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DEVELOPMENT OF TRACTOR OPERATED CARROT DIGGER AND ITS PERFORMANCE EVALUATION

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ABSTRACT

A study was conducted at Agricultural Mechanization Research Institute, Multan (Division Faisalabad) to design, develop and evaluate the performance of tractor operated carrot digger. In normal practice, at the time of carrot harvesting, its tops are removed manually and used as fodders for animals but manual digging of carrots is laborious and time consuming. In order to address lacking of accessibility of labour during peak load period, farmers needed an appropriate tractor driven carrot digger to facilitate timely digging of carrot for urgent supply to the market. So Agricultural Mechanization Research Institute (AMRI), Multan (Division Faisalabad) designed and developed a tractor rear mounted carrot digger in Agricultural Engineering Workshop, Faisalabad. Its field performance was evaluated at Chak No. 46, Jhok Hamdani, tehsil and district Chiniot in 2015 and 2016. The field efficiency of carrot digger was evaluated at three different tractor speeds i.e 2, 3 and 4 km hr^{-1}. Lower fuel consumption (4.5 l/acre) with higher percentage of wheel slippage (14%) and carrot's damage (2.2%) was observed at higher speed (4 km hr^{-1}). Low speed (2 km hr^{-1}) offered higher fuel consumption (9 l/acre) with lower percentage of wheel slippage (9%) and carrot's damage (1.25%). However, a moderate value of damage percentage (1.4%) was found at forward speed of 3 km hr^{-1} with fuel consumption of 6.75 l/acre that yielded only 0.15% higher damage giving 2.25 l/acre fuel saving as compared to 4 km speed. Hence, direct relationship exists among forward speed of tractor, wheel slippage and carrot's damage while inverse relationship was found between speed and fuel consumption. Overall performance of carrot digger was 0.7 acre hr^{-1} with net saving of Rs. 8430 ha^{-1} in terms of labour charges incurred on digging the carrot.

KEYWORDS: *Daucus carota;* carrot; harvesting; mechanization; digger; profitability, Pakistan.

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INTRODUCTION

Carrot (*Daucus carota*) is a very popular and one of the most important vegetables cultivated and consumed in Pakistan. It holds key position among the winter vegetables. Carrots are cultivated on an area of 13.9 thousand hectares, with a production of 242.3 thousand tonnes (FAO, 2007 and 2008). The national normal yield of carrot is just 17.5 t ha^{-1}, which is very low when compared with other propelled nations like Belgium (47.64 t ha^{-1}), Denmark (44.29 t ha^{-1}), and the United Kingdom (44.28 t ha^{-1}). Notwithstanding, in India and China, the normal yield is 30 and 38.54 t ha^{-1}, respectively (Anon, 2009).

Majority of agriculture community related to vegetable faces many problems like lack of input resources, less information related to new technology, marketing issues including variation in price (82%), postponed cash payment (72%), elevated cost of transportation (66%) and inaccessibility of market (64%) (Chendake and Chauhan, 2015). As carrots are cultivated both in the rural area and peri-urban zones, its potential for turning out employment is an additional benefit to enhance the financial status of the weaker section of general public. Further, carrots are a less expensive source of fundamental supplements in Pakistan. However, its utilization in life of the general population is low due to constrained information on the healthful significance of this crop. The leaves of this crop are additionally utilized as fodder for the homestead creatures. When the supply of fodder is rare in the region, it is an extra favourable position on this occasion. Mostly, vegetable zones are concentrated in peri-urban zones of urban centers like Lahore, Karachi, and Peshawar. Potato is generally sown all over the country but for its mass production, site specific areas include Sahiwal, Sialkot, Okara and Kasur around Lahore (Chaudhry and Ahmad, 2000). In Punjab, potato possesses the bigger share of area (34.01%) and the second essential vegetable is onion that involves around 8.87%, while relative share of carrot is just 2.67% of aggregate vegetable zone. The carrot is an essential vegetable on records of its plentiful measures of supplements, for example, protein, carbo-hydrate, fibre, vitamin A, potassium (K), and sodium (Na) (Ahmad *et al.,* 2004). Great potential in improving yield per acre can only be achieved by availability of the certified seed, the better

land preparation recommended dose of seed/fertilizer and timely harvesting of carrot (Ahmad *et al.,* 2005). At the development stage of carrot, temperature between 15°C and 20°C is considered best for shading carrots. Carrot flourishes best on profound, loose loamy soil having pH range of 5.5 - 6.5. Since carrot seed is somewhat tiny, a finely pulverized seedbed is vital to ensure that most extreme number of soil particles may contact the seed to encourage germination process. For efficient and economical use of irrigation water, land should be thoroughly leveled with laser land leveler. In Punjab, carrot is planted in August, September and November and harvested from November to March. Early crop fetches more price but less production per acre, while the late crop produces higher yield with lesser market price.

Manual harvesting of carrot is a laborious job and urbanization trend of living has made it much difficult by expelling labour from agriculture sector. Keeping in view its value among the other vegetable crops, attempts are being geared to make its harvesting easier. Some indigenous prototypes were developed that were not accepted by the farmers due to high percentage of injuries to carrot as injured carrots lose its aesthetic attraction as well as its market value. So attempts were made at Agricultural Mechanization Research Institute, Division Faisalabad to design and develop a tractor operated carrot digger to address the issues of carrot harvesting. Main focus of this study was to minimize labour force dependency through mechanization for carrot digging process.

MATERIALS AND METHODS

This development work of digger was carried out in Agricultural Engineering (Research) Workshop at Faisalabad, Pakistan and its extensive testing was done at Chak No. 46, Jhok Hamdani, tehsil and district Chiniot in 2015 and 2016. Agricultural Mechanization Research Institute, Division Faisalabad is actively engaged in innovative farm mechanization. In view of problems of carrot digging, this Division developed a tractor rear mounted two row carrot digger. Major components of the designed carrot digger are main frame, blade and shank, three pin linkage (A-frame) and lifting spike.

Newly developed carrot digger

Main frame

It is back bone of the machine and all other parts of the digger are mounted on it. It was made of MS Box 102 × 102 mm with wall thickness of 6.35 mm. The main frame was designed to bear a torsion force developed by the share while slicing up the lump of soil with pegged carrots. All other parts of the digger were temporarily fastened to the main frame with the provision of sliding over the bar.

Main frame

Blade and shank

It was horizontal blade just to slice up the ridge upto the depth of 380 mm. It was made of high carbon steel with 120 mm width and 16 mm thickness. Typically, sharp cutting edges of blade made possible the gentle slicing and elevating the sliced soil alongwith carrots over the lifting spikes. A set of two blades with separate mountings is attached to the main frame through shanks to address two ridges in one sweep. Both the units can easily slide over the bar of main frame to address variable inter-row distance. These blades were temporarily fastened to their shanks for its easy replacement and these shanks were welded to the mounting system for its attachment to the main frame. In order to decrease the draft, front face of the shank is sharpened for easy penetration into the soil to determine the width of soil slice.

Blade and shank

Three point hitch assembly (A-frame)

To mount the digger to the tractor, three pin linkage system (Category-II) was developed. It was made of MS flat of 64 mm width and 13 mm thickness. MS sheet of 12 mm thickness was also employed to develop the mast. The A-frame was mounted to the main frame with mounting clamp having MS plate 13 mm thickness and

MS round of 15 mm dia with threads on the both ends to have its variable adjustment. For strengthening the clevis, reinforcements were provided on each side of U-shaped prongs with standard hole diameter for clevis pin of upper hitch attachment. Upper hitch attachment pin, lower hitch attachment pin and linchpin were made from cold drawn MS and zinc coating was done for corrosion resistance. Specifications of A-frame were standardized for its compatibility to different models of the tractor available in the field.

A-frame

Lifting spike

MS bars of 16 mm dia and 229 mm length were provided at the rear edge of blade. These bars were curved in such a manner to elevate the sliced lump of soil. The elevated lumps of sliced soil alongwith carrots were forced to pass over lifting spikes provided at rear edge of digging blade. The lifting spikes were curved to lift the sliced soil upto 100 mm and breaks the lump of soil. Thus, pegged carrots were loosened in soil and manual culling of carrots was done by walking behind the tractor.

Lifting spike

Field testing

Carrot digger was tested at Chak No. 46, Jhok Hamdani, tehsil and district Chiniot. At site, a plot of 70 m × 70 m was selected. Soil type of the experimental area was sandy-loam, irrigated by the both sources canal and ground water. Carrot variety T-29 was sown over the ridges with 69 cm inter-ridge distance. Ridges were made with the tractor rear mounted vegetable ridger and the seed was broadcasted over the ridges manually. The crop was sown in September and was ready for harvesting 90 days after sowing. Fiat-480 tractor was used to mount the carrot digger on 3-pin linkage system. Before the operation of the tractor, stabilizer chains of tractor were adjusted to eliminate lateral swing of the machine. An area of 63m×32m was selected for experimentation. The plot was further divided into three sub-plots with size 21m×32m. The tractor was operated at three forward speeds i.e 2, 3 and 4 km hr^{-1} to evaluate the performance of digger.

Field testing

The digger was set to operate at depth of 33 cm. Productive and non-productive time was noted to work out the field capacity of the machine. Harvested carrots were manually culled from the selected plot and sorted out the damaged/injured carrots for determining the damage percentage on weight basis. Fuel consumption of the tractor was also worked out during the experimentation to study the economics of mechanized harvesting. To determine the fuel consumption, a graduated transparent plastic bag was filled with diesel and it was hanged above fuel tank. Fuel tank of the tractor was disconnected from the fuel line and the fuel line was directly connected with the transparent bag. The fuel level in the transparent bag was noted and after one-hour operation of the tractor, fuel level in the transparent bag was again noted. Fuel consumed was determined in liters per hour. For a known length of the selected field, wheel slippage at different forward speeds was also determined. After studying the operational parameters, economic analysis of the carrot digger was made to assess its feasibility.

RESULTS AND DISCUSSION

The data were collected on crop damage, wheel slippage, fuel consumption and machine capacity at different forward speeds. The data showed higher wheel slippage (14%) at forward speed of 4 km hr^{-1} which yielded higher carrot damage (2.2%), that was probably due to relatively less penetration of blade of the digger into the soil (Table 1). Forward speed of 2 km hr^{-1} offered less wheel slippage (9%) and less carrot damage percentage (1.25) but consumed double time (2 hr/acre) and fuel (9 l/acre).

Table 1. Effects of tractor forward speed on different crop parameters.

Tractor forward speed (km/hr)	Wheel slippage (%)	Carrot damage (%)	Time (hour/ acre)	Fuel consumption (liter/acre)
2	9	1.25	2	9
3	11	1.4	1.5	6.75
4	14	2.2	1	4.5

Damage percentage was found lowest (1.25%) at lower forward speed (2 km hr^{-1}) with highest fuel cost (9 l/acre) as compared to higher damage percentage (2.2%) at higher forward speed (4 km hr^{-1}) and lowest fuel cost (4.5 l/acre) (Table 1). However, a moderate value of damage percentage (1.4%) was found at forward speed of 3 km hr^{-1} and fuel cost of 6.75 l/acre that yielded 0.15% higher damage giving 2.25 l/acre fuel saving as compared to the results found at 2 km hr^{-1} forward speed.

Economic analysis

Feasible economic analysis provides guarantee of acceptance and expansion of any technology. In economic analysis, capital and operational cost are basic parameters. Compact design of a machine and within purchase power of an ordinary farmer makes it popular among the farming community. Efforts were focused to make it available with an ordinary farmer of carrot, sugarbeet and other cylindrical tuber type crops. Detal of economic analysis is given below:-

Cost effective comparison of manual v/s mechanized carrot

1. Capital cost of carrot digger = Rs. 25000.00
2. Salvage value = 10% of purchase price (Kepner *et al.,* 1972, Smith, 1971)
3. Life of tractor = 10 years
4. Life of carrot d = 10 years
5. Expected operative life of
   Tractor = 1000 hr/year
   Carrot digger = 300 hr/year
6. R&M cost of tractor = 10 % of total price
7. R&M cost of carrot digger = 10 % of purchase price
8. Depreciation:

$$\frac{\text{Purchase price} - \text{Slavage value}}{\text{Life period in years}}$$

Operational cost (Rs./hr) of tractor (Fiat-480) and carrot digger.

S.No.	Description	Amount (Rs/ha)
Fixed cost		
1	Purchase price	717000.00
2	Depreciation	64.53
3	Interest (12 % of avg. investment)	47.32
4	Insurance (1% of avg. investment)	3.94
5	Tax (1% of purchase price)	7.17
6	Housing (1% of purchase price)	7.17
7	Repair & maintenance cost	35.85
	Fixed cost tractor (A)	**166.00**
Variable cost		
1	Fuel @ Rs. 72.73/liter (4.5 liter/hr)	327.30
2	Lubricating oil etc (10% of fuel cost)	32.70
3	Labour (Tractor operator)	180.00
	Variable cost of tractor (B)	**540.00**
	Total operating cost of tractor (A+B)	**706.00**
Fixed cost (Rs./hr) of Carrot Digger (Two-row)		
1	Purchase price	25000.00
2	Depreciation	6.70
3	Interest (12% of avg. investment	5.50
4	Insurance (1% of avg. investment	0.50
5	Tax (1% of purchase price)	0.80
6	Housing (1% of purchase price)	0.80
7	Repair & maintenance cost	4.20
	Fixed cost of carrot digger (C)	**18.50**
Variable cost (Rs./hr) of Carrot Digger (Two-row)		
1	Culling operation (32 man-hrs/acre) @ Rs. 50/man-hr	200.00
	Variable cost of carrot digger(D)	**200.00**
	Total operating cost of carrot digger (A+B+C+D)	**924.50**

Cost effective comparison of manual v/s mechanized carrot digging

Description	Manual digging/acre	Mechanized digging/acre
Labour	128 man-hrs	32 man-hrs
Wages	Rs. 6400.00	1600.00
Operational cost	Nil	1387.00
Total digging cost	Rs. 6400.00	2987.00
Net saving/acre	Rs. 3413.00	
Net saving/ha	Rs. 8430.00	

Period of working season per year = 80 days
Rate of available working days in the season = 70%
Working hours per day = 8 hrs
Rate of actual operating time in daily working hours = 70%
Operating hours per year = (80/year) x (70/100) x 8hrs / day x (70/ 100)
Field capacity = 300 hrs/year
Fuel consumption = 0.7 l/hr
Labour charges = Skilled labour = Rs. 500/day
Un-skilled labour = Rs. 400/day

Hangen *et al.* (1993) described that on an average, about 250-300 man–hours/ha labour is required for trimming, digging and pulling of carrot. Economic analysis of tractor operated carrot digger revealed that only 79 man-hours/ha (32-man-hours/acre) is required for mechanical digging that resulted in net saving of Rs.8430 ha^{-1} (3413 $acre^{-1}$) which is an attractive amount for the farmer with minimal labor force. In a season of 80 days/year, with the operation of carrot digger, handsome amount of Rs. 749222/- seems to be quite reasonable profit and can support to uplift the living standard of an ordinary farmer. The digger will be more beneficial in unpredictable fluctuating trend of market as the farmer will be able to harvest the crop without facing the labor problems during peak market demand.

Future recommendations

- Carrot leaves trimmer should be designed in future.
- Manual culling be replaced with mechanized picking of harvested carrot.

REFERENCES

Ahmad, B., K. Bakhsh and S. Hassan. 2004. Economics of growing different summer vegetables. Faculty of Agricultural Economics and Rural Sociology, University of Agriculture, Faisalabad, Pakistan. A report submitted to Pakistan Agricultural Research Council (PARC), Islamabad, Pakistan.

Ahmad, B., S. Hassan and K. Bakhsh. 2005. Factors affecting yield and profitability of carrot in two districts of Punjab. Int. J. Agric. Biol. 07(5):794-798.

Ahmad, Z., N. Ali, M. Ahmad, S. Ulhag and S. Ahmad. 2005. Yield and economics of carrot production in organic farming. Sarhad J. Agric. 21(3): 357-364.

Anon. 2009. Carrots in today's world. September 9, 2009.

Chaudhry, M.G. and B. Ahmad 2000. Dynamics of vegetable production, distribution and consumption in Asia. Asi. Veg. Res. & Dev. Cent. Tai., Pub. No.498: 271-302.

Chendake, A. D. and P. M. Chauhan. 2015. Marketing strategy of greenhouse vegetable and flower growers in India. J. Agric. Res. 53(2): 277-286.

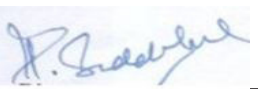
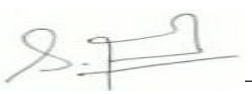
FAO, 2008. Food and Agriculture Organization database on agricultural production 2007-2008.

Hagen, K. B., H. Jostein and K. H. Ringdahl. 1993. Physiological and subjective responses to maximal repetitive lifting employing stoop and squat technique. E. J. App. Physiol. Occ. Physiol. 67(4):291-297.

Kepner, R. A., R. Bainer, and E. L. Barger. : 1972. Principles of Farm Machinery. The AVI Publishing Co., Inc., Westport, Ct.rs 2, 17.

Smith, R.E., 1971. The opportunity cost of participating in a training program. The Journal of Human Resources, 6(4), pp.510-519.

CONTRIBUTION OF AUTHORS

S. No.	Author name	Contribution	Signature
1.	Muhammad Ashraf	Developed carrot digger, conducted its laboratory testings, analysed the data and prepared write-up	
2.	Ghulam Sadique	Supervised research work and shared technical information regarding deign parameter of carrot digger	
2.	Shahzad Ahmad	Done fabrication work of plangter and assisted in literature review	
4.	Maqsood Ahmad	Done economic analysis of study and allied literature review. Also helped in overall field testing phase of carrot digger