Development of a Tractor Mounted Groundnut Harvester

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Abstract: A tractor mounted groundnut harvester was designed and constructed to harvest groundnuts on a flat field. Performance evaluation of the harvester was carried out to determine the effect of forward speed at a constant depth on the machine performance. The forward speeds, 1.6 km/hr, 2.4 km/hr and 3.2 km/hr were investigated at a constant depth of 10cm with three (3) replications in a Randomized Complete Block Design (RCBD). The Analysis of Variance (ANOVA) was carried at $P \leq 0.05$ significant level. When significant difference was observed, treatment means were separated using the F-LSD. The results obtained from the Analysis of Variance (ANOVA) shows that there was significant difference in the weight of harvested groundnuts and there was no significant difference in the weight of damaged and un-uprooted groundnuts. From the means separation, there was significant difference in the weight of harvested groundnuts between the speeds of 1.6 km/hr and 2.4 km/hr, 1.6 km/hr and 3.2 km/hr but there was no significant difference in the weight of harvested groundnuts between the speeds of 2.4 km/hr and 3.2 km/hr. From the results it was observed that the weight (kg) of groundnuts harvested decreased with increasing operation speed while both the weight (kg) of damaged groundnuts and the weight of un-uprooted groundnuts increased with increasing operation speed. It was also observed that the harvesting efficiency decreased with increasing speed of operation while both the percentage of damaged groundnuts and the percentage of un-harvested groundnuts increased with increasing speed of operation. This shows that the effective speed for the harvester is 1.6 km/hr.

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1. Introduction

Groundnuts also called peanuts or earthnuts *(Arachis Hypogaea* of the *Leguminocae* family) is grown as an oil seed and grain legume crop. Groundnut is also one of the most important and economical oilseeds in tropical and sub-tropical regions of the world. It is mostly grown due to its oil, protein and carbohydrates (Abdzad and Noorhosseini, 2010). Groundnut has several uses as whole seeds or is processed to make peanut butter, oil, and other products. The groundnut seed contains 25 to 32% protein and 42 to 52% oil (Putnam *et al*., 2013). Groundnut is currently grown on over 22.2 million hectares worldwide with a total production of over 35 million tons (Rao *et al*., 2013). Groundnut is harvested when most of the leaves turned yellow and pods became hard (Arakama, 2009). It usually requires a minimum of 100 to 150 days from planting to maturity depending on the variety (Putnam *et al*., 2013).

Groundnuts are eaten raw, roasted or pounded for sauce and cooking oil. It is also used in the manufacture of margarine and inferior quality oil for soap, and as a lubricant. High quality oil is used in the pharmaceutical industry. The cake after expression of the oil is a high- protein livestock feed. The best quality cake may be ground into flour for human consumption, while best quality nuts are used in making confectionary and are an important source of protein in many countries. The green haulms make excellent fodder and hay in general.

Harvesting of groundnut is most important and labour intensive. The digging of the soil is required for harvesting operation because groundnut produces its fruit below ground. The pods (fruits) are usually located up to a depth of 7-10 cm that is referred to as pod zone (Ademiluyi *et al*., 2011). Harvesting takes 100 men work/day for one hectare of land. Labour for groundnut harvesting is scare, expensive and tedious as the soil is to be shifted and each groundnut picked by hand. The present practice of harvesting groundnut normally consumes much time and labour, such that farmers that have 50 hectares of land cannot harvest their groundnut as fast as possible before October. While after October, groundnut not harvested begins to germinate and the leaves also die (Padmanathan *et al* 2006).

The subterranean nature of fruiting in groundnut and its indeterminate growth habit makes it difficult to determine the time of maximum maturity of pods (Seutra *et al*., 2014). Immature peanuts have poor flavor, are more difficult to cure, and often deteriorate faster in storage and are more likely to be affected by undesirable mold growth. Also, the more mature peanut pods can result in the loss through weakened pegs, decay organism activity and digging losses that cause due to adverse weather (Jordan *et al*., 2008). Therefore, early harvesting decrease the yield and quality while late harvesting may increase pods loss. Heavy digging loss is unavoidable when the pegs are weakened due to over maturity or premature defoliation caused by disease, or when the soil is very dry and hard (Roberson, 2002). Therefore, the adequate labors or machinery must be existence on the harvesting time. Beside during peanut harvesting in Nigeria, non-availability of labor on time, delayed harvesting caused in heavy loss to the farmer. One of the solutions is to mechanize groundnut harvesting operation. It also reduces the cost of groundnut harvesting and increase profit and productivity.

The soil moisture content and forward speed have much significant effect on machine performance. Ademiluyi *et al*. (2011) evaluated the performance of a developed tractor drawn groundnut digger/shaker in three levels of soil moisture content. From the obtained results, it was cleared the soil moisture content is a major factor influencing the digging efficiency of the implement and the soil moisture content between 12% - 15% will be preferable to work. Timeliness of operation is very vital in groundnut production and groundnut harvesting using the digger/shaker will produce a very low value of digging efficiency, when groundnut crops are not harvested during their right time of harvest. Also, Results showed that digging efficiency and percentage of total pod loss are inversely related to one another signifying that at lower digging efficiency there would be high percentage of total pod loss and vice versa.

Ibrahim *et al*. (2008) developed a multipurpose digger for harvesting root crops and evaluated it for peanut in three levels (1.4, 1.8 and 2.3 km/h from forward speeds) and different tilt angles in three levels (12, 18 and 24 deg.), once using the vibrating movement and once without using it. The results of this study revealed developed digger can be operated efficiently under harvesting depth of 15 cm, forward speed of 2.3 km/h and tilt angle of 12 deg. with using vibrating movement.

In another study, Padmanathan *et al*. (2006) designed a tractor operated groundnut combine harvester and evaluated it at different operating conditions. The results of their work revealed maximum harvesting efficiency of 92.3 percent, threshing efficiency of 82.30 percent, cleaning efficiency 72.30 percent and minimum percentage of broken pods of 4.43 was observed at 1 m width of harvester and at 1.5 km/h forward speed of operation. Also, the operation of groundnut combine harvester resulted in 39.00 and 96.00 percent saving in cost and time respectively, when compared to the conventional method of manual digging and stripping. The objective of this study is to develop an affordable groundnut harvester that is suitable to the local soil and environmental conditions.

2. Materials and Methods

2.1 Description of the groundnut harvester

The tractor mounted groundnut harvester is made up of the frame, soil loosening tool, tool (blade), pick up conveying mechanism, PTO drive mechanism, chain and sprockets, bearings, land wheel and gathering windrower. Figure 1 shows a pictorial drawing of the harvester and Figure 2 is a photograph of the harvester.

2.2 Design analysis

2.2.1 Pull prediction

The Hettiarachi and Reece (1974) model was adapted for evaluating the pull for the measured soil and blade values. Using the mean data of soil properties as presented, angle of shearing resistance, $\phi = 16.4^0$; Cohesion, $C = 27KNm^{-2}$; bulk density, $Y = 1{,}458Kgm^{-3}$; the soil – metal values (angle of soil-metal friction, δ and adhesion, Ca) were calculated. The angle of soil-metal friction δ was assumed as 66 percent of angle of shearing resistance, ϕ (Kepner *et al.,* 1982).

$\delta = 0.66 \times 16.4^0 = 10.8^0$

$Ca = C \tan\delta \cot\phi$

$= 27 \tan 10.8^0 \cot 16.4^0\ KNm^{-2} = 17.5KNm^{-2}$

The equivalent blade and predicted blade cutting depth was determined in order to use the Hettiaratchi and Reece (1974) model.

2.2.2 Calculated draft and power

Using the value of unit draft according to soil type as provided by Bosoi *et al*. (1988), the minimum and maximum draft expected in the field was determined. It was assumed that the harvester will work in the soil types ranging from light to very heavy soil Bosoi *et al*. (1988) defined the draft as:

$$Draft = Kab \quad (1)$$

Where; K=Specific soil resistance $Kgcm^{-2}$ unit draft, Nm^{-2}; a=Maximum operating blade depth, mm; b=Width of blade, cm.

Draft for light soil type=1.962x15x15=441.45N

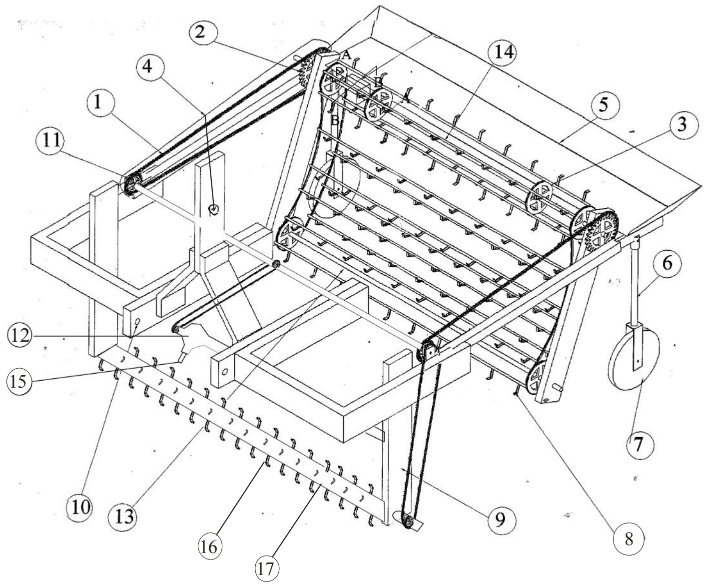
Draft for heavy soil type=14.71x15x15 =3309.75N

The draft of the groundnut harvester ranges from 0.441KN to 3.31KN and using the maximum value of the chosen tractor operating speed of $3.2Kmh^{-1}$ ($0.889m5^{-1}$) the power requirement of the harvester was determined.

$$Power = Draft \times Speed \quad (2)$$

For light soil = 0.39116 KW

For heavy soil = 2.94259KW



Part No.	Item	Material	Dimension	Qty
17.	Roller Shaft	Mild steel	90mm DIA	1
16.	Loosening Tool	Mild steel	100mm LONG	64
15.	PTO Shaft	Mild steel	6 Splines	1
14.	Chain Sprocket	Mild steel	1800mm DIA	1
13.	Picker Shaft	Mild steel	1200mm DIA	1
12.	Bevel (Pinion) gear	Mild steel	Standard	1
11.	Driven Sprocket	Mild steel	20mm LONG	2
10.	Linkage Point	Mild steel	Standard	3
9.	Frame	Mild steel	90x90x1.5DIA	1
8.	Picker	Mild steel	180mm LONG	192
7.	Land Wheel	Mild steel	150mm DIA	2
6.	Land Wheel Shaft	Mild steel	10mm thick 30.1mm	2
5.	Windrower	Mild steel	10mm Thick	2
4.	Pin hole (coupling point)	Mild steel	20mm hole DIA	3
3.	Picker wheel	Mild steel	100mm DIA	2
2.	Driver Sprocket	Mild steel	10mm DIA	2
1.	Chain	Mild steel	600mm LONG	2

Designed by:	Saakuma Vincent (M.ENG/3115/09)
Supervised by:	1. Dr. Umogbai, V.I. 2. Prof. Obetta S.E.
Title:	Development of a Tractor Mounted Groundnut Harvester
School:	University of Agriculture, Makurdi
College:	Engineering
Department:	Agric and Environmental Engineering
Scale:	1:10

Figure 1: Pictorial drawing of tractor mounted groundnut harvester

Figure 2: The developed tractor mounted groundnut harvester

2.2.3 Depth control mechanism

Maintaining the correct digging and uniform depth on level or flat land along the length of the groundnut farm is vital and requires a share depth control mechanism. The depth of harvester is regulated by adjusting the position of the wheel hydraulically from the top link of the tractor or through the pins position provided at the wheel shaft.

The depth wheel was designed as a driving wheel, while working along the field. The diameter of the depth wheel, D was determined by the required depth of operation from the formula.

$D = 2a_{max} + D_s + 2M_o$ (Bosoi *et al* 1988) 3

Where; D = Diameter of the wheel

a_{max} = max operating blade depth

D_s = Diameter of support of land wheel

M_o = Clearance between the soil and axle taken as 50-70 mm (Bosoi *et al* 1988)

Considering the maximum depth of cut, up to 15 cm of the harvesting blade and the maximum operating depth of land wheel to be 10 cm the wheel diameter was calculated as follows:

D = 2 (10) + 5 + 2 (7) cm = 39 cm

The diameter of the wheel (D) was checked for its adequacy by the relationship between the basic dimensions of the depth wheel, the load on it and draft has defined by Bosoi *et al* formula (1988). A wheel diameter of 15 cm was selected for the groundnut harvesting machine, since the calculated value was 39 cm less than that of 47.38 cm derived from Bosoi *et al*. (1988). This size of the depth wheel was also available in the local market and the land wheel does not have tyres.

2.3 Experimental design

The performance of the groundnut harvester was evaluated to determine the effect of harvester on damaged and un-uprooted groundnut crops. Also harvesting efficiency of the harvester was determined. The experimental design for the statistical analysis follows a one-treatment effect, operation speed (1.6 km/hr, 2.4 km/hr and 3.2 km/hr) in a Randomized Complete Block Design (RCBD) with three replications per experimental unit.

2.4 Performance evaluation

The groundnut harvester was tested on a flat field where groundnut was planted, three different speeds (1.6, 2.4 and 3.2 km/hr) and a constant operation depth of 10 cm were used on a 20 m field length. Each speed was repeated three times. At each speed, the quantity of groundnut harvested, quantity of groundnut damaged and quantity of un-harvested groundnut was measured. The harvesting efficiency of the machine was also determined.

2.4.1 Harvesting efficiency

Harvesting efficiency of the machine was determined using the equation:

$$E_h = \frac{W_h}{W_h + W_{uh}} \times 100 \qquad 4$$

Where; E_h = Harvesting efficiency in percent.

W_h = Weight of harvested groundnut per plot.

W_{uh} = Weight of un-harvested groundnut per plot.

2.5 Statistical analysis

All experiments were carried out in triplicates. Data collected were subjected to analysis of variance (ANOVA) to test for significant effects at 95 % confidence limit using the procedure recommended by Steel and Torrie (1980). When significant difference was observed, treatment means were separated using the F-LSD.

3. Results and Discussions

3.1 Effects of operation speeds on the weight (kg) of harvested groundnuts

Experimental results of the effects of operation speeds on the weight (kg) of harvested groundnuts is shown in Table 1, the Analysis of Variance (ANOVA) of the effects of operation speeds at $P \leq 0.05$ is presented in table 2 and results of the separation of means of the weight of harvested groundnut at $P \leq 0.05$ is shown in Table 3. It was observed from Table 1 that the weight (kg) of harvested groundnuts has a negative relationship with operation speeds. The weight (kg) of groundnuts harvested decreased with increasing operation speed. Mean groundnuts weights of 11.1 kg, 9.7 kg and 9.4 kg were obtained for the operation speeds of 1.6 km/hr, 2.4 km/hr and 3.2 kg/hr respectively. This shows that the effective speed for the harvester is 1.6 km/hr. From the ANOVA (Table 2) there was a significant difference in the operation speeds and from the means separation (Table 3), there was significant difference in the weight of harvested groundnuts between the speeds of 1.6 km/hr and 2.4 km/hr, 1.6 km/hr and 3.2 km/hr but there was no significant difference in the weight of harvested groundnuts between the speeds of 2.4 km/hr and 3.2 km/h.

Table 1: Experimental results of the effects of operation speeds on the weight (kg) of harvested groundnuts

Replications	Operation Speed (km/hr)		
	1.6	2.4	3.2
I	11.9	9.6	9.5
II	10.6	9.8	9.2
III	10.9	9.7	9.4
Total	33.4	29.1	28.1
Mean	11.1	9.7	9.4

Table 2: ANOVA of effects of operation speeds on the weight of harvested groundnuts

Sources	Df	SS	MS	F-Stat	F-Tab (5%)
Block	2	0.346	0.173	1.07^{ns}	6.94
Speed	2	5.286	2.643	16.31^{*}	6.94
Error	4	0.647	0.162		
Total	8	6.280			

* - Significant, ^{ns} - Not significant

Table 3: Effect of operation speeds on mean weight of harvested groundnuts

Operation Speed (km/hr)	Weight (kg)
1.6	11.1
2.4	9.7
3.2	9.4

FSLD: 0.91 at $P \leq 0.05$

3.2 Effects of operation speeds on the weight (kg) of damaged groundnuts

Table 4 is the experimental results of the effects of operation speeds on the weight (kg) of damaged groundnuts while Table 5 is the Analysis of Variance (ANOVA) of the effects of operation speeds on the weight (kg) of damaged groundnuts at $P \leq 0.05$. From table 4, it was observed that the weight (kg) of damaged groundnuts has a positive relationship with operation speeds. The weight (kg) of damaged groundnuts increased with increasing operation speed. Mean damaged groundnuts weights of 2.9 kg, 3.1 kg and 3.6 kg were obtained for the operation speeds of 1.6 km/hr, 2.4 km/hr and 3.2 kg/hr respectively. From the ANOVA (Table 5) there was no significant difference in the operation speeds.

Table 4: Experimental results of the effects of operation speed on the weight (kg) of damaged groundnuts

Replications	Operation Speed (km/hr)		
	1.6	2.4	3.2
I	2.3	3.6	3.7
II	3.4	3.2	3.8
III	3.1	2.5	3.2
Total	8.8	9.3	10.7
Mean	2.9	3.1	3.6

Table 5: ANOVA of effects of operation speed on the weight of damaged groundnuts

Sources	Df	SS	MS	F-Stat	F- Tab (5%)
Block	2	0.427	0.214	0.810^{ns}	6.94
Speed	2	0.647	0.324	1.227^{ns}	6.94
Error	4	1.056	0.264		
Total	8	2.130	0.266		

^{ns} - Not significant

3.3 Effects of operation speeds on the weight (kg) of un-uprooted groundnuts

Table 6: Experimental results of the effects of operation speed on the weight (kg) of Un-uprooted Groundnuts

Replications	Operation Speed (km/hr)		
	1.6	2.4	3.2
I	1.0	1.5	1.6
II	1.2	1.3	1.8
III	1.5	1.2	1.3
Total	3.7	4.0	4.7
Mean	1.2	1.3	1.6

Table 6 shows the experimental results of the effects of operation speeds on the weight (kg) of un-uprooted groundnuts and Table 7 is the Analysis of Variance (ANOVA) of the effects of operation speeds on the weight (kg) of un-uprooted groundnuts at $P \leq 0.05$. The result shows that the weight (kg) of un-uprooted groundnuts (Table 6) also has a positive relationship with operation speeds. The weight (kg) of un-uprooted groundnuts increased with increasing operation speed. Mean un-uprooted groundnuts weights of 1.2 kg, 1.3 kg and 1.6 kg were obtained for the operation speeds of 1.6 km/hr, 2.4 km/hr and 3.2 kg/hr respectively. From the ANOVA (Table 7) there was no significant difference in the operation speeds.

Table 7: ANOVA of effects of operation speed on the weight of Un-uprooted Groundnuts

Sources	Df	SS	MS	F- Stat	F- Tab (5%)
Block	2	0.127	0.064	1.488^{ns}	6.94
Speed	2	0.176	0.880	1.046^{ns}	6.94
Error	4	0.173	0.043		
Total	8	0.476			

^{ns} - Not significant

3.4 Performance efficiency of the harvester

The result of performance efficiency of the harvester is shown in table 8. It was observed that the harvesting efficiency decreased with increasing speed of operation while both the percentage of damaged groundnuts and the percentage of un-harvested groundnuts increased with increasing speed of operation.

From the results, harvesting efficiencies of 73.05%, 70.22% and 69.48% were obtained for the operation speeds of 1.6 km/hr, 2.4 km/hr and 3.2 kg/hr respectively, percentage damage of 26.35%, 27.84% and 32.04% were obtained for the operation speeds of 1.6 km/hr, 2.4 km/hr and 3.2 kg/hr respectively and percentage un-uprooted groundnuts of 10.78%, 13.75% and 16.73% were obtained for the operation speeds of 1.6 km/hr, 2.4 km/hr and 3.2 kg/hr respectively.

Table 8: Mean values of the Performance Efficiency of the Harvester

Parameter	Operation Speed (km/hr)		
	1.6	2.4	3.2
Harvesting efficiency	73.05	70.22	69.48
Percentage damage	26.35	27.84	32.04
Percentage un-uprooted	10.78	13.75	16.73

4. Conclusion and Recommendations

4.1 Conclusion

In operating the groundnut harvester, the developed tractor mounted groundnut harvester successfully harvested groundnuts with the aid of the harvesting tool (soil loosening tool). The soil loosening tool attached to the roller shaft penetrates into the soil and loosens the soil with the groundnuts and causes less damage to the groundnut pods. The soil loosening tool and the conveying mechanism were impressive; groundnuts were conveyed through the drive to the conveyor blades attached to shaft at various positions.

The results of the present study showed that operation speed is an important factor on the groundnut mechanical harvesting that has a significant effect on the weight of harvested groundnuts. The speed of operation had significant effect on the draft having less harvesting losses with minimum speed. The best performance efficiency of the developed groundnut harvester (73.05%) was obtained at the operation speed of 1.6 Km/hr. Delay of groundnut harvesting increases pods losses due to weakening pegs. Therefore, harvesters should be use at the proper speed, soil moisture and time.

4.2 Recommendations

i. The groundnut harvester should be operated at a speed of 1.6 Km/hr and at a constant depth of 10cm for optimum performance.

ii. Separation of the soil from harvested groundnuts needs to be enhanced by introducing some form of vibrating mechanism to shake of the soil during operation.

iii. Increase the diameter of the land wheels in order to ensure that the wheels do not come out of transport position.

iv. Provide chain covers at the chain drive to avoid soil sticking on them during harvesting operation.

v. The harvester developed is best used on flat land/field.

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9/20/2016