e ISSN-0976-7223 | Visit Us - *www.researchjournal.co.in* DOI : 10.15740/HAS/IJAE/7.2/391-394

RESEARCH PAPER **International Journal of Agricultural Engineering | Volume 7 | Issue 2 | October, 2014 | 391–394**

Development and performance evaluation of a digger for harvesting onion (*Allium cepa* L.)

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Received : 15.04.2014; **Revised :** 19.08.2014; **Accepted :** 03.09.2014

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■ **ABSTRACT :** Onion harvesting machinery like all other farm equipments has passed through various stages of development. In this study an effort has been made to develop and evaluate the performance of an onion digger. Blade made up of high carbon steel material (EN 45) was the main component having dimensions 143cm × 7cm × 1.5cm. Depth control wheels were provided to control the depth of cut by blade. Tests were conducted to check the comparative performance of developed onion digger and manual labor in the field. The digger was operated at a speed ranging 3.76 to 4.83 km/h with minimum losses at 4 km/h in first high gear at a field capacity of 0.46 ha/h. The average operational depth of 7.62 cm of the developed digger was suitable with practically no damage to the onion bulbs. The operational time of digger including and excluding the time in turning were 3.10 h/ha and 2.38 h/ha, respectively. Lift percentage, mean digger efficiency and damage percentage were 94.9, 89.8 and 5.1, respectively. It was found that there was 58 per cent and 49 per cent saving of labor and cost, respectively.

■ **KEY WORDS :** Development, Evaluation, Digger, Onion, Lift percentage, Efficiency

■ **HOW TO CITE THIS PAPER :** Singh, Mahesh Chand (2014). Development and performance evaluation of a digger for harvesting onion (*Allium cepa* L.). *Internat. J. Agric. Engg.*, **7**(2) : 391-394.

India is the world's second largest producer of onion (*Allium cepa* L.) after China being at top followed by USA, Turkey, Pakistan, Iran, Indonesia, Vietnam and Myanmar (Kabir, 2007 and Anonymous, 2009). In year 2007, the cultivated area under onion farming in India was 2.7 million ha (FAO, 2008). The area under onion cultivation was 1.064 million ha with productivity of 14.2 million tone/ha (NHB, 2011). In Maharashtra and Gujarat, this crop has gained the importance of a cash crop rather than a vegetable crop because of its very high export potential. The other major onion producing states are Orisa, Uttar Pradesh and Karnataka. In Punjab onion is generally a *Rabi* crop. The best time to sow nursery is mid October to mid November and first week of January is being the best time to transplant the crop (Anonymous, 2005). The onion root system is fibrous, spreading just beneath the soil surface to a distance of 45 cm (Al-Jamal *et al.*, 2001). Reports suggest that onion plays an important role in preventing heart diseases and other ailments (Augusti, 1990). In India most of the onion is harvested manually. Manual harvesting of onion is done by use of khurpa or spade which is a labor intensive and time consuming operation. Mechanization of onion harvesting is the need of the time as traditionally, the well-matured bulbs are harvested by hand shovel (*khurpa*) which requires 21.4 per cent of total expenditure of onion cultivation (Jadhav *et al.*, 1995). A lot of research has been done in the past to devise the best methods and machinery for the harvesting of onions in India as well as in other parts of world. A combination of machines for harvesting onions including the machine for removing onion leaves and weeds, the pull-type mounted onion digger, and the onion windrow pickup was developed by Penza State Agricultural Academy (Laryushin *et al.*, 2005). The pull-type mounted onion digger intended for two stage harvesting of onion cultivars with field capacity 0.42–0.6 ha/h and digging efficiency is 98.0–98.9 per cent (Laryushin and Laryushin, 2009). Study was conducted on design and evaluation of principles for mechanically harvesting sweet onions (Maw *et al.*, 1998). Studies had been conducted on stability of full bed elevator for onions (Maw *et al.*, 2002) and enhancing the performance of onion harvester (Maw *et al.*, 2002). In this study an effort has been made to develop a tractor mounted onion digger and to evaluate the same for onion digging.

■ METHODOLOGY

The onion digger was intended to be developed for

digging onions from between the wheels of the tractor. The track width of the tractor was 148.5 cm while the space between wheels was 132 cm. A little extra width was provided to prevent any missing. The inclination of blade with ground was kept between 14-20° (Kanafojski and Karwowski, 1976), provided for effective digging operation. The angle of blade if less than 14° will not disturb the soil sufficiently and angle greater than 20° will tend to collect soil in front of blade, unnecessarily increasing draft.

Structural components of digger :

Blade :

Blade was one of the main components of onion digger. For the construction of blade 143 cm long high carbon steel (EN 45) material was selected to prevent the blade from wear while passing through the soil. Width of material was 7 cm and thickness was 1.5 cm. Gas cutter was used to create an edge on the side of the blade and this cutting edge was sharpened using a grinding machine. Three holes on each side were drilled for bolting the blade to the shank.

Shank :

The shank connects the blade and frame. There are two shanks on each end of the blade. It is made of MS flat of length 51.5 cm, width 5 cm and thickness 1.5 cm. The blade is bolted to the lower end of the shank. Eight holes of diameter 1.5 cm each are drilled on the top end of the shank. These holes were drilled for fixing the shank to the frame and the cross member to the shank. It is through these holes that the depth of blade from the frame and the angle of blade can be controlled.

Frame :

The frame of the onion digger transfers the forces from the tractor to the digger and *vice- versa*. It was made of hollow square section created by welding together two lengths of angle cross section having dimensions of 6.5cm×6.5cm×0.64cm each. The frame is welded together using four lengths of square cross section. Overall front width of the frame was 184cm side width was 72cm. The frame had also got a three point hitch arrangement fixed for use of machine with tractor of 35 hp.

Cross member :

The cross member was made of MS flat having dimensions 40.5cm×5cm×1.5cm. There were two cross members and each is fixed to the frame as well as shank through 1.5 cm holes drilled at each end of the cross member. The mating of hole of cross member with the corresponding hole of the shank will control the blade angle.

Adjustable ground wheels :

A pair of ground wheels was provided for controlling depth of operation of the digger blade. The outer diameter of the wheel was kept 23 cm and it was connected to the frame through a fork. The fork had arrangement at the top for fixing it at pre-determined depth on the frame. During operation the clearance between the cutting edge of blade and bottom of the wheel was kept for controlling the proper digging depth so that the blade passes below the bulbs without damaging or leaving the bulbs in the soil.

The developed digger is shown in Fig. A, B and C.

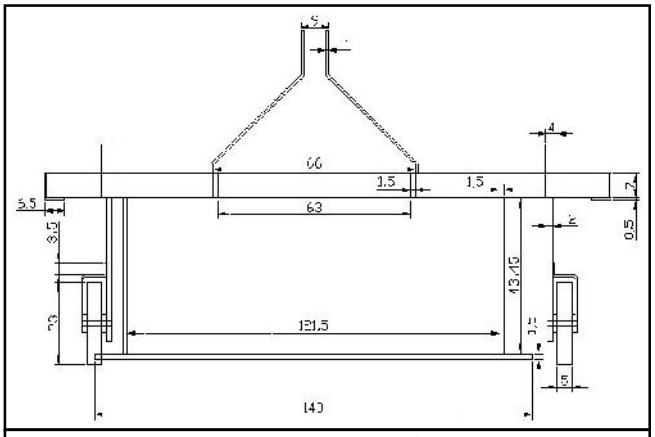

Fig. A : Assembled onion digger (front view with all dimensions in cm)

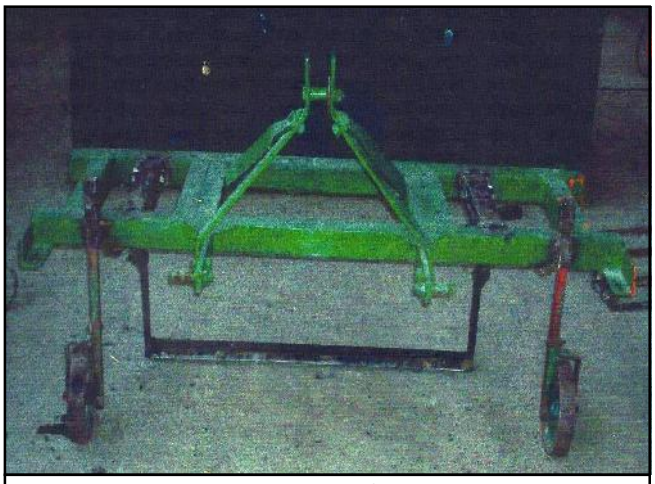

Fig. B : Assembled onion digger (front view)

Measurements :

Lifted root crop percentage (Lift %) :

The lift percentage was calculated using the equation given below (Ibrahim *et al.*, 2008). Where M_L=Mass of lifted root crop over the soil surface (kg) and M_{UL}=Mass of unlifted root crop (kg).

$$\text{Lift per cent} = \left[\frac{M_L}{M_L + M_{UL}}\right] \times 100$$

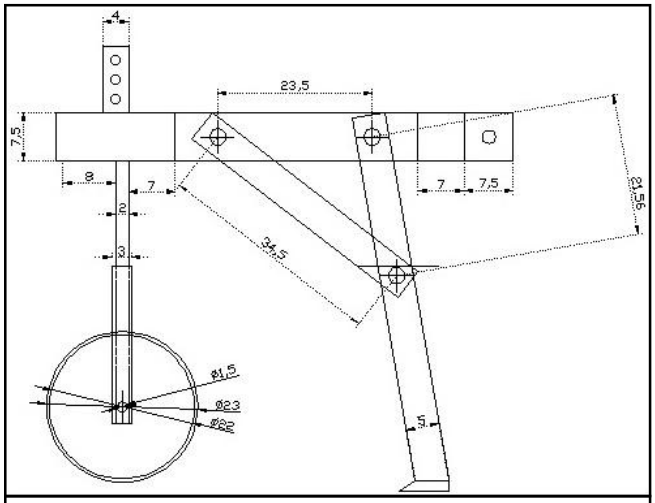

Fig. C : Assembled onion digger (side view)

Root crop damage percentage (D_t %) :

The damage percentage was calculated using the equation given below (Ibrahim *et al.,* 2008). Where M_D=Mass of seriously damaged or cut root crop (kg) and M_{ND}=Mass of root crop not damaged (kg).

$$D_t \text{ per cent} = \left[\frac{M_D}{M_D + M_{ND}}\right] \times 100$$

Digger efficiency (η_H) :

The digger efficiency was calculated using the equation given below (Ibrahim *et al.,* 2008). Where, M_R=Mass of raised root crop (kg), M_D=Mass of damaged root crop (kg) and M_T=Total mass of sample (kg).

$$\eta_H = \left[\frac{M_R - M_D}{M_T}\right] \times 100$$

Yield (Y) :

The yield of harvested onion crop was determined by weighing the onion lifted over surface after the harvesting operation (t/ha).

Cost of fuel consumption (l/h) :

Cost (l/h)=LCF×HP×SFC, where LCF holds for load co-efficient factor, HP holds for horse power of tractor and SFC holds for specific fuel consumption.

Performance evaluation :

Onions were transplanted on beds. The row to row spacing was kept as 15 cm and plant to plant spacing was kept as 7.5 cm. The bed was made 1.05 m wide containing seven rows. The crop was harvested at the age of 107 days after sowing. The various parameter recorded while evaluating the performance of the digger were operational speed of digger, depth of operation, operational time of digger, number of plants per unit area, weight of onion lifted or raised, weight of onion damaged, weight of onion left undigged, labour required for manual and mechanical digging and subsequent collection.

■ RESULTS AND DISCUSSION

The plant density at the time of harvesting was 2,76,700 bulbs/ha and yield obtained was 15.2 t/ha. The digger was operated at a speed ranging 3.76 to 4.83 km/h with minimum losses at 4 km/h in first high gear at a field capacity of 0.46 ha/h. The average operational depth of 7.62 cm of the developed digger was suitable with practically no damage to the onion bulbs. The operational time of digger including and excluding the time in turning were 3.10 h/ha and 2.38 h/ha, respectively. Lift percentage, mean digger efficiency and damage percentage were 94.9, 89.8 and 5.1, respectively. The results obtained from evaluation of digger were compared to manual picking. The comparisons were made on the basis of time, labor and cost saving. The labor requirement for manual harvesting and collection of onion was found to be 277.22 man-h/ha. The labor required for mechanical harvesting and manual collection were 2.20 man-h/ha and 113.48 man-h/ha, respectively.

The major cost involved while using the onion digger included cost of diesel fuel and labor employed. The cost of fuel calculated was 4.69 l/h which was equivalent to 14.5 l/ha for the complete mechanical digging operation.

The cost of mechanical harvesting, collection and manual harvesting were also calculated. It was found that there was 58 per cent and 49 per cent saving of labor and cost, respectively (Fig. 1 and Fig. 2).

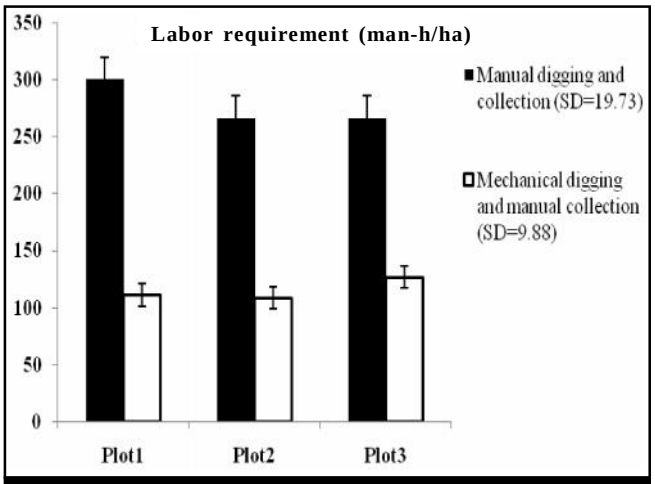

Fig. 1 : Labor requirement (bars represent standard deviation)

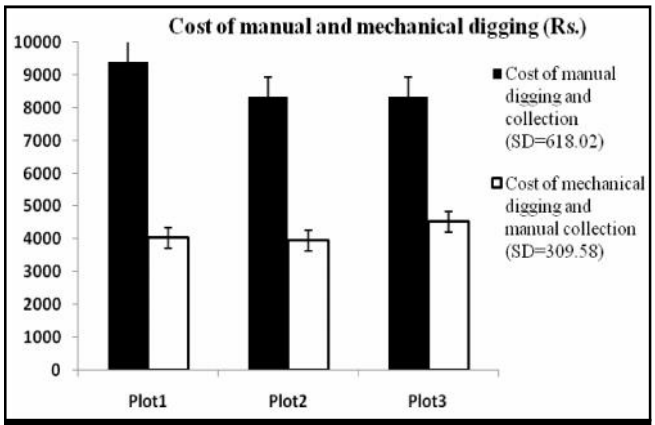

Fig. 2 : Cost of digging (bars represent standard deviation)

Conclusion :

The digger was developed and evaluated for its performance at the experimental site. The digger was operated with a speed of 4 km/h in first high gear with minimum losses at a field capacity of 0.46 ha/h. Depth control wheels were effective to control the depth of cut by blade. The average operational depth of 7.62 cm of the developed digger was suitable with practically no damage to the onion bulbs. The operational time of digger including and excluding the time in turning were 3.10 h/ha and 2.38 h/ha, respectively. The plant density at the time of harvesting was 2,76,700 bulbs/ha and yield was 15.2 t/ha. Lift percentage, mean digger efficiency and damage percentage were 94.9, 89.8 and 5.1, respectively. It was found that there was 58 per cent and 49 per cent saving of labor and cost, respectively. The developed digger can also be used to harvest other root crops such as groundnut.

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