International Journal of Engineering Research and Development
e-ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 11, Issue 06 (June 2015), PP.38-52

Performance Evaluation of Root Crop Harvesters

YOUNUS.A[1] and P.R.JAYAN[2]

[1]*P.G. Scholar, Kelappaji College of Agricultural engineering and Technology, Tavanur, Kerala, India*
[2]*Associate Professor, Kelappaji College of Agricultural engineering and Technology, Tavanur, Kerala, India*

Abstract:- roots and tubers are plants yielding starchy roots, tubers, rhizomes, corms and stems. They are used mainly for human food (as such or in processed form), for animal feed and for manufacturing starch, alcohol and fermented beverages including beer.Certain root crops, notably bitter cassava, contain toxic substances, particularly in the skins. As a result, certain processes must be undertaken to make the product safe for human consumption. Apart from their high water content (70-80 percent), these crops contain mainly carbohydrates (largely starches that account for 16-24 percent of their total weight) with very little protein and fat (0-2 percent each). Methods of propagating root crops vary. A live potato tuber or seed must be planted but only part of the live yam tuber and a piece of the stalk (not the root) in the case of cassava.

Both mechanical and manual harvesterscan be used for harvesting roots and tubers. In the case of sweet potato, harvesting is still done mostly by hand with the use of a garden fork to first loosen the soil and then lifting the vines with the tubers attached; the tubers are then removed from the vines and placed in harvesting crates. As with cassava, the ridge and furrow method facilitates harvesting far better than flat beds. Harvesting can also be done using mechanical harvesters but one need to pay attention to the depth of the harvesting blade, the speed of the tractor and soil conditions, in an effort to reduce the amount of physical damage to the tuber. In case of yam, harvesting is generally done by hand using spades or diggers. Yam harvesting is a labour-intensive operation that involves standing, bending, squatting, and sometimes sitting on the ground depending on the size of mound, size of tuber or depth of tuber penetration.

Still there is a need to develop sophisticated root crop harvesters. The lack of suitable mechanical harvester for root crops is due to a number of factors such as the geometry of tubers in the soil at maturity, soil conditions and the high draught requirement of machines. For the successful development of root crop harvesters, more research is recommended and should be directed towards the area of soil loosening in the root zone and lifting out the tubers with minimized damage to them.

I. INTRODUCTION

The tropical root and tuber crops are comprised of crops covering several genera. They are staple foods in many parts of the tropics, being the source of most of the daily carbohydrate intake for large populations. These carbohydrates are mostly starches found in storage organs, which may be enlarged roots, corms, rhizomes, or tubers. Many root and tuber crops are grown as traditional foods or are adapted to unique ecosystems and are of little importance to world food production. Others such as cassava (*Manihot esculenta* Crantz) and white-fleshed sweet potato (*Ipomoea batatas* L.) are known worldwide.

Several of these crops have been termed under-exploited and deserving of considerably more research input. In fact, these crops remained neglected in terms of scientific input until the establishment of the International Center for Tropical Agriculture (CIAT) in Colombia 1967, the International Institute for Tropical Agriculture (IITA) in Nigeria in 1968, and the International Potato Center (CIP) in Peru in 1971.

Although several of these crops have been grown in the U.S. during various periods over the past two centuries, with the exception of potato (*Solanumtuberosum* L.), they never gained a place of importance in the economy of this country. However, during the past 20 years several new root and tuber crops have appeared in U.S. markets. The increased demand is attributed to massive immigration of people from the tropics to the U.S., mostly from the Caribbean and S.E. Asia, where root and tuber crops are staple foods.

The lack of suitable mechanical harvester for root crops is due to a number of factors such as the geometry of tubers in the soil at maturity, soil conditions and the high draught requirement of machines. For the successful development of root crop harvesters, more research is recommended and should be directed towards the area of soil loosening in the root zone and lifting out the tubers with minimized damage to them

II. DESIGN CONSIDERATIONS

- The machine should achieve a reduction in the overall production cost
- It should increase the productivity of farmers currently harvesting manually.
- It should lead to the reduction of drudgery and tedium associated with the manual process of harvesting.
- It is to achieve decrease in root losses and damage
- The cost of the machine should be affordable by farmers and cheaper than similar imported machines.
- Materials used for the fabrication should be readily available and be such that will reduce the total power requirement.
- The machine should be adaptable to the common varieties of rootcrops and changing operational parameters.

Harvesting technique

In developing countries, most produce for internal rural and urban markets is harvested by hand. Larger commercial producers may find a degree of mechanization an advantage, but the use of sophisticated harvesting machinery will be limited for the most part to agro-industrial production of cash crops for processing or export or both. In most circumstances, harvesting by hand, if done properly, will result in less damage to produce than will machine-harvesting.

Hand-harvesting is usual where fruit or other produce is at various stages of maturity within the crop, that is, where there is need for repeated visits to harvest the crop over a period of time. Machine-harvesting is usually viable only when an entire crop is harvested at one time.

Root and tuber crops. Most staple roots and tubers that grow beneath the soil are likely to suffer mechanical injury at harvest because of digging tools, which may be wooden sticks, machetes (or cutlasses, pangas or bolos), hoes or forks.

Harvesting of these crops is easier if they are grown on raised beds or mounds, or "earthed up" as is common in potato-growing. This enables the digging tool to be pushed into the soil under the roots or tubers, which then can be levered upwards, loosening the soil and decreasing the possibility of damage to the crop

Other root crops, such as taro, carrots, turnips, radishes, etc. can be loosened from the soil in a similar manner by inserting the tool into the soil at an angle and levering the roots upwards. This method can also be used for celery if it has been earthed up or buried to blanch the stems.

Several field and vegetables crops, from tubers and roots below the surface of the soil. Those crops could be termed root crops and they may be classified according to the strategic important into major and minor root crops. The major root crops are potatoes, beets for sugar, sweet potatoes, onions and peanuts. AbouElmaged (2002). Potato and peanut consider two of the major root crops, potato is occupied in Egypt the first position according to exportation vegetables crops, yearly producing about 2.5 million ton, it is exported from about 200.000 to 250.000 ton, it is raised to 430.000 ton in (2004 / 2005) as a fresh and frozen potatoes to Arabian and European countries, according to Agricultural Researches Station-bull 813 (2005), Peanut is considered from the main summery crops, Egypt is occupied the second position at peanut production in (2003/2004) the quantitative production was about 156.000 ton, Egypt is exported from about 30-35 % to Arabian and European countries, according to Agricultural Researches Station-bull879 (2003)**.** Developing, testing and evaluation of agricultural machines are become a big problem should be studied and that is because expanding at agricultural areas, the agricultural machines are become the main factor to increase agricultural production, mostly the agricultural machines which tested in some country is not give the same results which it obtained in another country and that is maybe because local conditions (soil, fuel, oil, workers and climate conditions), and these conditions could be influence the properties of those machines, so developing, testing and evaluation those machines again is very important under local conditions, Harvesting is one of the most critical operation for potato and peanut production. Root crops are grown below the surface of the ground, therefore it requires specially designed machines to dig and separate them from the soil. The subject of vibrating diggers has drawn the attention of many researches.

Figure 1: Various landforms used for planting root crops

Manual Harvesting

This is the traditional method of harvesting cassava using a hoe, cutlass or mattock to dig round the standing stem to pull out the root before detaching the uprooted roots from the base of the plant. Figure 2 shows two different manual cassava harvesting

METHODS: one with the help of a cutlass and the other using a hoe.

Figure 2: Different manual harvesting methods (hoe and cutlass respectively)

This method is laborious especially during the dry season when soil moisture is at lower levels (IITA, 1992).According to Nweke*et al* (2002), manual harvesting requires about 22-62 man days per hectare.

Semi-manual Harvesters

The International Institute of Tropical Agriculture (IITA) in Nigeria designed and produced a manually operated cassava root tuber lifter to be used by small scale farmers for cassava growing areas in Africa (Figure 3).

Figure 3: The IITA cassava lifter in use

The National Centre for Agricultural Mechanization (NCAM) in Nigeria also developed and commercialized a semi-mechanised cassava lifter/harvester as shown in Figure 4 after Oni and Eneh (2004).

Figure 4: The NCAM cassava lifter (Source: Oni and Eneh, 2004)

The IITA cassava lifter consists of a frame to which an immovable griping jaw is attached and a lever (handle) which is hinged to the frame for lifting cassava roots. . Both implements have been tested to harvest up to 200 plants per man-hourand can be classified under semi-manual types of cassava harvesters since therequire some degree of human effort to be able to use them effectively for harvesting compared to the mechanised types (Oni and Eneh, 2004).

III. MECHANICAL HARVESTING

Mechanical harvesting of cassava involves the use of a harvesting implement integrally hitched to a tractor to uproot the cassava roots. Manual effort is however required after the uprooting has been completed to collect and detach the cassava root tubers. The following field requirements/conditions are also necessary to allowfor an optimum mechanical cassava harvesting operation:a field free from hidden obstructions (rocks, roots, stumps etc. down to 40 cm deep) of sizes that can interfere with lifting the tubers; good weed control as weeds block the lifters; Cutting down (coppicing) the cassava plant to a stalk level of about 30cm prior to harvesting (USDA and NRCS, 2003; Bobobee*et al*, 1994) to allow the tractor operator to work in a regular manner as shown in Figure 5; Ridge cultivation of cassava in rows is preferred to facilitate better orientation of stems for tractor operation during harvest as shown in Figure 6.

Figure 5: A cassava field being coppiced prior to mechanical harvesting

Figure 6: A ridged cassava field in rows

Planting cassava on ridges has several advantages, which include; higher root yield (Ennin*et al.,* 2009) due to increased number of roots per plant, effective means of reducing erosion (FAO and IFAD, 2001**)**, better weed control and field management (Ennin*et al.,* 2009) coupled with ease of mechanisation with respect to harvesting as compared to other landforms such as on flat and mounds (Ekanayake*et al.,* 1997; Ennin*et al.,* 2009). Ridges have the advantage of controlling the spread of the cassava root cluster to suitable lengths across and along the row and reasonable root tuber depth to allow for optimum mechanical harvesting (Odigboh and Moreira, 2002; Sam and Dapaah, 2009).

CASE STUDIES

Case study 1

Title: **Development of a tractor-mounted cocoyam *(Xanthosoma*spp.*)* harvester**

Done by: R. O. Akinbamowo, A. S. Ogunlowo and L. A. S. Agbetoye.

Introduction

A tractor – mounted harvester for cocoyam *(Xanthosoma*spp.*)* was designed and fabricated at the Federal University of Technology by using locally available materials. The major components of this machine are; the blade, ridge roller, variable angle bevel gear, and a cleaning web fabricated from flat leather belt slatted with steel rods which is powered from the tractor Power – take – off shaft (P.T.O).

Huge advances have been made in the mechanized harvesting of most temperate crops. This is not so fortropical crops, especially tuber crops. Most of the harvesters developed have brought about a remarkable reduction in the drudgery, labor. Requirementand production cost of such crops. Cocoyam (*Xanthosoma spp*.)is one of the popular tropical tuber crops; others are yams,cassava, ginger and sweet potato. Cocoyam constitutes amajor part of food consumed in Nigeria, and also in thetropical regions of the world. Early attempt to mechanize the harvesting of tropical root crops began with the use of the plough. The plough is a tractor or oxen drawn digger, which has a share and raising fingers as the primary components. In some cases, sifting fingers are attached at the back of the raising fingers for better separation. The potato spinner consists of a flat horizontal share that passes under the crop to loosen and lift the soil and crops. This mass is then passed into a series of rapidly rotating tines fixed on a hub which is either PTO or land wheel driven. The tines shatter the soil and separatethe crop. The elevator digger consists of a share, which raises the soil into a single continuous apron of steel rods (link conveyors) or two separate chains. The soils fall off as the crop moves to the back of the elevator that is given a shaken action by agitators and the potatoes are returned to the ground for hand picking. The manned elevator digger was developed initially as semi automatic harvester. Pickers are stationed on the extended or an additional conveyer of the machine to pick out either potatoes orrubbish to produce a clean sample (Hawkins, 1980). The complete harvester performs digging, separation, cleaning and delivery of tubers in a one pass operation of the harvester. In the present work, a harvester was developed to assist in the mechanized harvesting of cocoyam which is widely grown in Nigeria. A study of the reliability of the machine has been reported in Akinbamowo*et al*, (2009).

Materials and methods

Description of the machine

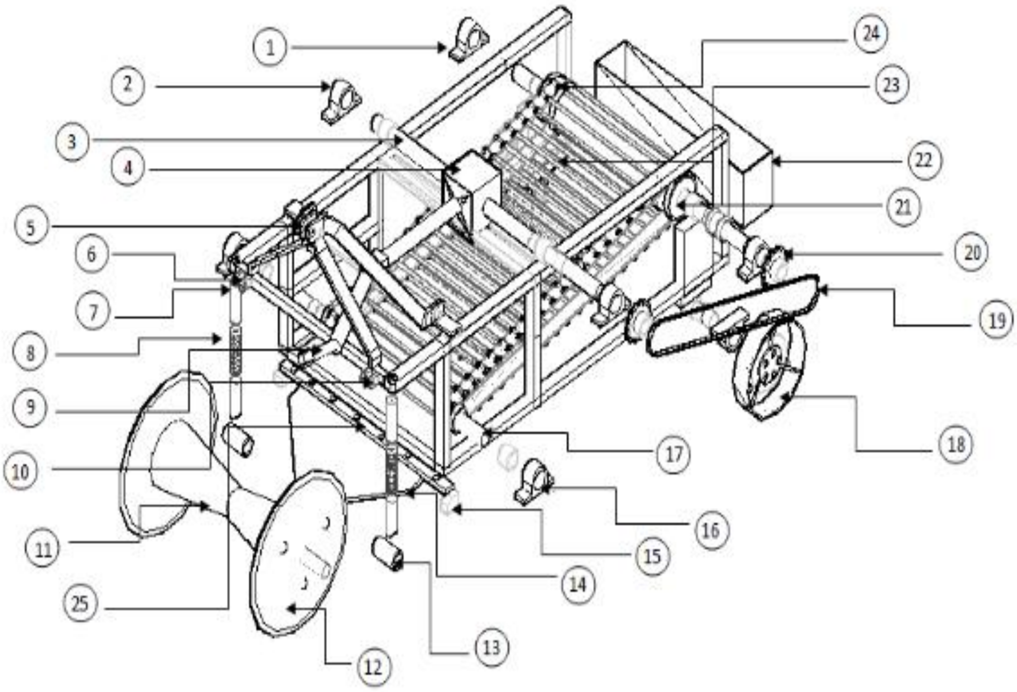

Fig 1. Exploded assembly drawing of component parts of the cocoyam harvester

This implement is designed to work as the second stage of a three stage harvesting operation for cocoyam. The first stage is to combine a topping operation with windrowing. This stage is to remove the vegetal mass of the crop including the weeds growing on the field to prevent the clogging on the elevator digger. The implement (Fig 1) is semi - mounted and attached into the tractor 3 – point linkage while the cleaning system is powered from the tractor PTO shaft. The Ridge roller (11) is the frustum of two cones inverted and joined at the smaller radius. It is made from steel tube and filled with concrete as ballast. The function of the ridge roller is to break soil clods and exert pressure on the soil to facilitate corm/cormels/soil separation. Two Disc coulters (12) are fixed at both ends of the roller to enhance a smooth cut and lifting of soil from the ridges. The digging blade (14) is almost triangular in shape and sharpened at the edge to enhance penetration is made from a rectangular steel section. At the rear part, the blade is fixed firmly to a flat bar (15) on the rectangular frame by means of rivets for easy maintainability and replacement. The blade is oriented at an angle of 15 - 25° to the horizontal so that upward soil forces will throw the cormels into the elevated digging web. The blade is designed to dig into the soil up to a maximum depth of 30 cm. Two Compression springs (7, 8) are fixed on the ridge roller so as to be able to achieve a constant depth of cut in pite of the unevenness of the field. Soil - cormel separation and cleaning is done on the Continental Web, which is made in form of a slatted conveyor with rod links (23) on flat belt (24). It is designed to accommodate a ridge of cocoyam on a 1m width on a total conveyor length of 1.2 m (center to center) so as to be able to accommodate two stands of cocoyam spaced at 60 cm apart on the ridge. The web is inclined at an angle of 10 to the horizontal to achieve a vertical rise of 0.26 m to enhance cleaning. The operating speed of the web is 2.5 m/s so that it has a

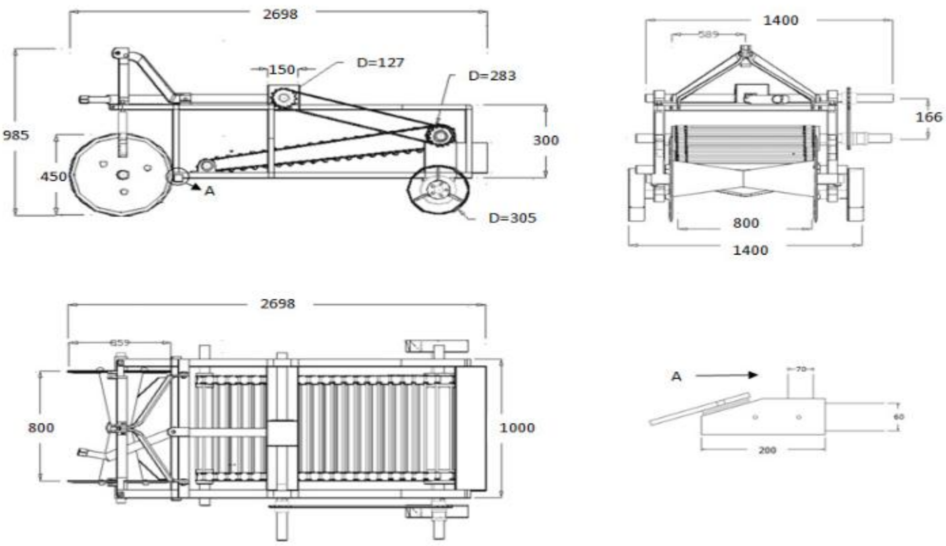

Fig 2.Orthographic drawings showing major dimensions of the machine components

capacity of 59.72 kg of soil and crop materials per second. 540 or 1000 rpm p. t. o. speed is provided to a variable angle bevel gear (4) at the top of the implement through a Universal joint (9) from the Tractor. 25 kW of power is transmitted from the variable angle bevel gears to run the continental web rollers from a Chain (19) drive positioned at the side of the digger. Two Land wheels (20) are provided on a rear axle shaft for mobility on the field and for transport. All component parts are assembled and carried on a Frame which is mainly made from a rectangular steel section 150 x 75 x 6.3 mm to provide adequate structural support for the proper functioning of the machine.

Design Analysis of the Harvester

The major components of the machine requiring design include the blade, power transmission system, cleaning web, ridge roller, rear axle, frame, hopper and the linkage system.

The blade

A flat, 80 cm wide, V – Shaped blade was chosen for the machine to achieve low draught requirements and higher digging efficiency. The soil / soil and soil/metal parameters
used are; f = 25°, C = 20 kN/m2, C = 2.6 kN / m2 (Crossley and Kilgour, 1983). Surcharge on the blade was calculated from:

$$q=\frac{W}{A}$$

Where: C = adhesion, C = cohesion and f = Angle of shearing resistance, w = cluster width and A = cross sectional area. It was found to be 0.23 kN / m3. The aspect ratio for wedge transition point (K) was found to be 0.8. According to Payne (1956) if K > 1.0, tine is narrow, therefore wide tine analysis was used for the design. The passive force P per unit width of blade is determined from the General soil mechanics equation (Godwin and Spoor, 1977).

The power transmission system

1000 or 540 rpm speed is provided to a variable angle bevel gear at the top of the implement through a universal joint from the Tractor. Power is transmitted from the variable angle bevel gears to run the continental web rollers from a chain drive positioned at the side of the digger. The transmission system consists of the following components:

1) Variable angle bevel gear that is connected to the tractor PTO shaft through the Standard universal coupling shaft and both the input and shaft rotates at 540 rpm.
2) Chain and sprocket. The bevel gear transmits rotary power through the chain and sprocket sited at the side of the machine to the cleaning web. The design of the chain and sprockets was done according to the methods outlined in PSG TECH (1982).

The cleaning web

The design uses the continental web where 68 round steel rods of 0.125 cm diameter and total mass of 42 kg are spaced 5.5 cm and fixed by rivets on a fabric band of webbing at the two ends. The web was designed as a slatted conveyor according to the methods outlined in PSG TECH (1982) and Alexandrov (1981). The operating speed of the web is 2.50 m/s so that it has a capacity of 215.46 tonnes of soil and crop materials per hour. The conveyor rollers (Head and take up rollers) are held in two shafts that were designed according to Hall *et al.* (1988) to be 48 mm and 35 mm.

The Ridge Roller

The function of the ridge roller is to crush soil crumbs and assist the separation of the soil / cormels prior to lifting. The steel casing of mass 3948.55 x 10 –3 kg and volume of 503 x 103 mm3 was ballasted up to 50% of its volume with dry sand of mass 23.55 kg. Two steel vertical cutting discs of 0.45 diameter and 3.7 kg are attached to the ridge rollers to cut along the edges of rows of ridges to minimize the lifting of roots and the remnants of vegetation.

Rear axle shaft

The rear axle shaft was designed taking into consideration the totality of the horizontal loads and vertical loads on the rear axle. The diameter of the shaft was found to be 90 mm..

Compression springs

The ridge roller is to be held by two compression springs made from carbon steel that was designed according to the procedures of the Spring Research Association (1974).

The Frame

The frame is the component that holds all other parts together for efficient functioning. For the design, it was considered to be two rectangular steel beams using Structural Hollow Section for structural stability and rigidity. The steps are outlined in AISC (1973), Roundal*etal*, (1992) and Baumister*et al*, (1978).

The three point linkage

Standard dimension of 3-point linkage for this category of implements are selected from dimensions available in ASAE standard S 217.10 (1989).

The hopper

The wooden hopper is conveniently placed under the tail end of the conveyer for collection of cormels. The total mass of wooden hopper is 22.85 kg

Testing of Harvester

Workshop tests

Following the fabrication and assembly of the various components of the prototype harvester, the harvester was coupled to the 3 point linkage and PTO shaft of a 53 hp tractor. The PTO drive was engaged at 540 rpm while the tractor is in a stationary position so that the transmission system and continental web could be observed under no load condition. This test was repeated for ten times using the 540 rpm and 1000 rpm PTO speeds before the machine was driven to the field for further tests. During each of these static tests the behaviour of the various systems; the universal coupling, the bevel gear, chain and sprocket drive and the elevator web were observed with regard to the vibration, alignment and rigidity of the various component parts and necessary adjustments weremade as required.

Field experimentation

The performance of the prototype harvester was evaluated under different operational conditions. The tests were to determine the machine output for the major indices of functional and quality performance efficiency.
Three operational parameters varied during the field tests were:
a) Forward speed (v)
b) Rake angle (α)
c) PTO speed (n).

The forward speed of 2.0, 4.0 and 6.0 km/h used during the tests were monitored on the tractor speedometer on the instrument panel.

The three levels of rake angle 15°, 20°, 25° was varied through a device attached to the frame while the two levels of web speed (n) 1000rpm, 540 rpm (n) was varied directly from the tractor PTO gear system. Other soil and crop conditions are assumed constant. The experimental layout of three replicates of a split plot design in a 3 x 2 x 3 factorial design. This gives a total of 54 sets of data for all the parameters tested. The experimental plot consists of a single replicate of the eighteen treatments.

V. RESULTS AND DISCUSSION

Harvested Cormels

Total mass of harvested cormels for the experimental plot was 1.69 tonnes. The mean values of the mass of harvested cormels per treatment are shown in Table 1. When extrapolated to estimated yield on hectare basis, the yield was found to be 39.13 tonnes per hectare. This result is higher than the average figure for tannia in Nigeria which is 12.20 tonnes / ha according to Onwueme (1982) and within the 25 – 40 tonnes/ha reported in Ekere – Okoro*et al.* (2005). Onwueme (1982) also cited crop yield of up to 37 tonnes per hectare for Pueto Rico, though crop yield generally depend on the condition and method of production. This slight increase in yield over the national average might be indicative of the improved tendering and husbandry practices given to the crops. As an experimental plot, improved handling may have led to higher yield. In addition, no sign of pest infestation that may account for yield reduction was noticed throughout the duration of the study.

Dug losses

The total mass of dug cormels collected from the soil is 285 kg (6.60 tonnes / ha). Maximum value is 14.10 kg at treatments T15. This is considerably higher than the results recorded for sugar beet in Davis (1977). This may be due to the influence of speed of operation and implement rake angle on the treatments.

Effect of rake angle on yield and dug loss

The effect of rake angle on the variables DL and HC shows that DL lowest at 20° (3.3 kg) and HC (35.2 kg) is highest at the same operational parameter. This is slightly lower than 26° - 90° recommended nose angle for yam harvesters in Itodo and Daudu, (2003). Dug loss at 25° (6.1 kg) is lower than 6.5 kg for 15° rake angle because of the greater angle of disc penetration to scoop cormels from the soil. Values of harvested cormels for the 25° rake angle is slightly lower than for 15°, although the reverse case is the commonest. Conventionally, the less acute the rake angle resulting in lower tool penetration, the lower the draft requirement that results in fewer amounts of soil and tubers lifted out of the soil (Davis and Hearns,1977). The probable reason for this trend may be misalignment of tractor outside wheels such that the tractor wheels sometimes run on ridges bordering the one harvested during the field tests.

Digging efficiency

The digging efficiency (DEFF) ranges from a maximum of 100% in T11 to 62.50 % in T3 as shown in the descriptive statistics presented in Fig. 3. Overall, mean digging efficiency for the test is 84.17 %. This slightly higher than 68.3 % obtained in Ogunlowo (1990) on cassava and 75% - 83% obtained in Bricero and Larson (1972) in Makanjuola*et al*. (1973).

Fig. 3 means digging efficiency

Effect of rake angle on digging efficiency

The maximum value of digging efficiency of 90.5% was obtained at 20° rake angle followed by 83.2% at 25° and 78.2% at 15° . Thus on account of digging efficiency alone and based on the conditions of these tests, the 20° rake angle appear to be the most suitable for complete digging out of cormels, followed by the 25° rake angle

Effects of web speed on digging efficiency

The effects of changes in web speed on the digging efficiency of the experimental plot appear to follow the trend of the result of harvesting rate. The values of treatments n1 and n2 compared rarely differ greatly among the treatments although the 540 rpm P.T.O speed (n2) appear to be marginally superior to 1000 rpm PTO speed(n1) in eight of the nine pairs of observations. The maximum values are 100% in respect of n2 and 98.1 % in n1. Similarly, minimum values are 62.5 % (n1) and 65 % (n2). Maw *et al.* (1998) found that a similar prototype harvester for sweet onions functioned most smoothly with a lifting belt speed of 100 – 125% of ground speed.

Optimum condition for use of Harvester

Based on the result of the test, a summary of the recommended operational conditions for the use of the cocoyam harvester to obtain desired values of performance are presented. The results show that, while the harvester can be operated for higher field capacity at 6 km/h, 20° rake angle with the cleaning web powered at 1000 rpm, the optimum condition of digging up most cocoyam cormels with minimum dug losses is at 4 km/h, 20° rake angle and 540 rpm web speed.

VI. CONCLUSION

A semi mounted, power – take – off (P.T.O.) driven cocoyam harvester was designed and fabricated from locally available materials. The performance of the harvester was evaluated in the laboratory and with field tests. The tests have shown that the prototype cocoyam harvester satisfied most of the general and functional requirements of a machine in this category. It is simple in design and mobile as a semi mounted implement. Power and labour use is low and parts are locally available. The mean harvesting rate at all values of forward speed of 12.02 tonnes/h give superiority over previous works on similar prototypes by Jakeway and Smith (1979); Ogunlowo 1990). Maximum total power requirement of 27 kW at 4 km/h is higher than 13.30 kW in Kang *et al.* (2001). However dug losses of 6.60 tonnes/ha are higher than recorded on similar commercial harvesters. In addition, high tuber damage, frequent breakdown and delays recorded during the field tests, among others, represented practical limitation during the field test and they prevented the full expression of treatments. However, according to Maw *et al*. (2002) such cases are common on machines during the first field test and often result in an increased understanding of the harvester prototype.

Case study 2

Title: **Design, Construction And Evaluation Of Potato Digger With Rotary Blade**

Done by: P. Azizi, N. Sakenian ,Dehkordi, R. Farhadi
(Depart. of Mechanical Engineering in Biosystems, Faculty of Agriculture, Shahrekord University, Shahrekord, Iran)

Introduction

Potato is one of the main human alimentary resources. It was the sixth alimentary product in the world after sugar cane, maze, rice and paddy, wheat and milk (FAO, 2011) and the third product in Iran after wheat and sugar cane (Ministry of agriculture, 2011) There are problems regarding potato cultivation and storage in Iran. The collection of these problems cause the cut of product yield and rise of wastage value as the mean of potato production is 24 tons/ha but this number amounts to 50 tons/ha at developed countries (Tarkesh, 2005). Head factors of low operation at harvest time and post harvest consists in disregard to finish physiologic maturity, unavailability of labor at harvest season, unsuitable methods of harvest, gradation, transport, packing and inaccessibility on proper technical storehouse (Modareserazavi, 1996). Potato wastage values during the investigation were 48% from harvest stage to consumption and wastages of harvest implements were declared 1.72% (NasreIsfahani, 2003). Mechanical harvest of potato relative to manual harvest causes 65% frugality at harvest time and 45% at harvest costs (Muhhamad*et al.*, 2003).

These statistics show importance of activities in the field of potato diggers. Misener (1985) made a potato digger and evaluated it. Mean of hurt potato tubers by set was stated 3.2%. Sharma (1986) designed a one row mounted potato digger that the hurts of harvested potatoes were reported 4% and up to skin. Saqib and Wright

(1986) studied a potato digger with oscillating blade. Generated clods with lower mean of geometric diameter were reported and volumetric density was decreased. Hyde (1986) compared performance and required power of potato digger with fixed and rotary blade. Tubers damages were about 3% at rotary state and blade cut was negligible. Kang and Halderson (1991) designed and tested a two row mounted potato digger and reported that potato bruises were increased with addition of frequency and amplitude of vibration but it had not much effect on theremained potatoes in soil. In addition,amplitude had not much effect on traction but with increase of frequency traction was diminished. Vasta*et al. (*1993) made a potato digger with oscillatory sieves and studied effects of blade shape, advance seed and sieve vibration on potato digger operation. The best results were related to V shape blade with 99.23% intact potato and minimum cut damages of 0.65% and zero bruise. Kang *et al.* (2001) tested a single-row commercial potato digger by replacing the fixed blade with a vibrating blade.

Yasin and others (2003) made a rotary potato digger atResearch Center of Agricultural Engineering in Faisalabad,Pakistan. Intact harvested, cut and bruised potatoes were 99, 4 and 1%, respectively, at field test with moisture 10.3% and speed of 6 km/h. Singh (2006) developed and tested a tractor mounted, two-row multipurpose potato digger. Maximum exposure percentage of tubers was gotten 84.5% at 4.5 km/h and damages were 1.48%. Pasaman and Zakharchuk (2012) determined the parameters of a ploughshare-rotorpotato digger.

Now there is a new potato digger and it`s different parts, mechanism simulation, performance and efficiency should be studied. The aim of this study is to probe these factors.

MATERIAL AND METHODS

Brief explanation of systemperformance

Set was designed into a semi mounted state.*Fig.1* shows various parts of set except power transmission system. The potato digger is connected by drawbar on tractors arms during work

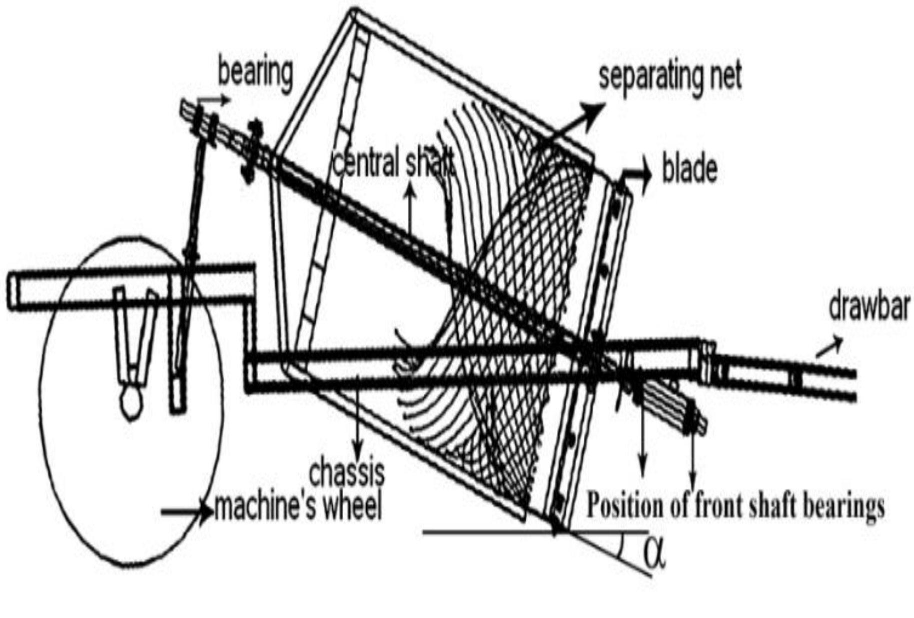

Figure 1 - Rotary potato digger

Blades

The blade is circular (*Fig. 2*) and formed from two parts of cutting and preserver. The cutting part contains crescent edges that slice soil hill. Preserver part contains steel belts with circular shape that their duty is blade keeping (the cutting blade connected to steel belts by bolt). Blade diameter (circle) D=76 cm and length L=10 cm was assigned.

Blades cut potato row and soils and potatoes arrive to separating nets. At this part, soils are severed from potatoes. Set blade has rotation about central axle. This motion is provided by tractor PTO. Because of rotational motion and it`s geometry, machine has capability to connect to rotary grader (Farhadi*et al.*, 2012).

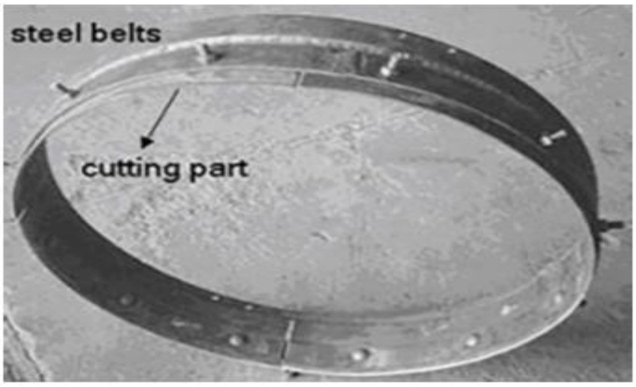

Figure 2 - Rotary potato digger blades

DESIGN, CONSTRUCTION AND EVALUATION OF POTATO DIGGER WITH ROTARY BLADE

- This normal force was calculated for the half of blade.
- Maximum torque was calculated as 0.8 kN.m.
- Maximum draft force was calculated as 1.8 kN. For summarizing, the details of calculation were not presented.

Separating net

Cut soil after blade path arrives to separating net; at this part, soil should be separated from potato tubers. For separating net, diameter of bars was selected 9 mm and distances between them 2.6 cm. Proper plan for separating is usage of net with helix shape. Separating net is formed by sweeping semi- circle on helix path (*Fig. 3*).

Figure 3- Semi- circle view and sweeping path

A model was prepared at Mechanical Desktop software (*Figs. 1 and4*) and potato motion on separating net was studied at visual Nastran software. The effects of advance speed of 0.42, 0.69 and 1.11 m/s and rotational speed of 15, 20 and 25 rpm and slopes of 10 and 15 were investigated on machine performance. It can be used as a pre-test of machine performance for main evaluation in field.

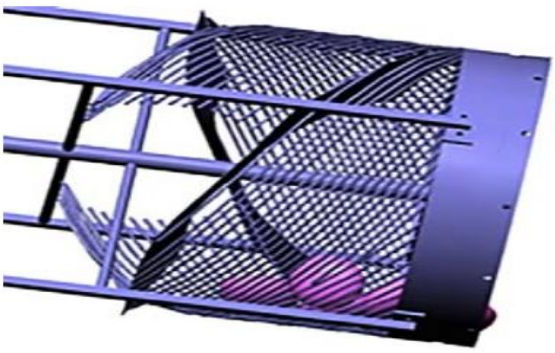

Figure 4 - Prepared model for potato motion study

Transmission system of rotational speed

Rotational motion transmission from tractor PTO to blade was performed by mechanical system. At this system according to *Fig. 5*belt and pulley, gearbox, chain and sprocket were used. The chosen system was reducer.

Figure 5 - Set connection to tractor and it`s situation at tractor behind

RESULTS AND DISCUSSION

Two problems existed in machine evaluation:

- Cut soil by blade had slow movement rearward on separating net (it caused soil and tubers accumulation at front of the blade).
- The tendency of cut soil to go beside the blade and become remote from blade input opening.

Because of the foregoing problems, losses and product injuries was high. For correction of the first problem, several various types of plates (square, rectangle and crescent) were installed into the blade and tested. Crescent plate had better operation with inner helix shape. *Figs.6 and 7*show their condition and installation situation.

A fixed plate was installed in opposite part and beside of the blade(with due attention to rotation direction) for the prevention of soil agglomeration at one side of the plate. Used plate is shown in *Fig. 7*.

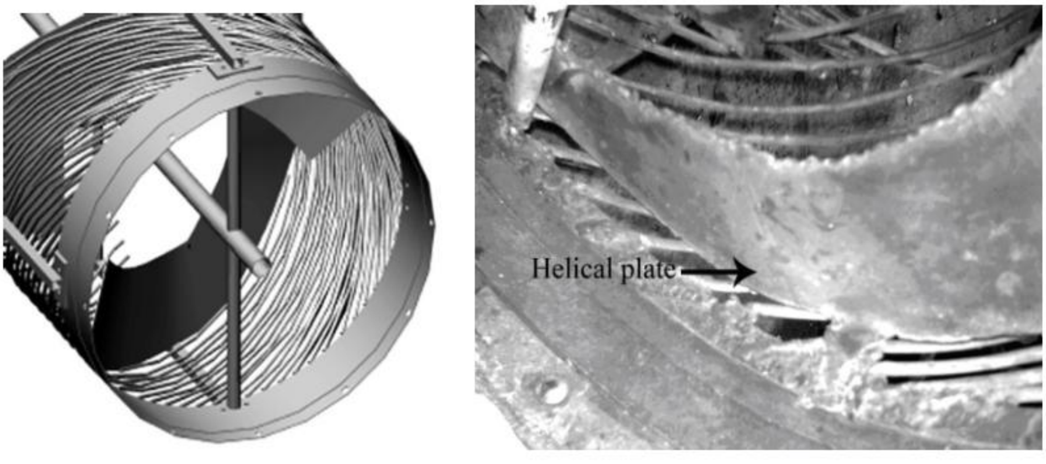

Figure 6 - Helical plates into the bale of potato digger

Soil transition into separating system and product motion rearward noticeably became favorable. The Percentage of mechanical injuries rose by the impact of potatoes on plates but their values were low. The average of damaged potatoes was got 4%. Following limitations for set operation got at filed experiments. The blade slope cannot be more than 15°. More slopes than 15° cause soil and tubers accumulation at front of the blade. Pasaman and Zakharchuk (2012) reported optimal angle of blade 12°at machine speed of 0.4 m/s. Increasing machine speed and the ploughshare angle leaded to a dangerous accumulation of soil in front of the blade.

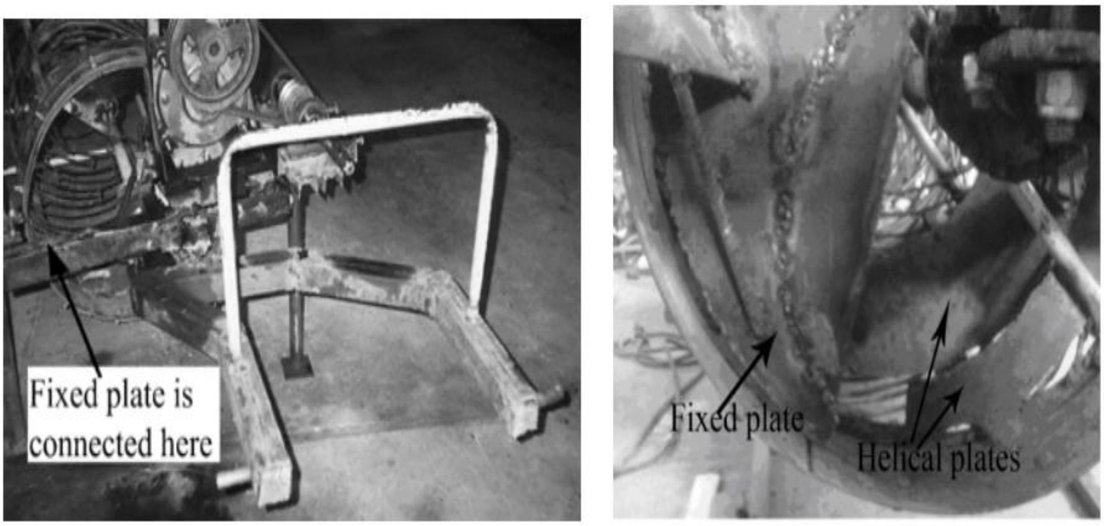

Figure 7 - Fixed plate at front and beside of the blade

The problem of penetration in soil was observed at slopes less than 10°. Advance and rotational speed cannot be considered more than 4 km/h and 25 rpm. System required power was calculated as 5.5 hp and entered soil into set as 227 ton/h.

CONCLUSIONS

Advance speed, rotational speed and blade slope is recommended asfollows according to computer simulation studies and field results:
1) Advance speed was 1.5-3 km/h;
2)Rotational speed of blade was 20-25rpm;
3) Blade slope was 10-15°

The use of hydraulic driver for blade activation is suggested because mechanical parts of power transmission system are eliminated and it helps to cut weight and increasethe machine effective capacity at different field conditions. Blade diameter should be increase to aid product transition and to reduce damages caused by blade operation.

CONCLUSION

Roots and tubers are plants yielding starchy roots, tubers, rhizomes, corms and stems. They are used mainly for human food (as such or in processed form), for animal feed and for manufacturing starch, alcohol and fermented beverages including beer.Certain root crops, notably bitter cassava, contain toxic substances, particularly in the skins. As a result, certain processes must be undertaken to make the product safe for human consumption. Apart from their high water content (70-80 percent), these crops contain mainly carbohydrates (largely starches that account for 16-24 percent of their total weight) with very little protein and fat (0-2 percent each). Methods of propagating root crops vary. A live potato tuber or seed must be planted but only part of the live yam tuber and a piece of the stalk (not the root) in the case of cassava.

Both mechanical and manual harvesterscan be used for harvesting roots and tubers. In the case of sweet potato, harvesting is still done mostly by hand with the use of a garden fork to first loosen the soil and then lifting the vines with the tubers attached; the tubers are then removed from the vines and placed in harvesting crates. As with cassava, the ridge and furrow method facilitates harvesting far better than flat beds. Harvesting can also be done using mechanical harvesters but one need to pay attention to the depth of the harvesting blade, the speed of the tractor and soil conditions, in an effort to reduce the amount of physical damage to the tuber. In case of yam, harvesting is generally done by hand using spades or diggers. Yam harvesting is a labour-intensive operation that involves standing, bending, squatting, and sometimes sitting on the ground depending on the size of mound, size of tuber or depth of tuber penetration.

Still there is a need to develop sophisticated root crop harvesters. The lack of suitable mechanical harvester for root crops is due to a number of factors such as the geometry of tubers in the soil at maturity, soil conditions and the high draught requirement of machines. For the successful development of root crop harvesters, more research is recommended and should be directed towards the area of soil loosening in the root zone and lifting out the tubers with minimized damage to them.

REFERENCES

[1]. Farhadi R., Sakenian N., Azizi P., 2012 -Design and construction of rotarypotato grader (Part I). Bulgarian Journal of Agricultural Science, 18 (2):304-314.

[2]. Hyde G.M., 1986 - Solid and perforated rotary blade performance on a potato harvester. ASAE Paper No.86-1557.

[3]. Kang W.S., J.L. Halderson J.L., 1991 – A vibratory, two-row, potato digger. Applied engineering in agriculture, 7(6): 683-687.

[4]. Muhammad Y., Mehmood A.M.,Rehman R., 2003 – Designdevelopment and performanceevaluation of rotary potato digger.AMA, 34(2): 43-46.

[5]. NasreIsfahani M., 2003 - Potato wastage in Freidan storehouse. Isfahan agricultural center research, Sapling and seed, 19 (2):191-208 (In Persian).

[6]. Pasaman B., Zakharchuk V., 2012 – The determination of the parameters of a ploughshare-rotor potato digger. Econtechmod an International Quarterly Journal (2): 43-47.

[7]. Singh S., 2006 - Design, developmentand field testing of a multipurposepotato digger. Potato Journal, 33 (34): 134-138.

[8]. Tarkesh S., 2005 - Potato operation comparison of American and European variety with use of molecular indicator of AFLP. M.Sc.

[9]. Yasin M., M.M. Ahmed, R. Rehman, 2003 - Design, Development andPerformance Evaluation of RotaryPotato Digger. AMA, 34(2): 43-46.

[10]. Agbetoye, L. A. S.,Dyson, J. and Kilgour, J. (2000). Prediction of the Lifting Forces for Cassava Harvesting.*J. agric. Engng Res*. 75: 39-48. Silsoe Research Institute.

[11]. Agbetoye, L.A.S. (2003). Engineering Challenges in Developing Indigenous Machinery for Cassava Production and Processing.*In:* Proceedings of the AnnualConference of the Nigerian Society of Engineers (Lagelu 2003), Ibadan, Nigeria, 8– 12 December 2003; pp. 80-86.

[12]. Agodzo, S.K. and Adama, I. (2003).Bulk Density, Cone Index and Water Content Relations for Some Ghanaian Soils.Kwame Nkrumah University of Science and Technology, Kumasi-Ghana. Available online:

[13]. AlHashem, H. A., Abbouda S. K., and Saeed, M. O. (2000).The Effect of Rear Wheel Track Width and Working Depth on Performance of A 2WD Tractor. Res.Bult., No. (93), Res. Cent. Coll. of Agri., King Saud Univ., pp. 5-21

[14]. Alves, A. A. C. (2002). Cassava Botany and Physiology. In: Hillocks, R. J., Thresh, J. M. and Bellotti A. (eds) Cassava: Biology, Production and Utilization. *CABI Publishing*, UK, pp. 67-83.