Research & Reviews

ISSN: 2319-9857

Research and Reviews: Journal of Agriculture and Allied Sciences

Modelling the Performance of a Tractor – Mounted Cocoyam Harvester

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Short Communication

Received: 13/02/2013
Revised: 12/03/2013
Accepted: 12/04/2013

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Keywords: Harvested tubers, tuber damage, Cluster width, Harvest rate, Digging efficiency, Clogging.

ABSTRACT

A cocoyam *(Xanthosoma spp.)* harvester was designed and fabricated at the Federal University of Technology, Akure using locally available materials. Field tests were conducted to evaluate the effect of different levels of operational parameters on the performance of the implement. The operational parameters were forward speed (v), rake angle (α) and web speed (n). The harvester was operated at the forward speeds of 2, 4 and 6 km/h, rake angles of 15˚, 20˚ and 25˚ and web speeds of 540, 1000 rpm. These combinations were tested on a factorial basis employing a split – split plot design with three replications. The performance of the implement investigated was the successfully harvested tubers and tuber damage analysed using ANOVA at $P < 0.05$. Cocoyam cormels were harvested from 10m long rows of crops on clay loam with a spacing of 0.8m x 0.6m according to each treatment. From the results, a mean harvest rate of 12.02 tonnes/h and mean digging efficiency of 84.2% were obtained. The results implies that, while the harvester can be operated for higher field capacity at 6 km/h. 20˚ blade 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˚ blade angle and 540 rpm web speed. The field tests also revealed that machine performance was limited by delays due to clogging and machine adjustments. Analysis of variance performed on the descriptive statistics for machine performance variables obtained showed that the results are significant for one of the response variables. Machine performance variables are significant at $P < 0.05$ for harvest rate.

INTRODUCTION

Huge advances have been made in the mechanised harvesting of most temperate crops; this is not so for tropical crops, especially tuber crops. Most of the harvesters developed have brought about a remarkable reduction in the drudgery, labour requirement and production cost of such crops. Cocoyam is one of the popular tropical tuber crops; others are yams, cassava, ginger and sweet potato.

Economic Importance of Cocoyam

Cocoyam constitutes a major part of food consumed in Nigeria, and also in the tropical regions of the world. The edible corms are roasted, cooked or pounded into paste for food [4]. The tender leaves and petioles are also eaten either as vegetables or meat supplements. Among its advantages over related tuber crops like yams and cassava is the simpler external morphology and husbandry practices; non possession of a woody stem, not requiring stakes for mechanical support and vegetative propagation from crop parts that are not of considerable economic importance.

Literature Review

Early attempt to mechanise the harvesting of tropical root crops began with the use of the plough. Others types of harvesters include the potato spinner, elevator digger, manned elevator digger and complete harvester. 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 separate the 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 or rubbish to produce a clean sample [2]. The complete harvester performs digging, separation, cleaning and delivery of tubers in a one pass operation of the harvester.

METHODOLOGY

Soil and crop parameters relevant to design of similar root crop harvesters were determined in a preliminary field experiment carried out at the FUTA Teaching and Research Farm. Such soil properties include; Soil resistance, row base width and height. The crop properties studied were; cluster properties, that is, number of cormels per plant and cluster width and tuber parameters that is, length, diameter and weight of individual cormels. Furthermore, detailed literature study was carried out to obtain design data for relevant soil engineering properties such as soil cohesion, c adhesion, $c\alpha$ angle of internal resistance, ϕ, angle of soil interface friction, δ among others that are required for the design of similar soil engaging tools.

Preliminary and detailed design analysis of the harvester was carried out. This was followed by computer aided (AUTOCAD) isometric and orthographic drawings of the machine and its component parts. The various components were fabricated using locally sourced materials. The whole machine was later assembled; a cocoyam farm was established at the research farm of the University for field evaluation of the machine prototype. The three experimental plot has a dimension of 14 m x 10 m, area of 144 m^2 and has a total of 300 stands of cocoyam in eighteen rows per plot and a total plant population of 20,833 plants per hectare. It was ploughed, harrowed, ridged and planted with Cocoyam cormels at the onset of the rains in May, 2007.

Procedure for Field Measurement

Determination of machine output

The rate of harvesting of dug cormels was determined with the machine running on the test field and the designated PTO rotation with other selected operational and implement parameters (forward speed and rake angle) for each row as shown on the plot layout.

Determination of dug losses

Harvested cormels are collected soon after harvesting. Dug losses were determined by digging up all the cormels left in the soil per plot after the machine has passed and the surface produce collected labelled, bagged and weighted. Two types of investigation were conducted into the digging efficiency of the machine a) Lifting efficiency of stands b) Lifting efficiency of cormels.

Data Analysis

Data collected were analyzed to determine the effects of three operational parameters (web speed, forward speed and rake angle) on machine performance indicators that include: harvesting rate, dug losses, tuber damage and time loss as a result of machine adjustments and breakdown.

The data obtained from field tests were analysed with Microsoft Excel software packages for the desired indicators of machine performance using the variables obtained during the field tests as shown in Table 1.

Table 1: Variables analysed for various indicators of machine performance

S/N	Performance indicators	Variables
1	Harvesting rate	Yield (HCOM)
		Harvesting Rate (HR)
2	Field Losses	Dug Losses (DLOSS)
		Skipped Stands (SKSD)
3	Machine faults	Machine Adjustments (MADJ)
		Breakdowns (BD)
4	Machine efficiencies	Digging Efficiency (DEFF)

Data obtained was also analysed to evaluate significant differences within treatments. A multiple regression model was fitted for each of the response variables (machine performance indicators) using the operation parameters as independent variables.

RESULTS AND DISCUSSION

The analysis of variance performed on the results presented in the descriptive statistics showed that the results are significant for only two of the response variables. Machine performance variables are significant at $P < 0.05$ for HR, and for MAJ at $P < 0.1$. This result is contrary to some previous studies such as Miscener et al [3], Sharma et al [5] and Culpin [1] where the effects of treatments on implement performance especially FEFF, DLOSS and clogging were directly affected by the selected operational parameters. The non expression of these treatments might be due to the several stops made for repairs, adjustments and data collection during field tests; the skill of the Tractor operator or other environmental factors.

Follow up tests were performed using multiple comparisons to evaluate the significance of specific treatments means on the indices of machine performance under consideration. A summary of this result shown in appendix iv, indicate that 29 % of the treatments means in respect of the HR tested significant at the 0.05 probability level while only 15 % are significant for MADJ at the same level. At $P < 0.1$, 39 % and 21 % of the treatment compared are significant for HR and MADJ. Comparing the treatment means of FEFF, HCOM, DLOSS and CLOGG, all the treatments recorded less than 10 % significance at 0.05 level while results for the 0.1 level are 14 %, 15 %, 15.7, and 4.5 % respectively.

Only three treatments T7, T13 and T16 of the SKSD are significant when compared with T3, while all the treatment means of BD are not significant at the levels tested.

Modelling of machine performance

A multiple linear regression model was fitted for each of the response variables using the operational parameters which are forward speed (FS), web speed (WS), Rake angle (RA), interaction between the variables; RAWS, RAFS, RAWSFS; as independent variables. The summary of the regression analysis and ANOVA are presented on Table 2.

The models are.

a) $HR = 3.375 + 2.163\ FS$
b) $DEFF = 99.74 - 3.89\ FS$
c) $DLOSS = -0.696 + 1.494\ FS$
d) $CLOGG = 498.037 - 2.52\ RAFS$
e) $MAJ = -29.57 + 151.84FS - 5.23\ RAFS$
f) $SKSD = 2.95 - 0.104\ RA - 0.008RAFS$
g) $BD = 1512 - 35RA$

The result indicated that a good fit exist for the dependent variables HR, MAJ and SKSD. The coefficient of determination (R^2) is high at 0.65, 0.58 and 0.57. The standard errors are also low from 2.77, 111.44 and 0.37. This showed that a linear trend may exists describing the association between the variables. The results of the ANOVA are also significant at $P < 0.05$

ISSN: 2319-9857

Table 2: Summary of the regression analysis and ANOVA

Model	R^2	SE	P
HR = 3.375 + 2.163 FS	0.647	±2.77	0.000
DEFF = 99.74 – 3.89 FS	0.328	±9.65	0.013
DLOSS = −0.696 + 1.494 FS	0.39	±3.22	.005
CLOGG = 498.037 – 2.52 RAFS	0.288	±155.92	.022
MAJ = −29.57 + 151.84FS – 5.23 RAFS	0.58	±111.44	.003
SKSD= 2.95 – 0.104 RA – 0.008RAFS	0.57	± 0.37	.008
BD = 1512 – 35RA	0.37	± 160	0.43

The result of multiple regression analysis also indicated that FS is the only reliable predictor of HR, DEFF, and DLOSS even though the linear relationship in respect of FEFF and DLOSS appear to be weak given R^2 of 0.33 and 0.39. Similarly the implement rake angle alone and its interaction with forward speed is considered as a reliable predictor of the skipped stands.

The result also show that the speed of operation is also a good determinant of some dependent variable in interaction with the implement rake angle, these include clogging (R^2 0.28), no of skipped stands and machine adjustments (R^2 0.58).

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