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Optimization and Performance evaluation of tractor operated digger for turmeric crop

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ABSTRACT

Manual digging of the turmeric (*Curcuma longa*) rhizome is labour intensive due ploughing of the land in which the clumps are carefully lifted with spade and gathered by hand picking. In view of this a tractor operated digger was developed and performance was evaluated at three level of speed (2.06, 2.9, 4.18 km/h) and blade angle (15°, 20°, 25°) of digger. The performance parameters viz. Exposed crop (%), Undug crop (%), Damage crop (%), Digging efficiency (%) and field capacity was evaluated at different levels of speed and blade angle. The saving in labour and cost of digging the turmeric crop was found to be 67.08 % and 65.43%, respectively. The field capacity of the developed digger was 0.133 ha/h.

Key words : *Tractor operated digger, Turmeric, Manual digging*

Introduction

Spices constitute an important group of agricultural commodities since antiquity has been considered indispensable in the culinary arts for flavoring foods. Some are used in pharmaceutical, perfumery, cosmetics and several other industries, and others possess colorant, preservative, antioxidant, antiseptic and antibiotic properties. In spice, India is leading turmeric producer and exporter in the world. Due to its various medicinal properties and versatility, turmeric has a unique distinction among spices. In India, the production of major spice crops was 11125 thousand tonnes with an area of 4389 thousand hectares during the year 2021-22, out of which the production of turmeric was 333 thousand tonnes in an area of 1221 thousand hectares (Indian Spice Board, 2023). it is need to develop a mechanical means of digging for turmeric and ginger. At present, there is no efficient, lightweight and low-cost digger or harvester developed in India which could be used efficiently for turmeric crop. So, it is necessary to introduce a machine that could dig these crops and reduce the digging time, human efforts and increases the mechanization on farmer's ground level. Taking these points into account, it was therefore, proposed to design and develop a suitable digger for turmeric and evaluated the various machine performance parameters in the field.

Materials and Methods

The performance of the machine was evaluated at the Horticultural Research Farm, Jawaharlal Nehru KrishiVishwa Vidyalaya, Jabalpur, (M.P). The root

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crop digger/machine was developed at Farm Machinery lab of College of Agricultural Engineering which is operated by the tractor. The performance of this digger wereevaluated according to the plan of the experiment. For each test, the experiment was replicated thrice for each combination of the variables. The crop was grown on the bed as per the machine width and as per recommended agronomical practices. The matured crop was dug by using a developed root crop digger. The soil type, moisture content and bulk density of soil were recorded. The method for the determination of moisture content, recommended by the Indian standards institution (I.S.I.), as prescribed in "IS: 2720 (Part-II)-1964: Methods of test for soils-Part-II Determination of Moisture Content." was followed. Bulk density of soil is measured as the mass of soil of a unit volume by core cutter method. Before conducting the experiments, the top dry leaves of the crop were removed manually before digging, which might increase load on the digger and also reduced the efficiency of machine.

Total no of treatment combination in the field= 3x3= 9
Number of replications= 3
So total no. of experiment= 9x3= 27
Therefore, the total no. of treatment for crop= 27
Design: Randomized Block Design (RBD)
Replications: 3

Performance parameters of developed root crop digger

The root crop digger/machine was operated with the help of tractor at different speeds and angle combination given in Table 1 to dig the turmeric crop. The following performance parameters were observed after the operation of digger in the field.

Exposed crop, %- It was calculated as total weight of visible crop to total weight of digged crop on the surface after digging.

Undug crop, %- Undug crop was calculated as the weight of the crop remained undug during the digging operation.

Digging efficiency, %- It was calculated as weight of digged crop to the total weight of the crop collected after the digging operation.

Damage crop, %- Damage crop was calculated as the ratio of the weight of the damaged crop to the weight of the total crop digged.

Field capacity and field efficiency: Field capacity and field efficiency of the machine was determined. Field capacity is the actual average rate of coverage by the machine, based upon the total field time. Field efficiency is the ratio of effective field capacity to theoretical field capacity, expressed in percent.

Cost of operation of digger: The total cost of the digger was determined based on fixed and variable cost. The cost of operation obtained was compared with conventional practice of digging by spade.

Results and Discussion

Optimization of machine operational variables for digging of turmeric crop

The tractor-drawn root crop digger was optimized for the operational variables with New Holland tractor for the turmeric crop.

Field experiments were conducted to study the various operational variables and the interaction for the selection of optimum machine variables. The studies were conducted at different levels of the forward speed and blade angle in accordance with design of experiment given in Table 1. The data was analyzed at 5 % level of significance for the entire operational variable.

Effect of forward speed and blade angle on digging efficiency

The influence of blade angle, speed and shape on digging efficiency was significant at a 5 % level of significance. It is observed fromFig.1, that as the blade angle increased from 15 to 25 degree of V-shape shape blade, the digging efficiency increased from 94.75 to 96.11 % at a forward speed of 2.06

Table 1. Plan of the experiment for the performance in field

Level of operational variable	Blade	Speed (3)	Angle (3)
	V-shape	2.06, 2.9, 4.18 km/h	15^o, 20^o, 25^o
Performance parameters	Exposed crop (%) Undug crop (%) Damage crop (%) Digging efficiency (%)		

km/h. Similarly, the digging efficiency was found to be increased from 93.58 to 94.93 and 93.16 to 94.23 % as the rake angle increased from 15 to 25 degrees in V-shape of the blade at forward speed of 2.90 and 4.18 km/h, respectively.

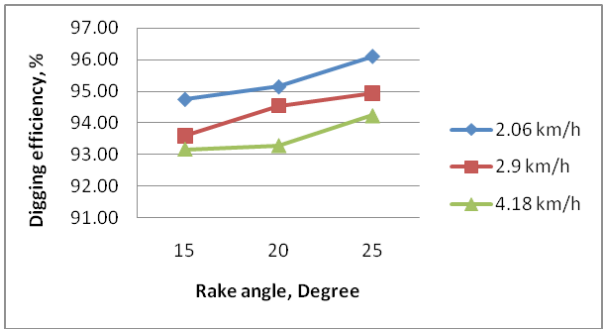

Fig. 1. Effect of speed and blade angle on the digging efficiency

The increase in digging efficiency may be due to the reason that the depth of turmeric rhizome in soil was not constant and when the angle was increased, the blade was furthered lowered down into the soil and thus could dig the turmeric rhizome at higher depth than the average depth of turmeric rhizome in the soil. A similar increasing trend of digging efficiency was found by Shirwal *et al.* (2015) and Narender *et al.* (2016) for other root crops.

Effect of forward speed and blade angle on undug crop

The influence of blade angle, speed and shape on undug crop was significant at a 5 % level of significance. It is observed from Fig.2, that as the blade angle increased from 15 to 25 degree of V-shape shape blade, the undug crop decreased from 5.25 to 3.89 % at a forward speed of 2.06 km/h. Similarly,

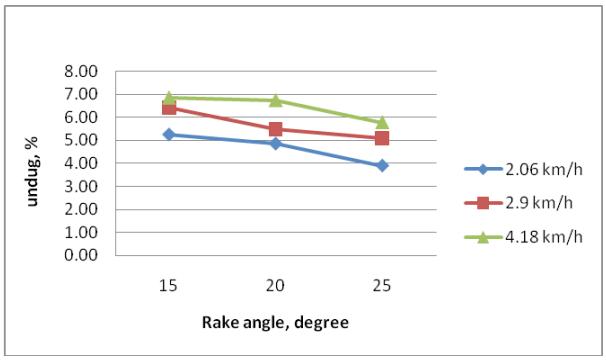

Fig. 2. Effect of speed and blade angle on the undug crop

the undug crop was found to be decreased from 6.42 to 5.07 and 6.84 to 5.77 % as the rake angle increased from 15 to 25 degree in V-shape of blade at forward speed of 2.90 and 4.18 km/h, respectively.

The decrease in undug crop with increase in rake angle may be due to the reason that the depth of crop in soil was not constant and when the angle was increased, the blade was furthered lowered down into the soil and thus could dig the crop at higher depth than the average depth of the crop in the soil. Similar trends of decrease in undug crop with increase in rake angle of digger have been reported by Kathirvel *et al.,* (2001), Narender *et al.,* (2016) and Yasin *et al.,* (2003).

Effect of forward speed and blade angle on damage crop

The influence of blade angle, speed and shape on damage crop was significant at a 5 % level of significance. It is observed from Fig 3, that as the blade angle increased from 15 to 25 degree of V-shape shape blade, the damaged crop decreased from 6.98 to 4.35 % at a forward speed of 2.06 km/h. This may be due to the reason that as the blade angle increased, the depth of digging blade increased in soil due to which, the crop at higher depth were digged without being damage or cut.

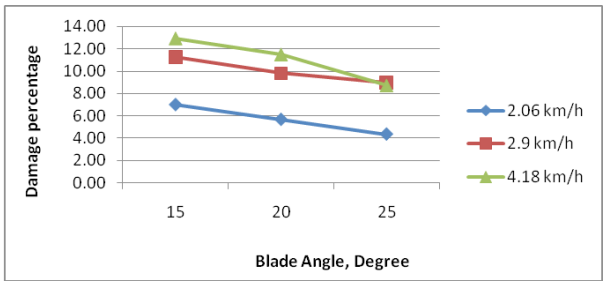

Fig. 3. Effect of speed and blade angle on damage percentage

Similarly, the damage crop was found to be decreased from 11.26 to 8.93 and 12.92 to 8.73 % as the rake angle increased from 15 to 25 degree in V-shape of blade at forward speed of 2.90 and 4.18 km/h, respectively. Results was on a par with Narender *et al.,* (2016), Ibrahim *et al.* (2008), Vatsa *et al.* (1993) and Sharma and Verma (1986) for damage percentage. Horia *et al.* (2008) also reported that crop damage will decrease with the increase in angle.

Effect of forward speed and blade angle on exposed crop

The influence of blade angle, speed and shape on exposed crop was significant at a 5 % level of significance. It is observed fromFig 4, that as the blade angle increased from 15 to 25 degree of V-shape shape blade, the exposed crop decreased from 65.83 to 64.19 % at a forward speed of 2.06 km/h. Similarly, the exposed crop was found to be decreased from 74.03 to 70.52 and 86.98 to 83.5765.83 to 64.11 % as the rake angle increased from 15 to 25 degree in V-shape of blade at forward speed of 2.90 and 4.18 km/h, respectively.

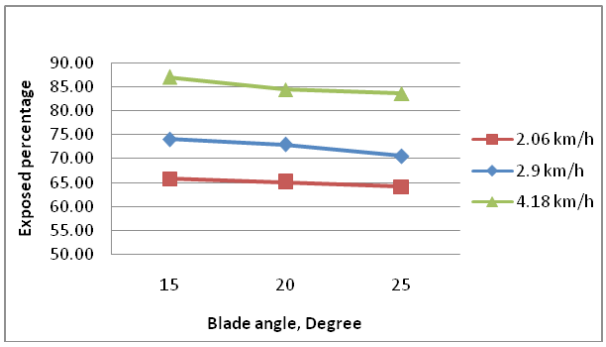

Fig. 4. Effect of speed and blade angle on exposed percentage

The decreasing trend might be due to the reason for digging the more soil at more depth of operation of the digger as the rake angle increased. As the angle was increased, the digging blade undergoes to more depth. At the same time digging blade conveys the more crop and soil material towards the soil separating unit.

Evaluation of the developed digger for turmeric crop at Optimized parameters

Optimization of machine variables for turmeric crop

The combination of the different levels of the variables rake angle and forward speed for maximum digging efficiency, maximum exposed crop, minimum damage and minimum undug crop would form the basis of optimum performance values for a digger as given in Table 2. As superior results were obtained at 25-degree rake angle and 2.06 km/h forward speed, so these optimized variables were selected for the evaluation of machine for other parameters of digging the turmeric crop. The tractor-drawn digger was evaluated with 45 hp New Holland tractor at the optimized value. The details of the evaluated parameters of the machine were given in Table 3

Table 3. Performance evaluation of the digger at optimized machine variable

Sr. No.	Parameters	Average
1	Depth of operation, cm	15.75
2	Digging efficiency, %	97.76
3	Exposed, %	85.93
4	Damage crop, %	3.30
5	Undug, %	2.24
6	Fuel consumption, l h^{-1}	5.1
7	Theoretical field capacity, ha/h	0.154
8	Field efficiency, %	86.53
9	Draft, kgf	688.85
Labour requirement for operation, man-h ha^{-1}		37.59

The performance of the digger was found to be satisfactory in respect of digging efficiency of 97.76 % and undug crop of 2.24 % at an average depth of operation of 15.75 cm. The damage was 3.30 per cent which was much low as compared to manual digging of turmeric crop *i.e.* 10.25%, Table 3. The machine takes 7.5 hours to dig one-hectare area of turmeric crop with field efficiency of 86.53 %. The average fuel consumption and force requirement of the machine was found to be 5.1 l/h and 688.85 kgf. One skilled labour is needed for operation of the tractor with developed digger and four unskilled labours were required for collection of the digged crop. The labour requirement of the developed digger was 37.59 man-hours per hectare. The saving in labour and cost of digging the turmeric crop was found to

Table 2. Optimized machine variables for turmeric crop

Parameters	Optimized of machine variables		
	Values	Rake angle, degree	Forward speed, km/h
Digging efficiency (Maximum)	96.11 %	25°	2.06
Undug (Minimum)	3.89 %	25°	2.06
Damage (Minimum)	4.35%	25°	2.06
Expose (Maximum)	86.98 %	15°	4.18

be 67.08 % and 65.43%, respectively. The field capacity of the developed digger was 0.133 ha/h. The payback period and benefit cost ratio of digger was found 1.78 years and 1.84, respectively.

Conclusion

The saving in labour and cost of digging the turmeric crop was found to be 67.08 % and 65.43%, respectively. The field capacity of the developed digger was 0.133 ha/h. The performance of the digger was found to be satisfactory in respect of digging efficiency of 97.76 % and undug crop of 2.24 % at an average depth of operation of 15.75 cm. Therefore, its concluded that machine may save time, labour, cost and reduce drudgery of digging operation.

Conflict of Interest - None

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