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Performance evaluation of gender friendly manually operated harvester for weat crop

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Abstract
Harvesting constitutes one of the most time consuming and laborious operations of farming as it is done mainly with sickles, despite all its deficiencies, in the absence of suitable/improved harvesting equipment. Manual harvesting is a cumbersome job and requires about 180 to 200 man h/ha to harvest a crop. However, gender friendly manually operated harvester perform maximum field capacity was obtained with 1.65 km h^{-1} but, the losses at this speed were higher. So average speed of 1.5 km h^{-1} is recommended for operation. The average power required for pushing the machine was 106.74 to 137.69 N for wheat crop and 113.66 to 137.8 N for rice crop respectively. The effective field capacity of the machine was found to be 0.042 ha h^{-1} at forward speed of 1.5 km h^{-1} for wheat crop. The field capacity was 70.00 per cent. The result showed that the field capacity of the machine compare to hand sickle was found to be 5.64 times higher of the machine.

Keywords: Performance evaluation, gender friendly, manually operated harvester, weat crop

Introduction
Contribution of agriculture is vital in the economy of India. About 58 percent of the rural population depends on the agriculture to spend live. Female agricultural workers in India play dominant role in increasing production and productivity. Moreover, there is concentration of operational holding 25.7 percent by women in the marginal and small holding categories. In agricultural worker different works performed by rural women such as grass cutting, weeding, picking and cotton stick collection etc. Out of which the participation of harvesting in India is 84 percent. Production of wheat is estimated at 93.50 million tons during 2016-17, and productivity area of wheat in India is about 31.78 million hectare. (Annual report 2017-18) [2]. Harvesting plays a vital role in production of crop. If it is delayed, it will have certain deter mental losses. The optimum period of harvesting of a crop is at its biological maturity, when yield is maximum and losses are minimum. The conceived gender friendly multi crop cutter will be a walking type manually operated machine which will be run by pushing force of the operator. And their performance is evaluated.

Materials and Methods
Harvesting is one of the important field operations. It consumes about 45 percent of the total energy spent in crop production (Today in energy, 2017). The traditional tools for harvesting is sickle and generally women carry out harvesting operation using this tool in squatting posture. As output is low, in a typical situation. About 185-340 man hour required to cover one hectare area, (Michael and Ojha, 1987). As the time for harvesting is limited manually operated harvester has been developed.

Force Limits for Standing Work
The maximum pushing/pulling power of the hand during standing work has been studied by many researchers. Handle position in pushing and pulling task have been studied biomechanically, anthropometrically and physiologically by many research workers. Their relevant two findings compiled by (Gite, 1985) [1] A selection of their result is given in Table 1.

Table 1: Maximum pulling and pushing power in standing posture in (N)

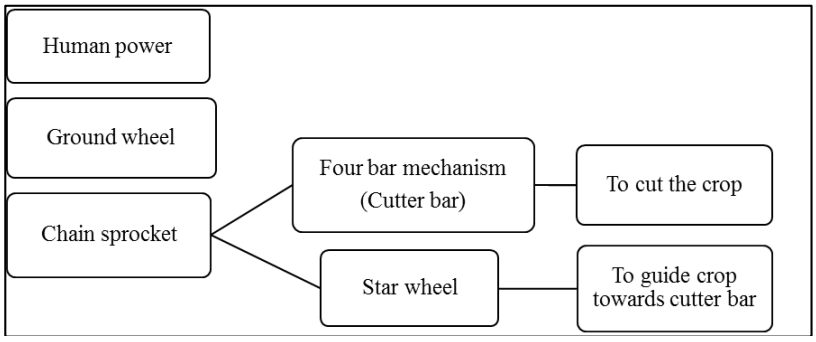
S. No.	Study conducted by	Female	
		Push (N)	Pull (N)
1.	Ciriello & Snook (1983)	186.32	137.29
2.	Chaffin *et al.* (1983) [8]	176.52	156.90
3.	Tiwari *et al.* (2009)	183.1	185.1
4.	Agrawal *et al.* (2010) [1]	119.7	88.8
5.	Premkumari *et al.* (2016)	176.23	136.42

Working principle of manually operated harvester

The gender friendly manually operated harvester was consist of various parts i.e. main frame, cutter bar unit, handle, crop lifter and divider, star wheel, ground wheel, supporting wheel, power transmission system and gear box.

Human power is used as a power source to supply power to cutter bar and conveyor of the harvester. The harvesting machine design with the chain sprocket power transmission system. In this machine human power direct transmitted to the ground wheel with the help of chain sprocket system. After that chain sprocket system operate four bar mechanism (cutter bar) and star wheel in same time. Cutter bar cut the crop and star wheel to guide the crop towards cutter bar. Gear box consists of spur gears received the human power through ground wheel and chain sprocket. Chain sprockets were used for transfer power from one system to another system of harvester.

Plate: Manually operated harvester



Performance Evaluation of the Developed Harvester for Wheat Crop

The overall performance of the harvester was evaluated on the basis of harvesting losses, stubble height, field capacity, field efficiency, physiological responses like heart rate, oxygen consumption rate and energy expenditure rate by varying forward speed, different age group and pushing force. The width of cut during the experiments was kept constant with a value of 200-250 mm as the wheat and rice crop was having row to row spacing of 200-250 mm and developed harvester was able to cut two rows at a time. The cutting angle was varied to access the feasibility of cutting the crop at below or above 100 mm height from the ground level, so that maximum straw may be obtained.

Theoretical field capacity

Theoretical field capacity was measured based on the forward speed and the cutting width of the harvester. Theoretical field capacity was calculated by following formula (Hunt, 1995)

Theoretical field capacity C_t (ha h^{-1}) = $\frac{W \times S}{10}$

Where,

S = Speed of operation, km h^{-1}
W = Theoretical width covered, m

Effective field capacity

Effective field capacity was measured based on area covered and actual time, including turning loss time. It was determined using the following formula (Hunt, 1995):

Effective field capacity C_e (ha h^{-1}) = $\frac{A}{T}$

Where,
A = Actual area covered, ha
T = Theoretical time required to cover the area, h

Field efficiency

The term field efficiency is used to describe the efficiency of the machine in operation. Field efficiency was measured from the ratio of actual field capacity to theoretical field capacity of the reaper. It was determined using the following formula (Hunt, 1995):

Field efficiency F_e (per cent) = $\frac{C_e}{C_t} \times 100$

Where,

C_e = Effective field capacity, ha h^{-1}
C_t =Theoretical field capacity, ha h^{-1}

Results and Discussion

The performance of this manually operated harvester was evaluated by considering force requirement, effective field capacity, timeliness of operation, cost of operation, field efficiency quality of work done, energy requirement during harvesting.

Machine parameters

The main variable of machine was considered as speed of operation. The fabricated machine was manually operated so, it was not performed in constant speed continuously. So a special range of speeds were selected to evaluate the different harvesting parameters that were categorized in low, medium and high speed. To determine that average speed, seven replications were taken for all three categories. The average speed under low, medium and high speed was observed to be 1.35, 1.50 and 1.65 km h^{-1} respectively and all the harvesting performance parameters were considered by taking this average speed.

Table 2: Average speed observed from analysis at low, medium and high speed of operation

Speed category	Mean	S.E.
Low speed	1.35	0.012
Medium speed	1.50	0.012
High speed	1.65	0.022
C.D.	0.053	
SE(m)	0.017	
SE(d)	0.024	
C.V.	3.019	

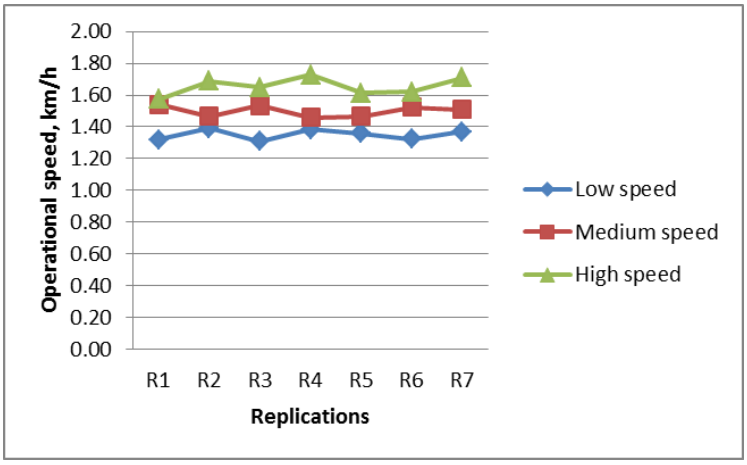


Fig 1: Variation in speed of all three categories *viz.* low, medium and high speed

Effective field capacity and field efficiency of the machine for harvesting of wheat crop

The effective field capacity and field efficiency obtained at the different forward speeds of the developed harvester for wheat harvesting. Both the effective field capacity and field efficiency of the developed reaper increased with increase in forward speed. This may be due to more coverage of the field in a particular time at higher forward speed. The minimum field capacity obtained was 0.036 ha h^{-1} at the lowest forward speed of 1.35 km h^{-1}, whereas, the maximum forward speed 1.65 km h^{-1} of the developed reaper gave the highest field capacity as 0.047 ha h^{-1}. Similarly, minimum field efficiency (66.68%) was obtained at the speed of 1.35 km h^{-1}, and maximum field efficiency (70.50%) at forward speed of 1.65 km h^{-1}.

Table 3: Effect of forward speed on effective field capacity and field efficiency of wheat crop

S. No.	Speed (km h^{-1})	Effective field capacity (ha h^{-1})	Theoretical field capacity (ha h^{-1})	Field efficiency (%)	Time required to (h ha^{-1})
1.	1.35	0.036	0.054	66.68	27.77
2.	1.50	0.042	0.060	70.00	23.80
3.	1.65	0.047	0.070	70.50	21.49

Pushing Force Measurement during Harvesting of Wheat Crop

The force was measured with the help of cone penetrometer. The average pushing force observed with different speeds and different age group for wheat the crop. The variation in the speed of machine and age group had significant effect on the pushing force. The highest pushing force for wheat harvesting was required 137.69 with the highest forward speed 1.65 km h^{-1}, which is significantly higher over others speeds. The statistical analysis of data reveals that pushing force required in the different treatment differs with each other significantly. It was found that, maximum pushing force required for the highest speed was lower than the force which can be exerted by women. Thus it can be stated that, the machine can be operated by a women satisfactorily for wheat crop.

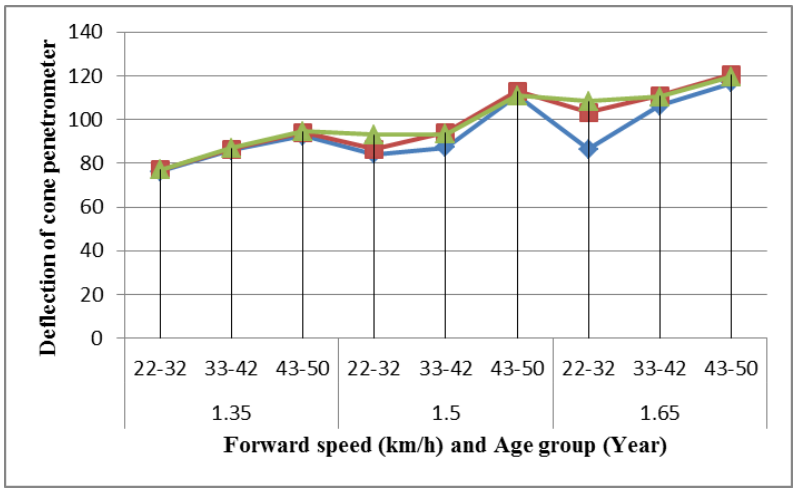


Fig 2: Deflection of pushing force for wheat crop

Table 4: Average pushing force measurement during harvesting of wheat and rice crop

Forward speed (km h^{-1})	Age group	Average pushing force during wheat harvesting (N)
1.35	22-32	106.74
	33-42	112.39
	43-50	119.52
1.50	22-32	114.40
	33-42	117.86
	43-50	124.56
1.65	22-32	118.03
	33-42	122.70
	43-50	137.69

Harvesting losses of wheat crop

Table 5: Data regarding harvesting losses of wheat crop at different forward speeds and age groups of operators

Forward speed (km h^{-1})	Age group	Header loss	Conveying loss	Total harvesting losses	
		(%)	(%)	(%)	Kg ha^{-1}
1.35	22-32	0.58	0.53	1.11	18.4
	33-42	0.60	0.99	1.58	26.2
	43-50	0.65	1.14	1.79	29.6
1.50	22-32	0.96	1.09	2.05	33.9
	33-42	0.64	0.94	2.00	33.0
	43-50	1.04	0.98	2.00	33.2
1.65	22-32	1.07	1.23	2.29	37.9
	33-42	0.85	1.24	2.09	34.5
	43-50	1.05	1.36	2.41	39.8

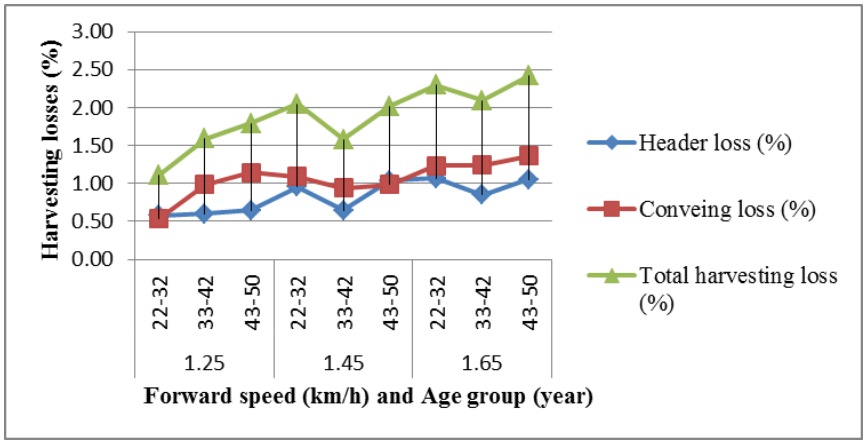


Fig 3: Effect of forward speed on harvesting losses of wheat crop

Summary and Conclusion

The developed gender friendly manually operated harvester enables to cut two rows of rice and wheat crop with suitable cutting mechanism used. This machine is capable to cut the wheat crop with field capacity of 0.042 ha h^{-1} respectively, which is quite higher than the sickle harvesting.

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