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DEVELOPMENT AND COMPARATIVE STUDY OF CAST IRON RASP BAR AND NYLON RASP BAR THRESHING CYLINDERS FOR PADDY THRESHING

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Abstract: Two types of threshing cylinders, namely cast iron rasp bar threshing cylinder and nylon rasp bar threshing cylinder, were developed and fitted with portable paddy thresher. Each threshing cylinder was tested for its performance in terms of threshing efficiency and grain damage at different levels of factors: concave clearance (15, 20, 25 mm), cylinder peripheral speed (11.7, 14.1, 16.5 $m \cdot s^{-1}$), grain moisture (13.5%, 16.5%, 19.5%) and feed rate (200, 400, 600 $kg \cdot h^{-1}$). Comparing the maximum threshing efficiency, minimum grain damage in different combinations was achieved at 20 mm concave clearance, 16.5 $m \cdot s^{-1}$ cylinder speed, 13.5% moisture content and at a feed rate of 600 $kg \cdot h^{-1}$. The grain damage occurred at this combination was 2.76% and 1.73% respectively, for cast iron rasp bar and nylon rasp bar threshing cylinders. The threshing efficiency occurred at this combination was 99.95% and 99.93% respectively, for cast iron rasp bar and nylon rasp bar threshing cylinders.

Key words*: paddy threshing, nylon rasp bar, cast iron rasp bar, grain damage, threshing efficiency.*

INTRODUCTION

Threshing is the detachment of paddy grain from the rice plant by striking, rubbing, squeezing or a combination. Impact is the most important phenomenon responsible for

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loosening of grain from the ear head, in all the threshers. Various designs of threshing mechanisms have been developed to thresh cereals crops and to obtain maximum threshing efficiency with reasonably less grain damage. [1] Reported that mechanical threshing caused more damage than any other methods of indigenous origin. The maximum difference in percent of damage was observed between mechanical threshing and hand threshing, 16.50% for rice. Further, they reported that higher the impact, the greater was the mechanical injury and higher the moisture content of the seed, greater was the mechanical injury. The threshing mechanism of mechanical threshers utilizes either rasp bars or wire loops as a functional component of the threshing mechanism. Concave clearance and cylinder peripheral speed are the operational parameters associated with threshing mechanism. In order to investigate the compatibility of wire loop and rasp bar cylinders, a comparative study was conducted for threshing rice crop. Authors in [2] and [3] stated that rasp bar mechanism will give best result. According to [4] rasp bar type thresher was the best among different methods of threshing. Authors in [5] used rubber lined rasp-bar for threshing wheat and later on this practice was discontinued as synthetic material was found withstand without high rate of wear. Eremin (1977) [6] studied the damage sustained by seeds from machines and working parts, such as threshing drums of various materials. He recommended reduction of mechanical damage by use of plastic coating on the contact surfaces. In commercial rasp bar cylinder, the bar was made from cast iron so the grains get more damage while threshing between the concave and rasp bar. In this concern we introduce nylon rasp bar instead of cast iron rasp bar to get more effective threshing with damage free threshing. The nylon rasp bar's abrasive surface was smoothen, less weight and equal strength when compare with cast iron bar.

MATERIAL AND METHODS

Cylinder- concave mechanisms

Study included functional effectiveness in relation to paddy threshing, with two types of experimental threshing cylinders. Namely, nylon rasp bar and cast iron rasp bar threshing cylinders were fabricated and are depicted in Fig. 1. To calculate the threshing efficiency and percentage of grain damage involved in threshing of each type of threshing cylinder fitted with cross flow portable paddy thresher. From the study suitable rasp bar cylinder (cast iron or nylon) was identified.

Development of a Threshing Cylinder

The threshing cylinder of 300 mm diameter and 300 mm length having four rasp bars on the periphery supported by a shaft fixed to the main frame of the thresher with the help of bearings. One end of the shaft is fitted with a stepped V-pulley to take power from the engine with the help of V-belts, to throw the threshed materials at the outlet.

Cast iron rasp bar threshing cylinder

Four commercially available rasp bars of 300 × 40 × 25 mm were fitted on the threshing drum 255 mm diameter, maintaining outer diameter as 300 mm with necessary wooden piece for proper sitting between the rasp bar and cylinder. Weight of each rasp bar is 2 kg (Fig. 2).

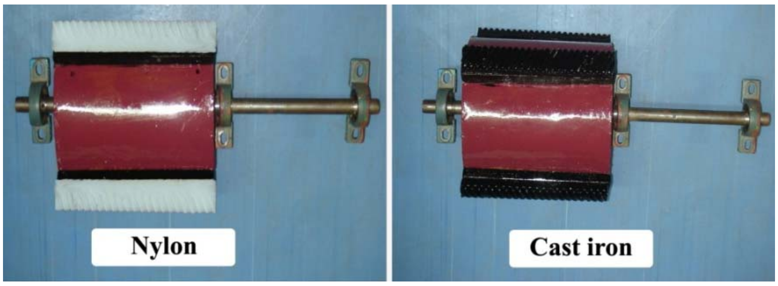

Figure 1. Comparison of threshing cylinders

Figure 2. Comparison of nylon and cast iron rasp bars

Nylon rasp bar threshing cylinder

Four commercially available rasp bars of 300 × 40 × 25 mm were fitted on the threshing drum 255 mm diameter, maintaining outer diameter as 300 mm with necessary wooden piece for proper sitting between the rasp bar and cylinder. Weight of the each rasp bar is 0.250 kg (Fig. 2). The rasp bar cylinder was developed and fitted with the portable paddy thresher (Overall size of 1500 × 900 × 1140 mm) and trial was taken up.

Experimental procedure

The thresher fitted with cast iron rasp bar cylinder surface was set to run at a fixed speed and concave clearance [7, 8]. The portable paddy thresher was run by electric motor for conducting trials (Fig. 3). A quantity of 3.4 kg of paddy panicles at a moisture content of 19.50% (d.b) was fed uniformly in to the thresher during a period of 60 seconds so as to get a feed rate of 200 $kg \cdot h^{-1}$. The grains collected at different outlet were weighed and the readings were recorded. All the readings from 3 replications were recorded. The experiment was repeated for the feed rate of 400 $kg \cdot h^{-1}$ and 600 $kg \cdot h^{-1}$. The cylinder speed varied from 11.7 to 16.5 $m \cdot s^{-1}$ with variable speed motor. Similarly, the concave clearance was changed to other levels and the observations were recorded for the three feed rates. Similarly for the other moisture levels of 16.50 and 13.50%, the above procedure was repeated and the observations were recorded and tabulated. This procedure was followed by nylon rasp bar threshing cylinder. An experiment with Factorial Completely Randomized Design was laid out. The factors considered and their levels are in Tab. 1. IRRISTAT was used to analyze the data. The treatment which gave good threshing efficiency with least grain damage was selected as the best.

Figure 3. Experimental study

Table 1. Design layout of FCRD experiment

Crop	Cylinder surface	Factors				Affected response variables
		Feed rate [kg·h^{-1}]	Cylinder speed [m·s^{-1}]	Concave clearance [mm]	Moisture content [%]	
Paddy	1. Cast iron rasp bar 2. Nylon rasp bar	200	11.7	15	13.5	Threshing efficiency and grain damage
		400	14.1	20	16.5	
		600	16.5	25	19.5	

No. of treatments: 3 × 3 × 3 × 3 = 81

RESULTS AND DISCUSSION

Effect of cylinder speed on threshing efficiency

From Tab. 2, it is seen that the increase in cylinder speed at each concave clearance had significant effect (Significant at 1 % level) on threshing efficiency, increasing the threshing efficiency from 98.489% to 98.726%. A maximum threshing efficiency of 98.889% could be achieved at a cylinder speed of 16.5 m s-1 with 20 mm concave clearance. Whereas it was 98.263% at a cylinder speed of 11.7 m s-1 with 25 mm concave clearance.

Table 2. Interaction effect of S × C factor means of threshing efficiency [%]

Concave clearance [mm]	Cylinder speed [m·s^{-1}]			
	11.7	14.1	16.5	C-Mean
15	98.644	98.762	98.850	98.752
20	98.561	98.654	98.889	98.701
25	98.263	98.363	98.439	98.355
S-Mean	98.489	98.593	98.726	98.603

Effect of moisture content on threshing efficiency

From Tab. 3, it is obvious that that the increase in moisture content from 13.5% to 19.5% and results in decrease in the threshing efficiency from 99.596% to 97.605%. The data are conformity with [9]. A maximum threshing efficiency of 99.677% could be achieved at a moisture content of 13.5% with 200 kg·h^{-1} feed rate. Whereas it was 97.532% at moisture content of 19.5% with 600 kg·h^{-1} feed rate.

Combined effect of cylinder speed, concave clearance and feed rate on threshing efficiency

Tab. 4 shows the combined effect of cylinder speed, concave clearance and feed rate. Increase in cylinder speed and increase in feed rate at each concave clearance had significant effect (at 1% level) on threshing efficiency varying the mean threshing efficiency from 98.258% to 98.851%. The maximum threshing efficiency of 98.961% could be achieved at a cylinder speed of 16.5 m·s^{-1} with a feed rate 600 kg·h^{-1} and concave clearance 20 mm. The minimum threshing efficiency was 98.161% at a cylinder speed of 11.7 m·s^{-1} with feed rate of 600 kg·h^{-1} and concave clearance of 25 mm. The data are in conformity with the results of Singh *et al.* (2003) [10].

Table 3. Effect of moisture content on threshing efficiency [%] at different feed rate

Grain moisture [%]	*Feed rate [kg·h^{-1}]*			
	200	*400*	*600*	*M-Mean*
13.5	*99.677*	*99.591*	*99.521*	*99.596*
16.5	*98.695*	*98.597*	*98.525*	*98.605*
19.5	*97.679*	*97.605*	*97.532*	*97.605*
F-Mean	*98.684*	*98.597*	*98.526*	*98.602*

Performance evaluation of nylon rasp bar threshing cylinder for threshing efficiency

The effect of cylinder speed, concave clearance, feed rate and grain moisture on threshing efficiency was shown in Tab. 5 Cylinder speed (*S*), concave clearance (*C*), feed rate (*F*) and grain moisture (*M*) were individually influencing on threshing efficiency at 1.00% level. The interaction effect of *S x C, S x F, S x M, C x M, S x C x F, S x C x M, C x F x M* and *S x C x F x M* were influencing on threshing efficiency at 1.00% level. The interaction effects *F x M* was not significant. There was an increase in cylinder speed commensurate with increase in threshing efficiency at each concave clearance had significant effect on threshing efficiency, Increase in moisture content at each feed rate had significant effect on threshing efficiency, decreasing the threshing efficiency.

Comparative performance of threshing cylinders for threshing efficiency

In using a cast iron rasp bar threshing cylinder, it was observed that a higher threshing efficiency of 99.954% with combination effect of 16.5 m·s^{-1} cylinder speed, 15 mm concave clearance, 200 kg·h^{-1} feed rate and 13.5% moisture content. It was followed by threshing efficiency of 99.951% obtained from the combination of 16.5 m·s^{-1} cylinder speed; 20 mm concave clearance, 600 kg·h^{-1} feed rate and 13.5% grain moisture.

Table 4. Interaction effects of S × C × F factor means on threshing efficiency [%]

Feed rate [kg·h^{-1}]	Cylinder speed [m·s^{-1}]			F-Mean
	11.7	14.1	16.5	
C = 15 mm				
200	98.740	98.857	98.957	98.851
400	98.645	98.769	98.829	98.748
600	98.546	98.659	98.763	98.656
C = 20 mm				
200	98.643	98.749	98.848	98.747
400	98.570	98.651	98.859	98.693
600	98.471	98.563	98.961	98.665
C =25 mm				
200	98.355	98.467	98.541	98.455
400	98.273	98.347	98.438	98.353
600	98.161	98.274	98.337	98.258
S-Mean	98.489	98.593	98.726	98.603

Table 5. Interaction effects of S×C×F×M factor means on threshing efficiency [%]

Concave clearance [mm]	Feed rate [kg·h^{-1}]									C-Mean
	F_1=200			F_2=400			F_3=600			
	Cylinder speed [m·s^{-1}]			Cylinder speed [m·s^{-1}]			Cylinder speed [m·s^{-1}]			
	S_1 11.7	S_2 14.1	S_3 16.5	S_1 11.7	S_2 14.1	S_3 16.5	S_1 11.7	S_2 14.1	S_3 16.5	
M_1= 13.5%										
15	99.70	99.83	99.98	99.53	99.77	99.83	99.38	99.63	99.73	99.71
20	99.58	99.73	99.83	99.47	99.63	99.87	99.34	99.57	99.93	99.66
25	99.12	99.47	99.53	99.22	99.33	99.47	99.12	99.28	99.33	99.32
M_2= 16.5%										
15	98.73	98.87	98.97	98.63	98.78	98.83	98.47	98.68	98.77	98.75
20	98.53	98.78	98.83	98.53	98.51	98.87	98.37	98.66	98.97	98.67
25	98.28	98.46	98.52	98.23	98.34	98.43	98.07	98.27	98.34	98.33
M_3= 19.5%										
15	97.63	97.74	97.83	97.54	97.67	97.74	97.48	97.53	97.63	97.64
20	97.53	97.64	97.78	97.49	97.57	97.77	97.38	97.44	97.88	97.61
25	97.23	97.35	97.43	97.17	97.28	97.38	97.13	97.18	97.28	97.27
S-Mean	98.48	98.65	98.74	98.42	98.54	98.69	98.30	98.47	98.65	-

In using a nylon rasp bar threshing cylinder, it was seen that higher threshing efficiency of 99.978% with combination effect of 16.5 m·s^{-1} cylinder speed, 15 mm concave clearance, 200 kg·h^{-1} feed rate and 13.5% moisture content, which is higher than the cast iron rasp bar threshing cylinder with same combination effect. It was followed by threshing efficiency of 99.926% that was obtained from the combination of 16.5 m·s^{-1} cylinder speed; 20 mm concave clearance, 600 kg·h^{-1} feed rate and 13.5% grain moisture, which is lower than the cast iron rasp bar threshing cylinder with same combination effect. The data are in conformity with the results in [11]. The comparative performance of the cast iron rasp bar gave higher mean threshing efficiency of 98.603% than the mean threshing efficiency of 98.551% of nylon rasp bar threshing cylinder.

Effect of cylinder speed on grain damage at different concave clearances

From Tab. 6a it is observed that the increase in cylinder speed at each concave clearance had significant effect (at 1 % level) on grain damage. The minimum grain damage was observed as 1.857 at a cylinder speed of 11.7 m·s^{-1} with 25 mm concave clearance. A maximum grain damage of 2.395% was observed at a cylinder speed of 16.5 m·s^{-1} with 15 mm concave clearance.

Table 6. Interaction effect of S × C factor means on grain damage [%]

Concave clearance [mm]	a. Cast iron rasp bar threshing cylinder				b. Nylon rasp bar threshing cylinder			
	Cylinder speed [m·s^{-1}]							
	11.7	14.1	16.5	C-Mean	11.7	14.1	16.5	C-Mean
15	2.302	2.347	2.395	2.348	1.316	1.379	1.444	1.380
20	2.174	2.230	2.285	2.230	1.269	1.317	1.386	1.324
25	1.857	2.111	2.156	2.042	1.214	1.277	1.318	1.270
S-Mean	2.111	2.230	2.279	2.206	1.266	1.324	1.383	1.325

From Tab. 6b it is observed that the increase in cylinder speed at each concave clearance had significant effect (at 1 % level) on grain damage, increasing the mean grain damage from 1.266% to 1.383%. The minimum grain damage was observed as 1.214 at a cylinder speed of 11.7 m·s^{-1} with 25 mm concave clearance. A maximum grain damage of 1.444% was observed at a cylinder speed of 16.5 m·s^{-1} with 15 mm concave clearance. The nylon rasp bar threshing cylinder was given minimum mean grain damage (1.325%) than the cast iron rasp bar threshing cylinder (2.206%).

Effect of moisture content on grain damage at different feed rate

From Tab. 7a it is inferred that the increase in feed rate at each grain moisture had significant effect (at 1 % level) on grain damage varying from 2.338% to 2.077%. The minimum grain damage observed was 1.469% at a feed rate of 600 kg·h^{-1} at 19.5% moisture content. The maximum damage was obtained as 2.975% at 200 kg·h^{-1} feed rate at 13.5% moisture for cast iron rasp bar threshing cylinder.

From Tab. 7b it is inferred that the increase in feed rate at each grain moisture had significant effect (at 1 % level) on grain damage varying from 1.465% to 1.176%. The minimum grain damage observed was 0.580% at a feed rate of 600 kg·h^{-1} at 19.5% moisture content. The maximum damage was obtained as 2.134% at 200 kg·h^{-1} feed rate at 13.5% moisture level for nylon rasp bar threshing cylinder. A nylon rasp bar threshing cylinder was given the minimum grain damage of 1.325% than the cast iron rasp bar threshing cylinder of 2.206%.

Combined effect of cylinder speed, concave clearance and moisture content on grain damage

Tab. 8 shows the combined effect of cylinder speed, concave clearance and moisture content. It is seen that the increase in cylinder speed and increase in moisture at each concave clearance had significant (at 1 % level) effect on grain damage. Tab. 8a shows that the mean grain damage varying from 1.266% to 2.953%. A minimum grain damage of 1.216% could be achieved at cylinder speed of 11.7 m·s^{-1} with 19.5% grain moisture at 25 mm concave clearance. A maximum grain damage of 2.996% could be achieved at a cylinder speed of 16.5 m·s^{-1} with 13.5% gain moisture and 15 mm concave clearance for cast iron rasp bar threshing cylinder.

Table 7. Interaction effect of F × M factor means on grain damage [%]

Grain moisture [%]	a. Cast iron rasp bar threshing cylinder				b. Nylon rasp bar threshing cylinder			
	Feed rate [kg·h^{-1}]							
	200	400	600	M-Mean	200	400	600	M-Mean
13.5	2.975	2.820	2.719	2.839	2.134	1.930	1.674	1.913
16.5	2.470	2.266	2.044	2.260	1.474	1.373	1.273	1.373
19.5	1.571	1.525	1.469	1.522	0.785	0.697	0.580	0.688
F-Mean	2.338	2.204	2.077	2.206	1.465	1.333	1.176	1.325

Table 8: Interaction effect of S×C×M factor means on threshing grain damage [%]

Grain moisture [%]	a. Cast iron rasp bar threshing cylinder				b. Nylon rasps bar threshing cylinder			
	Cylinder speed [m·s^{-1}]			M-Mean	Cylinder speed [m·s^{-1}]			M-Mean
	11.7	14.1	16.5		11.7	14.1	16.5	
C= 15 mm								
13.5	2.914	2.949	2.996	2.953	1.910	1.955	2.023	1.963
16.5	2.268	2.316	2.369	2.318	1.367	1.426	1.471	1.421
19.5	1.723	1.775	1.820	1.773	0.671	0.756	0.839	0.755
C= 20 mm								
13.5	2.846	2.902	2.951	2.900	1.850	1.914	1.956	1.907
16.5	2.203	2.263	2.326	2.264	1.329	1.369	1.432	1.377
19.5	1.473	1.526	1.578	1.526	0.626	0.667	0.770	0.688
C=25 mm								
13.5	2.215	2.8669	2.900	2.661	1.816	1.864	1.926	1.869
16.5	2.141	2.2020	2.251	2.198	1.268	1.328	1.370	1.322
19.5	1.216	1.2666	1.317	1.266	0.559	0.640	0.660	0.619
S-Mean	2.111	2.2297	2.279	2.206	1.266	1.324	1.383	1.325

Tab. 8b shows that the mean grain damage varying from 0.619% to 1.963%. A minimum grain damage of 0.559% could be achieved at cylinder speed of 11.7 m·s^{-1} with 19.5% grain moisture at 25 mm concave clearance. A maximum grain damage of 2.023% could be achieved at a cylinder speed of 16.5 m·s^{-1} with 13.5% gain moisture and 15 mm concave clearance. The minimum mean grain damage of 1.325% was observed for nylon rasp bar threshing cylinder than the cast iron rasp bar threshing cylinder of 2.206%.

Selection of best combination for minimum grain damage

The grain damage was minimum in case of the cast iron rasp bar threshing cylinder of 1.158% at grain moisture of 19.5% with 25 mm concave clearance, 11.7 m·s^{-1} cylinder speed and 600 kg·h^{-1} feed rate. The grain damage was minimum in case of the nylon rasp bar threshing cylinder of 0.475% at grain moisture of 19.5% with 25 mm concave clearance, 11.7 m·s^{-1} cylinder speed and 600 kg·h^{-1} feed rate. The minimum mean grain damage of 1.325% for nylon rasp bar threshing cylinder, which is lower than the cast iron rasp bar threshing cylinder of 2.206% for all combinations effects. The nylon rasp bar was best for all combination effects for getting minimum percentage of grain damage.

Selection of best combination of factors

The test results were statistically analyzed for achieving maximum threshing efficiency and minimum grain damage. Comparing the overall performance, the 20 mm concave clearance, 16.5 $m \cdot s^{-1}$ cylinder speed, 13.5% moisture content and at a feed rate of 600 $kg \cdot h^{-1}$ combination was selected as the best combination of factor at which, the threshing efficiency was 99.95% and 99.93% respectively for cast iron rasp bar and nylon rasp bar threshing cylinder. The corresponding values of grain damage were 2.760% and 1.730% respectively.

CONCLUSION

In this study cast iron rasp bar and nylon rasp bar threshing cylinders were developed for paddy threshing and compared. From the results, it was observed that there were no significant differences in threshing efficiency among cast iron and nylon rasp bar threshing cylinders. As far as grain damage is concerned, the nylon rasp bar threshing cylinder recorded minimum grain damage of 1.73% where as cast iron threshing cylinder recorded 2.76%. From these results it was very clear that when using nylon rasp bar threshing cylinder 62% of paddy grains were saved from the damage while threshing and it can be recommended for paddy threshing.

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RAZVOJ I KOMPARATIVNO ISPITIVANJE BUBNJEVA ZA VRŠIDBU RIŽE SA GVOZDENIM I NAJLONSKIM LETVAMA

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Sažetak: Dve vrste vršidbenih bubnjeva, sa gvozdenim i najlonskim letvama, su razvijene i ugrađene u prenosivu vršalicu za pirinač. Kod svakog bubnja su ispitivani efikasnost vršidbe i oštećenje zrna pri različitim vrednostima: zazora (15, 20 i 25 mm), periferne brzine bubnja (11.7, 14.1 i 16.5 $m \cdot s^{-1}$), vlage zrna (13.5% , 16.5% i 19.5%) i protoka mase (200, 400 i 600 $kg \cdot h^{-1}$). Poredeći maksimalnu efikasnost vršidbe, minimum oštećenja zrna u različitim kombinacijama je postignut sa zazorom od 20 mm, perifernom brzinom bubnja od 16.5 $m \cdot s^{-1}$, vlažnošću zrna od 13,5 % i protokom mase od 600 $kg \cdot h^{-1}$. Oštećenje zrna u ovoj kombinaciji je bilo 2,76% i 1,73% redom, za gvozdene i najlonske letve. Efikasnost vršidbe u ovoj kombinaciji je bila 99,95% i 99,93% redom, za gvozdene i najlonske letve.

Ključne reči: *vršidba riže, najlonska letva, gvozdena letva, oštećenje zrna, efikasnost vršidbe.*

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