DESIGN AND EVALUATION OF A LOCALLY- DESIGNED PEANUT DIGGER

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ABSTRACT

Manual peanut digging in the Philippines is still a practice due to the unavailability of low-cost mechanical diggers adaptable to local field conditions. Hence, the peanut digger design and evaluation were developed. The design involves benchmarking local field practices, ANSYS analysis of the digger blade, and CAD drawing. It is designed to dig, lift, convey, and drop the peanut stalk in a windrow. Its main parts are the main frame, digger blade, belt stalk conveyor, power transmission system, and hitching system. The pulling force and power requirement for the peanut digger is 1,387.48 N and 2.0 hp, respectively. The performance measures are the belt stalk conveyor speed levels at 205 rpm, 410 rpm, and 615 rpm, replicated three (3) times with three (3) plots per replication. They revealed an actual field capacity, digging efficiency, and mechanical physical damage of 0.025 ha/h, 95.31%, and 0.56%, respectively. Investing in the machine is economically viable with a benefit-cost ratio (BCR) of 2.09, a break-even point (BEP) of 5.33 ha/yr, and a payback period of 1.60 years. This implies that digging operations wider than 5.33 ha/yr start profit generation for farmers.

INTRODUCTION

Globally, the peanut is the 13th most important food crop, 50% of the total production is used as raw material for the manufacture of peanut oil, 37% for confectionery, and 12% for seed purposes *(Food and Agriculture Organization of the United Nations [FAO], 2002)*. It is the Philippines' second most important food legume, with slightly increasing production from 29,194.81 MT to 29,300.78 MT from 2015 to 2019, planted in 27,500 to 28,102 ha. This production came from the highest-producing provinces of Pangasinan (20.6%) equivalent to 6.03 thousand MT, La Union (9.3%) of 2.72 thousand MT, Lanao del Norte (6.4%) of 1.87 thousand MT, Cagayan (5.8%) of 1.70 thousand MT, Ilocos Sur (5.5%) of 1.60 thousand MT, and 15.37 thousand MT (52.3%) in the rest of the provinces *(Department of Agriculture [DA], 2021)*.

Peanuts can be grown in all climatic conditions in the country. In Ilocos Region, it is grown throughout the year. During the dry season, it is planted from October to January, and March to June for the wet season. Planting is done manually using conventional tools for drilling seed at 10 to 15 cm planting depth. Harvesting is done by either manual uprooting or a carabao-drawn plow at 15 cm to 20 cm depth. Without a carabao, digging requires up to 25 man-days/ha and another 10 man-days/ha for manual stripping of pods *(Department of Agriculture-Bureau of Plant Industry [DA-BPI], n.d.)*. A total of 35 man-days/ha with a cost of Philippine Pesos PHP13,020.00, considering the upgraded wage rate of PhP372.00/day *(Department of Labor and Employment [DOLE], 2022)*.

Manual harvesting is laborious and costly and could incur a total loss of as high as 20.23% or 621.06 kg/ha of the total production *(Mishamandani et al., 2014)*. This loss results from manual digging, which dislodges pods from the root system and over-maturity during the digging operation *(Warner et al. 2015)*. To reduce losses and costs, advanced countries use self-propelled peanut diggers and harvesters or four-wheel tractor-pulled diggers and harvesters *(Yang et al., 2022).* Through inclusive research and development, China developed a peanut picking-up harvester driven by a four-wheel tractor with a chain nylon elastic tooth pick-up device, transmission device, take-off equipment, cleaning equipment, and elevator set fruit device parts with a high capacity of 886 kg/hr *(Wang et al., 2013).* 90% of peanut farmers in India use four-wheel tractor peanut harvesters with strippers. Other advanced countries such as South Africa, Israel, France, and the United States have established peanut harvester manufacturing factories meeting the widespread need for mechanization *(Negrete, 2019).*

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Westler et al. (2017), Camara (2016), and Zerbato (2013), as cited by *Negrete (2019)* claimed that mechanizing peanut production from planting to harvesting is important for increased production and profitability. In the Philippines, where the mechanization level is low at 1.23 hp/ha, only rice and corn are intermediate to highly mechanized at 2.31 hp/ha *(Philippine Center for Postharvest Development and Mechanization [PhilMech], 2018).* Only the land preparation is mechanized for other crops, such as peanuts. *Briones (2021)* cited that the weak growth in the agriculture sector in the Philippines is due to slow growth in factors of production and productivity. Labor is declining, and arable lands are converted to industrial infrastructures with an average farm size of 1.29 ha. Considering small parcels of land and other constraints impeding agriculture growth, developing small machines suitable to the field conditions is timely and necessary. Adopting imported machines could be one intervention. However, it is expensive and impractical. The working size and capacity, the complexity of the design, and the availability of spare parts during repair and maintenance are some of the important considerations.

With all these undeniable status quo of peanut production, it is an avenue to contribute to addressing the specific need of reducing labor and cost of manual operation for digging. Thus, the design and performance evaluation of a locally designed peanut digger was conceptualized. Specifically, design the peanut digger adaptable to hand tractors and local farming conditions; fabricate the machine made of locally standard available materials; evaluate the performance in terms of Actual Field Capacity (AFC), digging efficiency, Mechanical Physical Damage (MPD); and calculate economics returns using the machine. According to *(Philippine Center for Postharvest Development and Mechanization [PhilMech], 2018),* 53% of farmers owned hand tractors and 90% used mechanical power for land preparation. Developing a peanut digger could maximize the availability of hand tractors; to be used not just for land preparation and transportation but for other field operations. Using a hand tractor as a prime mover could boost sustainable utilization, marketability, and adoption of locally developed machinery.

MATERIALS AND METHODS

Design of machine components

The machine for digging peanuts is driven by a hand tractor of 7 HP (Fig. 1). As the hand tractor moves forward, the digger blade is pulled through the soil underneath one (1) row of peanut, uprooting the root system while being transported into the belt stalk conveyor. The belt stalk conveyor is a locking mechanism of uprooted peanut stalk while conveying it to one side of the plot.

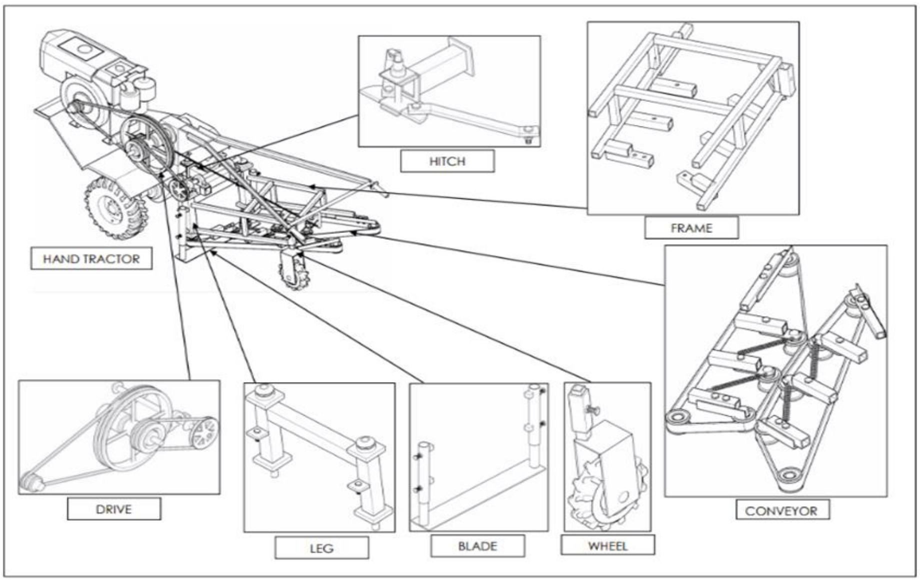

Fig. 1 – Major parts of the peanut digger

The mainframe is the foundation of peanut digger stability during operation. It is the mounting structure supporting the digger blade, belt stalk conveyor, and power transmission system. The digger blade is the penetrating medium uprooting the root system of peanuts from the field plots. It was designed with a working width of 377 mm to uproot one (1) row of peanuts and inclined at 12 º to the horizontal. The calculation of traction resistance with a free-body diagram (FBD) (Fig. 2) is based on the method used by *Liu et al. (2014).* Equation (1) was used in calculating digging blade traction resistance.

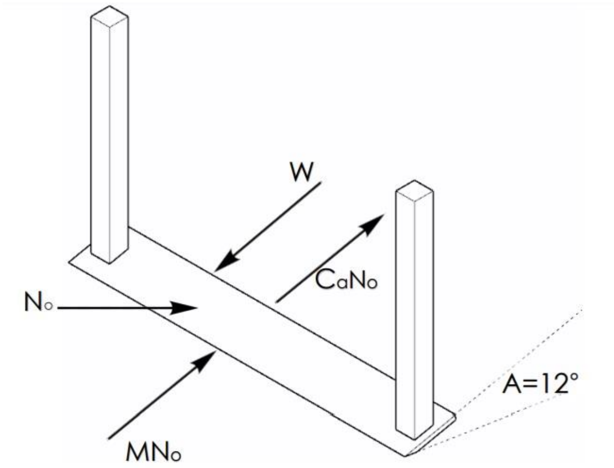

Fig. 2 – FBD of digging blade considering soil mechanics

The digger blade is the most forced member of the peanut digger during operation. It uses static structural analysis in ANSYS to obtain the required thickness of the digger blade. This is also to solve the total deformation, equivalent stress, and the equivalent elastic strain of the digger blade.

The belt-stalk conveyor is the holding mechanism of the uprooted peanut stalk from the digger blade, then it discharges the stalk to one side of the plot. It is composed of roller mechanisms meshing together to hold the peanut stalk simultaneously during the digging operation. The rotating speed of 410 rpm is synchronized to the forward speed of the hand tractor, ensuring stalk holding capacity, and avoiding the piling up of stalk in the digger blade.

The power transmission system provides a controlled application of power into the peanut digger. From the engine power, it uses a gearbox composed of sets of gears providing speed and torque conversions and rotating for the belt stalk conveyor assembly. The diameter of pulleys, length of belts, and number of teeth of spur gears were calculated and adapted to *PNS/PAES301:2000* and *PNS/PAES303:2000.*

Draft force is the energy used to overcome soil resistance and cut and invert the soil during tillage operation *(Almaliki, 2018).* The impact of draft force on the peanut digger depends on the type of soil, working width, harvesting depth, and running speed. The calculation of draft requirements of the peanut digger is assumed to be like the moldboard plow. Equations (1) and (2) adopted from the *American Society of Agricultural Engineers [ASAE] Standards (2000) and Coates (2002)* were used. The power requirement is the total power needed for the hand tractor and the peanut digger. This was calculated considering the power requirement for the digging blade and the belt stalk conveyor. Equations (3) to (5) were used to compute the total power requirement of the machine adopted from *Alhaseen et al. (2015).*

$$W = [N_o \times sin(\alpha)] + [\mu\, N_o \times cos(\alpha)] + [C_a\, N_o \times cos(\alpha)] \quad \text{[N]} \tag{1}$$

$$D = Fi \times [A + B(S) + C(S^2)] \times Wm \quad \text{[kN]} \tag{2}$$

$$HP_{draft} = \frac{D_a \times S}{C} \quad \text{[hp]} \tag{3}$$

$$P_{TDB} = \frac{D \times S}{C} \quad \text{[hp]} \tag{4}$$

$$T_{HP} = P_{DB} + P_{STD} \quad \text{[hp]} \tag{5}$$

where:

W - digging blade traction resistance, [N], A - digging blade tilt angle [°], μ - soil to metal friction factor [0.675], C_a - soil adhesion coefficient [30 $\mathrm{kN/cm^2}$], N_o - blade surface area [$\mathrm{cm^2}$], i - a dimensionless soil texture adjustment parameter, A,B & C - machine-specific parameters, S - forward speed of the hand tractor [$\mathrm{km/h}$], Wm - machine working width [m], D_a - adjusted draft value [kg], HP_{draft} - horsepower due to adjusted draft caused by speed [hp], S - forward speed of hand tractor [$\mathrm{km/h}$], C - conversion factor for hp, P_{TDB} - total drawbar power [hp], D– Total draft [kN], T_{HP} - total power requirement of the peanut digger [hp], P_{DB} - power requirement of digger blade [hp], P_{STD} - power requirement of belt stalk conveyor [hp]

Description of fabricated peanut digger

The prototype peanut digger was fabricated involving cutting, welding, boring, bending, and machining. The fabrication commenced with the main frame. It is made with 50 and 25-mm steel square tubes welded together. It is equipped with a wheel for easy mobility during operation and transport.

Said mainframe is the mounting structure of the digger blade, belt stalk conveyor, and power transmission system. It also has (2) two-depth adjustments to address the unevenness of field plots from 15 to 30 cm digging depth.

The power transmission consists of belts, pulleys, spur gears, and power shafts for transferring power from the engine to the moving assemblies of the peanut digger. The pulley combinations of 3, 16, 6, and 4 inches maintain the rotation of the belt stalk conveyor at 410 rpm. Said power shafts are attached to the mainframe using pillow blocks and flange bearings. The digger blade of 38 cm working width is made of an 8 mm leaf spring steel plate. It is bolted to the front portion of the main frame with adjustments from 10 to 20 cm digging depth. The land preparation is manually done. Thus, the digger blade is adjustable to address the unevenness of fields. The belt stalk conveyor comprises a series of rollers, springs, and two (2) endless belts. Said rollers have meshing mechanisms to hold the peanut stalks, convey, and drop them to one side of the plot. Said belt stalk conveyor is made with a rubberized timing belt for tight gripping during the operation. The hitch assembly was assembled based on the standard one-hole hitch specified in *PNS/PAES107:2000*; where the pin sleeve and hitch frame were adaptable to the hand tractor. Said hitch system support is made with a 6 mm thick plate to counteract draft or pull force during the digging operation. It is also full-weld and equipped with bolts and nuts to ensure tightening of support and stability eliminating the swiveling in the hitch system.

Research design

The peanut digger belt stalk conveyor speed levels were used as the performance measure. These are 205 rpm, 410 rpm, and 615 rpm. It was replicated three (3) times with three (3) plots per replication (0.3 x 10 m/plot), having a total experimental area of 81 m^2 excluding headlands. The evaluative parameters are the Actual Field Capacity (AFC), digging efficiency, and mechanical physical damage. Since it has only one (1) performance measure, one (1) operator, and the forward speed and engine speed (with load) are the same throughout the performance evaluation, the single factor- One-way ANOVA in Completely Randomized Design (CRD) was used. The data were analyzed using the Statistical Tool for Agricultural Research (STAR) (Version 2.0.1) developed by the International Rice Research Institute (IRRI).

The Actual Field Capacity (AFC) is the actual area of operation unit operation time. The total area covered was measured per plot before the start of the test. The turning time was measured from the plot's end to the next plot's start. The total operation time includes the unproductive time (i.e., adjustment and turning time) and the productive time (time during simultaneous operation without failure). The AFC was computed using equation (6) adopted from *PNS/PAES160:2011*.

The digging efficiency (DE) is the mass ratio of the lifted pods over the plot's unlifted/still buried pods and the mechanical physical damage. After digging using the machine in each plot, unlifted pods were manually dug, collected, and weighed. Also, the lifted pods were manually inspected for damage detection. The digging efficiency was determined using equation (7), adopted from *Ibrahim et al. (2008).*

The mechanical physical damage (MPD) is the total weight of cracked and broken pods collected after the digging operation per replication. Manual inspection of damages was implemented after the manual separation of peanut pods from the stalk and collection of exposed pods in the plots. The MPD was determined using equation (8) adopted from *Mishamandani et al. (2014).*

$$AFC = A / (Tp + Tn) \text{ [ha/h]} \tag{6}$$

$$DE = [Rt - (D + MPD)] / Rt \text{ [\%]} \tag{7}$$

$$MPD = C / Tp \text{ [\%]} \tag{8}$$

where:

AFC - actual field capacity [ha/h], A - area operated [ha], T_p - productive time [h], T_n - non-productive time [h], DE - digging efficiency [%], Rt - total weight of lifted peanut pods [kg], D - unlifted peanut pods [kg], MPD - mechanical physical damage of the machine [kg], C - weight of damaged pods collected from the sampling area [kg], T_P - total weight of peanut pods collected from the sampling area [kg]

Investment viability of peanut digger farmers' level

The three (3) parameters adopted in calculating the investment viability of the machine farmers' level are the break-even point, payback period, and benefit/cost ratio. The tractor cost or the cost of operation was calculated and included in the variable cost (VC).

Two (2) farmers implemented the manual digging of peanuts. This is to eliminate bias in data collection for manual digging capacity and machine operation.

The data for manual digging capacity in ha/h used in the calculation is the work actual duration of the two (2) farmers. The peanuts are not in plots and are manually planted. Thus, removing 1 hill side by side was implemented to give way for the wheels of the hand tractor.

The average time for manual digging was converted to PhP46.50/h, the allowable wage for agricultural works (plantation) *(Department of Labor and Employment [DOLE], 2022).* The fuel consumption of the machine is calculated using the current price of PhP71.80/li *(Department of Energy [DOE], 2022).*

The BEP analysis shows the point where there is enough revenue to pay all associated costs. It is the intersection point of total gross revenue and total cost. The BEP is a point where neither profit nor loss is made and known. Equations (9) to (17) were used to calculate BEP.

The PP points out the duration it will recover the investment or the duration in years where cash outflows and inflows are equal. It is also known as the simple payout method that concerns the recovery of investments rather than profitability. Equation (18) was used to calculate the payback period.

The BCR is the ratio of discounted benefits versus all associated costs. Project proponents use this standard procedure to make smart decisions on project investing. If the BCR > 1.0, the project is feasible. Therefore, investment is viable. However, if BCR < 1.0, the project is not feasible, the investment is not viable or recommendable.

Equations (19) to (21) were used to calculate BCR.

$$IC = COM + L \quad \text{[PhP]} \tag{9}$$

$$SV = 10\%\ IC \quad \text{[PhP]} \tag{10}$$

$$D = (IC - SV) / n \quad \text{[PhP/yr]} \tag{11}$$

$$FC = D + I + TIS \quad \text{[PhP/yr]} \tag{12}$$

$$VC = Cp + Cl + RM + Clu + Ct \quad \text{[PhP/yr]} \tag{13}$$

$$THC = FC + VC \quad \text{[PhP/ha]} \tag{14}$$

$$HC = (VC / C) * T \quad \text{[PhP/ha]} \tag{15}$$

$$BEP = (FC / Cr) - Bc \quad \text{[ha]} \tag{16}$$

$$ANI = C * T * (Cr - Tc) \quad \text{[PhP/yr]} \tag{17}$$

$$PP = IC / ANI \quad \text{[yr]} \tag{18}$$

$$PWB = AGI\ (P/A, I\%, N) \quad \text{[PhP]} \tag{19}$$

$$PWC = ATC\ (P/A, I\%, N) - SV\ (P/F, I\%, N) \quad \text{[PhP]} \tag{20}$$

$$BCR = PWB / (PWC + IC) \tag{21}$$

where:

IC- investment cost of the machine, [PhP]; COM- total cost of the materials, [PhP]; L-cost of labor of fabrication, [PhP]; SV- salvage value of investment cost, [PhP]; D- depreciation cost, [PhP/yr]; n -life span [yr]; FC- annual fixed cost [PhP/yr]; VC- variable cost [PhP/yr]; TIS – taxes, insurance, and shelter [PhP/yr]; I- interest on investment [PhP/yr]; C_p- cost of fuel [PhP/yr]; CI - cost of labor [PhP/yr]; Clu- cost of lubrication [PhP/yr]; Ct - cost of using the hand tractor [PhP/yr]; RM - repair and maintenance cost [PhP/yr]; THC - total peanut digging cost [PhP/ha]; C - digging capacity of the machine [ha/h]; HC-peanut digging cost [PhP/ha]; T annual operating time [ha/yr]; Cr - custom rate [PhP/ha]; BEP - total number of hectares the peanut digger will work to recover the IC [ha]; ANI - annual net income [PhP/yr]; TC- annual cost [PhP/yr]; PWB - present worth benefits [PhP]; AGI - annual gross income [PhP/yr]; $I\%$ - interest rate in investment cost [12%/yr]; PWC - present worth costs [PhP]; ATC- annual total costs [PhP]

RESULTS

Design ANSYS analysis on the digger blade

The depth, width, dip angle, and soil volume affect the digging soil resistance on the digger blade. The depth and width of the digger blade have a considerable effect because it defines the area of soil resistance. The maximum stress (Fig. 3a) of 17.4 MPa is much smaller than the allowable stress of mild steel of 155 to 165 MPa.

The maximum deformation (Fig. 3b) is 0.53644 mm. The red indicates that maximum deformation occurs at the middle part of the blade. Conversely, the maximum strain (Fig. 3c) was 9.36 e-5. It conveys that the deformation ratio to the blade's original dimension is 0.0000936, which is within the limit of proportionality.

It means no permanent deformation will occur, and the digger blade will return to its original shape after the operation. Thus, the 8 mm leaf spring hard steel can withstand the 77.44 N working traction resistance without breaking.

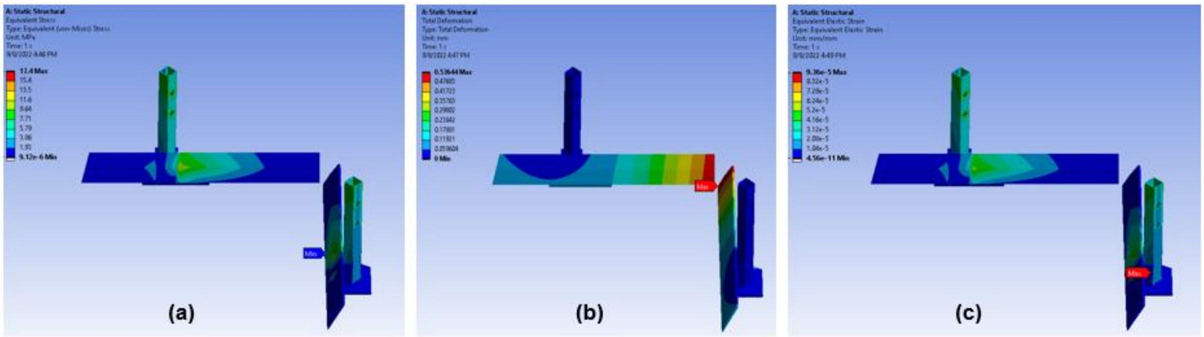

Fig. 3 – Digger Blade ANSYS

(a) stress map of the digger blade, (d) deformation map of the digger blade, and (c) strain map of the digger blade

Fabricated peanut digger prototype

The peanut digger (Fig. 4) is developed for digging, lifting, conveying, and dropping peanut stalks to one side of the plot simultaneously in one operation. It is an implement adaptable to a Philippine-designed hand tractor or “kuliglig” that lifts a 30 cm wide plot planted with 1 to 2 hills of peanut. It weighs 55 kg for ease of transportation, hitching, and operation. It has an overall dimension of 1,070 x 620 x 550 mm (l x w x h), giving ample space for the operator’s movement at the back of the hand tractor. The peanut digger is mounted at the rear portion of the hand tractor through a single-point hitch. The lever operation of the peanut digger is synchronous to the forward speed of the hand tractor. As the hand tractor moves forward, it engages the operation of the peanut digger. It is equipped with a single wheel to maintain the digger blade depth and support the weight for mobility and ease of operation. The pulling force or draft for the hand tractor to propel the peanut digger is 1,625.85 N at a forward speed of 1.93 km/h. The power requirement is 2.0 HP, which is lower than the available power of the hand tractor engine of 7 HP.

Fig. 4 – The locally-designed peanut digger hitched to the hand tractor or “kuliglig”

Actual field capacity (AFC)

The Analysis of Variance (ANOVA) at a 5% significance level, revealed a significant difference among the three (3) speed levels. It indicates that the speed of the belt stalk conveyor affects the AFC shown in Table 1. It is known that the Philippine hand tractor has only one forward speed and no reverse (PNS/PAES 111:2000). Said forward speed is designed for the pacing of the human as its machine operator. The digging depth is set at one (1) depth adjustment. Thus, the digging blade load bearing during operation is the same. However, increasing the belt stalk conveyor speed increases the AFC. Studies revealed that the belt stalk conveyor speed should be slightly faster than the forward speed of the hand tractor to avoid piling up of vines ahead of picking up *(Bader 2012, cited by Kirk et al., 2017*). The conveyor speed should also be synchronized with the forward speed to avoid dragging and snatching peanut stalks *(Roberson, 2016, cited by Kirk et al., 2017).*

The results revealed that when the belt stalk conveyor rotates too slowly at 205 rpm, it causes the stalk to pile up at the bottom of the conveyor, causing excessive agitation of the stalk, thereby stopping the rotation of the conveyor. As it stops, it increases the operation time, reducing the AFC. As it needs manual removal of piled stalks before continuing the digging operation. During the field test, from the length of the 10 m field plot, it stopped 4 to 5 times as the peanut stalk piled up at the bottom of the conveyor, prolonging the operation time when manually removed. Comparing it to higher rotation speeds at 410 and 615 rpm, the AFC is higher as the speed of the conveyor is synchronized to the forward speed of the hand tractor at 1.93 km/h. The AFC at 0.025 ha/h is five times higher than that of manual digging at 0.0049 ha/h, gathered during the field test. This agrees with the *Department of Agriculture-Bureau of Plant Industry [DA-BPI], (n.d.)* that manual digging requires 20 to 25 man-days/ ha. Converting said the manual capacity of 0.0049 ha/h is almost 26 man-days/ha.

Table 1

ANOVA of actual field capacity [AFC], digging efficiency [DE], and mechanical physical damage [MPD]

Performance Measure	AFC	DE	MPD
[rpm]	[ha/h]	[%]	[%]
205	0.008^b	83.07^b	1.06
410	0.025^a	95.31^a	0.56
615	0.023^a	94.52^a	0.24

**Means with same letter superscript is significant at a 5% level of significance*

Digging efficiency

The DE of the peanut digger shown in Table 1 revealed a significant difference at a 5% significance level. The lower the speed of the belt stalk conveyor at 205 rpm, the lower the digging efficiency. During operation, at 205 rpm, peanut stalks piled up into the bottom of the conveyor, dragging and causing the stripping of pods into the ground. Stripped/dislodged pods are dropped into the ground, thus, increasing the pod losses. According to *Warner et al. (2015),* losses came from dislodged pods due to manual uprooting and over-maturity of peanuts. The variety planted as a test crop is UPL Pn-10, and the maturity is 98 to 100 days upon planting. During the field test, the maturity exceeds 114 days. Thus, it is noticed that some pod losses manually picked in the ground, dislodged from the root system during the operation are easily cracked, and pegs are decayed.

Mechanical physical damage

The MPD of the peanut digger shown in Table 1 revealed no significant difference at a 5% significance level. It means that during operation, different speed levels could be used. However, considering the higher AFC of 410 rpm at 0.025 ha/h and the Mechanical physical damage is 0.56 %, it is favorable to use this speed level. These MPDs incurred are caused by the cutting in the digger blade or the dragging and agitation into the belt stalk conveyor. The piling up of stalk in the belt stalk conveyor caused pods to crack, especially those pods near the stalk. This MPD is lower than manual digging at 20.23% *(Mishamandani, et al., 2014).*

Investment viability of the peanut digger (farmer's level)

The investment analysis determines whether the machine is viable for digging peanuts. The assumptions used (Table 2) consider the investment cost of the machine of PhP47,866.00, covering the total cost of materials and fabrication labor. The Annual Fixed Cost (AFC) was PhP13,334.10/yr. It is the incurred cost due to depreciation of the machine with a 5-year lifespan, interest on investment of 12%, housing, taxes, and insurance. The Variable Cost (VC) was PhP118.49/hr. It is the total incurred cost for fuel at PhP71.80/li; lubricant cost, repair, and maintenance; labor cost at PhP46.50/h; and tractor cost. The tractor cost of PhP43.20/h was included as a variable cost since the hand tractor propelled the peanut digger. The calculation yielded Fig. 5 and Table 2. Figure 5 illustrates the BEP curve (ha/yr); Table 3 shows the summarized investment parameters of the peanut digger.

Table 2

Assumptions in the investment cost analysis of peanut digger

Particulars	Hand tractor	Peanut Digger
Purchase Price [PhP]	60,000.00	47,866.00
Salvage value [%]	10.00	10.00
Years [n]	10.00	7.00

Particulars	Hand tractor	Peanut Digger
Fuel consumption [l/h]		0.78
Fuel price per liter, PhP/l		71.80
Repair and maintenance [% PhP/100 h]	1.20	1.00
Rate of interest [%]	20.00	20.00
TIS [%]	4.00	4.00
Labor cost [PhP/day]		372.00
Annual hours [h/yr]	400.00	
Capacity [ha/h]		0.025
A. Fixed Cost Items		
Depreciation	5,400.00	6,154.20
Interest on investment	6,600.00	5,265.26
TIS	2,400.00	1,914.64
Total Annual FC [PhP/yr]	14,400.00	13,334.10
B. Variable Costs		
Fuel cost		56.00
Lubricant cost		11.20
Repair and maintenance	7.20	4.79
Labor		46.50
Tractor cost	43.20	
Total VC [PhP/h]	118.49	

Table 3

Summary of investment viability (farmer's level) of the peanut digger

Particulars	Value
Total annual fixed cost [PhP/yr]	13,334.10
Total variable cost [PhP/yr]	118.49
Digging cost [PhP/ha]	5,010.28
Net income generated [PhP/yr]	29,741.24
Break-even point [ha/yr]	5.33
Payback period [yr]	1.6
BCR	2.04

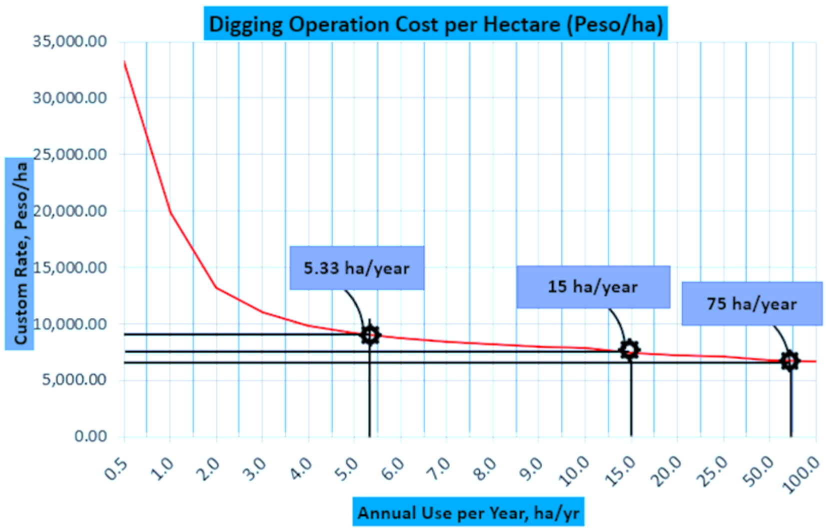

Fig. 5 – BEP point curve (ha/yr) of utilization

The cultivation of peanuts is twice a year. With this, the peanut digger was assumed to be operating at 25 days per cropping season or 400 hours/yr. Calculating using the digging capacity of 0.025ha/hr, the computed annual capacity is 10 ha/yr.

The rent of the machine or custom rate is assumed to be equal to the manual digging cost of PhP9,047.19/ha. This was calculated from the manual digging capacity of 0.0049 ha/h (gathered data during the field test).

The BEP yielded at 5. 33 ha/yr. This signifies that the peanut digger needs to finish or operate at the required BEP to recover the gross revenue. As the peanut digger increases its working capacity beyond the BEP, it will generate profit. The BEP is low and favorable as the harvesting season is one (1) month or more, thus, the 5.33 ha/yr could be finished in 15 to 20 days for continuous operation. From Fig. 5, the peanut digger increases its working capacity from BEP of 5. 33ha/yr to 15 ha/yr or higher at 75 ha/yr, the custom rate of the machine gets lower. The rent of PhP9,047.19/ha could be reduced, or as the machine is maximized, it adds profit to farmers by reducing the renting cost or custom rate. Investing in the machine is viable with a BCR of 2.09. However, if the farmer does not own the required BEP, it is best to rent the peanut digger. But, if land consolidation or grouping of fields is practiced to meet the BEP, investing is viable and recommendable.

Cost comparison of manual and mechanical digging of peanut

Due to the increasing cost of manual labor of PhP9,047.19/ha and 26 man-days/ha, utilizing the peanut digger reduces the associated cost and duration of the operation. From the results, the cost of the machine is PhP5,010.28 and requires a labor of 13 man-days/ha. The cost reduction of PhP4,036.91 implies a significant increase in farmers' profit. The reduction of 13 man-days/ha implies less labor requirement that could answer the labor shortage in the coming years. During the peak season of peanut harvesting, when labor is scarce, the adoption of the machine is timely and effective.

CONCLUSIONS

This research achieved its objectives. The peanut digger adapted to a hand tractor is effective in the digging of peanuts. It is suitable for local field conditions, light in weight, and easy to operate. It is simple in design that a local manufacturer could fabricate using standard available materials. Its main parts are bolted for easy assembly and disassembly during repair and maintenance. Using the machine decreases the manual labor requirement by 50% and the digging cost by 55.40%. Realizing this significant outcome of developing the machine, adopting the peanut digger could increase the production and profitability of peanut farmers in the country. Further, based on the results, it needs further research to increase machine performance, perform standard tests, and farmers' acceptability as the entry for technology commercialization.

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