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FABRICATION AND PERFORMANCE EVALUATION OF CARROT DIGGER

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Most of the farmers in Pakistan, still harvesting the carrot with spade or hand hoes. This conventional practice is tedious, labor intensive and time consuming. On an average, 250 to 300-man hours are required to harvest one hectare. With the passage of time skilled labor availability is decreasing each year. Therefore, this study was designed to see the performance of carrot digger for harvesting the carrots mechanically. A field of 0.75 ha was selected for machine evaluation. Data collected in response to different treatments were subjected to analysis of variance (ANOVA) using computer software MSTATC. The results of this study showed that, second level of tractor speed (3.1 km/h) was considered as an optimal speed (99.1% of carrots were dig at this speed). Moreover, fuel consumption increased with the increase in speed of the machine. Therefore; it is 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 calculated as 0.19 ha/h and 45% respectively. At the end of this study breakeven analysis of this machine was performed. The breakeven point of this digger was achieved after 170 hours of operation.
Keywords: Agricultural machinery, carrot, digger, field efficiency, machine testing

INTRODUCTION

Pakistan is pre-dominantly agricultural country. In recent decade shortage of skilled labour is a burning issue of country which leads the farmers to move to mechanization. Use of carrot in human food is increasing because of its large production and nutritional value (Metwalli and Ahmed, 2004). There is a wide range of time to cultivate carrot crop in Pakistan due to controversy in weather conditions. Carrot digging is labor consuming operations in carrot production (Wang *et al.,* 2007). Nearly, 250-300 man hours are required to harvest one hectare of crop (Shirwa *et al.,* 2015). Shortage of skilled labour and unfavorable weather conditions during peak harvest season delay harvesting and results in a great loss of carrot crop in the field (Bashir *et al.,* 2005). Majority of farmers in Pakistan still harvesting the carrot with spade or hand hoes. The conventional methods of carrot harvesting significantly increased the percentage of damage 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 (Chaudhary *et al.,* 2000) to overcome the labor problem. This mechanical harvesting can also save 60% of farm power (Sukhwindar *et al.,* 2007).

Many researchers (Shirwa *et al.,* 2015; Wang *et al.,* 2007; Hardenburg and Turner, 2007; Metwalli and Ahmed, 2004; Kathirvel and Manian, 2001) studied performance evaluation of carrot digger. Shirwa *et al.* (2015) fabricated and evaluated a carrot digger and stated that the mechanical carrot harvesting not only saved 49% of cost but also saved 96% of harvesting time. Wang *et al.* (2007) designed one carrot digger which harvested 99% safe carrots and only 1% damage during operation was observed. Hardenburg and Turner (2007) studied different parameters involved in carrot digging. Their findings concluded that speed of apron, type of digger and depth of digger are important parameters. Metwalli and Ahmed (2004) studied different shovel types for peanut digging. They found V-type shovel had least power draft requirement and was most efficient. Kathirvel and Manian (2001) fabricated a power tiller carrot digger. Kathirvel and Manian (2001) worked on power requirement of a carrot digger. Katiwat and Khommueng (1994) developed a carrot digger. Malay *et al.* (2000) used CERES II root crop yield monitor with a carrot digger. McGarry (1995) stated that carrots may be damaged due to impact force of the harvester shovel. Smith and Wright (1993) developed a machine to destroy above ground plant material to facilitate the carrot digging operation.

The need for mechanized carrot harvesting was felt because of scarcity of manual labour and rapidly increasing labour charges during carrot digging season. Hence a mechanical carrot digger was designed keeping in view the function to perform, fabrication facilities and skills, simplicity of design, social acceptability, knowhow of the end users, trend of local industry, local soil and environment conditions.

MATERIALS AND METHOD

This study was divided into two phases, viz. machine development and field performance evaluation.

***Design and fabrication of the carrot digger*:** Main components of carrot digger are shown in Figure 2, while Figure1 is showing the 2-D drawing of digger for easy understanding of machine. Now, we will discuss about the different individual components. 1. Main frame; 2. Mast (A) frame; 3. Clamp; 4. Tines and blades

A small description of all parts is given below

***Main frame*:** Main frame was made of high carbon steel to attach all operational parts on it. The length, width and breadth of main frame were 243.8cm, 10.2cm and 10.2cm, respectively.

***Mast (A-frame*):** Mast was made of mild steel and it attached the machine with tractor and also known as drawbar.

***Clamp*:** Clamp was made by mild steel. This part of the machine held the tines with main frames. The length of the clamp was 30.5 cm, width was 17.8 cm and breadth was 1.3 cm.

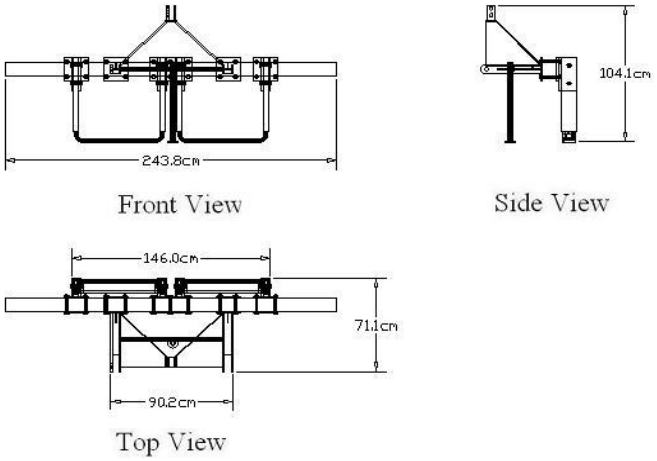
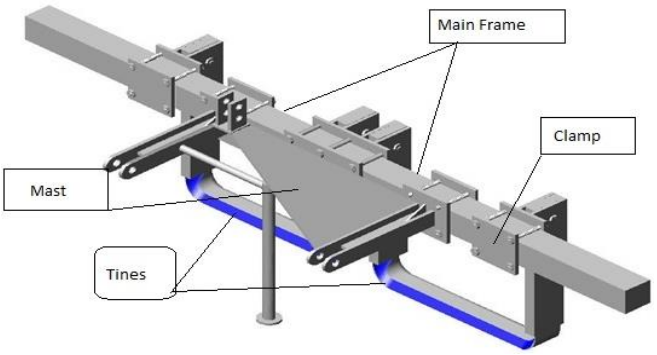


Figure 1. 2-D drawing of carrot digger.



Isometric view of carrot digger

Figure 2. 3-D Drawing of main components of carrot digger.

***Tines and blades*:** Tines and blades were made of high carbon steel. One end of each tine was attached with clamp and on the other end high carbon steel blades were attached. The angel of the blade was 15º along the direction of travel. The lengths of the tines were 64.8 cm, width was 14 cm and breadth was 3.8cm. The lengths of the blades were 0.70 cm and width was 11.4 cm.

Performance evaluation: The machine was designed, fabricated and evaluated for its performance. The following factors were selected for machine evaluation.

***Fuel consumption*:** Fuel consumption indicates the energy requirements and cost of operation. Before starting each test, the fuel tank of their tractor was completely filled with fuel and after finishing the test it was again filled to the same level by a graduated glass cylinder. The fuel needed to refill the tank was the fuel used during a test. It was determined at different levels of forward speed and moisture contents.

***Depth of operation*:** Depth of operation was determined by an accurate centimeter size measuring tape. Three points was selected randomly to achieve an average depth of cut.

***Forward speed of the machine*:** Forward speed of the machine was determined by recording the time taken by the digger for harvesting crop in a known distance. The averages of five values were recorded. The digger was operated at 2.7, 3.1 and 4.12 km/h forward speeds.

***Field capacity*:** The effective field capacity of machine can be expressed as the actual rate at which it can do work, taking into account such non-productive operations as turning at the end s of the field, stopping to add seed or fertilizer, stopping to check performance and the amount of overlap into previously traveled area. The field capacity of carrot digger was determined by following relationship

$$(\mathrm{EFC}) = \frac{S \times W \times E_f}{k \times 100}$$

RESULT AND DISCUSSION

***Effect of forward speed on fuel consumption*:** Fuel consumption increased with increase in the forward speed of the digger. It was 3.9, 4.5, and 5.2 liters at the forward speed of 2.7, 3.1 and 4.12 km/h, respectively (Fig. 3). Reason of this increase in draft was due to increase in machine forward speed. The relationship between machine forward speed and fuel consumption is shown in figure 3.

***Effect on carrot dig*:** The statistically analyzed results of total number of carrots dig at two moisture levels and three forward speeds and their interaction on carrot dig were found highly significant ($P<0.0001$). Carrots dig was significantly greater at a speed 3.10 km/hr than those at speed of 2.7 km/hr and 4.12 km/hr for both the moisture level. The reason of less number of carrots dig at low speed (2.7 km/hr) and high moisture could be the low force at the tip of bars of the carrots digger than those at the other two speeds. Carrots dig at low

moisture content (10.48%) were greater, at all the selected speeds than those at high moisture content (13.6%). This indicates that soil had more adhesive force at high moisture content than that at low moisture content and did not allow the carrots to be separated so easily than at low moisture content. The relationship between machine speed and number of carrot dug is shown in Figure 4.

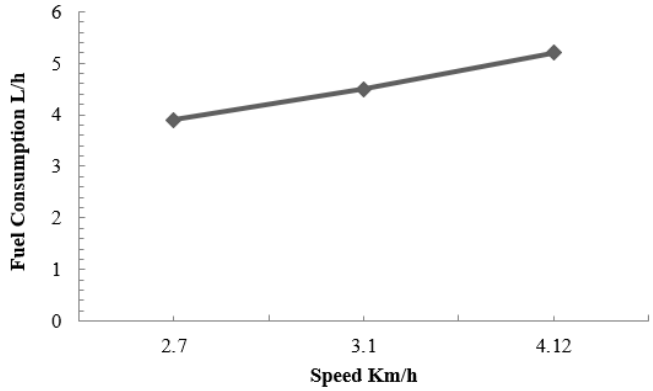


Figure 3. Fuel consumption of carrot digger at different forward speeds.

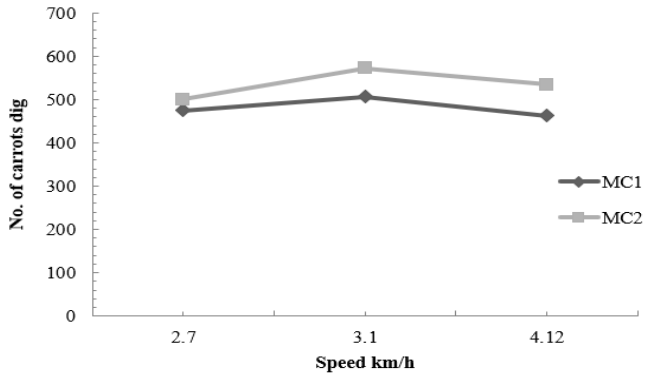


Figure 4. Number of carrots dig at different speeds and moisture contents.

***Effect of digger on un-dig carrots*:** The effects of moisture contents and forward speeds on carrots left in the soil were found highly significant (P<0.0001) at 5% level of significance. Carrot left in the soil at both the moisture levels were significantly greater (0.05 level) at low speed than those at the under higher speeds. The reason of greater number of carrots left under the soil at low speed (2.7 km/hr) could be the low force at the tip of bars of the carrots digger than those at the other two speeds. Numbers of carrots left under the soil at low moisture content (10.48%) were lower at all the selected speeds, than those at high moisture contents (13.6%). Carrots left at high moisture content (13.6%) were always greater than those at low moisture content (10.48%) for all the selected speeds. The relationship between machine forward speed, moisture content and un-dig carrots is shown in Figure 5.

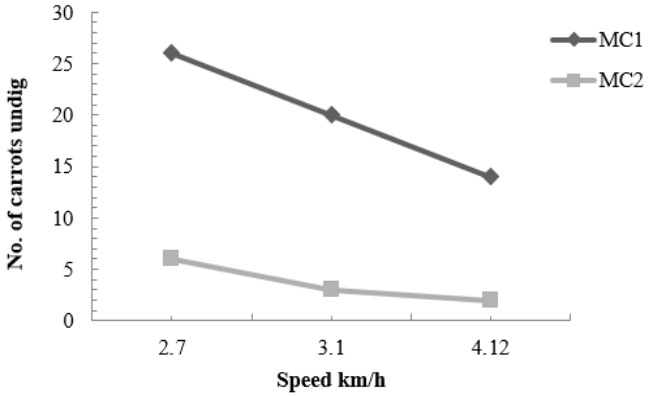


Figure 5. Number of carrots undig at different speeds and moisture contents.

***Effect of digger on carrots cut and damage*:** Results indicated that mean maximum number of carrots cut and damage were significantly greater at higher speed (4.12) at moisture content 13.6% which was high than those at medium (3.1) and lower speed (2.7). Figure 6 indicates that at speed 3 carrots cut and damage was 2 times greater than at speed one and 1.2 times greater than at speed two. Figure 6 shows that the mean maximum number of carrots cut and damage were significantly greater at higher speed (4.12) at moisture content 10.48% which was than those at medium (3.1) and lower speed (2.7). Table indicated that at speed three carrots cut and damage was 3.2 times greater than at speed one and 1.6 times greater than at speed two. Table indicated that maximum number of carrot cut and damage at speed three and moisture content 13.6%. Carrots cut and damage at low moisture content (10.3%) were smaller, at all the selected speeds than those at high moisture contents (13.2%).

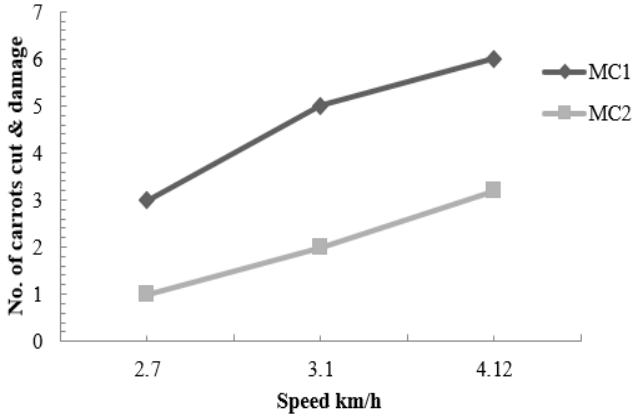


Figure 6. Number of carrots cut and damage at different speeds and moisture contents.

***Effect of speed on fuel consumption*:** Results indicated the fuel consumption of three different speeds S1, S2 and S3 was 3.80 l/h, 4.50 l/h and 5.20 l/h, respectively. It is indicated that all speeds was significant at 5% level of significant. It also indicates that fuel consumption at speed 3 was 5.20 l/h which was 1.15 times greater than speed 2 and 1.36 times greater than speed 1. Achieving peak performance of engines will result in many benefits, such as high fuel efficiency, reduced maintenance expenses, reduced downtime, and extended life.

***Field capacity and efficiency*:** An area of 0.075 hectare was harvested to calculate the average field capacity and efficiency of the machine and various time elements were calculated as under:

Actual harvesting time (t) = 0.97 hr
Time lost in turning = 0.758 hr
Time lost in adjustment, cleaning weeds and minor repair in the field = 0.403 hr
Total time lost = 1.16 hr
Total field time T = 2.13 hr
Field capacity = 0.19 ha/hr
Field efficiency = 45 %

***Break even analysis*:** The breakeven point is useful reference point in the sense that it represents the level of operation at which total revenue equals total cost. The breakeven point of the tested carrot digger occurred at 170 hours of use in a year (Fig. 7). One crop of carrot is being grown in a year in our country. In the light of the field capacity of carrot digger, it is certainly expected that a farmer can easily cross the breakeven point and earn more and more profit by renting the carrot digger to the other carrot growing farmers.

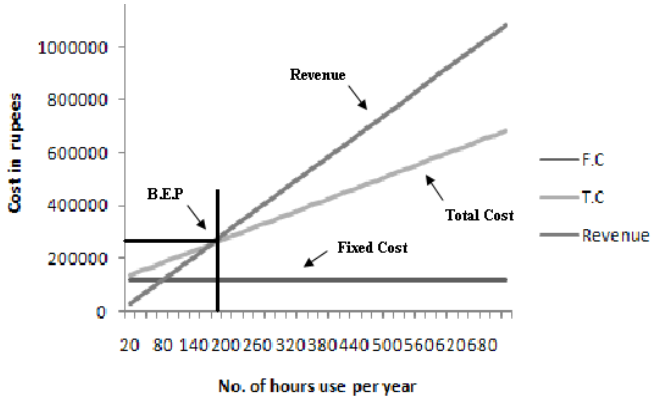


Figure 7. Break even point of carrot digger.

***Conclusions*:** The speed of the carrot digger for harvesting carrot crop should be in the range of 2.7 to 4.12 Km/h. The operations of carrot digger at speed 3.1 Km/h dig about 99.1 Percent of carrots. Fuel consumption increased with the increase in forward speed of the machine. Rate of increase was high at speed greater than 3.1 Km/h. It is therefore; better to operate the machine below or at the speed of 3.1 Km/h. The machine is a labor, time and energy saving device. Only one skilled operator can handle the operation of machine satisfactorily. Average field capacity of AMRI carrot digger at the forward speed of 3.1 Km/h was calculated as 0.19 ha/h with field efficiency of 45%. The low efficiency of the digger was mainly due to more time losses in turning and cutting of green leaves of carrot plant.

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