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Optimization of operational parameters of multi-crop spikes tooth thresher for threshing black gram

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ABSTRACT

The present study was aimed at optimizing operational parameters influencing threshing of mash or black gram (*Vignamungo*). Six spikes were arranged helically on cylinder by arranging one spike per row. Concave clearance was kept as 25mm. Peripheral speed (PS) of cylinder and crop feed rate (F) were independent parameters, whereas grain damage, non-collectable losses, sieve overflow, output of thresher, cleaning efficiency and threshing efficiency were dependent parameters. Peripheral speed of 21.9 m/s and feed rate of 1000kg/h was found optimum. At this combination the percent grain breakage was 0.47, percent non collectable losses were 0.51, percent sieve overflow was 1.90, output was 319.2 kg/h, percent cleaning efficiency was 97.80 and percent threshing efficiency was 99.06 respectively.

Key words: Crop feed rate, grain breakage, mash, multi-crop thresher, Peripheral speed, threshing efficiency

Black gram comes from the family of Leguminoseae and belongs to the sub family of Papilionaceae. The production of urad is mostly confined to the Asian countries as their tropical climates and soil type suit the pulse's cultivation. The largest producer of this pulse is India followed by Myanmar and Thailand. But being the largest producer of urad does not take India to a comfortable situation, as it is also the largest consumer of the black gram in the world and its total production is not able to fulfil its domestic consumption demand. The incapability of Indian production to satisfy its domestic demand makes it the largest importer of this pulse as well. The total exports of urad in the world figures around 62.5 million tons contributing to a 40% share in the total quantity of the beans and pulses(Anonymous, 2013).

In general, the pulse production is not keeping pacewith the domestic requirements, hence has to import 1.5-2.8 million tonnes per year and particularly a large quantity (7890 metric tonnes in 2001) of black gram is imported annually (Anonymous, 2014) and is a matterof concern.

One of the main hurdles in promotion and adoption of pulse crops by farmers is lack of mechanization of various farming operations for these crops. Sowing of these crops is more or less mechanized but a major hurdle is threshing of harvested crops. At present farmers thresh it manually and tread the crop below tractor tyres followed by winnowing in wind. Manual process is not only tedious but laborious whereas feeding pre-cut crop to stationary combine harvesters leads to huge losses. Threshing is very time consuming, drudgery and laborious farm operation if threshing of this crop is properly mechanised the area under this crop may increase which can reduce our import bills. Indian farmers have very low purchasing power they cannot afford crop specific thresher, thus they need a thresher which can thresh multiple crops. Multi crops thresher serves multiple purposes of threshing different crops by making some minor adjustments in the machine. At present very limited information is available in the literature reading the optimized operational parameters of thresher for threshing the mash or black gram, however it was found in some literature that for threshing pulsecropsspike tooth or peg tooth type thresher performed better than the other threshing mechanism. Peg tooth or spike type cylinder was found better as compared to loop type single cylinder threshing mechanisms in respect of total unthreshed grains and seed damage for threshing pigeon-pea (Neeraj *et al.* 1988).For reducing the drudgery of farmers, effective and timely threshing of mash or black gram and optimization of operational parameters there was a need to develop a thresher which can thresh mash with minimum damage to seed and has high threshing and cleaning efficiency. So present study was undertaken to evaluate the performance of multi-crop thresher and select the optimum level operation parameters for threshing mash.

MATERIALS AND METHODS

Brief description of machine: Commercially available spike tooth type thresher powered by electric motor has been used after incorporating few modifications based on preliminary testing. Two views of the machine are shown in Fig-1 and brief specifications are given in Table-1. The diameter of threshing cylinder is 580 mm and length is 326 mm. The threshing cylinder had thirty six spikes placed six in each row. For threshing pulses six spikes are retained on cylinder in 6 rows i.e. 1 in each row. These spikes are 16 mm studs. The arrangement of spikes on cylinder periphery is axial. Aspirator I & II are centrifugal type and having 4 & 3 blades respectively. Aspirator I separated the major chunk of chaff from sieve felling directly below the concave. Aspirator II accomplished the stage II cleaning. It picked chaff from screen just prior to discharge of grain from main outlet. Reciprocating sieve system consisted of replaceable set of sieve and screen mounted on oscillating frame. The amplitude of oscillations could also be varied. Upper sieve separated chaff bigger than grain while lower screen let the dust, smaller particles than grain pass through thus help in delivering clean grain at main outlet. The thresher is provided with four wheels made of cast iron for transportation and motor stand to fit the motor on it. It also has provision for attaching universal shaft for operating the thresher by tractor PTO. It also has provision to hitch it with three point linkage of tractor.

Modification in machine for threshing mash: Generally 36 spikes are provided on threshing drum for threshing wheat. However; only 6 spikes were provided on the threshing cylinder in 6 rows i.e. only one spike in each row for threshing Mash. The arrangement of spikes on cylinder periphery was helical. One spike is mounted in each row on the cylinder periphery and arranged helically because mash is a pulse crop and it requires less intensive threshing than the wheat crop for which the thresher developed.Pulse crop require lees intensive threshing as the seed damage at more intensive threshing due to splitting seed characteristics.Similarly, concave clearance was increased from 15 to 25mm by reducing length of spikes. Various modifications incorporated on multi-crop thresher for Mash have been indicated in Table 2.

Crop: Mash-338, variety grown with the standard agronomic practice as laid down in Package of Practices for Kharif crops (Anonymous, 2009 & 2010) at departmental farm of Department of Farm Machinery and Power Engineering, Department of botany and Department of Plant Breeding and Genetics, PAU, Ludhiana during Kharif season 2008-09 and 2009-10, was taken for the study. The crop was harvested when the leaves were shed and most of the pods turn greyish black.

*Evaluation procedure:*The performance tests of mash threshing were conducted at four levels of cylinder peripheral speed and three levels of crop feed ratesreplicated three times, by using completely randomized design (CRD) of a 4x3x3 factorial experiment with three replications in each treatment and comparison between treatment means by least significance difference (LSD) at 5% level. The peripheral speeds of 18.2, 20.1, 21.9 and 23.7 m/s were considered for experiment and were attained with the help of set of driver and driven pulley of different sizes. Three levels of feed rates 750, 800and 1000 kg/h were considered for experiment and were attained by varying the time of feeding the crop in the cylinder. The cylinder and concave clearance was kept 25 mm. Four levels of peripheral speed (18.2, 20.1, 21.9 and 23.7 m/s) and three levels of feed rate (750, 800and 1000 kg/h) were taken as independent variables for the experiment.The effect of both independent parameters on grain damage, non-collectable losses, sieve overflow, output of thresher, cleaning efficiency and threshing efficiency were studied.The thresher was tested at departmental farm, farms of Department of Farm machinery and Power Engineering, PAU Ludhiana. The thresher was operated by a 10 hp 3-phase electric motor. A tachometer was usedfor recording rpm. The weighing of crops was done on electronic balance. The grains collected for determining losses were also weighed on electronic balance. The harvested crop was dried for few days and bundles of 10 kg were formed. These bundles were fed to the thresher in specified time. The output of test was recorded and expressed in kg/h. The straw was collected for one minute from aspirator outlet using gunny bags. The material recovered from aspirator outlets was cleaned to recover the grains. A bag was stretched across the sieve to collect the sieve over flow loss for a period of two minutes. The loose grains collected were separated, weighed and expressed as percent sieve over flow loss. The threshed, un-threshed and broken grain blown out with straw collected from aspirator outlet. The collected materials were separated and expressed as percentage of non-collectable losses. The un-threshed grains from all outlets were separated, weighed and expressed as percent un-threshed grains. The clean grains from outlet were separated from unwanted material, weighted and expressed as percent cleaning efficiency. Broken grains were separated from clean grains weighed and expressed as percent broken.

RESULTS AND DISCUSSION

Grain Breakage: The effect of four levels of peripheral speeds and three levels of feed rates was studied on grain breakage (Table-2). Average grain breakage was 0.64 %. The data was statistically analyzed (Table-3 and Table-4). Factor means clearly indicated that breakage was inversely related to feed rate. In other words with the increase in the feed rate, breakage of grains decreased. The effect of peripheral speed and feed

Table 1: Brief specification of conventional spike tooth type thresher

Sr. No.	Particulars		Dimensions (mm)/Details
1.	Type of thresher		Spike tooth type
2.	Overall dimension:		
	a)	Length, mm	1765
	b)	Width, mm	1065
	c)	Height, mm	1570
3.	Power required		7.5 hp
4.	Concave clearance, mm		25
5.	Main drive		
	a)	Diameter of pulley on main shaft, mm	254
	b)	Diameter of pulley on motor, mm	101.6
6.	Diameter of cylinder, mm		580
7.	Length of cylinder, mm		326
8.	a)	No. of spike in a row	1
	b)	No. of rows	6
	c)	Total spikes	6
	d)	Type of spike	16mm diameter studs
	e)	Arrangement of spikes	Axial
9.	Aspirator I & II		
	a)	Type of aspirator	Centrifugal
	b)	No of blades	4 & 3
	c)	Diameter of aspirator	
		Aspirator-1	680
		Aspirator-2	560
10	Crop (thresher developed for)		Wheat

rate was significant at 5% level of confidence (Table-2). The breakage was also more at lower feed rate due to higher impact of threshing members. Factor means indicated that breakage was directly related to peripheral **speed. Breakage** was found to be the maximum at higher peripheral speed due to higher combined effect of impact and rubbing force (Neeraj and Singh, 1998). However, effect of interaction of both the factors on breakage was non-significant. The percent breakage ranged from 0.45 to 1.12. Minimum breakage of 0.45% was observed at lower peripheral speed (PS1) and higher feed rate (F3), while breakage was the maximum at higher peripheral speed (PS4) and lower feed rate (F1).

Table 2: Modifications on multi-crop thresher used for threshing Mash

S. No.	Particulars		
1.	Crops for threshing	Wheat	Mash
2.	Concave clearance, mm	15	25
3.	Description of threshing elements on cylinder a) No. of spike in a row b) Total no. of spike	6 36	1 6

Non-Collectable Losses: Non-collectable losses are those which cannot be collected, i.e. seed losses from aspirators. The effect of four levels of cylinder peripheral speeds and three levels of crop feed rates was studied on non-collectable losses (Table-1**). Average** non-collectable losses were 0.57%. The effect of cylinder peripheral speed was significant at 5% level of confidence. Factor means clearly indicate that non-collectable losses were directly related to the cylinder peripheral speed, i.e. with the increase in peripheral speed, the non-collectable losses also increased. However, the minimum non-collectable losses (0.25%) were observed at PS1F3 but these were statistically at par with PS1F2 (0.29%), PS1F1 (0.27%) and PS2F1 (0.26%) (cd =0.14, at 5% level of significance). Maximum non collectable losses (1.28 %) were observed at PS4F3. Non collectable losses increased with increase in cylinder peripheral speed because asthe peripheral speed of threshing cylinder was increased percent broken grains also increased. Since aspirator and threshing cylinder are mounted on same shaft the speed of aspirator increased simultaneously, leading to higher non-collectable losses. The effect of feed rate and interaction of both parameters was non-significant at 5% level of confidence.

Cleaning Efficiency: The effect of four levels of peripheral speed and three levels of feed rate on cleaning efficiency (Table-1) was studied. Overall cleaning efficiency was 97.75%. Effect of peripheral speed and crop feed rate was found significant (Table-2&3) at 5% level of confidence. It was revealed that the percent cleaning efficiency ranged from 95.20% at PS1F3 to 99.30% at PS4F1 respectively. Factor means (Table-3) of cleaning efficiency was directly related to the peripheral speed, i.e. with the increase in the peripheral speed the cleaning efficiency increased. The cleaning efficiency increased with increase in peripheral speed as the threshing cylinder and aspirators were mounted on the common shaft**. F**actors means of crop feed rate on cleaning efficiency did not show any definite pattern. The interaction (Table-4) of peripheral speed and crop feed rate was also significant at 5% level of significance. The interaction has occurred because of higher cleaning efficiency on increasing the feed rate at PS1F1 from PS1F2. This may have occurred due to some experimental error, some variation in moisture content of straw or different characteristics of straw. The interaction was ignored.

Threshing Efficiency: The effect of four levels of peripheral speeds and three levels of feed rates on threshing efficiency (Table-1) was studied. Average threshing efficiency was 98.48%. The effect of peripheral speed and crop feed rate was significant at 5% level of confidence. Minimum threshing efficiency (96.38%) was observed at peripheral speed PS1 and feed rate F3, while maximum threshing efficiency was (99.71%) observed at peripheral speed PS4 and feed rate F1 respectively. Threshing efficiency was directly related to the peripheral speed, i.e. with the increase in the peripheral speed the threshing efficiency increased. Factor means (Table-3) clearly indicated that threshing efficiency was inversely related to feed rate. However, the interaction of peripheral speed and crop feed rate was non-significant at 5% level of significance (Table-2).

Output: The effect of four levels of peripheral speeds and three levels of feed rates on output of thresher (Table-1) was studied. Average output of thresher was 262.4 kg/h. The

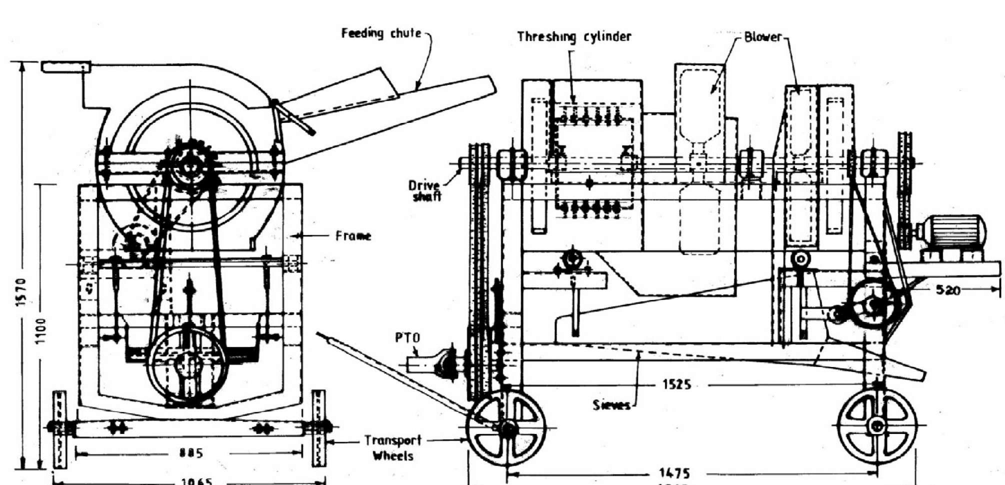


Figure 1. Front and side view of spike-tooth multi-crop thresher

Table 1: Field performance of multi-crop thresher for threshing Mash

Cylinder Speed	Feed rate	Output kg/h	Broken (%)	Non-collectable losses (%)	Cleaning efficiency (%)	Threshing Efficiency (%)	Sieve overflow (%)
PS1	F1	214.1	0.54	0.27	96.92	97.16	3.40
PS1	F2	240.7	0.51	0.29	97.69	96.92	2.32
PS1	F3	310.6	0.45	0.25	95.20	96.38	2.21
PS2	F1	210.8	0.57	0.26	97.50	98.56	1.81
PS2	F2	252.4	0.53	0.39	97.48	98.22	1.76
PS2	F3	313.0	0.46	0.40	96.96	97.89	1.83
PS3	F1	213.3	0.64	0.46	98.89	99.59	1.45
PS3	F2	256.0	0.57	0.49	98.95	99.48	1.87
PS3	F3	319.2	0.47	0.51	97.80	99.06	1.90
PS4	F1	245.7	1.12	1.04	99.30	99.71	3.20
PS4	F2	250.3	1.01	1.19	99.13	99.66	2.73
PS4	F3	322.2	0.85	1.28	99.05	99.09	3.25
Average		**262.4**	**0.64**	**0.57**	**97.75**	**98.48**	**2.31**

Table 2: ANOVA for the mashthreshing with multi-crop thresher

Source of Variation	(d.f.)	F- ratio					
		Output, kg/h	Broken (%)	Non-collectable losses (%)	Cleaning efficiency (%)	Threshing Efficiency (%)	Sieve overflow (%)
A	3	10.60*	63.98*	66.24*	61.83*	39.32*	1432.06*
B	2	582.43*	9.78*	1.52	20.15*	3.98*	100.61*
AB	6	5.26*	0.64	0.43	4.27*	0.00	184.26*
ERROR	24	-	-	-	-	-	-
CV	-	2.67	13.68	26.51	0.45	0.61	2.22

* Indicate significant at 5% level of confidence

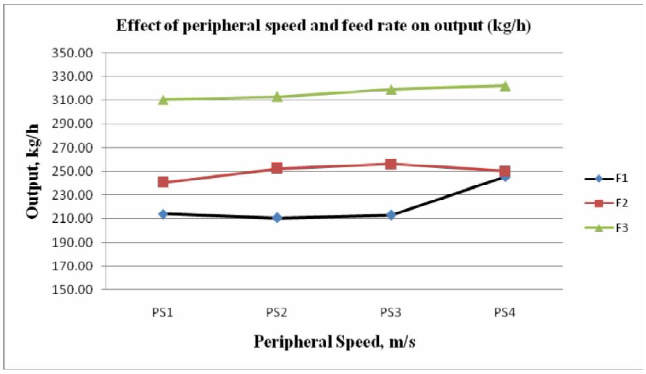
Table 3: Factor means of independent variables on dependent variables

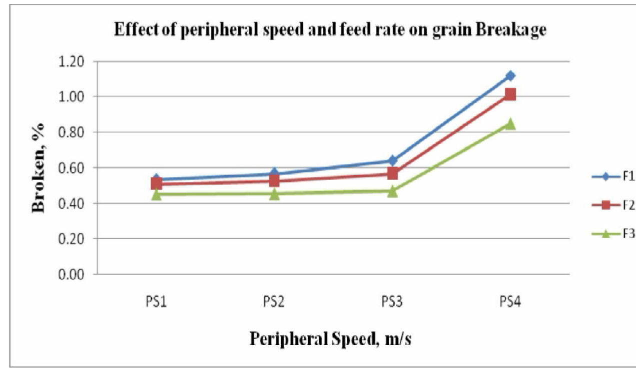
Parameter	Level	Output, kg/h	Broken (%)	Non-collectable losses (%)	Cleaning efficiency (%)	Threshing Efficiency (%)	Sieve overflow (%)
Cylinder speed (m/s)	18.2	255.12	0.50	0.27	96.60	96.82	2.64
	20.1	258.74	0.52	0.35	97.31	98.22	1.80
	21.9	262.84	0.56	0.49	98.54	99.37	1.74
	23.7	272.75	0.99	1.17	99.16	99.48	3.06
Feed Rate (q/h)	7.5	220.98	0.72	0.51	98.15	98.75	2.46
	8.0	249.86	0.66	0.59	98.31	98.56	2.17
	10.0	316.25	0.56	0.61	97.25	98.10	2.29

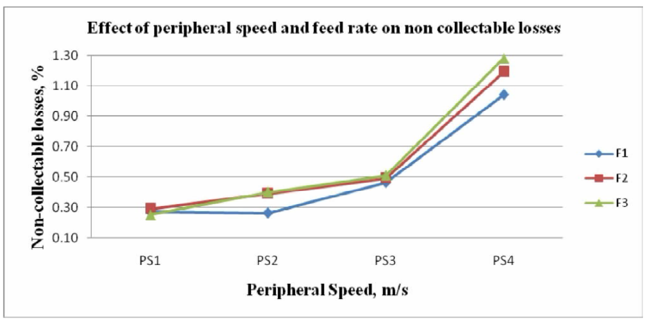
effect of peripheral speed and crop feed rate was significant at 5% level of confidence. Factor means of crop feed rate clearly indicated that feed rate was directly related to output or in other words with increase in feed rate the output of thresher increased. Minimum output of 210.8kg/h was observed at PS2F1 and maximum of 322.2 kg/h at PS4F3. The interaction (Table-5) of peripheral speed and crop feed rate was also significant at 5% level of significance. There was minor variation in the output at PS1F1, PS2F1 and PS3F1 combination but statistically these are at par. The interaction of effect of peripheral speed of cylinder and feed rate has occurred due to lesser output at PS2F1 and PS3F1 as compared to PS1F1. The results do not co-relate with other experimental results on these combinations. The higher output at PS1F1 may have occurred due to variation in straw grain ratio, therefore this interaction was ignored.

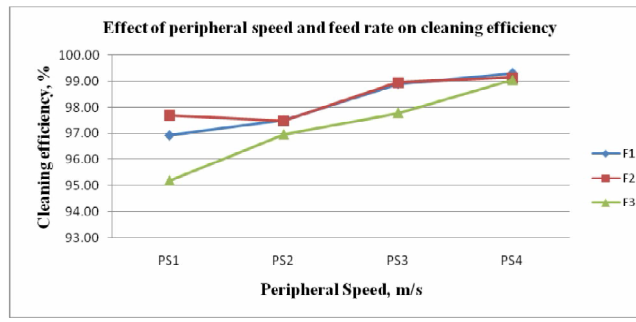
Sieve overflow: The effect of four levels of peripheral speeds and three levels of feed rates on sieve overflow of thresher (Table-1) was studied. Average sieve overflow was 2.31%. The effect of peripheral speed and crop feed rate on sieve overflow was significant at 5% level of confidence. Factor means (Table-3) show that sieve overflow initially decreased with increase in cylinder speed but reverse pattern was found at higher cylinder speed, it may be because the opportunity time was short for the material to sieving at lower speeds and at higher speeds more material gets carried away due to strokes of sieving system. The interaction of peripheral speed and crop feed rate was also significant at 5% level of significance. The interactions (Table-6) have been observed may be due to different straw characteristics or variation in moisture content of straw. No suitable explanation could be suggested for this behaviour.

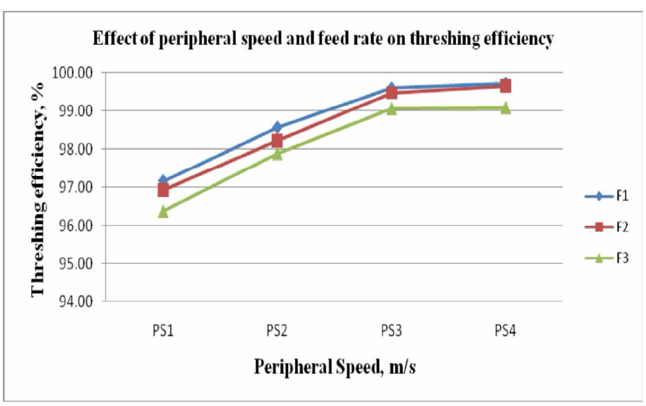
Optimum values of machine parameters for threshing mash: To obtain optimum combination of parameters the criteria adopted was that the threshing efficiency should be the maximum, percent breakage should be minimum, non-collectable losses should be minimum, cleaning efficiency should be the maximum, output should be maximum and sieve over flow should be minimum. Perusal of Table-1 revealed that threshing efficiency was more than 99% at PS3 and PS4 therefore any combination could be selected. Minimum breakage was observed for treatment combination

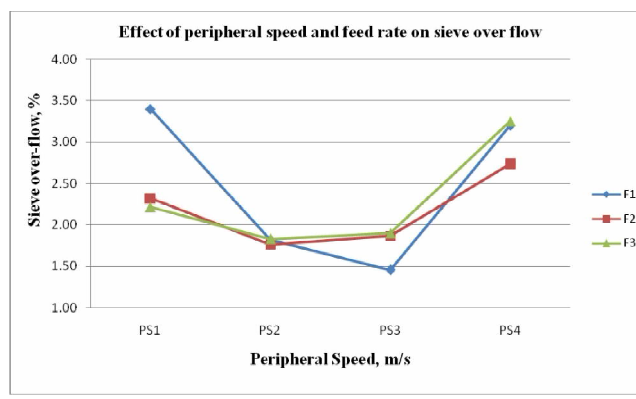












PS3F3followed PS3F2 and PS3F1. Therefore, any combination amongst these could be selected based on minimum breakage. Further perusal of Table-1 revealed that non-collectable losses were minimum at PS3F1 and these were statistically at par with PS3F2 and PS3F3 (cd =0.14, at 5% level of significance). Therefore any treatment combination amongst these could be selected. Amongst the shortlisted treatments combinations maximum cleaning efficiency was observed at PS3F1 followed by PS3F2 and PS3F3. Maximum output of thresher 319.2 kg/h was observed at PS3F3 amongstthe combination based on threshing efficiency, grain breakage, non-collectable losses and cleaning efficiency. Minimum sieve over flow 1.45% was observed at PS3F1 which was statistically at par with combination of PS3F2 and PS3F3. Therefore any combination among these could be selected based on the minimum sieve over flow. Higher output at PS3F3 outweighs slightly higher cleaning efficiency and sieve over flow. Hence, the recommended treatment combination was PS3F3. At the selected treatment combination peripheral speed was 21.9 m/s and feed rate was 1000 kg/h. The percent grain breakage was 0.47, percent non collectable losses were 0.51, percent sieve overflow was 1.90, output was 319.2 kg/h, percent cleaning efficiency was 97.80 and percent threshing efficiency was 99.06 respectively.

Peripheral speed and feed rate play an important role in affecting threshing efficiency, cleaning efficiency, breakage, non-collectable losses, sieve overflow and output of thresher for threshing mash of black gram. Threshing efficiency was more than 99% at cylinder peripheral speed of PS3 and PS4. The percent grain breakage was higher for higher cylinder peripheral speed and lower for higher feed rate. The grain damage was below 1% for all combination PS1, PS2 and PS3 cylinder peripheral speed. Amongst combinations selected based on percent threshing efficiency, grain breakage, sieve

Table 4. Factor Means for percent cleaning efficiency (cd=0.75)

	PS1	PS2	PS3	PS4	Average
F1	96.92	97.50	98.89	99.30	98.15
F2	97.69	97.48	98.95	99.13	98.31
F3	95.20	96.96	97.80	99.05	97.25
Average	96.60	97.31	98.54	99.16	97.91

Table 5. Factor Means for output, q/h (cd=11.81)

	PS1	PS2	PS3	PS4	Average
F1	214.10	210.80	213.27	245.73	220.98
F2	240.66	252.39	256.03	250.33	249.86
F3	310.60	313.00	319.23	322.20	316.26
Average	255.12	258.73	262.84	272.76	262.36

Table 6. Factor Means for percent sieve over-flow (cd=0.86)

	PS1	PS2	PS3	PS4	Average
F1	3.40	1.81	1.45	3.20	2.47
F2	2.32	1.76	1.87	2.73	2.17
F3	2.21	1.83	1.90	3.25	2.30
Average	2.64	1.80	1.74	3.06	2.31

overflow, non collectable losses, out-put of thresher and cleaning efficiency the recommended treatment combination was PS3F3. Peripheral speed of 21.9 m/s and feed rate of 1000 kg/hwas optimumfor threshing of mash on modified multi-crop thresher. At this combination the percent grain breakage was 0.47, percent non collectable losses were 0.51, percent sieve overflow was 1.90, output was 319.2 kg/h, percent cleaning efficiency was 97.80 and percent threshing efficiency was 99.06 respectively.

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