Design and Development of a Prototype Implement-Type Cassava Planting Machine

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Abstract- The Implement-type cassava planting machine was attached to a hand tractor and was designed using AutoCAD and made of locally available materials using local manufacturing technology. The purpose of this machine was to increase the production of planting cassava and to decrease labor requirements. The machine consists majorly of a hopper, discharge chute, furrow opener, harrower, ground wheel and metering device. The machine performance was evaluated using 2.14, 2.28 and 2.67 kph travelling forward speed. The study was laid-out in single factor experiment in complete randomized design. The performance of the machine was evaluated in terms of actual field capacity, planting and plowing efficiency, percent missing hills, fuel consumption rate, uniformity in spacing using different travelling forward speed. Results indicate that the speed has significant effect on the plowing and planting efficiency, actual field capacity, percent missing hills and uniformity in spacing, but has no significant effect on the fuel consumption rate of the prime mover of the machine. The dimension of the cassava stalk used was 17 cm in length and 15 cm to 20 cm used in manual planting. 2.28 kph gave the highest planting efficiency, actual field capacity, uniformity in spacing of 91.39%, 0.026 ha/h and 25.24%, respectively. Least missing hill of 8.61% was found at 2.28 kph. The machine has plowing efficiency of 77.45%. This machine is simple to operate and maintain for small cassava farmers. Furthermore, there was no damage stakes were observed, it had the ability to plant cassava stalks and capable of reducing labor requirement and cassava production cost. The machine had a break-even area of 0.78 ha/year when operating at 2.28 kph. Thus, a 20-day payback period of a planting area of 28.8 ha is required if planter was operated at 2.28kph. The machine requires two operators in planting cassava stalks. The performance test and cost analysis indicated that the machine could be used economically and simple to operate and maintain for small and medium scale farmers.

Index Terms- Actual Field Capacity, Design, Development, Cassava Planting Machine, Fuel Consumption Rate, Percent Missing Hills, Planting Efficiency, Plowing Efficiency, and Uniformity in Spacing.

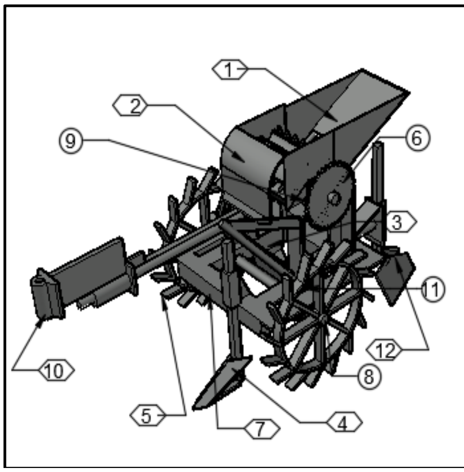
I. Introduction

Cassava is one of the substitute for rice and even used for feed consumption in animal production. In the Philippines, for cassava to be able to compete in the growing market such as in the field of animal sector and production cost and labor requirement should be kept as low as possible. One of the battle cries of the cassava farmers was high production cost especially in the high labor requirement in planting and harvesting of cassava. Cassava planted each year of about 120,000 hectares and produce about 1.8 million tons of cassava roots which contributes only about 2% to gross value adding in the Philippine agriculture sector (Bacusmo Jose L.). Most cassava farmers in the Philippines are not aware of available modern technologies for growing and processing of cassava and the lack of ability to use certain technologies. Moreover, the lack of technical advice hinders the ability of small and medium scale farmers to improve value chain efficiency and profitability of the cassava enterprise (Iita 2014). Most cassava farmers in the Philippines were planting cassava in traditional manual planting and it takes 8-10 persons per day per hectare to plant cassava. There are already available planters in the country and was imported to the advance countries only that its design and cost was not meant for the usage of small and medium cassava farmers. Therefore, the non-availability of planting machine to the locality during the planting season has demanded the development of this machine. The objectives of this study are to design and fabricate an implement-type cassava planting machine and evaluate the performance of the cassava planting machine in terms of actual field capacity, planting and plowing efficiency, percent missing hills, fuel consumption rate, uniformity in spacing and perform cost analysis of the machine.

II. MATERIALS AND METHODS

Description of the machine

Figure 1 shows the perspective view of the machine showing the various component parts. The cassava planting machine consists of hopper, cover, discharge chute, furrow opener, ground wheel, driven sprocket, frame, ground wheel shaft, pillow block, hitch, driving sprocket, harrower, and metering device. The hopper (Part No. 1) is made of galvanized sheet with a thick of 1.2mm, inclined at 30° degrees for easy sliding of the stalks into the metering device of the machine. The cover of the metering device (Part No. 2) is made of galvanized sheet of thick 1.2mm to prevent the stalks on overlapping to the front side of the machine. Discharge chute (Part No. 3) is made of galvanized sheet of 1.2mm thick, it is where the stalks will be slide down to the ground and will be covered by the harrower (Part No. 12). The machine is driven via hand tractor which attached to the hitch (Part No. 10) of the planter and attached also to the frame (Part No. 7) of the planter. The frame (Part No. 7) is made of angle bars (2" x 2" x 1/8") firmly welded together for its stability. Attached to the frame is the ground wheel (Part No. 8) which is 16" outside diameter and made of ¼" thick flat bar, it has a lag which is 45° from the bended bar of 12" diameter. The ground wheel has a shafting (Part No. 8) of 1 ¾" diameter. The discharge chute (Part No. 3) discharges the cassava stalks by gravity. The furrow opener (Part No. 4) of the planter is V-shaped solid steel that cuts the soil to a depth of 5cm to 10cm, the V-shaped is made of steel with a thickness of ¼" and vertical support made of square bar (¾" x ¾"). The trapezoidal harrower (Part No. 12) is made of flat bar of ¼" thick, the harrower was based on a double covering disc and has an angle of 30° from the land. The metering device (Figure 2) consists of stalk cell, cylinder block stalk holder and fork stalk holder and driven by a driven sprocket (Part No. 6). The metering device is made of 6" diameter circular steel and attached to a 1" driven shaft and driven by a driven sprocket (52T). Figure 2 shows the flow of the cassava stalks loaded from the hopper through the metering device and discharge chute to the ground.



CODE	DESCRIPTION
1	hopper
2	cover
3	discharge chute
4	furrow opener
5	ground wheel
6	driven sprocket
7	frame
8	ground wheel shaft
9	pillow block
10	hitch
11	driving sprocket
12	harrower

Figure 1. Perspective View of the Cassava Planting Machine

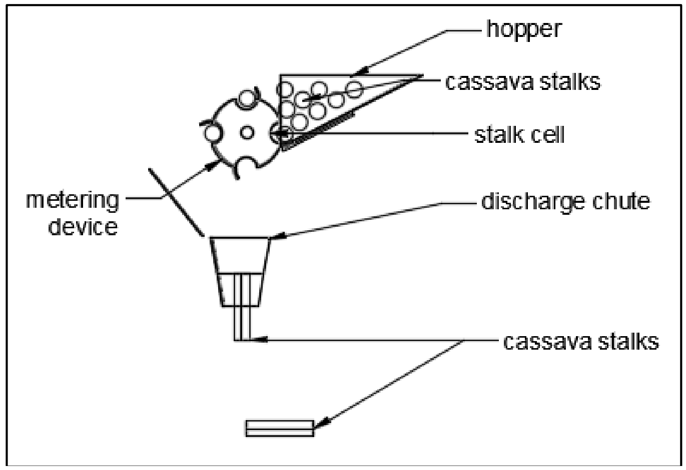


Figure 2. Diagram flow of the Cassava Stalks from hopper to Ground

Principles of Operation

The machine was attached to a hand tractor with 12 hp diesel engine. As the hand tractor moves forward, the furrow opener cuts the soil to a desired depth. The ground wheel then rotates and transmit rotational motion to the ground wheel shaft which rotates the chain and sprocket assembly. The sprocket-chain assembly moves with the ground wheel to rotate the metering device to pick up stalks from the loading hopper. Stalks are being placed to the loading hopper through gravity stalks are being placed to the stalk cell and moves down to the discharge chute. Stalks are being drop to the discharge as it moves the metering device by a quarter revolution. From the discharge chute, stalks are being drop to the ground by gravity and the harrower covered the stalks with plowed land by the furrow opener.

Design Consideration

The implement-type cassava planting machine was developed base on the following consideration:

1. The availability of materials locally to reduce cost of production.
2. The safety of the operator.
3. The operation of the machine should be simple for small scale farmers and rural farmers.
4. The ease of fabrication of component parts.
5. The materials available used in fabrication of the components.
6. It is desired that the cassava stalks should be well planted without mechanical damage on stalks and planted at desired distance between cassava stalks.
7. Sprockets should be carefully design/select to meet the required synchronized speed of the machine.

Performance Evaluation

The performance evaluation of the machine was carried out using one type of cassava stalks, one type of metering device and three varying travelling forward speeds (2.14, 2.28, and 2.67 kph). Cassava stalks were selected and cut with a length of 17cm and introduced to the cassava planting machine. The performance evaluation was found in accordance with the following definitions:

1. Planting Efficiency – ratio of the number of hills with seedlings to the number of hills expressed in percentage. (PAES 152:2010)

   $$P_e = \left(1 - \frac{H_m}{H_t}\right) x100$$

   where:

   P_e – Planting Efficiency
   H_m – Total number of missing hills
   H_t – Total number of hills

2. Plowing Efficiency – the ratio of the actual field capacity to the theoretical field capacity. (PAES 135:2004)

   Actual field capacity = (0.006 x A_e)/t

   where:

   A_e – Effective area covered, m
   t – time of operation, hr

   Theoretical field capacity = (W_e x v)/10,000

   where:

   W_e – theoretical width of furrow
   v – theoretical speed of operation, m/hr

   Effective area, A_e = wD

   where:

   w – width of furrow, m
   D – total distance travelled, m; D = A/S, A – area of plot and S – width of cut, m.

3. Actual Field Capacity – the ratio of total area planted to the total operating time. (PAES 152:2010)

   $$C = \frac{A}{t}$$

   where:

   C – actual field capacity
   A – total area planted, ha
   t – total operating time required for planting, hr

4. Fuel Consumption Rate – the amount of fuel consumed by the prime mover in L/hr. (PAES 135:2004)

   $$fuel\ consumption\ rate = \frac{v}{t}$$

   where:

   v – volume of fuel consumed, L
   t – total operating time, hr

5. Percent Missing Hills – ratio of the total number of hills without stalks to the number of hills expressed in percentage. (PAES 152:2010)

   $$H_{pm} = \frac{H_m}{H_t} x\ 100$$

   where:

   H_{pm} – percent missing hills, %
   H_m – number of missing hills in the sampling area
   H_{pm} – total number of hills in the sampling area

6. Uniformity of Spacing – ratio of spaces that meet the pre-determined hill spacing to the total number of spaces in the sampling area expressed in percentage.

   $$S_p = \frac{S_c}{S_t} x\ 100$$

   where:

   S_p – uniformity of spacing, %
   S_c – number of correct spaces
   S_t – total number of spaces

7. Functional and Field Testing – the implement-type cassava planting machine was subjected to preliminary testing to determine its functionality. Possible problems encountered during the operation were addressed and adjustments were made. Afterwards, series of actual field testing was done to evaluate its performance.

Statistical analyses were carried out using single factor experiments arranged in completely randomized design with three replications. Simple cost analysis was made to determine the financial and economic indicators of the machine.

III. RESULTS AND DISCUSSIONS

Table 1 shows the cassava planting machine performance test using hand tractor as a prime mover of the machine. The cassava stalks were cut in a length of 17cm and loaded to the loading hopper.

Plowing Efficiency

Plowing efficiency was significantly affected by its travelling forward speed ($p<0.05$). The highest plowing efficiency 77.45% was obtained at a speed of 1.14kph ($p<0.05$). In normal condition, increasing the travelling speed of the planter would result to a decreased in plowing efficiency of the machine. This significant decreased in plowing efficiency could be due to wheel slippage and the combined weight of the hand tractor and the planter is light which likewise contributed to wheel slippage. This conformed to the findings of Ranibarian (2015) that as the forward speed of a light machine increased and so as wheel slippage. Hence decrease in plowing efficiency.

Planting Efficiency

Planting efficiency of the machine was not significantly affected when operated at 1.14 to 2.28 kph but significantly decreased when operated at 2.67 kph travelling forward speed. It was observed that as it increases speed from 1.14 to 2.28 kph planting efficiency were increased from 89.26% to 91.39%. The decreased in the planting efficiency at 2.67 kph was attributed to the increased in wheel slippage as the speed increases. It should be noted that planting efficiency is directly affected by wheel slippage since this parameter accounts for the number of hills. Moreover, number of missed hills is dependent on the rotation of the ground wheel. Hence, increased in travelling speed would result to decreased in planting efficiency. According to PAES standards minimum field efficiency for planters the machine was passed.

Actual Field Capacity

Actual field capacity is significantly increased from 0.09 to 0.19 ha/h when travelling speed increased from 1.14 to 2.67 kph, respectively. The increased of travelling forward speed could result to greater field capacity. The significant increase of the actual field capacity could be due to the shortly of time travelled in the effective area accomplished as travelling forward increases. Hence, actual field capacity increases.

Percent Missing Hills

Percent missing hills is significantly increased from 10.74% to 22.68% when travelling forward speed is increased from 1.14 to 2.67 kph, respectively. The increased in travelling speed could result to greater loss of missing hills. Significant increased in missing could be due to the increased in wheel slippage as the travelling speed increases. Moreover, when slippage occurred, the tendency of the cassava stalks shall not drop since the wheel of the planter is directly connected to the metering device of the machine. Hence, increased in percentage of missing hills.

Uniformity of Spacing

The uniformity of spacing between stalks were comparable when operated at 1.14 to 2.67 kph travelling speed. The increased in travelling forward speed could result to poor spacing between stalks.

Fuel Consumption Rate

The fuel consumption rate tends to increase with the increased in travelling forward speed. However, the analysis of variance revealed that the fuel consumption rate was comparable. This means that when operating the engine at a speed of 1.14 kph, 2.28 kph and 2.67 kph would incur a fuel consumption rate of 0.38 Lph.

Simple Cost Analysis

The cost analysis showed that the total cost of the machine P 10,442.00. The depreciation cost annually was P 939.78 with an estimated machine life span of 10 years. The salvage value was assumed to be 10% of the machine cost. The interest on investment was P 574.31 annually with an annual interest of 10%. The repair and maintenance of the machine was P 2,506.08 annually with a total fixed cost of P 1,722.93 annually. The total variable cost was P 40,714.08 annually. The benefit cost ratio was 7 which shows that the machine utilization is economically viable for small and medium scale farmers to use and operate. The annual net income was P 216,000. This means that a farmer could recover machine expenses within 20 days of continues operation of the machine for 8 hours per day to payback the operating cost and cost of the machine with an internal rate return of 87%. The net present value was P 178,130.99.

Table 1. Performance Evaluation Test of the Implement-type Cassava Planting Machine.

Operation Used	Speed, kph	Replication	Length of Stalks, cm	Plowing Efficiency, %	Planting Efficiency, %	Actual Field Capacity, ha/hr	Percent Missing Hills, %	Uniformity of Spacing, %	Fuel Consumption Rate, Lph
Diesel Engine Hand Tractor	1.14	3	17	77.45	89.26^{a}	0.09^{b}	10.74^{a}	26.19^{a}	0.40
	2.28	3	17	59.13	91.39^{a}	0.18^{a}	8.61^{a}	25.24^{a}	0.37
	2.67	3	17	59.70	74.94^{b}	0.19^{a}	22.68^{b}	14.29^{b}	0.38
ANOVA				**	*	**	**	*	NS
CV				8.89	4.17	27.33	273.77	18.7	3.65

*means in columns carrying the same letter are not significantly different from each other.

(a) (b) (c)

Figure 3. (a) Field testing of the implement-type cassava planting machine (b) Loading of cassava stalks (c) Representative views of the dropped cassava stalks by the machine.

IV. CONCLUSIONS

i. Development and performance evaluation of an implement-type cassava planting machine was successfully carried out.
ii. The machine has planting efficiency of 91.39% and performed best at operational speed of 2.28 kph.
iii. As the operational speed increased there was a decrease in the efficiency.
iv. The performance test and simple cost analysis indicated that the machine could be used economically.

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