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PERFORMANCE EVALUATION OF A GINGER HARVESTING MACHINE WITH FOUR DIFFERENT TRACTOR FORWARD SPEEDS

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Abstract
Ginger is a potential agricultural commodity to be developed in Nigeria. Harvesting of ginger rhizomes in Nigeria is done manually by using hoes, fork, spade and other farm implements. The farmers are constrained with scarce labour for harvesting leading to increased labour cost and harvesting time. Experimental field trials were conducted at Michael Okpara University of Agriculture Umudike, primary school field on a bed of sandy clay loam soil, to evaluate the performance of the machine at four different tractor forward speeds; 4km/hr, 8km/hr, 12km/h and 16km/h. The field parameters recorded are the operation speeds on the number of ginger rhizomes harvested, weight of ginger harvested, number of ginger un-harvested, number of ginger rhizomes with cut, weight of ginger with cut, effective/theoretical field capacity and efficiency. The machine was tested at four tractor forward speeds to investigate the effect of tractor forward speed on ginger harvesting. Analysis of Variance (ANOVA) with Randomized Complete Block Design (RCBD) was used to test for significant differences at 4 tractor speeds. From the results, the tractor forward speed of 4km/h has the highest harvested rhizomes of 85.7%; while speed of 12km/h has the highest number of ginger un-harvested (41%) and number of ginger with cut (38.7%). The speed of 16km/h gave the lowest weight of harvested ginger rhizomes (3.4kg) and highest weight of cut (1.23kg). The ginger harvesting machine performed satisfactorily with effective field capacity, theoretical field capacity and field efficiency of 0.0261ha/h, 0.000505ha/h and 52% respectively.

Keyword: Ginger, mechanization, harvesting, performance evaluation, tractor speeds

Introduction

Ginger (*Zingiber officinalle*) is a rhizomatous spice of culinary and medicinal importance (Amadi, 2012), grown on sandy loam and clay loamy soil, and also an important commercially grown crop for its aromatic rhizomes which are used as a spice, condiment and medicine. It has been used as a spice for over 2000 years (Bartley and Jacobs, 2000). It is known for its hot, pungent aroma due to the presence in its rhizomes of oleoresin and essential oils. Ginger is used widely in the preparation of soft drinks and beverages. Nigeria produces an average of 369 metric tonnes of fresh weight of ginger per annum (FAO, 2009). It is one of the important articles of trade in the world spice market, widely grown spice and consists of over 90 species of perennial rhizomatous herbs. It can be found fresh, dehydrated, dried, powdered and in other forms. According to (Ezeagu, 2006), 20% of dried ginger is consumed locally for various uses and 80% exported. The production of ginger in Nigeria started in 1927 from an investigation carried out to find a crop that would generate internal trade for the people of Southern Kaduna, the traditional home of ginger production in Nigeria (Arene *et al.,* 1987). Ginger is cultivated commercially as an annual crop, by planting small rhizomes or pieces of rhizome either on flat soil or in furrows between ridges. The growing plants require adequate manure to get the best yield possible. Ginger is ready for harvesting 7 to 10 months after planting, when the leaves turn yellow and start drying, with harvesting done by digging the rhizomes up. Practically all the operations on ginger, including; planting, mulching, fertilizing, weed control, harvesting, and most processing are done by hand. Hoki *et al.* (1992) and Yohanna, (2007), pointed out that agricultural mechanization can be achieved simply by the introduction of advanced technologies which can reduce drudgery, increase productivity and enhance financial growth of the nation. Mechanization of ginger production and processing has received little attention in Nigeria. Its production operations need to be mechanized to increase the production and use (Nwandikom and Njoku, 1998).

Manual harvesting

Manual harvesting is the traditional method of harvesting ginger using a hoe to dig around the standing stem to pull out the root before detaching the uprooted roots from the base of the plant (Fig. 1)

Fig. 1: Traditional method of ginger harvesting

Methodology

The developed two row ginger harvesting machine was attached to a tractor PTO via the speed reducer. As the tractor moves, the digger turns and uproots the ginger rhizomes from the soil, while the rake carries the uprooted ginger rhizomes with the soil and conveys it to the separator, which separates the rhizomes from the soil and then conveys it to the collector. After the fabrication of the machine, performance tests were carried out on the harvester when coupled to a tractor in order to determine the following:

a)Effect of tractor forward speeds on the number of ginger harvested
b)Effect of tractor forward speeds on the number of un-harvested ginger
c)Effect of tractor forward speeds on the number of ginger with cut

These were arranged in a Randomized Complete Block Design (RCBD), and subjected to Analysis of Variance (ANOVA) at 5% level of probability. The effective / theoretical field capacity and efficiency were determined using equations 1, 2 and 3 respectively as:

Effective Field Capacity (EFC)

$$EFC = \frac{\text{Total Area}}{\text{Total Time}} \quad \text{..... (1)}$$

Where, Total Area = 0.00914ha, Total Time=0.35hr,

$$EFC = \frac{0.9144}{0.35} = 0.0261 \text{ ha/hr}$$

Theoretical Field Capacity (TFC)

$$TFC = \frac{\text{width} \times \text{speed}}{8.25} \quad \text{..... (2)}$$

Where, Width = 3 feet (0.9144m), Speed = 0.000456 m/hr,

$$TFC = \frac{0.9144 \times 0.00456}{8.25} = 0.000505 \text{ha/hr}$$

Field Efficiency (FE)

$$FE = \frac{\text{Effective field capacity}}{\text{Theoretical Field Capacity}} \times 100 \quad \text{..... (3)}$$

$$FE = \frac{0.0261}{0.000505} = 52\%$$

Results and Discussion

The effect of tractor forwards speeds on the number of ginger harvested shows that the speed of 4km/hr gave the highest mean value of 85.7% on number of ginger harvested, while the lowest number (52.7%) was obtained at the the speed of 16km/hr. For number of ginger rhizomes unharvested, the speed of 4km/hr gave the lowest mean value of 27%, while the highest (41%) was obtained at the speed of 12km/hr. Speed of 4km/hr has the lowest value value of 26.67% on number of ginger rhizomes with cut, while speed of 16km/hr has the highest value of 38.7% as indicated in Table 1.

Table 1: Effect of tractor forwards speeds on ginger harvesting

Parameters	4km/hr	8Km/hr	12km/hr	16km/hr
Number of Ginger Harvested	85.7±0.882^{a}	68±4.04^{b}	56.3±2.03^{c}	52.7±3.71^{c}
Weight of Harvested Ginger Rhizomes(kg)	8.0±0.4 ^{a}	5.4±0.81^{b}	4.73±0.87 ^{b}	3.4±0.31^{c}
Number of Ginger not Harvested	27±1.53^{b}	31±2.08^{b}	41±0.577^{a}	40±1.15^{a}
Number of Ginger with Cut	26.67±0.88^{c}	33.7±0.67^{bc}	34.3±1.33^{bc}	38.7±1.86^{a}
Weight of Ginger with cut(kg)	0.43±0.09	0.67±0.07	0.67±0.13	1.23±0.49

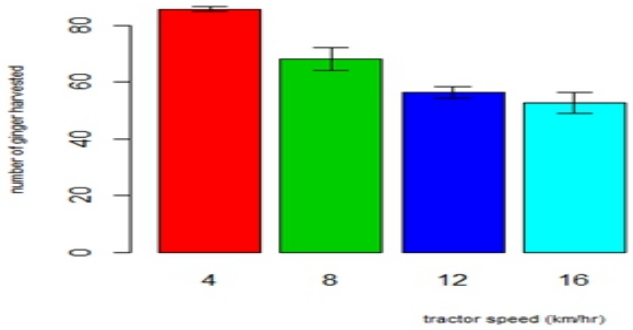

Fig. 2: Effects of tractor forwards speeds on number of ginger harvested

The results were subjected to statistical analysis using Analysis of Variance (ANOVA) as shown in Table 2. A p-value of 0.000135 was obtained, which is less than 5% (P<0.5), this implies a significant difference among the speeds as indicated in Table 1.

Table 2: Effect of tractor forwards speeds on the number of ginger harvested

Model	Df	Sum Sq	Mean Sq	F-Value	P(>F)
Tractor. Speed	5	4485	896.9	49.52	1.35e-04***
Residuals	12	217	18.1		

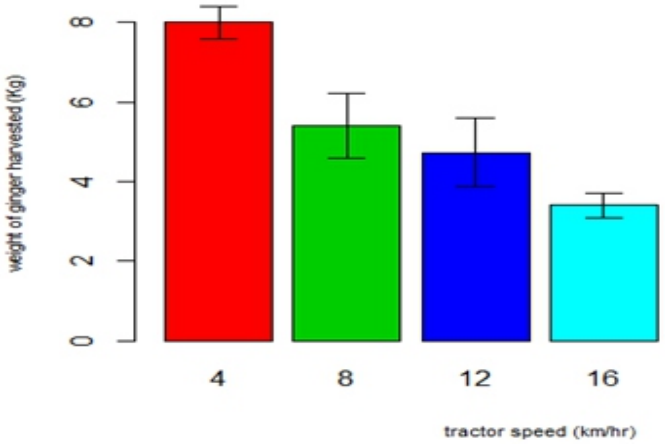

Fig 3: Effects of different tractor speeds on the weight of ginger rhizomes harvested

Fig. 3 shows that the speed of 4km/hr has the highest weight of 8.0kg; while speed of 16km/hr has the lowest weight of ginger rhizomes harvested (3.4kg).

Table 3 presents the analysis of variance (ANOVA) on weight of ginger rhizomes harvested. A p-value of 0.000233 which is less than 5% showed evidence of significant difference (<0.05) among the tractor speeds.

Table 3: ANOVA Table on weight of harvested ginger rhizome

Model	Df	Sum Sq	Mean Sq	F Value	P(>F)
Tractor. Speed	5	54.52	10.905	12.18	0.000233***
Residuals	12	10.75	0.896		

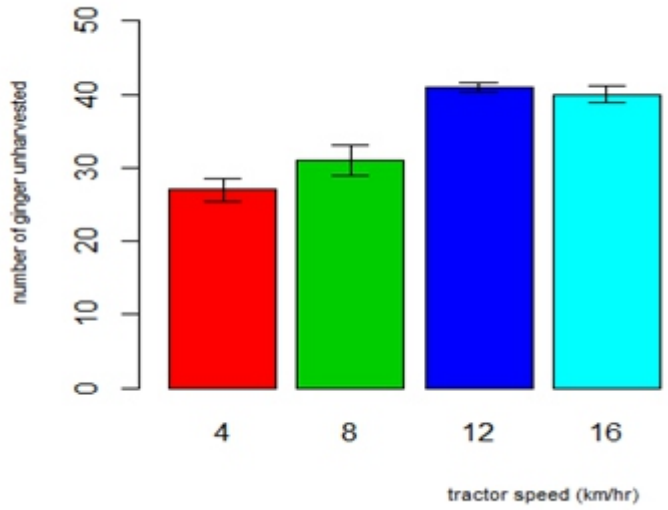

Fig. 4: Effects of tractor forwards speeds on number of un harvested ginger

Table 4 shows the analysis of variance (ANOVA) for the number of un-harvested ginger rhizomes. A p-value of 0.000156, which is less than 5% indicated significant differences (<0.05).

Table 4: Effect of tractor forwards speeds on number of un-harvested ginger

Model	Df	Sum Sq	Mean Sq	F Value	P(>F)
Tractor. Speed	5	1215.8	243.16	31.95	1.56e-04***
Residuals	12	91.3	7.61		

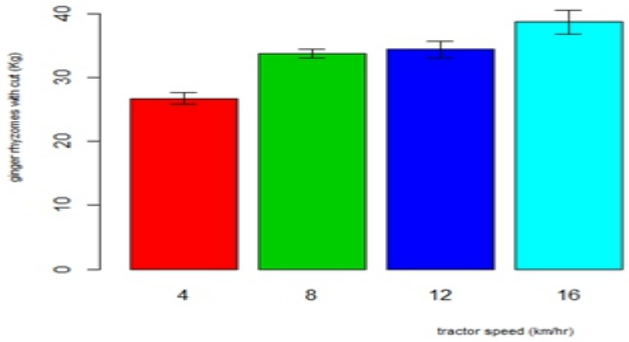

Fig. 5: Effects of tractor forwards speeds on number of ginger with cut

Table 5 shows the ANOVA table for the number of ginger rhizomes harvested with cut. A p-value of 0.000231 which is less than 5% showed a significant difference (<0.05) among the 4 tractor speeds.

Table 5: Effects of tractor forward speeds on number of ginger rhizomes harvested with cut

Model	Df	Sum Sq	Mean Sq	F Value	P(>F)
Tractor. Speed	5	548.5	109.7	12.19	0.000231***
Residuals	12	108.0	9.0		

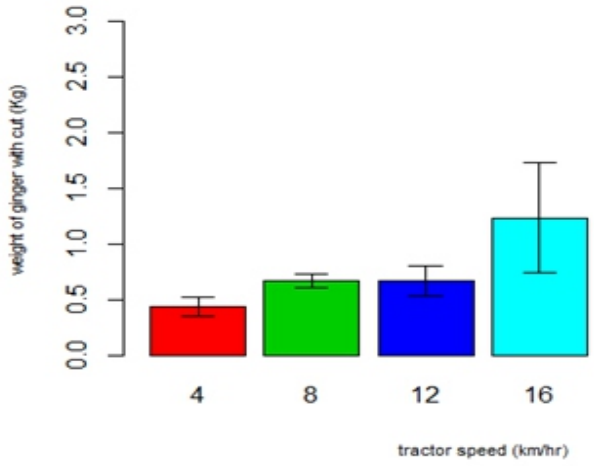

Fig 6: Effects of different tractor speeds on the weight of Ginger Rhizomes Harvested with Cut

The observed field trials which were represented in Fig. 6 shows that the speed of 4km/hr has the lowest weight of 0.43kg, while the speed of 16km/hr has the highest weight of 1.23kg of ginger rhizomes harvested.

Results in Table 6 shows the analysis of variance (ANOVA) on weight of ginger rhizomes harvested with cut indicating there were no significant differences based on the p-value.

Table 6: Effects of different tractor speeds on weight of ginger rhizomes harvested with cut

Model	Df	Sum Sq	Mean Sq	F Value	P(>F)
Tractor. Speed	5	6.873	1.3747	2.186	0.124***
Residuals	12	7.547	0.6289		

There were significant differences for the number of ginger harvested when 4 tractor speeds were applied. For weight of ginger rhizomes harvested, efficiency of harvest was same at 8km/hr and 12km/hr, but significantly different at 8km/hr and 16km/hr. Number of ginger un-harvested were same at tractor forward speed of 12 and 16km/hr, but significantly different at 4 and 8km/hr which were also same. As regards number of ginger with cut, results showed significant difference when the 4 tractor speeds were applied, which were same at 8 and 12km/hr, but significantly different with speed at 4 and 16km/hr. There were no significant differences in weight of ginger with cut at 4 tractor speeds.

Conclusion

The study was designed to fabricate a machine that will reduce the labour cost. This machine has economic value for fulfilling the needs for farmers. The machine has shown better performance at the speed of 4km/h for ginger harvesting in terms of effects of tractor forwards speeds on number of ginger harvested. From the investigation, as the speed reduces from 16km/h to 4km/h, from 16km/h to 4km/h, the number of ginger with cut reduces from 38.7 to 26.67. The lowest was obtained at speed of 4km/h, while the highest was obtained at the speed of 16km/h. It was also observed that the speed of 4km/h gave the lowest percentage of unharvested ginger at 27%, while the highest value of 41% was obtained at the speed of 12km/h. Decreasing the tractor forwards speeds increased the number of ginger rhizomes harvested. By adapting this machine, problems of the labour crises associated with ginger harvesting can be reduced.

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Appendices

Appendix 1: Harvester on the Field

Appendix 2: Fabricated Two Row Ginger Harvester