Agric. Rev., 28 (2) : 118-126, 2007

MECHANICAL PICKING OF COTTON - A REVIEW

M. Muthamilselvan, K. Rangasamy[1], D. Ananthakrishnan[2], R. Manian[3]

Agricultural Energy and Power Division, Central Institute of Agricultural Engineering, Nabi Bagh, Berasia Road, Bhopal - 462 038, India.

ABSTRACT

The cost of cotton production is excessively high, reducing the profit margin available to the farmer. Picking is one of the major labour intensive operations in cotton cultivation consuming the lion's share of the expenditure. Hence the only option available is the mechanical picking method. The development of cotton picker will be the first step into the mechanization of cotton cultivation. Cotton harvesters are of two basic types, viz, picker and stripper. The picker is selective where as stripper is non-selective. Modern strippers can be classified according to two general stripping principles. The finger principle and the roll principle, whereby the plants pass between two inclined rotating rollers or between a roller and a stripping bar, Strippers are most successful in the areas where plants are small and the fibres are rather short, hard bodies and easy to clean. By reviewing the mechanical picking methods, it may be concluded that by considering the cost of picking, break-even point, pay- back period, cost saving, time saving and energy saving, picking through cotton picker is promising.

Cotton, the most important commercial crop playing a key role in economic and social affairs of the world, continues to be acclaimed as 'king fibre'. India is currently first in area, second in yarn production and third in raw cotton production in the world. Cotton crop is cultivated in 8.92 million ha with a production of 24.30 million bales at an average of 463 kg/ ha in 2004-05. (Anonymous, 2005). In India, entire cotton is hand picked by human labour involving about 1565 man h/ha (Goyal, 1979) which is 0.9 man. h/kg of cotton. It is not only tedious work but also ten times costlier than irrigation and about twice that of weeding operation (Ahmed *et.al.*, 1987). In recent years it has been observed that labour shortages appear during peak periods of cotton harvesting. The use of picking machine will be useful in minimizing drudgery involved in hand picking as well as enhancing production of cleaner grade of seed cotton. The mechanized cotton picking system will also be helpful in achieving timeliness of operation for the subsequent crop.

Chaudhry (1997) analysed harvesting of cotton in the world and reported that about 30 per cent of world cotton production are harvested by machines. It was also noted that Australia, Israel and USA are the only countries where all cotton is picked by machine and the picking costs greatly varied among countries. Cotton harvesters now available to farmers are of two basic types, viz, picker and stripper. The picker is selective; that is, it harvests only the open bolls of seed cotton where as green, unopened bolls are left on the plant to mature for later picking. Two types of spindles are used in pickers, viz, tapered barbed spindle and straight spindle. Stripper is non-selective; it strips the entire plant of both opened and unopened bolls. It must therefore be used in an once-over operation after the entire crop is matured. Modern strippers can be classified according to two general stripping principles. The finger principle and the roll principle (brush type), whereby the plants pass between two inclined rotating rollers or between a roller and a stripping bar, Strippers are most successful in the areas where plants are small and the fibres are rather short, hard bodies and easy to clean. The literature reviewed on mechanical cotton picking is discussed below.

1. Stripper harvester

Batchelder *et al.* (1961) evaluated double and single stripping roll arrangements.

[1,2,3] Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore - 641 003, India.

Under the double roll arrangement, a pair of counter rotating rolls was mounted in a one - row stripper with one roll on each side so designed that all rolls to be evaluated could be interchanged in the stripper. Roll speeds were nominally 300, 500, 700, 900 and 1200 rpm. Four different materials were used in fabricating the stripper rolls; steel, nylon bristles, a vegetable fibre bristle and rubber. The steel rolls had greater and more variable machine losses on the ground than did the flexible rolls. Rubber finger and rubber strip rolls had less machine loss on the plant, and this loss was less variable than for any other roll. Based on the performance of the stripping rolls and the yields of cotton, highest harvesting efficiency can be expected if the plant population is at least 1,00,000 per ha. Slightly less fine trash was found with the single steel roll stripper. No lint grade differences due to stripping roll types were detected in this study.

Kirk *et al.* (1964) evaluated the performance of the experimental green boll separator for cotton stripper harvester and conducted that the separation efficiency of the experimental machine averaged 96.53 per cent compared to an average of 89.73 per cent for the commercial production model. It was reported that picker losses might be great as 15 to 20 per cent under less favourable conditions. It was also reported that strippers operating in suitable varieties often have losses of only 2 to 5 per cent. Kirk (1964) developed an experimental stripper type machine for harvesting cotton of close-row and 'broadcast' type spacing, and concluded that the potential of this type of culture depended upon the development of varieties specially, adapted for this purpose. Link and Bockhop (1964) have proposed model for evaluating weather probability and acreage as constraints on completing a particular machine operation in the crop production cycle, when machine capacity is known or assumed.

Smith (1964) reported that the stripper type cotton harvesters must be used in a one-over operation after all of the crop is mature as the stripper - type harvesters strip the entire plant of both opened and unopened bolls. As the sled moved forward, the stripping fingers applied an upward force to remove the cotton bolls from the plant while the plants were permitted to pass between adjacent fingers. Tupper (1964) reported that the stripper is a low cost machine with overall harvesting efficiencies averaging 92 per cent for open boll and 96 per cent for storm-proof varieties. Parish and Shelby (1974) compared stripper with the cotton combine and a conventional picker (which was run in conventional rows) and reported that the harvester efficiency was 92.2, 89.3 and 94.6 per cent respectively. The quality of the stripped lint was the same as the quality of the combined lint. Both were about one grade lower than that obtained by a conventional spindle picker.

Wanjura and Baker (1978) conducted a study in which roll type stripper was used and concluded that the amount of sticks and their condition were the primary factors that determined the level of bark in cotton lint after stripping and during processing in the gin. Colwick, *et al.* (1979) reported that the finger type stripper was more efficient than a spindle picker, but bark in lint reduced quality by 1 grade compared with spindle picked cotton. It was also reported that the high humidity normally limited stripper operation to 5 h/day and it was often clogged by large stems. Wanjura *et al.* (1979) compared two principles that are used on commercial cotton strippers to remove cotton from plants rotating rolls and fixed fingers, and concluded that the stick length at the point of stripping is longer for finger strippers than for roll strippers but the total weight of sticks was similar. A significant amount of stick breakage occurs in the conveying system of both strippers and this breakage was a contributing influence in removing bark slivers from sticks, which then became entangled in the seed cotton and ultimately in the ginned lint.

Brashears (1988) investigated the effects of stripper harvester combing pan spacing on harvest loss and foreign maternal content of seed cotton for pan settings of 1.25, 2.5 and 3.0 inches, stripper speed 3 and 6 mph and plant height 24 and 30 inches. Cotton was harvested with a 2-row self-propelled stripper with 3 rubber paddles and 3 brushes per roll. Forward speed also had a significant effect on harvest losses, but the effect of speed and pan spacing on foreign material content was lower than expected. Brashears (1989) reported that the narrow paddle wide combing pan spacing and harvesting speeds less than 6 mph in the cotton strippers reduced stick content in bur cotton and the number of grades reduced due to bark. Operating the stripper above the soil surface will reduce the amount of soil handled through the conveying system thus reducing fine material in the bur cotton.

2. Spindle type pickers

Colwick *et al.* (1957) reported that if spindle type pickers are to be used, hill dropping at relatively close spacing is satisfactory for harvesting. No significant differences in yield or picking efficiency were obtained in the population range of 35,000 to 65,000 plants per acre. Tupper *et al.* (1964) stated that the spindle picker is expensive to buy, operate and maintain. They added that it was a relatively inefficient harvesting machine with overall picking efficiency averaging 88 per cent for the open boll varieties. Corley (1966) tested the effect of speed of tapered spindles on picking efficiency. For fluffy bolls, the efficiency increased from 80 per cent at 700 rpm to 95 per cent at 230 rpm, remained constant from 2300 to 3900 rpm and then declined slightly at 4700 rpm. The loss at the slower speed consisted of cotton left at higher speeds was cotton thrown by the spindles. The picking efficiency of knotty bolls that had opened before maturity (contained hard locks) increased linearly with spindle speed, from 49 per cent at 700 rpm to 72 per cent at 3900 rpm.

Williamson *et al.* (1966) studied the differences in effect of three types of the mechanical cotton picker spindles (tapered tooth, straight smooth and straight tooth) and reported that the straight 1/4-inch spindle with teeth was significantly more efficient than the straight, fluted spindle and just as efficient as the tapered tooth spindle in picking efficiency. Stapleton *et al.* (1967) reported that the functional performance of a spindle cotton harvester depends on the availability of open cotton. If only 50 per cent of the bolls are open, not more than one - half of the potential crop can be picked, even if the harvesting efficiency is 100 per cent. Shpolyanskii *et al.* (1984) developed a prototype for row spacing of 90 and 60 cm, mounted and fitted with a vertical spindle harvesting apparatus and a pneumatic internal transport system. The height of the harvesting apparatus is 530 mm. It was concluded that with adjustment, the harvesters were capable of harvesting all type of cotton in 2-3 passes.

Ahmed (1985) found out that the ideal variety for the spindle type cotton picker should combine the following characteristics.

a. Plant of medium size with a relatively narrow space, growing in more or less upright position.

b. Fruits distributed evenly all over the plant, but beginning well of the ground. In this way the picker drum can be operated higher thereby reducing the amount of the soil and dirt collected with the lint.

c. Wide opening bolls with fluffy locks.

d. Maturity should take place early and in comparatively short time.

Ahmed *et al.* (1987) studied the technical and economic feasibility of mechanical harvesting of medium staple acala cotton, and investigated the performance of three makes of cotton harvesters using spindle type high drum, 2 row self propelled pickers. It was reported that the mechanical picking was technically feasible but seedbed preparation, weed control, cotton establishment and defoliation needed better management for machine picking. Cotton was of lower grade and more costly than hand picked cotton. Columbus *et al.* (1988) modified a spindle cotton harvester so that the open bolls on the top and bottom of the plant could be harvested separately or together. Four varieties were harvested and ginned in the micro gin and fibre quality analyses were performed. Differences were detected in the top, bottom and total crops with the total crop having the best overall quality parameters.

Mayfield (1989) suggested that with good management, spindle pickers can consistently put more than 95 per cent of the crop in the basket and maintain the natural fibre and seed quality at a reasonable cost. Even in modern pickers, high field losses and fibre quality problems such as spindle twist and excessive foreign material are often associated with marginal management and operational practices. The author emphasized the importance of having both the crop and the pickers in good condition before the harvest season starts and outlined the infield operational procedures necessary for quality preservation. It was also pointed out the importance of harvesting only when the cotton is dry. Bauer *et al.* (1998) conducted study to determine the variability of cotton yield. First, the large plots were subdivided into 44 ft long sections and two of the rows in each section were harvested with a spindle picker. Second, a 6-ft sample was hand-harvested from each of three soil map units within each plot. It was concluded that variability for yield or micronaire was not affected among machine-harvested samples.

3. Brush type harvester

Oates *et al.* (1952) developed brush - type cotton harvester and concluded that the combination of brush rolls and pneumatic - conveying system did an excellent job of harvesting the cotton, if the plant is not entirely dead. It was also reported that the combination of brush rolls and mechanical conveying system worked well under most adverse plant conditions at harvest time. Matthews and Tupper (1965) tested the brush harvesters and found that they were quite effective on conventional rows. Vories *et al.* (1991) studied the suitability of a brush stripper with onboard cleaning for cotton harvesting. The effect of row spacing on seed cotton yield, gin turnout and quality parameters were not significant. Seed cotton yield was greater with stripper. Grades were also higher with the stripper. Micronaire valve was lower with the stripper than the picker.

Brashears (1992) tested configurations of brushes and rubber bats for their effectiveness in reducing foreign matter and found configurations that significantly reduced stick content of bur cotton and bark is lint. Chen *et al.* (1992) developed a computer simulation model of cotton harvesting and handling system and reported that one harvester is more economical than two harvesters for a 283.3 ha farm. Vories and Bonner (1995) compared brush stripper and 4 row spindle picker for cotton harvesting and reported that the seed cotton yields, a number of quality factors (micronaire valves, strength, fibre length, length uniformity grayness, yellowness and trash percentage) and gross returns were not significantly different between harvesting methods. It was concluded that the use of stripper, a cheaper machine to purchase and maintain is feasible provided crop condition is good.

4. Trash content

Bennett (1938) reported that the mechanical cotton pickers gathered from 4.7

to 7.1 per cent of foreign matter as compared with 1.8 to 6.6 per cent by hand picking for the corresponding cotton. There was a striking difference in appearance between cotton picked by spindle picker, and those, which have been carefully hand picked. At the gins, it was possible to remove 53 per cent of total of 5.9 per cent of foreign matter (mostly leaf trash) from the mechanically picked as compared with 66 per cent from a total of 4.2 per cent of foreign matter (mostly burs) in the hand-picked cotton.

Dick *et al.* (1958) reported that the cotton leaf smoothness apparently had no effect on picking efficiency or on the total amount of wagon trash, but the smooth leaf trash was easier to remove in the gin. The development of smooth leaf varieties by cotton breeders has helped to minimize grade loss in machine - picked cotton. Colwick *et al.* (1965) described the modifications to be developed to reduce trash content in machine - picked seed cotton. One of these developments was the placement of air intakes in the picker head, which reduced the suction of air and trash through the bottom of the head and allowed some trash to be thrown out ahead of the doffer. It is possible for low boll pickup attachments to reduced trash content, primarily by preventing leaves and soil from entering through the bottom of the drum. Porterfield *et al.* (1964) evaluated the cleaning effectiveness and operating characteristics of some common conveyor components. The variables in conveyors used were spiked-tooth cylinders and augers. The speeds were 200, 350 and 500 rpm. The screening surfaces were 1/2 inch screen, slotted metal, grid bars perpendicular to and grid bars parallel to the flow of cotton. The cylinder conveyor consistently removed more of each component of trash than the auger, irrespective of screening surfaces and speeds. The cylinder conveyer, equipped with slotted screens or parallel grid bars gave greater trash removal. The auger conveyor equipped with grid bars perpendicular to the flow of cotton, removed more trash, when equipped with other screening surfaces.

Clayton *et al.* (1965) conducted field tests to determine sources of oil contamination in mechanically - picked cotton. This study resulted in the following recommendations.

a. Lubrication of the picker should be done as illustrated in the instruction manual.

b. An oil-lubricated picker should not be flushed with oil during the harvest day. The picking units should be rotated at full throttle with the doors open for a short period of time before resuming picking. This will throw excess oil off the spindles. Washing the picking unit with a high - pressure hose immediately after lubrication is also a good practice.

c. Only the proper amount of lubricant should be applied.

d. Pickers should be checked closely after servicing and all excess lubricant removed before harvesting begins.

Anon (1966) reported that the trash accounted for about 175 pounds of weight in a bale of machine - picked seed cotton. It was described that the most effective way of minimizing trash in machine - picked cotton is through cultural practices and defoliation. It was also noted that care in machine operation, adjustment and cleanliness are also important measures for minimizing trash. Shaw and Clayton *et al.* (1965) conducted experiment on trash concentration in the picker basket and reported that the trash was heaviest in the rear of the basket and in the top of the basket. The front half of the basket was very uniform in trash content. In late season picking, when the machine is being operated in very low yields, it is advisable to dump the basket before it is completely full and the rear gates become choked. This will prevent the trash from being continually blown over and through the upper layers of cotton in the basket, and the more frequent dumpings will facilitate more frequent cleaning of the top gates.

Kirk *et al.*, (1973) studied different field cleaning machine configurations and revealed that the percentage of total trash removed (trash removal efficiency) from the samples ranged from 39.0 to 75.4 per cent. Both of these extreme differences in performance were from machine configurations with three saw cylinders which indicated that just the addition of another saw cylinder would not ensure improved cleaner performance and that proper design was much more important to performance than the number of cylinders. Smith and Dumas (1982) reported that the initial trash content of the stripped material ranged from 29-38 per cent with an average of 34 per cent before cleaning. Brashears (1988) studied the effects of harvest yield, number of paddles and brushes and combing pan spacing on yields, foreign material in seed cotton and lint quality. Resets indicated that the foreign matter content and lint quality could be improved by 6.4 rather than 3.2 cm combing pan spacing and using a 3 brushes / 3 paddle stripper roll. Harvesting speeds of 9.7 km/h reduced the fine trash in bur cotton but increased bark in the lint.

5. Effect of spacing and population on picking

Williamson and Fulgham (1956) reported that the mechanical pickers could operate efficiently over a wide range of different spacing and populations. Hill spacing ranging from 2 to 24 inches on regular 40-inch rows and plant populations of 27,000 to 75,000 plants per acre did not affect picker efficiency. In dry years, both yield and picking efficiency were reduced when populations were above 75,000 plants per acre. Corley and Stokes (1964) evaluated the harvester performance in relation to plant characteristics for both irrigated and non-irrigated cotton. In non-irrigated cotton, the storm resistance appeared to be an important factor to consider in selecting a variety for mechanical harvesting, especially stripper harvesting. Open boll varieties showing storm resistance had high picker and stripper efficiency. The stripper was slightly more efficient than the picker, but this advantage was offset by other problems associated with stripper harvesting. In irrigated cotton, harvesting efficiency (picker) increased significantly as plant population increased. Based on the results of these tests, a stand of 20,000 to 60,000 plants/acre was recommended for mechanical harvesting.

Batchelder *et al.* (1982) reported that increased number of rows per bed would result in drastically increased harvesting losses if the cotton is harvested by mechanical picker. An increased number of rows per bed would result in narrower plants, there by presumably making their configuration more suitable for finger- type stripper harvesting. Wanjura and Brashears (1983) investigated the effects of spacing between stripping rolls, plant size and plant moisture content on cotton harvest losses and vegetative foreign material. The total harvest loss was not affected by plant size, but increased when spacing between stripping rolls widened. Stick content in harvested cotton increased when branch moisture decreased. Fine foreign material was not significantly affected by spacing between stripping rolls. Saifi and Azizov (1991) studied the effect of plant density on harvesting efficiency of the cotton harvester and concluded that the cotton harvester was most efficient in terms of picking the highest percentage of seed cotton and dropping the lowest percentage on ground, at 1,07,000 to 1,10,000 plants/ha.

6. Effect of time of planting and picking

Montgomery and Wooten (1958) tested morning versus afternoon picking of cotton and reported that more spindle twists (caused from difficult doffing of the spindles) were present in the early - morning - picked lots than were present in the afternoon picked lots. Williamson (1960) reported that picker efficiency is generally higher for high moisture cotton. On the other hand, cotton quality favours harvesting low-moisture cotton. Williamson and Riley (1961) studied the effect of mechanical picking on cotton quality and concluded that the picking efficiency dropped and total seed cotton loss increased as time of picking was delayed. They also recommended that daily, the pickers must be operated during the hours of correct seed cotton moisture content in order to minimize staining moisture and trash problems.

Sappenfield *et al.* (1983) compared the cotton production and harvesting systems and concluded that rows 76 cm wide and brush stripper harvested produced an average of 155 kg/ha of lint more than 96 cm rows spindle picker harvested. It was also reported that rows 76 cm wide in delayed plantings and brush stripper harvested produced over 227 kg/ha of lint more than 96 cm rows planted early and spindle picker harvested. Sappenfield *et al.* (1984) compared two types of cotton production system, *viz,* (a) the conventional, planted early; 96 cm rows (b) delayed planting 76 cm rows. They reported that the rows 76 cm wide and brush stripper harvested produced 16 per cent more lint than 96 cm rows spindle picker harvested. They also revealed that the rows 76 cm wide is delayed plantings and brush stripper harvested produced 24 per cent more lint than the conventional system of 96 rows planted early and spindle picker harvested. Khalilian *et al.* (1999) conducted a study to determine the effects of a harvest aid attachment called the boll saver, on harvest losses. It was concluded that the investment cost of a finger stripper is lower than that of the conventional picker harvester.

7. Other aspects of mechanical picking

Tupper (1966) indicated that the machine losses were 221.4 and 83.8 pounds of clean seed cotton per acre for picker and stripper respectively. It was also reported that harvesting efficiencies ranged from high of 98.5 per cent to a low of 95.5 per cent. The stripper overall efficiencies were 3.4 to 8.2 per cent higher when stripping storm proof varieties as compared with open - boll varieties which averaged 96.2 and 90.6 per cent, respectively. The spindle-picker overall efficiencies averaged 86.2 and 90.4 per cent for storm proof and open boll varieties respectively. Roberson (1966) studied flexible roll for cotton harvester and reported that the flexible roll was superior to the steel roll. Flexible rolls harvested less sticks requiring fewer field stops to remove large limbs and stalks. This was especially true in tank-irrigated cotton. Lindsey *et al.* (1967) reported that most cotton producers can reduce the harvesting costs by using some mechanical harvesting alternative when yields are above 300 pounds of lint per cent acre. These data also revealed that custom picking was the cheapest harvesting alternative for low yields exceeding 300 pounds. Mechanical picking costs for twice-over picking with new one-row and two-row cotton pickers decreased as the number of acres harvested and yield per cent are increased. Hudspeth (1971) reported that mechanical pickers are best adapted to irrigated areas or regions of high rainfall where yields are ordinarily high, the fibres are long, the bolls are of the open type, and vegetative growth is rank where the plants are small and yields are relatively low.

Corley (1970) reported that picker losses were less than preharvest losses or weather losses. It was also concluded that the picker efficiency was strongly correlated with overall efficiency and the overall efficiency was also strongly correlated with preharvest loss. The preharvest loss decreased as picking energy increased and there was a leveling off effect for high picking energies. Picking twice minimized weather losses and equalized picker losses trash content was not strongly correlated with picker efficiency. There were strong positive correlations of picker efficiency with boll diameter and dry boll weight but not with number of bolls per unit weight. There was a positive correlation of boll shape and picker efficiency indicating that pointed bolls were picked more efficiently than the rounder bolls. The boll shape was correlated positively with preharvest loss and negatively with boll weight. Peduncle length and boll length were correlated negatively with picker efficiency for twice-over picking, but not for once-over picking. Carpel flare of the degree of boll opening was correlated positively with picker efficiency. Lint percent was positively correlated with picker efficiency and picker yield. Seed weight was positively correlated with picking energy and negatively correlated with picker efficiency. Maturity, expressed as the percent of harvested yield obtained on the first picking was correlated positively with picker efficiency, but negatively correlated with picking energy.

Conclusion

By considering the cost of picking, break-even point, pay-back period, cost saving, time saving and energy saving, mechanical cotton harvesting is promising. The use of cotton harvester helps to reduce the cost of harvesting. The farmers particularly in cotton growing areas has to gradually accept and adopt the cotton picker on their farm, since this machine is better suited for removal of drudgery involved in human labour. It may be concluded that there is a very great scope for mechanized cotton picking, which will result in improved economics.

REFERENCES

Ahmed, M.H. (1985). *Agric. Mech. in Asia, Africa and Latin America,* 16 (4): 51-53.

Ahmed, M.H. *et.al.* (1987). *Agric. Mech. Asia, Africa & Latin America,* 18(2): 29-32, 36.

Anonymous. (2005). *Annual Report, Cotton Corpn. of India,12 pp.*

Batchelder, D.G., *et. al.* (1961). Oklahoma Agr. Exp. Sta. Bull. B-589.

Batchelder, D.G., *et. al.* (1982). *Trans. ASAE* 25: 62-64.

Bauer, P.J., *et. al.* (1998). Proc. of 21st Annual Southern Conservation Tillage Conference Arkansas, USA, 15-17 July 1998.

Bennett, C.A. (1938). *Agric. Engg.* September 19 (3): 386-388.

Brashears, A.D. (1988). ASAE Paper No. 68-1043, 13 pp.

Brashears, A.D. (1988). Proc. Beltwide Cotton Production Research conference, Louisiana, USA, 3-8 Jan 1988: 161-162.

Brashears, A.D. (1989). Proc. Beltwide Cotton Production Conference., National Cotton Council of America, Memphis, Tennessee, USA. 36-38 pp.

Brashears, A.D. (1992). ASAE Paper No.92-1035, 9 pp.

Chaudhry, M.R. (1997). Proc. Beltwide Cotton Conference, New Orleans, USA, Jan 6-10, 1997 Vol. (2): 16-18 pp.

Chen, L.H., *et. al.* (1992). *Trans. ASAE,* 35: 1071-1077.

Clayton, J.E., *et. al.* (1965). Contamination of cotton by lubricants from mechanical harvesters, USDA, ARS 42-111.

Columbus, E.P., *et. al.* (1988). Beltwide Cotton Production Research Conference, Cotton Engg. Systems Conference, Louisiana, USA, 3-8 Jan. 1988: 162-164.

Colwick *et. al.* (1953). *South Coop. Series Bull. 33, March*

Colwick *et. al.* (1957). *South. Coop. Series Bull.* 49. February.

Colwick *et. al.* (1965). *South. Coop. Series Bull.* 100. March.

Colwick, R.F., *et. al.* (1979). Tech. Bull., Mississippi Agric. Experimental Station, Mississippi State No. 94, 16 pp.

Corley, T.E. and Stokes, C.M. (1964). *Trans. ASAE:* 281-286 and 290.

Corley, T.E. (1966). *Trans. ASAE* (9): 326-328 and 332.

Corley, T.E. (1970). *Trans. ASAE:* 768-773 and 778.

Dick, J.B., *et. al.* (1958). Mississippi. Agric. Info. Sheet, 573.

Goyal, M.R. *et. al.* (1979) *Agric. Mech. Asia, Africa & Latin America. Spring, pp* 73-78.

Hudspeth, E.B. (1971). Texas Agric. Exp. sta. PR 1728.

Khalilian, A., *et. al.* (1999). *J Cotton Sci.,* 3 (3): 122-125.

Kirk. I.W. (1964). Texas Agric. Exp. Sta. PR 2258.

Kirk. I.W. *et. al.* (1964). Texas Agr. Exp. Sta. PR 2311.

Kirk, I.W., *et. al.* (1973). *Trans. ASAE:* 446-449.

Link, D.A. and C.W. Bocknop. 1964. *Trans. ASAE,* 7(1): 8-13 and 16.

Lindsey, *et. al.* (1967). Mississippi Agric. Exp. Sta. Bull. 739.

Matthews, E.J. and Tupper, G.R. (1965). *Trans. ASAE* **(8)**: 568-571.
Mayfield, W.A. (1989). Proc. Beltwide Cotton Production Conference, 38-39. National Cotton Council of America, Memphis, Tennessee, USA.
Montgomery, R.A. and Wooten, O.B. (1958). Studies of lint quality and moisture relationships in cotton through harvesting and ginning, USDA, ARS 42-14.
Narayanan, S.S. and Sundaram, V. (1999). International Seminar on Cotton held at CIRCOT, Mumbai, Dec. 10-12, 1999. Book of papers: 4-15.
Oates, W.J., *et. al.* (1952). *Agric. Engg.*. 33 (3): 135,136 and 142.
Parish, R.L. and Shelby. K.R. (1974). *Trans. ASAE* **(17)**: 1076-1077.
Porterfield, J.G., *et. al.* (1964). Oklahoma Agric. Exp. Sta. Tech. Bull. T-111.
Roberson, P.M. (1966). *Agric. Engg.,* **47** (1): 139 and 141
Saifi, E. and Azizov, M. (1991). *Khlopok.* No.4, 20-21.
Sappenfield, W.P., *et. al.* (1983). ASAE Paper No. 83-1577, 23 pp.
Sappenfield, W.P., *et. al.* (1984). *Trans. ASAE* **(27)** : 1287-1291.
Shaw, C. Scott and Clayton, J.E. (1965). Effects of trash deposits in cotton picker baskets, USDA, ARS 42-112.
Shpolyanskii, D.M., *et. al.* (1984). *Tekhnika V Sel'skom Khozyaistve,* No.8, 60-61.
Smith, H.P. (1964). Farm Machinery Equipment. McGraw-Hill, New York. pp. 356,
Smith, L.A. and Dumas, W.T. (1982). *Trans. ASAE,* **25** (2): 291-296.
Stapleton, H.N., *et. al.* (1967). *Trans. ASAE* **(10)**: 226-229 and 232.
Tupper, G. R. (1964). *Trans. ASAE* **(7)**: 306.
Tupper.G.R.(1966). *Trans. ASAE* **(9)**: 110-111, 113.
Vories, E.D., *et. al.* (1991). Proc. of Beltwide Cotton Conference held in New Orleans, USA, Jan. 10-14, 1993, 542-543.
Vories, E.D. and Bonner, C.M. (1995). *Bull., Arkansas Agric. Experi. Stn.,* No.945,16 p.
Warjura, D.F. and Baker, R.V. (1978). *Trans. ASAE*: **22** (2): 273-278 and 282
Wanjura, D.F., *et. al.* (1979). *Trans. of ASAE* **23** (2): 233-236 and 242.
Wanjura, D.F. and Brashears, A.D. (1983). *Trans. of ASAE* **27** (1): 54-58.
Williamson, E.B. and Fulgham, F.E. (1956). Mississippi Farm Res. Stn.
Williamson, E.B. 1960. Annual Mississippi S-2 Report (Unpublished), 42 pp.
Williamson, E.B. and Riley, J.A. (1961). *Trans. ASAE* **(5)**: 164-165 and 169.
Williamson, E.B. *et. al.* (1966). USDA Marketing Res. Rep. 730.