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Development of Potato harvester for hill terrain farming

Faizur Rahman A[1], Priyank Hanuman Mhatre[2]

[1]Associate Professor, Department of Mechanical Engineering, CSI College of Engineering, The Nilgiris, Tamilnadu, India
[2]Senior Scientist, ICAR-CPRS, The Nilgiris, Tamilnadu, India
faizurmech@gmail.com and priyank.mhatre@icar.gov.in

Abstract – *In hill terrain farming, potato harvesting is a challenging job due to bad weather conditions, frequent animal disturbances, and landscapes. In this paper, a potato harvester machine was designed and developed, especially for hill terrain regions. It can be easily coupled with available farm power. It can harvest 0.15 hectares per hour. Manual harvesting and machine harvesting were compared. The major factors considered in this paper were exposed potatoes, unexposed potatoes, damaged potatoes, time to complete the harvest, labour required in collecting plant debris, potatoes, and digging the soil. Approximately 64% of potatoes were damaged during manual harvesting compared to machine harvesting. Also, 48% of the cost was saved while using machine harvesting.*

Key Words: **Potato harvesting, Hill terrain farming, Potato-soil separation, K2 chain attachment, Manual harvesting, Potato harvesting machine**

1. INTRODUCTION

Potato (Solanum tuberosum.L) is regarded as one of the most important vegetable crops that meet India's nutritional needs. India is the second-largest potato producing country next to China. Potatoes are cultivated on 21.8 million hectares of land, producing 52.5 million metric tonnes per year. There is a projection of 711.5 million metric tonnes by 2050. The weather and the climate are the greatest challenges for the harvesting of potatoes. More than 90% of the potatoes in India are harvested during the October and March months that fall under short days in the northern hemisphere. Due to short daytime and lack of sunlight, the productivity of the potatoes leads to a lower potential yield.

In the Nilgiris, the potatoes are harvested from February to March. Small and marginal farmers compromise on the yield and opt for an early harvest of potatoes, which results in a 30–40% loss in productivity. Also, while harvesting the potatoes with either hand tools or machines, the tubers may get damaged. It was observed that the greatest percentage of damaged tubers occurred due to the greatest impact of the working bodies of the harvester [1]. Potato harvesting technologies need more improvements in areas like digging, picking, and grading. The potato harvesting machine is based on four basic operating principles: reciprocating, conveying, rotating, and spinning [2]. This paper presents the method of conveying and separating the potato-soil mass. Major parameters like exposed tubers, unexposed tubers, damaged tubers, machine field capacity, fuel consumption, and cost of harvesting operations were discussed [3]. Also, there is a need for more improvements in potato-soil separation. A neat potato-soil separating mechanism was developed and classified the whole mechanism into shearing area, bending area, throwing area, cleaning area, and conveying area. Only 0.89% of the damage rate of potatoes was observed in this mechanism [4]. The design and development of harvesting blades, gearboxes, and roller chain conveyors were the major roles played in this paper. The harvesting blade angle and conveyor rod space were kept at 21^0 and 20 mm, respectively [5].

2. MATERIALS AND METHODS

This potato harvester machine (PHM) can be used for harvesting different varieties of potatoes located in the Nilgiris district. This machine can harvest 0.15 hectares per hour. This potato harvester machine (PHM) consists of three main components. Harvesting Blade, Gear Box, and Chain Conveyor. This machine is connected with a tractor capacity from 18 hp to 30 hp through three-point hitch systems and a PTO unit. The harvesting blade continuously digs the soil and lifts the potato-soil mass to the conveyor. Power was transferred from the PTO shaft in the tractor to the gearbox of the potato harvester machine, whereas the same was transferred to the conveyor through roller chain arrangements. So, the potato-soil mass gets separated during conveying and the potatoes fall to the rear of the machine. All the parts in this harvester machine were easily replaceable and economical for the farmers. The total weight of the machine is 118 kg and the major parts of the machine are marked and it is shown in figure 1.

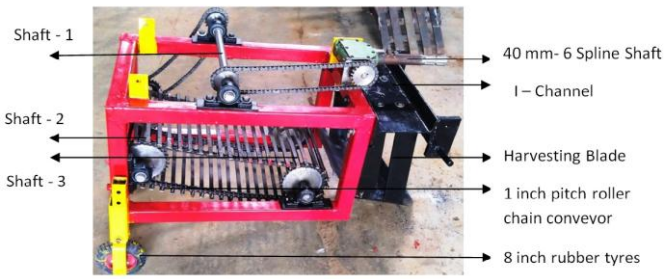

Fig -1: Parts of the Potato harvesting machine

2.1 Harvesting Blade

In Figure 2, it was shown that the furrows and ridges were the size of potatoes planted in the field. So, the potato digging blades were developed accordingly.

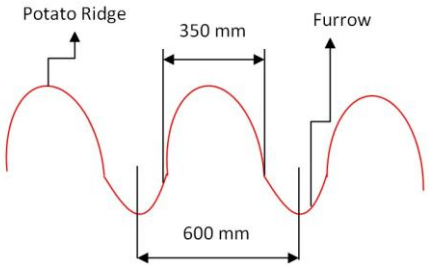

Fig -2: Schematic diagram of the potato plant ridges and furrows distance in the field

Hardened mild steel plates and flats are used for fabricating the digging blades. To reduce weight and drop the soil while digging, five laser-cut slots are made in the digging blade with dimensions of 20 mm width and 200 mm length, and it is shown in figure 3. Also, the blades were bent like a concave surface up to a depth of 4 inches to avoid potato cuts and enhance complete digging operations. Finally, digging blades with dimensions of 400 mm wide, 8 mm thick, and 210 (blade angle) were fabricated. The I-channel is made up of mild steel with dimensions of 300 mm in width and 500 mm in length, and is attached to the digging blade through fasteners. I-channel was used to connect these harvesting blades to three-point hitch systems in tractors. This harvest can be easily attached to the conveyor unit through fasteners.

(a) (b)

Fig -3: Potato harvesting blade (a) I-Channel attached with blade through fasteners (b) Laser cut slots provided in the blade to reduce the soil load

2.2 Gear box

A 1:1 right-angle bevel gear box attached to this harvester machine to rotate the conveyor is shown in figure 4. The 40mm hardened mild steel rod with 6 splines is attached to the gearbox as an input shaft. This input shaft is connected with the tractor's Power Take Off (PTO) shaft through a PTO joint. Basically, the PTO shaft in a tractor operates at 540 rpm. Also, the speed of the PTO shaft can be increased through the tractor throttle process depending on the soil and harvesting conditions. A 4 inch by 20 tooth hardened steel sprocket wheel is connected to the output shaft of the gearbox. In shaft-1, 2 sprocket wheels with a diameter of 4 inches of the same size are fixed through the keyway. One sprocket wheel of shaft-1 is connected with the gearbox output shaft sprocket wheel and the other is connected with shaft-2 sprocket wheel through 1 inch pitch roller chains.

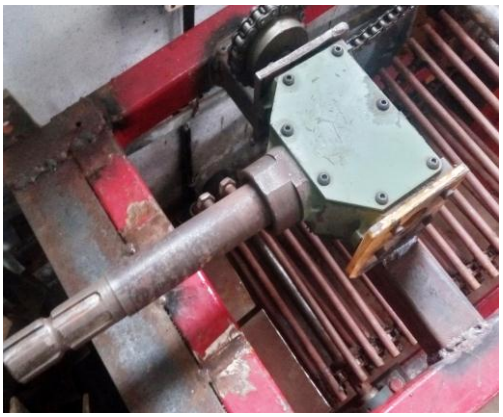

Fig - 4: Gear box fixed in Potato harvesting machine

2.3 Chain Conveyor

This conveyor is used in this harvesting machine to convey the soil and potato mass from the digging blade to the field. Also, it separates the soil and potatoes while conveying. Potatoes will never drop inside the conveyor gap because the chain gap was designed and fixed accordingly. Here, K2 attachments with 1" pitch roller chains of 10m length are used for conveyor fabrication and it is shown in Figure 5. 25 mm mild steel flats of 96 numbers are used to connect K2 attachments in the chain on both sides to perform the conveying operation. Initially, these mild steel flats are fastened using screws with lock nuts. After conducting many trial tests, it was observed that screws and nuts were getting loose, so flats were replaced by diameter 12 mm mild steel rods and they were welded. This conveyor has two shafts, namely Shaft-2 at the rear side and Shaft-3 at the front side. A diameter of 1 inch mild steel shaft of 550 mm and a diameter of 4 inch hardened steel sprocket wheels of 4 numbers are used in the conveyor system. P 205 Bearing units of 6 numbers are used. Furthermore, all bearing units are horizontally adjustable via slots in the channels. 8 inch rubber tyres of two numbers are used to support the harvester machine, and it is placed 600 mm wide in between according to the furrow distance.

(a) (b) (c)

Fig - 5: Conveyor unit (a) K2 chain attachment (b) Side view (c) 12 mm diameter mild steel rod welded in K2 attachment

3. RESULTS AND DISCUSSIONS

Details of the testing parameters and specifications are clearly indicated in Table 1. Figure 6 depicts the completion of all trail runs and field testing at ICAR-CPRS, Muthorai, Ooty, The Nilgiris district, Tamilnadu, India.

Fig -6: Potato harvesting machine under field testing at ICAR-CPRS, Ooty

3.1 Trial run observations

Approximately 25 trial runs were conducted in a field with hard soil at an approximate length of 330 feet. It was noted that 25 mm mild steel flats are missing and misaligned due to loosening of screwed fasteners running at high speeds, and it is shown in figure 7. Also, some potatoes remain unexposed while digging. In order to overcome the above-mentioned problems, mild steel flats were welded permanently in the roller chain K2 attachments and the dimensions of the harvesting blades were slightly altered to dig all the potatoes without any damage.

(a) (b)

Fig - 7. Various remarks noted after trial runs (a) 25 mm Mild Steel Flat missing due to screw joint failure (b) 25 mm Mild Steel Flat misaligned due to high speed running of conveyor

Table -1: Testing parameters and specifications

Test Place	ICAR-CPRS, Muthorai, Ooty
Tractor	Mitsubishi Shakti MT 180D series mini tractor
Hitching	Three point linkage
Soil	Sandy Loam
Moisture content (%)	7.6
Materials	Mild Steel & Hardened Steel
Trial runs	25
Factors	Dimensions of digger and thickness of digging blade
Observations	Exposed potatoes, Unexposed potatoes, Damaged potatoes, Time to harvest, Fuel consumption, Labours required to clean the plant debris - manual hoe and collecting potatoes
Angle	21^0
Field Area	330 feet
Potato variety	Kufri Jyoti & Kufri Swarna

3.2 Field test observations

Field tests of the developed harvester machine were compared with manual harvesting using labour with hand hoes. Two different field plots of the same size (1 hectare) were taken and compared. Two weeks before, a weed spray will be used to kill potato plants to completely remove the potatoes from the soil in dry conditions. At the time of harvesting, potato plants will be completely dried and can be easily picked up by hand. So, two labours are required to clean the plant debris for a 1 hectare field in one hour. Finally, potatoes were harvested using a manually operated and developed harvester machine, and the results are shown in Table 2. Few potatoes are left under the soil and two labours are required to dig the soil in two hours to complete 1 hectare of land. It was also noted that few potatoes were cut and damaged during harvesting due to the material used and the speed of the conveyor. These cut potatoes can be stored and used for seeding purposes. Also, four labours are required to collect the potatoes on the entire land and the time consumed is around four hours.

For the manual method, eight labours are required per day to complete the entire field. Six days to complete the harvest During harvesting, labours use hand hoes to dig the soil, and some of the potatoes will be damaged due to tool material.

From Table 3, it was noted that 48% of the cost was saved while using the potato harvester machine. Also, 64% of potatoes were damaged during manual harvesting compared with potato harvester machines.

Table – 2: Comparative results of machine harvesting and manual harvesting the potatoes

Observations	PLOT-1			PLOT-2		
	Potato Harvester Machine			Manual Method		
	Results		Cost in Rs.	Results		Cost in Rs.
Area Covered in hectare	1			1		-
Total potatoes harvested	19.83 tonne	19830 kg	-	18.79 tonne	18790 kg	-
Exposed potatoes	90.80%	18005.64 kg	-	100 %	18790 kg	-
Unexposed potatoes	6.20%	1229.46 kg	-	Nil		-
Damaged potatoes	3%	594.90 kg	-	8.30 %	1559.57 kg	-
Time to harvest	6 hours 30 min		-	8 hours/ day for 6 days		-
Fuel Consumption litres/hour	3		1853	Nil		-
Labours required to clean the plant debris	2 nos	1 hour	1400	Nil		-
Labours required for harvesting using hand hoe	2 nos	2 hour	2800	8 nos	48 hours	33600
Labours required for collecting potatoes from the field	4 nos	4 hour	11200	Nil		-
Miscellaneous			500			500
Total cost in Rs.			17753			34100

Table – 3: Consolidated results

Description	Manual Method	Potato Harvester Machine	Cost difference in Rs.
Cost save in Rs.	34100	17753	16347
Percentage of cost saving	48%		

4. CONCLUSION

A potato harvester machine is designed and developed especially for hill terrain farming. The harvesting blade, gearbox, and roller chain conveyor are the three major components used to fabricate the potato harvester machine. In this machine, K2 chain attachments on 1 inch pitch roller chain are used to fabricate the conveyor part. In the trial tests, it was noted that some potatoes were unexposed during harvesting and a few mild steel flats got misaligned due to the speed of the conveyor. Harvesting the potatoes was compared with manual and potato harvester machines with the same plot size of 1 hectare. It was noted that the cost of manual harvesting and potato harvesting machines was Rs. 34100/-and Rs. 17753/-respectively. Nearly 48% of the cost was saved while using a potato harvester machine, and 64% of the potatoes were damaged in manual harvesting compared to the potato harvesting machine.

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