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Computer aided refinement and development of tractor operated cotton stripper

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Cotton is an important commercial crop of India, having 12.81 M ha cultivated area which is largest in the World. In India 100% of the cotton is harvested manually (Anonymous 2016). The yield per ha which was stagnant at about 300 kg/ha for so many years, jumped to 472 kg in the year 2005-06 and now it has reached to the level of 504 to 566 kg per ha. Though this per ha yield is still lower against the world average of about 705 to 805 kg/ha, country is expected to make more strides in cotton production in the years to come (Anonymous 2017). In advanced countries like USA, Brazil, Australia, cotton pickers and strippers are available for mechanical picking of cotton. Cotton pickers with different mechanisms such as Drum type spindle and Chain belt type spindle likewise cotton stripper with different mechanisms like finger type and brush type are available and working successfully in advanced countries. Kohli *et al*. (2015) reported that for small holder cotton cultivation and manufacturers can be focused on to select, design and development of mechanical cotton stripper with finger type of mechanism. Attribute coding also helps the manufacturers to understand the kind of harvesters used for cotton picking in different countries as per the field conditions.

In recent years it has been observed that labour shortage appear during the harvesting time of cotton results delayed picking and subsequent sowing of next crop. Knowing the conditions of Indian farms and to overcome this situation of manual picking, efforts were made by different Institutions and Universities for the development of different types of cotton picker. Punjab Agricultural University (PAU), Ludhiana developed the pneumatic picker by using an industrial type vacuum cleaner for picking cotton in the field. Same type of study was done by TNAU, Coimbatore (Garg 1999). A tractor mounted vacuum type cotton picker was developed and evaluated by PAU, Ludhiana (Ankit 2008). The picking efficiency of the developed picker was in the range of 70-75 (%), but the output of these machines was very low. Singh *et al*. (2014) evaluated portable handheld type cotton picking machines for different cotton varieties and found that there was no significant difference in the picking rate among chain, roller and manual picking at 5 percent level of significance. The average picking rate of both chain type and roller type cotton picking machines was measured to be 3.44 and 3.09 kg/hr, respectively for selected cotton varieties which was lesser as compared to manual picking rate, i.e. 6.63 kg/hr. The percentage of trash content for both chain and roller type cotton pickers was also higher, i.e. 11.52 and 10.44 (%) as compared to trash content of 7.43 (%) measured for cotton picked manually.

The idea of development of indigenous cotton stripper was conceptualised from the study, conducted by Kohli *et al*. (2013) in which a Multiple Attributes Decision Making (MADM) technique was applied for selection and development of the mechanical cotton harvester, suitable for the local cotton varieties and agronomic practices. It was observed that if relative ranking was given to the pertinent attributes then the best mechanical cotton harvesters for existing planting system prevalent in India and high density planting system was brush and finger type cotton strippers, respectively. But, the big challenge in development of cotton stripper was crop geometry, agronomic practices for cultivation of crop and seed-cotton extraction from the cotton bolls harvested with boll shells and cleaning prior to ginning.

Sharma *et al*. (2015) designed and developed the self-propelled walk behind finger type cotton stripper. During study, a conceptual design of self-propelled finger type cotton stripper was generated to pick/harvest the local high density and dwarf cotton varieties mechanically. The developed prototype was evaluated on F 2383 and RCH 773 cotton varieties to observe its performance. The average value picking efficiency and picking capacity of developed cotton stripper was observed to be in the range of 76-80% and 135-325 kg/hr, respectively.

In spite of these mechanical cotton harvesters available worldwide, the cotton picking is still done manually in most of the countries including India. The main reasons of not

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using these mechanical harvesters in India are their high cost, difficulty in operation due to small/marginal farms and indiscriminate type cotton varieties grown in India. Keeping these in view, a tractor operated cotton stripper was developed and evaluated at Punjab Agricultural University, Ludhiana in the year 2015 (Mishra 2017). Based on the field trial conducted, it was decided to study the tractor operated cotton stripper and make design refinement for the improvement of the performance.

Working principle of tractor operated cotton header

The idea of development for finger type cotton header was derived from the study conducted by Tupper (1966) and Sharma *et al*. (2015). The designed cotton header works on the principle that when finger type header will move through the cotton field due to its forward motion, inclined fingers will strip the cotton bolls with burs from the plants and rest of the plant will remain in its position in the field. Cotton bolls with shells/burs will be stripped from the plants with the help of a series of stationery inclined fingers having a narrow gap among the fingers. The stripped materials will move upward to the inclined fingers with the force of next group of plants being stripped. A reel/paddle/kicker mounted at the rear-side of the fingers will help to convey the stripped materials to the conveying auger. The conveying auger will help to convey the material to feeder for further processing. The materials are conveyed through feeder to cleaner unit. Here, burs including green bolls, sticks and leaves were removed with the help of cleaner. After cleaning, seed cotton store into the storage tank.

Refinement and modifications of tractor operated stripper header

The first prototype of tractor operated cotton stripper was developed and evaluated at Punjab Agricultural University, Ludhiana in the year 2015. Some refinement and modifications were identified in the header on the basis of field trials conducted in the 2015 of tractor operated stripper header. Field observations their remedies and benefit expected are mentioned in Table 1.

Table 1 Observation, remedies and benefit of modification in cotton stripper

Observation/problem	Remedy	Expected benefit
Fingers were bent after the operation	Finger were hardened and length of supporting rib increased	Finger may not bend
Cotton got left at pan due to more space between reel and auger	Auger diameter increased to decrease the space	Conveying of cotton improved
Finger spacing adjustment takes longer time (Aprox. 35-40 minutes by two persons)	Mounting of finger with replaced with clamps	Adjustment time reduced
Paddle type reel contributed to increase the trash	Beater/kicker used in place of reel pad	Trash content may reduce by 2%
The working of stalk walker was not proper resulting in plant uprooting	Stalk walker profile was changed	Reduced plant uprooting
Stick percentage was more in trash content due to limited separation at the header	Perforations were given in auger bottom sheet having slot in both directions (similar as groundnut thresher concave) and also at back sheet of header	Trash content may reduce

Computer-aided 3D modelling of the header

The NX-8 CAD software (Make: Siemens PLM Software) was used for the study. It provides tools for design, simulation and manufacturing with high-definition 3D (HD-3D) environment, to enable rich visual interaction and information delivery for validation, product templates and other applications reporting and analytics tools. The CAD was done at Research and Development Department, Mahindra Applitrac, Mohali.There are five major sub-assemblies of finger type stripper header. Different sub-assemblies of header are categorized as follows: Header frame sub-assembly, Finger sub-assembly, Reel/Paddle sub-assembly, Auger sub-assembly, Power transmission.

Computer aided modelling of proposed modifications

The proposed modifications were done using computer aided 3D modelling. The finger sub assembly was generated using MS angle, square box section, sheets and square bar. For making of finger 25×25×4 mm MS angle having 600+100 mm length was selected. The front tip finger was pointed and 10 degree bend was provided to top side. The finger was attached with 4 mm thick MS sheet supporting rib. The supporting rib was attached with 140 mm long clamp. For creating the clamp 5 mm thick 35 mm MS flat (35 ISF 5) was selected. The 39 sets of finger having 16 mm spacing were created for coverage of three rows. All finger sets was clamped on 2030 mm long MS square pipe (40×40×4) with the help of fasteners. The spacing between two finger sets was adjustable and can be increased or decreased by the help of fasteners. The two MS square bars were used as finger locking shaft to the locking finger assembly on right and left side of frame of the header. The angle between finger and horizontal known as finger angle was also adjustable and can be increased or decreased with the help of finger locking shaft.

Stalk walker was as similar as in first prototype but only stalk walker profile was changed. For making stalk walker profile 3 mm thick MS sheet was selected which was similar to the v shape zigzag curve. Three profiles were created at 120 degree on round pipe having outer diameter of 42.3 mm and 2030 mm long.

Reel/Kicker assembly was generated using MS square pipe, sheet, and square bar. For making kicker, 3 mm thick MS sheet was selected. This kicker was attached with 3 mm MS sheet supporting ribs. The 68 kicker was mounted on the 45×45×3 MS square pipe on each along the 2030 mm length. To give rotary motion two 35 mm MS square bar shaft were used.

Auger assembly was generated using MS sheet and round bar. For making auger worm 3.15 mm thick MS sheet was selected and divided into two parts left and right side worm. The pitch of worm was 200 mm and outer diameter was 390 mm. These worms were mounted on the 2030 mm long and 250 mm diameter round pipe. For creating the round pipe 1.6 mm thick MS sheet was rolled. Three paddle having 5 mm thick MS sheet was created to kick or put the material into the feeder mouth. These three paddles were mounted on same pipe at 120 degree.

The auger bottom sheet was half round curved sheet which helped the auger worm to convey the material. For making auger bottom sheet 2 mm MS sheet was selected. The sheet was supported with 3 mm MS sheet rib and was having perforations of 13×76 mm slot, which helps to partially cleaning of seed cotton.

For back sheet, 2 mm MS sheet was selected and attached on chassis. This back sheet was strengthening the header frame chassis. The sheet was perforated with help of pocket command which helps to partially cleaning of seed cotton.

All the sub-assemblies like header frame, finger, reel, auger and power transmission were assembled using assembly domain of NX -8 CAD software.

Development and fabrication of modified header assembly

Different modified assemblies, i.e. header frame, finger, reel, auger and power transmission were fabricated in the proto shop of Mahindra Applitrac, Mohali to develop tractor operated stripper header. Computer aided 2D drawings of all the components were generated from 3D models. Based upon 2D drawings and bill of material (BOM), a tractor operated three row cotton header was developed and fabricated.

Field evaluation of modified tractor operated cotton header

Modified tractor operated cotton stripper was evaluated at research farm of RRS, Abohar. For the experiment, finger length, finger spacing and finger angle were fixed but forward speed was varied. Mishra *et al*. (2017) reported that variety F 2383 was suitable for mechanical picking. Hence, crop variety F 2383 was selected and sown at high density planting system, which was 675×10 m mm spacing. After sowing, the various field operations such as irrigation, weeding fertilizer application and spraying etc was done. The crop was harvested for about 170-190 days after sowing. In present experiment, 2-Chloroethyl-phosphonic acid (Ethrel) defoliant was used to fall off the leaves of cotton plant to improve and facilitate mechanical harvest (Singh *et al*. 2017). The defoliant was sprayed with the help of knapsack sprayer and self-propelled electrostatic sprayer. On an average plant height of variety F 2383 was observed 874 mm. The plant width (canopy) F 2383 was 530 mm. The number of opened bolls of variety F 2383 was 26. The number of green bolls of 4. It was found that the heights of lower and upper boll of F-2383 were observed 245 and 713 mm respectively. An operational view of tractor operated cotton stripper and harvested field is shown in Fig 1.

Effect of forward speed on picking capacity and picking efficiency

Picking capacity and picking efficiency for modified header at different forward speeds are depicted in Fig 2 On an average, picking capacity for 2.63 km/h (S1) and 4.5 km/h (S2) forward speed was observed 1311.10 and 2072.33 kg/h respectively. Picking capacity at 4.5 km/h (S2) speed was 36.44 % higher than 2.63 km/h (S1) speed. On an average, picking efficiency for 2.63 km/h (S1) and 4.5 km/h (S2) forward speed was observed 89.28 and 89.91 kg/h respectively. Picking efficiency at 4.5 km/h (S2) speed was 0.7 % higher than 2.63 km/h (S1) speed.

Fig 1 An operational view of tractor operated cotton stripper and harvested field

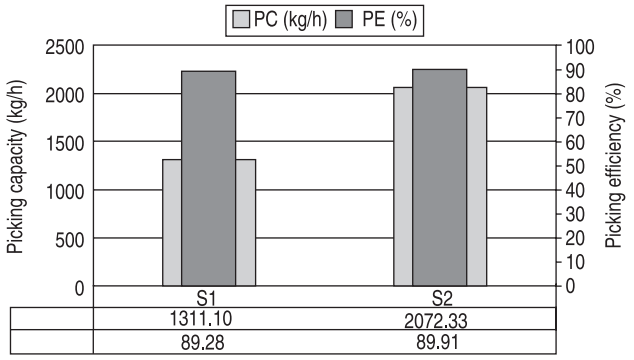

Fig 2 Effect of forward speed on picking capacity and picking efficiency

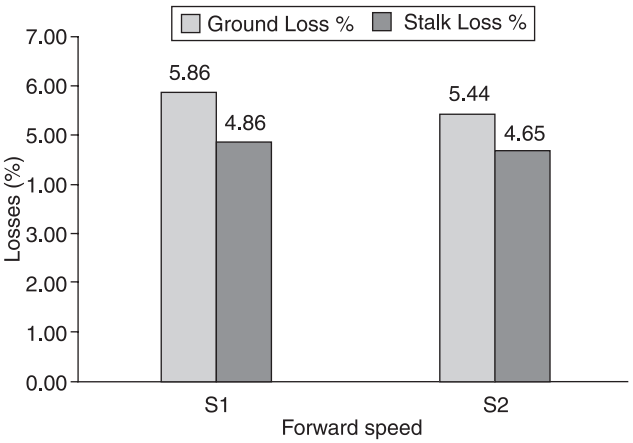

Fig 3 Effect of forward speed on ground loss and stalk loss

Effect of forward speed on ground loss and stalk loss

Ground loss and stalk loss at different forward speed is depicted in Fig 3. On an average, ground loss for 2.63 km/h (S1) and 4.5 km/h (S2) forward speed was observed 5.86 and 5.44 % respectively. Ground loss at 2.63 km/h (S1) speed was 7.16 % higher than 4.5 km/h (S2) speed. On an average, stalk loss for 2.63 km/h (S1) and 4.5 km/h (S2) forward speed was observed 4.86 and 4.65 % respectively. Stalk loss at 2.63 km/h (S1) speed was 4.3 % higher than 4.5 km/h (S2) speed.

Conclusions

The average value picking efficiency and picking capacity of developed cotton stripper was observed 89% and 1669.21 kg/h respectively. Picking capacity at 4.5 km/h (S2) speed was 36.44 % higher than 2.63 km/h (S1) speed. Picking efficiency at 4.5 km/h (S2) speed was 0.7 % higher than 2.63 km/h (S1) speed. On an average, ground and stalk loss was observed 5.65 and 4.75 % respectively. Ground loss at 2.63 km/h (S1) speed was 7.16 % higher than 4.5 km/h (S2) speed. Stalk loss at 2.63 km/h (S1) speed was 4.3 % higher than 4.5 km/h (S2) speed.

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SUMMARY

A tractor operated cotton stripper was refined and developed with help of CAD software for the improvement of the performance. In the modified tractor operated finger type cotton stripper, some refinement and modifications were done in the header on the basis of field trials conducted in the previous years. All the sub-assemblies like header frame, finger, reel, auger and power transmission were created using NX -8 CAD software at Mahindra Applitrac, Mohali. Based upon 2D drawings and bill of material (BOM), a tractor operated three row cotton header was developed and fabricated. The modified prototype was evaluated on RCH 773 cotton varieties to observe its performance. The average value picking efficiency and picking capacity of developed cotton stripper was observed of 89% and 1669.21 kg/h respectively. On an average, ground and stalk loss was observed of 5.65 and 4.75 % respectively.

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