Asian Jr. of Microbiol. Biotech. Env. Sc. Vol. 24, No. (4) : 2022 : 767-770

ISSN-0972-3005

DOI No.: http://doi.org/10.53550/AJMBES.2022.v24i04.025

DEVELOPMENT OF A BULLOCK–DRAWN DIGGER ELEVATOR FOR HARVESTING POTATO

ASHOKSURAJ B. S*[1]., SRINIVAS YARRAKULA[2], K. N. HANUMANTHARAJU[3] AND ABDUL REHMAN[2]

[1]Department of Agricultural Engineering, University of Agricultural Sciences, GKVK, Bengaluru, India
[2]National Institute of Food Technology, Entrepreneurship and Management, Thanjavur, India
[3]Department of Food Technology, Ramaiah University of Applied Science, Bengaluru, India

(Received 11 June, 2022; Accepted 18 August, 2022)

Key words : *Potato, Bullock drawn, Potato harvester, Harvesting efficiency*

Abstract – Potato, after corn, rice, and wheat, is the world's fourth most major food crop, producing 321 MT on 19.5 million hectares. Potato cultivation covers 1.86 million hectares in India. Potatoes are a labor-intensive crop. It is currently facing a labour shortage. The harvesting of potato tubers is the most important aspect of potato cultivation. AnAnimal-drawn potato digger has been developed to reduce drudgery and labour when harvesting potato tubers. The performance of the potato digger was evaluated in the field with soil moisture content of 8% (db), bulk density of 1.38 g/cc. The implement has a field capacity of 0.16 ha/h with field efficiency 85 per cent and turning losses 5.7 per cent when the harvesting of potato was done using the developed digger as the 5 per cent of the harvested potato was damaged and 4.7 per cent were left within the soil. For its efficient operation, this implement can be widely adopted by potato farmers, and it is best suited for small and marginal farmers.

INTRODUCTION

In India, the total area under cultivation is 329 million hectares, of which 1.86 million hectares are devoted to potato cultivation. The potato is a tuberous, starchy crop derived from the perennial nightshade *Solanum tuberosum* L (Hawkes, 1992). The potato, also known as "the king of vegetables," has risen to become India's 4thmost important food crop after wheat, rice,and maize (Kloosterman *et al.,* 2013). India has topped China to become the world's second largest producer of potatoes. During 2018-2019, India produced 42.34 million tonnes of potato with an average yield of 22.72 T ha^{-1} from 1.86 million ha area under the crop (National Horticulture Board, 2018). Though potato productivity in India has recently increased, it is unclear whether this level can be maintained or increased in the future. Knowledge of previous trends in area, production, and productivity will help planners determine the growth rates needed to meet the planned targets. Aside from that, trends in area, production, and productivity can be used to forecast future supply. Several studies attempted to estimate growth rates (Järvan and Edesi, 2009).

The yield trend, as shown in Table 1, can be used to assess the state's technological development. Given the variability in yield from year to year, the relationship between yield and yield variability must be investigated. As shown in Fig. 1, which depicts potato productivity in important Indian states, the relative contribution of area and yield on

Table 1. Major Potato Producing States in India

Sl. No.	State	Production (Tonnes)
1	Uttar Pradesh	13,869.94
2	West Bengal	11,550.00
3	Bihar	6,842.92
4	Gujarat	2,499.73
5	Punjab	2,129.79
6	Madhya Pradesh	1,998.35
7	Assam	975.27
8	Karnataka	698.30
9	Haryana	676.01
10	Jharkhand	659.61

Source: National Horticulture Board

([2]Research Scholar)

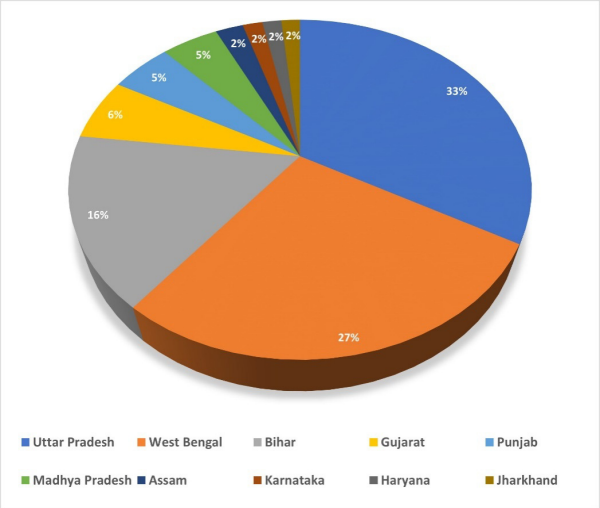

Fig. 1. Production status of Potato in India

potato production is required because it would be extremely valuable for future policy formulation (Dozorova *et al.*, 2016). Because crop production is determined by crop area and average yield.

As shown in Fig. 2, the majority of farmers in India have small and marginal land holdings. Farm mechanisation has addressed farmer needs such as timely field operations, higher field efficiencies, higher productivity, reduction in human drudgery, and reduction in human cost of operation. The challenge, however, is identifying appropriate mechanisation needs for various sizes of land holdings located in various agro-climatic regions and socioeconomic strata of farmers (Pandey, 2010).

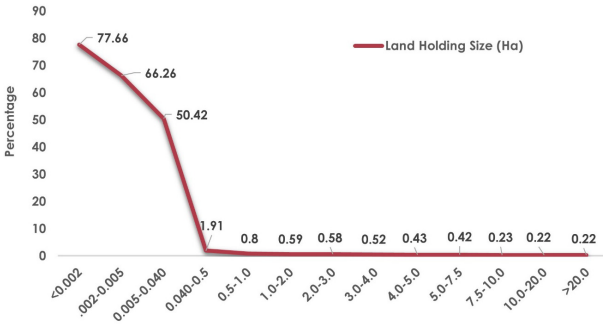

Fig. 2. Land holding size percentage distribution

In India, there are estimated 85 million draught animals available, and almost all tillage and sowing is still done with animal power. Animal power, on the other hand, is not widely used in harvesting and intercultural operations. Manual harvesting can produce clean results, but it is a time-consuming process, and labour shortages during peak season cause harvesting to be delayed. Manual potato harvesting is usually slower and more expensive than using an animal-drawn digger. Animal power is used to supplement manual picking within crop rows for some crops.

Potatoes are mostly removed from the field by hand, which has been seen as a hindrance to harvesting (Grandjean *et al.*, 1982). Potato harvesting by hand is regarded as a major constraint in its cultivation. During harvesting, most farmers face a severe labour shortage, reducing yield by more than 15%. Animal power will play an important role in root crop harvesting and will be by far the most widely used method of harvesting in the country for many years to come. Ergonomic considerations, ease of use and handling by unskilled farmers, less damaging nature to crops, the distance between two crop rows, maximum efficiency, important components such as blades, critical design areas, and, most importantly, the cost of purchase are all aspects of harvesting equipment.

MATERIAL AND METHODS

Design is the practice of developing or improving to perform a specific task (Gite *et al.*, 2009). As a result, the primary goal of design is to maximise the performance of the implement. A digger should be light, strong, durable, inexpensive, adjustable for different crops, and simple to manufacture locally. The materials used for design and fabrications of an animal drawn potato digger area 14 gauge flat iron, 22 mm dia hollow cylindrical pipe, 14 gauge square iron rod, wooden beam, 14 gauge rectangular iron flat (Fig. 3 & Fig. 4).

Frame

Frame is the part where all other parts are attached. We have used a solid square rod of 2 cm cross section for frame. The parts which are welded on the frame are iron plate to support handle. For beam support, hollow cylindrical pipe of 7.2 cm diameter and 9.5 cm in length is used. This cylindrical pipe is welded onto the frame which is bent from both sides with the help of hammer strokes using bench vice. The bending and welding of the cylindrical pipe is done such that to get a straight support for attaching the beam. On the adjacent face of the pipe, the handle is welded. The Shareis welded to the tine and lifting rods are welded onto the share. A hole is drilled onto the pipe and also into the beam and are

attached using a nut and bolt.

Tine

Tine of curved shape was made out of a square rod of 20 mm using bending machine. The bending was done to get an 41º angle. The bent part is flattened by heating and beating action. Now share is welded on this.

Share

As stated earlier, instead of straight share, angled share is more effective for cutting of soil. The share used by our project is V-shaped type. For formation of the share, first two iron plates of rectangular shape with sides 8.5 cm and 35.5 cm of length are joined together into V-shape. The share is furnished with the help of grinding machine and then welded on the tine.

Lifting rods

Rods are used for agitating of potatoes from soil. For Lifting rods cylindrical rod of 8 mm diameter is used and was cut 15, 22, and 30 cm lengths was grinded and bent equally at one end. These rods were then welded onto the share with 8 cm spacing between them.

Handle

A circular pipe of diameter slightly smaller than that of beam is taken and was cut into 59 cm, 41cm and 16.5 cm lengths, the 59 cm length pipe is welded onto the frame were the 41 cm length pipe is welded on the other side having equal lengths on sides for which the pipes of 16.5 cm length are welded on both the sides.

Specifications of the developed digger

Total width of coverage	:	520 mm
Total height	:	980 mm
Shape of share	:	V-shaped
Beam length	:	3000 mm
Weight of the implement	:	31 kg
Length of share	:	355 mm
Width share	:	520 mm
Number of lifting rods	:	6

RESULTS AND DISCUSSION

The field testing of the developed digger was carried out at University of Agricultural Sciences Bengaluru farm, where the field was prepared for the testing conditions with soil moisture content of 8 percent

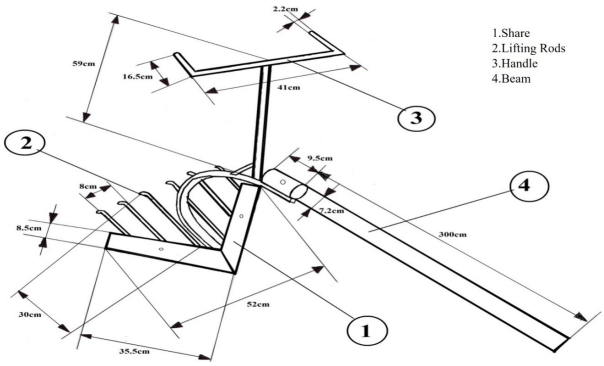

Fig. 3. Schematic of Developed bullock drawn potato digger

Fig. 4. Developed bullock drawn potato digger

under dry basis, bulk density of 1.38 g/cc.

The net thrust force F on an implement (Biswa and Yadavs, 2004) is given by the formula:

$$F = cA + W \tan\varphi \quad \text{... Eq.1}$$

where, c is soil cohesive strength, A is the area of cross-section, W is weight of the implement, and φ is angle of friction.

The angle of internal friction (φ) is typically around 25-350, the coefficient of internal friction (tanφ is taken as 0.6). As red soil is considered under medium clay soil, hence taking the value of c as 192 kPa, weight of the implement is 31 kg and area of cross-section of the furrow 0.0442 m^2 and thus, the net thrust force is 1.06564 kN (Lakshminarayana and Vikas, 2018). Therefore, power required for unit time operation is 0.8110 kJ per unit time. The power delivered by bullock pair is 1hp. Hence, we can see that animal power can be used for this implement as the power source. The speed of operation should be 2.7 kmph.

The implement was hitched to a pair of bullocks, an area of 200 m^2 of land in the field was marked for testing purpose and the time taken by the implement to carry out the given operation was noted along with the depth of plough and width of

the plough. It took a total time of 7 min to cover the area with a 2 min time for taking turns. Hence, the actual time taken by the implement for covering the given area is 5 minutes.

This implement has a total working width of 52 cm, depth of furrow opened is 17 cm with an operating speed of 2.74 km/h. The implement has a field capacity of 0.16 ha/h with field efficiency 85 per cent and turning losses 5.7per cent when the harvesting of potato was done using the developed digger as the 5 per cent of the harvested potato was damaged and 4.7 per cent were left within the soil. The implement has a draft of about 150 and requires a labour of 6.7 man-h/ha.

CONCLUSION

The findings shows that the animal drawn digger with a single row implement was suitable for digging out the potato. The digger has a V-shaped ridger type share for cutting the soil. The lifter rods are attached behind the share, which is spaced to allow clods and residual material to fall while operating the implement. When compared to the traditional method of digging with a spade and hand pulling, it saves 94% labour and operating time. Because of its efficient operation, this implement has the potential to be widely adopted by potato farmers. The developed implement is best suited for small and marginal farmers and can be used for harvesting ground nut vines.

ACKNOWLEDGMENTS

The authors acknowledge UAS(B), GKVK Bangalore for their kind assistance and co-operation during this study.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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