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Development of paddy stripper header mechanism

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■ **ABSTRACT :** Stripping is the process of removing the seeds from the plant and straw remained anchored to the soil. The main advantages of stripping is the increasing capacity of the combine harvester with reduced amount of material other than grain ratio (MOG) and power requirement for threshing and cleaning which promotes to develop small and light weight mechanism suitable for small and fragmented land. A laboratory stripper header mechanism (SHM) was developed for stripping paddy grains and collecting them in grain tank. It consisted of stripping rotor, stripping elements, hood, frame and grain tank. Two profiles of stripping elements *viz.*, slender arrow head (A) and spaced slender arrow head (B) of stripping elements were used. The performance of the developed SHM was evaluated on specially developed test rig to study the effect of two levels of forward speed (1.65 and 2.25 km/h) and four levels of peripheral speed (16.95, 19.78, 22.6 and 25.45 m/s) on shattered and un-stripped grain loss was studied. It consisted of track, platform and crop holders. SHM was stationary and platform was movable on track. Minimum shattered grain loss of 5.78 per cent was obtained with stripping element A at 2.25 km/h forward speed and at 19.78 m/s peripheral speed. Minimum un-stripped grain loss of 0.84 per cent was obtained with stripping element A at 2.25 km/h forward speed and 25.45 m/s peripheral speed. The performance of the slender arrow head stripping element was found to be better as compared to spaced slender arrow head.

■ **KEY WORDS :** Paddy, Stripping, Stripping element, Test rig, Grain loss

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Konkan is the coastal part of Maharashtra between Western Ghat and Arabian seacoast on the extreme western side of the Indian peninsula, receiving an annual rainfall of 2500-4500 mm (Anonymous, 2013). In Konkan, rice is one of the major crop cultivated over an area of 3.86 lakh hectares with an annual production of about 10.84 lakh tonnes with highest average productivity of 2810 kg/ha in Maharashtra (Anonymous, 2015). The fields in Konkan are small and fragmented land. During production of paddy crop, harvesting is one of the major operations among all other operation which plays significant role in realizing the full benefit of raised crop. Farm mechanization saves time and labour, cuts down crop production cost in the long run, reduces post harvest losses and boosts crop output and farm income (Mehta *et al.*, 2014). In this region woman is real workforce in cultivation of paddy and requires 25 man days per hectare harvesting using sickle (Anonymous, 2012).

Stripping is a very popular harvesting concept that encourages the designers for making easily available to farmers. In India, it is new concept. The principle of stripping is removing the seeds from the plant without harvesting the straw, presents a bright prospect in mechanical harvesting technology, since the amount of straw handled by the machine is considerably reduced (Tado *et al.*, 1998). This technology is becoming effective for rice and wheat harvesting (Adisa, 2013). The stripper rotor simultaneously carries out four functions as crop lifting, harvesting, partial threshing and crop transport which are functions of reel, cutter bar, threshing drum and belt conveyor, respectively of a conventional combine harvester (Adisa *et al.*, 2012). Economical part from the plant (grain) was removed during stripping which reduces the MOG intake. The reduced material other than grain (MOG) intake not only increases harvesting capacity at reduced power requirement with increasing combing hours for harvesting but also offers potential for a reduction in size and weight for a machine of given capacity (Tado *et al.*, 1998 and Peiris, 1990).

The labours are scarce now-a-days and their shortage, non-availability at proper harvesting time and high wages resulting in rice cultivation as uneconomical enterprise. *Kharif* paddy harvesting is generally done in the month of October and November. Due to changing climatic condition, rain occurred and makes the paddy fields more moist and sometimes water logged. Combine harvester and self-propelled reaper cannot be used in this condition. Small and fragmented land of Konkan is other hurdle in agricultural mechanization. The level of mechanization in this region is also quiet low. In order to make the agricultural operation easier, comfortable and considering the limitations of present harvesting machines as heavy weight, bigger size and high powered, there is a need of suitable harvesting and threshing machines or mechanisms.

Stripper harvesting technology, which strips only seeds and keeps straw erected in the field, has the bright prospects for mechanizing the harvesting operation in small and fragmented land. This technology can reduce the time required for threshing and winnowing operation with the light mechanism and lesser power compared to conventional cutter bar combine harvester. In order to develop a suitable technology for Konkan, stripper header mechanism was developed specially for paddy.

■ METHODOLOGY

Development of stripper header mechanism (SHM):

The developed SHM was consisted of stripping element, stripping rotor, hood and grain tank. The description of each component is given below.

Stripping element:

Stripping element is the main component of paddy stripping mechanism which strips paddy grain from the panicles. The combing process of panicles took place and the grains from the panicles were separated through a key hole at the base of element. The two profiles of stripping elements *viz.*, slender arrow head (A) and spaced slender arrow head (B) were selected for this study purpose. A flexible, abrasion resistance type rubber material was desired for stripping element, (Peries, 1990). Therefore, locally available industrial rubber was used for the making of the different profiles of the stripping element for the present study.

Stripper rotor:

An octagonal shaped stripper rotor with stripping element of ϕ 290 mm was made with M.S. flat of 40×5 mm. The eight stripping element on each side of octagonal rotor were fitted with nut and bolt on M.S. flat.

Hood:

The hood was made of M.S. sheet of 2 mm thickness. It was made in one piece of 780×695×670 mm to cover the whole stripping rotor and for conveying of stripped paddy material.

Grain tank:

The grain tank was made with M.S. sheet and angle. The frame of 780×695×670 mm made of M.S. angle (25×25×5 mm) for collection of the stripped paddy material.

Main frame:

All the functional components *viz.*, stripper rotor, hood and grain tank of the SHM were supported on the main frame of size 780×680×1640 mm, made of M.S. angle of 40×40×5 mm (Fig. 1). A provision was given for height adjustment of the hood with two M.S. flat of 25×5 mm welded with gap of 5 mm in arc shape. The clearance between the tip of stripping element and underside of hood was kept 90 mm.

Development of test rig:

A test rig was developed (Fig. A) for laboratory testing of developed SHM. It consisted of track, platform and crop holder. During testing field conditions were simulated in laboratory. For testing of SHM on the test rig, the SHM was kept stationary and crop is to be stripped allowed to move by providing suitable conveying mechanism. The methodology of development test rig is as given below.

Fig. A : Developed test rig

Track:

Track was developed for the movement of crop mounted on platform. For track, two M.S. angles of 25×25×3 mm were placed parallel in the inverted fashion to roll the wheels at the spacing of 0.7 m on square pipe base support. The base support of track was made of square M.S. pipe of 25×25 mm in C-shape having the dimension of 690×200 mm. The supports were welded with the inverted M.S. angle.

Platform:

Platform was developed to carry the harvested rice crop and it was made of plywood (0.68 × 4 m) and frame (0.6×3.9 m) of M.S. angle (25×25×5 mm). It was supported with vertical M.S. square pipe from both sides of platform. To make developed SHM suitable for different crop heights, the telescopic arrangement was made in vertical square pipe support of platform. The telescopic arrangement of pipe was able to raise the platform height from 300 to 550 mm. The crop holders were fitted on the movable platform for holding the harvested crop. A small wheel (ϕ 25 mm) with V-notch at centre was fitted at the bottom of vertical square pipe support of platform which moves in forward and backward direction on inverted M.S. angle of track.

Crop holder:

Crop holder was used for holding the harvested crop tillers on the movable platform. Crop holder consisted of C-channel, C-shape handle, pressure plate, spring, washer, quarter pin and nut. Crop holder assembly arrangement was facilitated to clamp harvested bunch of tiller in between the wall of C-channel and pressure plate with spring tension. For the laboratory testing, 36 crop holders were mounted on platform in two rows at interval of 250 × 150 mm.

Power transmission:

The stationary stripper header mechanism was powered using electric motor (3 phase, 3 hp), set of pulleys (4” and 8”) and V-belt (B-56). The various stripper rotor speeds 600 to 900 rpm (*i.e.* 16.95 to 25.45 m/s peripheral speeds) were obtained with the help of variable frequency drive (VFD). The platform was powered using D.C. motor (1 phase, 1 hp), horizontal roller, wire rope and pulleys at the end of track. The pictorial view of the power transmission to platform is shown in Fig. B. The motor shaft was coupled with M.S. shaft (ϕ 25 mm) 900 mm on which horizontal roller of 400 mm length (ϕ 45 mm) was welded. The wire rope was connected to platform from one end and other end was connected to the horizontal roller. The roller was rotated through drive (D.C. electric motor) so as to wind rope over it. The platform was moved forward at the selected forward speed *i.e.* 1.65 to 2.25 km/h during laboratory tests using D.C. motor with speed controller (220V and 4 AMPS).

Fig. B : Power transmission for track

Performance testing of developed paddy stripper header mechanism on test rig in laboratory:

The SHM was tested in laboratory on specially developed test rig by varying forward speed (1.65 and 2.25 km/h) and peripheral speed of stripper rotor (16.95, 19.78, 22.6 and 25.45 m/s) using two profiles of the stripping elements *viz.*, slender arrow head (A) and spaced slender arrow head (B). Shattered and un-stripped grain loss was taken as performance parameters. The grain moisture content for this study was kept constant within the range of 20-22 per cent (wb). The data was analyzed by factorial randomized block design with three replication of each experiment using SAS9.1.

Experimental procedure:

The harvested crop having moisture content ranged from 20 to 22 per cent (wb) was taken with erected panicles and weighed. The crop was fitted on crop holder with 10-15 tillers per hill with spacing of 250×150 mm in two rows up to 15 hills in each row. Initially, the stripper rotor was rotated at peripheral speed of 16.95 m/s and platform was allowed to move at forward speed of 1.65 km/h for stripping of the fixed crop material on the platform. The view of crop after stripping operation is shown in Fig. C. The stripped and un-stripped crop material was separated and weighed separately. Also the material collected in grain tank was separated as MOG and grains (*i.e.* threshed and un-threshed) and weighed separately. The same procedure was followed for 2.25 km/h forward speed and other peripheral speed of stripper rotor *viz.*, 19.78, 22.6 and 25.45 m/s and shattered and un-stripped grain loss were computed. The output parameters were computed as given below.

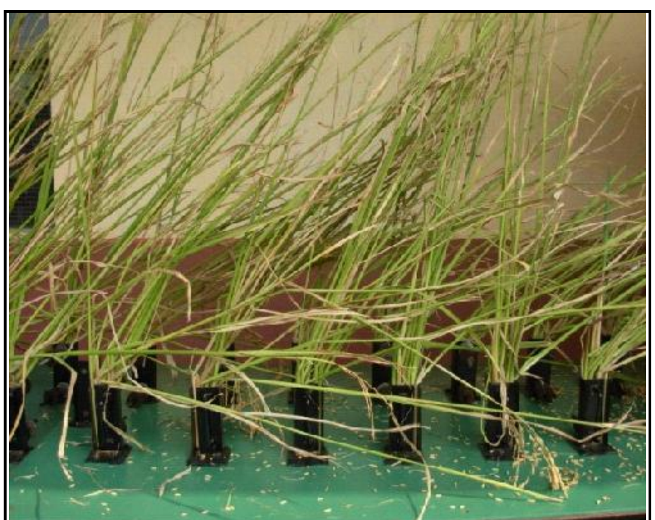

Fig. C : Crop view after stripping

Shattered grain loss:

Shattered grain loss is the loss of grain in the form free grains and ears fall on the ground.

$$\text{Shattered grain loss (\%)} = \frac{W_i - W_t}{W_i} \times 100$$

where,

W_i = Initial weight of the crop material, g

W_s = Weight of stripped straw, g

W_{us} = Weight of un-stripped straw, g

W_g = Weight of threshed and un-threshed grains collected in collection box, g

W_{mog} = Weight of material other than grain, g

$$W_t = W_s + W_{us} + W_g + W_{mog}$$

Un-stripped grain loss:

It is the loss of grain in the form grains remained un-stripped on standing crop

$$\text{Un-stripped grain loss (\%)} = \frac{W_{us}}{W_i} \times 100$$

■ RESULTS AND DISCUSSION

Analysis of variance (Table 1) revealed that stripping element, forward speed and peripheral speed had significant effect on shattered and un-stripped grain loss at 1 per cent level of significance. The combine effect of these parameters had non-significant effect on shattered and un-stripped grain loss.

Effect of stripping element on shattered and un-stripped grain loss :

The effect of different profiles of stripping element on shattered and un-stripped grain loss is presented in Table 2. The minimum shattered and un-stripped grain loss was observed to be 7.15 and 1.18 per cent obtained using stripping element - A. The uniform shape of each teeth of stripping element A allows more contact with panicle from both edges of triangular element might have conveyed more grains to grain tank and reduced escape or slippage of panicles which might be probable reason for reducing shattered and un-stripped grain loss.

Effect of forward speed on shattered and un-stripped grain loss:

The mean value of shattered and un-stripped grain loss as affected by forward speed is presented in Table 3. The minimum shattered grain loss of 7.43 per cent was obtained with forward speed of 2.25 km/h, which is significantly lower than 7.86 per cent obtained at forward speed 1.65 km/h. The similar type of results was observed by Tado (2002) and Chegini (2013). Similarly, higher un-stripped grain loss is observed 1.46 per cent at 1.65 km/h forward speed as compared to 1.24 per cent at 2.25 km/h forward speed. The similar type of trend was observed by Chegini (2013). Contact time of individual stripping element with straw was increased with increase in forward speed, which might have reduced shattering of grains and stripping more grain from panicle.

Effect of peripheral speeds of stripper rotor on shattered and un-stripped grain loss :

The mean value of shattered grain loss as affected by peripheral speed of stripper rotor is presented in Table 4. This effect was found statistically significant at 1 per cent level. Effect of peripheral speed of stripper rotor on shattered grain loss with different stripping element and forward speed is shown through Fig. 1. The shattered grain loss decreased from 8.24 per cent to 6.89 per cent when increased the peripheral speed of stripper rotor from 16.95 to 19.78 m/s. Further increase in peripheral speed of stripper rotor increasing trend of shattered grain loss was observed. The similar type of trend was observed by Tado (2002) and Chegini (2013).

The mean value of un-stripped grain loss affected by peripheral speed of stripper rotor is shown in Table 4. The minimum un-stripped grain loss was observed to be 1.05 per cent at 25.45 m/s peripheral speed of stripper rotor. The maximum un-stripped grain loss was observed to be 1.69 per cent at 16.95 m/s peripheral speed of stripper rotor. It is observed that un-stripped grain loss during stripping changes linearly with increase in peripheral speed. The similar type of trend was observed by Chegini (2013). The number of impacts of stripping element on the straw and air velocity increases with increase in peripheral speed of stripper rotor. The increased number of impacts of stripping element on straw and air velocity decreases shattered grain loss initially and more grains at higher peripheral speed might have blocked by the crop wall at exists than entrance, reducing air velocity at outlet might have increased shattered grain loss onwards. The increased number of impact of stripping element with straw, which might be possible reason for decreasing of un-stripped grain loss.

Table 1 : Analysis of variance for effect of stripping element, forward speed and peripheral speed on shattered and un-stripped grain loss

Source	DF	Shattered grain loss		Un-stripped grain loss	
		Mean square	F value	Mean square	F value
Replication	2	1.85	12.31	0.01	0.76
Stripping element (A)	1	11.87	78.67*	1.29	86.68*
Forward speed (B)	1	2.19	14.56*	0.57	38.33*
Peripheral speed (C)	3	6.21	41.19*	0.93	62.32*
A*B	1	0.005	0.04	0.05	3.57
A*C	3	0.24	1.60	0.12	8.08
B*C	3	0.04	0.27	0.01	0.90
A*B*C	3	0.01	0.07	0.01	0.70
Error	30	0.15		0.01	
Corrected total	47				

*indicates significance of value at P=0.01

Table 2 : Mean value of shattered and un-stripped grain loss with different stripping element

Stripping element	A	B	S.E. ±	C.D. (P= 0.05)
Mean shattered grain loss, %	7.15	8.14	0.07928	0.229
Mean un-stripped grain loss, %	1.18	1.24	0.0248	0.072

Table 3 : Mean value of shattered grain loss at different forward speed

Forward speed, km/h	1.65	2.25	S.E.±	C.D. (P=0.05)
Mean shattered grain loss, %	7.86	7.43	±0.0793	0.229
Mean un-stripped grain loss, %	1.46	1.24	±0.0248	0.072

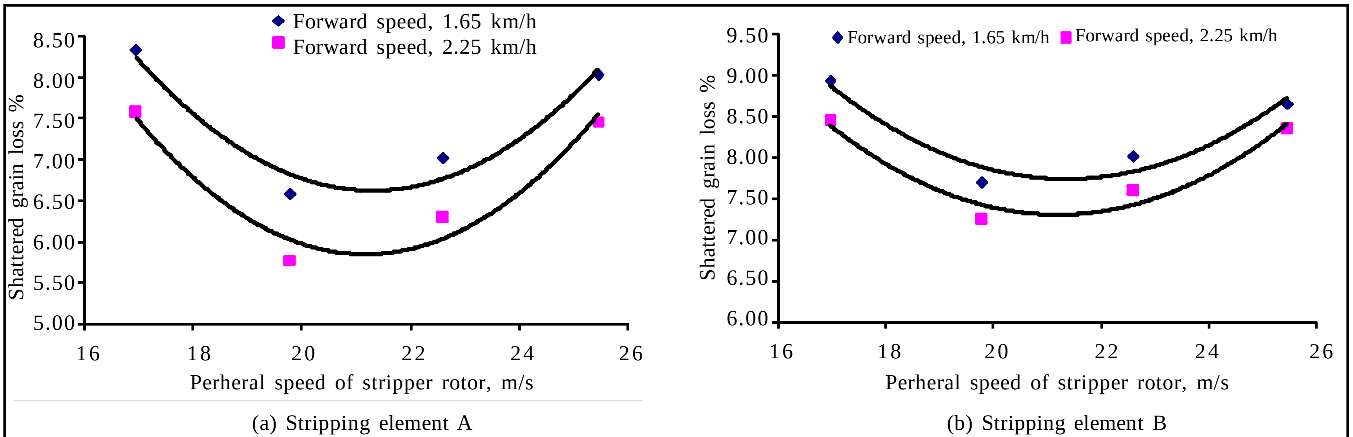

Fig. 1 : Relationship of shattered grain loss and peripheral speed at different foreward speed with different stripping elements

Table 4 : Mean value of shattered grain loss at different peripheral speed of stripper rotor

Forward speed, km/h	16.95	19.78	22.6	25.45	S.E.±	C.D. (P=0.05)
Mean shattered grain loss, %	8.34	6.89	7.26	8.06	±0.1121	0.3239
Mean un-stripped grain loss, %	1.69	1.43	1.22	1.05	±0.0352	0.1019

Table 5 : Combine effect of stripping element, forward speed and peripheral of stripper rotor speed on shattered and un-stripped grain loss

Stripping element	Forward speed, km/h	Peripheral speed, m/s			
		16.95	19.78	22.6	25.45
Shattered grain loss, %					
A	1.65	8.33	6.58	7.02	8.02
	2.25	7.57	5.78	6.29	7.46
B	1.65	8.93	7.70	8.02	8.66
	2.25	8.45	7.25	7.60	8.35
Un-stripped grain loss					
A	1.65	1.53	1.39	1.20	1.14
	2.25	1.29	1.08	0.97	0.84
B	1.65	2.15	1.71	1.47	1.18
	2.25	1.95	1.54	1.18	1.00

S.E. ±0.1585; C.D. (P=0.05) 0.4566 (Shattered) and S.E. ±0.0705 C.D. (P=0.05) 0.2031 (un-stripped)

Combine effect of stripping element, forward speed and peripheral speed on shattered and un-stripped grain loss :

Combine effect of stripping element, forward speed and peripheral speed had non-significant effect on shattered and un-stripped grain loss. The mean value of shattered and un-stripped grain loss for these variables is presented in Table 5. Minimum shattered grain loss of 5.78 per cent was obtained with stripping element A at 2.25 km/h forward speed and at 19.78 m/s peripheral speed of stripper rotor whereas, maximum shattered grain loss is obtained as 8.93 per cent at 16.95 m/s peripheral speed of stripper rotor and 1.65 km/h forward speed using stripping element B. The higher shattered grain loss was found with stripping element B at both forward speeds and at all peripheral speed of stripper rotor. The un-stripped grain loss was found decreased with increase in peripheral speed of stripper rotor from forward speed 1.65 to 2.25 km/h. However, at higher forward speed with stripping element A lower loss was observed compared with stripping element B. Minimum un-stripped grain loss 0.84 per cent was obtained with stripping element A at 2.25 km/h forward speed and 25.45 m/s peripheral speed of stripper rotor.

Conclusion :

The stripper header mechanism for stripping of paddy was developed. The developed SHM was tested on specially developed test rig to simulate field conditions in laboratory at 1.65 and 2.25 km/h of forward speed and 16.95, 19.78, 22.6 and 25.45 m/s peripheral speed of stripper rotor to study their effect on shattered grain loss and un-stripped grain loss, which is found statistically significant. The shattered grain loss and un-stripped grain loss was ranged from 8.93 to 5.78 per cent, 2.15 to 0.84 per cent, respectively for selected range of forward speed and peripheral speed of stripper rotor. Minimum shattered grain loss of 5.78 per cent was obtained with stripping element A at 2.25 km/h forward speed and at 19.78 m/s peripheral speed. Minimum un-stripped grain loss of 0.84 per cent was obtained with stripping element A at 2.25 km/h forward speed and 25.45 m/s peripheral speed. The performance of the slender arrow head stripping element was found to be better as compared to spaced slender arrow head.

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