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Performance Evaluation of Tractor Drawn Root Crop Harvester for Harvesting of Potato and Ginger Crop

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ABSTRACT: Potato and Ginger are important root crops grown in Madhya Pradesh and in India. Harvesting is one of the very crucial operation in potato and ginger crop production. In conventional method, the potato and ginger is harvested either by manually with spade or hand hoe or by bullock drawn equipment, which is tedious, labour intensive and time consuming operation. Also, the damage percentage of potato and ginger is sometimes more due to cutting action of spade or hoe or blade of bullock drawn equipment, which reduces market value and storage life of these root crops. Many researchers and local manufacturers have tried to develop the tractor drawn root crop harvester to overcome these problems with conventional method, but these machines are need to be evaluated in the field as per BIS standard, for further refinement in the design of machine, for standardization, for improving its performance and for checking its feasibility and suitability in different agro climatic conditions. Hence, the research work was undertaken to evaluate the performance of tractor drawn root crop harvester for potato and ginger crops. In the research work undertaken, the tractor operated root crop harvester developed by PAU was tested as per BIS test code at farmer's field and at JNKVV farm in Jabalpur. During performance evaluation of tractor drawn root crop harvester in the field, the digging efficiency of root crop harvester for potato was found 94-96 % and for ginger it was found 92-94 %. The draft requirement of root crop harvester for harvesting of potato was recorded 1060 kg and for harvesting of ginger was recorded 1180 kg. The actual field capacity of root crop harvester for harvesting of potato was recorded 0.21 ha/h and for harvesting of ginger was recorded 0.18 ha/h during field testing of machine. The field efficiency of root crop harvester for harvesting of potato was recorded 68% and for harvesting of ginger was recorded 64%. Total per cent saving in cost operation was found 85.64% for potato and 83.35% for ginger harvesting when compared with manual method. Payback period was found 0.40 year for potato and 0.25 year for ginger harvesting when used tractor drawn root crop harvester. Hence use of tractor drawn root crop harvester can save lot of time, cost of operation and labour required in harvesting of potato and ginger. The overall functional performance of various systems of tractor drawn root crop harvester was found satisfactory during laboratory and field testing.

Keywords: Root crop harvester, root crop digger, bruised, cut, exposed, digging efficiency, performance evaluation of digger.

INTRODUCTION

India is largest producer of vegetable after China and contribute about 34 per cent of world's vegetable production in the year 2015-16. By virtue of highly varied climatic & geographical conditions, different types of temperate, tropical & subtropical vegetables are grown in India. During recent years, the production and productivity of vegetables recorded impressive growth. The vegetable production in India was 146 million tonnes in an area of 8.50 million hectares with an average productivity of 17300 kg per hectare in the year 2010-2011. The growth trend of vegetables in India was 6.4% to 9.6% from 2009-10 to 2010-11 (Anonymous, 2015). Potato (*Solanum tuberosum* L.) is a major food crop of the world and is largely grown

during winter season in India, being mainly consumed as vegetable. In India potato is grown in an area 2203 thousand ha and potato production is 56173 thousand MT in 2020-21 and ginger is grown in an area 205 thousand ha and ginger production is 2225 thousand MT in 2020-21. (Anonymous, 2022). Madhya Pradesh is among the top ten potato growing states in India. Madhya Pradesh (MP) is the fourth largest potato producing state after Uttar Pradesh, Bihar, Gujarat and West Bengal in India. The five-year average potato production in Madhya Pradesh (2012-2016) was 2,858,300 tonnes, accounting for 6.30 percent of the overall potato production in India in this period. Potato Production in 2017 was 3144010.00 tonnes (Anonymous, 2022). Ginger (*Zingiber officinale*) is a flowering plant whose rhizome, ginger root or ginger, is widely used as a spice and a folk medicine. Ginger, known as "Adrakh" is most important major spice crop of India. India is leading producer of Ginger. It cultivated by all tropical and subtropical countries in the world, much of it is produced in India. By almost 30 percent to 40 percent of world production is produced in India. In India, states like Kerala, Arunachal Pradesh, Orissa, Meghalaya, West Bengal are widely cultivated and, Tamil Nadu, Andhra Pradesh and Karnataka are cultivated in the lower area. In Madhya Pradesh in highly rain fall districts the ginger is cultivated. Annual production of ginger in Madhya Pradesh in 2019-20, ranked first, the state accounts for 22.29% of ginger, produced in India. Cultivated over 25,402 hectares and average yield was 16,178 kgs/hectare (Anonymous, 2022).

A root-crop digger was designed by Punjab Agricultural University, Ludhiana for digging of potato, garlic, onion, carrot and turmeric crop (Khurana *et al.,* 2010). Potato diggers were reported to cause 2-3 % loss of potato (Bansal and Mukesh 2010). Danuwat and Seree (2012) developed and tested a cassava digger with conveyor unit and results indicated that the field capacity, field efficiency and conveying losses were 0.05 ha/h, 59.10 per cent and 3.23 per cent respectively. Bangar *et al*. (2016) developed a multipurpose digger for potatoes. The digger was tested at three different level of speeds and three level of tilt angles. Pavani (2017) designed and developed tractor operated digger and evaluated its performance. The damage per cent and draft requirement were 2.3 percent and 550 N at rake angle 20 degree with forward speed 2 km/h. The BEP and payback period of digger were 23.6 h and 1.06 years respectively. Pramod *et al.* (2018) designed and constructed potato digger cum elevator which was used for digging and elevating the soil and potatoes simultaneously. The test results of machine such as actual field capacity, digging efficiency, damage of tubers and field efficiency were observed as 0.30-0.40 ha/h, 94-96 per cent and 76.5 per cent respectively. Kawale *et al.* (2018) developed and tested a tractor drawn ginger harvester cum elevator at varying forward speeds. The theoretical field capacity, actual field capacity, actual field efficiency and digging efficiency of root crop harvester cum elevator were found 0.22 ha/h, 0.18 ha/h,81.80 percent and 99.18 per cent respectively. Wajire *et al.* (2018) developed a tractor operated digger cum elevator for harvesting of turmeric and ginger. The harvester consisted of soil cutting blade, crop and soil separator unit, main frame and hitching arrangement. Overall working of machine was satisfactory with the average field efficiency 82.73 and 81.70 per cent for turmeric and ginger respectively. Shailaja *et al.* (2019) developed a tractor drawn turmeric digger cum separator. Machine was evaluated in field to determine the draft, efficiency of digging, damage of rhizome, field capacity and power requirement. Narender *et al.* (2019) optimized the performance parameters of root crop digger for potato crop. The experiment was conducted on optimized parameters of exposed, undug, cut, bruised percentage and the digging efficiency. The best performance of digger was obtained at forward speed 2.3 km/h and the rake angle 23 degree for potato crop at which exposed, undug, cut, bruised percentage and digging efficiency was found as 90.62, 2.10, 1.71, 2.48 and 97.90 percent respectively. Basavaraj (2020) designed, developed and evaluated the performance of tractor drawn root crop harvester for various root crops. The maximum draft of 2009.52 N was recorded in straight blade and 1418.66 N was observed in v-type blade. The maximum digging efficiency of 99.89 per cent was noticed in V blade and 84.15 per cent in straight edge blade. The cost of operation saving was 89 per cent and the machine has BEP of 40 h PBP as 1.5 years and BCR as 10.7. Thus, to check suitability of machine, there is need to conduct more number of testing trials of tractor drawn root crop harvester for potato and ginger crop on farmer's field.

In addition to the demand for local consumption, there is an increased demand of vegetables as one of the most potential commodities for export. Vegetables play an important role in improving the economic condition of farmers. One of the constraints to increase production and productivity of vegetable crops is low level of mechanization. There is lot of scope for increasing yield in most of the vegetables by growing high yielding varieties and adopting improved production technologies. The root crops like potato, ginger, onion, garlic, carrot, turmeric etc. are harvested manually or by using bullock drawn implements and manual spade, kudali etc. this operation is labor-intensive and time consuming. The harvesting operation of potato is carried out manually with spade or hand hoe, which is tedious, labour intensive and time consuming. Tractor operated root crop harvester developed by PAU, Ludhiana and it has been commercialized. This tractor operated root crop harvester need to be tested on large area to evaluate its performance, for standardization, refinement and further improvement in the machine.

Considering the above facts, it is very crucial to conduct maximum testing trials of commercially available tractor operated root crop harvester with PAU design, for harvesting of potato and ginger. Therefore, the study has been undertaken to evaluate the performance of tractor operated root crop harvester for potato and ginger crop on farmer's field as well as on JNKVV field as per BIS test code with the objectives to evaluate the performance of tractor operated root crop

harvester for harvesting of potato and ginger under field condition and to check the suitability of machine for harvesting of different root crops.

MATERIAL AND METHOD

The tractor drawn root crop harvester of PAU design was tested in university and farmer's field to check its feasibility and performance evaluation. The basic component of the root crop digger are main frame, digging blade, coulters, vibrating conveyor, power transmission system, roller and windrowers. The root crop digger consisted of a digging blade made from high carbon wear resistant steel. The width and thickness of the blade was 1144 mm and 16 mm. The blade is mounted on the machine at an angle of 20° with the horizontal. The blade digs the crop and lifts it along with the soil which is subsequently pushed onto a vibrating conveyor. The elevator chain conveyor is located behind the blade. The power is transmitted in two stages, first from P.T.O. to machine gear box from which power is transmitted to the conveyor by belt. The spacing between the mild steel rods used for the fabrication of the elevator conveyor is 20 mm. The slope of the elevator conveyor was 18^0. Two oval agitators were provided in the conveying system for providing vibration to the conveyor, thus separating the soil particles from the digged crop. Finally, the crop is windrowed at the rear of machine for manually picking up with minimum damage to the crop. Two coulter discs are provided in front of the blade at the outer ends which helps in easy slicing and lifting of soil by the blade. The observations were recorded for field capacity, field efficiency, Fuel consumption and percentage of cut and remained buried ginger and potato in the soil. Tuber samples (exposed, buried, damaged and bruised) of each crop were then recorded and calculated as given below:

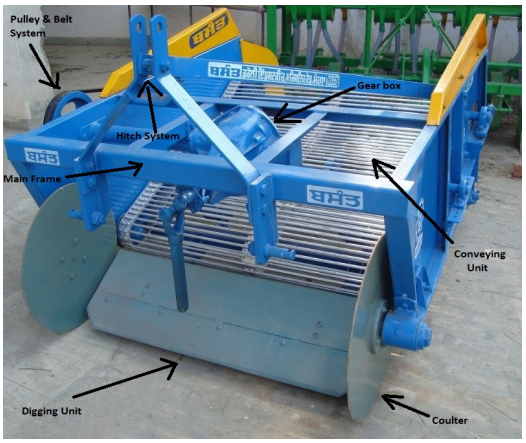

Fig. 1. View of tractor drawn root crop harvester.

Table 1: Brief specifications of the tractor operated root crop harvester.

Sr. No.	Parameters	Specifications
1.	Power source	35 HP or Above tractor
2.	Overall dimensions, L × W × H, mm.	1500 x 1400 x 700
3.	Blade, width × thickness, mm.	1144 x 16
4.	No. of coulter lade and diameter, mm.	2, 500
5.	Gear box speed ratio	5 : 27
6.	No. of agitators and lift, mm.	2, 25 mm.
7.	Type of conveyor	Chain conveyor made of M.S. rod of 9.0 mm.
8.	Spacing between the conveyors rods, mm	20.0 mounted of rubber straps
9.	Width and thickness of rubber strap, mm	60 and 6.0
10.	Slope of conveyor, degree	18^o
11.	Peripheral velocity of conveyor, m/s	2.10

A. Exposed root crop percentage

It was calculated to know how efficiently the oscillating conveyor was able to separate the root crop from soil. Exposed root-crop percentage was determined as the ratio of total number of tubers visible on the top surface of the soil after being dug by the root-crop digger to the total number of tubers dug by the root-crop digger. It was defined as follows

Percent Exposed Root Crop = (A / B) × 100

where,

N = Total number of tuber visible on the top surface of the soil after being digged by root crop digger.

M = Total number of tuber (root crop) digged by the root crop digger.

B. Undug root crop percentage

The undug root crop (tuber)was calculated to know how much of the tuber (root crop) remained undug. It was defined as follows

Percent Undug Root Crop = (C / D) × 100

where,

C = Total number of undug root crop (potato/ginger/carrot/onion) (digged manually after the operation of root crop digger)

D = Total number of root crop (potato/ginger/carrot/onion) (digged and undug both.

C. Bruised root crop percentage

Bruised crop percentage was determined as the ratio of total number of tubers which was bruised by the machine to the total number of tubers dug by the machine. Bruised root crop (potato/ginger) required to know the percentage of bruised root crop (skin comes cut) either by striking with soil clods or due to rubbing action while being conveyed on the oscillating conveyor. It was defined as follows

Percent Bruised Root Crop = (E / D) × 100

where,

E = Total number of root crop which are bruised by the root crop digger

D = Total number of root crop (potato/ginger/carrot/onion) (digged and undug both)

D. Percentage of cut root crop

Cut root crop (potato/ginger/carrot/onion) was calculated to know the percentage of cut root crop (potato/ginger/carrot/onion) which was cut by the digging blade. The percentage of cut-crop was calculated as the ratio of total number of cut-tubers by the digging blade and total number of tubers dug by the machine. It was defined as follows

Percent Cut Root Crop = (F / D) × 100

where,

F = Total number of cut root crop (potato/ginger/carrot/onion) by the digging blade.

D = Total number of root crop (potato/ginger/carrot/onion) (digged and undug both)

E. Digging efficiency

Digging efficiency was calculated to know how efficiently the digger worked in digging the root crop (potato/ginger/carrot/onion). Digging efficiency (per cent) was measured as the ratio of total number of dug tubers by the root-crop digger to the summation of total number of tubers dug and the tubers which remained undug by the machine. It was defined as follows

Percent Digging Efficiency = (F / D) × 100

where,

G = Total number of digged root crop (potato/ginger/carrot/onion) by the root crop digger.

D = Total number of root crop (potato/ginger/carrot/onion) (digged and undug both)

F. Draft

For determining the draft of root crop harvester, one of the tractor was used to pull the other tractor with root-crop digger attached to it. The tractor with root-crop digger was kept in neutral gear position and implement was kept in working state. The reading on the spring dynamometer was recorded, which was placed between two tractors. The same procedure was repeated again with the two tractors, but this time without the root-crop digger attached to the rear tractor. The difference between the two readings of spring dynamometer was taken as the draft of the implement.

G. Theoretical field capacity (TFC)

The theoretical field capacity was calculated using the relationship.

TFC = (W × S) / 10

Where,

TFC = theoretical field capacity, ha/h

W = Width of equipment, m

S= Speed of operation, km/h

H. Effective field capacity (EFC)

Field capacity is the actual average rate of coverage by the machine, based upon the total field time. The actual field capacity was calculated using the relationship given below

EFC = (W × L) / (T × 10000)

Where,

EFC= theoretical field capacity, ha/h

W= Width of field coverage, m

L= Length of field coverage, m

T= Time for covering area, hours

I. Field efficiency (FE)

Field capacity and field efficiency of the machine was determined. The field efficiency is the ratio of effective field capacity (ha/h) to the theoretical field capacity (ha/h) expressed in percent.

FE = (EFC / TFC) × 100

Where,

TFC= Theoretical field capacity, ha/h

EFC= Theoretical field capacity, ha/h

FE= Field efficiency, %

J. Fuel consumption

For fuel consumption an auxiliary tank of capacity 3 liters having the marking of 50 ml apart is used. The auxiliary tank was connected to the intake and over flow fuel line. The decrement in the level of the fuel, area covered and time of operation was recorded after each treatment.

Fig. 2. Root crop harvester during testing in the potato field.

Fig. 3. Root crop harvester during testing in the ginger field.

RESULTS AND DISCUSSION

In the research work undertaken, the testing trials of root crop harvester (PAU design) conducted were 11 and the total area covered was 6.40 ha at 07 different locations of Jabalpur district. Out of which was 3.50 ha were conducted at JNKVV fields and 2.90 ha were at farmer's field at 09 different locations. The following results were obtained during testing of tractor drawn root crop harvester for potato and ginger harvesting.

Table 2: Performance of root crop harvester for Potato and Ginger crop.

Sr. No.	Performance Parameters	Value	
		For Potato	For Ginger
1.	Fuel consumption, l/h	4.80	5.60
2.	Actual field capacity, ha/h	0.21	0.18
3.	Field efficiency, %	68	64
4.	Draft required, kg (@ blade angle 20^0)	1060	1180
5.	Exposed tuber, %	92-96	90-94
6.	Undug tuber, %	2.5-4.9	3.2-5.6
7.	Bruised tuber, %	1.4-2.5	2.2-3.9
8.	Cut tuber, %	2.2-3.4	3.3- 6.0
9.	Digging efficiency, %	94-96	92 - 94
10.	Labour requirement for picking (man-h ha^{-1})	160	180
11.	Labour saving, %	68	67

A. Exposed root crop

During field testing of tractor drawn root crop harvester, the percentage of exposed potato was found92-96% and percentage of exposed ginger was found 90-94 % (Table 2).

B. Undug root crop

During field testing of tractor drawn root crop harvester, the percentage of undug potato was found 2.5-4.9 % and percentage of undug ginger was found 3.2-5.6 % (Table 2).

C. Bruised root crop

During field testing of tractor drawn root crop harvester, the percentage of bruised potato was found 1.4-2.5 % and percentage of bruised ginger was found 2.2-3.9 % (Table 2).

D. Cut root crop

During field testing of tractor drawn root crop harvester, the percentage of cut potato was found 2.2-3.4 % and percentage of cut ginger was found 3.3-6.0 % (Table 2).

E. Digging efficiency

The digging efficiency of root crop harvester for potato was found 94-96 % and digging efficiency of root crop harvester for ginger was found 92-94 % (Table 2).

F. Draft required

The draft requirement of root crop harvester at 20° angle of digging blade for harvesting of potato was recorded 1060 kg and for harvesting of ginger was recorded 1180 kg during field testing of tractor drawn root crop harvester machine (Table 2).

G. Actual field capacity and Field efficiency

The actual field capacity of root crop harvester for harvesting of potato was recorded 0.21 ha/hand for harvesting of ginger was recorded 0.18 ha/h during field testing of machine. The field efficiency of root crop harvester for harvesting of potato was recorded 68% (Fig. 4) and for harvesting of ginger was recorded 64%during field testing of machine (Table 2).

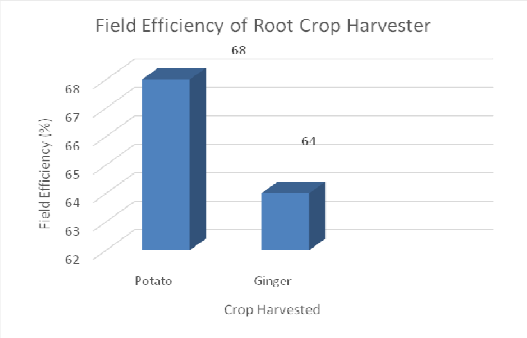

Fig. 4. Field efficiency of Root crop harvester for different crops during testing.

H. Labour requirement

The labour requirement for picking of potato was recorded 160 man-h/ha and for picking of ginger was recorded 180 man-h/ha after harvesting by root crop harvester (Table 2).

I. Fuel consumption

The fuel consumption of root crop harvester for harvesting of potato was recorded 4.80 l/hand for harvesting of ginger was recorded 5.60 l/h with 55 Hp John deer tractor during field testing of tractor drawn root crop harvester machine (Table 2).

J. Cost economics of root crop harvester

The cost of operation, manually was found Rs. 21875 per ha for potato and Rs. 22250 per ha for ginger harvesting (Table 3). The **c**ost of operation by machine was found Rs.3140 per ha for potato and Rs. 3704 per ha for ginger harvesting. Total saving in operating cost was found Rs.18735 per ha for potato and Rs. 18546 per ha for ginger harvesting when compared with manual method. Total per cent saving in cost operation was found 85.64% for potato and 83.35% for ginger harvesting when compared with manual method (Table 3). Breakeven point was found 32 hours/year for potato and 35hours/year for ginger harvesting when used tractor drawn root crop harvester. Payback period was found 0.40 year for potato and 0.25 year for ginger harvesting when used tractor drawn root crop harvester (Table 3).

The root crop harvester (PAU design) was operated at University and farmer's field in 6.40ha for harvesting of ginger and potato. Table 3 shows the details of evaluation trials conducted on farmer's field and on JNKVV farm.

Table 3: Cost economics of root crop harvester for Potato and Ginger harvesting.

Sr. No.	Performance Parameters	Value	
		For Potato	For Ginger
1.	Cost of operation, manually (Rs/ha)	21875	22250
2.	Cost of operation by machine (Rs/ha) (Rs/hour)	 3140 660	 3704 665
3.	Total saving in cost (Rs/ha) (%)	 18735 85.64	 18546 83.35
4.	Breakeven point (hour/ year)	32	35
5.	Payback period (Years)	0.40	0.25

Table 4: Details of feasibility testing trials conducted of root crop harvester on farmer's field and University field.

Sr. No.	Name of farmer	Village	Crop	No. of trials conducted	Total covered area (ha)
1.	Farmers field	Meergunj	Ginger	01	0.70
2.	Farmers field	Thana	Ginger	01	0.80
3.	Farmers field	Gour	Potato	01	0.30
4.	Farmers field	Pipariya	Potato	01	0.50
5.	Farmers field	Bamhni	Ginger	02	0.60
6.	Horticulture Farm	JNKVV, JBP	Potato	02	1.70
7.	Imaliya Farm	JNKVV, JBP	Ginger	03	1.80
Total				**11**	**6.40**

Fig. 5. Crop view of ginger before and after harvesting by root crop harvester.

CONCLUSIONS

The overall functional performance of various systems of tractor drawn root crop harvester was found satisfactory during laboratory and field testing trials. The digging efficiency of root crop harvester for potato was found 94-96 % and for ginger it was found 92-94 %. The draft requirement of root crop harvester for harvesting of potato was recorded 1060 kg and for harvesting of ginger was recorded 1180 kg during field testing of tractor drawn root crop harvester machine. The actual field capacity of root crop harvester for harvesting of potato was recorded 0.21 ha/hand for harvesting of ginger was recorded 0.18 ha/h during field testing of machine. The field efficiency of root crop harvester for harvesting of potato was recorded 68% and for harvesting of ginger was recorded 64% during field testing of machine. Total per cent saving in cost operation was found 85.64% for potato and 83.35% for ginger harvesting when compared with manual method. Payback period was found 0.40 year for potato and 0.25 year for ginger harvesting when used tractor drawn root crop harvester. Therefore, use of tractor drawn root crop harvester can save lot of time, cost of operation and labour required in harvesting of potato and ginger. Hence, from above research work it can be concluded that the tractor drawn root crop harvester is suitable for harvesting of potato and ginger and may be suitable for other root crops like onion, sweat potato, garlic, turmeric crops with little adjustments in the existing machinery.

FUTURE SCOPE

The tractor drawn root crop harvester machine has to be tested for their suitability in other root crop like carrot, onion, garlic, turmeric, sweat potato etc. More emphasis has to be given to develop root crop harvester or modify it with little adjustments, which are suitable for almost all root crops to cut down the cost of cultivation in view of saving time, energy and labour.

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Conflict of Interest. None.

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