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Assessment of morphological attributes of *Gossypium arboreum* genotypes under high density planting system in rainfed vertisol

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Abstract
A field experiment was conducted during kharif 2013-14 in rainfed Vertisols of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola with a view to study the performance of cotton compact varieties under high density planting system with different spacings and varied sowing time intervals for higher production and to reduce the cost of cultivation under changing climatic conditions. The experiment was laid out in factorial randomized block design in four replications. Three compact varieties AKA-5, AKA-7 and AKA-8 were taken as main treatments with three spacings, 60cmX15cm, 45cmX15cm and 45cm X 8cm. The results revealed that AKA-5 genotype found significantly superior (120 DAS) in terms of leaf area (60.18dm2/ plant), leaf area index (3.55), total dry matter production (79.76g/plant), whereas, spacing 45cm x 8cm found significant in parameters like Plant height (134.95cm) at 150 DAS and leaf area index (3.83) at 120 DAS compared to spacings 45cm x 15 cm and 60cm x 15cm.

Keywords: Morphological, attributes, rainfed, *Gossypium arboreum*

Introduction
Cotton (*Gossypium hirsutum* L.), is one of the most ancient and important commercial crop next to food grains. Due to its importance in agriculture as well as in industrial economy, it is also known as “white gold” (Udikeri and Shashidhara, 2017) [11]. The antiquity of cotton has been traced to the fourth millennium B.C. The fabric pieces from Mohenjo-Daro excavation were found to be made of cotton. Among the various factors responsible for low yield of cotton crop in the country, low plant population and use of low potential varieties are of primary importance. Various techniques like maintaining suitable plant density, use of optimum dose of fertilizers, growth regulators etc., are being used to overcome these constraints in cotton production (Udikeri and Shashidhara, 2017) [11]. Machine picking need changed geometry to accommodate more plant population per unit area. Brazil uses HDPS in which cotton plants are packed tightly together at 8 - 10 times the normal rate and planted in rows (Bharathi *et al.*, 2018) [1]. Manipulation of plant density, plant population and spatial arrangement of cotton plants continues to be topics of cotton research Worldwide and India is no exception. It is widely accepted that increasing planting density is an option to increase yield or profits and also to improve input use efficiency. The earliness usually associated with high density planting makes this system suitable for rainfed. Therefore, there is need to identify suitable genotypes with back ground of better which morphological, physiological and biochemical parameters associated with yield under high density planting under rainfed condition and the research work is proposed to screen suitable genotypes.

Materials and Methods
Experimental site
The experiment was carried out during kharif – 2013-2014 at the experimental field of Department of Agricultural Botany, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (MS), India located at 307.4 meters 304.415 meter altitude above mean sea level, 20030’ N latitude and 72°02’ longitude.

Experimental design and setting the experiment
Experiment was laid out in Factorial Randomized Block Design. There were nine treatments replicated four. Plant material includes four different cotton varieties and spacing like Factor A varieties V1=AKA-5, V2= AKA-7, V3= AKA-8 and Factor B spacing S1= 60 x 15cm (1,

11,111plants/ha), S2= 45 x 15 cm (1, 48,148 plants/ha), S3= 45 x 8 cm (2, 77,777plants/ha). Sowing method was dibbling and fertilizers applied, 50:25:25 NPK kg/ha (Basal dose of 50% N + full P2O5 and K_2O at sowing and 50% N at square initiation stage. Harvesting was done as per maturity of genotypes used.

Plant materials

The experimental material consisted of cultivar of AKA-5, AKA-7 and AKA-8 of cotton, which was procured from Senior Research Scientist (Cotton), Cotton research Unit, Dr. PDKV, Akola. Other material provided by Department of Agricultural Botany, Dr. PDKV, Akola (MS).

Morphological and physiological observations recorded

Morpho-physiological parameters *viz*., Plant height, Leaf area per plant, Leaf area index, Total Dry matter production per plant (g $plant^{-1}$), Number of monopodia/plant and Number of sympodia/plant were recorded at 30, 60, 90, 120 and at 150 DAS days after sowing.

Statistical Analysis

The analysis of variance was performed to get the significance of differences between the treatment for all the characters as per the methodology suggested by Panse and Sukhatme (1978).

Results and Discussion

Morpho-physiological parameters

Data regarding morpho-physiological parameters were recorded at 30, 60, 90, 120and at 150DAS. The morpho-physiological parameters as under high density planting system are presented in Table 1.

Table 1: Effect of different treatments through HDPS on Plant height (cm)

Treatments	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
A. Variety					
V_1 (AKA-5)	22.86	50.02	81.74	103.68	126.75
V_2 (AKA-7)	23.29	53.04	83.56	106.70	129.73
V_3 (AKA-8)	24.10	55.06*	86.20*	109.95*	132.78*
F test	NS	S	S	S	S
SE (m) ±	-	0.78	0.86	1.47	1.14
CD at 5%	-	2.28	2.50	4.29	3.32
B. Spacing/ Plant density ha^{-1}					
S_1 (60 x 15 cm)	22.80	50.58	82.01	102.85	125.93
S_2 (45 x 15 cm)	23.47	53.03	84.00	108.35	130.38
S_3 (45 x 8 cm)	24.86	55.32*	85.49*	108.85*	134.95*
F-test	NS	S	S	S	S
SE (m) ±	-	0.78	0.86	1.47	1.14
CD at 5%	-	2.29	2.50	4.29	3.32
C. Interaction					
F-test	NS	NS	NS	NS	NS
SE (m) ±	-	-	-	-	-
CD at 5%	-	-	-	-	-

(* indicates significant differences over highest performing treatment.)

Plant height $plant^{-1}$

Varietal differences on plant height were found statistically significant at all stages of crop growth expect 30DAS. Variety AKA-8 (V3) recorded significantly more plant height over AKA-7(V2) and AKA-5 (V1) during all stages, however at 60,120 and 150DAS, AKA-7 and AKA-8 found at par with each other. At 90, 120 and 150 DAS, variety AKA-8 recorded significantly more plant height over variety AKA-5 but it was at par with AKA-7. At 150 DAS, variety AKA-8 recorded significantly more plant height (132.78 cm) over the variety AKA-5 (126.75 cm) but remained at par with AKA-7 (129.73cm).

The difference in plant height due to high plant density was found non-significant at 30 DAS. As the crop advanced in growth, significant differences from 60 DAS were observed and continued up to harvest. Narrow plant spacing of 45x8 cm (S3) recorded significantly more plant height over of 60x15 cm (S1) and 45x15 cm (S2). Data recorded at 60, 90, and 120 DAS by 45x15cm and 45x8 cm spacing were at par with each other. At 150 DAS 45x8 cm spacing recorded (134.95cm) height was found significantly superior over 45x15 cm (30.38cm) and 60x15 cm (125.93 cm) spacing. At 150 DAS, closed spacing of 45x8 cm recorded significantly more plant height (134.95cm), however spacing of 45x8cm (134.95 cm) and 45x15 cm (130.38) were found to be at par with each other for plant height. It was cleared that, interaction effect of variety over spacing plant density was found non-significant (Table 1). It was observed that reduction in plant height under wider plant spacing may be due to less competition for light which may be suppresses apical dominance. Sisodia and Khamparia (2007) [10] also reported similar results that any increase in the plant population per unit area, the congestion in the growing crop plants increased which induced more vertical growth and the lateral spread (branching) was restricted.

Leaf area/$plant^{-1}$ (dm^2)

Differences among varieties in respect of leaf area per plant were observed significant at all stages of crop growth. Variety AKA-5 recorded significantly higher leaf area per plant over AKA- 7 and AKA-8 during all growth stages. However during the growth stages of 60 and 150 DAS, leaf area per plant of AKA- 7 (V2) and AKA-5(V1) were found at par with each other and AKA-8 recorded significantly lower leaf area per plant over AKA-5. At 120 DAS, i.e. at peak boll development stage, AKA-5 recorded highest leaf area (60.18 dm2/ plant) followed by AKA-7 (58.74dm2/ plant) and AKA-8 (57.86 dm2/ plant) however all these variety were found at par among themselves. At 150 DAS, variety AKA-5 (40.28dm2/ plant) recorded highest leaf area followed by AKA-7 (38.79 dm2/ plant) and found significantly superior over both the varieties. AKA-5 (40.28 dm2/ plant) and AKA-8 (37.19dm2/ plant) (Table 2).

Table 2: Effect of different treatments through HDPS on Leaf Area (dm^2)

Treatment	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
A. Variety					
V1 (AKA-5)	4.56*	26.32*	42.73*	60.18*	40.28*
V2 (AKA-7)	4.21	25.03	39.86	58.74	38.79
V3 (AKA-8)	3.80	24.28	37.56	57.86	37.19
F test	S	S	S	S	S
SE (m)±	0.90	0.46	0.71	0.92	0.49
CD at 5%	0.27	1.36	2.25	2.74	1.46
B. Spacing/Plant density ha^{-1}					
S_1 (60 x 15 cm)	4.50*	27.04*	43.00*	61.35*	39.86*
S_2 (45 x 15 cm)	4.28	25.18	40.15	58.14	38.92
S_3 (45 x 8 cm)	3.56	24.22	38.21	57.29	37.78
F-test	S	S	S	S	S
SE (m) ±	0.90	0.46	0.71	0.92	0.49
CD at 5%	0.27	1.36	2.25	2.74	1.46
C. Interaction					
F-test	NS	NS	NS	NS	NS
SE (m) ±	0.18	0.90	1.41	1.28	1.12
CD at 5%	-	-	-	-	-

(* indicates significant differences over highest performing treatment.)

Leaf area per pant was significantly influenced due to spacing / high plant density at all stages of crop growth. At 30, 60, 90,120 and 150 DAS. Wider spacing of 60 x15 cm (S1) produced significantly higher leaf area per plant than closer plant spacing of 45 x 15 cm (S2) and 45x8 cm (S3).Data regarding leaf area plant^{-1} show significant difference wider spacing (60x15 cm) with narrow spacing (45x8 cm) during all growth stages. At 30 DAS, spacing 60 x15 cm recorded significantly higher (4.50 dm2/ plant) followed by 45x15 cm (4.28 dm2/ plant) (S3) and 45x8 cm (3.56 dm2/ plant) however all these spacing found at par among themselves. At 120 DAS, spacing 60 x15 cm (61.35 dm2/ plant) (S1) recorded significantly higher leaf area over 45x15 cm (58.14 dm2/ plant) (S3) and 45x8 cm (57.29 dm2/ plant). At 150 DAS, spacing 60 x15 cm (39.86 dm2/ plant) (S1) recoded higher leaf area significantly followed by 45x15 cm (38.92 dm2/ plant) (S2) and 45x8 cm (37.78 dm2/ plant) (S3). (Table 2). However S2 and S3 spacing found at par among themselves. Leaf area decreased after 120 DAS. Interaction effect of variety over spacing / density was found non-significant for leaf area. Leaf area being photosynthetic surface plays a vital role in production and availability of photosynthates for increased seed cotton yield these results were similar to earlier findings of Bharadwaj *et al*., (1971) and Pettigrew et at., (2013) [6].

Leaf area index

Differences among varieties in respect of leaf area index per plant were observed significant at all stages of crop growth. At 30, 60, 90,120 and 150 DAS variety (V1) AKA-5 recorded significantly higher leaf area index per plant however (V2) AKA- 7at par with (V3) AKA-8. At 30 and 90 DAS, variety (V1) AKA-5 recorded highest leaf area index per plant followed by (V2) AKA-7 and (V3) AKA-8 however all these variety were found at par among themselves. At 120 DAS, variety (V1) AKA-5 (3.55) recorded significantly higher leaf area index followed by (V2) AKA-7 (3.31) and (V3) AKA-8 (3.29) but variety (V3) AKA-8 and (V2) AKA-7 both at par with each other. At 150 DAS, variety (V2) AKA-5 (2.46) recorded significantly higher leaf area index followed by(V2) AKA-7 (2.33) and (V3) AKA-8 (2.24) but variety AKA-8 (V3) and AKA-7 (V2) both at par with each other (Table 3).

Leaf area index per plant was significantly influenced due to spacing/ plant density at all stages of crop growth. At 30, 90,120 and 150 DAS spacing (S3) 45x8cm recorded significantly higher leaf area index per plant however (S1) 60x15cm at par with (S2). 45x15cm At 60 DAS, spacing(S3) 45x8cm (1.26) recorded highest leaf area index per plant followed by(S2) 45x15 cm (1.22) and(S1) 60x15 cm however all these variety were found at par among themselves. At 120 DAS, spacing(S3) 45x8 cm (3.83) recorded significantly highest leaf area index followed by(S2)45x15cm (3.40) and(S1) 60x15 (2.23) spacing. At 150 DAS, spacing(S3) 45x8 cm (2.47) recorded significantly highest leaf area index (Table 3) followed by(S3) 45x15cm (2.29) and (S1) 60x15 (2.28) but spacing (S1) 60x15cm and (S3) 45x15 cm both at par with each other. Interaction effect of variety over spacing / density was found non-significant for leaf area. It may be found leaf area index per plant was higher in closer plant spacing cm. similar findings of Bharadwaj *et al*., (1971).

Table 3: Effect of different treatments through HDPS on Leaf Area Index

Treatments	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
A. Variety					
V_1 (AKA-5)	0.49	1.29	2.51	3.55	2.46
V_2 (AKA-7)	0.45	1.20	2.47	3.31	2.33
V_3 (AKA-8)	0.43	1.18	2.31	3.29	2.24
F test	S	S	S	S	S
SE (m)±	0.1	0.02	0.06	0.08	0.05
CD at 5%	0.04	0.05	0.19	0.23	0.16
B. Spacing/Plant density ha^{-1}					
S_1 (60 x 15 cm)	0.43	1.20	2.30	2.23	2.28
S_2 (45 x 15 cm)	0.44	1.22	2.37	3.40	2.29
S_3 (45 x 8 cm)	0.50	1.26	2.57	3.83	2.47
F-test	S	S	S	S	S
SE (m) ±	0.1	0.02	0.06	0.8	0.05
CD at 5%	0.04	0.05	0.19	0.23	0.16
F-test	NS	NS	NS	NS	NS
SE (m) ±	0.02	0.3	0.11	0.13	0.10
CD at 5%				-	-

Total dry matter production plant^{-1} (g)

A differenced in total dry matter accumulation per plant among varieties was significantly at all stages of crop growth except 30 DAS. At 60, 90, 120 and 150 DAS variety AKA-5 (V1) accumulated significantly more dry matter per plant over to variety AKA-7(V2) and AKA-8 (V3). At 60 DAS variety (V1) AKA-5 (30.70g) recorded significantly more dry matter production plant^{-1} over (V2) AKA-7(27.64g) and (V3) AKA-8 (26.04g) where both at par with each other. At 90 DAS variety (V1) AKA-5 (68.99g) recorded significantly more dry matter production plant^{-1} over (V2) AKA-7(64.38g) and (V3). AKA-8 (59.36g) At 120 DAS variety(V1) AKA-5 (79.76g) recorded significantly more dry matter production plant^{-1} over all varieties (V2) AKA-7 (75.02g) and (V3) AKA-8 (71.46g) At 150 DAS variety AKA-5 (70.43g) (V1) recorded more dry matter production plant significantly over(V2) AKA-7(63.77g) and (V3) AKA-8 (58.34g) shown in Table 4.

Effect of spacing/ plant density on total dry production per plant was observed to be significant at all stages of plant growth except 30 DAS. At 60 DAS wider plant spacing of(S1) 60 x15 cm (31.76g) recorded significantly higher dry matter production followed by plant spacing(S2) 45x15cm (27.34g) and(S3) 45x8cm (26.49g) spacing 45x15cm and 45x8 cm both at par with each other. At 90 DAS, wider plant spacing of(S1) 60 x15 cm (67.02g) recorded significant higher dry matter production over plant spacing(S2) 45x15cm(63.97g) and(S3) 45x8cm (61.75g) spacing 45x15cm and 45x8 cm both recorded at par with each other. At 120 and 90 DAS (S2) an (S3) both were at par with each other and significantly lower over the(S1) (60x15cm) spacing. At 120 DAS, wider plant spacing (S1) 60 x15 cm (77.74g) recorded significantly more dry matter production followed by plant spacing(S2) 45x15cm(75.90g) and (S3) 45x8cm (72.74g) spacing 45x15 cm and 45x8 cm both were resulted at par with each other. At 150 DAS, wider plant spacing (S1) 60 x15 cm (66.77g) recorded significantly high dry matter production per plant over plant spacing (S2) 45x15cm (64.33g) and(S3) 45x8cm (62.72g) however (S2) and (S3) varieties were found at par among themselves at harvest (Table 4). Interaction effect of varieties over plant spacing/ density were statistically non significant. The higher dry matter production per plant is directly correlated with overall growth of plant under wider spacing this may be due to more availability of light, soil moisture and nutrient per plant per unit area than that of closer spacing. This may compete for resources due to which lower accumulation of dry matter per plant. These results were supported by the findings of Ravankar and Deshmukh (1994) [7] and Reddy and Gopinath (2008) [8].

Table 4: Effect of different treatments through HDPS on Total Dry Matter Production Plant^{-1} (g)

Treatments	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
Variety					
V1 (AKA-5)	2.08	30.70*	68.99*	79.76*	70.43*
V2 (AKA-7)	2.06	27.64	64.38	75.02	63.77
V3 (AKA-8)	2.02	26.04	59.36	71.46	58.34
F test	NS	S	S	S	S
SE (m)±	0.06	0.93	1.03	1.22	1.00
CD at 5%	-	2.27	3.02	3.56	2.91
B. Spacing/ Plant density ha^{-1}					
S1 (60 x 15 cm)	2.17	31.76*	67.02*	77.74*	66.77*
S2 (45 x 15 cm)	2.01	27.34	63.97	75.90	64.33
S3 (45 x 8 cm)	1.97	26.49	61.75	72.74	62.72
F-test	NS	S	S	S	S
SE (m) ±	0.06	0.93	1.03	1.22	1.00
CD at 5%	-	2.27	3.02	3.56	2.91
C. Interaction					
F-test	NS	NS	NS	NS	NS
SE (m) ±	0.11	0.62	1.79	2.11	1.73
CD at 5%	-	-	-	-	-

(* indicate significant differences over the higher performing treatment)

Number of monopodial branches plant^{-1} at harvest

Differences in monopodial branches plant^{-1} among varieties showed significant difference at harvest of crop. Variety (V1) AKA-5is recorded significantly highest number of monopodial (1.93monopodia/plant) followed by the variety (V2) AKA- 7(1.73monopodia/plant) and(V3) AKA-8 (1.54monopodia/plant) however varieties AKA-7 and AKA-8 were found at par with each other. Numbers of monopodial branches per plant were found significantly differed at harvest. At harvest number of monopodial branches per plant recorded among the spacing(S1) 60 x 15 cm (1.98 monopodia/plant) was significantly superior over (S2) 45 x 15 cm(1.69 monopodia/plant) and (S3) 45 x 8 cm (1.56 monopodia/plant) However, monopodial branches recorded (S2) 45x15cm and (S3) 45x8 cm both were at par with each other (Table 5). Interaction effect of variety over plant spacing /density were statistically non significant. Increase in monopodial branches may be due to the availability of space for lateral expansion of branches and chance to enhance auxiliary buds of plant as compared to closer plant geometry, which recorded more competition for space, light and nutrient. Similar results were reported earlier by Madiwalar and Prabhakar (1998) [4] they reported that lower plant density recorded significantly higher vegetative branches than higher plant density.

Number of Sympodia

Significant differences were recorded in number of sympodial branches per plant among different genotypes at harvest stages. Variety AKA-5 (7.25 sympodia/plant) is recorded highest number of sympodia over variety which recorded sympodial branches /plant AKA-7 (6.11 sympodia/plant) and AKA-8 (5.45 sympodia/plant). Effect of plant spacing/ high density planting on sympodial branches per plant was significant at harvest stages of crop growth. Plant under wider spacing60x15 cm (8.12/pant) recorded significantly highest number of sympodial /plant followed by spacing 45X15 cm (7.04) and 45x8 cm (6.0) (Table 5).

Interaction effect of varieties over plant spacing/density was statistically non-significant (Table 5). More number of sympodial branches produced under wider spacing was due to availability of more horizontal space. Thus plant grows better due to the availability of space and produced more sympodial branches than the closer spacing. Closer spacing might have increased competition for light which impose to increase plant height through internodal elongation, thus most of the photosynthetic consumed in vertical growth and restricted horizontal structural growth. Such significant increase in number of sympodia per plant under wider row spacing was also reported by Kalaichelvi (2009) [3] and Reddy and Kumar (2010) [9].

Table 5: Effect of different treatments through HDPS on Monopodia and sympodia

Treatment	No. of Monopodia	No. of Sympodia
A. Variety		
V_1 (AKA-5)	1.93*	7.25*
V_2 (AKA-7)	1.73	6.11
V_3 (AKA-8)	1.54	5.45
F-test	S	S
SE (m)±	0.10	0.36
CD at 5%	0.28	1.03
B. Spacing/ Plant density ha^{-1}		
S_1 (60 x 15 cm)	1.98*	8.12*
S_2 (45 x 15 cm)	1.69	7.04
S_3 (45 x 8 cm)	1.56	6.0
F-test	S	S
SE (m) ±	0.10	0.36
CD at 5%	0.28	1.03
C Interaction		
F-test	NS	NS
SE (m) ±	-	-
CD at 5%	-	-

(* indicate significant differences over the higher performing treatment)

Conclusion

Genotype AKA-5 found superior under high density planting system for rainfed vertisol of Vidarbha region of Maharashtra. Significant superior in terms of morphological attributes *viz.* leaf area, leaf area index, total dry matter production after 10 DAS and high density planting system spacing 45cm x 8cm found significant in parameters like Plant height and leaf area index.

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