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CONTENTS

Design and development of self-propelled onion (*Allium cepa* L.) digger

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ABSTRACT: In this study, an effort has been made to design and develop an onion digger for the onion field in India. The onion digger has four wheels and a two-wheel drive machine. The digging system consists of a blade made up of high carbon steel material (EN45), which was the central digging part of the machine having dimensions 1000mm*250mm*10 mm. Fingers of the reaper binder are also provided to protect the blade from obstacles like heavy rocks and tough metals. The spacing of fingers is 180 mm, and the width of each finger is 100mm. Fingers are fastened on the blade with the help of nuts and bolts, and they are easily replaceable when got damaged. The forward operating speed of the machine is 3-5 km/h, and the maximum speed is10 km/h, having a field capacity of 0.2 hectares per hour. The working depth of the machine is 100mm. Depth is suitable for the field with practically no damage to the onion bulb. The fuel consumption of the machine is 3.5 litres per hour when working at full capacity.

Key words: Digger, development, farm machinery, onion harvester

India is the second-largest onion-producing country in the world (Kumar *et al*., 2006). Indian onions are available round the year and have two seasons, first harvested from November to January and the second harvesting from January to May. The onion is a biennial but is usually grown as an annual crop. The bulb can be white, yellow, or red and require 80 to 150 days to reach harvest. The optimum time of harvesting is one week after 50% of leaves have fallen. Onions of an early harvest maturity had a higher storability than other maturities of harvest (Maw *et al*., 1997). Maturities symptoms include yellowing of leaf and dry at the top; bulbs turn red and attain their optimum varietal size (Talokar *et al*., 2014).The onion root system is fibrous, spreading just beneath the soil surface to a distance of 45cm (Al-Jamal *et al*., 2001). In India, most of the onions are harvested manually, and it is a time-consuming and labour-intensive job. When producing bulb onions from sets, the cost of manual labour on tending, harvesting, and postharvest treatment amount to 60–70% in the production cost structure (Laryushin and Laryushin, 2009). Matured bulbs are harvested by hand shovel (khurpa), which requires 21.4 % of the total expenditure of onion cultivation (Kawale and Ramappa, 2019). A lot of research has been done in the past to develop machinery for the harvesting of onions in India as well as in other parts of the world. In this study, an effort has been made to develop a self-propelled onion digger suitable for the Indian field.

MATERIALS AND METHODS

The onion digger was developed for digging the onion between the tyres of the machine, the track width of the machine is 1560 mm, and the width of the blade is 1000 mm. The inclination of the blade was kept between 15-20° for better penetration (Kanafojski and Karwowski, 1976), the angle between 15-20° is best for cutting soil with less resistance. The angle of the blade is adjustable, it can be adjusted by two nuts and bolt assembly. After the blade, there is a conveyor that conveys the dug onion and removes the extra soil. After conveying, onions are dropped on the soil and later pick-up by the labour easily.

COMPONENT OF MACHINE

ENGINE: For providing power to the digger, we use the Kirloskar CC418, 8-horse power Diesel Engine. Air-cooledengine works in the clockwise direction. A single-cylinder internal combustion engine is with

a decompression lever. The model number of the engine is CC418. For digging work, we need a sufficient amount of power which is provided by the engine.

BLADE: Blade is the main Digging unit of the machine. The material used for the blade is High Carbon Steel (EN45) which provides high wear resistance and is less ductile (Singh, 2014). The length of the blade is 1000mm and the thickness of the blade is 100mm. There are ripper binder fingers that protect against heavy stones and obstacles. The width of the fingers is 180mm and the spacing of the fingers is 100mm. The blade is connected to the conveying unit.

CONVEYOR DESIGN: Conveying system is used to convey the harvested crop and it also works as a separator simultaneously, which separates the onion bulb from the soil which provides an ease to lift the onion crop from the field. We use L-section bars to convey properly the upper end of the conveyor then the onion is passed to the hopper which is provided at the back of the machine. Our aim of the conveying system is to separate onion properly from the soil because hand separation is labour-intensive work and it also increases the cost of harvesting.

FRAME AND CHASSIS OF MACHINE: The chassis is the component in charge of supporting all other vehicles subsystem, and taking care of the driver safety at all times. The chassis design needs to be prepared for the impact created in any certain crash. It must be strong and durable taking into account the weight distribution for better performance. Mild steel is used for the formation of the chassis. It provides easy operation and reformation and it could easily be welded.

TRANSMISSION SYSTEM: The main function of our transmission system is to reduce the speed at the optimum level and provide sufficient torque for our operation. In our operation, were quire less speed because of less damage to the crop and proper cleaning and conveying of our crop. The torque is increased by reduction of driven shaft rpm, for the forward movement and digging of the blade to sufficient depth. The transmission system of power tiller (Shakti130DI) was used because it is one of the matchings to our requirements. There are three forward gears and a reverse gear. Constant and sliding mesh gears, Clutch type dry friction plate were used. There are a total of six forward gear ratios and two reverse gear ratios, three low forward, three high forward, and to high or low reverse.

STEERING SYSTEM: The steering system is similar to harvester steering, generally steering wheels are front-wheel but in this case steering wheels are rear wheels because maximum power will reach the digging unit and so that we provide power to front wheels and rear wheels are steering wheels. Ackerman steering with rocker-arm assembly, kingpin inclination is 15°, and turning radius is 2.8 meters was used.

TYRE: In all agricultural machines, traction is one of the most important aspects of both steering and getting the power to the ground. Research outcome

Table 1: Specification of the conveying system

Type of system	L-section Bars fitted on rubber belt
Length of the conveyer	1300 mm
Speed of conveying system	50 RPM
Spacing of L-section	35 mm
Diameter of driving pully	187.5 mm
Diameter of the second pully	95 mm
Conveyor angle	20°
Size of L-section Bars	20mm*20mm*1mm(thickness)

Table 2: Specification of Chassis

Material	Mildsteel
Cross section Dimension	4cm*7.5cm*0.5cm(C-section)
Thickness	80.5cm
Bending strength	250MPa
Density	7.85g/m^3

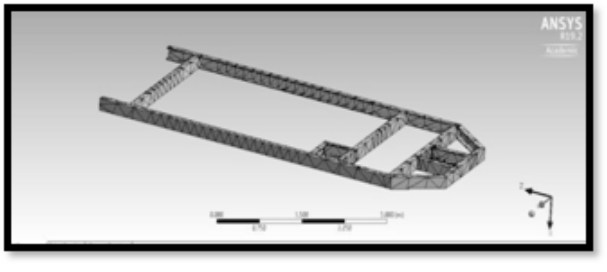


Fig.1: Chassis and frame design in isometric view

Table 3: The detailed specification of the digger

Overall Dimensions	2800*1840*1300 (mm) (length*width*height)
Ground Clearance	300 mm
Machine Weight Without operator	340 kg
Wheelbase	1930 mm
Wheel track	1560 mm
Average working depth of the blade	85-95 mm

Table 4: The gear ratio of input to the output speed of the gearbox

Gear Position	The ratio of Speed of Driving Gear to Driven Gear
1^{st}low Gear	200
2^{nd}low Gear	134.92
3^{rd}low Gear	85.75
Reverse low	230
1^{st}high Gear	55.91
2^{nd}high Gear	38.08
3^{rd}high Gear	24.29
Reverse high gear	64.48

Table 5: Tyre specification

Tyre	Size	Static loaded radius	Overall tyre diameter (OD)	Sectional width (SW)
Front	7.5"-16"	398mm	838mm	198mm
Rear	6.0"-12"	295mm	627mm	160mm

shows that approximately 20-55%of useful tractor energy is lost at the tyre-soil contact surface (Kumar *et al*., 2021).Tyre configuration tread depth, weight, and rotational inertia is a critical factor when choosing proper tyres. In the digger both the front and rear wheels are traction tyres, because traction is the key factor in any agriculture machine, all the agriculture operations are done on most uneven surfaces.

Objective: -

- Supporting vehicle load
- Absorbing the road shocks.
- Transmit the power to the road.

BRAKE SYSTEM: A Precise braking system is important for the performance & safety of the vehicle. The main requirement of a vehicle braking system is that it should be capable of locking all four wheels on a dry surface. Provide adequate braking power and minimum wear and tear and heat loss. An internal expanding friction brake on the rear wheel is used. There is a separate clutch provided to both the power wheels when vehicle is to be stopped just press the clutch, then press the break. There is one more option to stop the vehicle i.e., the hand clutch which disengages the power from the engine to the gearbox.

MEASUREMENTS

a. *Lifted root crop percentage (Lift %)*: It is the percentage of the lifted onion by the digger over unlifted onion by the digger, calculated by the equation given below (Ibrahim *et al*., 2008).

$$\text{Lift percentage} = \frac{ML}{MUL+ML} \times 100$$

Where,

M_L=Mass of lifted root crop over the soil surface (kg),

M_{UL}=Mass of unlifted root crop (kg),

b. *Root crop damage percentage (D_t %)*: It is the percentage of crop damaged by the digger over not damaged crop, calculated by the given equation below (Ibrahim *et al.,* 2008).

$$\text{Crop damaged percentage} = \frac{MD}{MND+MD} \times 100$$

Where,

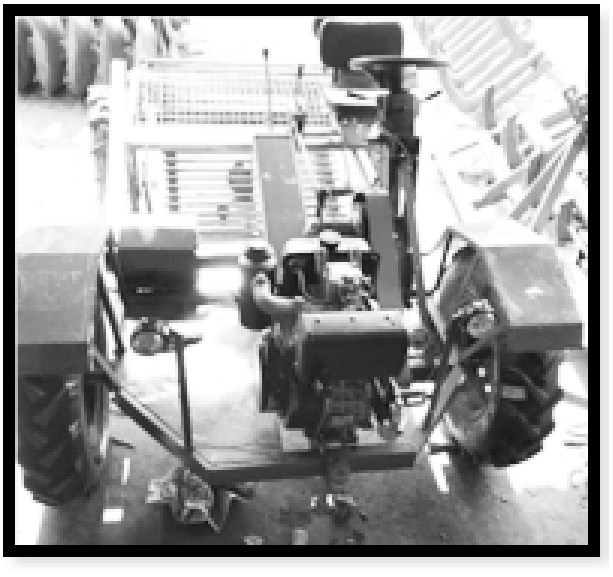


Fig.2: Onion Digger

M_D=Mass of seriously damaged or cut root crop (kg),
M_{ND}=Mass of root crop not damaged (kg),

c. *Digger efficiency (η)*: The digger efficiency was calculated using the equation given below (Ibrahim *et al.,* 2008).

$$\eta = \frac{MR - MD}{MT} \times 100$$

Where,

M_R=Mass of raised root crop (kg),
M_D=Mass of damaged root crop (kg),

Fig.3 Effect of speed of operation on lift and digger efficiency

M_T=Total mass of sample (kg),

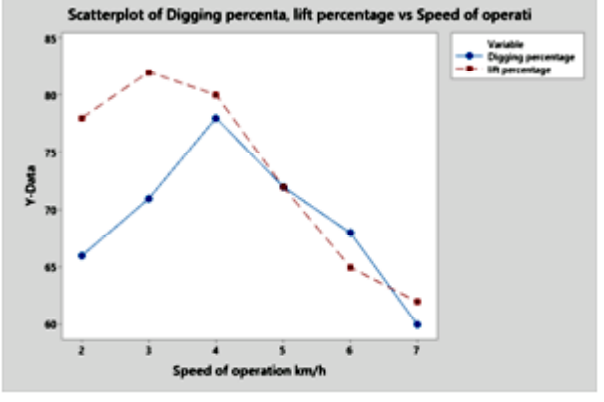
FIELD PREPARATION: Onions are transplanted on the bed, row to row spacing is 15cm, and plant to plant spacing is 8cm, there are 5 rows, and 3 same plots are used.

Table 6: Onion field specification

Onion variety	Bheema Shakti
Row to row spacing	15cm
Plant to plant spacing	8cm
Plot size	105cm
Number of plots	3

RESULTS AND DISCUSSION

The plant population of the field chosen is 2,60,000 (approx.) onion blubs in the hectare and the average field capacity of the digger is 0.2 hectares per hour, working on operational speed of 3-5 kmph. The lift percentage of the machine is 88% and the efficiency of the digger is 78%. The average working depth of the machine is 0.085-0.095 meters. Conveyor inclination is 18-20°.



The overall cost of the machine including all different parts and welding costs is 1.43 lack rupees. The fuel consumption of the machine is 3.5litres per hour which makes 17.5 litres per hectares.

CONCLUSION

The digger is designed for digging onion crops at the time of maturity but it can be used in potato, groundnut, and garlic by making some changes in conveyor and the blade angle. The test was performed in the loamy sand onion field.

Benefits:

- Reduce harvesting time of onion
- Reduce labor requirement
- Increased harvesting efficiency
- Reduce overall cost of harvesting

The average field capacity of the machine is 0.2 hectares per hour. The vibration and noise levels of the machine are under test code limits. There are adjustable blade angles and conveyor angles, with an adjustable conveyor speed of two levels. The fuel consumption of the machine is 3.5litres per hour when working at full capacity.

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