Review Article

CARROT HARVESTING METHODS: A REVIEW

Abstract needs to be reformulated to fit the conclusions
Results: Results of the study no are credible consistent with the objectives of the study.
Interpretation and conclusions: Results interpretation, discussion and conclusion not good .
References: some references cited in the manuscript old .
Importance of work: I believe the research addresses some important agronomic issues in the country or region where the study was conducted,
Other points: The research appears important and may be valuable to the country or region where the study was conducted

ABSTRACT

Carrot harvesting is one of the critical operations and is done once the carrot is matured after 90 – 110 days. Carrots grow on ridges and are harvested after loosening from the soil surface and pulling out roots by grasping the top. For harvesting carrots manually in one hectare, an average of 250 – 300 man-hours are required which is very expensive for farmers besides the quantum of labor, manual harvesting involves considerable drudgery and human discomfort. Manual harvesting is not only laborious work but also time-consuming. Severely increased wages of labor have made manual harvesting uneconomical. During peak time sufficient labors are not available that delay the harvesting and thus result in damage and loss to crop. The harvesting operation of carrots needs to be mechanized for time-saving, reduce drudgery involved, and also reduce harvesting cost due to these, the crop is cultivated on small scale and is one of the main bottlenecks in bringing more area under the carrot cultivation. The large-scale diversification and reduction in the cost of cultivation in carrot crops are mainly possible through the mechanization of the carrot digging process.

Keywords: *Carrot, harvesting, labor, discomfort, drudgery.*

INTRODUCTION

China is Carrot production King of the World, the US ranks among the other top nations in the production of carrots: fourth in acreage and volume, third in terms of yield (31.7 tons/ha). Russia, Japan, France and the United Kingdom are also leading producers. China had an annual production of carrots estimated to be 17.3 million tons between 1994 and 2014. In India, the cultivated area of carrot in 2018-19 was 108 thousand ha with a production of 1865

التعليق [M1]: Location of the study and year?

التعليق [M2]: Carrot yields variation as the most important characters must be compared in harvesting methods, as percent

التعليق [M3]: Please; mention the study characteristics, studied factors & statistical analysis type

التعليق [M4]: Carrot is a very important crop. It grows in diversified environments and it is a staple food of millions of people.
Carrot has a distinct place among the root crops. The moisture content has a different influence on grains properties. The study of Alsharifi et al. (2020) showed that, when root were subjected to uniaxial compression, it behaved as an elastic-plastic-viscous body which exhibited creep, stress relaxation and elastic after effects .

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thousand metric tons. However in Haryana it was 17.28 thousand ha & 266.82 thousand metric tons, respectively (Carrotmuseum, 2021).

In general, the farmers use traditional tools and methods for cultivation of vegetable crops.

As a result, the yields are low, cost of cultivation is high and there are huge losses ranging between 30% of the total produce due to damage caused during harvesting (Agriculture and Food, 2021). If improved hand tools, machines and modern technologies are used in action and processing of crops, crop yields could be increased substantially and losses could be minimized to a great extent (Srivastava, 2000). The average yield of vegetables in India is still lower than many Asian countries (APEDA, 2020). (add sourceadd) The reason is that the farmers use traditional tools and methods for cultivation of vegetable crops. Most vegetables have the potential to increase yield by cultivating high-yielding cultivars and implementing enhanced production techniques.

التعليق [M6]: Alsharifi et al. (2019),the combine harvester not only minimizes the post-harvest losses but also helps in shortening the harvesting period. While evaluating the performance of eight combines observed that time of harvesting, seed moisture content, relative humidity, field topography and varietal characteristics are the major factors affecting harvest losses.

التعليق [M7]: State the aim of the study

HARVESTING METHODS

Carrot harvesting methods are manual harvesting, animal power based harvester and mechanical power based harvester. Further the machine drawn harvesting method is categories as tractor operated carrot harvesting and self-propelled carrot harvester. Various reviews regarding these methods are studied as below.

Manual Harvesting

Carrots are lifted gently by hand where the soil is loose. Where the soil is heavy, loosen the soil with a spading fork and then lift the roots gently so that they don't get break. Carrots are pulled when the soil is moist it will not disturb the roots of carrots that remain in the soil. In manually harvesting method labour uses hand tools like, hoe (kudali), spade (fawada), pick axe (gainti), sickle (khurpi) and crowbar (sabbal) for loosening of soil (Fig. 1 to 5).

Fig. 1: Hoe (*kudali*) tool

Fig. 2: Spade (*fawada*) tool

Fig. 3: Pick axe (*gainti*) tool

Fig. 4: Sickle (*khurpi*) tool

Fig. 5: Crowbar (*sabbal*) tool

Animal Drawn Carrot Digger

An animal drawn single row implement V-shaped ridger type share (Digging part) is used for digging out root crops. The lifter rods are attached behind the share. These lifter rods are spaced to allow the clods and residual material to drop while operating the implement. The plant along with root is then collected manually. It saves time and cost of operation

compared to conventional method of digging with spade and hand pulling. This implement has been widely adopted by small farmers due to its efficient operation (MPUAT, 1998).

Mechanical Harvesting of Carrot

التعليق [M8]: geographic character of the location state

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El-Sherif (1996) developed and evaluated the performance of a root crop digger. He concluded that with the increased of forward speed of digger, number of cuts and bruises on roots are increased while decreased the lifting efficiency.

التعليق [M10]: Old source

Kowalczuk and Leszczynski (1999) evaluated the quality of carrot harvested with a single-row machine of Polish production. Tests were carried out at 0.25 m s^{-1} working speed. The harvest losses and mechanical damage of roots were determined. In total losses of carrot roots amounting 5.3 %, 1.5 % were the roots left in the ground, whereas the remaining 3.8 % roots were lost during harvest. Total root damages reached 22 %, where as 8 % were because of cracking and 14.0 % because of breaking carrot.

التعليق [M11]: Old source

Abd - Rabou (2004) concluded that the maximum damage in crop roots was found due to harvesting speed and also observed optimum speed of harvesting was 0.7 m/s. It decreased with forward speed. It was found that, increasing forward speed from 0.55 to 1.06 m/s tends to increase the total damaged roots from 4.51 to 5.4%. The highest value of the total damaged roots of 6.2% was obtained at forward of 1.06 m/s and, the lowest value of the total damaged 3.4% was obtained at forward speed of 0.55 m/s.

Tractor operated carrot harvester

التعليق [M12]: ?

Ozarslan and Erdogan (1990) investigated the possibilities of harvesting carrots mechanically in Turkey. They found reduced labor requirements and harvesting losses as compared to the ploughed up by manual harvesting.

التعليق [M13]: Old source

Chaudhary and Ahmad (2000) observed that the conventional methods of carrot harvesting significantly increased the percentage of damage of

carrot which not only reduced the market value but storability too. There is a need of hour to use the mechanical means for carrot harvesting to overcome the labor problem. This mechanical harvesting could also save 60% of farm power.

التعليق [M14]: ?

Mady (2001) found that the mechanical harvesting led to decrease the percentage of scarified roots and cut roots by 39.55 and 51.39%, respectively under mechanical planting. But it equal to 12.9 and 9.39% lower than traditional planting system. The mechanical harvesting increased the percentage of undamaged roots by 14.11 and 7.88% higher than traditional harvesting under mechanical and traditional planting systems.

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Kowalczuk *et al.*, (2003) evaluated the quality of carrots harvested with two different one-row carrot harvesters named Alina and Simon. The tests were conducted at three working speeds, *i.e.*, 1.5, 2.0 and 2.5 km/h. The percentage of losses caused by the failure of the machine to uproot the carrot from this soil ranged from 1.7% to 3.5% in the case of Simon harvester, and from 2.0% to 4.3% for Alina harvester. In the material collected with Simon harvester at the studied working speeds, the largest groups of damaged roots were the broken (22.1% - 45.6%) and fractured ones (1.7% - 4.1%), whereas in the case of Alina harvester most damaged roots were bruised (23.2% - 26.7%) or had their heads chopped off (1.2% - 6.9%). The lowest overall root damages for Simon harvester (27.4%) and Alina harvester (30.2%) were achieved at the speeds of 1.5 km/h and 2.5 km/h, respectively. The roots with leaves not sheared off constituted 1.3% - 3.4% of the material collected with Simon harvester and 0.3% - 1.9% of the material collected with Alina harvester.

Khurana *et al.*, (2012) tested a tractor operated root crop harvester. The machine was evaluated for digging root crops like onion, carrot and garlic sown on beds. The field capacity of the machine was 0.20, 0.25, 0.23 and 0.2 - 0.3 ha/h for digging onion, carrot, garlic and turmeric crop, respectively when operated at a speed of 2.1, 2.7, 2.5 and 2.1-2.9 km/h. The harvested crop percentages for onion, carrot, and garlic were 99.0, 96.3, and 98.6 percent, respectively. The damage by machine was less than 1.0, 2.8 and 1.1 per cent for onion, carrot and garlic, respectively. Saving in cost of operation for harvesting onion, carrot, garlic and turmeric was 54.74, 47.12, 45.91 and 30.48 per cent, respectively. The saving in labour was 69.0, 59.2, 61.41 and 40.97 per cent, respectively as compared to manual harvesting.

التعليق [M20]: Please rewrite. There is a problem with the text.

Shirwal and Mani (2014) studied the design parameters effecting mechanical carrot harvester. They observed that Carrot digging is labor consuming operation in carrot production. Nearly, 250-300 man-hours are required to harvest one hectare of crop. They took three lengths of soil separators (40 cm, 60 cm and 80 cm), three rake angles (15°, 25° and 35°) and three soil separators angles (0°, 10° and 20°) on the test set-up at optimum soil moisture content of 12%. The maximum percentage of carrot harvested of 97.4% was obtained at 60 cm length of soil separator, 25° rake angle and 20° of soil separator angles. Minimum carrot damage of 4.87% was obtained at 40 cm length of soil separator and 20° soil separator angle. Carrot damaged was obtained in the range of 4.63% to 4.97% for 25° and 35° rake angle. The soil separation index was most affected by length and angle of soil separator. A minimum soil separation index of 0.23 was obtained at 80 cm length and 20° angle of soil separator, respectively. Power requirement at a speed of 2.3 km/h was 4.44 kW, 5.3 kW and 5.75 kW at rake angle of 15°, 25° and 35°, respectively.

Naresh (2015) designed and developed a tractor operated carrot harvester, and used conveyer to handle harvested carrot. A sweep type blade was used for digging the carrots and two triple pitch roller chains rotating in opposite direction were used to hold the leaves of carrots digged by the digging blade. Detopping unit was provided to cut the leaves of carrots by the two serrated discs rotating in opposite direction, provided below the conveying unit. Crate (Collection box) holding frame was provided for placing crates, used for collecting the de-topped carrots. He found digging efficiency ($\eta_d = \frac{\text{Total no.of dug out carrots by carrot harvester}}{\text{Total no.of carrot (dug out and undug both)}} \times 100$), picking efficiency ($\eta_p\ \% = \frac{\text{Total no.of carrots picked by conveying unit}}{\text{Total no.of carrots (dug out)}} \times 100$) and cutting efficiency ($\eta_c\ \% = \frac{\text{Total no.of carrots without leaf in sample}}{\text{Total no.of carrots (dug out)}} \times 100$) of de-topping unit were 100%, 61.56% and 100%, respectively. Effective field capacity of the digger was 0.11 ha/h with field efficiency of 61.70%. Also, they found, time and cost saving to be 94% and 63.36%, respectively with the developed carrot digger in comparison to manual method of harvesting.

Shirwal *et al.*, (2015) designed and developed a tractor operated carrot harvester, and used soil separation unit to separate soil from carrot. The developed carrot harvester was consisted of two major components; a digging unit and a soil separation unit. The digging unit consisted of a V-shape digger blade with length and width of 350 mm and thickness of 15 mm. In soil separation unit the spacing between the rods of web was kept as 5 cm, width and length of soil separator was 700 mm, respectively. The developed carrot harvester was evaluated for different levels of rake angle, soil separator length and angle of soil separator. The performance parameters observed were, carrot harvesting percentage 97.8, carrot damage percentage of 4.6, soil separation index of 0.21, power requirement of 5.18 kW and field capacity of 0.21 ha/h when carrot harvester was operated at a speed of 3.8 km/h. Also, they estimated cost of single unit developed carrot harvester was INR 6,000/-. The cost of manual harvesting of carrots is INR 2925/- per ha, while the operational cost with a developed carrot harvester is INR 1,481/- per ha. They found saving in the cost of carrot harvesting was 49% and saved harvesting time less 96% than traditional harvesting. The breakeven point for the single unit carrot harvester was 148 h/year which was 52% of annual utility with a payback period of three years.

Kumar *et al.*, (2017) developed a tractor operated carrot digger. They used shovel and simple rectangular blade for digging. The developed implement was consisted of frame, carrot bed loosening unit and side thrust balancing unit. The bed loosening unit comprised a rectangular soil cutting blade mounted at an inclination on a tyne. The cutting blade was operated in soil below the depth of carrot to loosen the carrot bed. The carrots were then pulled by the labour. The implement loosened one bed row at a time. They observed that, the actual field capacity of the implement was 0.0108 ha/h with field efficiency of 69.26% and digging efficiency was

97.56%. Undug carrots were observed in 0.409 percent of the total, whereas damaged carrots were observed in 1.515 percent. They also focused on cost savings, conserving INR 59.9/- per hour as compared to traditional carrot harvesting.

Ikram *et al.*, (2018) fabricated a tractor operated carrot digger, and they used simple rectangular blade for digging. They found that, second level of tractor speed (3.1 km/h) was an optimal speed (99.1% of carrots were dig at this speed). Also, fuel consumption increased with the increase in speed of the machine. Therefore; they are recommended to operate the machine at a speed of 3.1 km/h or below. Average field capacity and field efficiency of carrot digger were observed 0.19 ha/h and 45% respectively. They also done breakeven analysis of the machine. They achieved, the breakeven point of digger was 170 hours of operation.

Kumar (2019) developed a tractor operated carrot digger. The developed carrot digger was a five row digger and it had a sweep, nose and shovel type blade. The experiment was carried out at three level of average forward speeds (2.5, 3.5 and 4.5 km/h) and three level of digging blades (sweep, nose and shovel type). He observed that minimum draft was 2.7 kN with shovel type blade and average forward speed 2.5 km/h. The main findings were, digging efficiency 97.20%, damage percentage 3.26%, actual field capacity 0.398 ha/h, and field efficiency 79.95%.

Self-propelled carrot harvester

التعليق **[M21]:** Old source

Horia *et al.*, (2008) developed a self-operated carrot harvesting machine suitable for the Egyptian agricultural conditions. The components of the developed machine were namely: pulling unit, transmission system and frame. In the study they determined physical and mechanical properties of foliage and root (dimensions, mass, pulling force and tension force) and soil properties. They developed the proposed harvester by relating dimensions design to the theoretical considerations. They evaluated the mechanics of the developed harvester as affected by different design parameters. The machine was evaluated at a constant speed of 0.3 m/s (1.08 km/h), under different operating parameters: pulling inclination angle,

pulling belt speed and the height of branch catch. The machine performance was determined by crop quality, lifting efficiency and root damage. The reported results showed that the root quality increased by decreasing the belt speed and root damage increased by increasing the belt speed. The lifting efficiency was increased with increase in belt inclination angle and decreased with increase in belt speed and height of branch catch. From the obtained results the optimum parameters of the carrot harvesting machine were belt speed 0.5 m/s, belt inclination angle 45° and height of branch catch 5 cm. The best root quality, root damage and lifting efficiency were 99.5 %, 0.5 % and 86.46 %, respectively.

CONCLUSIONS

Harvesting of carrot is done by different ways using human, animal and engine power. The most common method is manual method despite of number of drawbacks like shortage and high wages of labors, time consuming and very low efficiency.

Table: 1 Comparison of Harvesting methods

Sr. No.	Methods	Advantages	Disadvantages
1	Manual	Damage/Losses are low	Time and Labour consuming
2	Animal Drawn	Less Labour required for harvesting as compare to manual method	Damage/Losses are high as compare to manual method
3	Engine Powered	High efficient, Time saving, minimum labour required, etc.	Skilled operator required and Maintainace of machine required.

In past few decades numbers of animal-drawn carrot diggers were developed. Now, the use of animal power is becoming costly, thereby the use of animals in the farms are decreasing at a very fast rate. Therefore, whatever animal drawn equipment/implements are available most of them are not getting popularity for the further use.

As human power and animal power are becoming more and more costly with increasing dependency. Now, there is urgent need to mechanize these operations by using engine power. Many researchers have developed a no. of carrot harvesters either tractor drawn or engine operated self-propelled types. In views of our farmers, the most of these machines are either very costly or bigger in size or some with a few draw backs i.e. not suiting to the farmers of this region. However, these machines were tested

keeping the forward speed from 0.5 to 4.5 km/h and setting the rake angle from 15° to 45°. Therefore, there is a need to develop a new carrot harvesting machine suited to our farmers and their field conditions like, the tops of the carrot roots will be about 3/4 to 1 inch in diameter when ready to harvest for this region. For selection of testing and setting parameters for the to-be-developed machine, the above values given by different researchers stated in the reviews, may be used.

التعليق [M22]: Please provide standard references

REFRENCES

Abd-Rabou, A. F. 2004. Manufacturing a small machine to suit harvesting sugar beet under Egyptian conditions. PhD Thesis (Unpublished). Agric. Mech. Dept. Fac. of Agric. Kafr El-Sheikh. Tanta Univ.

Agriculture and Food. 2021: Minimising postharvest losses of carrots. Available at https://www.agric.wa.gov.au/carrots/minimising-postharvest-losses-carrots?page=0%2C3 accessed 30 October, 2021.

APEDA. 2020: Product data. Agricultural & Processed Food Products Export Development Authority. Available at http://apeda.in/agriexchange/India%20Production/India_Productions.aspx?hscode=1073 accessed 26 October, 2020.

التعليق [M23]: Alsharifi, S, K. Alwan ,Shtewy .N, Al-Janabi,T(2020).The effect of sowing methods on the growth characteristics of wheat in Alhashemia, Iraq. Asia Life Sciences 10(4) :675-685.

التعليق [M24]: Alsharifi, S. K. A., Aljibouri, M. A., & Taher, M.2019.Effect of two types of digger machines and speeds of tractor on the qualitative characteristics of potato. *Fayoum Journal. Agriculture. Res,&Dev.*, 33(1) : 308-322 .

التعليق [M25]: -

التعليق [M26]: -

التعليق [M27]: -

التعليق [M28]: -

التعليق [M29]: -

Carrotmuseum. 2021: Carrot Production Statistics. Available at http://www.carrotmuseum.co.uk/worldcarrots.html accessed 30 October, 2021.

Chaudhry, M. G. and Ahmad, B. 2000. Dynamics of vegetable production, distribution and consumption in Asia. Asian Vegetable Research and Development Centre, Taiwan. Publication No. 00-498. pp: 271-308

El-Sherif, R. R. 1996. A study on harvesting mechanization of Sugar beet. Ph. D. Thesis (Unpublished). Fac. of Agric., Kafr EL-Sheikh, Tanta Univ., Egypt.

التعليق [M30]:

Horia, M.; El-Sahhar, E. A.; Mostafa, M. M. and Abd-Elhady, F. A. 2008. A developed machine to harvest carrot crop. *Farm Machinery and Power*, **25(4):** 1163-1173.

Ikram, K.; Nadeem, M.; Ghani, M. U. and Mubashar, M. 2018. Fabrication and performance evaluation of carrot digger. *Glob. Innov. Agric. Soc. Sci.*, **6(3):** 84-87.

التعليق [M31]: Hamzah ,I.J. and Alsharifi.S.K. Alwan (2020).Innovative harvesting methods about the harvest losses for two machines .Bulgarian Journal of Agricultural Science, 26 (4): 913–918.

Khurana, R.; Manes, G. S.; Dixit, A.; Singh, A.; Mahal, J. S.; Singh, B. P. 2012. Proto type feasibility testing of tractor operated root crop harvester. Annual Report for 2013. Pp. 68. Punjab agricultural university, Ludhiana.

Kowalczuk, J. and Leszczynski, N. 1999. Qualitative evaluation of carrot root harvesting with Alina harvester manufactured in Poland. *Problems of Agricultural Engineering*, **4**: 19-24.

Kowalczuk, J.; Leszczyński, N. and Bieganowski, F.; 2003. Evaluation of the quality of carrot root harvested with Alina and Simon one-row harvesters. *Acta Agrophysica*, **2(1):** 105-111.

Kumar, R. 2019. Design, development and evaluation of carrot digger. M.Tech. Thesis (Unpublished). Dept. of F. M. P. E., College of agricultural engineering and technology, G. B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand, India.

Kumar, V.; Kumar, A.; Naresh, V. R.; Mukesh, S. and Pooniya, R. 2017. Performance and Evaluation of Tractor Drawn Carrot Bed Loosening Implement. *Annals of Biology*, **33(1):** 135-138.

Mady, M. A. 2001. Mechanization of some operations for sugar beet production. *Misr. J. Agric. Eng.*, **18 (2):** 339 – 355.

MPUAT. 1998. Annual Report for 1998. Udaipur, Maharana Pratap University of Agriculture & Technology. **56p.**

Naresh, 2015. Design, development and evaluation of carrot digger. M.Tech. Thesis (Unpublished). Dept. of F. M. P. E., College of agricultural engineering and technology, Agricultural University Hisar, Haryana.

Özarslan, C. and Erdogan, D. 1990. Mechanization possibilities on carrot harvesting. *In:* International Congress on Mechanization and Energy in Agriculture. Proceedings of a conference held in Adana, Turkey, 1-4 October 1990. Ministry of Agriculture, Forestry and Rural Affairs. pp. 374-382.

Shirwal, S. and Mani, I. 2014. Study on Design Parameters Effecting Mechanical Carrot Harvester. *International Journal of Engineering Sciences &Research Technology*, **3(3):**1664-1670.

Shirwal, S.; Mani, I.; Sirohi, N. P. and Kumar, A. 2015. Development and evaluation of carrot harvester. *Agricultural Mechanization in Asia, Africa and Latin America*, **46(1)**: 28-34.

التعليق [M32]: ?