J. Cotton Res. Dev. **34** (2) 278-290 (July, 2020) **ISSN No. 0972-8619**

Influence of single locking of cotton bolls on ginning performance of double roller gin for short staple cotton

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ABSTRACT: Spike cylinder feeder (M1), saw band cylinder feeder (M2) and combined feeder (M3) comprising of spike cylinder feeder with conventional autofeeder were developed to unlock cotton bolls to feed double roller (DR) gins. Ginning performance of DR gin with these single locking feeders was compared to conventional autofeeder (Control) for short staple cotton. Ginning performance was measured in terms of ginning output, specific energy consumption, degree of unlocking in terms of decrease in bulk density, trash content, colour grade and effect on fibre quality parameters. Degree of unlocking of cotton bolls was found to improve by 17, 14 and 17 per cent, respectively for M1, M2 and M3, respectively as compared to control. The improved unlocking of bolls resulted into increase in ginning output by 62.32, 36.80 and 48.53 per cent and decrease in specific energy by 27.89, 18.92 and 22.04 per cent, respectively for M1, M2 and M3 as compared to control. The highest ginning output of 41.23 kg/h and lowest specific energy consumption of 0.0685 kWh/kg was found for M1. Spike cylinder feeder showed higher colour grade improvement as compared to other two mechanisms and other fibre quality parameters tested by HVI and AFIS remain unaffected. Post hoc analysis with Tukey's test revealed that among three mechanisms, spike cylinder feeding mechanism (M1) was best in terms of improvement in ginning performance of DR gin.

Key words : Double roller gin, ginning, short staple cotton, single locking feeder

Cotton is an important commercial crop of India and has emerged as the largest producer in the world with its production touching 6.2 million tonnes in 2020-21 (USDA, 2020). Double roller (DR) gins are more prevalent in Indian ginneries than saw gins. DR gins has prominent share in ginning industries across the world. About 95% of the cotton produced in India is subjected to ginning by using DR gins. As compared to saw gin and rotary knife roller gin, the ginning capacity of DR gins is very low. Low production capacity of DR gin is the barrier for its widespread adoption across the world except in India and some African countries (Sharma, 2014).

Indian researchers have made efforts to improve DR gins to increase capacity and ginning efficiency. Improved models of DR gins were developed by increasing roller length from 1065 to 1525 mm with an increase in output from 40 to 90 kg lint/h. Roller and beater drives were seperated and driven independently to develop 'Variable Speed' DR gin (Jadhav *et al.,* 2007). To increase the gin productivity and to eliminate the chromium contamination a 'Self-grooving rubber roller' was developed as a substitute to chrome composite leather roller being used in DR gin (Arude *et al.,* 2017). The ginning efficiency is governed by lint output, lint quality and energy conssumption. Cotton to be ginned, moisture content, ginning roller speed, beater speed, setting and adjustments and feeding mechanism to DR gin influences the ginning output to a great extent (Patil *et al.,* 2007).

The method of feeding cotton to the knife edges of DR gin plays an important role in ginning process. Manual feeding never offer uniform feeding which results in loss of efficiency up to 20 per cent (Sharma, 2014). In Indian ginneries, autofeeder is commonly used as feeding mechanism to DR gin. Uneven, inconsistent, and feeding of lumps of cotton through conventional autofeeder to DR gin results in low ginning efficiency. For maximizing ginning efficiency, the feeding rate of seed cotton should be constant and should be limited to such an extent that, it ensures smooth and trouble free ginning (Antony, 1994).

Appropriate feeding mechanism to DR gin plays a significant role in enhancing ginning efficiency. Single locking of seed cotton ensures controlled feed rate and increases the production capacity with the increased bale value (Baker *et al.,* 1994). Feeders in saw and rotary knife roller gins are based on the principal of single locking of cotton bolls which results in higher ginning capacities. Since there was a need for a suitable feeder to enhance ginning efficiency of DR gins, the feeder based on the principle of single locking of cotton bolls was developed and evaluated. The purpsoe behind developing these feeding mechanism was to replace conventional autofeeder used in ginning industry in order to make ginning business more remunerative.

Cotton ginner's experienced difficulties in ginning short staple cotton with the present DR ginning system. Further it was observed that, DR gins are not effective in ginningshort staple cottonas they are effective in ginning medium, long and extra-long staple cottons. Ginning of short staple cotton with present DR gin is uneconomical due to low ginning output and poor energy efficiency. It was expected that, if DR ginsare employed with feeder based on single locking principle, it would result in improvement in ginning output and efficiency. Therefore, in the present work, attempts have been made to develop single locking feeding mechanisms forginning short staple cotton on double roller gin.

MATERIALS AND METHODS

Development of single locking feeding mechanisms : Three different feeding mechanisms spike cylinder single locking feeder (M1), saw band cylinder single locking feeder (M2) and combined feeding mechanism (M3) comprising of spike cylinder feederand conventional autofeeder were desinged and developed based on the concept of single locking of cotton bolls; with an aim to unlock cotton bolls and to maintain uniform feeding rate of individual locules; to ensure feeding locules near to the ginning point across the knife edges of DR gin. Spike cylinder single locking cotton feeding mechanism (M1) (Fig.1) was developed with a pair of feed rollers and spiked cylinders, grid bar housed in a feeder hopper and chute for cotton distribution on either side of the beater of DR gin. Saw band cylinder single locking feeding mechanism (M2) (Fig.2)was developed with a pair of saw band cylinders with hopper, reservoir box, doffing brushes and feeding aprons. Main purpose behind developing combined mechanism (M3) (Fig. 3) was to study the effect of feeding of unlocked cotton bolls from spike cylinder feeder to conventional autofeederand its impact on ginning efficiency of DR gin.

The conventioanl autofeeder (Control) (Fig. 4) consist of two endless belts, hopper, spike patti, rollers for mounting belt, UCT bearings and drive mechanism. In hopper of autofeeder, two counter rotating endless belts with metal strips are fixed at an angle to the vertical. The strips move through seed cotton in the hopper and cotton gets entangled to the spikes and carried over and fed it along the knife edges of beater.

Experimental method for performance evaluation : Performance of three feeding mechanisms was evaluated by mounting each mechanism on commercial DR gin with roller length of 1360 mm. Experimental setup of

Fig. 1. Spike cylinder feeder (M1)

Fig. 2. Saw band cylinder feeder (M2)

Fig. 3. Combined feeder (M3)

Fig. 4. Conventional autofeeder (Control)

Table 1. Experimental face centered CCD design and actual results of dependent variables for different feeding mechanisms

Standard run	M1					M2					M3				
	Actual variables		Dependent variables			Actual variables		Dependent variables			Actual variables		Dependent variables		
	X_1	X_2	Y_1	Y_2	Y_3	X_1	X_2	Y_1	Y_2	Y_3	X_1	X_2	Y_1	Y_2	Y_3
1	9	200	27.5	0.0916	15.89	9	150	26.0	0.0904	12.01	9	200	26.3	0.0905	15.63
2	9	300	31.0	0.0803	19.83	9	200	28.0	0.0854	16.03	9	300	29.4	0.0830	19.31
3	9	400	29.7	0.0865	23.34	9	250	27.2	0.0871	18.14	9	400	28.4	0.0870	22.91
4	12	200	34.0	0.0762	13.42	12	150	31.5	0.0794	10.75	12	200	32.6	0.0779	13.17
5	12	300	42.0	0.0695	17.18	12	200	36.2	0.0744	13.84	12	300	38.5	0.0731	16.95
6	12	300	41.8	0.0694	17.28	12	200	36.0	0.0746	14.04	12	300	38.6	0.0725	17.29
7	12	400	37.6	0.0747	20.56	12	250	33.5	0.077	15.89	12	400	35.1	0.0761	20.31
8	15	200	31.5	0.0781	11.97	15	150	30.4	0.0813	9.66	15	200	30.9	0.0799	11.75
9	15	300	36.0	0.072	14.22	15	200	33.6	0.0768	12.72	15	300	34.6	0.0749	13.87
10	15	400	33.0	0.0764	17.3	15	250	32.0	0.0791	14.20	15	400	32.6	0.0779	16.98

Fig. 5. Pictorial view of mechanism M1 with DR gin

mechanism M1 with DR gin is depicted in Fig. 5. Similarly other feeding mechanisms and conventional autofeeder were mounted on same DR gin for evaluation of their performance and optimization. Performance was measured in terms of degree of unlocking of cotton bolls, ginning output, specific energy consumption and fibre quality. Short staple cotton with 2.5 per cent span length of about 22 mm was ginned. The cylinder speed was varied with the help of a variable frequency drive. The clamp on power meter (CW240; Yokogawa, Japan) was used for measurement of energy consumption.Fogging machine was used to apply desired moisture in mist form on cotton to the desired extent.Moisture content of cotton was measured with portable C - 2000 moisture meter from Delmhorst. Degree of single locking of cotton bolls was determined by measuring change in Bulk density of seed cotton before and after passing through the feeder. The effect of the developed feeders on cotton quality was assessed by measuring the fibre quality parameters on

Table 2. Model summary for different feeding mechanisms for short staple cotton.

Response variable	RSMmodel	df	SS	MS	MSE	F	p-value	R^2	R^2Adj	LOF (p-value)
Mechanism 1 (M1)										
Output (kg/h)	Quadratic	5	210.23	42.05	1.3112	24.46	<0.0043*	0.968	0.928	0.0686
Specific energy (KWh/kg)	Quadratic	5	4.52E-04	1.69E-04	0.001211	115.71	<0.0004*	0.987	0.971	0.0372
Decrease in bulk density (kg/m^3)	Linear	5	107.66	21.53	0.4125	220.37	<0.0001*	0.996	0.992	0.1437
Mechanism 1 (M2)										
Output (kg/h)	Quadratic	5	111.04	22.21	0.7288	41.81	0.0015*	0.981	0.975	0.1233
Specific energy (KWh/kg)	Quadratic	5	2.67E-04	5.34E-05	1.75E-04	1751.81	<0.0001*	0.999	0.998	0.5010
Decrease in bulk density (kg/m^3)	Linear	5	59.08	11.82	0.1398	604.52	<0.0001*	0.998	0.997	0.6154
Mechanism 3 (M3)										
Output (kg/h)	Quadratic	5	148.19	29.64	0.8987	36.69	0.0019	0.978	0.951	0.0501
Specific energy (KWh/kg)	Quadratic	5	3.15E-04	6.30E-05	6.64E-04	143.11	0.0001	0.994	0.987	0.3999
Decrease in bulk density (kg/m^3)	Linear	5	104.25	20.85	0.39	133.40	0.0002	0.994	0.986	0.3811

*Significant at 5% level of significance

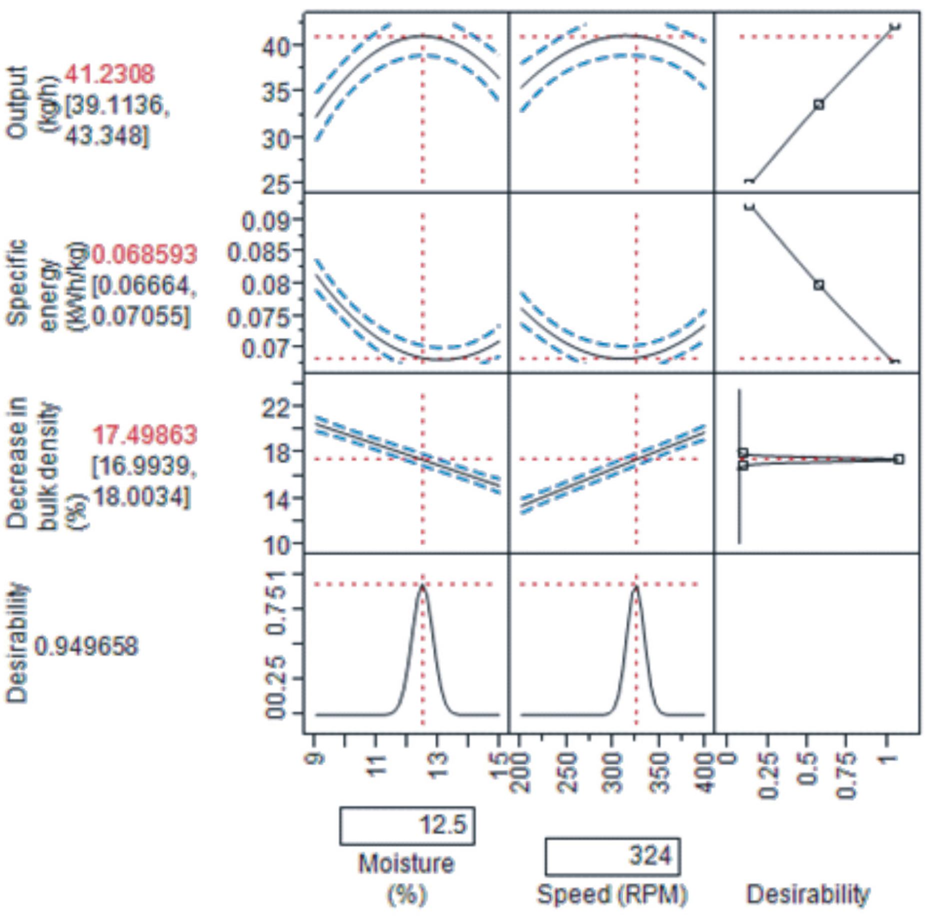

Fig.6. Desirability and levels of moisture and speed by multiple response optimisation for M1

High Volume Instrument (HVI) and Advanced Fibre Information System (AFIS). The trash analyser was used to measure the trash content and thereby the cleaning efficiency of the developed prototype.

Optimization by response surface methodology (RSM) : Response surface methodology (RSM) was used to optimize performance of developed feeders. Face-Centered Central Composite Design (CCD) was used to optimise machine and crop parameters and to generate experimental matrix and model equations by using SAS JMP software(Praveen *et al.,* 2009). Face-Centered CCD consisted of two independent factors with three levels each i.e. cotton moisture content (X_1) and cylinder speed (X_2) of developed feeder. The ginning efficiency parameters viz. ginning output (Y_1) and specific energy consumption (Y_2) of DR gin and degree of unlocking of cotton bolls in terms of decrease in Bulk density of cotton (Y_3) were the dependent variables. The developed feeders were optimised with these variable to maximize Y_1 and to minimize Y_2. Data in Table 1 depicts the independent variables and their levels for face centered CCD and actual experimental results for Mechanisms M1, M2 and M3. Experiments were carried out for each mechanism as per design matrix that consisted of 10 runs for short staple cotton. The analysis of variance (ANOVA) and lack of fit (LOF) tests were generated for the responses from the experimental data and used to analyze models for significance. Single optimum solution was obtained by multiple response analysis and using desirability function (Philip *et al.,* 2005).

Comparative analysis of different feeding mechanisms : The purpose of comparative analysis was to identify which mechanism among the three mechanisms performed better in comparison to conventional mechanism. The developed mechanisms M1, M2 and M3 were compared to that of conventional autofeeder (Control) on the basis of ginning performance. Improvement in ginning performance was indicated by increase in ginning output, decrease in Bulk density, reduction in specific energy, reduction in trash content, improvement in colour grade of cotton and impact on fibre quality. The effect of different mechanism on colour grade of cotton was studied. Post - hoc analysis using Tukey's test was done to compare different mechanisms.

RESULTS AND DISCUSSION

Results of face centered CCD experimental design : Ten experimental runs with two independent variables at three levels were conducted for each mechanism. The experimental face centered CCD design and actual results of dependent variables i.e. ginning output (Y_1), specific energy for ginning (Y_2) and decrease in Bulk density (Y_3) are presented in Table 1. Ginning output was found to vary from 27.5-42, 26.0-36.2 and 26.3-38.6 kg/h, and specific energy was found between 0.0695-0.0916, 0.0744-0.0904 and 0.0725-0.0905 kWh/kg and decrease in Bulk density was found in the range of 11.97-23.34, 9.66-18.14 and 11.75-22.91 per cent for mechanism M1, M2 and M3, respectively.

The result revealed that moisture content and spike cylinder speed played a vital role in unlocking cotton bolls as evidenced from the decrease in Bulk density. Single locking of cotton bolls in M1 was achieved as the spike tips were spaced closer to the feed rollers than the thickness of a lock of cotton and spiked cylinder travelled at a greater linear speed than feed rollers, thus striking the bolls of cotton momentarily held between the feed rollers. Single locking of cotton bolls was increased with increase in spike cylinder speed and decreased with increase in cotton moisture content.

It was observed that moisture content and saw band cylinder speed played a key role in unlocking the cotton bolls as seen from the decrease in Bulk density. Single locking of cotton bolls in M2 was achieved by saw band cylinder which does the function of opening and unlocking the cotton bolls. Single locking of cotton bolls was increased with increase in saw cylinder speed and decreased with increase in cotton moisture content. It can be seen that saw band cylinder speed had positive effect whereas the moisture content has the negative effect on single locking of cotton bolls. The lowest ginning output was observed at 5 per cent moisture content. This is due to the fact that as moisture content of cotton becomes less, fibre becomes more brittle and as relative humidity lowers static electricity begin to build which leads to fibres wrapping on rollers or failing to doff properly resulting in negative impact on ginning efficiency. Conversely, if relative humidity is allowed to increase too high there are potential problems with the fibres drafting and doffing improperly as well as the propensity for blockages during ginning operation.

Table 3. Critical values of moisture and cylinder speed for maximizing output and minimizing specific for different mechanism.

Parameters	M1	M2	M3
Ginning Output			
Moisture content (%)	12.45	12.86	12.66
Speed (RPM)	313	208	315
Output at critical values (kg/h)	41.27	36.03	38.24
Specific energy			
Moisture content (%)	13.08	12.99	13.05
Speed (RPM)	313	209	312
Specific energy at critical values (kWh/kg)	0.0681	0.0738	0.0717

Establishment of regression models : The analysis of variance (ANOVA) and lack-of-fit (LOF) tests were generated for three responses from experimental data. Data in Table 2 depicts model summery for three feeding mechanism.

Large F-values for ginning output (Y_1), specific energy (Y_2) and decrease in Bulk density (Y_3) and p-values <0.001 indicate that developed regression models are extremely significant at 5 per cent level of significance for all three mechanisms. The lack of fit was not significant as evidenced from the p values for all three responses and mechanisms. Quadratic model was fitted for prediction of responses $Y_1$and Y_2whereas linear model was fitted for prediction of responseY_3. Values of R^2 exceeding 0.95 indicated that the fitted models are in excellent agreement with the experimental values.

The optimum solution for each response and mechanism i.e. critical values of moisture and spike cylinder speed were generated through SAS analysis. Data in Table 3 illustrates the critical values of moisture content and speed for maximizing ginning output and minimizing

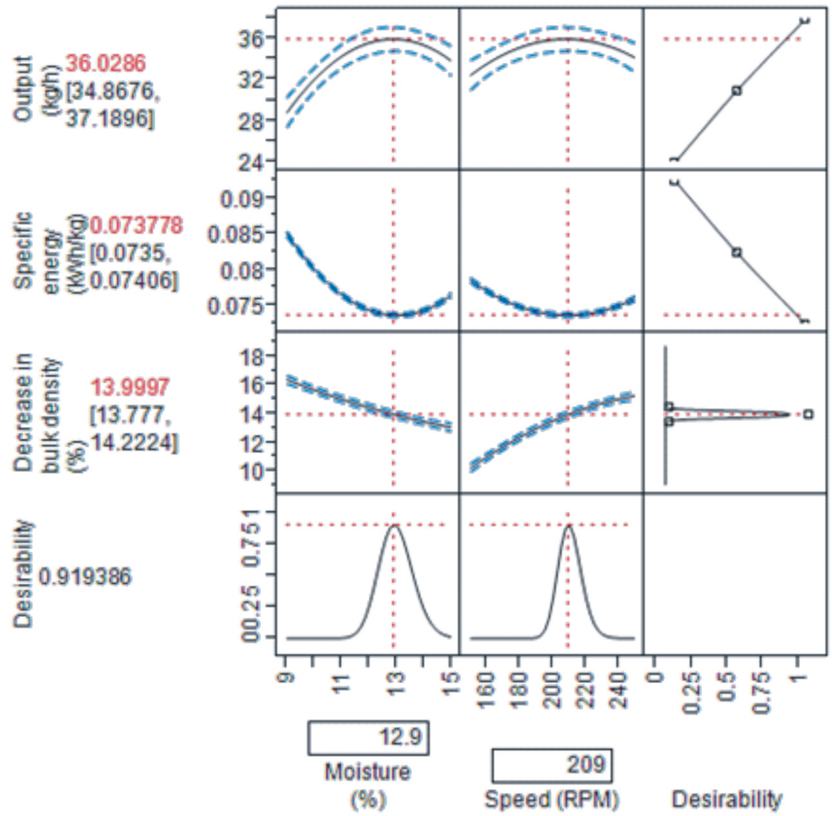

Fig.7. Desirability and levels of moisture and speed by multiple response optimisation for M2

specific energy.

Multiple regression analysis: Optimization of responses and desirability : The aim of the study was to find out the optimal parameters *i.e.* cylinder speed and cotton moisture content to enhance ginning efficiency on one hand and to reduce specific energy on the other hand without affecting fibre quality.The different critical values of moisture and cylinder speed were given by the fitted models for ginning output and specific energy. Therefore single optimum solution was obtained separately by multiple response analysis.

Desirability technique determines optimum settings of input factors that achieve optimum performance levels for one or more responses. The optimum settings may be maxima, minima, target settings or a combination of these. The JMP software allows multiple optimization using models derived from designed experiments. JMP's approach to optimization for multiple response is based upon the concept of desirability (Philip *et al.,* 2005).

Optimization process was conducted, by assigning the constraints 'in the range' for independent variables for maximizing output and minimizing specific energy. In case of response variable decrease in bulk density; neither maximum nor minimum could be obtained (saddle point). Since the interest is to achieve maximum output, minimum specific energy with desired unlocking of the bolls, the multiple response optimization was done keeping the target values for the response decrease in Bulk density in the range of 17.9±0.5%, 14.0±0.3% and 17.0±0.62%for M1, M2 and M3respectivelyto get maximum ginning output and minimum specific energy.

The single optimum solution was obtained by multiple response analysis for mechanism M1 (Fig.6), mechanism M2 (Fig. 7) and Mechanism 3 (Fig. 8). For mechanism M1, ginning output of 41.23 ± 2.1172 kg/h and specific energy of 0.0686 ± 0.001953 kWh/kg was observed at optimum levels of moisture content of 12.5% and speed of 324 RPM with desirability of 0.9047. For mechanism M2, ginning output of 36.03 ± 1.161 kg/h and specific energy of 0.0737 ± 0.00028 kWh/kg was observed at optimum levels of moisture content of 12.9% and speed of 209 RPM with desirability of 0.919386. For mechanism M3, ginning output of 38.10208 ± 1.39998 kg/h and specific energy of 0.071869 ± 0.001029 kWh/kg at optimum levels of moisture content of 13.0 per cent and speed of 330 RPM with desirability of 0.914954. Ginning output was higher and specific energy was lower for M1 as compared to M3 at optimum solutions obtained by using multiple response analysis and desirability function.

Effect of different feeding mechanisms on colour grade of cotton : The colour grades were assigned to each sample following USDA HVI colour chart for American upland cotton. The first two digits in the colour grade indicates colour grade and last digit after hyphen indicates

Table 4. Effect of single locking on colour grade of short staple cotton

Independent variables			Colour grade	Independent variables			Colour grade	Independent variables			Colour grade
X_1	X_2	M1	control	X_1	X_2	M2	control	X_1	X_2	M3	control
9	200	32-2	32-2	9	150	32-2	32-2	9	200	32-2	32-2
9	300	32-1		9	200	32-1		9	300	32-1	
9	400	22-2		9	250	22-2		9	400	22-2	
12	200	32-2	32-2	12	150	32-2	33-2	12	200	32-2	32-2
12	300	32-1		12	200	32-1		12	300	32-1	
12	300	32-1		12	200	32-1		12	300	32-1	
12	400	22-2		12	250	32-1		12	400	22-2	
15	200	33-2	32-2	15	150	33-2	43-1	15	200	33-2	32-2
15	300	32-2		15	200	32-2		15	300	32-2	
15	400	22-2		15	250	32-1		15	400	22-2	

Table 5. Enhancement in ginning performance of DR gin with different feeding mechanisms

Parameter	M1	Control	change (%)	M2	Control	change (%)	M3	Control	change (%)
Ginning output (kg/h)	41.23	25.40	62.32	36.02	26.33	36.80	38.10	26.0	48.53
Decrease in bulk density (%)	17.00	0	17.00	14.0	0	14.0	17.0	0	17.00
Specific energy (kWh/kg)	0.0685	0.0950	27.89	0.0737	0.0909	18.92	0.0718	0.0921	22.04

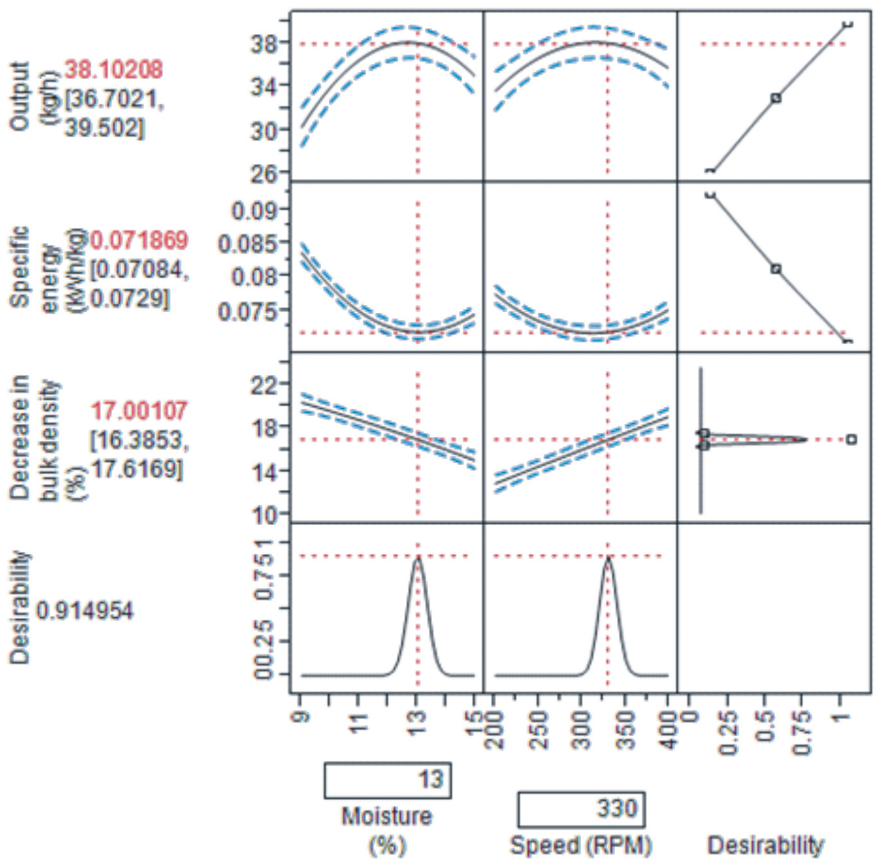

Fig.8. Desirability and levels of moisture and speed by multiple response optimisation for M3

leaf grade. Colour grades of cotton were improved with application of different feeding mechanisms as compared to application of conventional autofeeder. Mechanism M1 showed higher colour grade improvement as compared to other two mechanisms. Higher cylinder speeds resulted in better colour grades as compared to lower speed because of better unlocking of cotton and removal of fine dust. Comparatively low colour grade was observed at higher moisture content than lower moisture content for all cottons and all mechanisms.

For mechanism M1, colour grade improved from middling light spotted to (32-2) to middling light spotted (32-1) at 12 per cent moisture content and 300 RPM cylinder speed. For mechanism M2, colour grade improved from middling light spotted to (32-2) to middling light spotted (32-1) at moisture content and speed of 12 per cent and 300 RPM respectively. For M3, cotton colour grade improved from middling light spotted to (33-2) to middling light spotted (32-1) at 12% moisture content and saw band cylinder speed of 200 RPM (Table 4).

Enhancement in ginning efficiency of double roller gin : The main focus of investigation was to enhance ginning efficiency of DR gin by using developed single locking feeding mechanism. All three mechanisms attempted were found to significantly enhance ginning efficiency of DR gin to that of conventional auto feeder. Enhancement in ginning efficiency was worked out in terms of percentage increase in ginning output, degree of unlocking in terms of percentage decrease in Bulk density and reduction in specific energy. Multiple regression analysis with desirability had provided the optimum solution for ginning performance parameters for each mechanism. The response values for output, specific energy and decrease in bulk density obtained by multiple regression analysis for M1, M2 and M3 were compared to the mean values of respective response of control. Data in Table 5 represents enhancement in ginning efficiency of DR with different feeding mechanisms. Ginning output increased by 62.32, 36.80 and 48.53 per cent and specific energy decreased by 27.89, 18.92 and 22.04 per cent for M1, M2 and M3, respectively as compared to conventional auto-feeder. The highest ginning output of 41.23 kg/h and lowest specific energy consumption of 0.0685 kWh/kg was found for M1 *i.e.* spike cylinder type feeder.

Results revealed increase in output of DR gin for short staple cotton with all three mechanisms. It is pertinent to mention that, it was difficult to gin short staple cotton with double roller gin and conventional auto-feeder. But single locking feeding mechanisms significantly increased ginning output of DR gin while ginning short staple cotton. It was mainly due to unlocking of cotton bolls which created more opportunity for more fibres to come in contact with ginning roller and get ginned faster which otherwise not possible with the conventional mechanism.

Table 6. Post hoc analysis of different feeding mechanisms on ginning efficiency

Parameters	M1	M2	M3	Control
Ginning performance parameters				
Output (kg/h)	33.6[a]	30.9[a]	32.0[a]	25.9[b]
Bulk density (kg/m^3)	49.24[a]	50.73[a]	49.09[a]	59.00[b]
Decrease in bulk density (%)	17.08[a]	13.69[a]	16.76[a]	0.00[b]
Specific energy (kWh/kg)	0.078[a]	0.081[a]	0.080[a]	0.093[b]
Trash content (%)	2.21[a]	2.64[b]	2.24[a]	2.67[b]
HVI fibre quality parameters				
UHML (mm)	18.9[a]	19.0[a]	19.0[a]	19.0[a]
UI (%)	74.1[a]	74.3[a]	74.3[a]	73.7[a]
MIC (μg/inch)	7.2[a]	7.2[a]	7.1[a]	7.2[a]
Tenacity (g/tex)	21.2[b]	21.3[a]	21.4a	21.4[a]
SFI (%)	60.9[a]	62.6[a]	63.0[a]	60.3[a]
Rd (%)	73.2[a]	72.8[a]	73.0[a]	70.9[b]
Plus b	10.3[a]	10.3[a]	10.4[a]	10.4[a]
AFIS fibre quality parameters				
UQL (w) (mm)	19.3[a]	19.3[a]	19.4[a]	19.4[a]
Fibre neps (c/g)	85.9[a]	86.0[a]	88.5[a]	86.3[a]
Seed coat neps (c/g)	34.4[b]	34.5[b]	34.3[b]	28.2[a]
Total trash (c/g)	338[a]	433[ab]	347[a]	502[b]

Post hoc analysis for comparative assessment of different feeding mechanisms : In order to explore the specific differences between the different feeding mechanisms, the post-hoc test was carried out. For the post-hoc analysis, mean values of ten replications of ginning performance parameters and fibre quality parameters obtained using different feeding mechanism were taken. The comparisons of means of the ginning performance parameters and fibre quality parameters obtained using three different feeding mechanism and control (conventional auto-feeder) was done using Tukey's test or Tukey's HSD.

The effect of different feeding mechanism to improve the ginning efficiency for short staple cotton was analyzed using the t-test. The results showed that the feeding mechanisms (M1, M2 and M3) improved ginning efficiency in terms of ginning output, decrease in bulk density, specific energy and trash content compared to control. The different feeding mechanism did not affect HVI and AFIS quality parameters. The analysis also revealed that use of feeding mechanisms has significantly improved colour grade of the cotton being processed as reflected from the values of degree of reflectance. Overall results showed improvement in ginning efficiency with use of feeding mechanisms developed based on the concept of single locking of cotton bolls.

Data in Table 6 depicted the post-hoc analysis of different feeding mechanisms for short staple cottons. The post hoc analysis done to differentiate the significant difference among the different mechanism being studied. Post hoc analysis showed that Mechanisms M1, M2, M3 and control are significantly different from each other. Post hoc analysis revealed no significant difference in M1, M2 and M3, however ginning performance was found significantly different than control. It was also observed that mechanism (M2) created more fibre and seed coat neps which is not desirable. Mechanism M2 did not aid in reducing the trash content in cotton. Further the improvement in ginning efficiency was comparatively less in case of M2 than M1 and M3. The study revealed that mechanism M3 performed comparatively better than M2 in terms of improvement in ginning efficiency. The comparative analysis revealed that among the three mechanisms (M1, M2 and M3) studied, spike cylinder type single locking cotton feeder (M1) was the best mechanism followed by M3 and M2 in terms of improvement in ginning efficiency of double roller gin. Overall results indicated that spike cylinder cotton feeder (M1) based on the principle of single locking of seed cotton ensured uniform feeding with improved ginning efficiency as compared to conventional autofeeder for ginning of short staple cotton.

CONCLUSIONS

Three mechanisms *viz.,* spike cylinder single locking cotton feeding mechanism (M1), saw band cylinder single locking cotton feeding mechanism (M2) and combination of spike cylinder single locking cotton feeding mechanism with conventional autofeeder (M3) were successfully designed and developed based on the concept of single locking of cotton bolls. It may be concluded that among the three developed mechanism,spike cylinder single locking cotton feeder (M1) is a better option to improve the ginning performance of double roller gin for short staple cotton as compared to conventional auto feeder. The study found that ginning output were increased by 62.32, 36.80 and 48.53 per cent while specific energies were decreased by 27.89, 18.92 and 22.04 per cent for spike cylinder feeder, saw band feeder and combined feeder, respectively as compared to conventional auto feeder.Spike cylinder feeder showed higher colour grade improvement. However other fibre quality parameters tested by HVI and AFIS remain unaffected.

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Received for publication : August 13, 2018
Accepted for publication : December 20, 2018