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Influence of material of spindle and surface texture on cotton left over and spilled over under variable conditions for picking cotton

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■ **ABSTRACT :** Cotton is one of the major commercial crops being cultivated both in irrigated and in rain fed conditions in many states of the country. India ranks third in global cotton production after China and the USA. In India harvesting of cotton is done manually by hand picking. Manual picking is not only tedious and labour consuming but also costlier than other agricultural operations. In recent years it has been observed that labour availability is scarce during peak periods of cotton harvesting. The use of mechanical picking by machine is, therefore, considered to be a viable option in minimizing the drudgery involved in hand picking. By keeping these factors in view, the present investigation was undertaken to study the mechanism involved in picking of cotton by the rotating spindles. The spindles were fabricated with the materials selected for the study and they were evaluated for their performance in picking cotton from bolls under laboratory conditions. The cotton left over and cotton spilled under variable conditions ranged from 0 to 30.33 per cent and 0 to 41.35 per cent for the selected varieties. The cotton left over and cotton spilled over were observed to be minimum with hylum spindle for all the varieties. The cotton left and cotton spilled over were minimum upto the speed of 2000 rpm and increased greatly with the increase in speed of rotation of 2500rpm and higher speeds. The cotton spilled over was minimum at higher level of moisture and cotton left over was minimum at lower moisture levels. The surface texture of the spindles did not show any particular trend of increase or decrease of cotton left over and cotton spilled over.

■ **KEY WORDS :** Cotton picking, Picking spindles, Cotton leftover, Spindle speed

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Cotton is one of the important commercial crop in India. It sustains the country's cotton textile industry, which is perhaps the largest segment of organized industries in the country. Textile industry contributes about 5 per cent to the GDP and 30 per cent to export earnings. India earns foreign exchange to the tune of $10-12 billion from exports of cotton yarn, thread, fabrics, apparel and made-ups. Cotton provides gainful employment to millions of people in the country who are engaged in its cultivation, trading, processing, manufacturing, fabricating and marketing. Cotton accounts for more than 75 per cent of the total fibre that is converted into yarn by spinning mills in India and 58 per cent of the total textile fabric material produced in the country.

India accounts for approximately 23 per cent of total

area of cotton being produced in the world, but the average productivity of cotton is markedly low at about 268 kg/ha as compared to the world average of 563 kg/ha per year.

In India harvesting of cotton is done manually by hand picking. Manual picking is not only tedious and labour consuming but also costlier than other agricultural operations. In recent years it has been observed that labour availability is scarce during peak periods of cotton harvesting. The use of mechanical picking by machine is, therefore, considered to be a viable option in minimizing the drudgery involved in hand picking. The mechanical cotton picking system will also be helpful in facilitating timeliness in operations for the next crop.

Due to the staggered blooming characteristics of Indian cotton varieties, mechanical pickers are not considered suitable for Indian farming conditions. As per the available reports, the research on mechanical picking or cotton pickers are very meager or no information is available in India. Consequently this area of research and development needs immediate attention of researchers for development of suitable mechanical pickers. As the biological scientists are gearing upto develop suitable cotton varieties which are amenable to mechanical picking, it is necessary to develop/ identify a mechanical picker suitable for cotton crop cultivated in Indian conditions.

Harvesting of cotton is being done either by hand picking or by machine. It is estimated that about 6 million tonnes or 30 per cent of the total cotton produced in the world is picked mechanically. All the cotton grown is picked only by machine in Australia, Israel and the U.S.A. (Smith, 1964). Over 90 per cent of cotton produced is machine-picked in Greece, Mexico and Spain. Almost 75 per cent of total production of cotton is picked by machines in Brazil. In most of the other countries including in China, India and Pakistan, three of the five largest cotton producing countries in the world the entire cotton is picked manually. Two types of machines namely; strippers and spindle pickers are used to pick cotton mechanically (Kepner *et al.*, 1978).

In India the entire cotton grown either in rain fed or in irrigated conditions is hand-picked manually. Normally farmers will go for 2 to 5 pickings of cotton till the final stage of harvesting of crop is being done. It is expected that 85 per cent of the seed cotton is picked during the initial three pickings and the subsequent pickings some times may not be economical even by manual labour. Manual picking is not only drudgerous and tedious but also it is costlier and time consuming. Studies have shown that recovery of lint is more in case of machine-picked cotton than that of machine-stripped seed cotton due to presence of lower trash content.

By Keeping these factors in view, an attempt has been made to identify crop machine and operational variables which influence on the picking mechanism of the cotton pickers and to develop the picking spindles and to conduct exhaustive trials using different spindles for picking cotton under variable conditions and their suitability for different varieties grown in the region.

METHODOLOGY

The present investigation was undertaken to study the mechanism involved in picking of cotton by the rotating spindles. The biometric parameters of the selected varieties of cotton crop were noted down which are useful for development of test rig. The criteria adopted for development of spindles of different materials, development, fabrication and working of the test rig are explained. The details of the tests conducted for the measurement of performance parameters are also given.

Mechanics of picking :

The basic principle of the revolving spindle is penetrating through the cotton plant, winding the seed cotton from the open boll and retracting to a doffing zone, which is employed by all the commercial pickers now available (Hesston, 1962 and Corely, 1966). The rearward movement of the spindles, while in the picking zone is substantially the same as the forward movement of the machine, generally 3.2 to 5.6 km/hr, so that the spindle while in the picking zone, do not move forward or backward with respect to the cotton plant. Each rotating spindle merely probes straight into the cotton plant from the side of the row and works on an open boll if it encounters one and then withdraws straight with a minimum of disturbance and damage to the reminder of the plant. The spacing of the spindles, approximately 38x38mm, is such that they can slip past unopened bolls and leave them on the plant to mature for a latter picking.

The spindles are carried either on bars arranged in vertical drums or on vertical slats attached to the endless chain belts. Tapered spindles are commonly employed on drum type pickers and have three to four longitudinal

rows of sharp barbs or grooves for engaging the cotton. The tapered shape facilitates easy removal of the cotton (doffing) after they leave the picking zone. Spindle speeds range from 1850rpm at a forward speed of 2.9km/h to 3250rpm at 5.0km/h (Prasad *et al*., 2007).

Biometric parameters of test crop :

The measurement of biometric parameters of cotton crop helps in fixing the optimum dimensions of the test rig to facilitate the movement of the spindle in horizontal, vertical and transverse directions to pick the cotton from the bolls. The details of cotton crop with respect to selection of varieties, procedure for measurement of various physical parameters are discussed in this section.

Selection of varieties :

The cotton crop presently grown by the farmers of the region are mainly BT cotton varieties and a few hybrids. The selection of cotton crop varieties for the study was done by keeping in view the different varieties grown in the region. Three predominantly grown varieties of cotton crop were selected from within the BT cotton and hybrid varieties grown in the region.

Size of spindles :

The dimensions of spindles were decided by considering the size of spindles available on the existing cotton pickers.

Development of test rig for evaluation of picker spindles :

A laboratory test rig was developed to facilitate for testing the performance of spindles at different peripheral speeds. The test rig developed had the provision to move the spindle in all three directions i.e, horizontal, vertical and transverse directions. The test rig was fabricated by using standard fabrication techniques. Two variable speed dc motors were selected, one for rotating the spindle at different speeds and the other to move the spindle in all three directions. The test rig was mounted on a table attached to a pedestal. The test rig can be moved up and down along with the table by rotating the handle.

Selection of variables of study :

The evaluation of the picking spindles were carried out by taking into consideration the different independent variables. The working of the spindles under variable conditions influenced the different parameters, these parameters were considered as dependent variables.

Independent variables :

Material type	**4 levels**
– Mild steel	M_1
– Aluminum	M_2
– Nylon	M_3
– Hylum	M_4
Surface texture	**3 levels**
– Tapered plain	S_1
– Tapered with grooves	S_2
– Tapered with grooves and knurl	S_3
Spindle speed	**5 levels**
– 1000 rpm	N_1
– 1500 rpm	N_2
– 2000 rpm	N_3
– 2500 rpm	N_4
– 3000 rpm	N_5
Moisture content	**3 levels**
– 2.5 – 3.5 %	mc_1
– 3.5 – 4.5 %	mc_2
– 4.5 – 5.5 %	mc_3
Varieties	**3 levels**
– NHH-44	
– NCH-145	
– RCH-2	
Replications	**3**

Dependent variables

– Weight of cotton left over in the boll, g
– Weight of cotton spilled over, g

Measurement techniques for various parameters of study :

The spindles developed for the study were evaluated under variable conditions at College of Agricultural Engineering, Raichur, for their performance with the help of the developed test rig.

Laboratory tests were conducted to evaluate the performance of selected spindles at three levels of moisture content and five different spindle speeds. The cotton left over in the boll and cotton spilled over were observed and recorded during the trials. The methodology followed is as under.

Spindle speed :

The different types of spindles developed for the study were rotated by holding them in the chuck of the variable speed motor in the test rig. The spindle speed is recorded as indicated in the digital speed indicator attached to the test rig. The different speeds required for the study were obtained by regulating the speed with the help of a dimmer connected to the motor.

Moisture content of cotton :

The moisture content of cotton from each boll was measured by using a digital moisture meter. The digital moisture meter was pre calibrated by adopting the standard procedure. The cotton picked from the boll was filled in the cup and the ram was pressed against the cotton in the cup by rotating the handle for required number of revolutions. The moisture content was noted on the indicator panel.

Cotton left over in the boll :

The quantity of cotton left over in the boll after picking with the spindles was recorded by detaching the left over cotton and weighing in an electronic balance.

Spilled over cotton :

While conducting tests some amount of cotton detached from the rotating spindle and spilled away. This spilled over cotton was collected and weighed by using an electronic balance.

Picking efficiency :

The picking efficiency of cotton by each spindle type under variable conditions for three varieties of cotton was calculated using the following formula.

$$n_p = \frac{n_1 - n_2}{n_1} \times 100 \quad (1)$$

where, n_p = Picking efficiency, per cent

n_1 = Total weight of cotton, g

n_2 = Weight of the cotton left over in the boll, g

RESULTS AND DISCUSSION

The observations on the different parameters were recorded as per the methodology discussed earlier. The spindles were fabricated with the materials selected for the study and they were evaluated for their performance under laboratory conditions for picking the cotton from the bolls. The spindles were evaluated at variable conditions with the help of the test rig developed for the purpose and the cotton left over and spilled over by the spindles was recorded.

Varieties taken for study :

Selection of cotton varieties for the study was done by keeping in view the different varieties grown in the region. Three most promising varieties of cotton crop grown in this region namely NHH-44 a hybrid variety and NCH-145 and RCH-2 from BT cotton varieties were selected for the study.

Development of picking spindles :

The development of spindles was carried out by considering various boll parameters and the spindles were fabricated by adopting standard fabrication techniques and also by taking into consideration the shape, surface texture and size of the spindles available in the existing cotton pickers.

Selection of the materials :

The selection of the material for spindles was done by taking into consideration the machinability aspects, availability and the cost of the materials. Four types of material namely mild steel, aluminum, nylon and hylum were selected for the study.

Selection of surface texture :

The shape and surface texture of the spindle were selected by considering the ease of picking, ease of doffing, machinability aspects etc. The tapered shape was commonly adopted for all the materials. Three types of surface textures namely tapered plain, tapered with grooves and tapered with grooves and knurl, were selected for study. The surface texture was formed by adopting standard fabrication techniques.

Size of spindles :

The size of spindle was determined by considering the spindles available on the existing cotton pickers. The total length of the spindle is 125 mm out of which the length of the tapered portion is 75mm. A length of 25mm on the other side of the spindle is used for holding the spindle with the chuck for rotating the spindle. The diameter of the spindle is 10mm at the larger end of the taper and is 2 mm at the smaller end of the taper.

Development of test rig for evaluation of picking of cotton by spindles :

The biometric observations of the crop were considered for the development of test rig. The test rig was fabricated by using standard fabrication techniques. Two variable speed dc motors of 0.25 hp were used, one for rotating the spindle at different speeds and the other to move the spindle. A regulator is provided to vary the speed of the motor from 0 to 3000 rpm. An electronic speed indicator is provided to display the speed of rotation of the spindle. The test rig is mounted on a table attached to a pedestal. The test rig can be moved up and down along with the table by rotating the handle. The height of the pedestal was fixed as 125 cm so that it can guide the spindle to the level of the uppermost boll. The arm of the table is pivoted to the pedestal so that it can swing at any angle required. The arm of the table can move forward upto 75 cm to facilitate the spindle to reach the boll nearest to the stem. The table can also move in the transverse directions to reach the bolls at the extreme ends of the plant.

Evaluation of picking spindles under variable conditions :

The spindles were evaluated at College of Agricultural Engineering, Raichur, for their performance with the help of the test rig, under variable conditions.

The laboratory evaluation of the above spindles were carried out for three varieties of cotton namely NHH-44, NCH-145 and RCH-2, at three range of moisture contents namely 2.50 to 3.50 percent, 3.50 to 4.50 per cent and 4.50 to 5.50 per cent and five speeds in the range of 1000 to 3000 rpm with steps of 500 rpm. The cotton left over and spilled over was observed during the trials.

Cotton left over in the boll :

The cotton left over in the boll for different varieties under variable conditions is shown in Fig.1 to 12. The cotton left over in the boll after picking by the spindles under variable conditions ranged from 0 to 30.33 per cent for the selected varieties. The cotton left over in the boll observed to be minimum with mild steel and hylum spindles at lower speeds for all the varieties. The speed of rotation greatly influenced the cotton left over. The percentage of cotton left over was minimum at lower speeds upto 2000 rpm and increased with the increase in speed of rotation above 2500 rpm. This is because of the smoother winding of cotton at the time of picking at lower speeds. The moisture content also influenced the

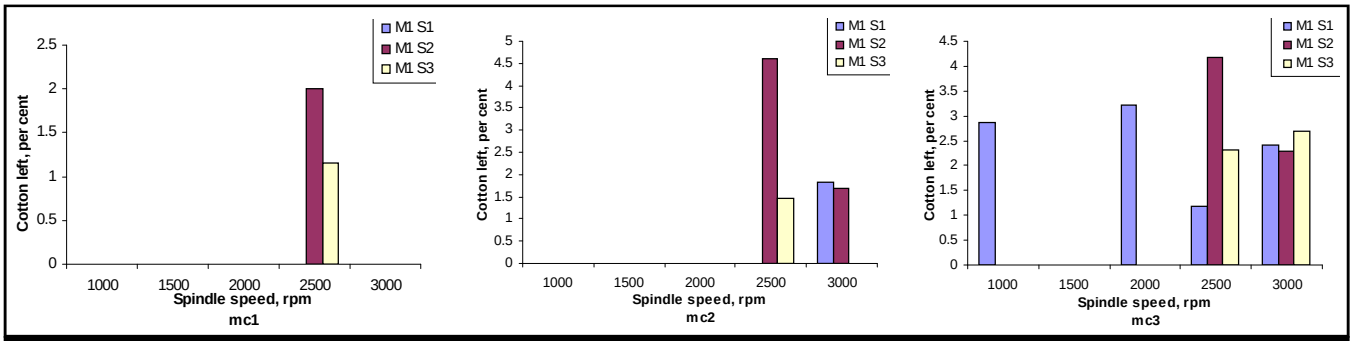

Fig. 1 : Cotton left over by mild steel spindle under variable conditions for NHH-44 variety

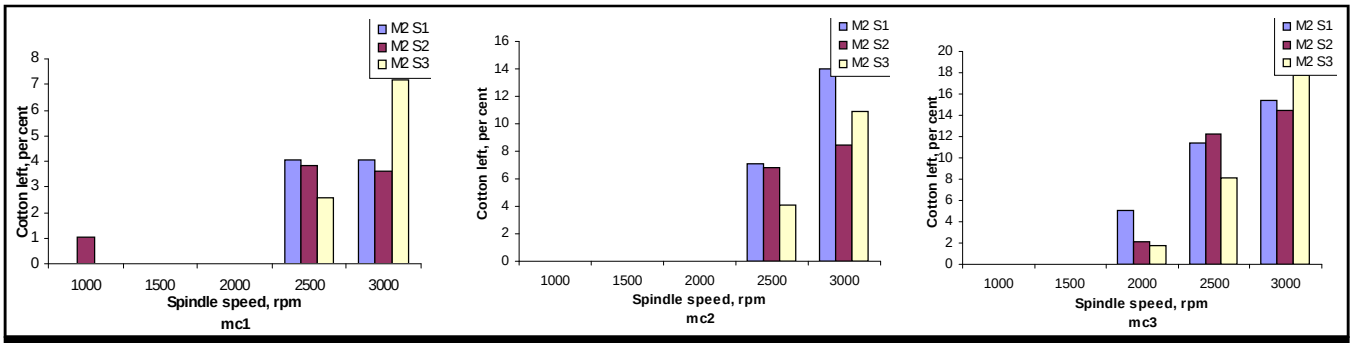

Fig. 2 : Cotton left over by aluminum spindle under variable conditions for NHH-44 variety

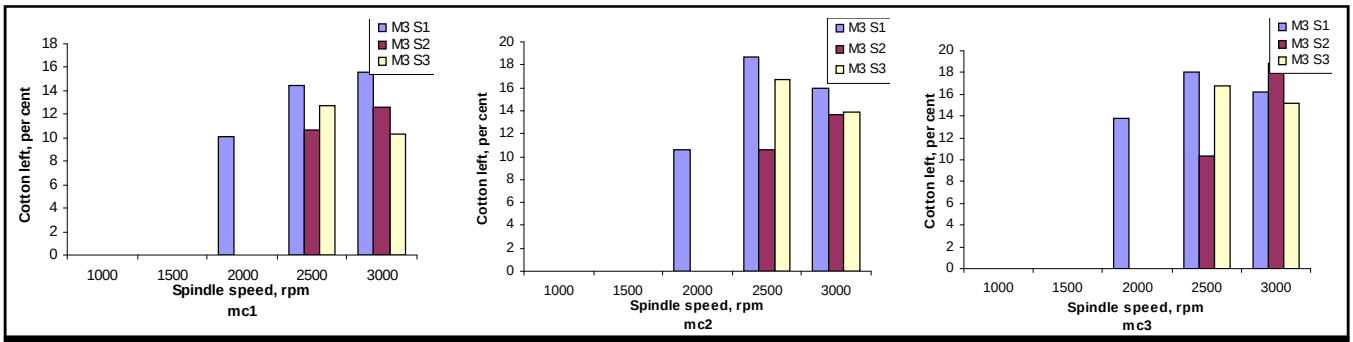

Fig. 3 : Cotton left over by nylon spindle under variable conditions for NHH-44 variety

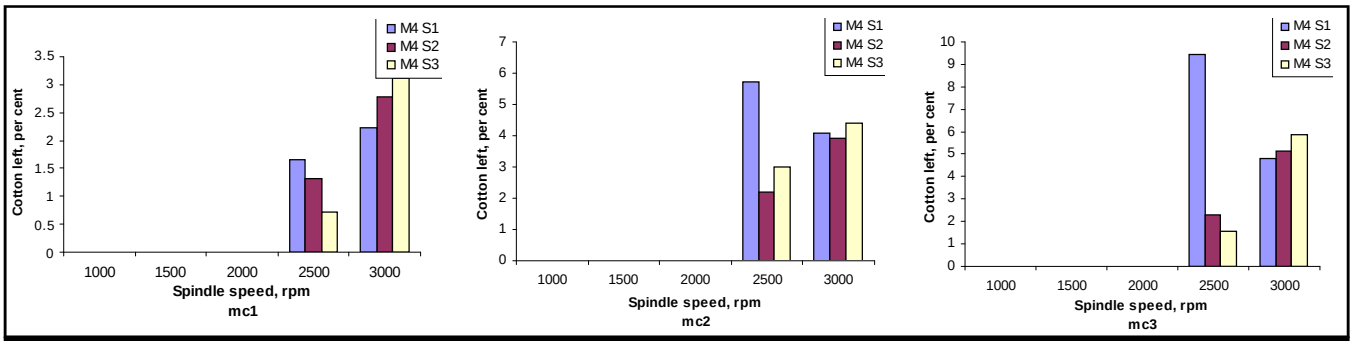

Fig. 4 : Cotton left over by hylum spindle under variable conditions for NHH-44 variety

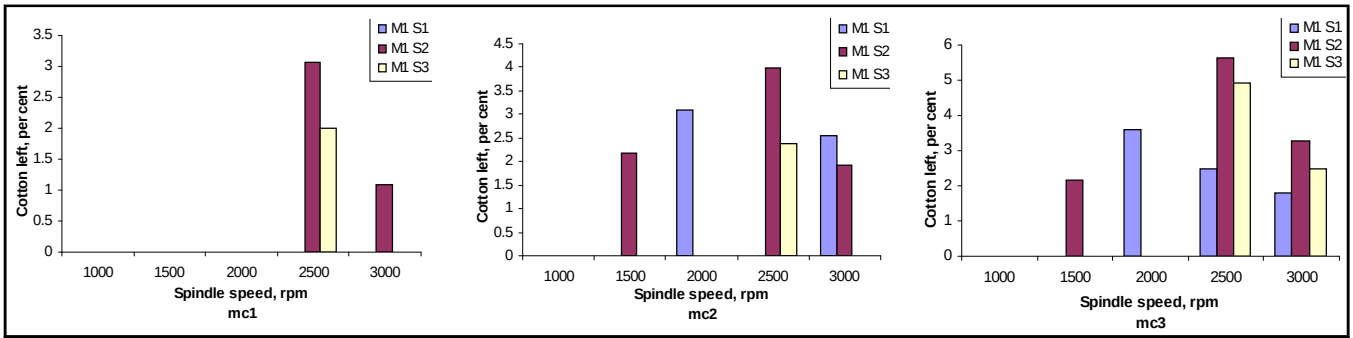

Fig. 5 : Cotton left over by mild steel spindle under variable conditions for NCH-145 variety

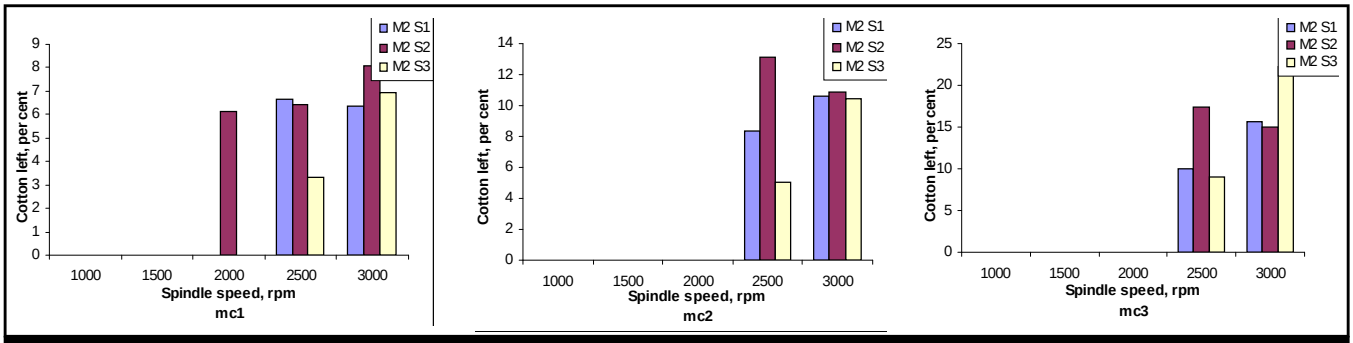

Fig. 6 : Cotton left over by aluminum spindle under variable conditions for NCH-145 variety

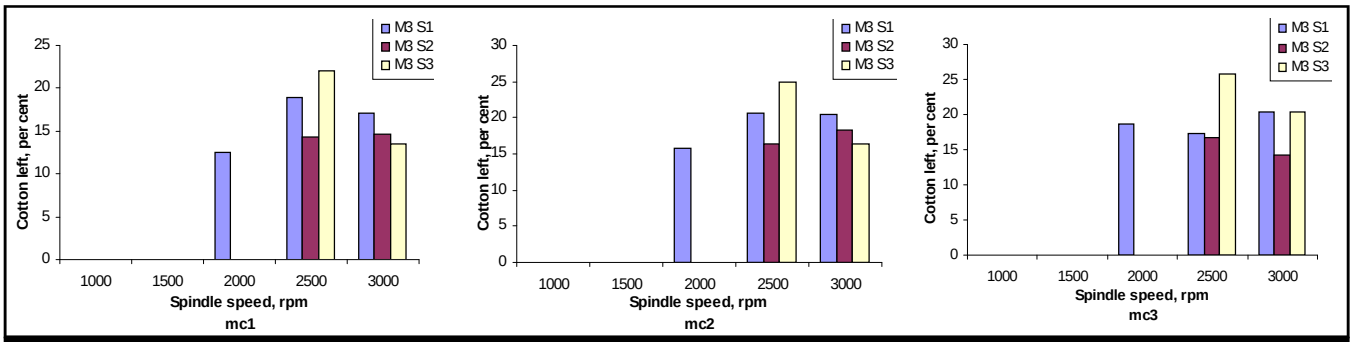

Fig. 7 : Cotton left over by nylon spindle under variable conditions for NCH-145 variety

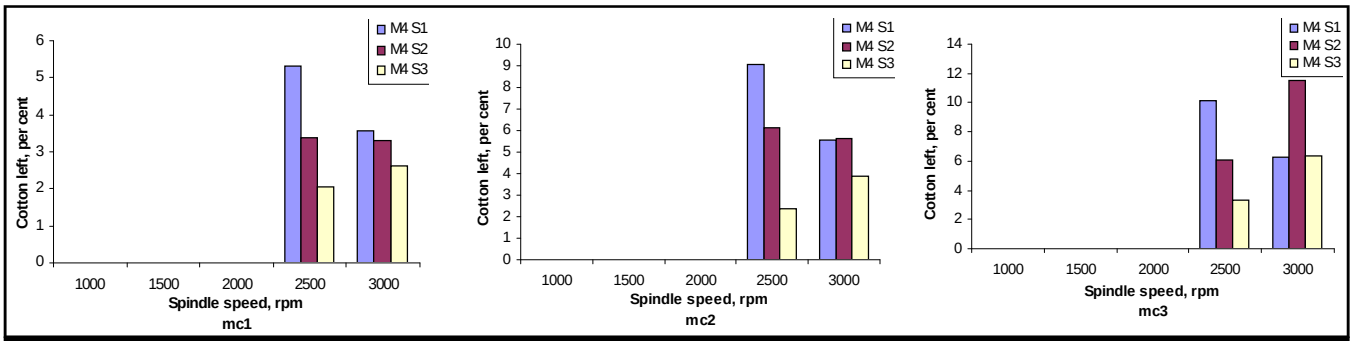

Fig. 8 : Cotton left over by hylum spindle under variable conditions for NCH-145 variety

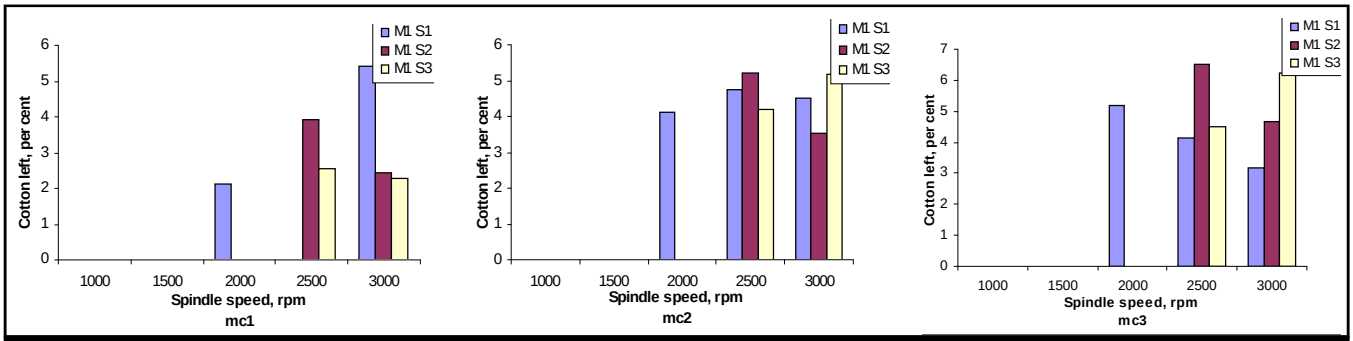

Fig. 9 : Cotton left over by mild steel spindle under variable conditions for RCH-2 variety

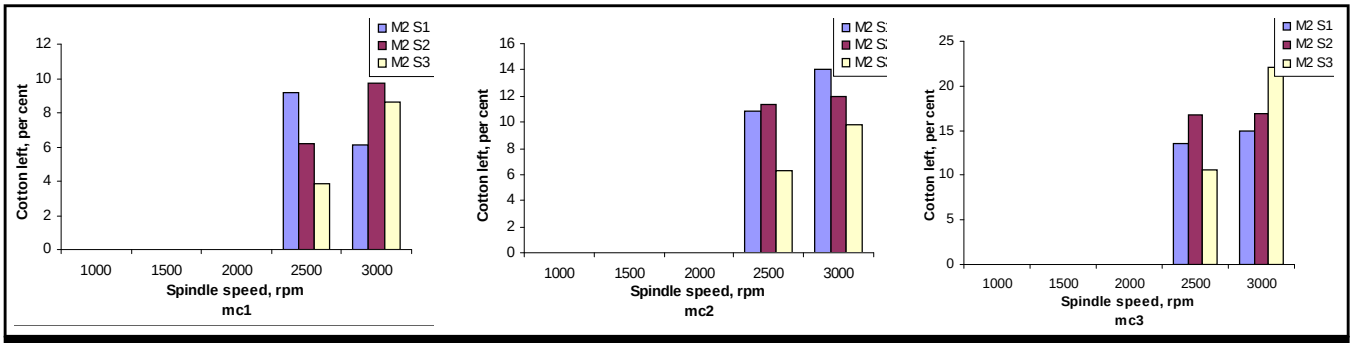

Fig. 10 : Cotton left over by aluminum spindle under variable conditions for RCH-2 variety

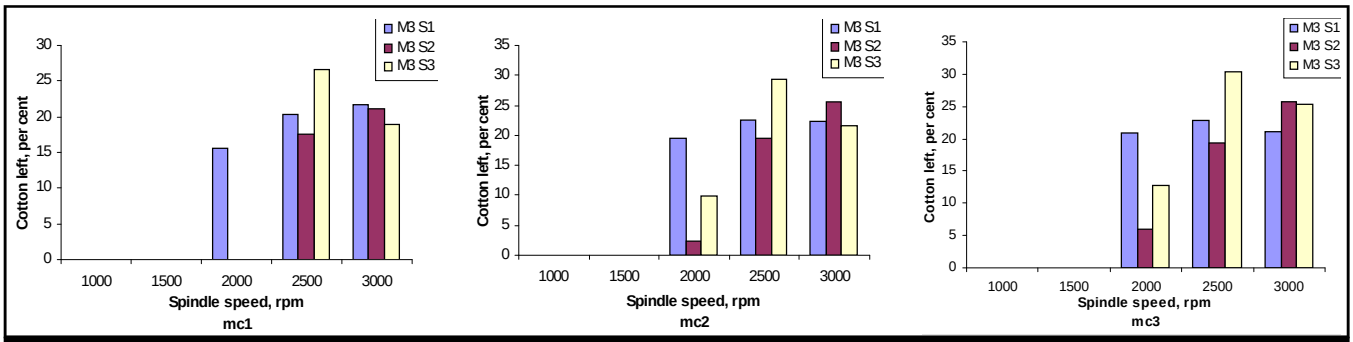

Fig. 11 : Cotton left over by nylon spindle under variable conditions for RCH-2 variety

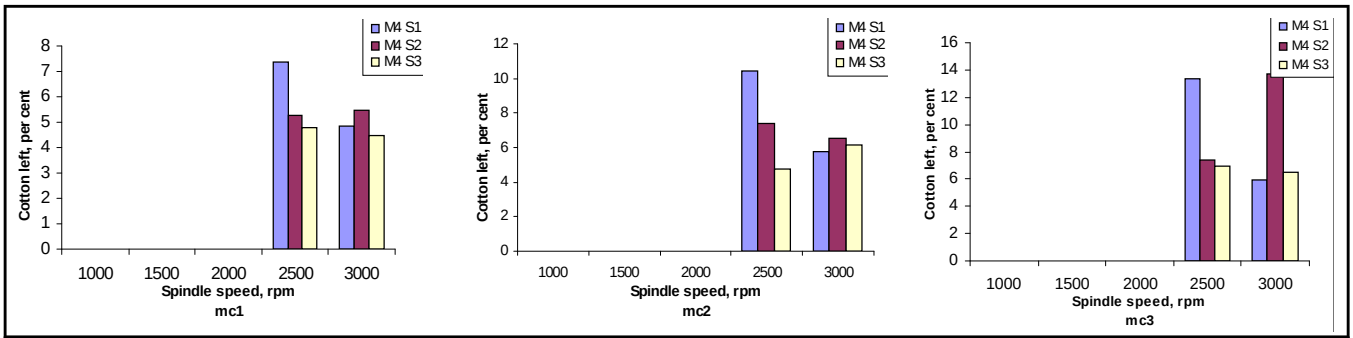

Fig. 12 : Cotton left over by hylum spindle under variable conditions for RCH-2 variety

amount of cotton left in the boll. The cotton left over increased with the increase in moisture content at higher speeds above 2500 rpm, which was due to the higher force of attachment of cotton with the locks at higher levels of moisture content. The surface texture of the spindles did not show any particular trend in the increase or decrease of left over cotton.

Cotton spilled over :

The cotton spilled over for different varieties under variable conditions is shown in Fig.13 to 24. The cotton spilled over after picking by the spindles under variable conditions ranged from 0 to 41.35 per cent for the selected varieties. The maximum cotton spilled over was observed to be minimum with hylum spindles which was almost at par for mild steel spindles for all the varieties this was due to lesser time taken by the spindles particularly at lower speeds. The speed of rotation greatly influenced the cotton spilled over. The percentage of cotton spilled over lowest at lesser speeds upto 2000 rpm and significantly increased with the increase in speed of rotation of 2500 rpm and above. This is because of the centrifugal force acting on the picked cotton at higher speeds. The moisture content also influenced the amount

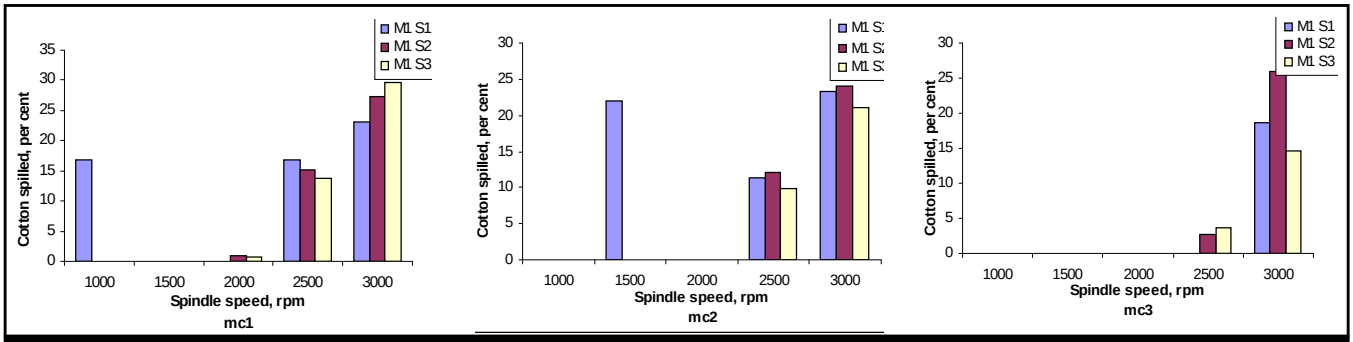

Fig. 13 : Cotton spilled over by mild steel spindle under variable conditions for NHH-44 variety

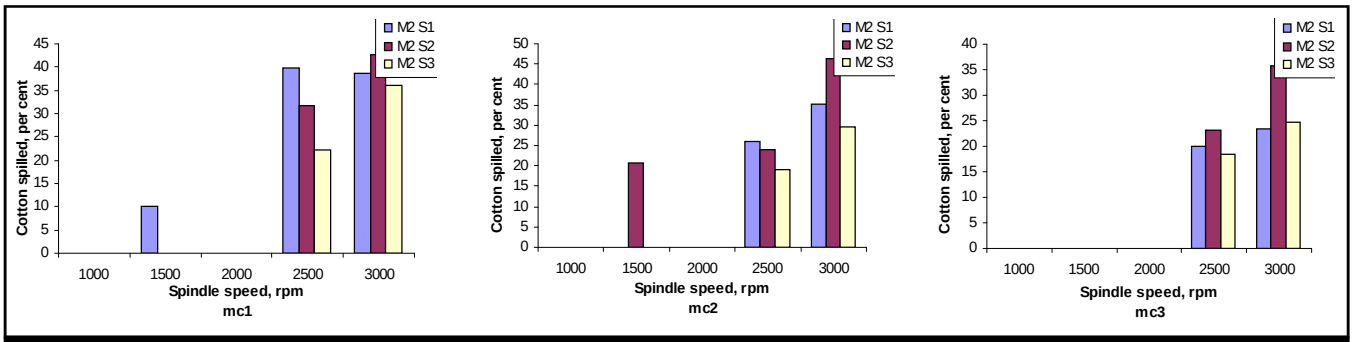

Fig. 14 : Cotton spilled over by aluminum spindle under variable conditions for NHH-44 variety

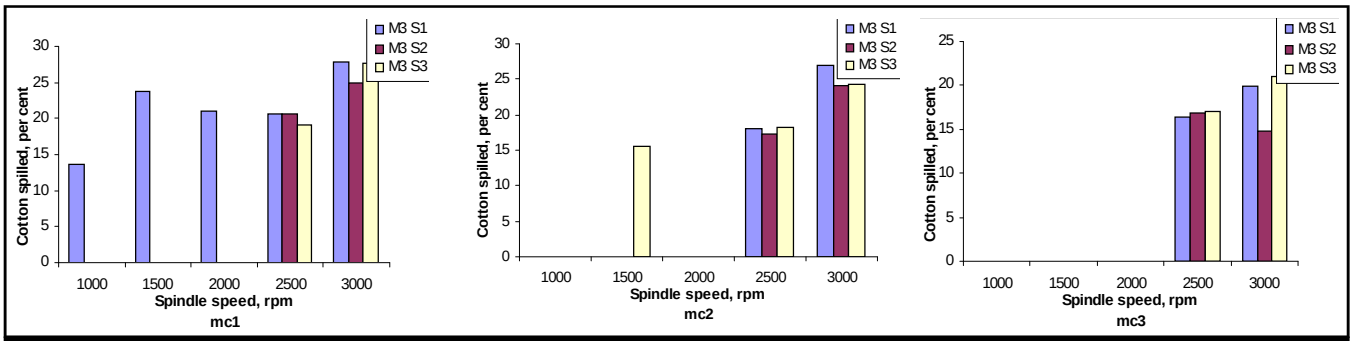

Fig. 15 : Cotton spilled over by nylon spindle under variable conditions for NHH-44 variety

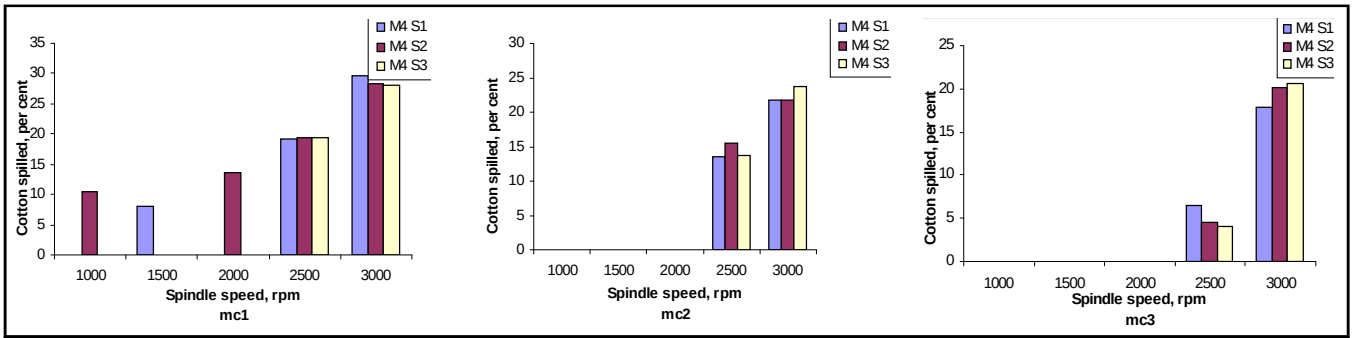

Fig. 16 : Cotton spilled over by hylum spindle under variable conditions for NHH-44 variety

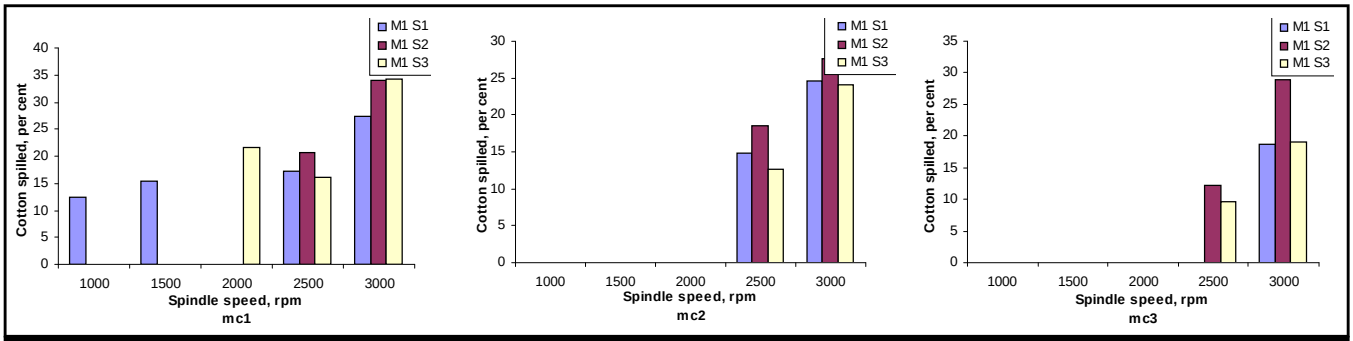

Fig. 17 : Cotton spilled over by mild steel spindle under variable conditions for NCH-145 variety

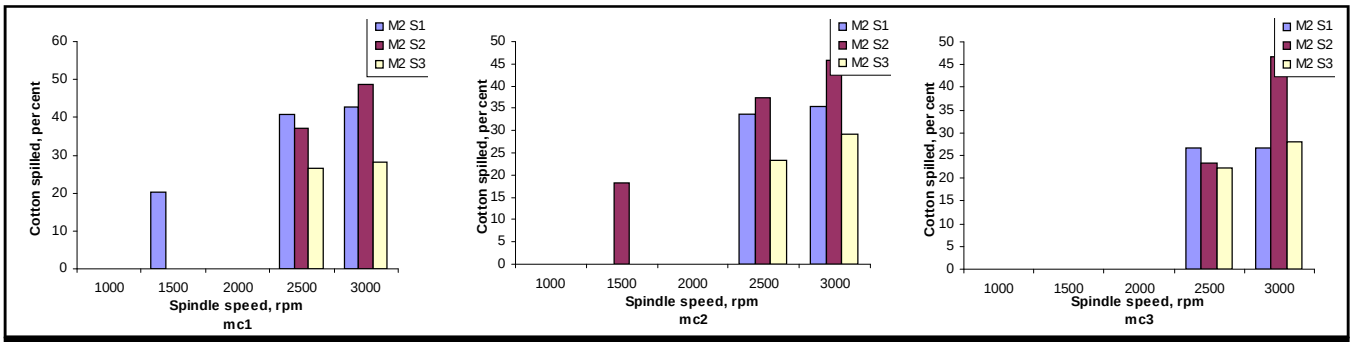

Fig. 18 : Cotton spilled over by aluminum spindle under variable conditions for NCH-145 variety

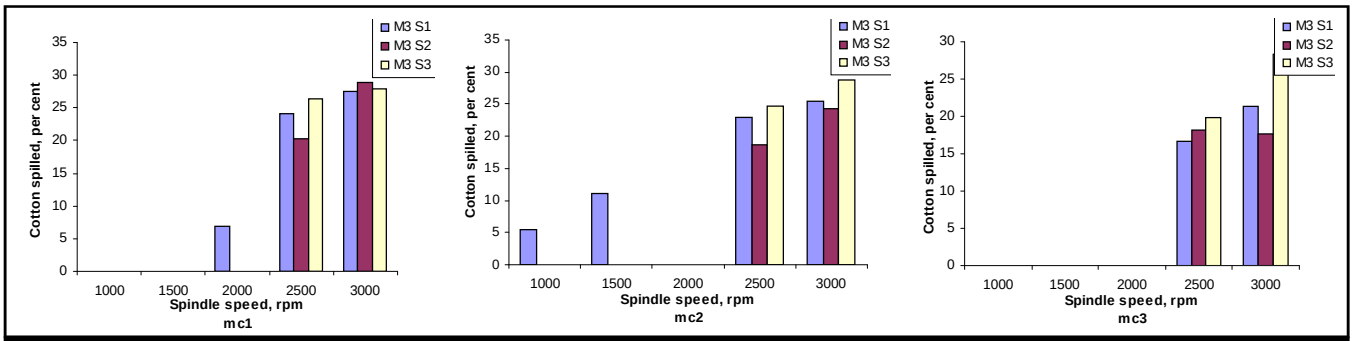

Fig. 19 : Cotton spilled over by nylon spindle under variable conditions for NHH-44 variety

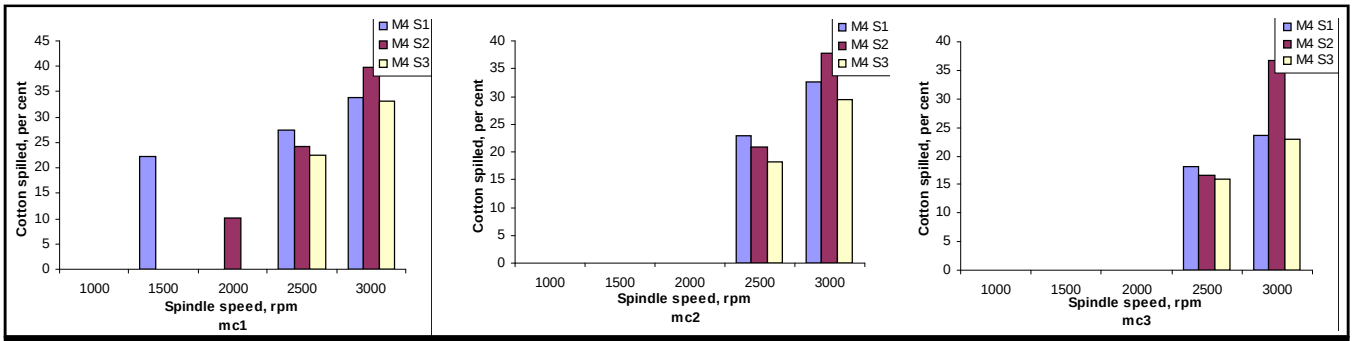

Fig. 20 : Cotton spilled over by hylum spindle under variable conditions for NCH-145 variety

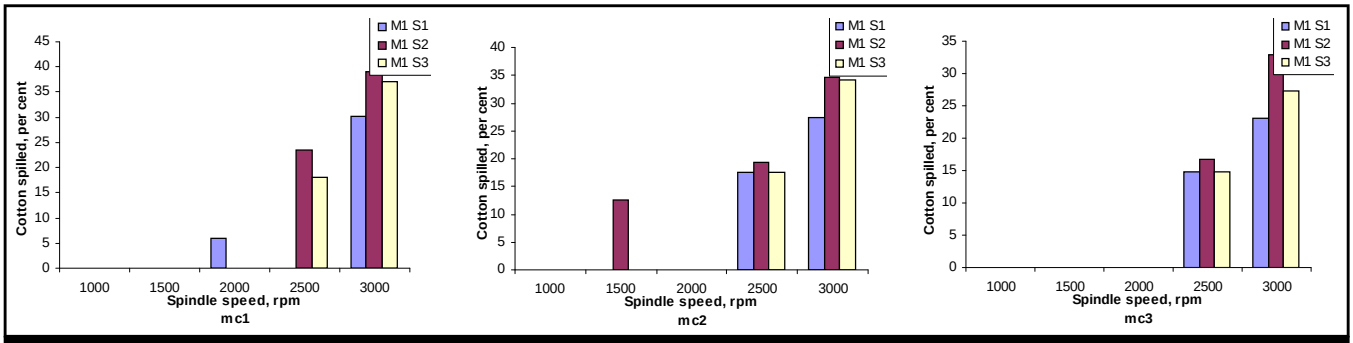

Fig. 21 : Cotton spilled over by mild steel spindle under variable conditions for RCH-2 variety

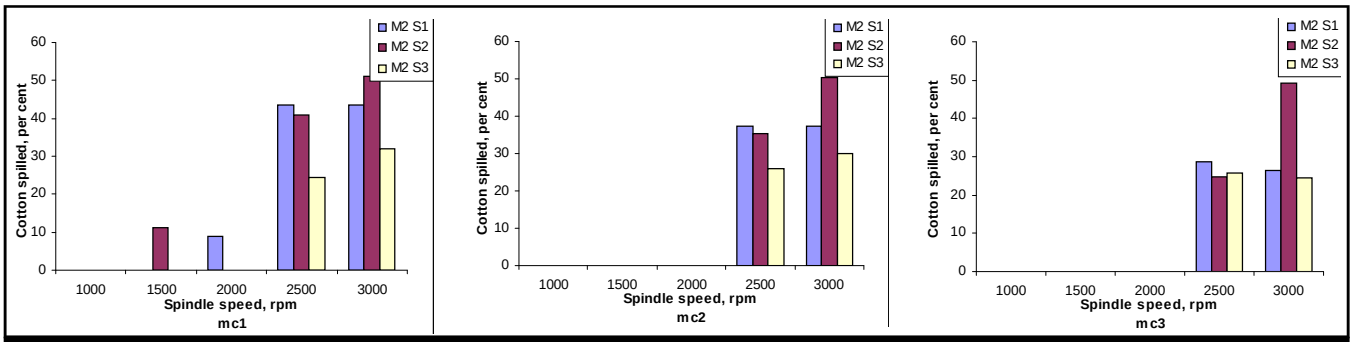

Fig. 22 : Cotton spilled over by aluminum spindle under variable conditions for RCH-2 variety

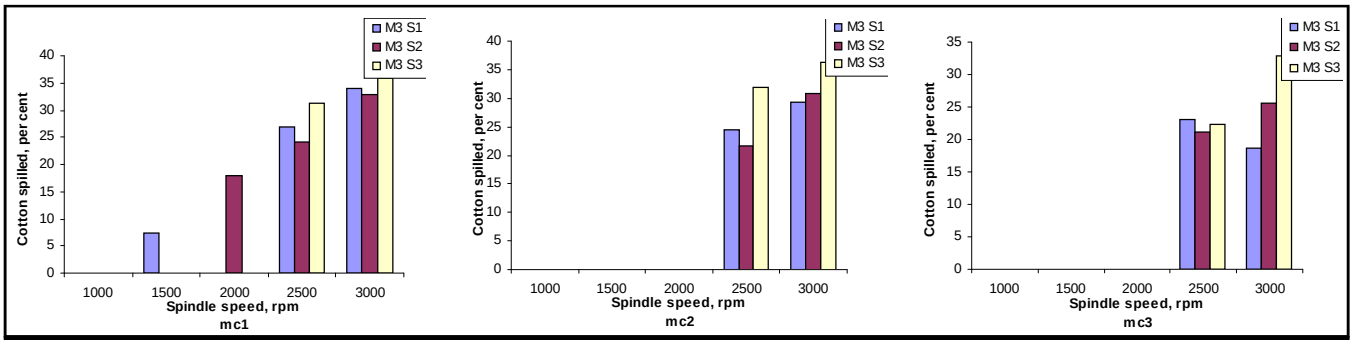

Fig. 23 : Cotton spilled over by nylon spindle under variable conditions for RCH-2 variety

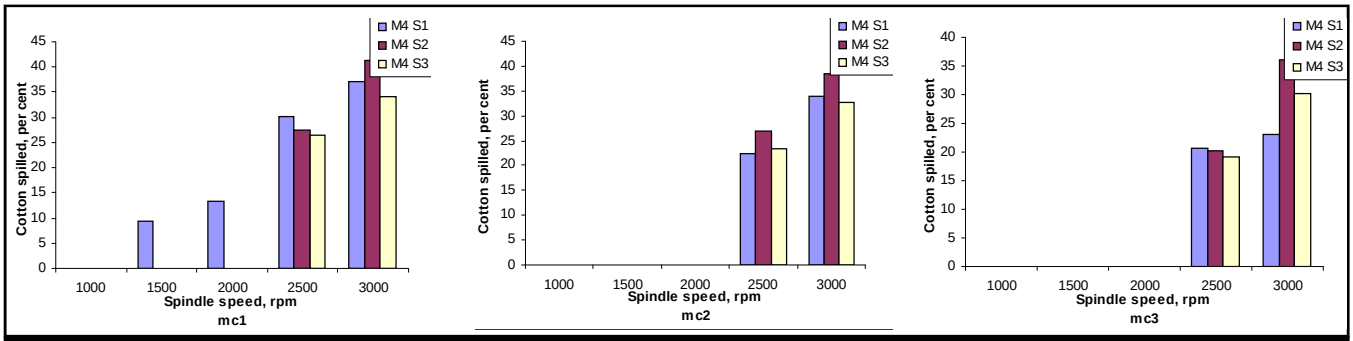

Fig. 24 : Cotton spilled over by hylum spindle under variable conditions for RCH-2 variety

of cotton spilled over. The cotton spilled over increased with the decrease in moisture content particularly at speeds above 2500 rpm, because of the lesser detaching force required by cotton at lower moisture content. The surface texture of the spindles did not show any particular trend in the increase or decrease of spilled over cotton.

Conclusion :

The conclusion drawn from the study are, the laboratory trials of the spindles revealed that, the maximum cotton left over in the boll observed to be minimum with mild steel and hylum spindles at lower speeds for all the varieties. The percentage of cotton left over was minimum at lower speeds upto 2000 rpm and increased with the increase in speed of rotation above 2500 rpm. The cotton left over increased with the increase in moisture content at higher speeds above 2500 rpm.

The maximum cotton spilled over was observed to be minimum with hylum spindles which was almost at par with mild steel spindles for all the varieties. The percentage of cotton spilled over lowest at lesser speeds

upto 2000 rpm and significantly increased with the increase in speed of rotation of 2500 rpm and above. The cotton spilled over increased with the decrease in moisture content particularly at speeds above 2500 rpm.

The above conclusions drawn from the study help in getting the basic information regarding the mechanism of picking with the spindles under variable conditions of picking. This helps in building a base for further development of cotton picker indigenously and also to develop suitable varieties of cotton crop for efficient picking of cotton by machine pickers.

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