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RESEARCH ARTICLE

Development Of Red Onion (Allium Cepa L.) Stem Cutting Machine

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ABSTRACT

The developed Red Onion (Allium cepa L.) Stem Cutting Machine is a trolley-type cutting machine designed and fabricated to reduce production costs, labor, and time required for cutting onion stems. A single person can operate it. The machine weighs 64.8 kg and has overall dimensions of [illegible] mm in height, [illegible] mm in length, and 525 mm in width. The machine's major components include counter-rotating blades, counter-rotating gears, frame assembly, collecting bin, wheels, and power transmission assembly. Onions are fed into the input chute where the counter-rotating blades are located. The cut onions are collected in the bin below the machine. Three treatments were used to evaluate the study: 4[illegible]0 rpm, 660 rpm, and 990 rpm. The experimental layout followed Completely Randomized Design (CRD) and was analyzed using the Analysis of Variance test. The mean comparison was carried out using the Least Significant Difference (LSD) method, with a 5% significance level. The machine's performance was evaluated in terms of machine cutting capacity, efficiency, and energy demand. The results indicate that at 660 rpm, the machine achieved a Capacity of 57.91 kg/h, efficiency of 95.51%, and Energy demand of 4.3 W-h/kg. Cost analysis revealed that the machine needs to cut a total of 7,513.67 kg of onions to break even, assuming a custom rate of Php 1.30/kg. The payback period is approximately two and a half harvesting seasons. This machine is recommended for local onion farmers to help them streamline their post-harvest onion processing.

KEYWORDS:
Red Onion, Cutting Machine, Allium cepa L., Cost analysis, Post-harvest onion processing optimization

1 | INTRODUCTION

Bulb onion (Allium cepa L.), locally known as 'sibuyas,' is arguably one of the most essential culinary ingredients, not only in the Philippines but also worldwide. According to an article in Helgi Library, onion consumption per capita reached 2.29 kg in 20[illegible] in the Philippines [1]. During the same year, the country produced approximately 222.1 thousand metric tons of onions. Onions are cultivated in 22 provinces across the country, with Central Luzon contributing significantly, accounting for 51.9% of the total production at 19.74 thousand metric tons. The Mindoro, Marinduque, Romblon, and Palawan Region (MIMAROPA) rank second, comprising 42.4%, followed by the Ilocos Region at 2.6%. The most commonly grown varieties include red creole, yellow granex, and shallots or multipliers. The Philippine Statistics Authority stated that the peak onion harvest in Oriental Mindoro occurred in the municipality of Bulalacao in 2016, with an average yield of 7.2 MT/ha. According to benchmarking results, the product was exported to neighboring provinces such as Iloilo and Bacolod for further market utilization. With the enactment of the Agricultural and Fisheries Mechanization Act Law in 2013, continuous and extensive mechanization and modernization programs in agriculture have been implemented. According to Niravkumar Bulsara, data have been provided and updated for major crops, but not for onion crops. Harvesting and postharvest operations in onion production are still largely manual, with mechanical power only being utilized during hauling [2]. Tasks such as pulling onions, cutting stems and roots, cleaning, and bagging are all performed entirely manually with the assistance of small hand tools. The removal of onion of stems and leaves and roots requires the most labor in onion cultivation and management, and it is still manual operation [3].

At the present times onion are processed by hand labor after harvest to remove leaves and roots. This operation is referred as topping [4]. Mostly the matured leaves of onion were removed manually using sickle or knife which require a huge demand of labor thereby harvesting task consumes a significant amount of time [5] [6]. Also, with the scarcity of labors, it is very difficult to timely harvest the crop, which affects the shelf life of the onions. Timely harvesting is imperative for better storage, minimizing harvest losses and for higher storage life [7]. Based on benchmarking, onions are processed through manual labor starting from the growth of seedlings, transplanting, weeding, application of fertilizers, harvesting, and postharvest processes. One of the major reasons that slows down the postharvest process is the removal of leaves and other unwanted foliage from onions, including excess soil. Accordingly, the standard practice for trimming the foliage is to leave at least 2.5 cm of the stem at the neck [8]. A single person can cut 10 bags of red onions in a day, and it takes 30 people to cover one hectare. Given that one red bag of onions is equivalent to 25 kg and a laborer works 8 hours a day, the manual capacity for cutting onion leaves by a person is 31.25 kg per hour. Furthermore, the available manpower is unskilled and insufficient for performing the job effectively. As a result, manual labor results in non-uniformly cut onions, with many becoming unsellable. It also consumes a significant amount of time and labor. Hence, the main objective of this study was to develop a red onion (Allium cepa L.) stem cutting machine. Specifically, the study aimed to design the machine using locally available materials and fabricate it using local manufacturing technology. The performance of the machine was evaluated based on its cutting capacity and cutting efficiency. Additionally, the electrical consumption of the red onion stem cutting machine was calculated, and a simple cost analysis of using the machine was conducted.

2 | METHODS

2.1 | Conceptualization of the study

The design conceptualization of the study considered the issues associated with manually cutting the onion stem. Depending on the variety, harvest can occur 90 – 150 days after transplanting. Bulb onions are ready for harvesting when the leaves collapse, or 75% of the crop's tops have dried and fallen over. Post-harvest handling of onions involves curing, a process intended to dry the necks and outer leaves of the bulbs. Moreover, curing includes the removal of excess soil, trimming foliage, leaving a 2.5 cm section of stem at the neck, and placing onions in a single layer on a large flat tray [8]. Figure 1 illustrates the study's conceptual framework, employing the input-process-outcome methodology. The framework primarily aligns with the study's overarching goal of creating a Red Onion (Allium Cepa L.) Stem Cutting Machine.

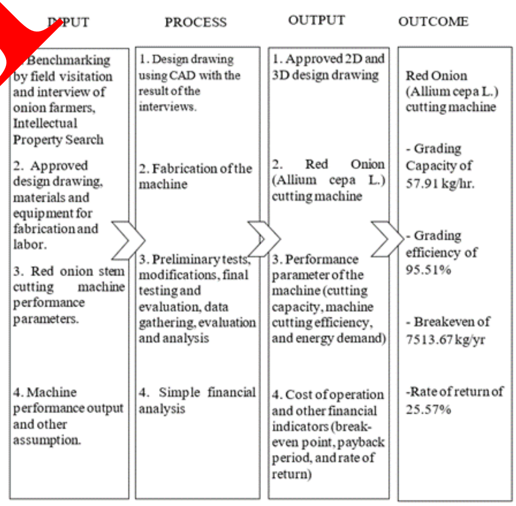

FIGURE 1 Conceptual Framework of the study

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2.2 Prior Arts

Prior research served as the foundation for designing and conceptualizing this machine. In the Philippines, there's a notable absence of locally developed machines for onion leaf cutting. Consequently, post-harvest onion leaf cutting heavily depends on manual labor, as confirmed during field visits. Although there are some onion leaf cutting machines available, they are primarily sourced from overseas, making them challenging to obtain and costly. Table 1 shows the existing machines used for onion leaf cutting, along with their specifications, features, and/or prices.

TABLE 1 Existing Onion leaf-cutting machine

NO.	MACHINE/DEVICE	SPECIFICATIONS/FEATURES/PRICE
1	Otake Onion Roots and Leaves Cutting Machine TK-3 [9] 	Specifications • Model Name: TK-3 • Length (mm): 780 • Width (mm): 355 • Height (mm): 705 • Weight (kg): 49 • Leave length (mm): 10 to 30 • Cutting method: Disk cutter • Conveying method: Holding • leaves by V belts • Conveying speed (mm/s): 120 • Motor: Single-phase 100V / 60W • Applicable onion size S to LL Diameter up to 120mm Height up to 115mm Leave length (mm) longer than 100 Dried onions only Price: **Php120,700.00**
2	Automatic Onion Leaf and stem cutting machine [10] 	Specifications Specially designed for cutting the leaf and root of fresh onion and dry onion. The worker needs to put the onion with leaf into the machine inlet hand one by one; it's very suitable for for fieldwork. The cutting depth can be adjusted according to the different sizes of the onion. If experienced worker, hourly capacity can reach up to 2000-3000kg Model: RM-RLC2 Type: Double Inlet Port Power: 0.37kW Dimension: 1100 x 800 x 1300mm Price: **Php35,000.00**

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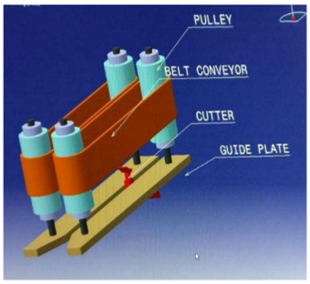
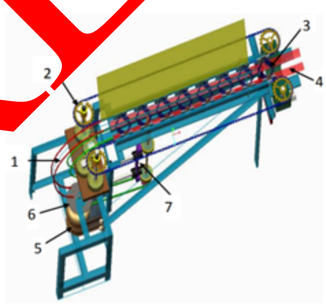
Table 1 continued from previous page

NO.	MACHINE/DEVICE	SPECIFICATIONS/FEATURES/PRICE
3	Onion Leaf Cutting Machine [3]  	Advantages To reduce Human effort and Labor costs. To replace the traditional method with an efficient one. To reduce the period between harvesting and packaging. To leave onion unharmed during the process with safety to the operator. Designed and fabricated a semi-automated machine to help the farmers sort out the onion effectively. It will reduce the yielding cost of farmers, and it will increase their profit in trading. The operation of the pneumatic Weeding machine is well-controlled. Well balanced system. It has higher efficiency than the old system. Only simple support structures are required. Design fabrication is easy. More accurate and economical in large-scale cutting operations. Faster cutting speed than conventional methods. It increases [illegible] safety and working conditions during cutting. Effective for longer period cutting Operations. Material is easily available for spear parts. Limitations Necessary of Electricity. In rural areas, there is a load-shedding problem. Maintenance is required. The setup cost is high. Application It is generally used for cutting off onion, beat, garlic leaves, and vegetables.
	Design of Onion Root and Shoot Cutting Machine [2]  	Legend 1-Toppling mechanism 2-Sprocket chain drive 3-Holding devices 4-Guideways 5-Motor 6-Disk type shoot cutter 7-Chain tightening mechanism

2.3 | Design and fabrication of the machine

The major components of the machine include counter-rotating blades, a counter-rotating gear, a handle, a frame assembly, a collecting bin, wheels, ventilation, and a power transmission assembly. Based on the results of interviews, workers who manually cut onion stems have no reference for the proper cutting measurements. A person can cut ten (10) bags of red onions in one (1) day. Therefore, the machine was designed to achieve a 2.5 cm to 5 cm cut from the bulb using a stopper. Figure 2 displays the perspective view of the red onion stem cutting machine.

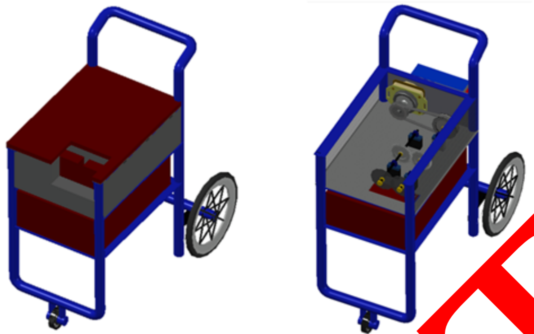


FIGURE 2 Red Onion (Allium cepa L.) Stem Cutting Machine Design and Perspective View.

2.3.1 | Counter-rotating blades

The machine consists of two counter-rotating blades, as depicted in Figure 3, which are made from stainless steel and attached to the gears via a shaft. The onion stem is wedged between these two blades, cutting it into the desired size. The rotation of the counter-rotating blades is dependent on the power transmitted by the gear [illegible]nt.

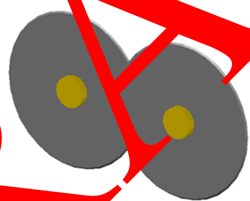


FIGURE 3 Counter Rotating Blade of the Machine.

2.3.2 | Power Transmission Assembly

The machine is versatile and suitable for both field and onion storage facilities. It can be directly plugged into an electrical socket for power or, as an alternative, can be operated using a rechargeable battery when electricity is not available. The design of the machine takes into account the placement of the battery. The power transmission assembly, as depicted in Figure 4, efficiently conveys power from the source to the moving components of the machine, including the shafts, pulleys, gears, and blades. The machine is equipped with a readily available ¼ hp electric motor for its power source.

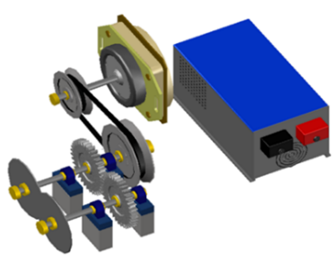


FIGURE 4 Perspective View of Power Transmission Assembly of Red Onion Stem Cutting Machine.

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The design of the power transmission was calculated with the used of the following formulas [11],[12],[13]:

$$N_1 D_1 = N_2 D_2 \qquad (1)$$

where N_1 is the diameter of the driver ($motor$); $N_2 = diameter$ of the driven shaft ($machine$); D_1 is the speed of the driver ($motor$) (rpm); $D_2 = speed$ of the driven shaft ($machine$) (rpm).

$$L = 2C + \frac{\pi}{2}(D_L + D_S) + \frac{(D_L + D_s)^2}{4C} \qquad (2)$$

where L is the length of the belt (mm); $C = distance$ between centers of pulleys (mm); $D_L = pitch$ of the large pulley (mm); $D_S = pitchdiameter$ of the small pulley (mm).

$$C = \frac{b \pm \sqrt{b^2 - 32(D_L - D_S)^2}}{16} \qquad (3)$$

where C is the center distance; $D_L = pitchdiameter$ of the large pulley (mm); $D_S = pitchdiameter$ of the small pulley (mm); $b = 4L_s - 6.28(D_L - D_S)$; $L_S = standardbeltlength.$

2.3.3 | Frame assembly

The frame serves as the enclosure for the machine. The frame assembly of the machine consists of metal pipes and flat metal, as illustrated in Figure 5. The machine's cover is constructed from stainless steel sheet. Checkered stainless steel is used on the right and left sides of the frame to prevent motor overheating. All components are securely installed onto the frame, which is designed to ensure the safe operation of the machine. During operation, it is constructed to withstand various loads and vibrations.

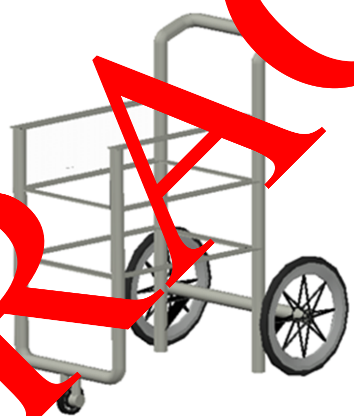

FIGURE 5 Perspective view of the frame assembly.

For the calculation of allowable stress,

$$\sigma_{Allow} = \frac{YS}{FOS} \qquad (4)$$

where σ_{Allow} is the Allowable Stress, MPa; YS = Yield Strength or Ultimate strength, MPa; FOS = Factor of Safety. To solve for Section Modulus, the following formula was employed:

$$z = \frac{1}{Y} \qquad (5)$$

where Z = Section modulus of hollow pipe; Y is the distance from Neutral Axis, mm; I = Moment of Inertia, N.mm.y
To solve for the ratio of gyration:

$$k = \frac{\sqrt{D_2 + d_2}}{4} \qquad (6)$$

where k = radius of gyration; D = outside diameter of the hollow pipe; d = inside diameter of the hollow pipe.

2.3.4 | Spur gears

The machine employed steel metal spur gears, shown in Figure 6. The driven pulley was connected to the gears via a shaft, and as the gears rotated, the attached blades also rotated. The number of teeth on the spur gear determined the speed at which the blades rotated [14]. Detailed calculations for the spur gear design can be found in Table 2.

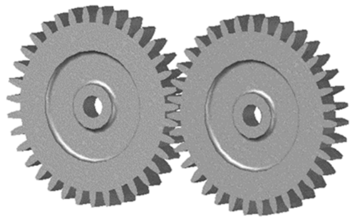

FIGURE 6 Counter-rotating gears of red onion stem cutting machine

TABLE 2 Spur Gear equations

TO OBTAIN	GIVEN	FORMULA
Module	Circular pitch	$\frac{Circularpitch}{\pi}$
	Number of teeth and pitch diameter	$\frac{Pitchdiameter}{Numberofteet}$
Pitch diameter	Number of teeth and module	Number of teeth x Module
Number of teeth	Pitch diameter and module	$\frac{Pitchdiameter}{Module}$
Tooth thickness of the pitch line	Module	1.5078 x Module
Outside diameter	Pitch diameter and addendum	Add 2 addendums to the pitch diameter
Minimum whole depth	Pitch	Coarser than 1.0583 module, 2.35 x module
Addendum	Module	addendum = module
Dedendum	Module	dedendum = 1.25xmodule
Clearance	Whole depth and addendum	Subtract two addendums from the whole depth
Center distance	Number of teeth of driver and driven gear, t_1 and t_1 Module	$\frac{module(t_1 and t_1)}{2}$

2.4 | Performance Parameters

The red onion stem cutting machine was evaluated as it was installed for normal operation. Red onion varieties were used as test materials with one person operating the machine for each treatment. Three replications were conducted for each treatment using the same materials as in the preliminary test. The treatment levels were determined by the number of revolutions per minute (rpm) or the speed of the driven pulley. The dimensions of the pulley necessary to achieve the desired speed for each treatment (440 rpm, 660 rpm, and 990 rpm) were calculated using Equation 1. Data were collected from the three rpm levels to determine which means performed best in terms of cutting capacity and efficiency. Other measured, observed, and computed items included: (a) machine capacity, (b) the number of cleanly cut onions (2.5 cm to 5 cm in length from the bulb), (c) the number of uncut/damaged onions (<2.5 cm and >5 cm in length from the bulb), and (d) the energy consumption of the machine. The test materials used during the evaluation were onions from Bulalacao, Oriental Mindoro, with fifteen (15) kilograms of onions utilized in each replication of the treatment.

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The following formulas were utilized for the purpose of this study. It was adopted from the Philippine Agricultural Engineering Standards (PAES):

For the input capacity of the device the formula used [15]:

$$C_i = \frac{W_i}{T} \qquad (7)$$

where C_i is the Input Capacity, Kg/hr; W_i = Weight of Input Materials, Kg; T = Operating Time, hr.
The Efficiency of the machine was computed using the formula:

$$E_s = \frac{W_s}{W_i} \, x \, 100 \qquad (8)$$

where E_s is the cutting Efficiency, Kg; W_s = Weight of cutted Materials, Kg; W_i = Weight of Input Material, Kg.
For the electrical energy demand of the device, the working formula used [16]:

$$E_d = \frac{Pi \, x \, T}{W_i} \qquad (9)$$

where E_d is the Energy Demand, $kW - hr/kg$; P_i = Power Input, Kw; T = Operating Time, hr; W_i = Weight of Input Material, Kg.

3 | RESULTS AND DISCUSSION

3.1 | Description of the machine

The developed Red Onion Stem Cutting Machine, as shown in Figure 7, aims to address the issues faced by local onion farmers. It has overall dimensions of 1050 mm in height, 1010 mm in length, and 525 mm in width. The machine is constructed from materials readily available in the market. Its major components include the input chute, collecting bin, frame, handle, ventilation, wheels, and the transmission assembly, all of which are enclosed by the frame. The fabricated machine operated in a continuous feeding mode, allowing materials to be fed into the machine continuously until completion, unless the machine clogged. The machine's design is optimized for single operator use. Loading of the input materials into the input chute commences once the machine reaches its maximum speed. Continuous feeding of red onions is sustained until the last stem is cut. Afterwards, the input materials descend into the collecting bin. The cutting action is executed by two sets of counter-rotating blades, powered by a 0.186kW electric motor. A pair of identical-sized spur gears is utilized to ensure the counter-rotation of the blades, thereby maintaining consistent RPM levels across the shafts. The specifications of the developed machine can be seen in Table 3, while Figure 8 illustrates a sample of the test materials before (a) and after (b) the cutting operation.

FIGURE 7 Perspective view of the fabricated machine.

FIGURE 8 The (a) freshly harvested onions and (b) the cut onions by the machine.

TABLE 3 Specification of the Red onion cutting machine.

ITEM	SPECIFICATION
Main structure	
Overall dimensions, mm	
Length	750
Width	525
Height	1000
Weight, kg	25
Power Transmission system	
V-Pulley	152.[illegible] diameter, single groove
V- Pulley	76.2mm diameter, Single groove
V-belts	Size A
Gear	127mm outside diameter, 32 teeth, AISI 1045
Shafts	12.7mm diameter, ASTM A36 Steel
Cutting Assembly	
Cutter blades	[illegible]30mm diameter, 1mm thickness, Stainless Steel 304
Prime Mover	
Electric Motor	0.186kW, Single Phase
Covers (Ventilated)	1mm thickness checkered Stainless
Frame Assembly	25mm hollow steel tube
Machine Performance	
Cutting Capacity	57.91 kg/hr
Cutting Efficiency	95.51%

3.2 | Performance Evaluation of the Designed and Fabricated Red Onion Cutting Machine

The performance of the red onion stem cutting machine was evaluated to determine its cutting efficiency (%), cutting capacity (kg/h), and energy demand (kWh/kg). Table 4 presents the parameters collected during the testing and evaluation of the cutting machine. It was found that the highest cutting capacity was recorded at 660 RPM, reaching 57.91 kg/h, with an efficiency of 95.51% and a total operating time of 15.81 minutes. However, the analysis of variance shows that there is no significant difference in the cutting capacity and efficiency of the device when subjected to different shaft speeds of 440, 660, and 990 RPM. The result might align with a study in 1987, which concluded that cutting speed slightly affected cutting power [17]. The study noted that power losses resulting from material acceleration often increased with higher cutting speeds. Additionally, in Ibrahim's study titled 'Development of a garlic root and stem cutting machine,' found that the most suitable conditions for optimizing cutting performance were observed at combinations of knife speeds ranging from 8.5 to 20.5 m/s or 406 to 979 RPM [5].

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TABLE 4 The performance of red onion (Allium cepa L.) stem cutting machine

	440RPM			660RPM			990RPM		
	R1	**R2**	**R3**	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**
Clean-cut (kg)	12.228	12.824	12.378	11.456	11.922	10.638	11.9	12.242	12.336
Uncut/Damaged (kg)	0.038	0.588	0.38	0.468	0.378	0.354	0.166	0.622	0.[illegible]
Time of Operation (minutes)	16.08	17.44	14.8	13.02	16.38	18.04	20.38	15.1[illegible]	23.4
Energy Demand	0.0048	0.0048	0.0052	0.0036	0.0044	0.0047	0.0052	0.004[illegible]	[illegible].0066
Cutting Efficiency (%)	99.69	96.48	98.68	95.12	96.93	94.48	96.91	[illegible]7.19	[illegible]39
Cutting Capacity (kg/hr)	55.56	51.72	60	68.18	55.56	50	44.12	60	38.4[illegible]

3.3 Cost Analysis

A simple financial analysis was conducted to assess the feasibility of the machine. The initial cost of the machine is Php 17,840.00, which includes the total material cost and fabrication cost. The estimated lifespan of the machine is at least 5 years, with a salvage value of 10% of the initial cost. The minimum wage in Oriental Mindoro was Php [illegible]0 per day. Table 5 shows the assumptions based on the data gathered. Table 6 presents the cost analysis of using the machine, and Figure 9 shows the cost curve of using the machine.

TABLE 5 Assumptions

ASSUMPTIONS	
Cutting Capacity	[illegible]7.91 [illegible]hr
Cutting Efficiency	95.51%
Wage/Labor (Or. Mind[illegible]imum wage	Php 320/day @ 8 hours of operation per day
Number of Operator[illegible]	1
Operating Time	8 hours
Annual Operation	480 hours
Power Consumption	0.186425 kW
Custom Ra[illegible]	Php 1.30/kg
Initial cost	Php 17,840.00

TABLE 6 Cost Analysis of using the machine

PARTICULARS	
[illegible]. Annual Fixed Cost	Php 4058.60/yr
Depreciation	Php 3211.20/yr
Interest on Investment	Php 490.60/yr
Tax and Insurance	Php 356.80/yr
2. Variable Cost	Php 21121.07/hr
Operator's Wage	Php 19200.00/yr
Repair and Maintenance	Php 892.00/yr
Power Cost	Php 1029.06/yr
3. Breakeven Point	7,513.67kg
3. Annual Revenue	Php 31618.86/yr

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4. Net Income	Php 6439.19/yr
5. Payback Period	2.49348 yrs (2 ½ harvesting seasons)
6. Rate of Return	25.57%.

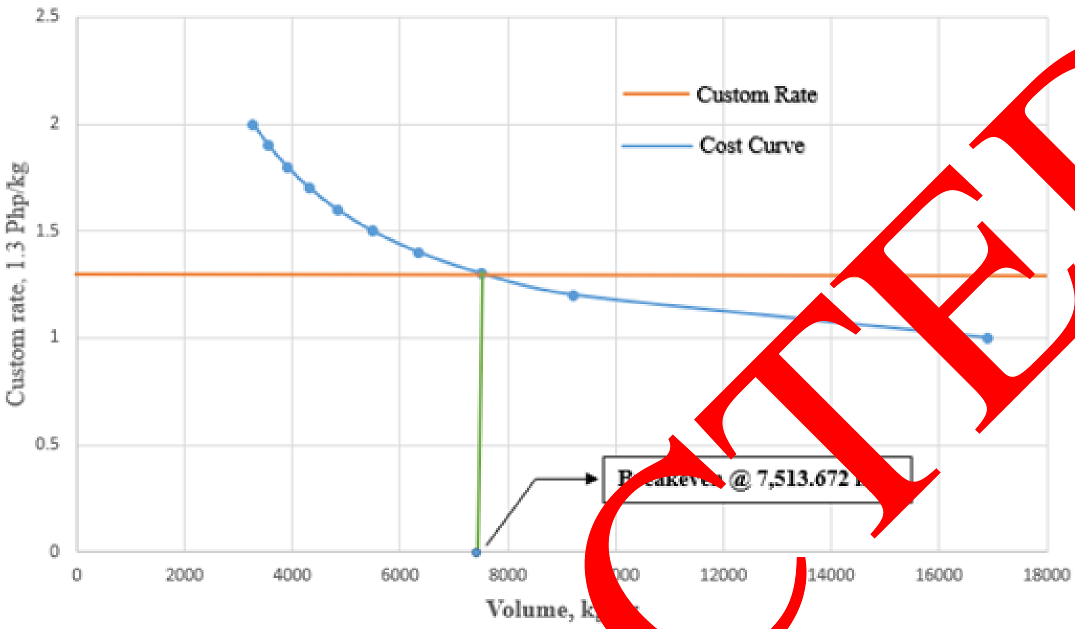

FIGURE 9 The cost curve of using the machine.

4 | CONCLUSIONS AND RECOMMENDATIONS

The development of the Red Onion (Allium cepa L.) Stem Cutting Machine represents a significant step towards addressing the challenges faced by local onion farmers. The study's objectives and findings lead to the following conclusions: Firstly, the developed Red Onion (Allium cepa L.) Stem Cutting Machine has proven its effectiveness in efficiently cutting red onion stems. This achievement holds substantial promise for optimizing onion harvesting and post-harvest processes. Secondly, the total cost of constructing the machine amounts to Php 17,840, utilizing locally available materials. This cost-effectiveness enhances accessibility for local farmers. Moreover, among the treatments tested, Treatment 2 (660RPM) demonstrated the highest cutting capacity at 57.91 kg/h, achieving an impressive cutting efficiency of 95.51%. This treatment employed a readily available 6-inch diameter pulley, offering practicality and convenience. In addition, the machine's power consumption proves to be economical, with an energy demand of 4.3 W-h/kg, as evaluated in Treatment 2. Given an electric rate of 11.5 Php/kWh in Oriental Mindoro, the operational cost per kilogram amounts to only 0.046 Php/kg, reinforcing its cost-effectiveness. Lastly, the machine exhibits promising financial viability, with a break-even point of 7,513.672 kg/year and a rate of return of 25.57%. The payback period is approximately two (2) years and five (5) months, equivalent to two (2) and a half harvesting seasons. These financial indicators underscore the machine's potential for economic sustainability and long-term benefits for local onion farming practices.

ACKNOWLEDGEMENT

To God be the glory!

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