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Design, Fabrication and Performance Evaluation of Mobile Engine-Driven Pneumatic Paddy Collector

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Abstract**—**A simple mobile engine-driven pneumatic paddy collector made of locally available materials using local manufacturing technology was designed, fabricated, and tested for collecting and bagging of paddy dried on concrete pavement. The pneumatic paddy collector had the following major components: radial flat bladed type centrifugal fan, power transmission system, bagging area, frame and the conveyance system. Results showed significant differences on the collecting capacity, noise level, and fuel consumption when rotational speed of the air mover shaft was varied. Other parameters such as collecting efficiency, air velocity, augmented cracked grain percentage, and germination rate were not significantly affected by varying rotational speed of the air mover shaft. The pneumatic paddy collector had a collecting efficiency of 99.33% with a collecting capacity of 2685.00kg/h at maximum rotational speed of centrifugal fan shaft of about 4200rpm. The machine entailed an investment cost of P 62,829.25. The break-even weight of paddy was 510,606.75kg/yr at a collecting cost of 0.11 P/kg of paddy. Utilizing the machine for 400 hours per year generated an income of P 23,887.73. The projected time needed to recover cost of the machine based on 2685kg/h collecting capacity was 2.63 year.

Keywords**—**Mobile engine-driven pneumatic paddy collector, collecting capacity and efficiency, simple cost analysis.

I. Introduction

RICE farming in the Philippines took a complete turn when modern technologies were introduced which include the adoption of high yielding varieties, application of inorganic fertilizer, better crop pest control, water management, and other improved farming practices. The immediate adoption of these new technologies was the result of a greater demand to increase production to cope with the fast growing population of Filipinos which was estimated to grow to 103 million by the year 2015 AD[7].

The adoption of improved production technology increases yield and likewise gives birth for new challenges on how to deal or handle tons of wet paddy that need to be dried to maintain good rice quality, storability and high commercial value [5].

Drying is the process that reduces grain moisture content to a level where it is safe for storage. Drying is the most critical operation after harvesting a rice crop. Delays in drying, incomplete drying or ineffective drying reduce grain quality and result in losses. Drying and storage are related processes and can sometimes be combined in a piece of equipment (in-store drying). Storage of incompletely dried grain with moisture content higher than the acceptable level leads to grain deterioration regardless of storage facility used. In addition, the longer the desired grain storage period, the lower the required grain moisture content must be [9].

Confronted by problems on drying, the government activated various agencies like the Department of Agriculture (DA), National Food Authority (NFA), Philippine Rice Research Institute (PHILRICE), Philippine Center for Postharvest Development and Mechanization (PHILMECH), and other institutions to take steps to ease the problems.

To date with all the postharvest technologies being developed and offered by the government, there are gray areas in the postharvest aspect of drying paddy that should harmonize with the practice of small farmers as well as big rice millers and traders.

Several drying technologies were introduced to farmers, big rice millers and traders. The rate of return from sun drying operation is high while the rate of return from the best mechanical dryers available in the country is low. Farmers unanimously use sun drying and none adopts mechanical dryers [12]. In the light of this development and present practices, it is obvious that sun drying will stay as one of the post harvest technologies in the Philippines.

Angeles cited the inappropriateness of imported technologies over the country's socio-economic conditions had created awareness of developing our own equipment and machine out of local materials using locally manufacturing technologies and manpower [2]. Owing to significant development of sun drying as a socially accepted technology and its possibility of development through mechanization, he also added that continuous efforts have to be undertaken to conduct development studies of local machinery based on the appropriate features of existing commercial machinery from developed countries and emerging economies.

It is for this reason that this research was undertaken to design, fabricate a pneumatic paddy collector out of local material using locally manufacturing technology and man power that would help farmers, rice traders and millers to contribute to the reduction of losses, save time, labor, and cost of collecting and bagging.

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II. Materials and Methods

A. Conceptual Framework

The traditional sundrying method of a paddy is still widely practiced by most farmers. The practice includes hauling of a paddy in bags to the drying area, spreading out the paddy in the drying floor using wide board, then evened and slightly furrowed with wooden rakes. Mixing and turning the paddy are done regularly to ensure that the paddy is dried evenly. After drying, the paddy is piled using a wooden board. After wards, the paddy is placed into a bag using a metal scoop (Panake). All of the above operations are done manually consuming too much time and effort [5]. Collecting and bagging operation is considered one of the difficult tasks in sundrying.

This study was then conceptualized by looking into existing designs of pneumatic conveyor from developed, emerging and developing countries that could replace manual bagging and collecting of paddy on concrete pavement during sundrying. Based on the results, good features of the existing design were considered for adoption, adaptation, and simplification to come up with the prototype machine. Design requirements satisfying local condition were identified. Design data then were based on market information of available parts and components of machine. Based on design requirements and design data, a design drawing was prepared. Fabricated prototype was subjected to evaluation to determine its operating characteristics. Fig. 1 shows the conceptual framework of the study.

INPUT	• Relevant information gathered on existing design of pneumatic paddy conveyor, paddy characteristics, and availability of machine parts and components
⬇	
PROCESS	• Design conceptualization, calculations and design plan of the machine • Fabrication of machine components • Performance evaluation of the machine
⬇	
OUTPUT	• Mobile engine-driven pneumatic paddy collector • Operating characteristics of the machine

Fig. 1 Conceptual framework of the study

B. Design of Major Components

Design requirements were synthesized based on the analysis of findings in the various literatures reviewed and from patented and commercial pneumatic paddy collectors. Some of the identified design requirements were the following: 1) the machine should collect paddy at varying thickness under sun drying condition and bag the same; 2) the machine should help reduce drudgery and quicken collecting and bagging of paddy during sun drying; and 3) the machine should be of intermediate technology, made from local materials using local manufacturing technology, simple and safe to operate and maintain, functionally and structurally sound, and with minimum tooling [2]

1. Power Transmission System

Design of power transmission system was based on Philippine Agricultural Engineering Standards [13]. The design data gathered from the literature reviews that were considered in the design were the following:

a. Prime Mover
- ✓ Power : 7.5kW[10]
- ✓ High speed engine to match the required rpm of the air mover
- ✓ Engine shaft diameter: 25.4mm
- ✓ Direction of drive shaft rotation: counterclockwise

b. Air mover
- ✓ Service factor (Delivery): 1.3 [13]
- ✓ Direction of driven shaft rotation: clockwise

2. Air Mover

The air mover used in the study was radial flat bladed centrifugal fan. The blade 380 mm Ø is like a paddle wheel with side rims. The blades were perpendicular to the direction of the wheel's rotation and the fan runs at a relatively medium speed to move a given amount of air. The radial blade type was designed for material handling applications, features rugged construction and simple field repair.

3. Suction Nozzle Assembly

Design of the suction nozzle assembly was based on Walinga design. Design data needed in the design were the following: 1) thickness of paddy when drying in concrete pavement, 2-4cm [8]; 2) diameter of the suction pipe, 80mm; and 3) anthropometric data such as knuckle-to-elbow length, elbow height, and hand grip diameter. Overall length of the suction nozzle assembly was determined using (1) [6].

$$z = \frac{y + x\cos ß}{\sin \Theta} \tag{1}$$

where: z = overall length
y = elbow height
x = knuckle-to-elbow length
ß = angle made by arm from the vertical, 110^o
ϴ = angle made by the handle with the horizontal, 45^o

4. Air-paddy Separator

Cyclone separator was used as air paddy separator. Design of the cyclone separator was based on the diameter (d) of the suction pipe and the recommended typical proportion of cyclone separator [15]. Dimension of the cyclone separator was determined using (2)-(4).

$$L = 2d \tag{2}$$
$$Lc = 3L \tag{3}$$
$$Db = Du/3 \tag{4}$$

where: D =diameter of the suction pipe, mm
L =height of the cylindrical portion, mm
Lc =height of the conical portion, mm
Db =bottom diameter of conical portion, mm

Du =upper diameter of the conical portion,

C. Fabrication and Assembly of the Machine

1. Power Transmission System

A 14.20-hp air cooled, four stroke cycle, single cylinder, direct injection, high speed diesel engine was used as prime mover of the paddy collector. The prime mover was connected to the frame using high strength 10 mm Ø x 75 mm bolt. The power from the prime mover is transmitted to the shaft of centrifugal fan using 200 mm Ø double groove driver pulley, 125 mm Ø triple groove driven pulley, and 2 pieces of V-belts (B-81 section)

2. Air Mover

A radial flat bladed centrifugal fan was used as air mover of the machine. The blade 380 mm Ø was like a paddle wheel with side rims. The blades were perpendicular to the direction of the wheel's rotation and the fan runs at a relatively medium speed to move a given amount of air. Prior to the installation of the centrifugal fan, a 10 mm Ø hole was made using power drill. The centrifugal fan was connected to the frame using 10 mm Ø x 37.5 mm bolt with nut and washer.

3. Conveyance System

The conveyance system of the paddy collector included suction nozzle assembly, suction hose, air- paddy separator, check valve, and diverter valve assembly.

Suction Nozzle Assembly

The suction nozzle is an important device in vacuum conveying system. The suction head was flat. A gauge 16 galvanized iron sheet was used in the fabrication of the rectangular suction nozzle head. Downstream portion of the suction nozzle assembly was made of 80 mm Ø PVC pipe. It was provided with a G. I. pipe handle and two 37.5 mm Ø plastic wheels to regulate the suction depth during operation.

Suction Hose

A 75 mm diameter, 3 m long vinyl wire reinforced flexible hose was used as conveyance line from the suction nozzle assembly to the air-paddy inlet of the cyclone separator. The air outlet at the top of the cyclone separator was connected to the air inlet of the centrifugal fan using 100 mm vinyl wire reinforced flexible hose.

Air- Paddy Separator

A cyclone separator was used as air-paddy separator of the machine. The cyclone separator included a 600 mm Ø x 300 mm high cylindrical and 600 x 150 x 900 mm (upper diameter x lower diameter and height) conical truncated housing. The cylindrical housing has a 100 mm Ø axial air outlet at the top, and a 100 x 100 mm tangential air-paddy inlet at the upper wall. The conical-shaped housing was provided with a paddy outlet at the bottom in communication with the inlet of check valve and swing diverter assembly. The cyclone was made of gauge 16 galvanized iron sheets. The cyclone separator was supported by angular bar welded to the main frame and it was installed just above the bagging area of the machine.

Check Valve and Paddy Diverter Assembly

A swing diverter assembly was used to divert the flow of paddy into two routes for continuous bagging during operation. The assembly was made of 2.3 mm thick mild steel plate, flange bearing attached to the side wall of the valve that supports the 12 mm Ø swing gate shaft, and 15 mm Ø G. I. pipe connected to the 25 x 6 mm flat bar arm of the swing gate shaft to actuate the swing gate in diverting the flow of paddy during bagging operation. The check valve was made of 2.3 mm thick mild steel plate; the gate was made of rubber and 2.3 mm thick MS plate welded to a 12 mm square bar; the square bar was connected to a level arm made of 6 mm x 25 mm flat bar, 10 mm Ø x 75 mm bolt with nut and 6 mm thick 75 mm Ø circular plate; the lever arm was connected to the round bar of the fabricated cylinder hinges made of G. I. pipe.

4. Bagging Section

The bagging section below the cyclone separator supports two sacks to be filled with paddy alternately for continuous bagging during operation. It was made of a 2.3 mm thick mild steel plate welded from the top of a channel bar main frame. A framed wire mesh was provided between the flat base part of the bagging section and the prime mover to protect the sack from the moving parts of the prime mover and the power transmission system. A hook welded to the frame wire mesh and the diverter valve was provided to hold the sack during bagging operation.

5. Frame

The main frame was fabricated using 75 mm channel bar and 6 x 40 mm angular bar cross members. Upper support frame connected to main frame was made of 6 x 40 mm angular bar. The main frame was provided with two swivel caster rear wheels and two solid rubber front wheels and 32 mm Ø G. I. pipe push handles for mobility.

D. Principles of Operation

A 14.20-hp air cooled, four stroke cycle, single cylinder, direct injection high speed diesel engine provides power through the V-belt and pulley transmission system to drive the radial flat bladed centrifugal fan. The centrifugal fan provides suction to collect paddy without passing through the impeller of the fan. Paddy is collected and conveyed by an intake air stream through the suction nozzle and flexible hose where it is drawn to the cyclone separator. When the air-paddy mixture enters the cyclone separator, the paddy is separated from the air; the air is drawn to the inlet of the centrifugal fan while the paddy falls down because of its weight and centrifugal force which cause it to move outward toward the wall during its downward helical travel. As the paddy approaches the wall, the velocity decreases because of wall friction and the paddy settles into the bottom of the cyclone separator. The check valve attached to the bottom of the cyclone separator prevents the air being sucked into the cyclone other than the suction hose during the start of the operation and unloads the grains from the cyclone separator. The swing diverter assembly at the bottom of the check valve diverts the flow of paddy into two routes (2 sacks) alternately for continuous bagging of paddy during operation. Two laborers are needed to operate the machine: one is in-charge in bagging at the bagger, and pushing the machine during operation; and the second is responsible in moving the suction nozzle over the paddy during collection operation.

E. Performance Evaluation

1. Preparation of Test Materials

Five cavan rice paddy per replication was used as test material. A medium grain variety (C-18) having initial moisture content of 14- 15 % was used in the study. The paddy was spread manually on the 1.5 x 15 m concrete pavement evenly at approximately 3 cm thick.

2. Measurement of Operating Characteristics of the Machine

Collecting Capacity

This refers to the quantity of paddy collected per unit time. Collecting capacity of the machine was determined using (5).

$$Fc = \frac{Wpc}{T} \quad (5)$$

where: F_c = Collecting capacity, kg/h
W_{pc} = Weight of collected paddy, kg
T = Total time of collection, h

Collecting Efficiency

The collecting efficiency of the machine is the ratio of paddy collected and the sum of paddy collected and suction losses. A single pass over the 2-4 cm thick paddy using the suction nozzle of the machine was done to collect the paddy spread on a 1.5 x 15 m concrete pavement. The collecting efficiency of the machine was determined using (6).

$$Ce = \frac{Wpc}{Wpc+Sl} x100 \quad (6)$$

where: C_e = collecting efficiency, %
W_{pc} = weight of paddy collected, kg
S_l =Suction loss, kg

Noise Level

The noise emitted by the machine, with or without load, was measured using a noise level meter both at the location of the operators and baggers. The noise, expressed in db (A), was taken approximately 5cm away from the ear level of the operators and baggers.

Air Velocity

The air velocity generated by the air mover at the inlet of suction nozzle without load was measured using an air velocity meter in m/s.

Fuel Consumption

The amount of fuel consumed per replication by the prime mover in L/h. The fuel tank was filled to its capacity, after each test trial the tank was refilled using graduated cylinder. The amount of refueling is the fuel consumption for the test. When filling up the tank, keep the tank horizontal so as not to leave empty space in the tank.

3. Grain Quality Analysis

The grain samples taken before and after the test were subjected to quality analysis. The following were determined.

Augmented cracked grains percentage

The percentage of augmented cracked grain after using the machine was determined using (8).

$$P_{acg} = C_{gb} - C_{gc} \quad (7)$$

where: C_{gb} =Percent cracked grains of sample taken from the grains collected by the machine
C_{gc} =Percent cracked grains of sample taken from control sample

$$\%\text{Cracked grains}, (Cgb\ , Cgc) = \frac{Ncg}{Ng} x100 \quad (8)$$

Ncg =Number of cracked grains taken from selected 100-grain sample
Ng =Number of selected grains sample (100)

Germination Rate

This refers to the germination rate of grains and it was computed using (9). To determine the germination rate, one hundred grains were taken at random from each sample. For each treatment two samples were taken, first sample was taken from grain spread in the concrete pavement (Control sample) and the second sample was taken from the grains collected by the machine.

$$G_r = \frac{N_{gg}}{Tg} x100 \quad (9)$$

where: G_r =Germination rate, %
N_{gg} =Number of grains germinated
T_g =Total number of grains

4. Simple Cost Analysis

Simple cost analysis was done to determine financial and economic indicators of the mobile engine-driven pneumatic paddy collector. The annual cost equation by Hunt [4] was used in performing the simple cost analysis.

$$AC = FC + W(Vc)/C \quad (10)$$

where: AC =Annual cost, P/yr
FC = Fixed cost, P/yr
W =Total weight of paddy, kg/yr
Vc =Variable cost, P/h
C =Collecting capacity, kg/h

4. Data Analysis

All the data gathered were analyzed using single factor experiments arranged in completely randomized design with three replicates. Analysis of variance (ANOVA) was used to determine if there were significant differences among treatment means. The Duncan's Multiple Range Test (DMRT) was used to determine which among the means would be significantly different from each other.

III. Results and Discussions

A. Description of Mobile Engine-driven Pneumatic Paddy Collector

A simple mobile engine-driven pneumatic paddy collector made of locally available materials using local manufacturing technology was designed, fabricated and tested for collecting and bagging of paddy dried on concrete pavement. The mobile engine-driven pneumatic paddy collector had the following major components: power transmission system, air mover, conveyance system, bagging area, and frame. Fig. 2 shows the actual mobile engine-driven pneumatic paddy collector. The specification of the machine is presented in Table I.

Fig. 2 Mobile engine-driven pneumatic paddy collector

TABLE I
Specification of the Machine

COMPONENTS	SPECIFICATIONS
Overall Dimension and weight	
Length x Width x Height	1750 x 1450 x 3000 mm
Weight	300 kg
Discharge Cyclone Separator	
Inlet opening, L x W	100 x 100 mm
Outlet opening diameter	100 mm
Cylinder dimension, H x D	300 x 600 mm
Inverted cone dimension, h x b	900 x 150 mm
Material	2.3mm mild steel plate for cylinder and ga. 16 galvanized iron for the inverted cone
Air Mover	
Type	Radial flat bladed centrifugal fan
Overall dimension, L x W x H	700 x 300 x 670 mm
Weight	78kgs
Impeller	
Type	Radial flat blade
Dimension, diameter x width	380 x 160 mm
No. of rotor	6
Suction side	
type	Circle
Diameter	200 mm
Discharge side	
Type	Rectangular
Dimension, Wx h	195 x 200 mm
Material	Mild steel, 2.5 mm
Paddy diverter assembly	
Type	Swing type
Dimension of the inlet, Wx L	150 x 150 mm
Size of the outlet, W x L	150 x 180 mm
Number of outlet	Two
Material	Mild Steel plate, 2.3mm
Suction nozzle assembly	
Type	Flat
Diameter of the downstream side	80 mm
Size of the pick up side, HxW	15x 290 mm
Length	1192 mm
Material	G. I. sheet, ga 16 for pick up, uPVC, 80mmØ for downstream side, and G.I. Pipe 20 mm Ø; flat bar, 6 x 25 mm. and G.I. sheet for the handle
Suction line	
Type	Flexible hose
Siz, Diameter x Length	75 x 3000 mm
Material	Vinyl wire reinforced
Wheel	
Front	
Type	Solid rubber tire
Size , Diameter x Width	300 x 70 mm
Material	Rubber
Rear	
Type	Swivel caster
Size, Diameter x width	125 x 100 mm
Material	Rubber
Prime mover	
Type (Stroke/ignition)	4 stroke
Rated power	14.2 hp
Rated speed	3600 rpm
Cooling system	Air cooled
Starting system	Rope ranking
Dry weight	49 kg
Machine performance parameters	
Collecting capacity	2685.00 kg/h
Collecting Efficiency	99.33%

B. Operating Characteristics of the Machine

1. Collecting Capacity

Table II shows the collecting capacity of the machine as affected by the rotational speed of air mover shaft. Analysis of variance revealed that the capacity of the machine as influenced by the rotational speed of air mover shaft was highly significant. Comparison among treatment means revealed that the highest average collecting capacity of the machine was 2685 kg/h when operated at 4200 rpm. This collecting capacity was significantly different from 2344.04 and 2192.34 kg/h when operated at 3800 and 4000 rpm respectively. In normal condition, increasing the rotational speed of air mover would result to an increased collecting capacity of the machine. Results revealed that collecting capacity decreased from 2344.04 to 2192.34 kg/h when operated from 3800 to 4000 rpm. Familiarization and consistency in the operation of the machine might be the reason of decrease in the collecting capacity when the machine was operated from 3800 to 4000 rpm. On the other hand, one of the factors that affected collecting capacity was air velocity. It can be noted that the highest velocity at the inlet of the suction nozzle was lower than the recommended maximum air velocity for pneumatic conveying. This means that air velocity could still be increased to improve the capacity of the machine.

2. Collecting Efficiency

The computed collecting efficiency of the machine at varying rotational speed of centrifugal fan shaft is presented in Table II.

Collecting efficiency exhibited by the machine was 98.99, 98.77, 99.33 % at 3800, 4000, 4200 rpm respectively. Parallel to the results obtained in the preceding section regarding the decrease of collecting capacity when operated at 3800 to 4000 rpm, again the same scenario was observed on collecting efficiency of the machine. Consistency in operating the suction nozzle might be the reason of a slight decrease in the collecting efficiency when the machine was operated from 3800 to 4000 rpm.

Analysis of variance revealed that the collecting efficiency of the machine was not significant as influenced by rotational speed of air mover shaft. Results of study support the claim of Walinga incorporated that flat suction nozzle was effective and efficient in collecting grain left over the floor of silos that cannot be collected by round suction nozzle[16].

3. Noise Level

Table II shows the mean noise level emitted by the machine as influenced by rotational speed of centrifugal fan shaft. Analysis of variance revealed that noise level emitted by the machine as influenced by varying rotational speed of air mover shaft was highly significant.

Comparison among treatment means shows that the machine exhibited statistically comparable noise level of 99.35 and 99.84 dBA operated at 4000 and 4200 rpm respectively. These are significantly higher from noise level emitted by the machine with a value of 98.22 dBA when operated at 3800 rpm. The accepted noise level of any machine is 92 dBA [3]. High noise level emitted by the machine could be attributed to the vibration of the centrifugal fan because of unbalanced blade, engine operated at high engine speed, loose connection of the diverter valve swing gate shaft and the sound emitted by the paddy moving around wall of cyclone separator.

4. Air Velocity at the Inlet of Suction Nozzle

The air velocity at the inlet of suction nozzle of machine as influenced by varying rotational speed is presented in Table II.

Analysis of variance shows that the machine exhibited statistically comparable air velocity. An increase of air mover shaft rotational speed of about 400 rpm and below did not significantly increase the air velocity at the inlet of the suction nozzle using the centrifugal fan as air mover.

The maximum air velocity at the inlet of the suction nozzle of the machine was 13.05 m/s operated at air mover shaft rotational speed of 4200 rpm. This velocity is higher than the terminal velocity of paddy of 5.7 m/s [1]. However this is lower than the recommended velocity of paddy from the commercial pneumatic conveyors which ranges from 20 – 25 m/s. Result dictates that the velocity could still be increased to improve the performance of the machine.

5. Fuel Consumption

The fuel consumption of the machine in collecting paddy at varying rotational speed of the air mover is presented in Table II. Analysis of variance revealed that fuel consumption of the machine significantly differed as influenced by varying rotational speed.

Comparison among means shows that the machine consumption of 1.43 L/h when operated at 4200 rpm was statistically comparable to 1.31 L/h when operated at 4000 rpm. Fuel consumption of 1.16 L/h at 3800 rpm was significantly lower than when operated at 4200 rpm but was significantly the same when operated at 4000 rpm. Results revealed that fuel consumption increased as the air mover shaft rotational speed increased. In four-stroke internal combustion engines, fuel enters into the cylinder in every two revolution. Hence, as the rotational speed of the engine shaft increases, intake stroke increases and fuel consumption increases.

TABLE II
OPERATING CHARACTERISTICS OF THE MACHINE

TREATMENT	PARAMETERS				
	Collecting capacity, kg/h	Collecting Efficiency, %	Noise level dBA	Air velocity at the inlet of suction nozzle, m/s	Fuel consumption, L/h
T1 (3800 rpm)	2344.04b	98.99	98.22b	10.46	1.16b
T2 (4000 rpm)	2192.34b	98.77	99.35a	12.09	1.31ab
T3 (4200 rpm)	2685.00a	99.33	99.84a	13.05	1.44a

Means with the same letters within columns are not significant at 1% level using DMRT.

C. Augmented Cracked Grain Percentage

Table III presents the results of augmented cracked grain percentage as influenced by varying air mover rotational speed.

Analysis of variance revealed that augmented cracked grain percentage as affected by varying rotational speed was not significant. The augmented cracked percentage for a single pass ranged from 0.33 to 0.67%. This indicates that if the numbers of passes through the collector are kept to a minimum, grain damage would not be a problem.

D. Germination Rate

Table III shows the results of germination test observed on paddy collected by the machine as affected by varying rotational speed of the air mover shaft. Based on the laboratory analysis conducted, mean germination rate observed in seeds collected at 3800, 4000, and 4200rpm were 95.00, 96.67, and 92.67% respectively. These germination rates are higher than the Philippine standards of 85% and above.

Analysis of variance revealed that germination of seeds collected by the machine as influenced by varying rotational speed of the air mover shaft did not differ significantly.

Germination rate of seeds collected by the machine was also compared to the control sample. The t-test revealed a non significant difference in seeds collected by the machine and the seeds taken from control sample. This means that germination rate of a paddy collected by the machine was not affected. Based on the results, the machine could be used by seed growers to collect paddy during drying.

TABLE III
AUGMENTED CRACKED GRAIN PERCENTAGE AND GERMINATION RATE OF PADDY

TREATMENT	PARAMETERS	
	Augmented cracked grain, %	Germination rate, %
T1 (3800 rpm)	0.67	95.00
T2 (4000 rpm)	0.33	96.67
T3 (4200 rpm)	0.67	92.67

E. Simple Cost Analysis

Simple cost analysis was made to guide potential users of possible benefit projections in using mobile engine-driven pneumatic paddy collector.

The machine is assumed to be utilized for 400 hours per annum at four hours of operation per day. Two operators are required to operate the machine, one is in-charge in bagging at the bagging section and in pushing the machine, and the second is in-charge in moving the suction nozzle over the paddy during collecting operation.

The total cost of the machine was P62, 829.25. Fixed cost of collecting paddy using the machine annually was P 20, 424.27 while variable cost was P73, 828.00. The cost of collecting paddy using the mobile engine-driven pneumatic paddy collector was 0.07 P/kg (3.50 P/cavan) while the custom rate of collecting paddy was 0.11 P/kg (45.83 % of prevailing sun drying cost, 12.00 P/cavan = 5.50 P/cavan).

The break-even point was 510,606.75 kg/yr (P 56, 166.74). Utilizing the machine for 400 hours per year will generate an income of P23, 887.73. The projected time needed to recover the cost of the machine based on 2685 kg/h collecting capacity and custom rate of 0.11 P/kg was 2.63 year (Fig. 3).

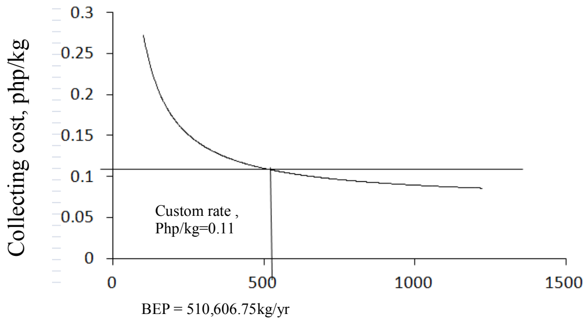

Fig. 3 Determining the break even point using the machine

IV. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A. Summary and Conclusions

This study was conducted to design, fabricate, and evaluate the performance of mobile engine pneumatic paddy collector. It aimed to evaluate the operating characteristic of the machine, evaluate the quality of grain collected in terms of augmented crack grain percentage and germination rate, and perform simple cost analysis.

The machine was tested at varying rotational speed of air mover shaft (T1: 3800rpm, T2: 4000 rpm, T3: 4200 rpm) with three replicates arranged in completely randomized design. Analysis of variance (ANOVA) was used to determine if there were significant differences among means. Duncan's Multiple Range Test (DMRT) was used to determine which among the means would be significantly different from each other.

The mobile engine-driven pneumatic paddy collector had the following major components: power transmission system, air mover, conveyance system, bagging area, and frame.

Results of the performance test showed that the mobile engine-driven pneumatic paddy collector had a mean collecting capacity of 2685.00 kg/h when operated at air mover rotational speed of 4200 rpm having a collecting efficiency of 99.33 percent. The noise level produced by the machine significantly increased as the rotational speed of air mover shaft increased. The maximum air velocity at the inlet of the suction nozzle of the machine was 13.05 m/s at 4200 rpm. The fuel consumption of the machine significantly increased from 1.16 to 1.43 L/h from 3800 to 4200 rpm.

The average augmented cracked grain percentage ranging from 0.33 to 0.67 % did not differ from each other as affected by varying rotational speed of the air mover. The germination rate was statistically comparable at any rotational speed of air mover shaft.

The machine entailed an investment cost of P 62, 829.25; break-even point of 510,606.75 kg/yr (P 56,166.74); annual generated income of P 23, 887.73 at a collecting cost of 0.11 P/kg. The projected time needed to recover cost of the machine based on 2685 kg/h collecting capacity was 2.63 year.

B. Recommendations

To further enhance the performance of the pneumatic paddy collector, the following are recommended:

1. Replace the check valve by rotary valve to unload continuously the rice paddy inside the cyclone separator during collecting operation. This would lessen the unloading time during operation.
2. Reduce to minimum the total height of the cyclone separator following the recommended typical dimension of cyclone [15]. This could increase the collecting capacity of the machine because of the decrease in collecting height.
3. Transfer the clutch near the operator in order to reduce the time of operation.
4. Discharge cyclone separator could be provided at the discharge outlet of the centrifugal fan to collect dust and rice hull coming from the said outlet.
5. Provide near the bagging section an open box holder good for 100 sacks.
6. Provide a transmission system to utilize some power from the prime mover to move the machine. This could lessen the work of operator in-charge of pushing the machine during collecting operation.
7. Reduce engine speed using pulley combination, and provide spring or shock absorber on the wheel the machine. This would reduce the vibration of the machine.
8. Conduct a study on design of suction nozzle that effectively and efficiently collect paddy spread on a concrete pavement. A wider nozzle could be used; the upstream portion of the nozzle of scoop (Panake) type which could collect the grain by pushing the nozzle until it reaches the downstream side of the nozzle in which the velocity of air is high enough to suck the grain. The nozzle could be attached to the pneumatic paddy collector in order to reduce labor during operation.
9. Conduct a study to assess the performance of pneumatic paddy collector to unload the rice paddy on flatbed dryers. This could maximize the utilization of the machine even in rainy season when sun drying on pavement would not be possible.

APPENDIX

TABLE A.I
DIFFERENT FORMULA USED IN COST ANALYSIS

PARAMETERS		FORMULA
Investment Cost, P	IC	
Salvage Value, P	SV	10% IC
Depreciation, P/yr	D	(IC-SV)/EL (EL: Economic life span, yrs)
Interest on investment, P/yr	I	$\left[\frac{IC+SV}{2}\right] i$, (i: interest rate, decimal)
Housing, Taxes & Insurance, P/yr	HIT	5%IC
Fixed Cost, P/yr	Fc	D+I+HIT
Variable Cost, Php/yr	Vc	Cf + Cl + Rm + Clu (Cf: Cost of fuel, P/yr; Cl: Labor Cost, P/yr; Rm: Repair and Maintenance (5%IC/100h use), P/yr; Clu: Lubricant cost(15%Cf), P/yr)
Total collecting cost, P/yr	Tc	Fc +Vc
Collecting Cost, P/kg	Cc	Vc/C*T (C: Collecting capacity of the machine, kg/h; T: Annual operation, h)
Break-even point, kg/yr	BEP	Fc/(Cr-Cc) (Cr: Custom rate, Php/kg)
Net income generated, P/yr	NI	C*Cr-Tc
Payback period, yr	PBP	IC/NI

TABLE A.II
ASSUMPTIONS USED IN THE DETERMINATION OF ANNUAL COST CHARGES

ITEMS	ASSUMPTIONS
Investment cost (IC), Php	62,892.25
Useful life(n) [a], yrs	
Centrifugal Fan	5
Cyclone separators, diverter valve, frames, suction nozzle, bagging section and frames	5
Engine	10
Collecting Capacity, kg/h	2685
Custom rate, Php/kg (Php/bag) [f]	0.11 (5.50)
Fuel Consumption, L/h	1.43
Interest rate (i),%/year [b]	21
Taxes, insurance and shelter, Php (5% IC) [a]	3,144.61
Repair and maintenance, Php (5%IC/100h use) [a]	12,578.45
Operating period [e], h/d	4
Number of working [e], days/a	100
Hours of operation/a [e]	400
Number of operators [e]	2
Labor cost [c], PhP/ /hr	37.5
Cost of diesel fuel [d], Php/L (Feb , 2013)	47.50
Lubricants [a]	15% of fuel cost

[a] Depreciation, salvage value, repair and maintenance, tax, insurance and shelter, and lubricants computation and assumed useful life [4]

[b] Prevailing bank interest rate on agricultural loans [14]

[c] Computation of interest on investment and assumed labor cost [11]

[d] Cost of diesel fuel at Bayombong, Nueva Vizcaya dated February , 2013

[e] The machine was assumed to be used in 400 hours per annum or equivalent to 100 days per year at four hours of operation per day. Two operators is required to operate the machine; one is in-charge in bagging at the bagging section and pushing the machine during operation, and the second is in-charge in moving the suction nozzle assembly over the paddy during collection operation

[f] The custom rate was based on prevailing sundrying cost of Php 12.00/bag, (Spreading and mixing, Php3.50/bag; **Piling and bagging (custom rate) , Php5.50/bag**; Sewing and hauling, Php3.00/bag)

TABLE A.III
BILL OF MATERIALS AND OTHER RELATED COST

PARTICULARS	SPECIFICATION	QTY	UNIT COST	TOTAL COST
Supplies and materials				
V belt	B-85	2	330.00	660.00
Mild steel plate	2.3mm	2m²	846.00	1,692.00
Angle bar	¼ " 1 ½" x 6.0m	3	795.00	2,385.00
Angle bar	1/4 ' x 1"	8m	85.00	680.00
Flat bar	¼" x 1" x 6m	1	265.00	265.00
Round bar, plain	12mmØ x 3 m	1	110.00	110.00
Square bar	12mm	4m	20.00	80.00
Bar, channel	3" x 6.0m	1	1325.0	1,325.00
Pipe, G. I.	S40, 1 ¼"Ø x 6.0m	1	870.00	870.00
Pipe, G. I.	S20, ¾"Ø	1.5 ft	87.50	87.50
Pipe, Pvc	3"Ø x 1.0m	1	106.00	106.00
Pipe, B. I.	3"Ø x 3.0m	1	700.00	700.00
Elbow, G. I.	3"	2	230.00	460.00
Coupling, G. I.	3"	1	124.00	124.00
Solid shaft	1"Ø	2ft	120.00	240.00
G. I. sheet	#16	2.4 m²	465.00	1,116.00
Bolt with nut and Washer	5/8" x 2"	4	45.00	180.00
Bolt with nut and washer:	7/16 x 2"	4	25,00	100.00
Bolt with nut and Washer:	5/16" x 1"	28	6.00	168.00
Wheel, swivel caster wheel	5"Ø x 2 ½"	2	700.00	1,400.00
Wheel, solid rubber,	12"Ø x 2"	2	1,000.0	2,000.00
Wheel: plastic	1 1/2"Ø	2	24.00	48.00
Vinyl, wire reinforced flexible hose	3"Ø	3m	250.00	750.00
Wire mesh	1.0m x 1.2	1	150.00	150.00
Hose clamp, heavy duty	4"Ø	5	20.00	100.00
Welding rod	E6013	10kg	65.00	650.00
Red oxide primer (Boysen)		1L	109.00	109.00
Paint: QDE (Boysen)	yellow	1L	162.00	162.00
Paint: QDE (Boysen)	black	1L	116.00	116.00
Hack saw	24TPI	5	50.00	250.00
Steel Cutting Disk	#4	5	80.00	400.00
Grinding stone	#4	3	80.00	240.00
Paint brush:	2"	1	25.00	25.00
SUB-TOTAL				17,792.25
Equipment				
Diesel engine	14hp, air-cooled	1	14,500	14,500.00
Centrifugal blower		1	20,000	20,000.00
SUB-TOTAL				34,500.00
Labor Cost for the fabrication (25MD @ Php400/MD)				10,000.00
Labor Cost for the threading of solid shaft and bending of push handle G . I. pipe				600.00
GRAND TOTAL				62,892.25

TABLE A.IV
SIMPLE COST ANALYSIS

PARTICULARS	
Investment Cost, P	**62,892.25**
Useful life (L), yrs	
Centrifugal Fan	5
Cyclone separators, diverter valve, frames, suction nozzle, bagging section and frames	5
Engine	10
Salvage Value, P	6,289.22
Capacity of the Machine, kg/h	2685.00
Diesel fuel consumption rate, L/h	1.43
Price of Diesel, P/L	47.50
Number of operators required	2
Labor rate for operator	37.50
Interest rate(i), decimal	0.21
Fixed Cost:	
Depreciation, P/yr	**10,015.61**
Centrifugal Fan	3,600.00
Cyclone separators, diverter valve, frames, suction nozzle, bagging section and frames	5,110.61
Engine	1,305.00
Interest on investment, P/yr	7264.05
Tax, Insurance, and Shelter, P/yr	3144.61
TOTAL FIXED COST	**20,424.27**
Variable Cost:	
Diesel fuel, P/h	67.93
Lubricants, P/h	10.19
Repair and Maintenance, P/h	31.45
Labor Cost, P/h	75.00
TOTAL VARIABLE COST, P/h	**184.57**
Cost of collecting, P/yr	94,252.27
Cost of collecting; P/kg (P/cav)	0.07 (3.50)
Custom rate of collecting, P/kg (P/cav)	0.11 (5.50)
Annual net income generated, P	23,887.73
Payback Period, yrs	2.63
Break-even point, kg/yr	510,606.75

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