The Pharma Innovation Journal 2022; 11(12): 1264-1268

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(12): 1264-1268

www.thepharmajournal.com
Received: 22-09-2022
Accepted: 25-10-2022

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Mechanization in cotton harvesting India's status, issues and challenges

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Abstract
In India, efforts into mechanisation of cotton crops are being attempted for more than a decade. Numerous designs have been evaluated by Govt. and Private Organisations. However, most of the designs failed to perform under field conditions. A commercial cotton picker prototype suitable for Indian cotton farms is being evaluated for harvesting of cotton crops sown on high density planting system for two cotton seasons. This prototype is developed by attaching the picker head of the worldwide used 6-rows cotton picker at the side of a 60 HP tractor with some specially designed attachments. The issues like cost of processing, yarn realisation percentage, fibre losses during cleaning operations, development of suitable genotypes, agronomic practices etc. that need to be addressed for successful mechanical harvesting of cotton crops in India are discussed in great length. The fibre parameters and trash analysis data pertaining to the field trials are also presented in this study. The field evaluation data and fibre quality indices reveal that the commercial picker to be launched for mechanical picking of cotton in India is promising.

Keywords: Spindle picker, cotton harvesting mechanization, defoliation, trash content, naps, cotton processing cost, harvesting efficiency and losses

Introduction
Cotton is a very important cash crop of India and it plays a leading role in the industrial and agricultural economy of the country. Cotton is main source of income in India for around 6 million farmers and about 40-50 million people are directly or indirectly engaged in cotton trade and processing [1]. India tops the world in cotton acreage and is the second only to China in cotton production with 35.1 million bales (i.e.170 kg each) production in 2012-13 [2]. Unlike the developed cotton growing countries (i.e. USA, Australia, Israel, etc.) where cotton is harvested using sophisticated machines called as cotton pickers/strippers, entire cotton in India is picked manually [3]. Moreover, there are around 28 cotton growing countries that harvest part of its cotton crop using cotton pickers/strippers. Cotton picking machines have spindles that pick (twist) the seed cotton from the opened cotton bolls [1]. The twisted seed cotton is doffed with the help of moist doffing pads wherefrom it is directed into a bucket attached at the top of the picker. Whereas cotton stripping machines use rollers equipped with alternating bats and brushes to knock the open bolls from plants to a conveyor [1]. The cotton picker plucks only the open bolls while the stripper strips both the open and the unopened bolls and some plant matters as well. Hence the stripped cotton contains more than two-three times trash content as compared to the machine picked cotton.

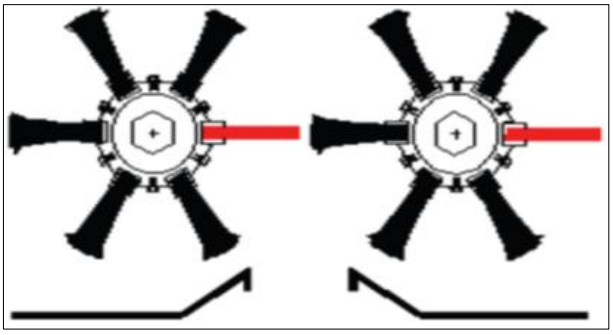

Fig 1: Image of picker head (right) and stripper rolls with bats (lefts)

Though, the researches into cotton mechanisation in India started in around year 2000 under the NATP programme, the requirement of a suitable cotton mechanisation system has been felt very badly in last couple of years as the cost of cotton picking in India (i.e. around Rs. 4-6 per kg seed cotton) has doubled in recent past mainly due to high inflation rate, migration of landless farm labours to cities and implementation of the *National Rural Employment Guarantee Act* (*NREGA*). Moreover, the shortage of labours during peak season results in the delay in sowing of the next crop leading to low yield [4]. At present, the manual cotton picking cost in India is around 10-12% of the total cotton selling price, which is much higher than the harvesting cost of any other crop grown in India. For instance, the rice harvesting cost is almost negligible compared to its selling price i.e. 0.01%. In order to meet the scarcity of labour and to reduce the cotton picking cost, efforts need to be concentrated on mechanization of cotton harvesting [3].

In the last ten years, cotton acreage has been growing at an average annual rate of around 3%. However, the average cotton yield in India is steady at around 500 kg per hectare compared to world average of 730 kg per hectare (ICAC, 2010). The low yields of cotton in India are primarily due to rainfed cultivation, inadequate inputs usage, untimely field operations and inefficient crop production technologies. The lack of disease resistant and high yielding cotton varieties/hybrids also contribute in low yield of cotton. Low cotton yield and increased cotton cultivation cost have reduced the farm income leading to a series of suicides committed by farmers in some cotton growing states of India. The mechanisation of cotton harvesting particularly in USA, Brazil, Turkey, etc. has led to significant increase in cotton productivity, decrease in cultivation cost and increase in farm income. Heinicke and Grove [5] have demonstrated positive effects on cotton yield by using machines for cotton harvesting in USA. Similarly, Isin *et al.* [6] have also reported considerable increase in cotton yield in Turkey on adoption of mechanical picking. A recent study by Konduru *et al.* [7] has estimated potential increase in cotton farm income in India i.e. around Rs. 10,000/- per acre, if cotton is harvested mechanically. The increased productivity in case of mechanical picking is mainly achieved by reducing row-row and plant-plant spacing which in turn increases the plant density by 4-5 times than the conventional method. The reduction in plant spacing is obtained by controlling the height and branches of the cotton plants.

Though, the farmers are in dire need for a suitable cotton harvester and it has potential for increasing productivity, farm income, availability of labours for other crops etc., there are many issues and challenges that need to be addressed for adoption of cotton harvesters in India. Adoption of mechanical harvesting in India is not dependent upon just the availability of suitable harvesters. The successful adoption of cotton harvester in other part of world suggests the requirement of holistic change in the entire chain of cotton cultivation including breeding and agronomic practices, harvesting and processing operations for successful adoption of cotton pickers as all operations are interlinked. This paper explores the status, issues and challenges that require group efforts from scientists and technologists belonging to cotton breeding, agronomy, farm machinery, extension, cotton processing etc. for successful adoption of cotton harvesting and its economic feasibility.

Appropriate plant physiology

Manual crop harvesting, particularly manual cotton picking is mostly independent upon plant height, width, location of bolls on plants, etc. However, there are certain limitations in the functionality and capability of even highly sophisticated harvesting machines. It is required to suitably modify the plant physiology through genetic or breeding interventions to obtain a particular plant height, branch structure, locations of fruits on plants, etc. in order to successfully automate the harvesting operations. Mechanical cotton pickers require medium plant height i.e. around 1.0-1.2 m with minimum branches and bushes i.e. spreading into 0.5-0.6 m diameter for efficient and viable harvesting of cotton crops. Countries that employ mechanical cotton pickers have developed suitable plant genotypes having required plant physiology amenable for mechanical picking. Cotton varieties with the right plant architecture and height, amenable for mechanical harvesting need to be developed for mechanical pickers to work efficiently and effectively.

It is normal practice to sow about 25,000 to 40,000 plants per acre (two to three plants per foot of a row in conventional spaced rows: 38-40 inches) for picker-type varieties [8] whereas 2 to 3 feet spacing per plant (i.e. 5000-6000 plants per acre) is the normal practice for sowing of Bt seeds in India. Though, the reduction of plant height and width results in less number of bolls per plant, the increased plant population per acre area results in more number of bolls than the convention method leading to increased productivity. Cotton breeders and scientists from government research organisations and private seed companies are working for past couple of years to develop cotton varieties, which are suitable for mechanical picking. M/s. Ankur Seeds Pvt. Ltd. and M/s. Nuzivedu Seeds Ltd. are working in tandem with M/s. John Deere India, a cotton picker manufacturer for development of suitable plant genotypes. In this cotton season, M/s. Ankur Seeds Pvt. Ltd. have evaluated its regular products, Ankur 8120 and Ankur 3028 hybrid Bt seeds for their suitability for mechanical pickers. It shows that instead of developing exclusive genotypes amenable for mechanical picking, most of the work is directed on identifying varieties from their regular products. The growth of the plants was regulated by using growth inhibitors or growth regulators developed by M/s. Bayer Crop Sciences, a German well known company for production of chemicals required for mechanical harvesting of cotton.

Synchronize boll opening

It is normal practice in India to harvest the cotton crops in 3-4 pickings because of occurrence of multiple flowering and fruiting of cotton that lead to development of 3-4 flushes of cotton bolls [9]. Though cotton pickers collect only fully open bolls and leave the unopened bolls on the plants unaffected, it's not economically viable to operate the mechanical picker more than once primarily because of high diesel prices prevailing in the market. Delayed cotton pickings have also been attempted in earlier trials in order to allow unopened bolls to get matured. However, it did not work well as locules of bolls which were opened initially got unattached from its burrs and had fallen on the ground. Moreover, there is every chance for damage of opened bolls unpicked for a long time due to incessant rain and wind. There are some chemicals that are used to enhance the rate of boll openings. However, these chemicals affect the natural boll-opening process, but they do

not cause bolls or fibre to mature faster. There is chance of affecting the maturity and micronaire values of fibres by improper timing and doses of chemicals. Hence, there are requirement for identification of proper chemicals, optimisation of its doses, timing etc.

Development of suitable cotton pickers

It has been observed by the numerous researchers that among the different methods tested for cotton picking, the conventional spindle type picker based mechanism appeared to be working satisfactorily for picking of cotton. This method was also evaluated in Indian cotton farms by cotton pickers imported from then USSR [14]. However, the further progress in this direction was constrained by the fall of former USSR.

The potential for mechanical pickers in Indian market have attracted the global giants like John Deer and New Holland for development of mechanical pickers suitable for picking of cotton from small cotton fields. Efforts have been made by the researchers and agricultural machinery manufacturers for attaching the cotton picking heads in the side of existing tractors so as to avoid the high initial investment in purchasing a self-propelled spindle type picker. John Deer India has already come out with a single row cotton picker in which picker head is attached at the side of a 55 HP tractor (2). This machine is being evaluated for two cotton seasons at different part of the country along with several stakeholders including ICAR research institutes, state govt. officials, seed producing companies, chemical manufacturers, ginneries etc. [15]. New Holland is also carrying out the field-testing of a cotton picker prototype specially designed for the Indian market expecting to be launched in 2-3 years' time. The proposed picker is tractor-propelled and tailored specifically for the small farms suitable for Indian farmers.

Fig 2: Cotton crop before defoliant application (left) and after defoliation (right)

Defoliation

Defoliation is the shedding of cotton leaves that naturally occurs when leaves become physiologically mature. It is required to artificially shed the cotton leaves using certain chemicals called as defoliants or harvest aids in order to eliminate the main source of stain and trash to enter the cotton while harvesting. Defoliation also helps in improving lint grades, reduces moisture, improves storage of cotton and opens the green and unopened bolls [16]. There are a number of chemicals used for defoliation of cotton meant for mechanical harvesting [17]. The effectiveness of defoliation depends on several factors like temperature and rain fall at the time of treatment, periods of cloudy weather after treatment, soil moisture and nitrogen levels, calibration of application rates, etc. Weather conditions at the time of application and three to five days following application have a significant effect on cotton response to harvest aids. Harvest aids are most active when temperature, sunlight intensity and relative humidity are high. The yield and condition of the cotton crop are also deciding factor for the choice of defoliants. Optimisation and standardization of defoliants still remain a challenge in India causing 4-5% additional trash content in harvested cotton using mechanical picker in form of un-shedded leaves. It has also been observed in several cases where defoliation did not work properly due to certain unfavorable conditions resulting in 20-25% trash content in harvested cotton against 10-12% for properly defoliated cotton.

Field losses in terms of left over and fallen bolls

The cotton picker machine plucks the cotton from open bolls while unopened bolls are left over on the plants. Moreover, some part of the open bolls is also left un-plucked on the plants and some part of harvested cotton falls on the field while harvesting. The issue of harvesting losses was also raised by group of farmers who witnessed the demonstration of cotton picker harvesting at Abohar, Punjab. The field loss due to mechanical harvesting of any crop is not a new phenomenon. Though combine harvesters also result in field losses, combine harvesting of wheat has become indispensible particularly in Northern part of India. The net margin of cotton farmers has bottomed out in recent past due to increased inputs and labour costs. However, benefits of cotton picker in terms of increased productivity by means of high plant density system and reduction of labour cost for picking have potential to offset the harvesting losses.

Fig 3: Hand picking of cotton (left) and mechanical harvesting of cotton crop (right)

Requirement of additional pre-cleaning machinery

It is widely reported in literature [12, 14, 19-21] that the machine picked cotton contains around 10-15% trash content, which includes burs, sticks, leaves, grasses, motes, etc. However, the imperfection of defoliants under Indian conditions has led to increase in trash content in mechanical picked cotton by 4-5%. Moreover, trash content in range of 20-25% was also observed in certain cases where defoliation did not work properly. The handpicked cotton particularly available in India hardly contains trash content in range of 2-5% depending upon cotton varieties, skill of pickers, precautions taken during picking, number of flushes etc. The cylinder type pre-cleaner removes around 25-30% trash content from the cotton and the remaining trashes are removed in pneumatic conveying and lint cleaning operations. Finally, the bales processed from properly managed modern Indian ginneries contain around ≤1% trash content using a cylinder type pre-cleaner and lint cleaner. On contrary, there is requirement of 3-4 number of additional special type pre-cleaning machines based on combing and extracting principles for making the machine picked cotton ginnable. Cylinder cleaners use rotating spiked cylinders that open and clean the seed cotton by scrubbing it across a grid bars that allows the trash to sift

through .The cylinder type pre-cleaners are meant for removal of kawadi/immature bolls, fine/pin trash, separation of metallic pieces and opening of the cotton. However, machine picked cotton contains large vegetative content like sticks and burrs and significant amount of green and dry leaves that require combing and extracting actions for dislodging of large and fine trashes. Large foreign matters are removed by combing action and centrifugal force in extractor type cleaners as seed cotton is pulled across a series of grid bars by a rotating saw/toothed cylinders. This cleaning mechanism is referred as the "sling-off" principle.

Moreover, the machine picked cotton is likely to be wetter than handpicked cotton due to application of water for doffing of cotton in case of mechanical picking. The efficiency of pre-cleaning machines depends to considerable extent on moisture in cotton. There is requirement of optimum moisture content in cotton for pre-cleaning machine to function effectively. The greater the moisture, lower the efficiency and vice versa. Hence, there is requirement of a tower drier system for bringing down moisture content in machine picked cotton to optimum level prior to pre-cleaning.

Trash content and fibre parameters for the machine picked cotton

Fibre quality parameters analysed using HVI does not show any significant effect on fibre qualities for cotton variety Ankur 8120 after cleaning it in set of machines. However, significant differences in fibre parameters were observed for cotton variety Ankur 3028 after cleaning it in the set of machines. It is probably due to reason that the Ankur 3028 contained much higher amount of trash content than to Ankur 8120 that led to deterioration in the fibre qualities. Fibre parameters analysed using AFIS shows significant differences in the fibre parameters for both the cotton varieties tested in this study after pre-cleaning (Table 4). Fibre neps that used to be around ≤100 count/g for roller ginned Indian cotton have increased to around 250 count/g. Moreover, upper quartile length (UQL) measurements that corresponds to upper half mean length (UHML) of HVI values shows significant loss in fibre length (about 0.5 mm) for the pre-cleaned cottons. Higher neps count leads to reduction in yarn realisation and increase in fibre losses in spinning mills resulting in reduction in mill profits. The AFIS data clearly shows that the pre-cleaning machines need to be optimised and fine-tuned in order to avoid damage in fibre qualities. Table 5 shows that the trash content in the machine picked cotton has been brought down to 4.2% and 5.7%, respectively for the properly defoliated and improperly defoliated cottons.

Increased investment for fixed and processing cost

As mentioned in the preceding section that the machine picked cotton requires 3-4 numbers of additional cleaners for its processing. The cost of additional pre-cleaners including a tower drier and conveying system is around Rs. one crore at prevailing market rates for a ginning plant of around 10-15 bales per hour capacity. It is very difficult to convince the Indian ginners to invest additional one crore rupees in procurement of pre-cleaning machinery meant for handling of the machine picked cotton.

Increased cost of processing

The additional cleaning machinery requires around 100 HP additional connected electrical load and a heating device for drying of the machine picked cotton in the tower drier. There is requirement of around 60 litre diesel and 60 unit electrical energy in an hour for running of the tower drier and the cleaning machinery resulting in expenditure of around Rs. 5000/h (including maintenance and operator cost) for pre-cleaning and drying of the machine picked cotton. The increased cost on the processing comes to around Rs. 1/kg of seed cotton, which is around 67% of the total cost of ginning of the handpicked cotton (around Rs. 1.5/kg seed cotton).

Increased losses of fibres in ginneries

It is well known fact that the ginners particularly in India are reluctant for employing even a light cylinder pre-cleaner and post cleaner. It is mainly because of the reasons that the pre-cleaners lead to losses of some fibres i.e. 1% along with the removed trash content. However, most of the separated fibres are short fibres. The study by Arude *et al.* [22] has showed processing losses to the tune of 1.8% and 3.3%, respectively for handpicked cotton of the first and the second pickings. The application of 3-4 pre-cleaners for the processing of the machine picked cotton shall lead to increased loss in fibres that may concern to the ginners.

Conclusions

This study presents an overview of status, issues and challenges for mechanization of cotton harvesting in India. The following conclusions can be drawn from this work:

- Spindle type picker specially developed for harvesting of Indian cotton is found to be promising.
- It is required to develop suitable varieties/hybrids to obtain suitable plant types that are required for successful operation of the mechanical picker.
- There is requirement for adoption of certain agronomic practices like application of growth regulators, boll openers, defoliants etc. for successful operation of the mechanical picker.
- Trash content in the machine picked cotton was 13.3% and 22.2% for properly and improperly defoliated cottons, respectively.
- There is requirement of 3-4 additional cleaners based on sling off principles and a tower drier for processing of the machine picked cotton.
- Ginners shall have to make a substantial investment in machinery to get their gins properly equipped to process the machine picked cotton.
- The processing cost of the machine picked cotton is 67% higher compared to the handpicked cotton.
- There is slight deterioration in the fibre parameters due to processing in additional cleaners.
- Spinners shall have to make some investment in machinery to process bales with higher neps content.

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