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RESEARCH PAPER

Optimization of variables of a digger for digging of carrot crops

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Abstract : In India, most of root crop is harvested manually and it consumes high labour and time for harvesting. The optimization of a tractor operated digger was evaluated at farmer's field for the carrot crop. The digger was optimized for forward speeds of 2.2, 2.7 and 3.2 km h^{-1} and the rake angles of blade as 17^0, 20^0 and 23^0. The parameters *viz.,* digging efficiency, undug, cut, bruised and exposed percentage was optimized as per the experiment. The performance of the digger was found to be best at a speed of 2.2 km/hr and blade angle of 23 degree with a The digging efficiency, cut percentage, exposed percentage and bruised percentage of carrot crop was found to be 100 , 46.2, 92.12 and 28 %, respectively. The capacity of the machine was 0.18 ha/h. The break-even point for digger was 35.14 hour per year. The payback period of digger was 0.24 year.

Key Words : Variable, Carrot, Digger, Angles

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INTRODUCTION

Carrot (*Daucus carota* L.) belonging to family Umbelliferae, is one of the most important cool season root vegetable grown extensively in various countries particularly during winter season in tropical regions while during summer season in temperate countries (Kalra *et al.,* 1987). In India annual production of carrot is around 0.35 million tonnes (FAO, 2006). The major carrot growing states are Uttar Pradesh, Assam, Karnataka, Andha Pradesh, Punjab and Haryana. Carrot is a rich source of carotene (precursor of Vitamin A). Of various carotenoids in carrot, β-Carotene constitutes a large portion about 60-80% followed by β- Carotene and Lutein (Chen and Tang, 1998). One hundred gram of edible portion of carrot root contain 86.0 g water, 10.6 g carbohydrate, 0.9 g protein, 0.2 g fat, 1.2 g fibre, 1.1 g minerals, 80 g calcium, 30 mg phosphorus, 2.2 mg iron, 1890 µg carotene, 0.04 mg thiamine, 0.02 mg riboflavin, 0.5 mg niacin, 15 µg folic acid, 3.0 mg vitamin C and 48 kcal energy. In India, the production of carrot crop was 1648 thousand metric tonne with an area of 97 thousand hectare and it was 26.56 thousand hectare with a production of 445.99 thousand metric tonne in Haryana (NHB, 2018). Special carrot harvesting machines are not available in India. Limited work has been done on carrot harvesting machines in India. The crop is cultivated

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on small scale and is totally labour dependent. The large scale adoption of these crops will help in diversification which is only possible though mechanization. Keeping in view, a PAU developed digger was evaluated at farmers field for the performance parameters of machine.

MATERIAL AND METHODS

The test was conducted at farmer's field. The tests on experimental digger were conducted in carrot crop. A variety of crop for testing was Lalima.

The performance parameters of digger were optimized as per the procedure adopted by Narender *et al.*, 2016. While testing, the digger was installed on level ground. The machine was run at no load to ensure that each component of the digger was working properly. Experiments were conducted according to the plan of the experiment indicated in Table A. For each test, three replications were taken at each combination of the variables.

Table A : Plan of experiment of digger

Crop	Level of variables		Performance parameter	
Carrot	Blade angle	17^0	1.	Undug tuber
		20^0	2.	Exposed tuber
		23^0	3.	Bruised tuber
	Speed -	2.2 kmh^{-1}	4.	Cut tuber
		2.7 kmh^{-1}	5.	Digging efficiency
		3.2 kmh^{-1}		

Draft :

The draft was measured by using the dynamometer attached between the two tractors. The digger was attached to the tractor in lowered position and kept the tractor in neutral position and this tractor was pulled by another tractor and the draft was measured. Similarly the draft was measured, when the digger was in not working condition. The difference between the two readings of the dynamometer was taken as the draft of the machine.

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 per cent.

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.

Conventional procedure for digging of carrot:

Digging of carrot is done by spade. Soil is digged upto the depth of carrot and then the carrot is pulled out. The carrots are then collected manually from field.

Statistical analysis:

In order to see the significance of results for exposed, undug, bruised, cut and digging efficiency; the data were subjected to statistical analysis at at 5 per cent significant level of confidence by the analysis of variance programme.

RESULTS AND DISCUSSION

The machine was evaluated with provision of varying the blade angle and forward speed of the tractor. Experiments were conducted for determining the

Table 1 : Average observations on performance of digger in carrot crop

	Parameters of carrot				
Treatments	Exposed, %	Undug, %	Cut, %	Bruised, %	Digging efficiency, %
T_1	93.86	0.00	46.93	1.16	100.00
T_2	92.82	0.00	46.41	1.70	100.00
T_3	92.12	0.00	46.06	2.28	100.00
T_4	94.96	0.00	47.48	1.56	100.00
T_5	93.10	0.00	46.55	2.51	100.00
T_6	91.18	0.00	45.59	3.18	100.00
T_7	95.55	0.00	47.78	1.92	100.00
T_8	94.74	0.00	47.37	2.93	100.00
T_9	93.92	0.00	46.96	3.77	100.00

T_1= S_1 (2.2 kmh^{-1}) + A_1 (17°) T_2= S_1 (2.2 kmh^{-1}) + A_2 (20°) T_3= S_1 (2.2 kmh^{-1}) + A_3 (23°)
T_4= S_2 (2.7 kmh^{-1}) + A_1 (17°) T_5= S_2 (2.7 kmh^{-1}) + A_2 (20°) T_6= S_2 (2.7 kmh^{-1}) + A_3 (23°)
T_7= S_3 (3.2 kmh^{-1}) + A_1 (17°) T_8= S_3 (3.2 kmh^{-1}) + A_2 (20°) T_9= S_3 (3.2 kmh^{-1}) + A_3 (23°)

optimum machine parameters for maximum machine efficiency and minimum damage to crop. The average moisture content and bulk density of soil at the time of digging was found to be 10.70 per cent and 1.58 g/cc, respectively.

Optimization of machine variables:

Exposed carrot's: The influence of forward speed on exposed carro't was highly significant at 5 per cent level of confidence. The mean values of exposed carrot at different forward speed and blade angle are shown in Fig. 1 and Table 1. From Fig. 1 and Table 1, it can be seen that as the forward speed of digger increased from 2.2 to 3.3 km h^{-1}, the exposed carrot's increased from 93.86 to 95.55 per cent at blade angle of 17^0. Similarly the exposed carrot's increased from 92.82 to 94.74 per cent and 92.12 to 93.92 per cent as forward speed increased from 2.2 to 3.2 km h^{-1} at blade angle of 20^0 and 23^0, respectively. The increase in exposed carrot's may be attributed to increase in vibration of the conveyor due to increase in forward speed of the root crop digger. As the vibration of the conveyor increased, the soil clods sticked to the carrot's got separated and the clods of bigger size got broken down, due to which the small size of soil clods were able to pass through the spacing between the rods of the conveyor on to the ground instead of being conveyor with carrot's to the rear of the root crop digger. The labour involved in picking up the carrot's had also convenience in picking up the carrot's as they didn't require breaking up clods for separating carrots.

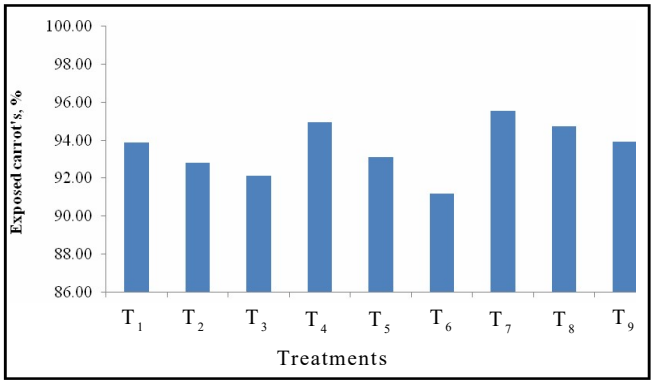

Fig. 1 : Influence of blade angle and forward speed on exposed carrot's

The value of exposed carrot's was non- significant for different blade angles.The interaction effect of forward speed and blade angle was also non- significant. The exposed carrot's were found to be 100 per cent by conventional method.

Bruised carrot's

The influence of forward speed and blade angle on bruised carrot's was highly significant at 1 per cent level of confidence. The mean values of bruised carrot's at different forward speed and blade angle are shown in Fig. 2 and Table 2. From Fig. 2 and Table 2, it can be seen that as the forward speed of digger increased from 2.2 to 2.7 km h^{-1}, the bruised carrot's increased from 1.16 to 1.56 per cent and further increased to 1.92 per cent as speed increased to 3.2 km h^{-1}at blade angle of 17^0. Similarly the bruised carrot's increased from 1.70 to 2.93 per cent and 2.28 to 3.77 per cent as forward speed increased from 2.2 to 3.2 km h^{-1} at blade angle of 20^0 and 23^0, respectively.

Table 2 : Performance parameter of digger in carrot crop

Parameters		Carrot
Draft, kgf		
Angle-	17^0	1110
	20^0	1170
	23^0	1270
Fuel consumption, l h^{-1}		5.50
Actual field capacity, ha h^{-1}		0.18
Field efficiency, %		65
Labour requirement for picking, man-h ha^{-1}		180

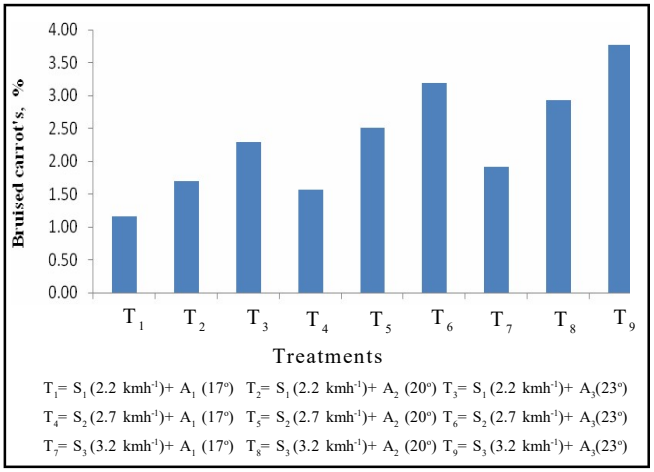

Fig. 2 : Influence of blade angle and forward speed on briosed carrot's

From Fig. 2 and Table 3, it can also be seen that as the blade angle of digger increased from 17^0 to 20^0, the bruised carrot's increased from 1.16 to 1.70 per cent at forward speed of 2.2 km h^{-1} and further increased to

2.28 per cent as the blade angle increased to 23^0, at forward speed of 2.2 km h^{-1}. Similarly the bruisness increased from 1.56 to 3.18 per cent and 1.92 to 3.77 per cent as the blade angle increased from 17^0 to 23^0 at forward speed of 2.7 km h^{-1} and 3.2 km h^{-1}, respectively. The interaction effect of forward speed and blade angle was non- significant. There was no bruised carrot's left by conventional method.

Undug carrot's

There were no undug carrot's found during digging operation by the digger and conventional method.

Cut carrot's

The influence of forward speed on cut carrot's was significant at 1 per cent level of confidence. The effect of blade angle was also significant at 1 per cent level of confidence. But the interaction effect of forward speed and blade angle was non- significant

The mean values of cut carrot's at different forward speed and blade angle are shown in Fig. 3 and Table 2. From Fig. 3 and Table 2, it can be seen that as the forward speed of digger increased from 2.2 to 2.7 km h^{-1}, the cut carrot's increased from 8.55 to 12.91 and further increased to 14.89 per cent at a blade angle of 17^0. Similarly the cut carrot's increased from 8.34 to 14.32 per cent and 7.53 to 13.04 per cent as forward speed increased from 2.2 km h^{-1} to 3.2 km h^{-1}, at blade angle of 20^0 and 23^0, respectively.

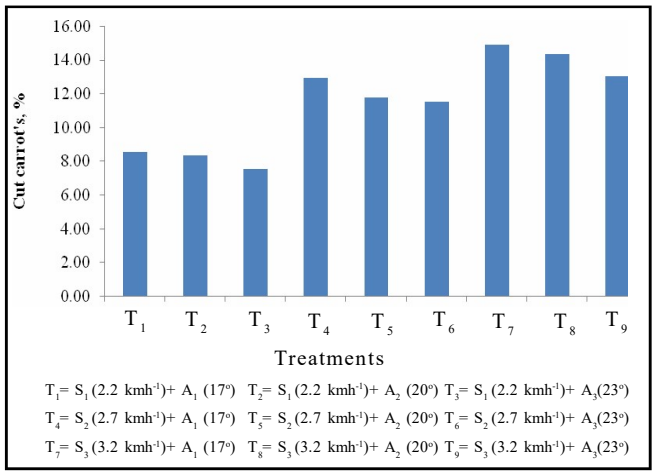

Fig. 3 : Influence of blade angle and forward speed on cut carrot's

From Fig. 3, it can also be seen that as the blade angle of digger increased from 17^0 to 20^0, the cut carrot's decreased from 8.55 to 8.34 per cent and further decreased to 7.53 as blade angle increased to 23^0 at forward speed of 2.2 km h^{-1}. Similarly the cut carrot's decreased from 12.91 to 11.50 per cent and 14.89 to 13.04 per cent as blade angle increased from 17^0 to 23^0, at forward speed of 2.7 km h^{-1} and 3.2 km h^{-1}, respectively. Ibrahim *et al*. (2008) reported that root damage will increase with the increase in belt speed 0.5 m s^{-1} to 1.5 m s^{-1}. Similar trends of increase in cut carrots with increase in forward speed of root crop digger have been reported by Horia *et al*. (2008).

The cut carrot's was found to be 9.93 per cent by conventional method for carrot crop.

Digging efficiency

The digging efficiency of digger and conventional method was found to be 100 per cent for carrot's crop.

Optimized values of blade angle and forward speed for carrot crop:

From Table 2, it may be seen that the treatment T_3 may be considered the best optimized treatment *i.e.* the blade angle 23^0 and forward speed 2.2 km h^{-1}. The machine performance of digger is indicated in Table 3. From Fig 3, it is observed that the minimum cut carrot's were found at treatment T_3. Though the bruised carrot's are minimum for treatment T_1, but the cut carrot's increase to 8.55 per cent for treatment T_1. The cut percentage should be minimum as otherwise market value of carrot's will decrease. Therefore, T_3 treatment can be considered best considering cut and bruised carrot's. The exposed per cent of carrot's is maximum for treatment T_7 (95.55) and 92.12 per cent at treatment T_3. Since we have to give prior importance to cut percentage than exposed percentage, T_3 can be considered the best optimized treatment *i.e.* the blade angle 23^0 and forward speed 2.2 km h^{-1}. Digging efficiency was 100 per cent for all treatments.

Table 3: Comparative cost of digging with digger and conventional method

Parameters	Carrot
Cost of operation of machine, Rs. ha^{-1}	2641
Rs. h^{-1}	475
Cost of operation of manually, Rs. ha^{-1}	15625
Saving in cost, Rs. ha^{-1}	7359
Breakeven point, hr per year	35.14
Payback period in year	0.24

Economics :

The cost of machine was Rs. 60000/- and hourly cost of operation of machine for carrot was found to be Rs. 475. The comparative cost of operation of machine

and manually digging is shown in Table 3.

The saving in cost was Rs. 7359 carrot. The break-even point for digger was 35.14 hour per year. The payback period of digger was 0.24 year.

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