Design, Development and Evaluation of a Mechanical Cacao Pod Bagger/Sleever

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Abstract— This paper presents a mechanical cacao pod bagger/sleever that is expected to address the challenges on cacao pod bagging. The developed bagging device will provide solution in increasing the farmers' productivity, reducing drudgery, and eliminate accident. Eighteen (18) trees, each with 20 pieces of pods ready for bagging, were randomly selected and assigned to (T1) mechanical cacao pod bagger and (T2) manual bagging method. Three (3) workers were assigned to perform both treatments (T1=3 workers, T2=3 workers). T-test was used to analyze the significant difference between two treatments. Result of the evaluation showed that the mechanical cacao pod bagger has an effective capacity of 311 pods/hr. It was almost five times faster than the manual bagging method (58.6 pods/hr). Further, statistical analysis presented that the mechanical cacao pod bagger capacity was significantly better than manual bagging at 0.000039 probabilities. Meanwhile, a marginal cost-benefit ratio of 2.72 showed that using the mechanical cacao pod bagger is economically feasible and viable.

Index Terms— Cacao, Mechanical Cacao Pod Bagger, Cacao Pod Borer, Bagger/Sleever

1 Introduction

BAGGING of fruits like guava, bananas, jackfruits and star apples was proven to be an effective method in controlling insects and pests. In the same way, bagging of cocoa/cacao pods at reasonable age is effective in reducing crop loss caused by cocoa pod borer (CPB). Multiple sets of studies on cocoa pod sleeving were conducted in April, 2004 to December, 2006 at Cocoa Research and Development Center, Hilir Perak, Perak, Malaysia. The study recorded the lowest CPB infestation on bagged pods compared to unbagged and pesticide treated pods.[1]

It was discovered that pest infestation of cacao pod borer has always been a serious problem. Several methods of controlling pests are employed on cacao production. The two methods found to be effective are application of pesticides and plastic bagging. The common practice is manually bagging the pods when they are about 8-10 cm long using plastic bags. The pods stay inside the bags throughout their maturation period. The farmers often need to climb the taller cacao trees with or without ladders when performing manual bagging. These method damages the leaves and branches including the pods for they will be detached from the tree. The same manual process of protecting the pods places the farmers at risk into falling. [2]

With the continuing growth and progress of cacao plantations in the Island of Mindanao especially in Davao Region due to high demand in the world market, there is a need to address problems on manual bagging or pest infestation. Manual bagging method has been observed to be effective, but laborious, time consuming, and prone to cause accidents. Wood and Chung [4] specified that sleeving of pods with plastic bags is effective but majority of the workers think that it is timewasting and completely hard to do. Saripah et. al. [5] stated that the practice of manual bagging method is laborious more so when cacao trees are tall. They put a cacao pod apparatus, called Eze-Jr sleever, into test and compared it with manual bagging method. Test results showed that the Eze-Jr sleever is capable of bagging 924 pods in an eight-hour operation, while the manual method can only take 428pods/day. In Mindanao, there has been no noted innovation or mechanism that makes bagging operation easier, faster, and safer. Thus, the development of a mechanical cacao pod bagger with provision of magazine type will increase the productivity of the farmer, reduce drudgery and eliminate accidents.

This paper describes the design, development and performance evaluation of a mechanical cacao pod bagger. The comparative performance between mechanical bagger and manual bagging is also presented in this paper. This paper also provides information on the economic viability of the device.

2 Methodology

2.1 Procedural Framework

Figure 1 shows the procedural framework of the study covering the design phase to report writing. If the pretesting of the first fabricated design prototype fails to provide satisfactory results (unable to meet criteria), a modification of

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component parts is required to be done. This process will be repeated until the desired functionality of every component is met. When the components' functionalities are satisfied, then testing evaluation stages follow.

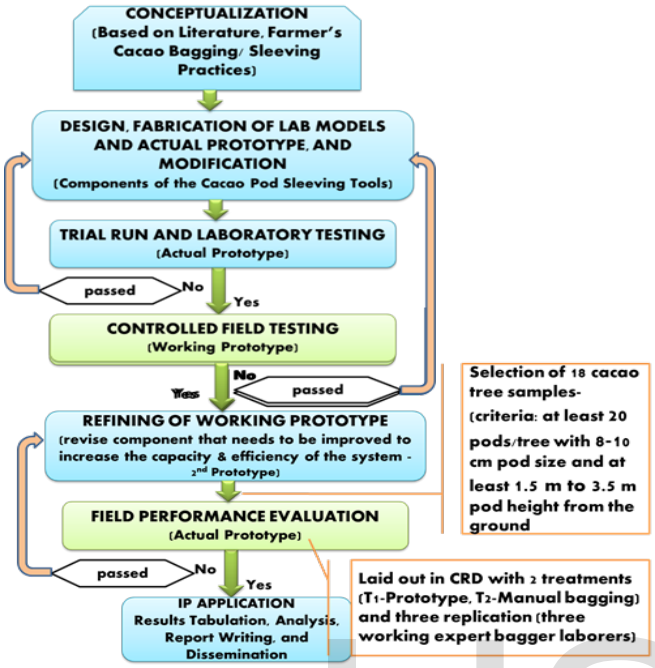

Figure 1. The Conceptual Framework

2.2 Conceptual Design, Design Criteria, and Materials of the Study

Majority of the materials used for fabrication were made of a lightweight PVC and aluminium supplies. The design criteria used in the development of the mechanical pod bagger includes: (1) simple and should be made in lighter materials, (2) adjustable length or replaceable pole based on the common height of working cacao tree, (3) should have higher bagging/sleeve capacity and more efficient than manual bagging on tree heights greater than 2-m, and (4) low cost and can be locally fabricated.

The conceptualized design was translated into plans with detailed specifications as shown in Figure 2. The concept design is to bag the young cacao pod measuring 2 cm to 4 cm in diameter which are unreachable by hand of the standing bagger. This can be achieved using plastic bag materials tied with rubber bands by a mechanical bagger without climbing the tree. A PVC pipe will be utilized as sleeving device where the plastic bag materials with rubber band are attached. Mechanisms in manual bagging method and using farmers design bagging tools were evaluated to come up with new design using the same materials such as PVC pipe, plastic bagging materials and rubber band.

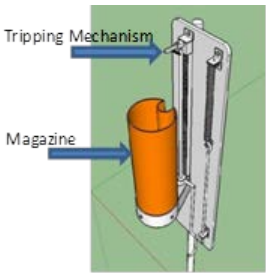

Figure 2. The Concept Design

The design of a sleeving device PVC pipe is fully inserted to a young cacao pod up to peduncle tip and the plastic bag with rubber band will be released using the tripping device at the end of the pole. The tripping device will be triggered using a cable wire or nylon twine. A sleeving PVC device will be made detachable and had enough length and space to serve as magazine of plastic bags of around 20 pcs to 40 pcs to hold (Figure 2). This will lessen the preparation of plastic bag during operation. The design will be made to provide an easier way to bag cacao pod using mechanical bagger instead of manually bagging the fruit.

2.3 Test Plants Condition and Experimental Set-up

Test plants were selected purposely based on the number of fruits. Every tree is required to have at least 20 young pods ready for bagging. Each test plant should be at least 10 years old measuring at least 1.8 m (6 feet) tall.

A total of eighteen test plant trees were randomly assigned to (T1) mechanical pod bagger/sleever and (T2) manual bagging operation (traditional) laid out in Completely Randomize Design (CRD) Experiment (Figures 3). Three expert operators/laborers were chosen and randomly assigned to the test plants to do the manual method and using mechanical pod bagger. Each bagger operator performed replication.

Figure 3. Mechanical bagging (left) Manual Bagging (Right)

2.4 Bagging Operation using the Mechanical Bagger

The following steps for the operation of the mechanical cacao bagger were as follows:

(1) An option on preparation of plastic bagging materials shall be carried out either in the home or farm shed before the operation. A plastic bagging material shall be loaded or inserted into the PVC magazine with around 20 to 30 pcs. Each plastic bag shall be accompanied with rubber bands which serve as tying material.

(2) The prepared magazine shall be loaded to the mechanical bagger ready for the bagging operation.

(3) Each bagging material will be lifted near the tip of the magazine and shall be position on the peduncle of young cacao pod (Figure 5).

(4) After positioning the magazine into the cacao pod peduncle, a tripping device is connected into the cable to release the plastic bag and tied to the cacao pod.

(5) The operation will be repeated on the next pod.

2.5 Data Gathering and Analysis

Time of bagging operation was recorded in every tree and treatment which pertains to manual bagging operation and with the use of mechanical cacao fruit bagger. Bagging performance was measured in terms of effective bagging capacity on both the mechanical pod bagger and manual bagging.

Actual field (effective) bagging capacity is the number of pods bagged over the total bagging operation time. Total bagging operation includes the time of climbing the tree, bagging materials preparation and actual time of bagging. Actual bagging time is the period covered from preparation of bagging materials, pointing/inserting bag to the fruit, tying the plastic bag, and picking of another bag in preparation on the next pods.

T-test or ANOVA was used to analyse the significant difference between the traditional method and using the mechanical cacao pod bagger.

Economic analysis of using mechanical pod bagger was computed using the marginal benefit cost ratio. Assumption of service area of 1 to 5 hectares (ha) was considered in this study with 1,100 trees per hectare. Each bearing tree is estimated to provide 70 pods per tree-yr. Labor for manual bagging and using mechanical pod bagger is P 250.00 per day-man with effective working time of 7 hours. The ratio of savings for the labor using the mechanical pod bagger was then divided to the annual total cost to determine the marginal benefits cost ratio.

3 Result and Discussion

3.1 Description of the Mechanical Cacao Pod Bagger

A lot of difficulties are experienced by the cacao farmers during the pre-harvest and crop maintenance, specifically in bagging the cacao pods. Excessive and prolonged operation time is consumed in inserting each of the cacao fruit into a bag and tying. Difficulty and risks in climbing cacao trees are also experienced by the farmers during the manual bagging operation coupled with significant amount for manual labor. The development of this device is beneficial in the crop care and maintenance of cacao. It is made up of locally available and light materials for easy fabrication and operation. This mechanical cacao pod bagger can also be used with cacao pods in taller trees safely.

The mechanical cacao pod bagger consists of a base plate, a replaceable 15 cm long, 5 cm PVC diameter magazine, a magazine holder, a trigger/tripping device and a removable pole. It has a magazine where the cellophane bag and rubber band is placed for the continuous bagging operation and a trigger mechanism which removes the rubber band as the pull string is released and fastens the bag that sacks the cacao fruit. The magazine has a capacity of but not limited to 20 pcs of plastic bags with rubber bands (Figure 4). Furthermore, the trigger device provided with fastening is meant to prevent the difficult and time-consuming bagging operation of cacao fruits. It was fix-welded to the upper end of the left return spring connected to the trigger guide horizontally positioned above the left return spring. The lower end of the left return spring is connected to the left rod guide welded together with the right rod guide and is connected to the hook operably coupled to the pull string. The trigger device can only be folded upwardly for it to pass through the tube slot blocked with rubber band as the magazine is inserted downwardly in the magazine holder. The tube slot is located in the magazine facing the trigger.

When the pod to be bagged is positioned inside the bagger the string attached is pulled as a result tripping mechanism will be pulled downward passing through the rubber band' which held the bag to the magazine. The pulling of the tripping mechanism will create a big potential energy and when released the energy gained during pulling will push the rubber band and the bag upward towards the cacao pods.

Figure 4. The bagger and magazine

3.1 Performance Evaluation

The performance of the mechanical bagger was tested in terms of pod height variation (Table 1). Higher bagging capacity was obtained between 1.5 to 2.5 m high cacao pods with 2,881 pods per day (8-hrs working condition). It was much easier to bag pods at the lower level height than at the height of 2.5m to 3.5m. There was a slight decreased in bagging capacity of approximately 27.08 percent when bagging pods at more than 2.5 m high. At this height, it is difficult to position the bagger because of the branches and leaves covering the pods.

The performance of the mechanical bagger and manual bagging method in terms of bagging capacity was tested on cacao trees having pods on 1.5 m to 3.5 m high. Results of the evaluation showed that the mechanical cacao pod bagger had an effective capacity of 2,488 pods for 8-hrs day of work (Table 2). This bagging capacity result was almost thrice the capacity of Eze-Jr cacao pod sleever apparatus conducted by Saripah et. al. (2005). Moreover, it is almost five times faster than the manual bagging method which was results of this testing experiment (468 pods/day) and manual bagging method of 428-pods/day [5].

When the two methods were compared, statistical analysis

showed that the mechanical cacao pod bagger's capacity was significantly better than manual bagging at 0.000039 probabilities (Table 3). In addition, no damage was found on the cacao tree while using the mechanical cacao pod bagger during the operation.

Table 1. Effective Capacity of Mechanical bagger

Treatment (Pod Height)	Replication (pcs/hr)	
	R1	R2
1.5m to 2.5m	363.64	367.35
2.5m to 3.5m	267.33	257.12

**Mean with different letters is significantly different @ 1% level. (probability 0.00458)*

Table 2. The effective capacity of mechanical pod bagger vs manual bagging method

Treatment	Replication (pcs/hr)	
	R1	R2
T1 Mech. pod bagger	315.48	312.24
T2 Manual bagging	58.04	59.19

**Mean with different letters is significantly different @ 1% level. (probability 0.000039)*

3.1 Operating Cost, Savings and Marginal Benefit-Cost Ratio

Table 4 shows the economic analysis of cacao production using manual bagging and with mechanical cacao pod sleever. Initial investment cost of the mechanical cacao pod sleever is Php 650.00 with computed fixed cost of Php 367.25 per year. For the computation of variable cost, it was assumed that the service area of the device covering one (1) to ten (10) hectares (ha) per year. Each hectare of land is planted with 1,110 cacao trees with an average yield of 70 pods/tree-year. Laborer will be paid a daily rate of Php 250.00 for both manual bagging and using the mechanical bagger in 7-hr effective working time. Based on this given data, the computed total operating cost using the mechanical bagger was Php 412,426.55. Considering that the effective mean capacity using mechanical pod bagger and manual bagging method are 311.39 pc-pods/hr and 58.85 pc-pods/hr, respectively, this would corresponding result to total labor savings of Php 228,666.41 per year (Php 38,111.07 per yr-ha). This data translate into a marginal benefit cost ratio of 2.72 to 2.79. This indicates that investing Php 1.00 will triple (3x) the investment. It is therefore economically viable and low in cost. Moreover, Saripah et.al. (2005) suggested that to minimize the cost of materials and labour, it is suggested to combine manual plastic sleeving technique for lower pods position and Eze Jr Sleever for a high pods position. The mechanical cacao pod sleever has the advantage over Eze Jr apparatus since it can do the job-sleeving for both lower and higher pods position.[5]

Table 3. Marginal Benefit Cost Analysis

Investment Cost	**650.00**	**650.00**	650.00	650.00
Fixed Cost				
Depreciation (3 years)	195.00	195.00	195.00	195.00
Interest on Investment (25 %)	178.75	178.75	178.75	178.75
Tax (0) and Insurance (1%)	6.50	6.50	6.50	6.50
TOTAL Fixed Cost	**367.25**	**367.25**	**367.25**	**367.25**
Variable Cost				
Repair and Maintenance (10 %)	65.00	65.00	65.00	65.00
Labor Cost @ (Php 250/day)	53,536.98	44,614.15	8,922.83	89,228.30
Service Area	6ha	5 ha	1 ha	10 ha
# Cacao tree per ha = 1,110 @ 3 -m spacing				
# Cacao pod per tree = 70 pcs/year				
Effective working time = 7 hours/day				
Mean bagging capacity = 311 pods/hour				
of the prototype				
Plastic Bag Cost (Php 70 per 1000 pcs)	32,634.00	27,195.00	5,439.00	54,390.00
Rubber Band Cost (Php 44 per 500 pcs)	41,025.60	34,188.00	6,837.60	68,376.00
TOTAL Variable Cost	**127,261.58**	**106,062.15**	**21,264.43**	**212,059.30**
TOTAL OPERATING COST (Prototype bagger)	**127,706.83**	**106,507.40**	**21,631.68**	**212,426.55**
TOTAL OPERATING COST (Manual Bagging))	**355,862.99**	**296,552.49**	**59,310.50**	**593,104.98**
Mean manual bagging = 59 pods/hour				
LABOR SAVINGS	**228,666.41**	**190,555.34**	**38,111.07**	**381,110.69**
TOC (Prototype without depreciation & Investment)	127,333.08	106,133.65	21,257.93	212,052.80

Table 4. Marginal Benefit-cost ratio and net present value for 3 years life span and 1 ha service area

ITEM	YEARS				
	0	1	2	3	Total
Cash inflow (Total operating cost manual bagging)	0	59,310.50	59,310.50	59,310.50	177,931.5
Cash outflow					
Equipment cost	650				
Operating cost	0	21,257.93	21,257.93	21,257.93	63,773.79
Amortization (650/3 years)	0	216.67	216.67	216.67	650.01
Total cash outflow (prototype operating cost)	650	21,474.60	21,474.60	21,474.6	65,073.8
Net cash flow (savings of using prototype)	-650	37,835.90	37,835.90	37,835.9	112,857.7
Discount factor (25%)	1	0.8	0.64	0.512	
Present value benefits	0	47,448.40	37,958.72	30,366.98	115,774.1
Present value cost	650	17,179.68	13,743.74	10,994.99	42,568.42
Net present value	-650	30,268.72	24,214.976	19,371.98	
Marginal Benefit/cost ratio					**2.72**

4 CONCLUSIONS

Based on the results of this study, the mechanical cacao pod bagger performs in accordance with the design criteria and considerations. The mechanical cacao pod bagger performed better/higher bagging capacity and efficiency than manual method. It is portable, easy to operate, and user-friendly even if the user is new to bagging operation. It is much safer to use and risk-free because the operator does not need to climb the tree when the pods are unreachable by hand. Moreover, it is low cost, easy to fabricate even in small scale local fabrication shops since the design is made of PVC pipe and aluminum materials.

5 REFERENCES

[1] Saripah, B and I. Azhar, 2014. Implementation of Cocoa Pod Sleeving in Controlling Cocoa Pod Borer Infestation. In Proceedings 2007 Conference on Plant Plantation Commodities. 3-4 July 2007, Kuala Lumpur, Malaysia. Pp 221-227

[2] Cocoa Industry Development Sub-committee, 1996. The World Cocoa Economy: Past and Present.

[3] Wood, B.J. and Chung, G.F. (1989) Integrated management of insect pests in cocoa in Malaysia. Planter 65 (762): 389-418

[4] Azhar, I and M.A. Sabudin. (1988). A field evaluation of an insecticide formulation for the management of cocoa pod borer (Lepidoptera: Gracillariidae). MARDI Res. J. 16: 181-186.

[5] Saripah, B., Azhar, I., Roslan, S. & Abdul Shukor, M. 2005. Efficacy of Pod Sleeving in Cocoa Pod Borer Management. In Proceedings of 4th Malaysian International Cocoa Conference (MICC). Kuala Lumpur, Malaysia 18th –19th July 2005. Pp. 169-175.