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Performance Evaluation of Axial Flow and Tangential Axial Flow Threshing System for Basmati Rice (*Oryza Sativa*)

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Abstract: *Among all the food grains, Basmati rice (Oryza sativa) has tremendous export potential. The basmati rice cultivar is very sensitive to mechanical abuses. The commercially available machines for paddy harvesting and threshing are not suitable for basmati varieties because of relatively delicate nature. There is an opinion regarding the performance of the axial flow machines that the breakage of grain is less than that of cross flow machine. To know the exact status of grain breakage and other losses for basmati rice cultivar, a tangential axial flow threshing cylinder was compared with fully axial flow cylinder for threshing basmati rice. The total grain loss in fully axial threshing cylinder was less as compared to TAF threshing cylinder. Grain breakage in was also less in axial flow cylinder as compared to TAF cylinder. Threshing efficiency of TAF system was less as majority of the threshing takes place in first portion of the cylinder where threshing action is of cross flow type. Cleaning efficiency was more in TAF cylinder as compared to axial flow cylinder. This may be due to higher separation length in case of TAF cylinder.*

Keywords: *Tangential axial flow (TAF), Axial flow, Basmati Rice*

1. Introduction

Among all the food grains, Basmati rice (*Oryza sativa*) has tremendous export potential. It is evident from the report given by the ministry of commerce that the basmati rice has been listed under ten agricultural commodities for sustainable export promotion and planning a consistent policy for the export of the same. Despite high production and growth rate that has been achieved over the years, farmers are facing multidimensional problems as well as low net benefit. High yielding varieties and better crop husbandry results in better production but there is a significant loss in quantity during harvesting operations. Post - production losses of rice may be quantitative or physical which means a reduction in weight or volume of the final usable product obtained from the harvestable paddy. The extent of losses are linked with cultivar as well as method of operations adopted. The basmati rice cultivar is very sensitive to mechanical abuses. Manual harvesting of paddy is a labour intensive work and further its efficiency depends upon the various cultural practices, the plant density and variety, degree of lodging, the soil condition and the skill of the labour. Lodged paddy and saturated soils may reduce the cutting rate by 50 per cent. Labour in harvesting has become scarce due to industrialization or migration to employment-rich areas and has become a teething problem for paddy growing framers. Unfortunately the commercially available machines for paddy harvesting and threshing are not suitable for basmati varieties because of relatively delicate nature. Based on type of flow of material through the threshing cylinder there are three types of combine are available namely cross flow, fully axial flow and tangential axial flow. In axial flow machines the crop moves spirally between the threshing drum and concave for several complete turns. Crop is thus threshed for longer duration by repeated impact of threshing pegs (Sessiz, 2003). This principle permits multi-stage threshing and grain straw separation, resulting in a high output and cleaning efficiency (Harrison, 1992). There is an opinion regarding the performance of the axial flow machines that the breakage of grain is less than that of cross flow machine (Majumdar, 1985). Ahuja et al. (1986) evaluated an axial flow thresher for paddy crop. The grain loss ranged from 1.53-2.71 % at recommended speed whereas broken grain percentage varied from 2.21-2.51 %. To know the exact status of grain breakage and other losses for basmati rice cultivar, a tangential axial flow threshing cylinder was compared with fully axial flow cylinder for threshing basmati rice.

2. MATERIALS AND METHODS

Field experiments were conducted at the research farm of Department of Farm Machinery & Power Engineering, Punjab Agricultural University during *Kharif* season of 2009 to evaluate the performance of tangential axial flow threshing system and fully axial flow threshing system for assessing cylinder losses and performance efficiencies.

2.1. Brief Description of the Machines

2.1.1. Axial Flow Cylinder

The thresher cylinder was of beater type. The diameter of threshing cylinder was 672 mm and length of threshing cylinder was 1230 mm. The cylinder had 6 rows of beaters with each row having 11 beaters of bar type. The spacing between beaters was 110 mm. The casing of cylinder had 9 louvers for moving the crop axially along the threshing cylinder. The concave was made of 8.60 mm round bars and cylinder concave clearance was 30 mm. Detailed view of the threshing cylinder is shown in Figure 1 and its brief specifications are given in Table 1.

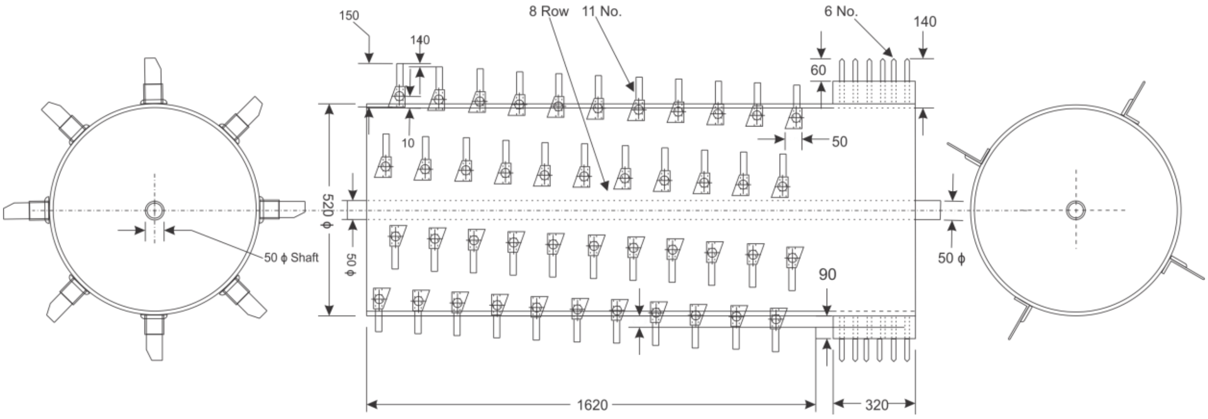

Figure 1. *Details of threshing cylinder of paddy thresher*

Table 1. *Specifications of Axial Flow Paddy Thresher*

S.No.	Parameters		Specification
1.	**Threshing Cylinder**	:	
	Diameter x Length, mm	:	672 x 1230
	Type and size of pegs, mm	:	Flat, 12 x 50
	Concave clearance, mm	:	30
	Number of louvers	:	9
	Number of rows of pegs	:	6
	Number of pegs per row	:	11
2.	**Cleaning System**		
	Number of sieve	:	Two
	Number of blower	:	One
	Number of aspirator	:	Two
	Number of thrower	:	One

2.1.2. Tangential Axial Flow Cylinder

In this type of threshing system the crop is fed tangentially into the cylinder and then crop moves spirally along the length of the cylinder as in case of axial flow machine. The crop flow diagram in TAF threshing cylinder is shown in Fig. 2. The tangential axial flow type threshing cylinder had rotor diameter of 450 mm. The first portion of the rotor had spike tooth type threshing mechanism of length 575 mm and the second separation portion of length 1255 mm consisted of serrated bars along the length of the cylinder for further separation of grains from the straw Fig. 2.

Figure 2. *Exploded photograph of developed of Pusa Basmati Rice thresher*

2.1.3. Evaluation Procedure

The fully axial flow threshing cylinder was evaluated for two basmati rice varieties Punjab Mehak & Pusa Basmati 1121 at one cylinder speed of 610 rpm for assessing cylinder losses and performance efficiencies. Further the threshing cylinder was evaluated at three cylinder speeds for variety Pusa Basmati 1121 to assess cylinder losses and performance efficiencies at different speeds for a single variety. The grain straw ratio was 0.4 and 0.18, moisture content for grain (db) was 11.02 and 14.43 % and moisture content for straw (wb) varied from 57.04 and 57.53 % for Basmati Punjabi Mehak and Pusa Basmati 1121 respectively.

Feasibility evaluation of a tangential axial flow (TAF) threshing cylinder was conducted at department research farm for basmati rice variety Mehak No. 1. The grain straw ratio was 0.4, grain moisture content (db) was 15.29 %, and straw moisture content (wb) was 57.07 %. Crop parameters are given in Table 2.

Table 2. *Crop Parameters*

Parameters	Fully axial threshing cylinder		TAF threshing cylinder
Variety	**Punjabi Mehak**	**Pusa Basmati 1121**	**Mehak No. 1**
Grain straw ratio	0.4	0.18	0.4
Moisture content Grain % (db) Straw % (wb)	 11.02 57.07	 14.43 57.53	 15.29 57.07

Keeping in view the capacity of thresher the samples were collected from all outlet of the machine for one minute to compute the various dependent parameters. Thrower loss was collected by spreading a plastic sheet on the ground where the thrower material was falling. The samples of grains collected from all outlets were analyzed for threshed, unthreshed and broken grains. The grains collected at various outlets of thresher were weighted using electronic digital balance. Threshing efficiency, cleaning efficiency and broken from main were determined by taking 100 gram sample from main gain outlet.

3. Results and Discussion

The fully axial flow threshing cylinder was evaluated for two basmati rice varieties Punjab Mehak & Pusa Basmati 1121. The threshing efficiency, cleaning efficiency and output capacity of the thresher should be high whereas the pod losses (thrower loss, broken loss and sieve over flow) and specific energy consumption should be low are the requirement for a good thresher.

3.1. Non-Collectable and Collectable Losses

Non collectable losses include losses at thrower and aspirator and collectable losses include losses at sieve and main tank.

3.2. Non-Collectable Losses at 610 Cylinder Rpm

Percent threshed grains at thrower for basmati rice varieties, Punjab Mehak and Pusa Basmati 1121 were 0.85 and 0.48 percent and percent unthreshed grains were 0.035 and 0.00 percent respectively.

Percent broken grains for Punjab Mehak and Pusa Basmati 1121 were 0.003 and 0.01 percent respectively. Similarly percent threshed grains at aspirator for basmati rice varieties Punjab Mehak and Pusa Basmati 1121 were 0.07 and 0.08 percent and percent unthreshed grains were 0.004 and 0.00 percent respectively. Percent broken grains for Punjab Mehak and Pusa Basmati 1121 were 0.003 and 0.00 percent respectively (Table 3).

3.3. Collectable Losses at 610 Cylinder Rpm

Percent threshed grains at sieve for basmati rice varieties Punjab Mehak and Pusa Basmati 1121 were 0.92 and 1.81 percent and percent unthreshed grains were 0.102 and 0.01 percent respectively. Percent broken grains at sieve for Punjab Mehak and Pusa Basmati 1121 were 0.0005 and 0.00 percent respectively. Percent unthreshed grains at main tank for Punjab Mehak and Pusa Basmati 1121 were 2.31 and 0.42 percent respectively and percent broken grains at main tank were 0.09 and 0.25 respectively (Table 3).

Table 3. *Non-collectable and collectable losses at 610 cylinder rpm, % Collectable losses at different cylinder speed*

Variety	Non-collectable losses							
	Output (kg/h)	Thrower			Aspirator			Total loss
		Threshed grain (%)	Unthreshed grain (%)	Broken grain (%)	Threshed grain (%)	Unthreshed grain (%)	Broken grain (%)	
Basmati Punjab Mehak	1697.93	0.85	0.035	0.003	0.07	0.004	0.003	0.964
Pusa Basmati 1121	1029.45	0.48	0.00	0.01	0.08	0.00	0.00	0.09

Variety	Output (kg/h)	Collectable loss					
		Sieve overflow			Main Tank		Total loss
		Threshed grain (%)	Unthreshed grain (%)	Broken grain (%)	Unthreshed grain (%)	Broken Grain (%)	
Basmati Punjab Mehak	1697.93	0.92	0.102	0.0005	2.310	0.09	3.42
Pusa Basmati 1121	1029.45	1.81	0.01	0.00	0.42	0.25	2.49

3.4. Non-Collectable Losses at Different Cylinder Speeds

Percent threshed grain at thrower for basmati rice variety Pusa Basmati 1121 first increased with cylinder peripheral speed and then decreased with further increase in cylinder peripheral speed. Similarly percent broken grain at thrower first increased with cylinder speed and then decreased with further increase in cylinder speed. However, percent threshed grain and percent broken grain at aspirator increased as cylinder peripheral speed increased from 550 to 660 rpm (Table 4).

Percent threshed grain and percent broken grain at sieve increased with cylinder peripheral speed. Similar trend was observed for percent broken grain at main tank however percent unthreshed grain at main tank decreased from 0.74 to 0.41 percent as cylinder peripheral speed increased from 550 to 660 rpm (Table 4).

Table 4. *Non-collectable and collectable losses at different cylinder speeds for basmati rice variety Pusa Basmati 1121, % Cylinder losses and performance efficiencies at 610 cylinder rpm*

Cylinder speed, rpm	Non-collectable losses							
	Output (kg/h)	Thrower			Aspirator			Total loss
		Threshed grain (%)	Unthreshed grain (%)	Broken grain (%)	Threshed grain (%)	Unthreshed grain (%)	Broken grain (%)	
550	946.39	0.19	0.00	0.00	0.03	0.00	0.00	0.22
610	1029.45	0.48	0.00	0.01	0.08	0.00	0.00	0.57

660	860.99	0.06	0.00	0.00	0.25	0.00	0.04	0.35

Cylinder speed, rpm	**Output (kg/h)**	**Collectable loss**					
		Sieve overflow			**Main Tank**		**Total loss**
		Threshed grain (%)	Unthreshed grain (%)	Broken grain (%)	Unthreshed grain (%)	Broken grain (%)	
550	946.39	0.14	0.01	0.00	0.74	0.08	0.97
610	1029.45	1.81	0.01	0.00	0.42	0.25	2.49
660	860.99	2.03	0.01	0.01	0.41	0.36	2.82

Percent broken grain for basmati rice varieties Basmati Punjab Mehak and Pusa Basmati 1121 were 0.1 and 0.3 percent respectively and percent unthreshed were 2.4 and 0.4 percent respectively. Threshing efficiency was 97.69 and 99.40 percent for Basmati Punjab Mehak and Pusa Basmati 1121 respectively. Cleaning efficiency was 91.70 and 97.70 percent for Basmati Punjab Mehak and Pusa Basmati 1121 respectively whereas broken percentage was 0.1 and 0.3 percent for Basmati Punjab Mehak and Pusa Basmati 1121 varieties respectively (Table 5).

Table 5. *Cylinder Losses and performance efficiencies at 610 cylinder rpm, %*

Variety	**Cylinder loss, %**									**Performance Efficiencies, %**		
	Output (kg/h)	**Broken**				**Un-threshed**				**Main Tank**		
		Broken from main	Broken from thrower & aspirator	Broken from sieve	**Total loss**	Un-threshed from main	Un-threshed from thrower & aspirator	Un-threshed from sieve	**Total loss**	Threshing Efficiency %	Cleaning Efficiency %	Broken Efficiency %
Basmati Punjab Mehak	1697.93	0.1	0.0	0.0	**0.1**	2.35	0.0	0.1	**2.4**	97.69	91.7	0.1
Pusa Basmati 1121	1029.45	0.3	0.0	0.0	**0.3**	0.4	0.0	0.0	**0.4**	99.4	97.7	0.3

3.5. Cylinder Losses and Performance Efficiencies at Different Cylinder Speeds

Percent broken loss increased as the cylinder peripheral speed was increased from 550 to 660 rpm whereas percent unthreshed grains decreased with increase in cylinder peripheral speed for paddy variety Pusa Basmati 1121. Threshing efficiency and broken efficiency increased with increase in cylinder speed whereas cleaning efficiency first increased with increase in speed and then decreased with further increase in cylinder speed (Table 6).

Table 6. *Cylinder Losses and performance efficiencies at different cylinder speeds for paddy variety Pusa Basmati 1121, %*

Speed	**Cylinder loss, %**									**Performance Efficiencies, %**		
	Output (kg/h)	**Broken**				**Un-threshed**				**Main Tank**		
		Broken from main	Broken from thrower & aspirator	Broken from sieve	**Total loss**	Un-threshed from main	Un-threshed from thrower &aspirator	Un-threshed from sieve	**Total loss**	Threshing Efficiency %	Cleaning Efficiency %	Broken Efficiency %
550	946.39	0.1	0.0	0.0	**0.1**	0.7	0.0	0.0	**0.7**	99.3	96.3	0.1
610	1029.45	0.3	0.0	0.0	**0.3**	0.4	0.0	0.0	**0.4**	99.4	97.7	0.3
660	860.99	0.4	0.0	0.0	**0.4**	0.4	0.0	0.0	**0.4**	99.6	96.0	0.4

The performance of the TAF threshing cylinder is given in Table 7. Threshing efficiency varied from 97.62 to 98.02 % and cleaning efficiency varied from 95.28 to 96.47%. The total grain losses for Basmati rice varied from 5.79 to 6.46 %. The average header loss for basmati Mehak No. 1 was 2.08 percent. This may be due to crop maturity. Average sieve loss for basmati rice was 2.36 %.

Table 7. *Performance results of TAF threshing cylinder on basmati rice variety Mehak No. 1*

Parameters	**Observation**
Non-Collectable losses (%) • Header loss • Separation loss • Sieve loss	 2.01-2.15 0.56-1.08 2.31-2.42
Collectable losses from tank, % (un-threshed)	0.66-1.06
Total grain loss,%	5.79-6.46
Grain breakage in tank, %	2.02-2.17
Threshing efficiency, %	97.62-98.02
Cleaning efficiency, %	95.28-96.47
Output kg/h	1198.52-1320.6

The total grain loss in fully axial threshing cylinder was less (0.4-2.4 %) as compared to TAF threshing cylinder (5.79-6.46 %). Grain breakage in was also less in axial flow cylinder as compared to TAF cylinder. Threshing efficiency of TAF system was less as majority of the threshing takes place in first 575 mm section of the cylinder where threshing action is of cross flow type. Cleaning efficiency was more in TAF cylinder as compared to axial flow cylinder. This may be due to higher separation length in case of TAF cylinder. This might also have caused in more grain breakage in TAF system as there might be less cushioning of straw on grains. The axial flow threshing cylinder can be modified to reduce broken and losses. For this purpose the diameter and length of the cylinder can be increased for better separation of grains from straw and to give more time for threshing at lower impact.

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