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An approach for developing compactness measurement indices in cotton (*Gossypium* spp.)

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Cotton, the best options for rainfed regions would be early-maturing short duration straight varieties, resistant to sucking pests, dwarf statured, zero-monopodial, which are amenable for high-density planting at populations of 1,00,000 per acre or more. High density planting system has been suggested as an alternative strategy instead of conventional one to increase yield as reported by Darawsheh *et al.* (2009). Higher productivity in Brazil was achieved through development of compact sympodial varieties suited for high density planting (Kranthi 2012). Machine picking ultimately warrants high density planting system with compact genotypes for its suitability. Compact plant and HDPS are need of the hours for Indian situation (Venugopalan *et al.* 2013) hence; there is a need to develop proper indices to measure compactness in plant and to screen available genotypes. A more compact plant structure (Reddy *et al.* 1990) improves light penetration in the canopy. Compact plant type with zero monopodia and short sympodia is suitable for high density planting.

In cotton, main stem has an erect, indeterminate monopodial growth habit. Sympodial branches bear fruit directly, so they are called fruiting branches (Oosterhuis 2001). Under high density planting system (HDPS) encourages formation of sympodial branches. The length of sympodial branch is maximum at base of the plant and decreased proportionately towards top of the plant. Sympodial branches on the main stem are located in a spiral order, angled along the main stem. Proportionate decreasing and spiral order of sympodia could make conical morphoframe for cotton plant above the ground. Cotton is planted in rectangular geometry by higher row to row spacing with less plant to plant spacing for need of easy intercultural operation and other management. Thus influences the sympodial length, higher length by perpendicular to row direction and short branches are formed adjacent to row direction; which make elliptical in shape by area occupied by the plant.

Biometric observation on 100 plants were made in three compact genotypes (CICR CSH 19-2, PAU 1 and CICR RS 2013) planted at 75 cm × 30 cm at Central Institute for Cotton Research, Coimbatore during 2018 in summer cotton at 90 DAS revealed that the sympodia with highest mean length was observed in 3/4th node then sympodial length was proportionately decreased towards top of the plant. The results confirmed that proportionate decreasing and spiral order of sympodia could make conical morphoframe for cotton plants. Genotypes were planted at 75 cm row to row distance with 30 cm of plant to plant spacing. The sympodial length is varying with direction especially opposite and adjacent to row direction. The results observed highest length of 17.9 and 16.3 cm with both side opposite to row direction. The adjacent to row direction observed the length of 13.8 and 13.7 cm in both side of the plants. Spiral order of sympodia could make conical morphoframe for cotton plants. However, Cotton is planted in rectangular geometry commonly by higher row to row spacing (75 cm) with less plant to plant spacing (30 cm) for want of easy intercultural operation and other management. Which influenced the growth behavior resulted in variation in length of sympodia; thus ultimately resulted as elliptical cone morphoframe for cotton plants with elliptical base.

Compactness measured by different approaches includes sympodial length (cm), plant height (cm), sympodial length per plant height, plant height per sympodial length, area occupied by individual plant (cm^2) and total volume of the plant (cm^3). Measurement on sympodial length (cm) or plant height (cm) alone does not provide correct picture of land area occupied by the plant or total volume of the plant, which is essential for measuring compactness. The ratio of sympodial length (cm) per plant height (cm) did not provide correct pictures of compactness in all situations. Compact plant may not be productive always. Hence necessity arises to work out efficacy of compactness. The two indexes are proposed here. The compactness efficiency index CEI 1 (area) (mg/cm^2) was measured by kapas yield (mg) of plant divided by area occupied by plant (cm^2). The compactness

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efficiency index CEI 2 (volume) (mg/cm^3) was measured by kapas yield (mg) of plant divided by total volume of the plant (cm^3).

$$\text{Compactness Efficiency Index CEI 1 (area)} = \frac{\text{Kapas yield (mg) of plant}}{\text{Area occupied by plant (cm}^2\text{)}}$$

$$\text{Compactness Efficiency Index CEI 2 (Volume)} = \frac{\text{Kapas yield (mg) of plant}}{\text{Total volume of the plant (cm}^3\text{)}}$$

The area occupied by plant is calculated by using formulae of elliptical base

$$\text{Area } A = \pi \times R \times r$$

The volume of the individual plant was calculated by using elliptical cone formulae

$$V(\text{cm}^3) = (\pi \times R \times r \times h)/3$$

where R, mean of highest sympodial length (cm) measured in both side of the plant opposite to row direction; r, mean of highest sympodial length (cm) measured in both side of the plant adjacent to row direction; h, height of the plant.

The data of Bt varietal evaluation trial (25 genotypes) conducted at Central Institute for Cotton Research, Coimbatore during 2017 was used to calculate land area occupied by individual plant to identify compact genotype (Table 1). The genotype NSBT 108 (101.3), OUAT Bt 2 (125.6), PAU 1 (129.5), CICR-K 34007 (142.0), CICR-F1861 (154.2) and NSBT (154.6) were identified as compact genotypes, which needs less land area (cm^2) for cultivation.

Table 1 Compactness index and yield of different genotypes

Genotype	Ht (cm)	Sympodial length (R) opposite to row direction (cm)	Sympodial length (r) adjacent to row direction (cm)	Area (cm^2)	Volume (cm^3)	Index I	Index II	Yield (q/ha)
PAU1	42.8	9.2	4.6	129.5	1847.8	43.4	3.0	7.5
Rahuri 1	42.8	12.3	5.1	194.9	2780.4	41.6	2.9	10.8
OUAT Bt 2	47.8	8.5	4.8	125.6	2001.3	80.0	5.0	13.4
OUAT Bt 1	49.6	12.0	4.7	175.9	2909.0	58.4	3.5	13.7
CICR-Suraj	56.7	16.1	4.7	232.7	4394.8	51.6	2.7	16.0
CICR-Rajat	52.5	14.4	4.2	185.9	3255.5	64.9	3.7	16.1
CICR-SRI-5	48.9	12.4	5.2	198.7	3240.5	41.5	2.5	11.0
CICR-CSH 19-1	53.3	11.8	4.7	170.2	3022.3	39.7	2.2	9.0
CICR-CSH 19-2	43.8	11.4	4.5	159.1	2323.3	38.2	2.6	8.1
CICR-RS 2013	52.6	12.2	4.7	175.8	3081.7	45.7	2.6	10.7
CICR-F 1861	52.3	11.3	4.4	154.2	2690.3	58.8	3.4	12.1
CICR-K 34007	52.7	10.9	4.2	142.0	2492.6	48.6	2.8	9.2
CICR-SRI 1	54.5	15.7	4.8	232.5	4221.1	43.9	2.4	13.6
CICR-GH 5	48.7	15.4	4.8	228.1	3699.7	40.8	2.5	12.4
CICR-GH 8	49.0	10.1	5.1	158.7	2591.7	54.4	3.3	11.5
CICR-PKV 081	48.8	15.7	5.0	243.7	3964.1	39.4	2.4	12.8
Shakti	61.1	10.8	4.8	161.5	3291.5	66.9	3.3	14.4
CICR-CPT 1	55.9	16.0	5.1	251.4	4681.0	43.3	2.3	14.5
CICR-CPT 2	53.8	13.4	4.9	202.7	3634.9	63.3	3.5	17.1
CICR-CPT 3	62.9	13.3	5.0	207.4	4346.2	46.3	2.2	12.8
NSBT 145	57.6	11.2	4.5	154.6	2968.1	72.3	3.8	14.9
NSBT 306	65.7	16.3	4.7	235.6	5161.3	57.6	2.6	18.1
NSBT 207	47.9	12.6	4.6	180.3	2881.0	64.9	4.1	15.6
NSBT 108	51.3	7.0	4.7	101.3	1730.5	67.4	3.9	9.1
BG II check	31.5	12.2	5.0	189.3	1989.3	24.2	2.3	6.1
Mean	51.4	12.5	4.7	183.7	3168.0	51.9	3.0	12.4
SED	3.6	1.9	0.2	27.5	644.6	6.4	0.4	1.7
CD (5%)	7.2	3.8	0.4	55.4	1296.0	12.8	0.9	3.4
CV	8.4	18.1	5.7	18.2	24.1	19.1	32.0	20.9
S/NS	S	S	NS	S	S	S	S	S

The results on total volume of individual plant to identify compact genotype found that the genotype CICR-CSH 19-1 (3022.3) NSBT 145 (2968.1), OUAT Bt 1 (2909.0), NSBT 207 (2881.0), Rahuri 1 (2780.4), CICR-F 1861(2690.3), CICR- GH 8 (2591.7), CICR-K34007 (2492.6), CICR-CS19-2(2323.3), OUAT Bt 2(2001.3), PAU 1(1847.8), and NSBT 108 (1730.5) were identified as compact genotypes, which showed less plant volume (Table 1).

The compactness efficiency index CEI 1 (area) (mg/cm^2) used to identify compact and efficient genotype. The genotype OUAT Bt 2 (80.0), NSBT145 (72.3) and NSBT 108 (67.4) were identified as compact efficient genotypes, which needs less land with high performance. The compactness efficiency index CEI 2 (volume) (mg/cm^3) used to identify compact and efficient genotype with respect to volume of the plant. The genotype OUAT Bt 2 (5.0), NSBT 207 (4.1) and NSBT 108 (3.94) were identified as compact efficient genotypes with respect to volume of the plant. In agriculture, land is limited resource and there is no limitation to use vertical space for utilization of plants to increase productivity of crop. Hence better indices for compactness is area occupied by plant is calculated by using formulae of elliptical base A (cm^2) = $\pi \times R \times r$. The correlation matrix observed that high significant correlation is observed $((R\times r) \times \sqrt{h})$ with area (r = 0.954) occupied and volume (r= 0.979) of the plant and this may be the better indicator for compactness.

SUMMARY

High density planting with compact genotypes proved, as high potential system of cotton cultivation. There is a need to develop proper indices to measure compactness in plant, is necessitated for screening of genotypes. Compactness measured using $((R\times r) \times \sqrt{h})$ was identified as an efficient method, based on that genotypes NSBT 108 , PAU1 , OUAT Bt 2 , CICR- K 34007 and CICR-CSH 19-2 were identified as compact genotypes. Compact Efficiency Index (CEI 1) was suitable for measuring efficiency of compactness.

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