the Cassava harvester model P600 (Shadrack kwadwo *et al.*, 2011).

Figure 9:CLAYUCA mechanised cassava harvester model P600 (Shadrack kwadwo et al.,2011)

The rigid-blade model is different from the previous model in that instead of having points or weeding hoes, it has a solid blade system in the form of a “V”. This system may generate compaction, damaging the soil (Bernardo ospina *et al.* 2002).

Figure 10:Prototype of a cassava harvester with a rigid V-shaped blade (Bernardo ospina et al.,2002)

Agri-Machinery Research Institute of Chinese Academy of Tropical Agricultural Sciences in the long years of research time has successfully developed 4UMS series of cassava harvester. The structure of the original implement model has three parts namely the framework, the suspension structure and the working parts as shown in the figure below (Yuan zhang *et al.*, 2011).

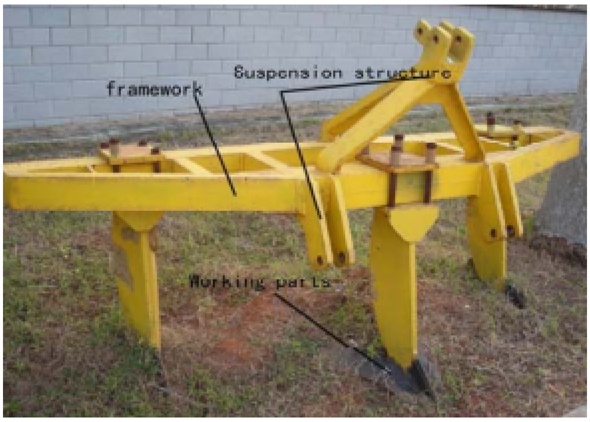

Figure 11:Structure of the 4UMS cassava harvester(Yuan zhang et al.,2011).

NCAM Tractor-drawn Tuber Harvester (Shadrack kwadwo *et al.*, 2011)
The National Centre for Agricultural Mechanization (NCAM) in Nigeria designed and manufactured a mechanized cassava harvester which was adapted for use in most farming communities in Nigeria. The harvester consists of a combination of a standard chisel plough preceding a serrated disc plough, both mounted on a tractor-drawn toolbar. The equipment has a field capacity of 0.8 - 1.2 ha per hour. Figure 12 shows the NCAM tractor-drawn cassava harvester.

Figure 12: NCAM mechanized cassava harvester(Shadrack kwadwo et al.,2011).

The TEK Mechanical Cassava Harvester (TEK MCH)
The TEK mechanical cassava harvester was developed and manufactured at the department of agricultural engineering of the Kwame Nkrumah University of science and technology in Ghana. The TEK mechanical cassava harvester is a fully mounted implement which operates according to the dig and pull principle. The digger is lowered to set the required depth and then digs out the cassava root cluster. Due to the inclination of the slatted conical mouldboard, the roots are brought onto the surface for collection and detachment. Figure 13 shows the TEK mechanical cassava harvester with labelled parts A to G (Shadrack kwadwo *et al.*, 2011).

A – Beam to which digging unit is attached B – Conical mouldboard C – Top link hitching point D – Digger E - Vertical support F – Lower link hitching points G – Slatted rods for shaking off soil.
Figure 13:The TEK mechanical cassava harvester with labelled parts(Shadrack kwadwo et al.,2011).
Tractor-mouthed cassava digger (14)
In Thailand based on the shear blade used, the existing cassava diggers can be broadly grouped as fork shear blade type and curve shear blade type (Sahapat chalachai *et al.*, 2013).

a) Fork shear blade type

b) Curve shear blade type

Figure 14:Types of cassava diggers available in Thailand(Sahapat chalachai et al.,2013).

The College of Mechanical and Electrical Engineering in Hainan University, China developed a structural bionic design for a digging shovel implement.

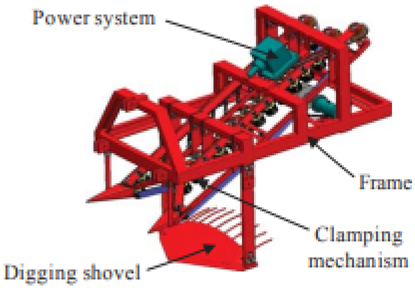

Figure 15:3-D model of digging-pulling style cassava harvester implement and cassava harvester prototype's field test(Shihao liu et al.,2014)

The field test results show that the digging shovel's tubers uprooted process runs smoothly, and the harvesting effect has been improved.

Department of Mechanical and Manufacturing Engineering of the University of the West Indies in Trinidad and Tobago designed a new harvester after detecting faults from Beau's Harvester. Results showed that Beau's harvester had an average field efficiency of 66% and the worked soil had an average coefficient of curvature (Cc) of 1.8 and an average coefficient of uniformity of 7.8. From the faults observed from this model, Seepaul Cassava harvester was, the final design. Harvesting with the Seepaul Cassava Harvester, would result in a harvesting time that is at least 33.7 times lower than manual harvesting which can be 22-62 man days per hectare (Samella seepaul *et al.*, 2015).

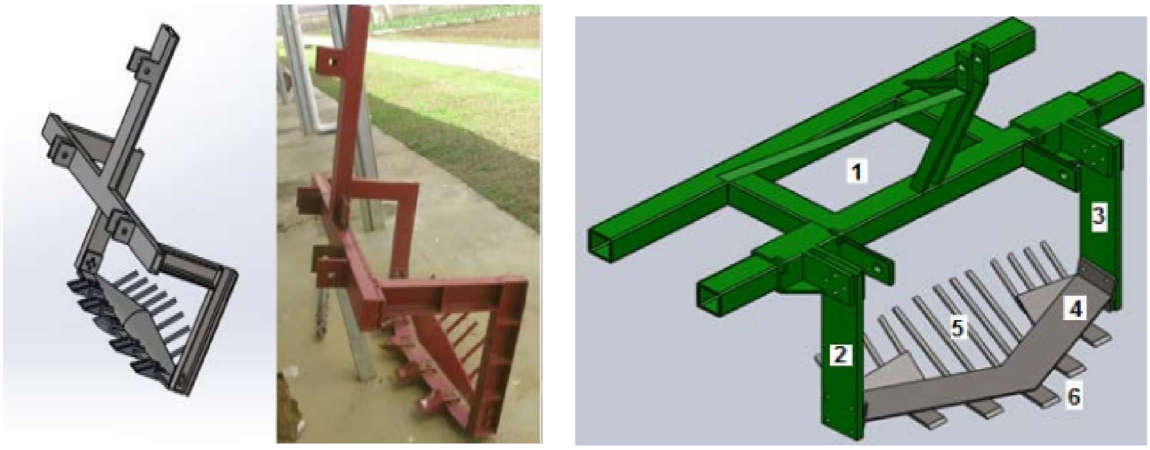

Figure 16:Selected concept design Beau's Harvester and Seepaul cassava harvester(Samella seepaul et al.,2015).
The Department of Agricultural and Bio-Environmental Engineering of the Federal Polytechnic, School of Engineering Ekiti State in Nigeria developed a cassava harvester made up of the following components: Frame, leg, shoe, bolt and nut, Spikes, Point of Attachment (left, right and top Linkages) (Isinkaye *et al.*, 2021).

Figure 17:Fabricated cassava harvester implement(Isinkaye et al., 2021).

A cassava harvester was released by Agricultural Machinery Research Centre, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University. It is suitable for harvesting in single row and or two row planting system. This can be operated with 50 HP tractor. By using this harvester we can able to harvest 0.7 ha/day in single row planting and 1.0 ha/day in two planting system (Velmurugan *et al.*, 2020).

Figure 18:Demonstration of tractor operated cassava harvester(Velmurugan et al.,2020).

2.4 Fully mechanized harvesting method equipments

In fully mechanized harvesting, all processes from digging of roots, lifting of uprooted roots onto the soil surface to transport are mechanically done.

A group of cassava growers and processors in Brazil financed the development and adaptation of prototypes that were based on a potato harvester. The prototypes eliminate all labour from the initial harvesting phase, using workers only for selecting and packaging roots. Before operation, stems must be cut at 20 to 40 cm above the soil surface
The Model WH-15.2L has a weight of 700 kg, a daily output of 5 ha/8-h day, a cutting width of 80 cm, requires a power of 100 hp and works with a mat system, where soil is removed from the roots, using blades

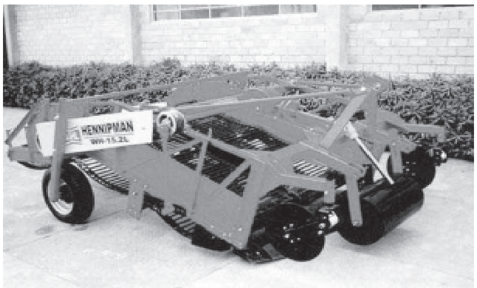

Figure 19:Prototype of a mechanical harvester,model WH-15.2L(Bernardo ospina et al.,2002).

Model WH-CM 4000 is similar to the previous model. It has the following features: Roots are mechanically taken up to a large sack bag. The big-bag sack is released by a hydraulic system, enabling the machine to operate continuously It possesses a work platform where workers remove roots from stems, average capacity is 7 to 10 t/h, required power is 120 hp, cutting width is 240 cm, the machine weighs 3500 kg.

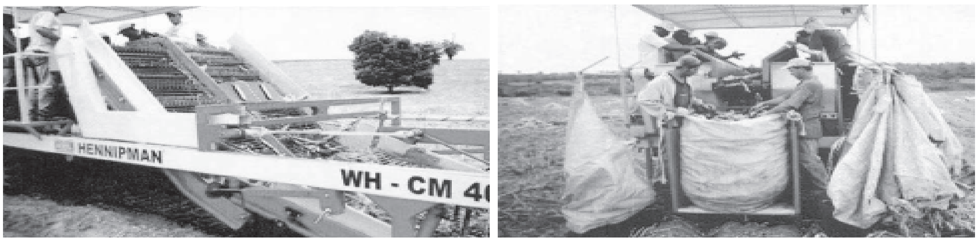

Figure 20:Model WH-CM 4000 mechanical harvester(Bernardo ospina et al.,2002).

The Leipzig Mechanical Cassava Harvester (Shadrack kwadwo *et al.*, 2011)
It was developed at the Leipzig University of Germany.The structural arrangement of the harvester consist of: a digging share rising into a conical shaped mouldboard between two legs, a frame of digging tool, a stem guiding device, a frame for stem pulling device and hydraulically operated belt pulling elements. This implement operates according to the "dig and pull" principle. It cuts and loosens the growth area of the root cluster by two vertical beams, and a share attached to the base plate. The cassava root cluster is loosened carefully, lifted to about 20 cm and delivered to the transport unit made of two belts and a set of steel/plastic press rollers. The windrowed root clusters are then detached with hand or cutlass and finally collected. The harvesting process produces a well pulverised field, thus effectively eliminating the tedious and energy intensive conventional primary tillage operation. Figure 21 shows the Leipzig mechanical harvester prototype in operation (Shadrack kwadwo *et al.*, 2011).

Figure 21:Leipzig mechanical cassava harvester prototype in operation(Shadrack kwadwo et al.,2011).

III. Conclusion

From the above analysis, it is seen that cassava harvesting plays an important role in the cassava value chain because cassava harvesters are designed almost everywhere where the crop is cultivated. Constructing such equipments increases cassava harvesting output. Also, it is seen that efficient, ergonomics and cheaper harvesters should be design and constructed and that more research should be focused on soil loosening in the root zone and lifting out the tubers with minimal damage. Additionally, it has been noticed that both in the semi-manual, semi-mechanized and fully mechanized equipments, the harvesting of leaves and stems are not done. In the design and construction of new harvesters, more research should be focused on parts that will be placed in front of the machine to cut and convey the stem and leaves to a storage bag. At the rear of the machine, the implement can equally be hitched to the equipment combined with a conveyor unit and a root-stem separating unit to store the roots in the storage tank of the machine.

ACKNOWLEDGMENTS

This work was supported by the Institut de la Francophonie pour le Development Durable (IFDD/Canada)/Projet de Deploiement des Technologies et Innovations Environementales (PDTIE) funded by the Organisation Internationale de la Francophonie (OIF), the organisation of African, Caribbean and Pacific States and European Union (EU) (FED/220/421-370).

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