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Investigating physical and biometric properties of local grown cotton varieties during *kapas* picking stage to estimate the crop canopy characteristics

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Abstract : India being the world's largest producer of cotton still practices manual picking. Cotton production has been increasing over the years but so is the cost of cultivation due to increased labour dependency. The objective of the study was to investigate the physical and biometric parameters of cotton to optimize the design parameters of cotton picker. To design and develop a self propelled cotton picker suitable for multi-picking practice, information related to physical properties such as cotton boll equivalent diameter, density and force required to pick a fully opened cotton boll are necessary. Also average cotton crop canopy dimensions otherwise called biometric parameters are necessary to design picker finger arrangement. Average weight of cotton boll was found to be 5.46 g with an equivalent diameter of 4.89 mm. Bulk density and tapped density of cotton was found to be 0.05 and 0.18 g cm-3, respectively. Force required to pick a full opened cotton boll was found to be 2.92 – 2.94 N (≈3N).Crop canopy characteristics and ideal conditions for machine picking were estimated by rigorous field visits and preliminary studies.

Keywords: Biometric parameters, cotton boll, density, equivalent diameter, picking force

Cotton also known as "White Gold" is most important fiber as well as cash crop of India with a commanding role in the industrial and agricultural economy. Cotton production has been increasing quantitatively in the country over the years which is estimated to be around 13 million hectares with productivity of 486 kg/ha and a production of 371 lakh bales in the year 2020-2021 (COCPC, 2021). Increase in wage rate of human labourh as led to escalation in the cost of cultivation drastically reducing the net income. Labour charges account for 30-40 per cent of the total cost of cultivation (Reddy *et al.*, 2018).

Rise in the wagerate is not specific to cotton cultivation alone as agricultural wages rose steeply after 2007-2008. Also with accelerated economic growth, job opportunities in non-agricultural sector are created much faster that leads to a pull on labour away from agriculture where productivity and wages are relatively high (FICCI 2015). Hence, the key in reducing the cost of cultivation of cotton is by reducing the dependence of human power which can be achieved by the advent of mechanization.

Cotton picking is still one of the most costly operations representing about 30 per cent of total cotton production cost. In general, it is done either by hand picking or by machines. Only 30 per cent of the total cotton produced in the world is picked mechanically. And India, being one of the five largest cotton producing countries in the world, the entire 100 per cent cotton is picked manually. This is because the commercially available mechanical cotton harvesters are not suitable for multi picking practice and needed huge investment which farmers in India couldn't afford.

In view of these, a research work has been undertaken to develop a cotton picker suitable for multi-picking practice of Indian cotton varieties. As a part of above mentioned research, cotton physical and biometric properties have

been studied to optimize the design parameters of cotton picker.

MATERIALS AND METHODS

The present investigation was undertaken during the year 2021-2022 to study the biometric and physical parameters of the selected varieties of cotton crop. To design a cotton harvester that includes picking mechanism and storage, one should be well aware of cotton crop biometric and physical properties such as spread of the canopy (height, width across and along the row), force required to pluck the bolls, density, equivalent diameter of bolls and maturity period.

Physical properties such as equivalent diameter, density and picking force are needed to design a suitable picker spindle as well as storage duct. Equivalent diameter represents the mean diameter of cotton boll which help in optimizing the diameter of picker spindle. Picking force, volume and density play a major role in optimizing the picking roller speed, impact required to pluck the boll and storage duct construction. Imparting a high force through spindle rotation might result in plant and unopened boll damage. Hence picking force of selected cotton bolls were measured to find the exact force necessary to pick the cotton. It helps in optimizing the rotational speed of picker roller embedded with spindles as well as avoids damage to unopened bolls.

Equivalent diameter

Equivalent diameter, also known as geometric mean diameter of cotton boll is defined as the cubic root of length, width and thickness (not necessary that the three intercepts should intersect with each other). Dimensions (l,b,t) of the bolls were measured along larger sides using a vernier calliper (LC = 0.01 mm).

Equivalent diameter = $(lbt)^{1/3}$..... (Sahay and Singh, 2001)

Where l, b and t are the maximum length, breadth and thickness of cotton bolls

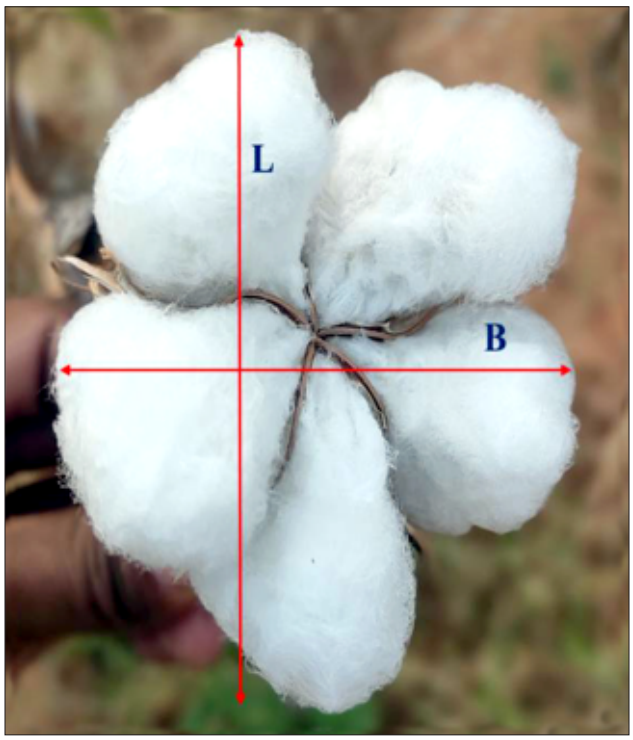

Fig. 1. Cotton boll

Density

Density is determined as the weight of the cotton bolls divided by its volume, expressed in g mm-3. Both bulk density and tapped density were measured following the similar procedure. A50 ml empty cylinder of radius 'r' was weighed and volume of the cylinder was measured. Cotton boll wasgently pressed into the empty container and change in weight of container was noted. Procedure was replicatedfor 5 different bolls and average density was calculated.

Volume = Πr^2 h ..... (Sahay and Singh, 2001)

Dimensions of the cylindrical container are 4.5×7 cm (d×h). And volume is calculated as 111.3 cm-3.

$$\text{Density} = \frac{\text{change in weight}}{\text{Volume}}$$

Picking force

Picking force was measured using two

techniques. In the first technique, a test rig was developed to simulate actual field condition for measuring the cotton picking force as shown in Fig.2(a). The setup consisted of a circular frame of diameter 125mm and two straight projections of height 125mm with 4mm diameter rod. At the top, a rod of 4mm diameter was used to connect the two straight projection ends. A clamp has been fixed at the top centre to hold the fully opened cotton bolls. The developed frame was directly mounted on the electronic weighing balance.

Fully opened cotton bolls were fixed at the top centre using the clamp. A downward pulling force was applied with fingers. Force required to detach *kapas* from cotton bract was transmitted to electronic weighing balance through supporting frame (Murugesam and Manojkumar, 1999).

Fig. 2(a) & 2(b) Test setup for measurement of picking force

In the second technique, a hanging type digital electronic balance was used to note the picking force. Cotton boll was knotted to the hook as shown in Fig. 2(b). Results from both the techniques are further corelated to find the average picking force of cotton boll.

Comparision of biometric parameters for local grown cotton varieties

Biometric parameters of few selected local grown cotton varieties are needed to optimize the working space of cotton picker, maturity period and ideal condition for machine picking. Different parameters considered for the study are height of plant, width of plant along row and across row, number of fully opened, partially opened and unopened bolls (Veerangouda *et al.*, 2012). Fields with predominant local grown cotton varieties (A.P & TG) *viz.*, ZCH-545 BG-II, SWCH 4749 BG-II, KDCHH 532 BG-II, KSCH 232 BG-II, KCH-14K59 BG-II, LHDP-1 and LHDP-5 were selected to collect the information during *kapas* picking stage and are tabulated as follows (Table. 2).

The height of the plant was measured by erecting the plant vertically. Width of the plant along row and across row were measured in a similar way by spreading the extreme ends horizontally. The number of fully opened bolls, partially opened bolls and unopened bolls in each plant were counted manually and recorded. Measurements were taken from 5 randomly selected plants and are replicated for 20 plants in each variety.

Fig. 4. Preliminary investigation in cotton crop

RESULTS AND DISCUSSION

Physical and biometric properties of cotton bolls play an important role in the design optimization of mechanical cotton boll picker. Variety of the cotton boll was not given any attention while measuring the physical properties since all cotton bolls are identical except for their maturity and spatial distribution of bolls (Dochia *et al.*, 2012). Physical properties of the cotton bolls were calculated and tabulated in Table.1.

Table1. Physical properties of cotton bolls

S. No.	Weight of cotton boll (g)	Equivalent diameter (mm)	Bulk density(g cm-3)	Tapped density(g cm-3)	Picking force (N) 1	2
1	5.82	4.85	0.052	0.175	2.89	2.84
2	4.01	4.78	0.036	0.190	3.10	2.94
3	6.54	5.03	0.059	0.183	2.76	3.04
Average	5.46	4.89	0.05	0.18	2.92	2.94

Equivalent diameter

Equivalent diameter was calculated by measuring the major, minor and intermediate axis lengths of a cotton boll. It increased with the weight of the boll and average equivalent diameter was calculated to be 4.89 mm.

Density

Density plays an important role in collection and storage of picked cotton. Bulk density and tapped density were found to be 0.05 and 0.18 g cm-3, respectively. Hence, in a 150×6 cm (h×r) cylindrical collection tank, if loosely fed 850 g and in case tapped 3 kg of cotton can be collected.

Picking force

Force required to pick was measured by using a small experimental frame as well as hanging type weighing balance. Results from both the techniques were correlated as shown in Table.1. Force required to pick the cotton boll was found to be ranging between 2.92 – 2.94 N (≈3N). Hence equal force needs to imparted by the picker spindle in order to pluck the boll. Increasing the force help in achieving higher picking rate but might cause damage to branches and unopened bolls.

Biometric parameters for local grown cotton varieties

Investigating the biometric parameters of local grown cotton varieties during *kapas* picking stages will enable us to find an ideal condition for machine picking. Ideal condition means less plant damage where branches will be live and flexible enough to overcome the impact of the picker spindle.

In few cases, height of the plant was noted more than 160 cm because of an indigenous practice followed by farmers *i.e.*, cutting of crown portion which they believe to increase the height along with yield.

Study revealed that 85 per cent of the cotton was picked during the initial three pickings with second picking being more economical during 120-150 DAS depending on the variety. Average plant height was noted to be 115 cm. Width of the plant across the row and along the row was noted to 87 and 88 cm, respectively. Hence crop canopy reach and spatial distribution of cotton bolls for a single cotton plant was noted to be in the range 115 × 87 × 86 cm 3. The noted readings are kept as a standard in further designing the cotton picking setup.

CONCLUSION

Physical properties of cotton bolls and biometric parametric of cotton crop are investigated as a primary objective in designing a cotton picker. Variety of the cotton boll was not given any attention while measuring the physical properties since all cotton bolls are identical except for their maturity and spatial distribution of bolls (Dochia *et al.*, 2012). Average weight of cotton boll was found to be 5.46 g with an equivalent diameter of 4.89 mm. Bulk density and tapped density of cotton was found to be 0.05 and 0.18 g cm-3, respectively. Force required to pick a full opened cotton boll was found to be 2.92 – 2.94 N (H”3N). From rigorous preliminary studies in various cotton varieties, average plant height was noted tobe 115 cm. Width of the plant across the row and along the row was noted to 87

Table.2 Biometric properties of local grown cotton varieties

Parameters	Plant height (cm)	Plant width along the row (cm)	Plant width across the row (cm)	Fully opened bolls	Partially + Unopened Bolls
			ZCH-545 BG-II		
Minimum	127	90	80	22	6
Maximum	160	120	135	31	15
Mean	**142.4**	**102**	**99**	**26.4**	**10.2**
Median	140	100	90	26	9
SD dev	12.9	10.9	21.3	3.36	3.4
			SWCH 4749 BG-II		
Minimum	120	70	70	25	8
Maximum	160	90	95	38	14
Mean	**137**	**82**	**83**	**29.8**	**11.2**
Median	135	85	80	29	12
SD dev	14.8	9.1	9.7	5.2	2.3
			KDCHH 532 BG-II		
Minimum	105	85	78	28	8
Maximum	120	100	100	31	16
Mean	**114**	**94**	**89.6**	**27.4**	**12.2**
Median	115	95	90	26	13
SD dev	6.5	6.5	8.6	2.5	2.9
			KSCH 232 BG-II		
Minimum	95	85	80	26	7
Maximum	120	100	100	30	14
Mean	**105**	**93**	**89**	**27.8**	**10.8**
Median	100	95	90	28	12
SD dev	10.0	5.7	7.4	1.5	3.1
			KCH-14K59 BG-II		
Minimum	81	60	80	22	6
Maximum	111	100	90	29	12
Mean	**94.2**	**79**	**87**	**25.6**	**9.6**
Median	92	80	90	27	10
SD dev	12.0	15.2	4.5	3.0	2.3
			LHDP - 1		
Minimum	100	75	70	26	6
Maximum	140	90	100	34	11
Mean	**115**	**84**	**92**	**31**	**8.4**
Median	110	85	100	32	8
SD dev	17.3	6.5	13	3.2	1.8
			LHDP - 5		
Minimum	95	65	50	27	9
Maximum	110	90	80	31	14
Mean	**102**	**80**	**70**	**29.2**	**11.2**
Median	100	80	70	29	10
SD dev	5.7	9.3	12.2	1.8	2.2

and 88 cm, respectively. Carrying out machine picking will be effective between 120-150 DAS since preliminary study revealed 80% of the bolls were opened.

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