Development and performance analysis of low cost combined harvester for rabi crops

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Abstract:The number of farmers in India especially in Vidarbha Maharashtra is decreasing due to the continuous loss in cultivation. Harvesting technique is one of the primary reasons behind losses. Manual harvesting is dreary and tedious. To overcome this issue harvesting machines are accessible yet these are substantial and costly. Since farmers with small lands have constrained utilization and furthermore harvesting is done hardly twice or thrice in a year, so it is difficult to afford expensive machines. So, there is a need to develop a small scale and cost-efficient harvesting machine which is affordable and also evacuates the issue of manual harvesting. In the proposed research work combined harvester is manufactured and tested for wheat and rice. The examination work is on the simplicity of harvesting operation to the small landholders for harvesting wheat and rice crops in minimum time and at a minimum operating cost in view of various factors. Experimentation results are compared with traditional manual harvesting and standard tractor harvesting with regarding different parameters. Manufactured harvester found adequate with respect to time, labor and operating cost for small farm farmers.

Keywords: harvesting, performance analysis, combine, grain damage

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1 Introduction

Harvesting is the process of obtaining the grains from the plant when all the nutrients and edible parts have been matured properly and ready for further processing (Chandrajitha et al., 2015). Wheat and rice harvesting is the process of obtaining the mature wheat and rice crop from the farm which involves the different exercises like as cutting, cultivating, collecting, threshing and cleaning. These all exercises can be performed manually and in addition with the aid of harvesting machines (Mali et al., 2015). Because of the shortage the skilled labor in Vidarbha region maximum farmers preferred to use harvesters but because of high initial costs, they are unreasonably expensive. However, these costly harvesters are accessible for lease on an hourly basis but the small-scale farm owners don't require the full-featured combine harvesters (Chakaravarthi et al., 2016). There are various combine harvesters for wheat and rice such riding-tractor, pull-type and self-propelled are not inadequate technologies to a small-scale farmer due to limitations in field sizes and lack of awareness of operating and keeping up the machines (Amponsah et al., 2017). According to the statistics report by the Food and Agriculture Organization, 477,000 combine harvesters are using in India till the year 2007.

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Processing loss of combine harvesters for the wheat crop is 2.5% and forward speed of combine 2.5 to 4.5 kmh^{-1}for standing crop is acceptable as per Indian Standard. Combine harvesters tested at standard conditions qualify previously mentioned conditions when operated but these standard conditions do not stand at farmers farm. Manual harvesting needs an average time of about 80 to 160 man-hours per hectare (Kiran et al., 2017). Considering the above data, these operations are tedious if performed manually. Accordingly, the combined harvester is essential to reduce the harvesting losses and to perform the operation in minimum time. The specific objectives of the proposed research are

i. Design and manufacturing of combine harvester for wheat and rice.

ii. To carryout field performance evaluation of the developed combine harvester and compare it to manual harvesting.

2 Materials and methods

2.1 Manufacturing of combined harvester

A farmer needs to run harvester which is powered by the 7.6 hp, 5500 rpm, 2-stroke petrol engine. The petrol engine is used for transmitting power to the drive wheel, conveyer, and reel. The power was transmitted from gearbox to reel and conveyer through chain and sprocket mechanism. The gearbox has four forward gear was used for getting the desired motion to the harvester. Figure 1 shows the diagrammatic sketch of harvester machine with all the components.

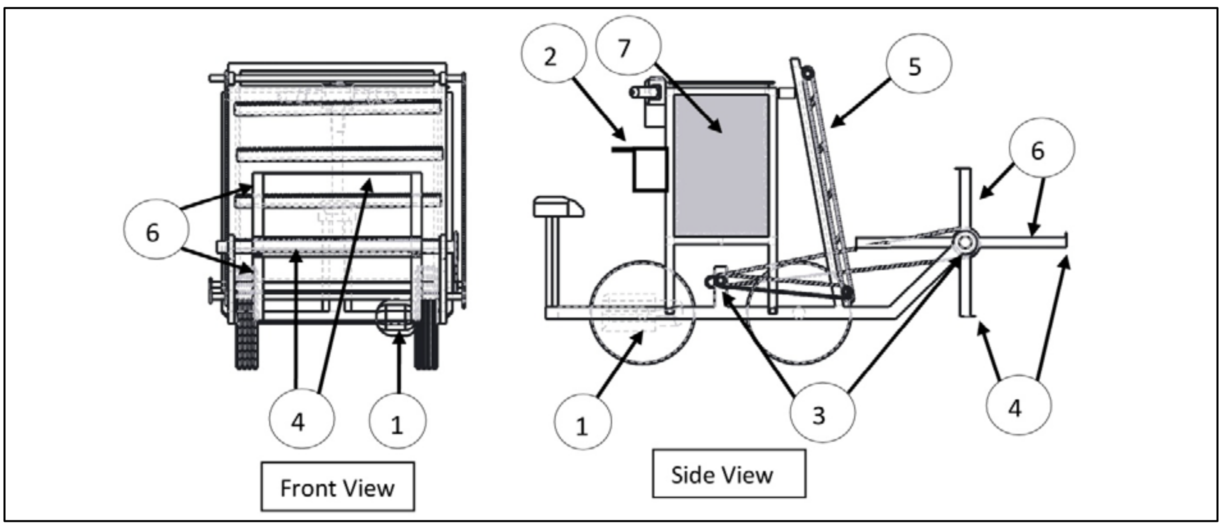

Figure 1 Diagrammatic sketch for harvester machine

Note: 1: Two-stroke petrol engine, 2: Fuel tank, 3: Chain sprocket assembly, 4: Cutter, 5: Conveyer System, 6: Reel, 7: Storage container

Figure 2 Manufactured harvester machine

Note: 1: Two-stroke petrol engine, 2: Fuel tank, 3: Chain sprocket assembly, 4: Cutter, 5: Conveyer System, 6: Reel, 7: Storage container

Figure 2 shows the actual manufactured harvester machine with all the components. For cutting of the crop, cutter follows reciprocating motion. The direction of the reel wheel is in clockwise which twists crops towards cutter which slices the crop and sends to chain conveyor through guider. Conveyor transferred the collected crop with the assistance of a conveyor belt towards the threshing unit for additional processing. Threshing unit separates the grains from chaff and straws. Separated grains are stored in the container having a capacity of around 35 kg.

The combined harvester machine having specifications (Zaied et al., 2014) as in Table 1 was manufactured in a workshop of Priyadarshini College of Engineering Nagpur. In this project, two-stroke engine is used instead of using four-stroke engine because of the main factor of the position of the engine as the farm is not plane surface, the engine can be tilt in any direction so the two-stroke engine can work in any position as lubrication is done through the means of fuel. Also, we have used a two-stroke engine considering the minimum cost factor of the project.

Table 1 Specification of the combined harvester

S.N.	Particular	Details
1	Engine power	7.6 hp @ 5500 rpm
2	Weight of machine	73.2 kg
3	Fuel tank capacity	10 liters
4	Power transmission	Chain, sprocket, and gears
5	Machine Size (length×width×height)	2.20 m × 1.00 m× 1.34 m
6	Effective width	0.82 m
7	Number of Cutter	4
8	Rake angle -	22^{o}
9	Number of teeth on Each Cutter	65
10	Reel Wheel Diameter	0.73 m
11	Number of chain sprocket assembly	2
12	Number of teeth on Cutter	65
13	Diameter of rotating Cutter	0.73 m
14	cylinder	25 cm
15	Diameter of the sprocket (small)	0.064 m
16	Diameter of the sprocket (big)	0.14 m
17	Number of teeth on the sprocket (small)	14
18	Number of teeth on the sprocket (big)	44
19	Chain Length	1.02 m

3 Experimentation of combined harvester

The experimentation was carried out in field conditions of Nagpur came under Vidarbha which is came under state Maharashtra of India. During experimentation combined harvester of the specification as Table 1 were utilized. For experimentation field of the 1acre, each was chosen for harvesting by a standard tractor, traditional manual harvesting and harvesting by manufactured machine for rice and wheat separately.

For minute observation of manufactured harvester, the 1acre land is divided into 4 equal parts and operated under variable speeds (Isaac et al., 2017). Experimentation conditions for wheat and rice are as shown in Table 2.

Table 2 Field conditions for wheat and rice

S.N.	Particular	For Wheat	For Rice
1	Total area of field	1 acre	1 acre
2	No of plots	4	4
3	Plot size	55m × 19m	55m × 19m
4	Plot area	1011 m^2 (Approx. 1/4 Acre)	1011 m^2 (Approx. 1/4 Acre)
5	Variety of grain	WSM-1472	PKV-HMT
6	Types of soil	Black	Black
7	Temperature during the season	22^{o}Cto 25^{o}CWinter	22^{o}Cto 39^{o}CWinter

3.1 Biometric parameters

In the field experiments, two basic crops i.e wheat and rice were harvested for a small land of 1 acre was chosen. For the performance evaluation and cost comparison, the same size of land was harvested manually and by harvesting machines which are accessible on a lease.

3.2 Forward speed of operation:

Forward speed of operation of the combined harvesting machine was measured after the speed has stabilized. Forward speed of operation calculated by harvested distance divided by time (Kumar et al., 2017).

3.3 Grain damage

While doing the experimentation, samples of 1 kg grain were gathered arbitrarily. Damaged grains were expelled from a subsample of 0.05 kg and the average quantity of the damaged grain was found by doing the same method 10 times.

3.4 Consumption of petrol

Consumption of petrol was computed by adding the petrol in the fuel tank completely at the beginning and after completing the harvesting in every experiment and measured the quantity of petrol added (Smith et al., 1994). A graduated plastic bottle was utilized for adding the petrol. It is observed that harvester is consuming approximately 1.03 liter of petrol for 1 acre of land for wheat and rise on full load condition.

3.5 Machine behavior

Machine behavior on the field was for betterment in performance and operation were recorded, and suggested for modification in the upcoming machine.

4 Results and discussions

Harvesting results acquired by manufactured harvester is compared on the basis of the forward speed of operation, grain damage, grain loss and time for harvesting as shown in Table 3.

Table 3 Experimentation result of the combined harvester

Plot No.	Forward speed of operation (Kmh^{-1})		Grain Damage (%)		Time (H)	
	Wheat	Rice	Wheat	Rice	Wheat	Rice
1	3.27	3.17	1.72	1.67	0.39	0.40
2	3.15	3.05	1.51	1.47	0.40	0.41
3	2.95	2.81	1.42	1.39	0.43	0.45
4	2.80	2.52	1.40	1.38	0.45	0.50

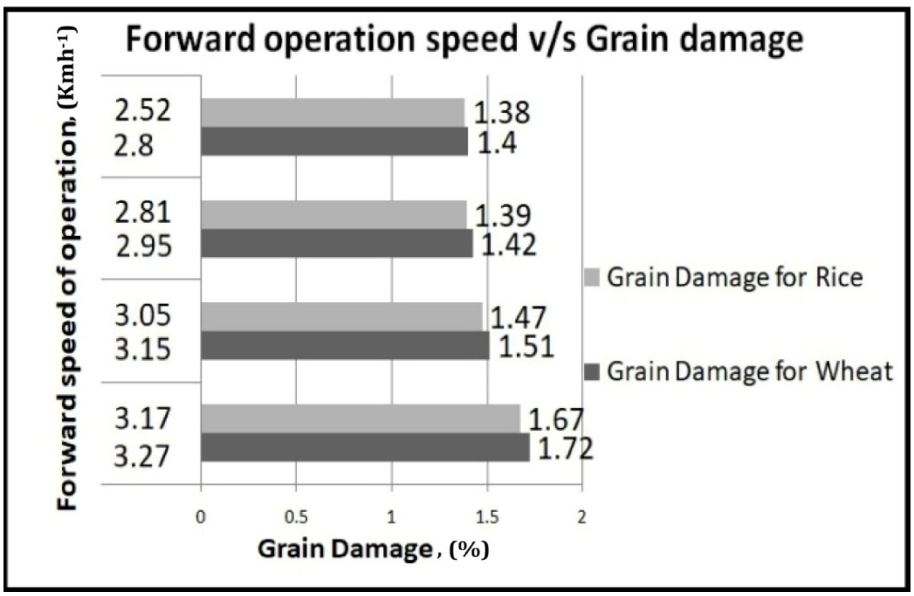

Figure 3Comparison between forward operation speed and grain damage

Figure 3 shows, the forward speed of operation of the manufactured harvester is directly proportional to the grain damage. To minimize the grain damage, the speed of the harvester should be optimum.

Harvesting results obtained by a standard tractor, traditional manual harvesting and manufactured harvesting machine were compared on the basis of the forward speed of operation, grain damage, time, labor and operating cost per acre are computed and shown in Table 4.

Table 4 Comparison of experimentation results of various harvesting method

Operation Type / Grain	Forward Speed of Operation Kmh^{-1}		Grain Damage %		Time Required for 1 Acre in H		Labor Required		Cost per Acre in Rupees	
	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice
Harvesting by Standard Tractor	3.42	3.22	1.99	1.79	1.20	1.28	2	2	700	900
Traditional manual harvesting	N/A	N/A	1.23	1.1	4.95	5.98	4	4	1200	1200
Harvesting by manufactured machine	3.04	2.89	1.51	1.47	1.67	1.76	1	1	450	600

Forward speed of operation in all the cases is directly proportional to the grain damage. The time required for harvesting by manufactured machine is very less than traditional manual harvesting and the cost of harvesting is lowest of all the cases.

5 Conclusions

The following conclusions are made based on the experimentations:

1. The forward speed of the machine is the main factor which influences the performance of the combined harvester. Grain damage was decreased with the decrease in forward speed.

2. The operational cost of the harvester machine is significantly low as compared to manual and standard tractor operated harvesting.

3. Performance of manufactured harvester was found relatively satisfactory with respect to time, labor and operating cost.

4. The combined harvester was observed to be adequate for the harvesting of the wheat and rice. This harvester is appropriate for farmers having a small farm like 4 to 6 acres as it is able to run of field effortless.

5. The manufactured harvesting machine is capable of harvesting the whole wheat and rice crop.

6. Harvester machine minimizes the risk of harm to operating personnel as in the case of manual harvesting.

7. The machine has tested for a limited field; by adopting some design changes will maximize the field performance.

8. Replacement of two-stroke engine with four-stroke engine may be done considering the efficiency and environmental factor.

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