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A comparative performance evaluations of pedal operated paddy threshers on farm labour

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ABSTRACT

Pedal operated paddy (POP) threshers are widely used in the rice growing countries. Pedal operated paddy thresher is most popular among the farmers of West Bengal. The present study deals with performance evaluation of the available threshing machines. Three (Arjun, Mayur-1 and 2) commercial POP threshers were evaluated under same operational condition (field condition) for same variety of paddy. The feed rate of the threshers were 318, 192 and 260 kg h^{-1} respectively with a threshing efficiency 99.6 , 99.5 and 99.55 percent respectively while the pick rate of heartbeat of the labour were 132, 158 and 151 per min after 12, 15 and 15minutes. The performance and measurement of the parts of the paddy thresher is different for different threshing machines. Arjun model is best suited for threshing as cardiac cost of operation is low and feed rate of paddy is more.

***Keywords*:** Cardiac cost, feed rate, heartbeat, thresher, threshing

Threshing is the detaching of the kernels from the ears or pods, accomplished by a combination of impact and rubbing action. The conventional tangential threshing unit threshes mostly by impact and some other threshing devices like rotary threshing units act more by rubbing. All conventional methods and semi developed threshers are tedious, time and labour intensive (Sale *et al.,* 2017). Additional tasks of threshing units in which the crop is fed axially or tangentially into the rotor were becoming more popular. India is the second largest rice producing nation in the world after China. During the year 2015-2016, the rice was grown in 43.38 million hector area and total rice production was 104.32 million tons. The small plot size has forced the majority farmers to turn to small implements and machinery. To improve mechanization it is required to emphasize on small implements and machinery.

In the 70s, IRRI developed an axial flow thresher, which has been widely manufactured at local level. More recently, a small thresher (POP) was developed provided with either one or two persons. This machine has been widely adopted in many rice-growing areas. The simple design and work rates of these machines seem to meet the requirements of rural communities. It consists mainly of a well-balanced cylinder with a series of threshing teeth fixed on wooden slates. Torque required to operate the threshing cylinder is derived from the force applied on the pedal through the leg of operator. Pedal is attached on a long lever pivoted on the frame of the thresher. It oscillates during operation. It forms extension of follower link in a planar four bar linkage mechanism crank, which is driven link, and can make full rotation. Rotation of crank is transferred to the threshing cylinder through a pair of gears, which increases the speed of rotation by a factor varying from 1:3 to 1:5. He or she operates the pedal by one leg, keeping the other leg on the ground in a standing posture. The grains were separated by the combing as well as by hammering action of the threshing teeth (Sahay, 2010). In terms of workload classification threshing operation with POP thresher is considered as moderately heavy to heavy work involving more than the average physiological load to operator. Effect of different cylinder drive linkage mechanisms on the pedal force requirement and human physiological workload were reported in this study. After operating the thresher for a long time different body parts feel pain or discomfort.

Olugboji (2004) developed a rice threshing machine and from the design calculation, the total power required to comb off grains from stalk is 267.04 W and to be driven by a 1.5HP electric motor. The mean heartbeat of farm women and energy expenditure rate (EER) are comparatively less during operation of POP threshers than manual beating of paddy (Kwatra *et al.,* 2010; Sharma *et al.,* 2015), whereas the total cardiac cost of work (TCCW) and physiological cost of work (PCW) reduced by 60.28 percentage with the use of paddy threshers (Kwatra *et al.,* 2010). The percentage of broken grains, cracked grain and threshing efficiency depend on drum speed and moisture content (MC) of grain (Alizadeh and Khodabakshipour, 2010; Kumar *et al.,* 2015; Yamba *et al.,* 2017). The rate of heartbeat and energy expenditure rate are directly related with force-displacement and physiological workload on the operators (Agarwal *et al.,* 2013).

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MATERIALS AND METHODS

The performance evaluation of POP threshers was conducted with farm labour of Nadia, West Bengal. The threshing of paddy was done in winter season. The POP threshers were operated by two persons. At the end of every experiment, it subjected a 20 min rest for bringing all the parameters in their resting level. The specifications of the threshers are given in the table 1 as the capability and efficiency depends on the physical characteristics. Bureau of Indian Standards declared a specific physical measurement based on the acceptability of Indian farm labour. In total, operations were done 13 times for evaluating performance for each thresher. After every threshing operation the physiological parameters were noted. Completing all parameters, subjected a 20 minutes rest to reduce deviation of physiological parameters.

Selection of subjects

The age of selected two labours was 35, because labour of 20-45 years old attain their highest strength (McArdle *et al.*, 2001). Both the subjects were right handed, physically fit and were not suffering from any physical problem that may create problem to perform the activity.

Calibration of the subjects

Physiological load of human body during thresher operation depends on rate of heartbeat, oxygen consumption rate blood pressure and concentration of lactic acid in blood. Heart rate and oxygen consumption rate were also used as indicators of physiological energy expenditure rate. For determining the resting heartbeat, the selected persons were allowed to take minutes rest before starting the activity.

Moisture content

The initial MC (wb) of the sample was determined by using air oven method (AOAC, 2005). For this 4-5 g sample was taken and kept in a hot air oven maintained at 105±10 ºC for 24 h, where MC (wb) was determined gravimetrically by taking mean of four replications and MC were calculated by using formula :

$$MC\% = \frac{Wi - Wd}{Wi} \times 100$$

Where,

Wi = initial weight of sample (kg)

Wd = dried weight of sample (kg)

Feed rate capacity

The feed rate capacity of the machine in terms of the total quantity of crop that feed per unit time was determined by using formula :

$$\text{Feed rate capacity (kg hr}^{-1}) = \frac{Fs}{T}$$

Where,

Fs = Quantity of feed crop (kg)

T = Time taken for a complete operation (h)

Grain output capacity

The grain output capacity of the machine in terms of the total quantity of cleaned sample per unit time was determined as :

$$\text{Output capacity (kg hr}^{-1}) = \frac{Qs}{T}$$

Where,

Qs = Quantity of grain collected after cleaning operation (kg)

T = Time taken for a complete cleaning operation (h)

Un-threshed grain

All the un-threshed grains were sorted out from the straw. The un-threshed grains were threshed manually and the grain recovered was weighed. Percentage of the un-threshed as total grain loss was calculated by the following formula :

$$\text{Un-threshed grain} = \frac{w}{W} \times 100$$

Where,

w = weight of grain separated from un-threshed ear heads in kg

W = total grain (threshed and un-threshed) input in kg

Threshing efficiency

A sample threshed material was collected and then cleaned. The clean grain was weighed on an electronic balance. The un-threshed grains were threshed again by hand beating, cleaned and weighed. They were used to find the threshing efficiency. The percentage of threshing efficiency was calculated using the following formula:

$$\text{Threshing efficiency (\%)} = 100 - \frac{w}{W} \times 100$$

Where,

w = quantity of un-threshed grain in the sample

W = total grain in the sample

Physiological cost of work

Saha (1976) described the cardiac cost of recovery as the total number of heartbeats above the resting level occurring between the end of work and return to the resting state. Rate of heartbeat was measured with polar heart rate (HR) monitor and recorded as beats/min. Following formula was used to calculate the total cardiac cost of work (TCCW) and physiological cost of work (Badiger *et al.*, 2006; Singh *et al.*, 2007; Kwatra *et al.*, 2010).

Table 1: Comparative observation of threshers

Details	Arjun	Mayur 1	Mayur 2
Length	900	860	860
Width	700	720	720
Height	750	770	765
Distance between ground to centre of cylinder	570	560	560
Distance between ground to pedal board	80	100	100
Base size	MS angle 30×30×3	MS angle 30×30×3	MS angle 30×30×3
Side frame	30×30×3	30×30×3	30×30×3
Front grain shield	MS 0.6	MS 0.6	MS 0.6
Rear grain shield	MS 0.6	MS 0.6	MS 0.6
Axel diameter	18	17	17
Average rpm	380	350	370
Diameter of the drum	305	300	290
Length of drum	630	600	600
Wire loop height	42	50	50
Base gap of wire loop	35	28	27
Rear grain shield to tip of teeth	60	65	65
Tip distance	42	37	35
Size of slot	70×17	70×14	70×14
Slats gape	18	10	12
Cylinder end disc	1.5	0.6	0.6
Diameter of cylinder end disc	400	340	337
Shaft diameter	17	17	17
Gear ratio (driver: driven)	80:20	80:20	80:20
Crank	9	9	9
Pedal board cross section	70×20	68×18	68×18
Pedal board length	690	688	690
Distance of pedal frame fulcrum	390	385	395
Inside diameter	18	18	18
Thickness	8.5	8.5	8.5
Outer diameter	35	35	35

Note: All length in millimetre

Table 2: Condition of crop

Test conditions	Arjun	Mayur-1	Mayur-2
Name of crop	Paddy	Paddy	Paddy
Variety of crop	Satabdi-4786	Satabdi-4786	Satabdi-4786
Susceptibility to shattering	Not applicable	Not applicable	Not applicable
Length of harvested crop (cm)	77.2	77.2	77.2
Grain crop ratio	42.5	40.8	41.2
Moister content (wb) percentage	10.2±0.09	11.4±0.16	11.5±0.18
Grain Straw ratio	7.4±0.12	15.0±0.11	13.9±0.12

Table 3: Threshing performance of the thresher

Test conditions	Arjun	Mayur-1	Mayur-2
Time lost due to adjustment	0	0	0
Power	Two persons	Two persons	Two persons
Feed rate of crop (kg ha^{-1})	318±5.29	192.8±5.68	260±4.58
Output capacity (kg ha^{-1})	136±4.58	78.86±3.81	106.6±3.65
Damaged grain	0	0	0
Un-threshed grain (%)	0.4±0.05	0.5±0.1	0.45±0.04
Total grain loss (%)	0.4±0.05	0.5±0.1	0.45±0.04
Threshing efficiency (%)	99.6±0.05	99.5±0.1	99.55±0.04
Operation result	Easy	Very tough	tough
Breakdown, repair, replacement	Nil	Nil	Nil

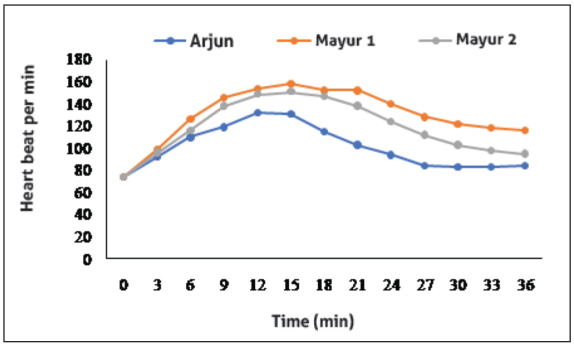

Fig. 1: Workability of the threshers and suitability for the labour

TCCW = Cardiac cost of work (CCW) + Cardiac cost of recovery (CCR)

Where, CCW = Average HR × Duration of activity

Where, Average HR = Avg. working HR- Average resting HR

CCR = (Avg. recovery HR- Average resting HR) × Duration

$$\text{Physiological cost of work} = \frac{\text{TCCW}}{\text{Duration of work}}$$

Energy expenditure (EE) was calculated using the formula:

$$\text{EE (Kj min}^{-1}) = 0.159 \times \text{HR (beats min}^{-1}) - 8.72$$

RESULTS AND DISCUSSION

Details of crop

Description of the selected crop that was used for threshing performance is in the table 2. The length of bunch (length of harvested paddy) was 77.2 cm and same for all experimental operation as the crop was from same variety and same region. The grain crop ratio was varied (nearly same) because the percentage of moisture content of grain (10.2±0.09 to 11.47±0.18%) and straw (7.4±0.12 to 15±0.11%) was different for different experiments.

Threshing performance

The threshing report of all three threshers was recorded. Table 3 describes the comparative threshing performances of threshers. Output capacity varied from 136±4.58, 78.86±3.81, 106.6±3.65 kg h^{-1} where the feed rate 318±5.29, 192.8±5.68, 260±4.58 kg h^{-1} for Arjun, Mayur-1 and 2 respectively. Total un-threshed grain (grain loss) was 0.5 percent and less whereas Mayur-1 was very difficult to operate and Arjun was very easy to operate. Though threshing efficiency, damaged grain and grain loss are nearly same for all threshers but the output capacity for Arjun is very high compared to other two threshers. For Arjun output capacity is 136 kg h^{-1} when Mayur-1 is only 78.86 kg h^{-1}. This is for the suitability of Arjun threshers as the there are some constructional difference between the POP threshers. The feed rate as well as the output capacity depends on the speed of the drum of the thresher.

Physiological cost of work

The average age of the subjects is 35 years with an average body weight and height of 68 kg and 165 cm respectively. The peak rate of heartbeat was 158 beats min^{-1} for Mayur-1 and 132 beats min^{-1} for Arjun. Table 4 describes all the physiological parameters cost of threshing. Total cardiac cost of work for Mayur-1 (1337.38) was more than two times compared to Arjun (572.25) and PCW was also nearly two times. High

Table 4: Physiological parameters between threshers

Parameters	Arjun	Mayur-1	Mayur-2
HR rest	74.50	75.00	74.00
HR average	102.50	134.25	122.25
HR maximum	132.00	158.00	151.00
EE average	7.58	12.62	10.71
EE peak	12.27	16.40	15.29
TCCW	572.25	1337.38	1099.38
PCW	35.49	68.58	56.38

physiological cost of work reduces the working capability of farm labour and they failed to operate the POP for long time.

Performance evaluation of threshers of threshing activity is related with physiological responses and physiological cost of work. POP thresher reduces the physiological cost of threshing. When the comparative study was undertaken between all three threshers, Arjun is very good for threshing as its physiological cost is very low. The pick of heartbeat is 132 which are very less compared to others. Low heartbeat reduces the physiological cost. But a further study is required for measurement of muscular stresses.

The performance of cleaning may be developed by adding winnowing blower device at an optimized rpm of 1640. The performance of thresher and workability may be improved by adding power supply system.

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