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Research Cotton Mechanisation in Asian Countries

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Abstract: Cotton Harvesters has proven to be a promising approach for cotton harvesting in India and developing countries. However challenges still remain in its implementation in India though considerable progress has been made in recent years. Developed countries have 100% mechanized cotton picking. With increasing labor charges and its unavailability, mechanization has gained pace in Indian agriculture sector. This review paper provides an overview of cotton harvesters and its various types. It also covers the anatomy of cotton plant, production, and its importance in Indian economy. Indian cropping pattern are studied in detail and various mechanism discussed and their pros and cons are evaluated in this paper.

Keywords: Cotton Picker, Mechanization, Defoliation, Cotton Boll, Cotton Stripper, Spindle.

Introduction. Cotton commonly called 'The white gold' is a soft, fluffy staple fiber that grows in a boll, or protective capsule, around the seeds of cotton plants of the genus Gossypium. It is one of the most important commercial crops playing a key role in the economic, political and social affairs of the country. The plant is a shrub native to tropical and subtropical regions around the world, including the America, Africa, and India. The fiber is most often spun into yarn or thread and used to make a soft, breathable textile. Current estimates for world production are about 25 Million tones or 110 million bales annually, accounting for 2.5% of the world's arable land. China is the world's largest producer of cotton. The United States has been the largest exporter for many years. In the United States, cotton is usually measured in bales, which measure approximately 0.48 cubic meters (17 cubic feet) and weigh 226.8 kilograms (500 pounds).India today is the third largest producer of cotton in the world. About one third of total crop is irrigated and rest is rain fed. The yield of crop is 307 kg/ha as compared to 783 kg/ha in USA, 659 kg/ha in China and 988 kg/ha in Egypt. The current yields tend to linger on lower averages, which has been a matter of concern and a national challenge. The low yields of cotton are attributed to inadequate inputs, untimely field operation, lack of irrigation (70 %area under rain fed conditions) and inefficient crop production technologies [1].

METHODS AND OBJECTS OF RESEARCH

The cotton is a perennial plant with height variations from a shrub to a full grown tree. For commercial proposes it is restricted to 3-4 feet. Cotton planting period is from March to September and harvested from October to February. The flower bud that first appears on the plant when reproductive growth begins is called a 'square'. The flower bud is enclosed by three bracts. Squares grow for about three weeks before a flower appears. Cream or yellow flowers open during early morning hours. During this time the male and female flower parts expand rapidly. The flower petals turn pink on the second day and later dry up and drop off and then form boll.The major stages of cotton flowering process is shown in Fig. 1.

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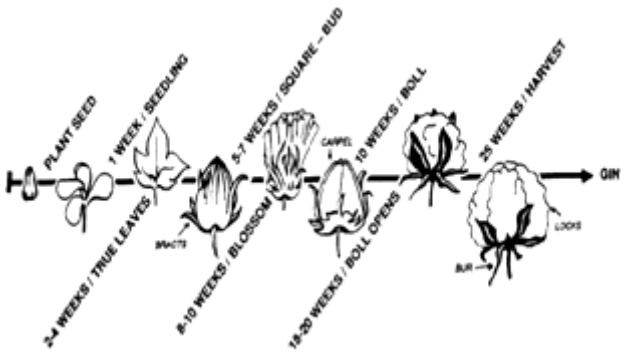

Fig. 1 Stages of Cotton Flowering

There are four major cotton species of cultivated cotton, of which two are diploid (Gossypium arboreum and Gossypium herbaceum) and the other two tetraploid (Gossypium hirsutum and Gossypium barbadense).India is the only country to grow all four species of cultivated cotton. In addition, hybrid cotton, which is produced from crossing tetraploid species Gossypium hirsutum are also cultivated in the central and southern zones. The country type diploid species referred to as the 'Desi' cotton, having low productivity and low quality cotton, contributes 25 - 30% of the country production. The tetraploids variety contributes remaining 70% of the cotton production in India. These varieties have fine quality fiber, and are normally used by the textile industry. Gossypium hirsutum represents 90% of the hybrid cotton production in India [2].The rapid growth in yields (between 2002/03 to 2007/08) is attributed to the introduction of biotech varieties of cotton, Although potential exists for a further increase in yields, cotton farmers will have to invest more in production technologies for improved management of irrigation, fertilizers, micro nutrients, pest and diseases [3].

NEED OF MECHANIZATION

It can be observed from the previously discussed facts though India ranks first in the cotton planting land it is the third largest producer in the world. The reasons for the same vary from the varied crop patterns to shortage of labor for manual hand picking. The Indian cotton bolls do not mature at the same time and thus picking needs to be done in 2-3 rounds. Bolls opening later thus are of reduced quality. Cotton picking is a laborious task and is seen as a punishment in some countries. Continuous working in the cotton filed can lead to bruises and cuts on labor's hand and toxication caused due to use of pesticides. Thus the way ahead lies in the mechanization of cotton picking. Mechanization of farming operation is the only way of reducing drudgery. This will release laborers particularly from the tedious work of many farming operations to spend their time more productively on other activities. Mechanization can generate increased ventures, which manifest themselves in a variety of interrelated ways. More area can be brought under cultivation, as capacity to do more work in the available time becomes a possibility. New crop and livestock systems can be practiced as labor output increases because of mechanization, off farm employment opportunities are generated in the servicing sector i.e. manufacturers, dealers, repair workshops of agricultural machinery. Mechanization is thus a labour augmenting technology increasing the output per worker rather than output per unit of land. The benefits of mechanization have been greatest where labor is scarce and therefore expensive or land is plentiful. This characteristic of mechanization has important implication for its role and impact in the small holder system, where in majority of the cases land, capital and management are limited and labor is generally abundant. All over the world machinery proves one of the most important inputs in cotton production, because of the obvious benefits as discussed above [4]. With the country facing labour shortage and farm wages rising, cotton growers are looking at various ways to cut costs. For example, labour availability dropped from 70.3 per cent of the population in 1961 to 48.9 percent in 2010 [4].

JOURNEY OF COTTON MECHANIZATION

Starting from the early 1920s, cotton was still picked by hand and caused a lot of manual labor; people would go day by day picking the flowers from the plants placing them in bags continuing the traditional cotton picking which was in place since long as shown in Fig. 3.

Fig. 3 Manual Picking in 1920

In the late 1930's,as shown in Fig.4, the first one row cotton picker was developed by John Rust but was not commercially sold since the picker proved to be less durable and so the inventor was reluctant to sell many [4].

Fig. 4 Cotton Picking in 1930

Then in the early 1940's, as shown in Fig. 5, the cotton picker was commercially made and sold. The barbed spindles would pick the cotton off the plants and would drop it to the ground this did potentially degrade the cotton but it was mechanical and this meant less labor [5].

Fig. 5 Cotton Picking in 1940

In the 1950's,as shown in Fig.6, the original spindle for the cotton picker was re-designed into a more durable and stronger metal, which could pick multiple rows and had a basket to catch the cotton instead of dropping it on the ground [5].

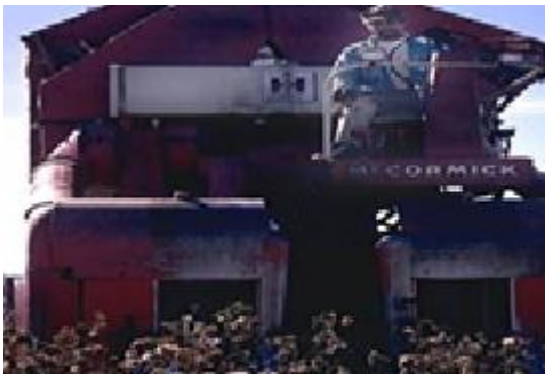

Fig. 6 Cotton Picking in 1950

From the 1960's to 1980's, various modifications were made in the cotton pickers as shown in Fig.7, keeping the basic concept same. In the 70's the first picker with a driver's cabin was introduced. This ensured the driver's safety and comfort making working on fields a pleasant experience [6].

Fig. 7 Cotton Picker with Cabin

The 4-row cotton picker, as shown in Fig.8, was introduced by John Deere in 1980 which increased operator's productivity by 85-95%. This increased the efficiency of cotton picking to a large extent and was welcomed by the farming community [6].

Fig. 8 John Deere Cotton Picker

In the late 90's,as shown in Fig.9, the six row cotton picker had been introduced with a large basket on the back this new picker made cotton picking much faster and easier as the cotton was just tipped into a module builder where it was pressed [6].

Fig. 9 Multiple Row Big Basket Cotton Picker

In 2009, as shown in Fig.10, John Deer released the first round baler which picks the cotton, rolls it, places it in a tarp and drops it to the ground. Therefore, less manual labor was needed again and the module builders were no longer needed to press the cotton [6].

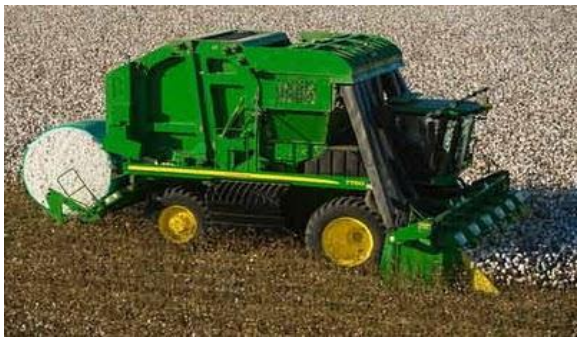

Fig. 10 Cotton Baler

COTTON PICKING MECHANISMS

Over the years, many people have tried various methods to pick up cotton effectively from the plant without damaging the plant and without ruining the quality of cotton picked. Different mechanism and inventions find use in different region of the world depending upon the variety of cotton in that region and on the cultivation practice in the region. Someof the mechanisms are as follows.

Cotton Strippers

Cotton strippers as shown in Fig.11 are used as an once-over harvest machine. Found in areas where weather conditions prevent repeated harvests, strippers 'pull' the entire boll, ripe or not or sever the stalk near the surface of the ground and take the entire stalk, together with cotton bolls into the machine and another machine is used to remove the burr and vegetative matter.

Fig. 11 Cotton Stripper

Early implements used a wooden sled drawn by a horse or mule to pull cotton off the stalk. The sled was designed to harvest cotton by pulling the plants through a tapered opening wide enough for the stalks to pass through but narrow enough to catch and remove open and unopened bolls. Most sleds harvested one row per pass, but multi row sleds were available. After “sledding,” farmers often piled cotton on the turn-row to allow unopened green bolls to open before ginning. Aggressiveness in harvesting directly influences the amount of seed cotton and foreign material harvested. The more aggressive the harvesting actions, the higher the probability is to harvest more foreign material and generate bark. You need to adjust stripper row units to the correct level of stripping aggressiveness with goal of harvesting the least foreign material and causing the least seed cotton field losses. Harvesting efficiency for brush-roll strippers is high, usually in the range of 98-99%. However, some aspects of fiber quality (such as micron ire and length uniformity) can bereduced for stripped cotton due to the presence of immature fiber from bolls located at the top of the plant. The presence of immature fiber can also influence fiber length, strength, and color grade [7].

Spindle Cotton Picker

A Spindle Cotton Picker as shown in Fig.12 does just 'picks' the cotton from the boll by means of revolving spindles fingers or prongs without material damage to foliage or unopened bolls. And a picker usually is used more than once since cotton is a continuous fruiting plant during the growing season. A picker may make repeated trips through cotton asthe bolls ripen.

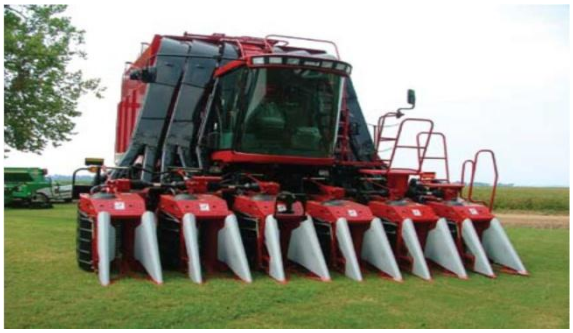

Fig. 12 Spindle Type Picker

The spindle picking arrangement is shown in Fig. 13.The plants would pass over a series of spindles that were turning at fairly high speed. When the spindle encountered an open boll, the cotton fibers would wrap around the spindle. The spindle would then move around to a "doffer" where the spindles would rotate in the opposite direction and the doffer would doff the fibers off the spindles further the spindles pass through the moisturizing units which easily pick the cotton and holds it on to the spindle accelerating the picking efficiency [7].

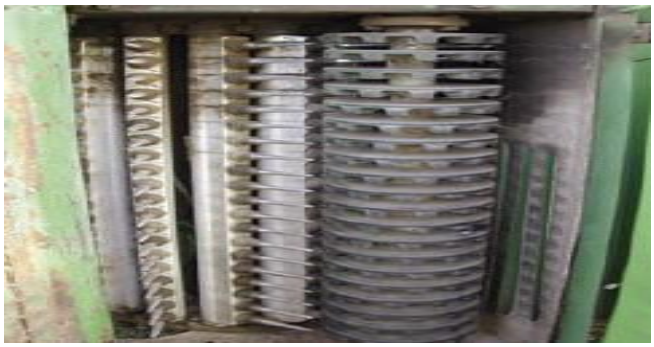

Fig. 13 Spindle and Doffer Arrangement

Spindle picker design is being modified to achieve increased speed and decreased weight is thought to have resulted in a general decrease in cotton fiber quality, particularly regarding spindle twists. Results of laboratory evaluation of different spindle designs showed that the smaller, straight spindle was more aggressive in removing cotton from the boll. There was approximately twice as much fly-off from the barbed spindle than from the smaller straight spindle. Field tests found that stalk losses in the field were significantly greater at a spindle speed of 1500 rpm than for speeds of 2000 rpm or greater for all varieties. This indicates that a spindle speed of at least 2000 rpm is needed to minimize picker losses. Stalk losses were greater with speeds of 3000 and 4000 rpm than for a speed of 2000 rpm.

Cotton Picking with Electrostatically charged Spindles

Spindle picker machines depend for their effectiveness upon the rotating spindles actually contacting the ripened cotton fiber and accomplishing physical adherence of the fiber to the spindles. This necessitates a multitude of spindles to accomplish physical engagement with the cotton bolls, and even with a greater number of spindles; many of the bolls naturally are missed and left unpicked in the field. The use of water for wetting the ‘spindles introduces mechanical problems and special servicing needs. The water on the spindles also promotes discoloration and staining of the cotton. Special attention is required to feed the water evenly and in the optimum amount. Moreover, in cold weather the water moistening system may at times freeze. Basically the invention comprises the applying of an electrostatic charge to the picking spindles and inductively to the cotton being picked, thus in effect creating an attractive force reaching out and drawing the cotton to the spindles, gaining contact thereby, with cotton which otherwise would not be contacted. These electrostatic forces pull the fiber to the spindles and cause it to adhere to the spindles, thus assisting the wrapping operation and eliminating loss by dropping the cotton. The invention thus comprises further and the preconditioning of the cotton in the open bolls by induced electrostatic force so as to cause the individual fiber to stand and reach out for the rotating picker spindles entering the picking zone [8].

Cotton Picking Robot

This is an Intelligent Cotton Picking Robot (ICPR) based on machine vision including the motion control subsystem and machine vision subsystem. Picking robot for visual identification of the cotton detects seed cotton grade text standard, the size of seed cotton, whiteness, yellowness, and miscellaneous quality characteristics. Robot in the actual picking has the eyes in the form of cameras with frame grabber who operates and collects cotton image. After image collection, it's processing, analysis and positioning coordinates of the location of cotton is done by the system. Near the plant, the robot manipulator completes the cotton picking action. This technology still needs further development to reduce its complexity, cost and make machine easy for operation and affordable for field workers [8].

Pneumatic Cotton Picker

The pneumatic cotton harvesting apparatus as shown in Fig. 14 includes a plurality of harvesting heads arranged in adjacent spaced relation side by side with each having a side panel opposing a side panel on an adjacent opposing harvesting head. An air intake manifold within each side panel has a plurality of extraction units with air intake ports for harvesting of seed cotton. The extraction units are each arranged in a staircase configuration to extract cotton into a pass through chamber housed within the harvesting head. The cotton is transferred through the air plenum transfer chamber attached to the harvesting heads to a cotton storage container. Air supply nozzles arranged before the extraction units aid the extraction of cotton by blowing air on the cotton plant before entering the extraction units to loosen the cotton. Horizontal ledges above and below the air intake ports and raised deflectors forward and rearward of the of the air intake ports deflect the cotton plants away from the air intake ports and support the vacuum mechanism for extraction of the cotton seed through the extraction.

Fig. 14 Pneumatic Cotton Picker

Portable Hand Held Cotton Picker

This portable cotton picker as shown in Fig.15 has specific mechanical arrangement so that cotton from each boll can be picked. It is a hand operated machine and has a pair of chain with small sharp edged teeth and sprockets and is operated by a light weight 12 V battery. Cotton gets entangled with the chain and is collected and guided into the collection bag. It has two rollers inside having blades on their outer periphery [9]. Design of machine makes it easy to operate and affordable for field operators. But it was observed it had more drawbacks than benefits. Average heart rate, oxygen consumption, workload, energy expenditure was more in case of cotton picking by manual cotton picker as compared to manual picking for both the subjects for all three cotton variety types. Oxygen consumption varied from 0.81 to 0.97 l/min, workload varied from 36.32 to 46.16 W and energy expenditure varied from 16.83 to 20.33 kJ/min for both the subject in case of machine picking for all three cotton varieties. The maximum discomfort experienced by the subjects during picking cotton by manual cotton picker was in right wrist palm, right forearm, upper and lower back, left shoulder and in lower legs and both feet.

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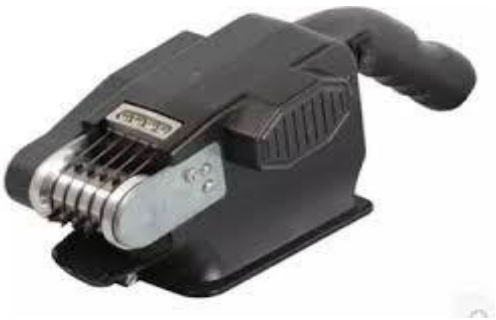

Fig. 15 Portable Hand Held Cotton Picker

Portable Pneumatic Cotton Picker

It works on principle of generating vacuum and sucking cotton from each cotton ball. It consists of a suction tube which can be moved by operator from one boll to other as shown in Fig.16. Vacuum is generated in the pipe which helps in sucking cotton from the boll and taking it to the storage bag which can be carried by operator on his back. Whole assembly can be carried by field operator which makes the device easy to operate. The main limitation of pneumatic multiple cotton picker is vacuum can take leaves and other trash of the plant with it. If trash gets trapped in cotton then it is very difficult to separate trash from cotton, cotton being a very fibrous material. Time required for cotton picking by pneumatic cotton picker is more as cotton from boll cannot be picked at a time. Weight of the machine also increases due to use of compressor or blower for generating vacuum. Operator has to be skilled before using machine to pick the cotton efficiently. Due to all these constraints pneumatic cotton picker is not used worldwide [10].

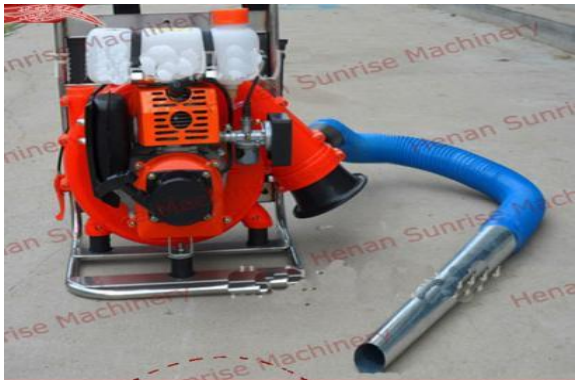

Fig. 16 Portable Pneumatic Cotton Picker

Cotton Picking In India: Present Scenario

Almost 100% cotton is picked manually in India; though a lot of modern technology is available worldwide Indian farmers go with conventional farming techniques. The main reasons for this over years was that most of the cotton farmers in India are small farmers (i.e. Small land farmers) and most of the technology does not favor it, also huge amount of money has to be spent on some of the above mechanism which is a major roadblock. It is also found that a large percent of farmers are not aware of the existing technology which could benefit them. Over the years, there was large labour force available for farm works and the farmer felt no need to utilize the technology, but now–a–days, there is labor shortage which will be acute in near future. Almost all cotton is picked by women and children as they have small finger tips compared to men and cotton can be easily picked, this has resulted in large use of child labors in cotton farms. Overall, half of the farmers faced difficulty in obtaining labour, mostly large farmers. Small farmers had little difficulty in hiring laborers. Farmers that faced difficulty in hiring the female laborers from their own village need to bring labors from other villages and provide transportation.On average, nearly 5 to 6 hours were spent to pick one hectare of cotton by a team of 32-35 laborers during first and second pickings. Picking generally start in last week of October and ends in January with amount of cotton decreasing with each picking. Cotton pickers were paid both in kind and cash. However pickers preferred wages to be paid in kind because they earn more that way. Sixty percent of the farmers paying cash faced difficulties in

obtaining laborers. The average cost of picking one quintal is around five hundred rupees (approx. 7.5 US dollar). Cotton production was highest for the second and third picks, when the bulk of the crop is picked. [10] The only way to get labour available is to increase their wages by 40%.Labours are paid around Rs 5 to 6 per kg during second and third picking while the rate goes to Rs 7 to 8 per kg during sixth and seventh picking. Almost 35% of the total money spent on cotton cultivation is spent on picking which constitute a major portion and mechanization in cotton picking can lower it to around 8-10% and thus increase the profit margin of farmers, Also the prices given by government to cotton are very less and farmers find it difficult to make money from cotton. Women workers face problems like back pain, burrs and wounds on hands due to cotton boll pricking. A lot of cotton is also wasted due to negligence of workers in the fields during manual picking.

RESULTS

Based on the above study, we can decide the mechanism best suitable for global and particularly for Indian conditions arediscussed as follows;

1. The use of Stripper type cotton picker does not favor the Indian type of cultivation as farmers go for multiple picking and stripper destroys the crop during picking. Though in future when improved varieties of seed are developed and used it can find use in India also.
2. The spindle type cotton picker is currently being used in India, though at smaller scale. It picks cotton without damaging the plant as well as unopened bolls. The only problem faced is that the field has to be defoliated before using it as leaves may also get picked up and deteriorate the quality of cotton. It can be used only for irrigated farms, also the defoliants are not easily available, but spindle type cotton picker can be considered as futuristic step in mechanization as it has good results.
3. Portable type of cotton picker is the best options to suit Indian conditions, Firstly no need of defoliation and the machine is quite cheap compared to above harvesters, The unsynchronoused boll opening can be taken to an advantage for this machine and the farmer can pick up cotton at his will when the cotton pops out, though the efficiency of this machine is under question but it can help farmers start with mechanization. Suitable for small land farmers and reduces the farmer's dependence on labors.

Conclusion. Millions of people survive on cotton crop directly or indirectly and a recent advance in cotton mechanization is playing an important role in the life of a farmer. Their dependence on labors is decreasing and revenue improving. Cotton which was popularly known as "Cash Crop" is now a days losing its shine among farmers and can be given its status back only by mechanization.

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