Effect of Disc Characteristics on the Performance of Soil Loosening System of a Cassava Harvester

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Abstract- Cassava (Manihot esculenta Crantz) provides food and income to approximately 500 million farmers, but the most significant barrier to commercial production is the harvesting of cassava, hence this research aims to investigate the impact of disc properties on the performance of a cassava harvester's soil loosening system. The materials used for the modification entail a double chain system, P30 bearing, two shafts of 40mm diameter and 2ft in length. The cassava harvester was attached to a tractor using the 3-point linkage system and 4 turns were carried out on the field in the planting season of 2020/2021 (sandy-clay soil) both on cassava planted on a ridge and flat manual clearing using TMS 419 and TME 419 cassava varieties at an angle of 30°, 45°, 60°, and 90° at depth of 10 cm, 20 cm, and 30 cm. The best results were seen in field testing utilizing the cassava harvester/soil loosening on a cassava farm land planted on a ridge. This ensures that the cassava growth and penetration are well defined with little or no damage to cassava tubers than flat manual clearing. Due to its bunchy form, TMS 419 adapted more easily to mechanized harvesting than TMC 419 cassava variety. The cassava harvester performed best on farmlands with a moisture content of 13.57%, a penetrative depth of 20cm and on dry soils with little or no weed. The best harvesting performance was carried out at an average speed of 4.2km/hr with a soil bulk density of 1.36 g/cm and a field capacity of 1.9 to 2.5 h/ha a tractor speed of 4.2 km/h, soil bulk density of 1.36 g/cm, and a field capacity of 1.9 to 2.5 h/ha. The field is left ploughed after mechanized harvesting, conserving fuel, time, and money. However, to select acceptable regions for mechanical harvesting of Cassava and to advance its acceptance, it is advised that the harvester be tested on the field in all agroecological zones and under a variety of soil moisture regimes.

Keywords: Bulk density, cone index, field capacity, harvesting efficiency, root damage.

1. Introduction

According to [1], it is estimated that by 2030 and 2050, the demand for food will hit 50% and 70% mark respectively, while the world's population is forecasted to reach 8.3 billion in 2030 and 9.3 billion in 2050. Furthermore, contributing to food availability are important factors such as population growth, per capita consumption trends, diversion to biofuels, and food wastage as mentioned by [2]. From a global standpoint, the demand for food is greater or increased in this part of the world (Africa)) due to the fact that we mostly practice subsistence farming and with our continuous geometric increase in population, it is nearly impossible for us to produce what we eat. Hence, the need for importation to augment local production. However, in Cameroon, the economy is predominantly agrarian, with agriculture and exploitation of natural resources remaining the driving forces behind the national economy. The region's deforestation is being accelerated by population increase and the associated requirement for additional production for subsistence and other economic concerns. If resources are not managed sustainably, soil depletion and reduced productivity will occur in the medium to long term [3].

Optimal development at all phases of the crop life cycle is the essence of agricultural mechanisation. This ensures maximum resource use, including direct labour volume savings, lower production costs, less time spent on each activity per unit area, and lower overall agricultural production costs. This enables more land to be planted while justifying the original gear investment [4].

Agricultural sectors in developing countries are facing harsh competition from agricultural products imported from developed countries, where they were largely produced under elaborate subsidy schemes to promote agricultural operations, as a result of the present trend toward economic globalization. Rural economies in developing nations are weak and susceptible as a result of consumers' preference for affordable imports, which makes it challenging to market domestically produced agricultural products. In these conditions, access to technology that can lower production costs and increase the productivity and competitiveness of agricultural systems is critically needed by farmers [4].

Mechanising harvesting is a significant issue for agriculture given the cassava harvest predictions in the local and international markets. However, there are just a few technological devices available right now in both domestic and international markets. It is first required to determine whether the machine is appropriate for the country's circumstances [4].

Cassava (Manihot esculenta Crantz) is the major carbohydrate food source for approximately 500 million people in underdeveloped countries in the tropics and subtropics, behind rice, sugarcane, and maize [5]. It belongs to the Euphorbiaceae family and is a perennial woody shrub with more than 5000 distinct varieties. The store roots of this plant, whose dry mass contains more than 80% starch, are where the majority of its value is found. The flat sections, particularly the leaves, are also frequently consumed as vegetables and are a good source of protein, vitamins, and vital minerals [6]. Due to the manufacturing of ethanol, bread, and glucose syrup using high-quality cassava flour, root vegetables are becoming more and more important industrially. Cassava thrives in low-fertility, acidic soils and can often grow with minimal inputs without fertiliser, unlike the majority of other crops [7]. The photoperiodic process of root growth is sped up by brief days and slowed down by days longer than 10 to 12 hours [8]. A warm, humid environment with average yearly temperatures of 25 to 29 °C and 1100 to 2000 mm of uniformly distributed annual rainfall is necessary for optimal development [9]. Low yearly precipitation is compensated for by advantageous soil characteristics such as adequate drainage, topography, and texture [9]. Even while cassava can withstand dry conditions and barren soils, ongoing production without good management can cause serious soil nutrient depletion and crop failure. However, due to demographic pressures, it is no longer justifiable to establish natural long fallow lands, which are frequently used to replenish soil fertility. As an alternative, agroecosystems are increasingly thinking about using legumes as cover crops (improved fallow), which enables shorter fallow cycles. Utilising better cultivars following a brief, but effective fallow period ought to increase production. Before bringing in new kinds, it's crucial to compare yields with those of the regional types [3].

One of the main constraints in the cassava crop value chain is harvest. Manual harvesting takes a long time, requires a lot of labour, and seriously damages the roots, especially in dry conditions [10]. Farmworkers are frequently needed during harvest to satisfy local and industrial demands. This circumstance often raises the total cost of manufacturing when the market price of cassava rises [11].

To address these issues, many robotic harvesting solutions have been created for usage in various parts of the world over time. Attempts to mechanize cassava harvesting in the past have been thwarted primarily by ineffective planting methods, field topography, and agricultural scale. This research report aimed to study the effect of disc characteristics on the performance of the soil loosening system of a cassava harvester.

Harvesting of cassava can be carried out via three major methods which include manual, semi-manual and automatic. These methods have evolved over time and with advancement in science, and research. Aside the manual methods which involves the use of farm tools such as cutlass and hoes, numerous researchers have built on this manual method which birthed the semi-automatic and automatic which are gradually taking over cassava harvesting operations in developing countries. According to [11], approximately 23-47-man h/ha is required for manual lifting of cassava with hands compared to the use of a hoe which requires between 42-51-man h/ha. He further opines that manual harvesting tools are preferable on moderately dry soils while soils with moderately higher moisture content are best for manual uprooting techniques for cassava. The Council for Scientific and Industrial Research, Crop Research Institute (CSIR-CRI) Ghana, and the National Centre for Agricultural Mechanization (NCAM) Nigeria have made significant contributions to the development of simple harvesters. [32] and [12] both focused on cassava harvesters, with [32] reporting the development of a labour-saving technology for harvesting cassava in Nigeria, and [12] assessing the response of different cassava varieties to mechanical harvesting in Ghana. Furthermore, the cassava harvester and conveyor equipment constructed by [34] considers the gathering of the cassava on the field. The results shows that the harvester has a field capacity of 0.05 ha/h, a field efficiency of 59.10%, and a loss of 3.23% due to the conveyance of the cassava root, according to the test assessment. Additionally, several researchers in Latin America and the Caribbean conducted studies on the cassava harvester model P900 to aid in the creation of semi-mechanized harvesters [33]. In Columbia, the harvester prototype's performance was assessed and tested. Similarly, the harvester features a cutting disk that allows it to reach deep into the soil in areas where hand harvesting is not feasible. Before harvesting, trim the plant's stems to a height of 20–40 cm to make the operation easier. These studies collectively highlight the potential for simple harvesters to improve efficiency and reduce labour in agricultural production.

2. Materials and Methods

2.1. The Study Location

The study area was located at the Step B demonstration plot and Research Farm, Federal University of Technology Akure, Ondo State, Nigeria (70 15°N, 50 15°E). The site was selected based on its potential for relatively higher cassava production and consumption. Akure experiences tropical rainfall, i.e., bi-modal rainfall pattern and wet semi-equatorial climate, characterized by double maxima rainfall that occurs from March to July and September to November, which is ideal for two seasons of cropping. The mean annual rainfall is 1200 mm. Temperatures range between 20°C (minimum) in August and 32°C in March (maximum). The relative humidity is fairly moderate but quite high during the rainy seasons and early mornings. The research field had a land size of 0.5 ha (being the main research site), the on-farm study sites had 0.1 ha of land planted with cassava and a 40 m2 area plot was used for the experiment. A nine (9) month old cassava of variety TMS 419 was planted on the farm study site in rows on the ridged landform.

2.1.1. Soil Chemical and Mechanical Analysis

Prior to harvesting, soil samples were gathered from specific locations on the research site before and after tillage. Before ploughing, the research site's bulk density of 10-20 cm and 20-30 cm and soil moisture content of 45°C at depths of 0-10 cm, 10-20 cm, and 20-30 cm were repeated five times. Measurement was taken after harvesting and ploughing [12]. A soil sampler with a 5 cm diameter and a hammer were used to gather soil samples for bulk density measurements. An earth borer was used to collect soil samples, and the moisture content was assessed. Soil moisture was calculated using the dry method whereby the initial moisture soil samples were dried in an oven for 24 hours at a temperature of 105°C using the gravimetric technique [13]. Additionally, before tillage and throughout harvest, composite soil samples were obtained using an auger at depths of 0–20 cm and 20–40 cm for chemical and physical analyses [12]. These soils' soil pH (1: 1H2O), organic carbon content (%), total nitrogen (%), base saturation (%), exchangeable cations (Ca, K, Mg, Na) in me/100g, Commutative A (AI + H), and accessible P and K (ppm) were all measured. Additionally, soil samples were examined to establish the texture class based on the percentages of sand, silt, and clay present.

2.2. Description of Existing Soil Loosening and Tuber Lifting Unit of Cassava Harvester

The cassava harvester's loosening and tuber lifting unit is made up of the following components: sticks and hubs, a frame, a lifting mechanism made up of smooth discs, shafts, chains, bearings, connection points, and vertical supports. The soil loosening and tuber lifting component of a cassava harvester is structurally depicted in detail in Figure 1 for reference. This piece of equipment functions as an attachment using the grab-pull method, when linked to a tractor and meets the necessary field requirements of bulk density of 1.58 g/cm3, moisture content of 1.4%, and resistance to cone index of 1.02 MPa. Using a lever, lower the machine to the desired digging depth (based on the depth of the collected cassava variety's roots). To dig up the mass of cassava roots, adjust the disc's angle before it enters the ground. The spherical disc's slope enables the roots to ascend to the top for collecting and removal.

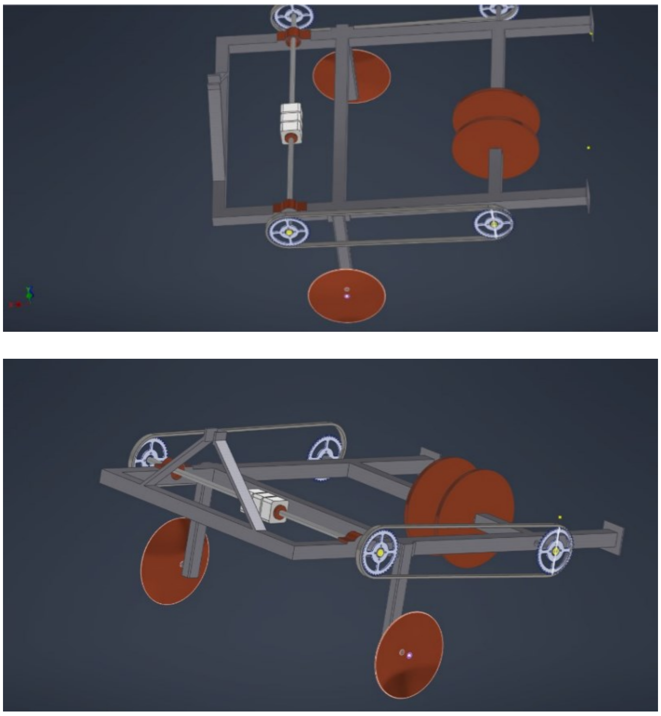

Fig. 1: Detailed view of the existing soil loosening and tuber lifting unit of the cassava harvester

2.3. Limitations and Solutions

The frame of the soil loosening and tuber lifting unit of the cassava harvester was not at the right height and the round disc was not able to throw out the soil accumulation during the harvesting thereby causing the loosening of the soil not to be effective, the round disc was therefore changed to serrated disc. The chain and bearing were not able to provide the required power to the lifting unit therefore the chain was doubled, and the bearing changed (P208).

2.4. Design Modification of Soil Loosening and Tuber Lifting Unit of The Cassava Harvester

The materials used for the modification of the machine were:

i. Pulley, chains, and bearing: The pulley was employed to provide the shaft's necessary rotation, and it was coupled with the gearbox through a chain drive. The chain drive is the mechanism that transfers the rotational motion and speed generated by the gearbox to the rotating pulley of the lifting unit. The shaft rotates more steadily and with assistance from the bearing.

ii. Double chain and sprocket: This mechanism was improvised instead of a belt drive to give more grip and power. The lifting unit was improved because the chain has no slip; it gives a good velocity ratio; high transmission efficiency and can be used for both long as well as short distances.

iii. Spring for the lifting unit: The springs are lightweight and give torsion and compression to the soil loosening and tuber lifting unit of the cassava harvester

iv. Disc for loosening the soil: The round disc loosens the soil more thoroughly, pulverizes the soil and crop remains, and also can be used in rocky terrains. The disc was serrated to solve the issue of soil clogging on the surface of the disc during operation; the gaps on the serrated disc were 6 each 10cm in diameter.

2.5. Redesign Consideration

Design considerations for the modification of the soil loosening and tuber lifting unit of the cassava harvester include the power requirement of the machine, speed of the tractor, disc configuration, safety to man and its environment by avoiding sharp edges, and the type of soil.

2.6. Design Analysis

The major components of the machine requiring design include the blade, power transmission system, frame, and linkage system. Figure 2 and 3 shows the CAD design for the soil loosening and tuber lifting unit of the cassava harvester for the existing machine.

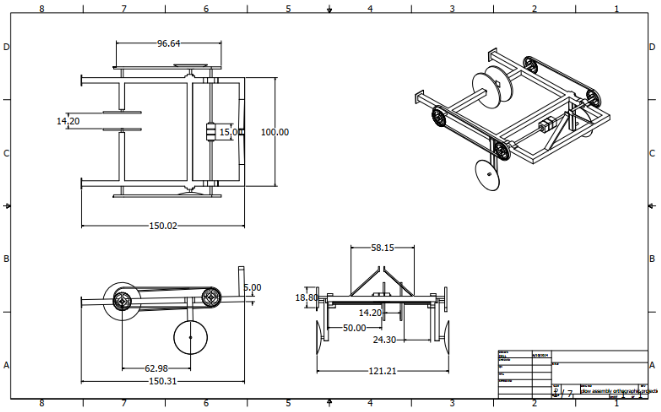

Fig. 2: Isometric and orthographic view of the cassava harvester's modified soil loosening and tuber lifting unit.

v. The blade: A serrated disc of 80 cm wide, circular was chosen for the machine to achieve low draught requirement and higher loosening efficiency.

vi. Maximum shearing stress at failure was calculated using equation 1 as recommended by [14] while the soil and metal parameters are $\phi = 250$, $\sigma n = 20$ kPa, $Cn = 2.6$ kPa

vii.

viii. $\tau max = Cc + \sigma n \tan \Phi$ (1)

ix. where, τmax is maximum shearing stress at failure (kPa), Cc is soil cohesion (kPa), σn is normal stress (kPa), and Φ is angle of internal friction of soil (deg.)

x. The blade's surcharge was computed and determined to be 0.23kPa. The wedge transition point (K) has an aspect ratio of 0.8. Because [15] states that if $K > 1.0$, the tine is narrow, broad tine analysis was employed for this design. The general soil mechanics equation was used to calculate the passive force P per unit width of the blade [16].

xi. The power transmission system: Through a universal joint, the tractor transmits a speed of 1,000 (1,000) or 540 rpm to a variable gearbox on top of the implement. A chain drive on the side of the shield served as the means by which power was transferred from the gearbox to drive the lifting unit. Components of the gearbox system include the chain, sprocket, and gear. The bevel gear delivers rotary power to the lifting unit via the chain and sprocket on the machine's side. The chain and sprockets were designed using the techniques specified in [17].

xii. The Frame: All other pieces must be held together by the frame in order for them to work effectively. In order to maximise structural stability and stiffness, the design took into account the two rectangular steel beams with structural hollow sections [18], [19].

xiii. The three-point linkage: The standard 3-point linkage dimensions for this class of tools were chosen from those available in [20].

2.7. Experimental Design

A preliminary test of an existing cassava harvester's soil loosening/tuber lifting unit was conducted to measure harvesting efficiency and to identify flaws and limitations. The following summary design changes were made chain, bearing, cassava grasping unit height, spring, shaft additions, and serrated disc. The following parameters are included in the performance evaluation: harvester working depth, harvesting efficiency, field capacity, and disc angle. The cassava harvester and soil loosening machine after fabrication was attached to the tractor (New Holland) for evaluation of the modified implement. A cone penetrometer was first used to determine the cone index before and after loosening. The depth was varied at 10 cm, 20 cm, and 30 cm at a constant speed of 0.67 m/s, and different disc angles of 300, 450, 600, and 900 were considered. Tests were conducted in four replicates for all the depths, speed, and disc angles respectively to obtain the percentage of crop harvested, percentage of the crop left unharvested, percentage of crop damaged, width of soil loosed, and depth of soil loosed. The parameters were obtained using the meter rule to measure the width of soil loosed, while the depth was measured using a cone penetrometer (Rinik C4 11).

2.8. Estimated Cost of Bought out Components

The cost of the bought-out components is shown in Table 1.

Table 1: The cost of bought-out components

S/N	Components	Functions	Qty	Cost ($)
1	Roller bearing	To provide free turning motion	4	20
2	Bolts and nuts	For securing components parts	8	4
3	Shafts	For supporting other components	2	40
4	Double chain	To transmit power	2	16
	Total			80

2.9. Statistical Analysis

The data obtained were analysed using a graphical method and statistical inherent analysis to get the significant effect of the factors with the response using ANOVA in Microsoft Excel to test whether there is a significant difference between the means of the soil disturbances collected in the field when the soil loosening and tuber lifting unit of the cassava harvester coupled to the tractor operates at a constant speed for various spacing and disc depth.

3. Results and Discussion

3.1. Soil Properties of The Study Area

Table 2 shows the result of the soil properties of the study area. The result shows that loam soil gave the highest percentage of 64.47%, followed by clay soil which gave 23.20%, while sand soil gave the lowest percentage of 13.19%. The pH, organic carbon, organic matter, nitrogen, phosphorus, potassium, sodium, calcium and magnesium gave 5.5, 0.92 mol/kg, 1.58 mol/kg, 0.35 mol/kg, 12.06 mol/kg, 0.42 mol/kg, 0.52 mol/kg, 1.30 mol/kg and 1.01 mol/kg respectively.

Table 2: Soil properties of the study area

Soil Properties	Value
Loam %	64.67
Clay %	23.20
Sand %	13.19
pH	5.50
Organic Carbon (mol/kg)	0.92
Organic Matter (mol/kg)	1.58
N^{3}- (mol/kg)	0.35
P^{3}- (mol/kg)	12.06
K+ (mol/kg)	0.42
Na+ (mol/kg)	0.52
Ca^{2}+ (mol/kg)	1.30
Mg^{2}+ (mol/kg)	1.01

3.2. Effect of Disc Angle on Harvesting Efficiency Of The Machine At Various Depths

Figure 3 depicts the impact of disc angle on the machine's harvesting efficiency at 10 cm, 20 cm, and 30 cm depths. This indicates that when the disc angle increases, the harvesting efficiency decreases. The best harvesting efficiency was 83.5 percent and 90.2 percent at 30 cm depth and a disc angle of 30^0, respectively, while harvesting efficiency was 90.2 percent and 87.3 percent at 10 cm and 20 cm. With a harvesting efficiency of 51.6 percent, the harvesting efficiency at 90^0- disc angle was the lowest. Table 3 shows the effect of disc angle on harvesting efficiency since the p-value is less than 0.05, it means the disc angle had a substantial level of interaction with harvesting efficiency, with a p-value of 5.42E-10 ($p<0.05$).

Equation 2 presents the relationship between dependent variable (harvesting efficiency) and the independent variable (the disc angle). The harvesting efficiency increases as the disc angle decreases. The result shows that there is an optimum disc angle which is 300 that is required for the soil loosening of a cassava harvester to perform effectively, thus disc angle greater than 300 will bring about decrease in harvesting efficiency of the cassava harvester.

$$f(x)=0.25x^2-6.85x+98.44 \quad (R^2=0.98) \qquad (2)$$

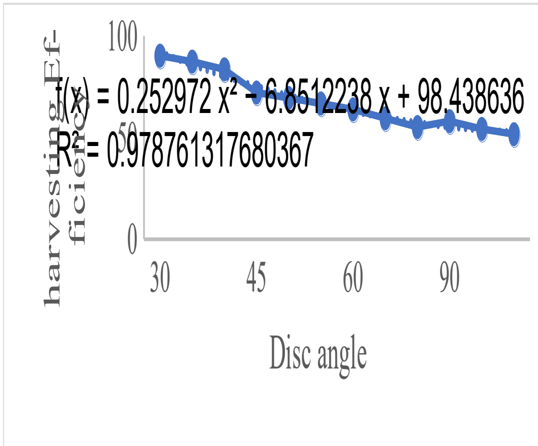

Fig. 3: Harvesting efficiency against disc angle at 30^0, 60^0 and 90^0

Table 3: ANOVA analysis of the effect of disc angle on harvesting efficiency

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	13599.32	1	13599.32	109.13	5.42E-10	4.30095
Within Groups	2741.61	22	124.62			
Total	16340.93	23				

The model of fit can be found in Figure 4, along with the R2 values. While R2 values for 10 cm depth compared to others and there was a significant effect, as the disc angle decreases, the harvesting efficiency increases and this is due to the planting of cassava in ridges, the highest R2 value of 0.9361 was observed at 20 cm. This is due to the penetration into the soil to accommodate the area of the tuber, while R2 values for 10 cm depth compared to others and there was a significant effect, as the disc angle decreases. According to [21], cultivating cassava in beds offers the possibility for further mechanisation and is more effective at collecting cassava tubers. It also provides better and simpler field management. lessen strenuous labour and boost cassava output. This may be because it is simpler to spray dirt onto the ridge and set the cutting angle of the disc than it is to do it on level ground. How readily the ridges may be crushed may also be a consideration. In other words, on ridged terrain as opposed to level land, the reaper blade penetrates deeper into the ridges and breaks the ground more readily.

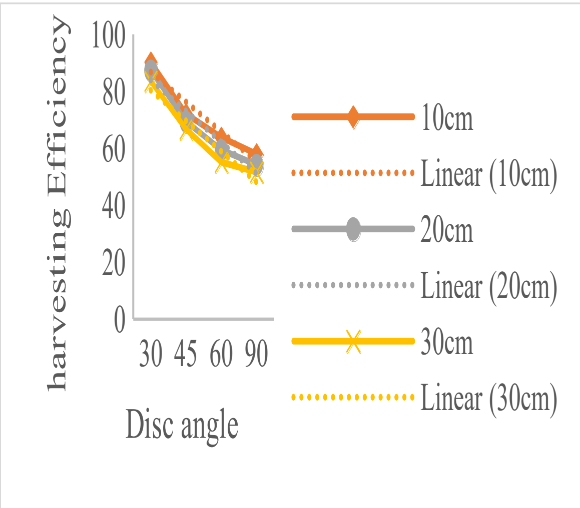

Fig. 4: Effect of disc angle on harvesting efficiency at different depths

3.3. Effect of Disc Angle On Root Damage To Cassava Tubers At Various Depths

The relationship between disc angle and root damage at various depths is depicted in Figure 5. The root damage was reduced as the disc angle was increased. This means that the loosening of the soil is influenced by the orientation of the root tuber created by its growth, which means that every contact made with the tuber causes damage, and as the angle increases, the wider the area covered by the device becomes, resulting in little or no contact, resulting in little or no damage to the tuber. Root damage was highest at 10cm deep, with a value of 58 percent, followed by 44 percent and 31 percent at 20cm and 30cm depths, respectively. The least root damage along the row was 22 percent at an angle of 900 at a depth of 10 cm, while the least was 13 percent and 9 percent at an angle of 900 at 20 cm and 30 cm depths, respectively. As indicated in Table 3, the disc angle had a significant effect on root damage ($p<0.05$). A model of fit can be obtained as illustrated in Figure 5 with R2 values. The maximum R2 was found at a depth of 20 cm with a value of 0.9832, while the lowest R2 was found at a depth of 30 cm with a value of 0.2613. The values at depth 10 cm and 20 cm were 0.8445 and 0.9832 respectively, which accords with reports by [22] and [23] concerning the benefit of ridges in regulating cassava root spread to appropriate lengths both across and along rows. This could be attributed to its roots being bunchier than other cassava cultivars and having a shorter root spread both along and across the row. The Leipzig mechanical harvester was found to have 10.7% tuber damage by [24], whereas another mechanical harvester was found to have 23.3 percent tuber damage by [25].

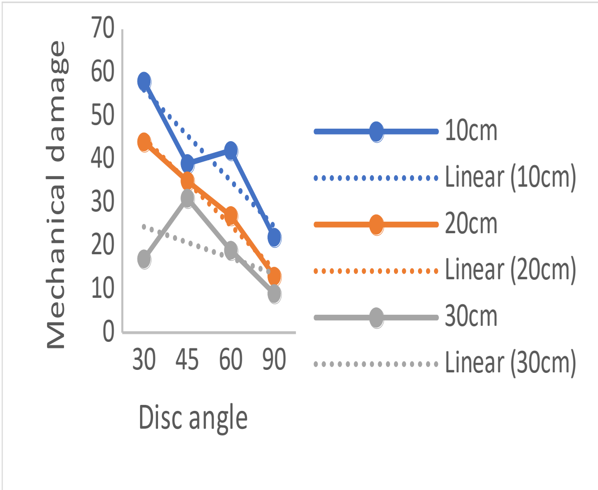

Fig. 5: Effect of disc angle on mechanical damage

Table 3: ANOVA analysis of disc angle against mechanical damage

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2120.02	1	2120.02	6.92	0.02	4.60
Within Groups	4291.42	14	306.53			
Total	6411.44	15				

3.4. Effect of Disc Angle On-Field Capacity At Various Depths

Figure 6 depicts the impact of disc angle on the soil loosening/lifting cassava harvester's field capacity. For the ridge landform, harvesting with the machine resulted in field capacity ranging from 0.028 ha/h to 0.08 ha/h, with the least capacity seen at 600 disc angle. Table 4 shows the ANOVA which reveal the interaction between disc angle and field capacity at different depths, the result obtained also supports the former result presented. The reason may be related to the extremely low soil moisture levels seen during harvest. This is consistent with the findings of [13], [26], [27] who posit that slopes are more amenable to harvesting by mechanisation than level land. This could be due to the fact that the flat landform required more effort to pulverise the soil and also difficult to determine the depth of cut than the hill did due to the expanse of the cassava tubers beneath the earth's surface. The maximum field capacity was 0.08 h/ha at 10cm depth, while the lowest was 0.028 h/ha at 30 cm depth. The model was fitted as shown in Figure 6, with an R2 value of 0.9459 at 10 cm depth, compared to 0.9389 and 0.861 at 20 cm and 30 cm depths, respectively.

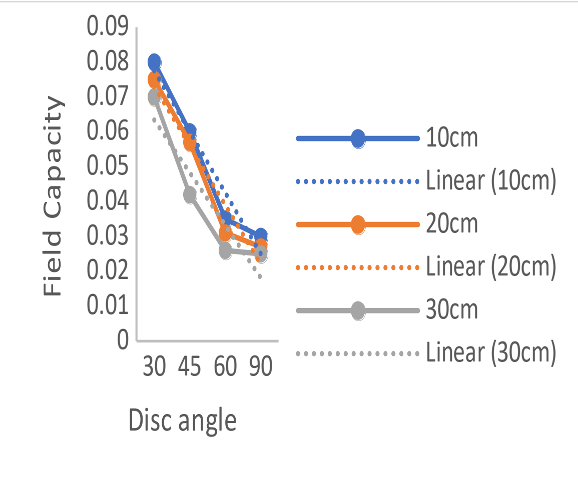

Fig. 6: Effect of disc angle on-field capacity at different depth

Table 4: ANOVA analysis on effect of disc angle on field capacity at different depth

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	9476.50	1	9476.50	67.39	1.01E-06	4.60
Within Groups	1968.76	14	140.63			
Total	11445.25	15				

3.5. Effect of Disc Angle On Cone Index At Various Depths

Figure 7 presents that the cone index (CI) measurements showed linearity with the disc angle of the double-disc soil loosening device. The three depths recorded show a significant result between the CI at different disc angles of the soil loosening device. High cone index CI values were recorded at a disc angle of 900 and depth of 30 cm while the low cone index CI was recorded at a disc angle of 300 and depth of 10 cm. It can be inferred that the higher the disc angle, the higher the cone index which may be due to the increase in the area of soil disturbance as the angle widens or increases. High cone index values of 600 MPa, 1.4 MPa and 2.5 MPa were recorded at depth 30 cm, 20 cm and 10 cm depth before the soil loosening device was used. After soil loosening, the cone index was reduced to as low as 250MPa. 700 Mpa and 1800 Mpa respectively, which falls within the range of penetration resistance suitable for tuber crops such as cassava and potato. These were in agreement with the previous findings of [28], who observed an increase in cone index with depth in three different tillage treatments (no-till, minimum tillage, and secondary tillage), [29], [30] reported that greater penetration resistance was found under no-tillage, especially the upper 10cm. [31] plotted penetration force against depth and their results showed an increase in cone index with depth. The resultant effect of the double-disc soil loosening device reduced the penetration as observed up to a soil depth of 30 cm. Table 5 presents ANOVA analysis on effect of disc angle on cone index at different depth. The results shows that there was significant difference among the cone indexes at different depth due to the effect of the disc angle. [35] reported that for cassava (Manihot esculenta, Crantz) to be harvested efficiently, it is essential to first loosen the soil in the root zone before lifting the tubers out of the ground. This will reduce the lifting force and prevent tuber damage

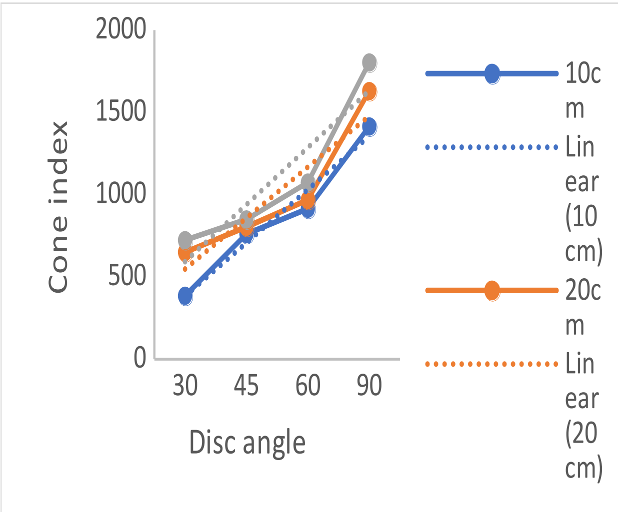

Fig. 7: Effect of disc angle on cone index at different depth

Table 5: ANOVA analysis on effect of disc angle on cone index at different depth

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2659267	1	2659267	19.36	0.00	4.60
Within Groups	1923295	14	137378.2			
Total	4582562	15				

4. Conclusions

A double-disc soil loosening device was designed and fabricated for use as cassava harvesting equipment. The materials for the parts were sourced locally while their fabrication did not go beyond common machine shop and fabrication workshop capability. The result of the performance evaluation of the developed double-disc soil loosening in cassava harvesting showed that with an appropriate speed of 4.2km/hr, 20 mm depth of operation, field capacity of 1.9 to 2.5 h/ha, 13.57% moisture content (db) of the soil, bulk density of 1.36g/cm in a sandy-loam soil, the device worked effectively well with high efficiency for cassava harvester. The tilt angle of 300 used at a depth of 30cm will conveniently loosen the soil better but without many areas to cover while a tilt angle of 900 can be used to cover many grounds but with a depth of 10. Any of the conditions stated will work effectively as most of the cassava tuber was left on the top of the ridge with little damage from the disc operation. A range of studies have explored the development and performance of cassava harvesting and processing technologies. [32] developed a labour-saving cassava harvester, reporting a digging efficiency of 58.9% and a field capacity of 0.11 ha/hr. Also, [34] developed a cassava harvester by digging with conveyor to move the cassava intoa trailer. The Digging and Preparing Unit was found to be working at an angle of 200 degrees which is similar to the finding of this study at 300 for efficient loosening and harvesting of the cassava. The Conveyor Unit found to be scooping with less than 1.5 m/s of speed. The field performance test were showed that: filed capacity, field efficiency, and conveying losses were, 0.05 ha/hr., 59.10%, and 3.23% respectively without any losses caused by digging and preparing process. [12] and [11] both focused on mechanical and manual cassava harvesting, with the former finding that ridged landforms and the "Nkabom" variety were most suitable for mechanical harvesting, and the latter evaluating an improved manual harvesting tool.

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