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Performance evaluation of manual drawn engine powered leafy crop harvester

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Abstract
Different leafy vegetables are important class of agricultural products at the national and international levels. Coriander leaves are harvested and the plant continues to produce new foliage until it matures to seed formation. The major components of the machine include the cutting unit (reciprocating cutter bar), the slider crank mechanism, the reel, conveyor, storage crate and the frame. Experiments were conducted in the coriander field by varying crank speeds (200, 300 and 400 rpm) by throttle of engine and forward speed ranges (0.9-1.2, 1.3-1.6 and 1.7-2.0 km/h) in different nine combinations. Two factorial completely randomized design was adapted for the experiment by taking three replications. The results were analysed statistically. The highest effective field capacity was found to be 8.6×10^{-3} ha/h for the combination of crank speed at 200 rpm and 1.7-2.0 km/h of forward speed. The highest field efficiency and cutting efficiency were found to be 87.29% and 96.28% respectively with the combination of crank speed of 400 rpm and forward speed of 0.9-1.2 km/h. Economic point of view, it was found that hourly cost of operation was ₹ 129.73/h and cost of harvesting was ₹ 1907.79/ha.

Keywords: Leafy crop, coriander, leaf harvesting, harvester, coriander harvester

Introduction
Indian economy is greatly influenced by agriculture. Different leafy vegetables are important class of agricultural products at the national and international levels. Coriander is an annual herb and according to the climatic conditions, it is cultivated as a monsoon or winter annual crop. India ranks first in the production of coriander. Our country is exporting coriander to Malaysia and Pakistan. The plants attain heights from 20 to 120 cm depending upon the variety and whether irrigated or rain fed (Sharma *et al.*, 2012) [7]. Leaves are harvested and the plant continues to produce new foliage until it mature to seed formation.

In India, mostly harvesting of leafy crops is done manually with the help of sickle. This important operation is labour consuming and its cost has gone up considerably due to increase in the area of cultivation and unavailability of labour (Ojha and Michael, 2003) [4]. The harvesting machinery and associated labour costs are often the largest contributor to the cost of producing and delivering forages (Buckmaster, 2006) [2]. Over the last century and a half, farming practices have been revolutionized by the advent of mechanical harvesters, but there was a disparity between available agricultural technology and the technology used in the farm equipment that was affordable for operators of small farms. (Kraines, 2013) [3]. The percentage of damage of leaves decreased by decreasing the conveyor linear velocity and forward speed when the original mower forward speeds of 0.98 to 2.55 km/h (Amer, 2012) [1].

Materials and Methods
The major components of the machine include the cutting unit (reciprocating cutter bar), the slider crank mechanisms, the reel, conveyor, storage crate and the frame. Cutter bar type blade was used. Leafy crop stem was cut by the cutter bar blade which was powered by engine. The slider mechanism was an arrangement of crank and connecting arm which convert the rotary motion of eccentric wheel to reciprocating motion of the cutter bar. Harvested plants were guided to conveyer belt by reel. Linear speed of reel was 25 to 50% higher than forward speed (Singh, 2017) [8]. Plants were conveyed to crate by inclined conveyer. Cutter bar, reel and conveyer were powered by engine through gear box and belt and pulley arrangement. The details of machine are given below figure.

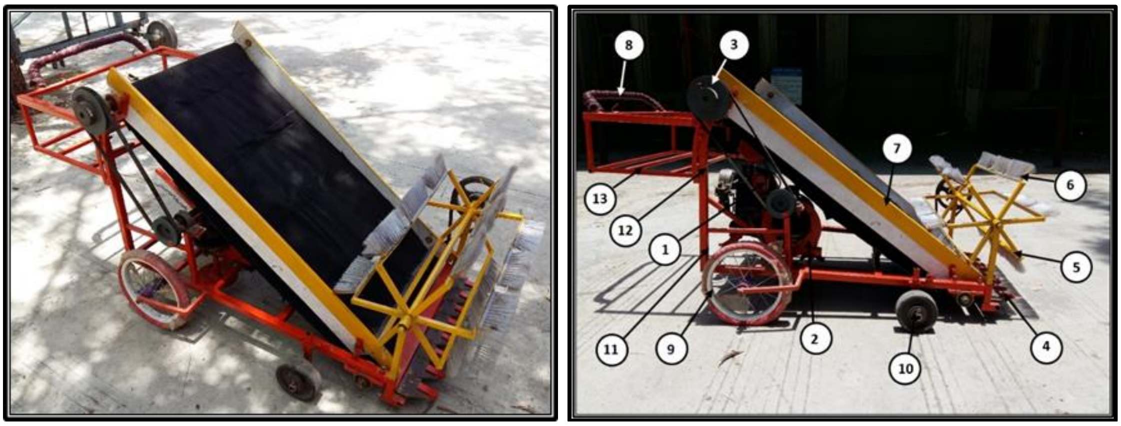

Fig 1: 1. Engine, 2. Gear box, 3. Belt and pulley 4. Cutter bar unit, 5. Reel unit, 6. Brush, 7. Conveyer unit, 8. Handle, 9. Transportation wheel, 10. Cutting height adjustment wheel, 11. Main frame, 12. Curved frame, 13. Crate frame. Different components of leafy crop harvester

Location of Experiment

In order to evaluate the performance of leafy crop harvester, coriander crop was chosen and experiments were carried out at Department of Farm Machinery and Power Engineering, Collage of Agricultural Engineering and Technology, JAU, Junagadh (Gujarat) during the year 2019.

Performance Evaluation of the Leafy Crop Harvester for Coriander Crop

Experiments were conducted by varying crank speeds (200, 300 and 400 rpm) and forward speed ranges (0.9-1.2, 1.3-1.6 and 1.7-2.0 km/h) in different combinations. Two factorial completely randomized design was adapted for the experiment by taking three replications (Panse and Sukhatme, 1985) [5]. The results were analysed statistically. The performance of the device was evaluated by determining effective field capacity, field efficiency and cutting efficiency. The cost of harvesting with harvester was also calculated. The depreciation was calculated by straight line method (Witney, 1988) [9]. The harvester was able to cut three rows at a time sown at 20 cm row to row spacing. Thus, effective width of the machine was 60 cm. Engine speed was decreased with help of throttle lever to adjust crank speed to 200, 300 and 400 rpm. This speed in rpm was measured by digital tachometer.

Effective field capacity

The Effective field capacity is the actual rate of coverage by the machine, based upon the total field time. The machine was operated with a fixed speed for continuous field work for a particular time the area covered during the period was measured to determine the average output per hour.

$$\text{Effective field capacity, ha/h} = \frac{\text{width of coverage (m)} \times \text{length of strip (m)} \times 0.36}{\text{time taken (s)}}$$

Field efficiency

The term field efficiency is used to describe the efficiency of the machine in operation. The Field efficiency of the harvester was calculated by the productive and non-productive time. (Sahay, 2004) [6].

$$\text{Field efficiency (\%)} = \frac{\text{productive time (s)}}{\text{productive time (s)} + \text{non-productive time (s)}} \times 100$$

Cutting efficiency

Number of plants in 0.4 × 0.5 m area of 20 m length of strip counted before and after operation. Cutting efficiency was calculated by following equation.

$$\text{Cutting efficiency, \%} = \frac{W_1 - W_2}{W_1} \times 100$$

Where,
W_1 = Number of plants before cutting
W_2 = Number of un-cut plants after cutting.

Results and Discussion

Effect of Crank Speed and Forward Speed on Effective Field Capacity

The effective field capacity of the harvester was calculated by fixing the area of which had the fixed length of 20 m and fixed width of 0.6 m. A stop watch was used to measure the time. This is the actual area covered by the harvester and calculated in terms of ha/h. Statistical analysis shows that crank speed was found non-significant on effective field capacity. Whereas forward speed was found highly significant on effective field capacity at 1 per cent significant level. The interaction between crank speed and forward speed was found non-significant on effective field capacity.

Table 1: Effect of different crank speed on effective field capacity

Crank speed, rpm	200 (C_1)	300 (C_2)	400 (C_3)
Effective field capacity, 10^{-3} ha/h	69.76	68.53	67.68

SEm = 0.89; CD = non-significant

It was found that crank speed 200 rpm (C_1) gave maximum effective field capacity (69.76×10^{-3} ha/h) whereas crank speed 400 rpm (C_3) had minimum effective field capacity (67.68×10^{-3} ha/h). This was because at 400 rpm crank speed machine vibrate more compare to 200 rpm crank speed so handling the machine was slightly difficult due to that forward speed was slightly decreased.

Table 2: Effect of different forward speed on effective field capacity

Forward speed, km/h	**0.9-1.2 (F_1)**	**1.3-1.6 (F_2)**	**1.7-2.0 (F_3)**
Effective field capacity, 10^{-3}ha/h	51.93	69.11	84.94

SEm = 0.89; CD = 2.64

It was found that forward speed of 1.7-2.0 km/h (F_3) resulted in maximum effective field capacity of 84.94×10^{-3} ha/h whereas forward speed of 0.9-1.2 km/h (F_1) gave minimum effective field capacity of 51.93×10^{-3} ha/h. This was because forward speed is directly proportional to effective field capacity.

Table 3: Combined effect of different crank speed and forward speed on effective field capacity

Forward speed (F), km/h	Effective field capacity, (10^{-3} ha/h) Crank speed (C), rpm		
	200 (C_1)	300 (C_2)	400 (C_3)
0.9-1.2 (F_1)	52.08	52.26	51.43
1.3-1.6 (F_2)	70.76	68.62	67.94
1.7-2.0 (F_3)	86.42	84.73	83.66

SEm = 1.54; CD = non-significant

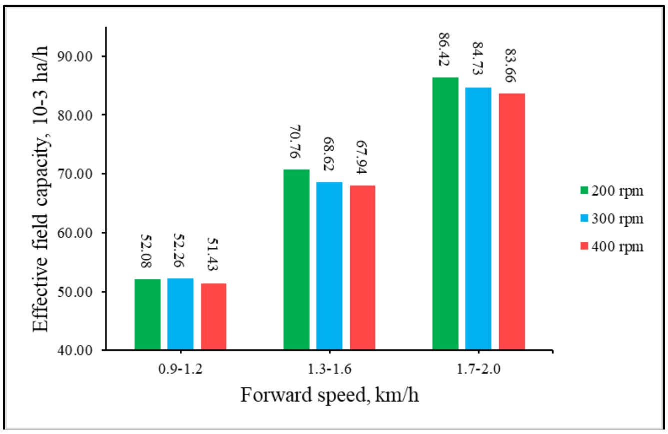

Fig 2: Effect of interaction of crank speed and forward speed on effective field capacity

The maximum value of effective field capacity was found to be 86.42×10^{-3} ha/h when crank speed was 200 rpm (C_1) and forward speed was 1.7-2.0 km/h (F_3) and the least value was found to be as 52.08×10^{-3} ha/h when crank speed was 400 rpm (C_3) and forward speed was 0.9-1.2 km/h (F_1). It shows that effective field capacity was slightly increased with crank speed C_3 followed by C_2 and C_1 respectively. It also shows that effective field capacity was highest for forward speed F_3 followed by F_2 and F_1 respectively.

Effect of Crank Speed and Forward Speed on Field Efficiency

The Field efficiency of the harvester was calculated by fixing the area of which had the fixed length of 20 m and fixed width of 0.6 m. A stop watch was used to measure the productive and non-productive time. This is the ratio of productive time to total time taken by the harvester and determined in terms of percentage. Statistical analysis shows that crank speed was found non-significant on field efficiency. Whereas forward speed was found highly significant on field efficiency at 1 per cent significant level. The interaction between crank speed and forward speed was found non-significant on field efficiency.

Table 4: Effect of different crank speed on field efficiency

Crank speed, rpm	200 (C_1)	300 (C_2)	400 (C_3)
Field efficiency, %	81.77	82.21	83.30

SEm = 0.66; CD = non-significant

It was found that crank speed 400 rpm (C_3) was having maximum field efficiency (83.30%) whereas crank speed 200 rpm (C_1) was working with minimum field efficiency (81.77%). This was because at 400 rpm crank speed machine vibrate more compare to 200 rpm crank speed so handling the machine was slightly difficult due to that non-productive time increased.

Table 5: Effect of different forward speed on field efficiency

Forward speed, km/h	0.9-1.2 (F_1)	1.3-1.6 (F_2)	1.7-2.0 (F_3)
Field efficiency, %	86.77	81.91	78.60

SEm = 0.66; CD = 1.96

It was found that forward speed of 0.9-1.2 km/h (F_1) resulted in maximum field efficiency of 86.77% whereas forward speed of 1.7-2.0 km/h (F_3) was working with minimum field efficiency of 78.60%. This was because higher forward speed resulted is more non-productive time.

Table 6: Combined effect of different crank speed and forward speed on field efficiency

Forward speed (F), km/h	Field efficiency, (%) Crank speed (C), rpm		
	200 ($_1$)	300 (C_2)	400 (C_3)
0.9-1.2 (F_1)	86.34	86.69	87.29
1.3-1.6 (F_2)	81.00	81.50	83.24
1.7-2.0 (F_3)	77.97	78.45	79.38

SEm = 1.15; CD = non-significant

The maximum value of field efficiency was found to be 87.29% when crank speed was 400 rpm (C_3) and forward speed was 0.9-1.2 km/h (F_1) and the least value was found to be as 77.97% when crank speed was 200 rpm (C_1) and forward speed was 1.7-2.0 km/h (F_3). It shows that field efficiency increased with crank speed C_1 followed by C_2 and C_3 respectively. It also shows that field efficiency was highest for forward speed F_1 followed by F_2 and F_3 respectively, because by increasing forward speed non-productive time for 20 m length of strip is more.

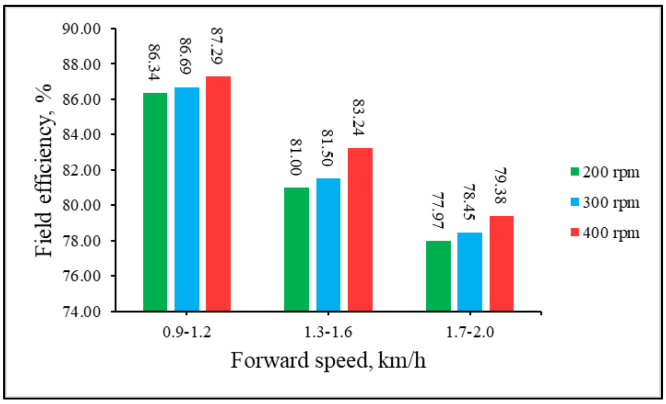

Fig 3: Effect of interaction of crank speed and forward speed on field efficiency

Effect of Crank Speed and Forward Speed on Cutting Efficiency.

The cutting efficiency of the harvester was calculated by calculating numbers of plants before and un-cut plants after harvesting from the area of which had the fixed length of 20 m and fixed width of 0.6 m Statistical analysis shows that crank speed and forward speed were found highly significant on cutting efficiency at 1 per cent significant level. The interaction between crank speed and forward speed was also found highly significant on cutting efficiency.

Table 7: Effect of different crank speed on cutting efficiency

Crank speed, rpm	200 (C_1)	300 (C_2)	400 (C_3)
Cutting efficiency, %	88.83	91.80	95.00

SEm = 0.21; CD = 0.61

It was found that crank speed 400 rpm (C_3) gave maximum cutting efficiency (95.00%) whereas crank speed 200 rpm (C_1) resulted in minimum cutting efficiency (88.83%). This was because at 400 rpm crank speed cutter bar cut more plants compare to 200 rpm crank speed.

Table 8: Effect of different forward speed on cutting efficiency

Forward speed, km/h	0.9-1.2 (F_1)	1.3-1.6 (F_2)	1.7-2.0 (F_3)
Cutting efficiency, %	94.07	92.08	89.47

SEm = 0.21; CD = 0.61

It was found that forward speed of 0.9-1.2 km/h (F_1) was working with maximum cutting efficiency of 94.07% whereas forward speed of 1.7-2.0 km/h (F_3) was working with minimum cutting efficiency of 89.47%. This was because increased in forward speed reduced opportunity time to cut the plants due to that number of un-cut plants were increased.

Table 4: Combined effect of different crank speed and forward speed on cutting efficiency

	Cutting efficiency, (%)		
Forward speed (F), km/h	Crank speed (C), rpm		
	200 (C_1)	300 (C_2)	400 (C_3)
0.9-1.2 (F_1)	91.22	94.73	96.28
1.3-1.6 (F_2)	89.22	91.17	95.85
1.7-2.0 (F_3)	86.04	89.49	92.86

SEm = 0.36; CD = 1.06

The maximum value of cutting efficiency was found to be 96.28% when crank speed was 400 rpm (C_3) and forward speed was 0.9-1.2 km/h (F_1). However, it was found at par with 95.850% when crank speed was 400 rpm (C_3) and forward speed was 1.3-1.6 km/h (F_2). The least value was found to be as 86.04% when crank speed was 200 rpm (C_1) and forward speed was 1.7-2.0 (F_3). It shows that cutting efficiency was increased with crank speed C_1 followed by C_2 and C_3 respectively. It also shows that cutting efficiency was highest for forward speed F_1 followed by F_2 and F_3 respectively.

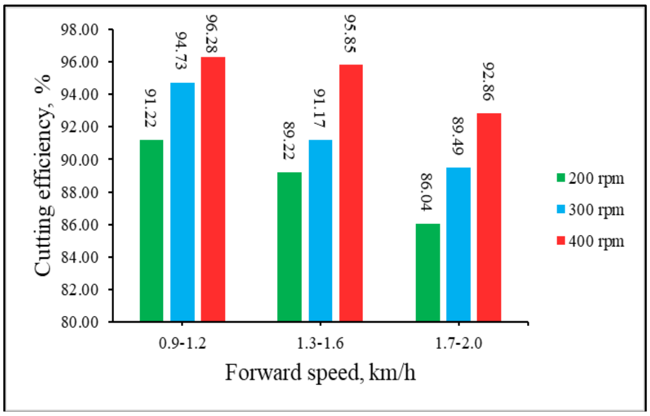

Fig 4: Effect of interaction of crank speed and forward speed on cutting efficiency

Cost Economy

Annual use of developed machine was considered as 400 hours. Total fixed cost of developed leafy harvester was ₹ 25.82/h. While total variable cost was ₹ 103.91/h. Also, total operating cost of developed harvester was ₹ 129.73/h and harvesting cost was ₹ 1907.79/ha.

Conclusions

Effective field capacity of harvester increased with increase in forward speed. The highest effective field capacity of harvester was found to be 86.42×10^{-3} ha/h for the combination of crank speed at 200 rpm and 1.7-2.0 km/h of forward speed. Field efficiency of the harvester decreased with increase in forward speed. Cutting efficiency of the harvester decreased with decrease in crank speed and increase in forward speed. The highest field efficiency and cutting efficiency were found to be 87.29% and 96.28% respectively with the combination of crank speed of 400 rpm and forward speed of 0.9-1.2 km/h. From the nine treatment during the experiment optimum combination was found to be 400 rpm of crank speed and 1.3-1.6 km/h of forward speed. Economic point of view, it was found that hourly cost of operation of ₹ 129.73/h and cost of harvesting of ₹ 1907.79/ha.

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