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Development of potato (*Solanum Tuberosum* L.) haulm cutter

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Abstract. Manual haulm cutting using bolo is a practice of potato farmers in the Philippines prior to digging the potato tubers. The operation requires about 40 man-hours per hectare and with the current practice, the workers are exposed to risk of injuring themselves or their co-workers during the operation. This study was then conducted to develop a potato haulm cutter for potato farmers. The device was designed and fabricated using locally available materials. The working performance of the machine was evaluated using the following cutter speed: 833 rpm, 1115 rpm and 1392 rpm with three replications at an engine speed of 2526 rpm. Results revealed that the cutter speed of 1392 rpm gave the highest cutting capacity of about 0.15 ha/hr with field efficiency of 98 .64% and cutting efficiency of 88.33%. The machine capacity of 1457m^2/hr was five times higher than manual cutting capacity of 287 m^2/hr. Cost analysis of using the machine indicated a break-even point of 3.87 ha/yr. Cost analysis also indicated an expected income of ₱101,772.00 per annum and a payback period of 5.4 months for the haulm cutter cost. Finally, the machine was perceived acceptable and beneficial to the potato growers.

1. Introduction

In the Philippines, plantations of potatoes mostly found in the Cordillera Region, wherein 85 percent of the total potato production in the country was coming from Benguet and Mountain Province, while the remaining 15 percent was from the island of Mindanao [1]. In Benguet, potatoes are mostly grown in the municipalities of Buguias, Bakun, Kibungan, Atok, and Mankayan including some parts of the Mountain Province like Bauko, Sawmill, and Sadsadan. Potato production in these different municipalities is favorable due to its soil condition and temperature.

Potato production in the Philippines involves different operations from planting to harvesting. Most of these operations are carried out by hand. Harvesting the crop is one of the important field operations as this is the time that the farmers reap the fruits of their labor. The harvesting process involves the following field operations: a) cutting and collecting the haulms (stems) of potato, b) digging the fruits of potato, and c) collecting the potatoes.

Potato haulm cutting is one of the operations being done before digging the fruits of potato, this provides a fast and efficient harvesting. Haulm cutting is done manually by using a bolo or a sickle. In preparation for early harvesting, farmers usually cut the haulms of potato 10 to 15 days to expose its fruits to the sunlight to harden the skin before harvesting. The cutting and collecting of the haulms of potato is a labor intensive which involves 40 man-hours/ha and requiring much time, energy, and physical capacity to do the work. Mechanizing the field operation is deemed to be very necessary to

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reduce the drudgery of the operation, improve the safety of the workers, and increase precision and timeliness of operation.

Thus, this study was conducted to design and fabricate a potato haulm cutter that is adoptable to the small-scale mountainous enterprises of Cordillera particularly in Benguet. The operating performance in terms of field capacity, field efficiency, cutting efficiency, and fuel consumption were evaluated. These parameters were compared to the manual cutting operation. The cost of operations using the machine were also analyzed and the perception on the acceptability of the device were determined.

2. Methodology

Potato haulm cutting in other countries is done by a machine, which is faster and easier to operate. Such machine is not locally available in the Philippines. The current available machine is impractical to use on the topographical farm set-up in the country. The machine is also expensive and unaffordable. Hence, this study was conceived to develop a potato haulm cutter adaptable to the topographical situation of potato farms in the Philippines.

2.1 Design and Fabrication

To address the burden in haulm cutting in the Cordillera Region, the following considerations were observed in the design and fabrication of the potato haulm cutter: the machine must be a self-propelled, adoptability to the terrain condition of Cordillera Region, easily carried by four persons, can cut and shred the potato haulms and other foreign plants, must fit the majority of farm plots, materials must be available in the local market, should provide a significant reduction of labor force, and must be affordable. The design of the potato cutter components was based on available literatures and information in Philippine Agricultural Engineering Standards [2-5]. The fabricated potato haulm cutter has a five major components which are prime mover, transmission assembly, cutting unit, wheels, and handle.

2.2 Data Gathered

The primary data gathered for performance evaluation of the potato haulm cutter included the following: rotational speed of shafts (RPM), effective cutting time (sec), turning time (sec), wheel revolution, fuel used (L), cut haulms (count), uncut haulms (count) and manual cutting time (sec). These primary data are then used in computing the following machine-related data:

2.2.1. Forward speed (kph). This was calculated by measuring the time travel of the machine between two points at a known distance of 9 meters. The time incurred was measured using a stopwatch [6], which is 10.30 secs. Based on the data gathered, the forward speed of the machine was 3.1 kph.

2.2.2. Theoretical Field Capacity (ha/hr). The theoretical field capacity of the machine was calculated using the formula below [7].

$$C_T = \frac{SW}{10} \tag{1}$$

where:

C_T = theoretical field capacity, ha/hr
S = speed, kph
W = width of cut, m

2.2.3. Effective Field Capacity (ha/hr). The time consumed for the actual work including time lost for the activities like turning and adjustments was calculated using the formula below [7].

$$C_{ef} = \frac{A}{T_p+T_l} \tag{2}$$

where:

C_{ef} = effective field capacity, ha/hr
A = area covered, ha
T_p = productive time, hr
T_l = non-productive time, hr

2.2.4. Field Efficiency (%). The ratio of the effective capacity to the theoretical field capacity was calculated from the following relationships [7].

$$E_{ff} = \frac{C_{ef}}{C_T} \text{ x } 100 \tag{3}$$

where:

E_{ff} = field efficiency of the device,%
C_{ef} = effective field capacity, ha/ hr
C_T = theoretical field capacity, ha/hr

2.2.5. Fuel Consumption (L/hr). This was calculated using the fuel consumed in each replication over the digging time [6].

$$E_f = \frac{V_t\text{- } V_f}{t} \tag{4}$$

where:

E_f = fuel consumption, Lph
V_i = initial volume of fuel in tank, L
V_f = final volume of fuel in tank, L
t = time of operation, hr

2.2.6. Wheel Slip (%). This was determined using the formula below [6].

$$Wheel\ Slip\ (\%) = \frac{N_l\text{- } N_o}{N_l} \tag{5}$$

where :

N_l = the sum of the revolutions of all driving wheels for a given distance with load,
N_o = is the sum of the revolutions of all driving wheels for the same distance without load

2.2.7. Cutting efficiency (%). This is the ratio of the number of cut potato haulms to the total number of potato haulms per replication. This was calculated using the formula below [6].

$$Cutting\ eff. = \frac{total\ no.\ of\ cut\ haulms}{total\ no.\ of\ \ haulms\ in\ the\ test\ plot} \text{ x } 100 \tag{6}$$

2.3 Machine and Manual Cutting Performance

To determine if there are any significant impact on the introduction of the machine over the traditional or manual cutting, the machine performance was compared to the traditional cutting practice in terms of capacity and time consumed. Manual cutting capacity (ha/hr) is the ratio of the time (hr) spent to cut the haulms to the cut plot area (2). Cutting efficiency was computed using same equation used on machine (6).

2.4. Cost Analysis
A simple cost analysis was done in order to evaluate the financial and economic indicators of the potato haulm cutter. The total operating cost per hectare was estimated based on the acquisition cost and capacity of the potato haulm cutter. The following cost equations used in analyzing the cost of using the haulm cutter was based from the annual cost equations [8].

$$AC = FC + \frac{A(Vc)}{Ca} \tag{7}$$

$$BEP = \frac{FC}{CR - \frac{Vc}{Ca}} \tag{8}$$

where:

A	=	Annual area, ha/yr
AC	=	Annual cost, Php/yr
BEP	=	Break-even point, Ha
FC	=	Fixed Cost, Php/yr
CR	=	Custom rate, Php/hr
Vc	=	Variable Cost, Php/hr
Ca	=	Cutting Capacity, ha/hr

2.5 Acceptability of the Device
Viability of the device is measured not only through cost and return analysis. What matters most is that, the device is functional and acceptable by the end users. Nearby farmers were invited during the field testing evaluation to witness how the machine works and to operate the device. The farmers were requested to answer a simple survey questionnaire for the assessment of the operation. Assignment of weight for the acceptability questions were evaluated using the Analytic Hierarchy Process (AHP) specifically the pair-wise comparison.

2.6 Statistical Analysis
The data gathered in this study were analyzed statistically using single factorial experiment arranged in completely randomized design (CRD) with three replications. Analysis of variance (ANOVA) was used to determine whether the differences among the treatment means are significantly different. Duncan's Multiple Range Test (DMRT) was used to determine which among the means would be significantly different from each other.

3. Results and Discussion
The potato haulm cutter shown on Figure 1 is a machine that is capable of cutting and shredding potato haulms and other foreign plants present in the plots. It is a self-propelled machine and can be operated by an individual. It was designed using locally available materials and it was fabricated adopting the local manufacturing technology.

3.1 Machine Performance Characteristics
The machine performance characteristics were compared among treatments in terms of effective field capacity, field efficiency, cutting efficiency, fuel consumption, and wheel slip.

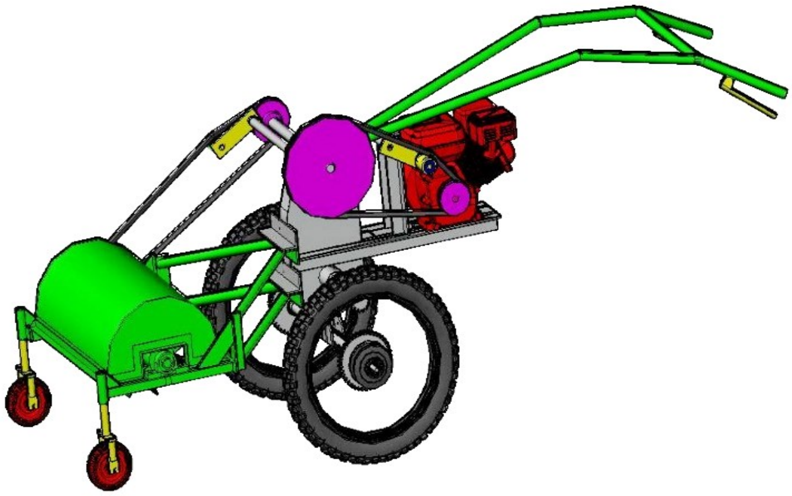

Figure 1. Perspective view of designed potato haulm cutter

3.1.1. Effective Field Capacity. The highest capacity was 0.146 ha/hr when operated at rotor speed of 1392 rpm followed by 0.144 ha/hr at 1115 rpm and the lowest capacity is 0.142 ha/hr at 833 rpm. While the effective capacity had an increasing trend as the rotor speed was increased, the analysis of variance indicated that rotor speed did not significantly affected the effective field capacity This was attributed to an almost constant forward speed since the engine speed was same for all treatments. The engine speed was also transmitted to the transport wheels independently to that of the rotor speed. The slight increase in field capacity as the rotor speed increased was attributed to the fact that the faster rotary speed of the blades might somehow have aided the forward travel of the machine. Hence, the total time of covering the whole area was somehow reduced with the rotor speed increased. These results agreed with the observation of Mausoud (1982) that field time is an important factor that must be considered when measuring the field capacity of any machine, spends in the field, measured from start of functional activity until the field operation is completed. The operation also entails mastery on the maneuverability of the machine to attain the maximum capacity and efficiency.

3.1.2. Field Efficiency. The machine attained its highest field efficiency (98.64 %) at cutter speed of 1392 rpm. Similarly, field efficiencies of 97.30 percent and 96.60 percent were observed at cutter speed of 1115 and 833 rpm, respectively. The differences in efficiency were not due to the failure of the machine to utilize its operating width, but mainly due to time losses incurred in turning at the headlands.

3.1.3. Cutting Efficiency. The highest cutting efficiency obtained was 88.33 percent, which was the result of operating the device at cutter speed of 1392 rpm. In contrary, the lowest cutting efficiency obtained was 84.77 percent at cutter speed of 833 rpm, result of the pulley combination of 127 to 127 mm (transmission assembly to cutter).

Result showed that the cutting performance of the machine increased as the speed of cutter dramatically increased from 833 rpm to 1,392 rpm, whereas, the cutting efficiency affectedly decreased with the decrease of cutter speed. The result of this study was similar with that of Godeša (2004) in which the researcher recorded that the higher the cutter speed, the higher the percentage of cut potato stalks.

3.1.4. Fuel Consumption. The lowest fuel consumption is recorded as 0.58 L/hr at cutter speed of 1392 rpm followed by 0.60 L/hr and 0.61 L/hr at cutter speed of 833 rpm and 1115 rpm, respectively whereas the forward speed is 3.1 kph.

This was an expected setting because the engine speed was set to 2526 rpm in order to maintain the forward speed of the machine that also complements the walking speed of the operator.

3.1.5. Wheel Slip. The highest rear wheel slippage is 28.89 percent was obtained using the device at cutter speed of 833 rpm followed by 20 percent for both 1115 and 1392 rpm. This anticipated scenario because treatments were tested is at fixed forward speed.

Factors seen which affected the wheel slip were the irregularities on the soil surface of the canal, presence of debris or solid materials such as stones, and soil moisture content. This soil moisture content has an effect on the slippage as Jebur et al. (2017) proved on his study that soil moisture content has a significant effect on the forward speed of a machine wherein, the higher the moisture content of the soil the higher the slippage on the wheels causing it to move slowly.

3.2 Manual and Mechanized Digging

Working performance between the machine and the manual cutting in terms of capacity and cutting efficiency showed that the machine cutting capacity was 1457 m^2/hr. This is five times higher than manual cutting capacity of 287 m^2/hr. The cutting efficiencies were 83.33 percent and 100 percent for the machine and manual cutting, respectively. The result of this study also assessed an 80 percent decrease on the traditional manual cutting operation from five man-days/ha to one machine-man-day/ha with the use of the fabricated potato haulm cutter.

3.3 Cost Analysis

Cost analysis of using the machine indicated a break-even point of 3.87 ha/yr based on the potato haulm cutter cost of ₱45,717.83 (covering materials and labor cost), machine capacity of 0.15 ha/hr and manual labor cost of ₱4,000/ha (contract based) as the custom rate. Using the machine in more than 3.87 ha/yr of potato farms justifies ownership of the machine. With the numerous potato growing areas and if the annual area of operation is increased to at least 10 ha/yr, the custom rate can be reduced to an amount of ₱3000 per ha. This has a profit margin already of about 50 percent. Moreover, the owner may also engage in custom service operation in order to gain additional profit. Cost analysis also indicated an expected income of ₱101,772.00 per annum and a payback period of 0.45 years for the haulm cutter cost.

3.4 Acceptability of the Device

Owning a machine is a decision to make, but it does not mean that the cost of such machine is the only factor to be considered. Although some considers the brand name in the selection, the machines' capability and adoptability to the local conditions as advertised by those who had seen and tried it is a great factor of consideration.

Based on the consolidated result, 100 percent of the respondents indicated that they would use the machine in the future, which also entails that the machine was acceptable to the farmers.

4. Conclusions

From the results of this study the following conclusions were made:

1. the developed potato haulm cutter can be fabricated by local machine shops using locally available materials and adaptable to potato growers even in highland areas;
2. cutting of haulms using the machine had an effective field capacity of about 0.15 ha/hr, field efficiency of 98.64 percent and cutting efficiency of 88.33 percent, thereby reducing the man-hour requirement of this operation by at least five times;
3. using the machine at engine speed of 2526 rpm, can consumed a fuel rate of 0.60 L/hr;
4. the machine can be used for custom service operations since the cost of haulm cutting can be reduced from ₱4000 per ha using manual labor to about ₱3000 per ha when done by the machine; and
5. the machine was perceived acceptable and beneficial to potato growers.

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