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Development of Manually Drawn Engine Powered Fodder Crop Harvester

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A B S T R A C T

Fodder harvesting is a tedious operation in agriculture field. In India, agriculture is facing serious challenges of scarcity of agricultural labour not only in peak seasons but almost throughout the year. It is very time consuming and stressful operation. A manually drown engine powered fodder crop harvester was developed in the department of FMPE at CAET, JAU, Junagadh. Three different forward speed (0.3-0.6, 0.6-0.9 and 0.9-1.2 km/h) were used for the test performance. The maximum cutting efficiency (96.06 %), field efficiency (81.47 %) and minimum plant damage (7.08 %) were found at speed range of 0.6 - 0.9 km/h. The total cost saving of developed fodder crop harvester was found 58.07 % as compare to manual harvesting.

Introduction

Fodder maize is one of the important fodder crops of India. India is one of the top 10 maize producers in the world; it contributes around 2-3% of the total maize produced globally from the area of 9.47 Mha and with production of 28.72 MT. From total production of maize around 13 % is used for livestock feed. Gujarat is one of the medium maize productivity states. Traditionally, the harvesting of fodder crop is done manually by sickle, which demands considerable amount of labor, drudgery, time and cost to harvest, which reflects on total production cost of the fodder.

Therefore, a manually drawn engine powered fodder crop harvester to reduce working stress and increase working capacity of a man, was developed and it's performance was evaluated in the department of farm machinery and power engineering at collage of agricultural engineering and technology, JAU, Junagadh.

Amer Eissa *et al.*, (2008), found the shear strength of maize stalks at bottom, middle and top parts of stalks were 8.94, 7.06 and 5.14 MPa respectively. Michael (1978), found that manual harvesting generally involves slicing and tearing action that resulted plant structure failed due to compression, tension or shear. The serrated sickles combine a slicing and sawing action in cutting devices restricted the sliding action of the plant on the blade edge and helped to retain the plant on the blade for adequate cutting. It has also been reported that sickle with serrated edge required the re-sharpening rarely as compared to smooth edge sickle.

Yiljep and Mohammed (2005), found the critical cutting speed for sugarcane was 13.8 to 18.4 m/s while, for sorghum, it was between 5.2 to 7.3 m/s.

Kongre *et al.,* (2016), advised that the carbide metal tip may be used for toughness of cutting mechanism on periphery of cutting disc. They used the blade of stainless-steel having diameter of 150 mm and number of teeth was 40.

Hosseinzadeh *et al.,* (2009), showed that the shearing stress of wheat stems decreased as the moisture content decreased. The shearing force of stems decreased as the cutting height of stalk increased, because of a reduction in stalk diameter.

Alandkar (2017) used high Carbon steel shearing type circular shape blades with serrated edge. Diameter of each cutting blade was 300 mm, thickness 4 mm and rpm of cutting blade was 376.

Materials and Methods

A manually drawn engine powered fodder crop harvester was developed to harvest fodder maize crop. It cuts the fodder crop at minimum height from ground level and windrows it. The machine has a vertical structure. The machine is pushed manually moves forward easily due to four wheels. It cuts single row at a time. There is a conveying unit to windrow the fodder crop after harvesting. The machine was consisted of main frame, 1.5 hp-2 stroke petrol engine, 4-wheels for easy movement, cutting unit, conveying unit and throttle lever. To transmit power to cutting unit and conveying through chain-sprocket and belt-pully mechanism were used.

The most common variety of fodder maize i.e. African tall was taken for the study. During the harvesting the average height, diameter and row to row distance of the plant were 145 cm, 2 cm and 60 cm respectively. The study was conducted at CAET, JAU, Junagadh, Gujarat. The test plot had medium black soil, levelled surface and moisture content was 21.88 % on dry basis.

Developed fodder crop harvester

Main frame: The overall dimensions of main frame are 45 cm × 35 cm × 100 cm (L × W × H). It consisted of square bar pipe of galvanized iron.

Power source: A single cylinder 2- stroke petrol engine of 1.5 hp power, was used as a power source.

Cutting blade: For harvesting the fodder crop, saw circular cutting blade of 250 mm diameter and made of high carbon steel was selected.

Supporting wheel: To move the machine over the field, two solid polyurethane plastic front wheels and two cast iron rear wheels were provided. The front wheels have 18 cm diameter and 4 cm in thickness. The diameter and thickness of each rear wheel were 24 cm and 4 cm respectively.

Handle: It was fabricated from the galvanized iron pipe having a round cross section with thickness 1 mm. The overall length of the handle was 480 mm.

Gear box: The gear box having aluminium body with gear reduction ratio of 10:1 was used. The output engine shaft which is having

3600 RPM was directly connected with gear box and maximum output RPM was 360.

Conveyor unit: The output shaft of gear box was connected with conveying unit through belt pully mechanism. Conveyer belt having 5 cm width with lugs were attached on it.

Crop guide: To gather all stems of plant, a triangle shape crop guide was used. Crop guide was fabricated form cast iron having square cross section. The length of this guide is 30 cm.

Star wheel: The star wheel was used to convey the harvested crop at one side. Stare wheel helps the conveyor belt to efficiently convey the harvested crop (Fig. 1).

Field testing

Cutting efficiency

It is the ratio of the number of harvested stalks (number of stalks before harvesting minus number of unharvested stalks) to number of stalks before harvesting in a 1 m^2 area.

Cutting efficiency= $(W_1–W_2)/W_1×100$

Where,

W_1 = Number of stalks before harvesting
W_2 = Number of Unharvested stalks

Field efficiency

The term field efficiency is used to describe the efficiency of the machine is in operation. It is the ratio of effective field capacity to the theoretical field capacity and expressed in percentage.

Field efficiency= (Effective field capacity)/(Theoretical field capacity) ×100

Plant damage

After harvesting, a number of observations were taken randomly to measure the damaged stems of the maize. A frame of 1 m × 1 m was used to count the number of plants clog/crushed/damaged. It was measured at S_1 (0.3 - 0.6 km/h), S_2 (0.6 - 0.9 km/h) and S_3 (0.9 - 1.2 km/h) speed of the machine.

Statistical analysis

Statistical analysis was carried out by Complete Randomized Design method in which the effect of various treatments on various parameters were analysed.

Economics

The cost of fabrication of fodder crop harvester was worked out on the basis of cost of used material, machining cost and the labour cost. This cost was considered as fixed cost. The variable cost was determined by the operational cost of the developed machine.

Performance evaluation

The performance of the developed machine was evaluated in terms of cutting efficiency, field capacity, field efficiency, plant damage and economics. The results data were analysed statistically and discussed under the following heads.

Cutting efficiency

Effect of different forward speed on cutting efficiency was found highly significant at 5 % and 1 % level (Table 1). The maximum cutting efficiency i.e. 96.06 % was recorded at S_2 forward speed. The minimum cutting efficiency i.e. 86.98 % was observed at S_3 forward speed, while at S_1 forward speed it was observed 88.46 %.

The cutting efficiency was plotted against forward speed of machine as shown in Fig. 2. The cutting efficiency increased as forward speed increased from S_1 to S_2. But it decreased with further increase of speed from S_2 to S_3. Increased cutting efficiency with S_2 (10.44 %) followed by S_1 (1.71 %) as compared with S_3. From figure it is clear that, the maximum cutting efficiency i.e. 96.06 % was observed in the range of the forward speed of 0.6 - 0.9 km/h as compared to other speeds. It might be due to at lower speed (S_1) the disc could not developed sufficient impact and shear force required to get a sharp cut and at higher speed (S_3) some plants remained uncut. Thus, S_2 speed is recommended.

Table.1 Effect of forward speed on cutting efficiency

Treatment	Cutting efficiency (%)
S_1 = 0.3 - 0.6 km/h	88.47
S_2 = 0.6 - 0.9 km/h	96.07
S_3 = 0.9 - 1.2 km/h	86.98
S.Em.±	1.75
C.D. at 5%	5.27
CV %	4.73

Table.2 Effect of forward speed on field efficiency

Treatment	Field efficiency (%)
S_1 = 0.3 - 0.6 km/h	79.1774
S_2 = 0.6 - 0.9 km/h	81.4749
S_3 = 0.9 - 1.2 km/h	69.8910
S.Em.±	0.703
C.D. at 5%	2.1186
CV %	2.24

Table.3 Effect of forward speed on plant damage

Treatment	Plant damage (%)
S_1 = 0.3 - 0.6 km/h	11.49
S_2 = 0.6 - 0.9 km/h	7.077
S_3 = 0.9 - 1.2 km/h	18.00
S.Em.±	0.52
C.D. at 5 %	1.56
CV %	9.5

Table.4 Cost parameters of fodder crop harvester

Sr. No.	Parameters	Values
1	Capital cost of the developed fodder crop harvester	□ 40,000
2	Cost for harvesting operation	□ 111 per h
3	Custom hiring charge	□ 138 per h
4	Payback period	4 year
5	Benefit Cost ratio	2.49

Fig.1 Developed fodder crop harvester

Fig.2 Effect of forward speed of machine on cutting efficiency (%)

Fig.3 Effect of forward speed of machine on field efficiency (%)

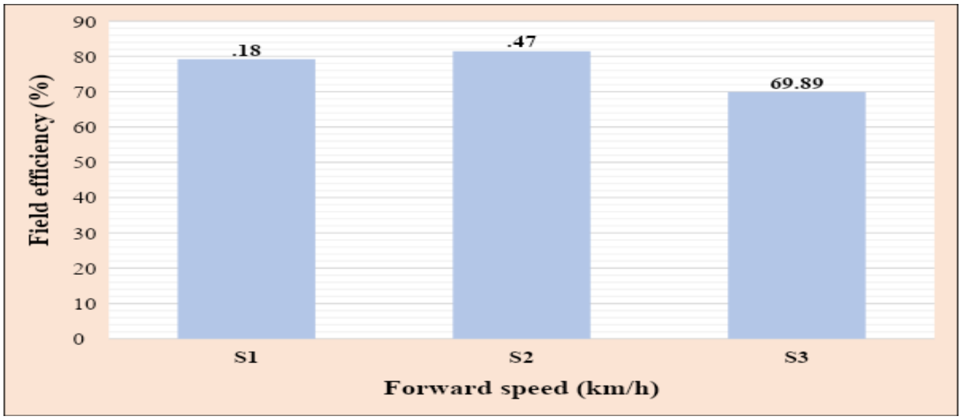
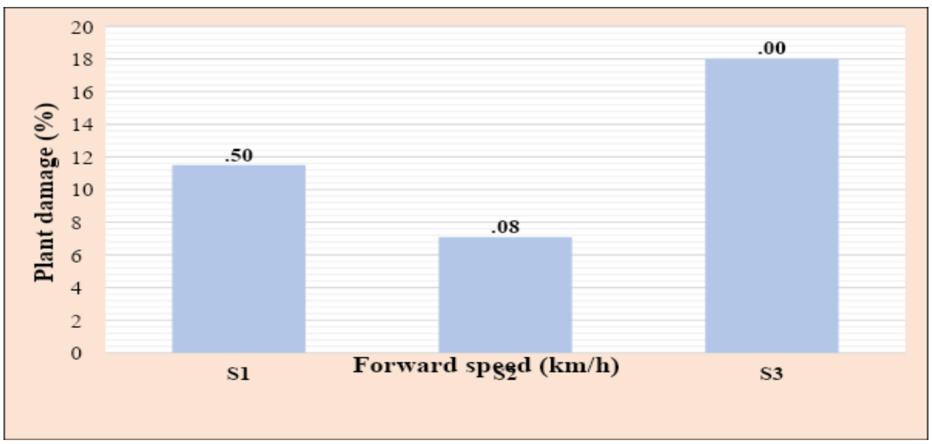


Fig.4 Effect of forward speed of machine on plant damage



Field efficiency

Effect of the forward speed on field efficiency was found highly significant at 5 % and 1 % level (Table 2). The maximum field efficiency i.e. 81.47 % was recorded with S_2 forward speed. The minimum field efficiency i.e. 69.89 % was observed with S_3 forward speed, while at S_1 forward speed it was observed 79.18 %.

The field efficiency was plotted against forward speed of machine as shown in Fig. 3. From figure it is clear that the field efficiency increased as forward speed increased from S_1 to S_2. But it decreased with the further increased of speed i.e. from S_2 to S_3. At first instance, the field efficiency increased 16.56 % as speed increased from S_1 (0.3 - 0.6 km/h) to S_2 (0.6 - 0.9 km/h). However, further increased in speed from S_2 to S_3, the field efficiency decreased 14.21 % as compared to S_2.

Plant damage

Effect of different forward speed on plant damage was found highly significant at 5 % and 1 % level (Table 3). The minimum plant damage (7.08 %) and maximum plant damage (18.00 %) were observed at forward speed S_2 and S_3 respectively, while at S_1 forward speed it was found 11.49 %.

The plant damage is plotted against forward speed of machine as shown in Fig. 4. From Figure it is clear that, the minimum plant damage i.e. 7.08 % was observed in the range of the forward speed of 0.6 - 0.9 km/h i.e. S_2 as compared to other speeds, while maximum plant damage was found at higher speed range of 0.9 - 1.2 km/h i.e. S_3. The reason of this might be due to at lowest speed not cut completely and fall down in front of the machine and get damaged. While in case of highest speed plant get down before cutting and get crushed due to machine sections. Thus, for minimum plant damage S_2 speed is recommended.

Economics

The operation cost was determined and analysed for the developed fodder crop harvester. Depreciation cost was calculated on the basis of straight-line method. Cost of the manual harvesting was found ₹ 5400 per ha, while the operating cost of the developed fodder crop harvester was found ₹ 2515 per ha. Thus, the total cost saving by the developed fodder crop harvester was found 58.07 % as compare to manual harvesting (Table 4). Considering the custom hiring cost as 25 % more than the total operation cost, it was found ₹ 138.76 per h. Average net annual benefit of machine was ₹ 9990.9. The payback period of machine was found 4 years. Benefit cost ratio of the machine was found 2.49.

In conclusion

The developed machine gave its best performance at forward speed of 0.6 - 0.9 km/h.

The cutting efficiency, field efficiency and plant damage of the developed machine were found 96 %, 81 % and 8 % respectively.

The developed harvester could harvest one hectare in 22 hours while by manually harvesting it required 138 hours.

The cost of operation for harvesting fodder maize was found ₹ 2515 per ha while by manually harvesting it costed ₹ 5400 per ha.

The developed machine could reduce 58.07 % cost of operation.

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