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Assessment of production potential of long-linted *Gossypium arboreum L.* genotypes under different sowing times

K. Sankaranarayanan[1*], M. V. Venugopalan[2] and D. Kanjana[1]

Abstract

Background: *Gossypium arboreum* is one of the cultivated diploids which has inherent resistance against insect pests and diseases, can withstand moisture stress, needs less nutrients and is suitable for erratic, less rainfall and marginal soils. Due to its smaller boll size and poor locule retentivity, adoption of species by farmers is very low. So, best long-linted *G. arboreum* genotypes with high yielding potential and suitable sowing time will be identified for rainfed tracts of cotton cultivated areas in India.

Results: The pooled analysis results found that the significantly highest mean seed cotton yield was recorded with Phule Dhanwanthry (1069 kg/ha) which was on par with K12 (1027 kg/ha), DLSA 17 (977 kg/ha) and PA 812 (951 kg/ha). Planting at 4 August yielded the significantly higher seed cotton yield (1345 kg/ha) in comparison with 4 September sowing (536 kg/ha). The interaction results in pooled data revealed that Genotype PA 812 planted at 4 August registered the significantly highest seed cotton yield (1487 kg/ha) which was on par with all genotypes sown on 4 August except PA 402. Amongst long-linted genotypes, PA 760 recorded the significantly highest upper half length (29.9 mm), mean length (24.9 mm) and fibre strength (27.0 g/tex) and fibre quality index (349.7); which was on par with DLSA 17, PA 812 and PA 402. The quality characters had not been influenced significantly by different times of sowing.

Conclusions: The results concluded that the significantly highest mean seed cotton yield was recorded with Phule Dhanwanthry (1069 kg/ha) which was on par with K12 (1027 kg/ha), DLSA 17 (977 kg/ha) and PA 812 (951 kg/ha). Planting at 4 August found that the significantly higher seed cotton yield (1345 kg/ha) in comparison with 4 September sowing (536 kg/ha). Amongst long-linted genotypes, PA 760 recorded the significantly higher fibre quality index (349.7)

Keywords: Cotton genotypes, Times of sowing, Long-linted *G. arboreum*, Seed cotton yield

Background

Cotton is one of the most important cash crops of India. Among the four cultivated species of cotton, today, *Gossypium arboreum* L. (*G. arboreum*) is grown to a limited extent in Africa and Asia. In tropical Africa, *Gossypium arboreum* is grown for domestic use only (Brink 2011). The area under *G. arboreum* in India reduced from 65% of the total cotton area in 1947 to 17% in 2000 to around 3% a decade after the introduction of Bt hybrids (Blaise et al. 2020; Kranti 2015; Narayanan et al. 2014). *Gossypium arboreum* has the ability to provide resistance against insect pests and diseases, can withstand moisture stress, needs less nutrients and is suitable for erratic, less rainfall and marginal soils (Sankaranarayanan et al. 2010; Iqbal et al. 2019). Despite these advantages, this species is not currently preferred by farmers due to their small boll size and poor locule retentivity (Venugopalan et al.2016).

*Correspondence: sankaragro@gmail.com
[1] ICAR-Central Institute for Cotton Research, Regional Station, Coimbatore, Tamil Nadu 641003, India
Full list of author information is available at the end of the article

The efforts were made for development of high yielding *G. arboreum* genotypes with high-quality lint by interspecific hybridization (Manivannan et al. 2018). Recently released *G. arboreum* genotypes have industrially acceptable fibre properties with high yield potential. These improved long *G. arboreum* may be suitable for rainfed tracts of India where production by current Bt hybrids has reached a plateau. One of the most significant agronomic considerations for growers to maximize yield is to select a suitable sowing time. In the present investigation, new genotypes of long-linted *G. arboreum* have been evaluated to assess the performance on yield, and fibre quality traits as well as to identify the best genotype and sowing time for rainfed conditions in Coimbatore tract.

Methods

Experimental site

Studies were conducted during growing seasons 2017/18, 2018/19 and 2019/20 at ICAR- Central Institute for Cotton Research, Coimbatore (N 11°, E 77° with an altitude of 427.6 m above MSL) Tamil Nadu, India. The region has a subtropical climate with annual rainfall of 657 mm (70 years average). The soil was clay loam in texture, low in available N (180.3 kg/ha), medium in available P (17.5 kg/ha) and high in available K (812 kg/ha) with a pH 8.6 and EC 0.23 dS/m. Soil test on micronutrient showed 0.48, 1.2, 3.62, 2.64 and 0.06 ppm of DTPA-extractable zinc, copper, manganese, iron and boron (hot water extract), respectively. The rainfall received during cropping periods reported in Table 1.

Experimental design and field management

Six long-linted *G. arboreum* genotypes viz., G1.DLSA17, G2.PA760, G3.PA812, G4.PA402, G5.PA528 and G6.K12 were planted at two different times of sowing (4 August and 4 September) with high density (60 × 10 cm). These genotypes were compared with a short-stapled genotype G7.P.Dhanwanthry (60 × 10 cm). The experiment was designed in a factorial randomized complete block design with three replicates. The recommended level of nutrients for *G. arboreum* 20:0:0 kg/ha of N, P_2O_5&K_2O/ha was followed uniformly. The crop was raised by providing pre-sowing irrigation and then treated as rainfed crop. Weed control practices included pre-plant incorporated pendimethalin 1.25 kg *ai*/ha (stomp extra) and hand hoeing to maintain weed-free plots. The net plot size of 26.8m^2 was followed for experimentation.

Table 1 Monthly Rainfall (mm) of experimental years (2017, 2018 & 2019)

Standard months	Rainfall (mm)		
	2017	2018	2019
August	38.5	58.4	223.9
September	218.1	2	54.7
October	132.6	178.2	227.5
November	78.1	30.5	202.1
December	1.2	12	21
January*	2.2	0	0

* Succeeding year

Data collection and analysis

Randomly selected plants (five) were used for biometric observations that include growth characters and yield attributes. Seed cotton yield was obtained from each net plot. Plot wise seed cotton was ginned to determine fibre quality parameters. Fibre quality parameters were estimated by using HVI (Statex-Fibrotex). Fibre quality index, $FQI = LT/\sqrt{M}$, where L, upper half length (mm), T, fibre bundle tenacity at 3.2 mm micron (g/tex) and M, micronaire value (μ/inch) were estimated. Nutrient uptake was also estimated. A combined analysis of variance was performed to determine the effect of genotype (G), different sowing dates (T) and G × T interaction on studied traits from three trials in three years. All data were subjected to analysis of variance at $P < 0.05$. To estimate the significance between means, the standard error of difference and critical difference were used. Correlation studies have been carried out in *G. arboreum* genotypes between quantitative characteristics. Combined analysis of variance, correlation coefficients (r) and their significance have been determined according to Snedecor and Cochran (1980).

Results

Growth characters

Amongst genotypes tested in the trial, the mean tallest plant observed with K12 (119.0 cm) in the year 2017–18 and with PA 402 (125.8 and 150.1 cm) in the years of 2018–19 and 2019–20, respectively (Table 2). The shortest plant observed with Phule Dhanwanthry of 91.0, 100.5 and 120.4 cm in the years of 2017–18, 2018–19 and 2019–20, respectively. The result on height to node ratio (H/N) revealed that Phule Dhanwanthry registered significantly shortest in the years of 2018–19 (4.49) and 2019–20 (5.12). The significantly highest H/N ratio was observed with PA 402 in the years of 2017–18 (4.38), 2018–19 (5.64) and 2019–20 (5.93). The times of sowing did not significantly influence plant height (cm) in 2018–19 and 2019–20. The number of nodes per plant was not significant among genotypes in all three years of experimentation. However, between dates of sowing significant differences were observed in 2017–18 and 2018–19. Planting on 4 August observed significantly

Table 2 Plant height (cm), Number of nodes and Height/nodes ratio (H/N) of *G. arboreum* genotypes as influenced by different dates of sowing at harvest

Genotypes	Plant height (cm)									No of nodes								
	2017–18			2018–19			2019–20			2017–18			2018–19			2019–20		
	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean
G1.DLSA17	97.9	99.9	98.9	104.1	112.4	108.3	134.5	141.7	138.1	24.2	26.3	25.3	23.1	21.2	22.1	24.1	26	25
G2.PA760	109.4	76.7	93.1	115.3	123.7	119.5	134.7	147.7	141.2	24.9	20.1	22.5	23.1	21.5	22.3	23	26.3	24.7
G3.PA812	115.3	75.1	95.2	111.1	105.9	108.5	148.6	140.5	144.5	28.1	20.7	24.4	22.4	21	21.7	24.9	25.6	25.2
G4.PA402	123.8	110	117	127.1	124.6	125.8	146.7	153.4	150.1	28.5	24.9	26.7	23	21.5	22.3	25.5	25	25.3
G5.PA528	116.5	82.6	99.5	110.3	132.3	121.3	147.3	150.3	148.8	26.5	20.4	23.4	21.9	21.2	21.6	24.6	27.1	25.9
G6.K12	131.1	107	119	112.4	121.1	116.8	136.7	137.5	137.1	29.5	25.6	27.6	22.3	21.7	22	23.1	25.9	24.5
G7.P.Dhanwanthry	106.3	75.7	91	105.4	95.5	100.5	120.3	120.6	120.4	24.6	20.7	22.7	22.7	22.1	22.4	23	24	23.5
Mean	114.3	89.6	102	112.2	116.5	114.4	138.4	141.7	140	26.6	22.7	24.6	22.6	21.4	22	24	25.7	24.9
ANOVA	G	T	GxT	G	T	GxT	G	T	GxT	G	T	GxT	G	T	GxT	G	T	GxT
SEd	4.77	2.57	6.81	5.6	3.02	8	5.77	3.11	8.24	1.4	0.7	2	1.2	0.6	1.7	1.4	0.8	2
CD (5%)	9.8	5.29	14.3	11.51	NS	NS	11.86	NS	NS	NS	1.5	NS	NS	1.3	NS	NS	NS	NS

Genotypes	H/N ratio								
	2017–18			2018–19			2019–20		
	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean
G1.DLSA17	4.05	3.80	3.91	4.51	5.30	4.90	5.58	5.45	5.52
G2.PA760	4.39	3.82	4.14	4.99	5.75	5.36	5.86	5.62	5.72
G3.PA812	4.10	3.63	3.90	4.96	5.04	5.00	5.97	5.49	5.73
G4.PA402	4.34	4.42	4.38	5.53	5.80	5.64	5.75	6.14	5.93
G5.PA528	4.40	4.05	4.25	5.04	6.24	5.62	5.99	5.55	5.75
G6.K12	4.44	4.18	4.31	5.04	5.58	5.31	5.92	5.31	5.60
G7.P.Dhanwanthry	4.32	3.66	4.01	4.64	4.32	4.49	5.23	5.03	5.12
Mean	4.30	3.95	4.15	4.96	5.44	5.20	5.77	5.51	5.62
ANOVA	G	T	GxT	G	T	GxT	G	T	GxT
SEd	0.15	0.08	0.22	0.21	0.11	0.30	0.23	0.12	0.33
CD (5%)	0.32	0.17	NS	0.43	0.23	NS	0.47	NS	NS

Table 3 Number of monopodia and sympodia of *G. arboreum* genotypes as influenced by different dates of sowing at harvest

Genotypes	No. of monopodia/plant									No. of Sympodia/plant								
	2017–18			2018–19			2019–20			2017–18			2018–19			2019–20		
	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean
G1.DLSA17	0.7	0.1	0.4	3.5	1.5	2.5	1.6	0.1	0.9	21.3	23.3	22.3	16.9	13.9	15.4	15.5	20.7	18.1
G2.PA760	0.6	0.1	0.4	2.5	1.4	1.9	1.3	0.3	0.8	21.7	16.5	19.1	16.5	14.3	15.4	16.3	19.3	17.8
G3.PA812	0.3	0.1	0.2	3.2	1.1	2.1	0.7	0.3	0.5	23.7	19.0	21.4	16.7	14.7	15.7	15.9	18.1	17.0
G4.PA402	0.4	0.2	0.3	4.1	0.7	2.4	0.8	0.4	0.6	25.9	15.3	20.6	17.1	15.1	16.1	16.3	19.7	18.0
G5.PA528	0.0	1.2	0.6	3.9	0.5	2.2	0.0	2.4	1.2	23.4	16.4	19.9	16.4	13.9	15.2	17.6	20.2	18.9
G6.K12	1.0	0.4	0.7	3.1	0.8	1.9	1.9	0.8	1.4	26.6	22.9	24.8	17.7	14.1	15.9	15.9	20.7	18.3
G7.P.Dhanwanthry	0.3	0.3	0.3	3.3	1.5	2.4	0.7	0.5	0.6	21.4	17.6	19.5	16.1	14.5	15.3	15.4	19.4	17.4
Mean	0.5	0.3	0.4	3.4	1.1	2.2	1.0	0.7	0.8	23.4	18.7	21.1	16.8	14.3	15.6	16.1	19.7	17.9
ANOVA	G	T	GxT	G	T	GxT	G	T	GxT	G	T	GxT	G	T	GxT	G	T	GxT
SEd	0.05	0.03	0.08	0.1	0.1	0.2	0.06	0.03	0.09	0.9	0.5	1.2	0.60	0.32	0.86	0.70	0.38	1.00
CD (5%)	0.11	0.06	0.16	0.2	0.1	0.3	0.13	0.07	0.19	1.8	1.0	2.6	NS	0.67	NS	NS	0.78	NS

mean higher number of nodes with 16.6 and 22.7, respectively, at the two years of 2017–18 and 2018–19 (Table 2). The H/N ratio was significantly differed between times of sowing and 4 August registered the highest of 4.32 and 4.64 in the years of 2017–18 and 2018–19, respectively. The result on number of monopodia per plant was found to be significantly influenced by genotypes and times of sowing. Amongst all genotypes, K-12 registered the significantly highest number of mean monopodia with value of 0.7 and 1.4 during 2017–18 and 2018–19 years, respectively (Table 3). The early sowing of *G. arboreum* on 4 August showed the significantly highest number of monopodia with value of 0.5, 3.4 and 0.7, respectively, across years of 2017–18, 2018–19 and 2019–20. The similar result observed with number of sympodia per plant of 23.4, 16.8 and 16.1 which was significantly higher in 4 August sowing in respective with all three years 2017–18, 2018–19 and 2019–20 (Table 3). The Leaf Area Index (LAI) at 150 DAS was significantly influenced by genotypes and times of sowing factors. The significantly mean highest LAI of 3.5 with K 12 at 2017–18, 8.4 with Phule Dhanwanthry in 2018–19 and LAI of 3.0 with PA 528 in 2019–20 were found (Table 4). Between the times of sowing, 4 August registered the significantly highest LAI of 3.6 and 6.9 in 2017–18 and 2018–19, respectively. The results on dry matter production (kg/ha) revealed that the significantly highest of 4456, 4850 and 5156 kg/ha in 2017–18,2018–19 and 2019–20 recorded with K 12, respectively, and which was followed by DLSA 17 in 2017–18 and 2019–20 and PA 402 in 2018–19 (Table 4).

Yield attributes

The results revealed that the genotypes and times of sowing significantly influenced number of bursted bolls and boll weight (g) traits. The significantly highest mean number of bursted bolls of 5.5 with K-12 in 2017–18, 6.7 with PA 528 in 2018–19 and 1.7 with Phule Dhanwanthry in 2019–20, respectively, were counted (Table 5). Planting of *G. arboreum* on 4 August significantly increased mean number of bursted bolls of 4.2, 9.5 and 1.9 in the years of 2017–18, 2018–19 and 2019–20, respectively. Planting of *G. arboreum* on 4 September recorded 26.2, 75.8 and 78.9% reduced bursted bolls per plant as compared to 4 August planting in 2017–18, 2018–19 and 2019–20, respectively.

In this study, it is observed that genotype, PA 402 (2.5 g), PA 760 (2.4 g) and Phule Dhanwanthry (2.5 g) exhibited significantly mean highest boll weight in 2017–18, 2018–19 and 2019–20, respectively (Table 4). Between times of sowing, 4 August planting registered significantly higher boll weight with value of 2.6, 2.3 and 2.5 in 2017–18, 2018–19 and 2019–20, respectively, which was 30.0, 15.0 and 19.0% higher than 4 September sowing of respective years.

Seed cotton yield

The first year (2017–18) results indicated that amongst the genotypes, K-12 registered the significantly highest seed cotton yield (1360 kg/ha) followed by Phule Dhanwanthry (1050 q/ha) and DLSA -17(929 q/ha). In 2019–20, the results revealed that PA 812 (490 kg/ha) showed significantly mean highest seed cotton yield (Table 7 and Fig. 1). However, genotypes were not varied significantly in the year of 2018–19. Significantly higher yield was recorded with 4 August sowing in 2017–18(1060 kg/ha), 2018–19 (2451 kg/ha) and 2019–20 (528 kg/ha) than 4 September sowing in 2017–18 (800 kg/ha), 2018–19 (678 kg/ha) and 2019–20 (134 kg/ha), respectively.

The combined analysis of variance of years, genotype and different sowing dates in this study found that significant variation between years, interaction of year with times of sowing, interaction of year with genotypes and interaction of year with genotypes and times of sowing. The pooled analysis results found that the significantly highest mean seed cotton yield was recorded with Phule Dhanwanthry (1069 kg/ha) which was on par with K12 (1027 kg/ha), DLSA 17 (977 kg/ha) and PA 812 (951 kg/ha) (Table 6). Planting at 4 August found that the significantly higher seed cotton yield (1345 kg/ha) in comparison with 4 September sowing (536 kg/ha). The interaction results in pooled data revealed that genotype PA 812 planted at 4 August sowing registered the significantly highest seed cotton yield (1487 kg/ha) which was on par with all genotypes sown on 4 August except PA 402.

Nutrient uptake

The data on nutrient uptake (kg/ha) revealed that the significantly highest mean nitrogen of 111.7 and 104.6 kg / ha as well as phosphorus uptake of 21.13 and 22.3 kg/ha were estimated with K 12 in the years of 2017–18 and 2019–20, respectively, which was followed by DLSA17 with respect to nitrogen in the years of 2017–18 and 2019–20 (Tables 7 and 8). In the year of 2018–19, the significantly highest uptake of nitrogen (157.9 kg/ha), phosphorus (30.9 kg/ha) and potassium (134.8 kg/ha) was estimated with DLSA 17 which was followed by PA 528 with respect to all nutrients. The nutrient uptake (kg/ha) was significantly influenced by times of sowing and the significantly highest nitrogen uptake (kg/ha) of 83.2, 157.5 and 78.9, phosphorus uptake (kg/ha) of 16.0, 30.3 and 18.3 as well as potassium uptake (kg/ha) of 74.5, 133.7 and 81.1 were estimated with 4 August planting, respectively, in the years of 2017–18, 2018–19 and 2019–20, respectively.

Table 4 LAI at 90 DAS and Dry matter production (kg/ha) at harvest in *G. arboreum* genotypes as influenced by different dates of sowing

Genotypes	LAI									Dry matter production (kg/ha)								
	2017–18			2018–19			2019–20			2017–18			2018–19			2019–20		
	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean
G1.DLSA17	3.1	2.1	2.6	5.9	3.9	4.9	2.1	2.6	2.3	4795	1504	3150	4831	2700	3766	6584	2133	4358
G2.PA760	3.0	2.1	2.5	7.3	7.5	7.4	2.3	2.5	2.4	2610	1863	2237	3605	3653	3629	3213	3585	3399
G3.PA812	3.4	1.7	2.6	4.7	6.8	5.8	2.4	2.7	2.5	2992	1593	2293	4186	2748	3467	3855	2978	3417
G4.PA402	4.3	2.3	3.3	8.1	5.3	6.7	2.4	2.6	2.5	2176	3630	2903	3548	4548	4048	2579	5056	3818
G5.PA528	3.6	2.2	2.9	5.9	5.1	5.5	2.6	3.4	3.0	3080	1188	2134	3924	2755	3340	3895	2162	3028
G6.K12	4.2	2.8	3.5	6.4	3.8	5.1	2.1	2.0	2.0	4712	4200	4456	4293	5407	4850	4916	5396	5156
G7.P.Dhanwanthry	3.4	2.4	2.9	10.2	6.6	8.4	2.1	2.1	2.1	3333	3597	3465	4385	5182	4783	3770	5728	4749
Mean	3.6	2.2	2.9	6.9	5.6	6.2	2.3	2.6	2.4	3385	2511	2948	4110	3856	3983	4116	3863	3989
ANOVA	G	T	GxT	G	T	GxT	G	T	GxT	G	T	GxT	G	T	GxT	G	T	GxT
SEd	0.21	0.11	0.30	0.4	0.2	0.5	0.20	0.11	0.29	137	74	195	203	110	290	240	130	343
CD (5%)	0.43	0.23	0.63	0.8	0.4	1.1	0.41	0.22	0.60	281	152	410	418	226	610	493	NS	720

Table 5 Boll weight (g) and Number of bursted bolls of *G. arboreum* genotypes as influenced by different dates of sowing at harvest

Genotypes	Boll weight (g)									No of bursted bolls/plant								
	2017–18			2018–19			2019–20			2017–18			2018–19			2019–20		
	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean
G1.DLSA17	2.4	1.8	2.1	1.9	2.1	2.0	2.8	2.1	2.5	5.0	1.0	3.0	8.1	1.9	5.0	2.2	0.3	1.2
G2.PA760	2.8	1.9	2.3	2.8	2.0	2.4	2.9	1.7	2.3	3.8	2.8	3.3	9.8	2.7	6.2	1.6	0.2	0.9
G3.PA812	2.7	2.2	2.4	2.7	2.0	2.3	2.3	2.1	2.2	2.8	2.3	2.5	7.9	1.7	4.8	2.3	0.5	1.4
G4.PA402	2.8	2.1	2.5	2.3	1.7	2.0	2.4	2.1	2.3	2.8	5.0	3.9	10.3	2.1	6.2	1.7	0.3	1.0
G5.PA528	2.4	2.4	2.4	2.2	2.5	2.3	2.1	2.6	2.4	4.9	1.5	3.2	10.5	2.9	6.7	1.5	0.3	0.9
G6.K12	2.5	1.7	2.1	2.5	1.8	2.1	2.3	1.6	1.9	5.9	5.2	5.5	8.9	2.6	5.7	1.4	0.5	1.0
G7.P.Dhanwanthry	2.5	2.1	2.3	2.0	2.2	2.1	2.5	2.5	2.5	4.2	3.9	4.1	11.1	2.2	6.6	2.4	1.0	1.7
Mean	2.6	2.0	2.3	2.3	2.0	2.2	2.5	2.1	2.3	4.2	3.1	3.6	9.5	2.3	5.9	1.9	0.4	1.2
ANOVA	G	T	GxT	G	T	GxT	G	T	GxT	G	T	GxT	G	T	GxT	G	T	GxT
SEd	0.08	0.04	0.12	0.08	0.04	0.12	0.1	0.06	0.16	0.20	0.11	0.29	0.5	0.3	0.7	0.10	0.05	0.14
CD (5%)	0.18	0.1	0.26	0.18	0.1	0.26	0.22	0.12	0.32	0.41	0.22	0.60	1.0	0.5	1.4	0.21	0.11	0.30

Quality parameters

The quality parameters analysis found that significantly least upper half length (23.4 mm), mean length (17.9 mm) and fibre strength (21.8 g/tex) but micronaire (6.5 μ/inch) had maximum. Amongst long-linted *G. arboreum* genotypes tested, PA 760 recorded the significantly highest upper half length (29.9 mm), mean length (24.9 mm) and fibre strength (27.0 g/tex) which was on par with DLSA 17, PA 812 and PA 402 (Table 9). The highest fibre quality index of 349.7 was calculated with PA 760 followed by DLSA 17 (290.1), PA 812 (289.1) and PA 402 (276.9). The lowest FQI of 276.0 was calculated with Phule Dhanwanthry.

Growth characters VS Seed cotton yield

The values of correlation coefficients (r) and their significance are presented in Table 10. The result on growth characters of *G. arboreum* genotypes planted in two different times of sowing was significantly correlated with seed cotton yield. Number of monopodial branches per plant are significant and positively correlated with seed cotton yield ($r=0.748$). Plant height has negative and significantly contributed towards increase in the final seed cotton yield ($r=-0.334$) and also exhibited negative association with number of bolls /plant. The positive significant correlation noticed with number of bursted bolls versus seed cotton yield (r = 0.975). The results further revealed that seed cotton yield was not significantly correlated with number of sympodia, number of nodes, H/N ratio, boll weight and dry matter production traits.

Yield model

The regression fit of Y = -17,711.4 + 617.32 Max. Temp. (46–90 DAS) + 1.72SSH (90–120 DAS)-1.525RF (mm) (1–150 DAS) was developed by using three years mean seed cotton yield data of *G. arboreum* genotypes correlated with weather parameters (r^2 value of 0.806). The predicted values are compared with actual data by Chi-square test and Chi-square values which indicated its non-significance (Table 10). Thus, mean that the equation could be used for prediction.

Discussion

Growth characters

Growth characters are varied amongst genotypes because of different genetic background and genotypes × year interaction. Amongst genotypes, the tallest plant was observed with K12 and PA 402 genotypes and shortest one was with Phule Dhanwanthry. The height to node ratio (H/N) was also shortest with Phule Dhanwanthry, and the highest one was observed with PA 402. The results interpreted that Phule Dhanwanthry is compact amongst all but PA 402 is non-compact and bushy type. The number of nodes per plant was not significantly differed with genotypes but number of monopodia and sympodia per plant, LAI and dry matter production were varied. Amongst genotypes, K-12 registered the significantly highest number of monopodia and sympodia per plant and dry matter production in many situations. Earlier, Bolonhezi et al. (2000) reported that varied growth characters attributed to their genetic makeup but the inconsistency among years indicated the strong environmental influence. Growth characters are varied amongst genotypes because of different genetic makeup (Hussain et al. (2007).

The times of sowing significantly influenced the number of nodes per plant, H/N ratio, monopodia, sympodia, LAI and dry matter production. The planting on 4 August observed higher growth characters thus indicated that the specific periods received optimum weather condition for plant growth. Monopodial and sympodial branches in *desi* cotton were found to be significant for different sowing dates as presented by Jan et al. (2017).

Yield attributes

Yield is polygenic trait and does not controlled by single gene, but yield components are controlled by single gene (Chinchane et al. 2018). Thus, the yield is an end product of interaction between yield components and the environment. Seed cotton yield is the end of product of many factors, which singly and jointly influence it (Grafius 1959). The genotypes were varied with number of bursted bolls and boll weight (g). The variability of bursted bolls amongst genotypes was reported by Dhivya et al. (2014), Reddy and Sarma (2014) and Latif et al. (2015). Boll weight (g) is not up to the mark as compared to existing Bt hybrids under cultivation; however, maximum of 2.5 g was observed with high performing genotypes (PA 402, PA 760 and Phule Dhanwanthry). In *G. arboreum* (*desi*) cotton, boll weight is generally low as compared to *hirsutum* genotypes (Chinchane and Baig 2018).

Planting on 4 August observed higher number of bursted bolls and boll weight (g), and reduction of 26.2, 75.8 and 78.9% of bursted bolls was calculated with 4 September planting in 2017–18, 2018–19 and 2019–20, respectively, as compared to 4 August. The planting of 4 August observed 30.0, 15.0 and 19.0% higher boll weight than 4 September sowing for the respective years of 2017–18, 2018–19 and 2019–20. Delayed planting usually reduces number of bursted bolls due to delayed physiological maturity and carbohydrate deficiency (Gwathmey and Clement 2010). Delaying of planting pushed cotton plants for unfavourable weather for crop growth thus consistently decrease number of opened bolls (Elayan et al. 2015). The weather data recorded from 46–120 DAS of growth stage of 4 August and 4 September planting

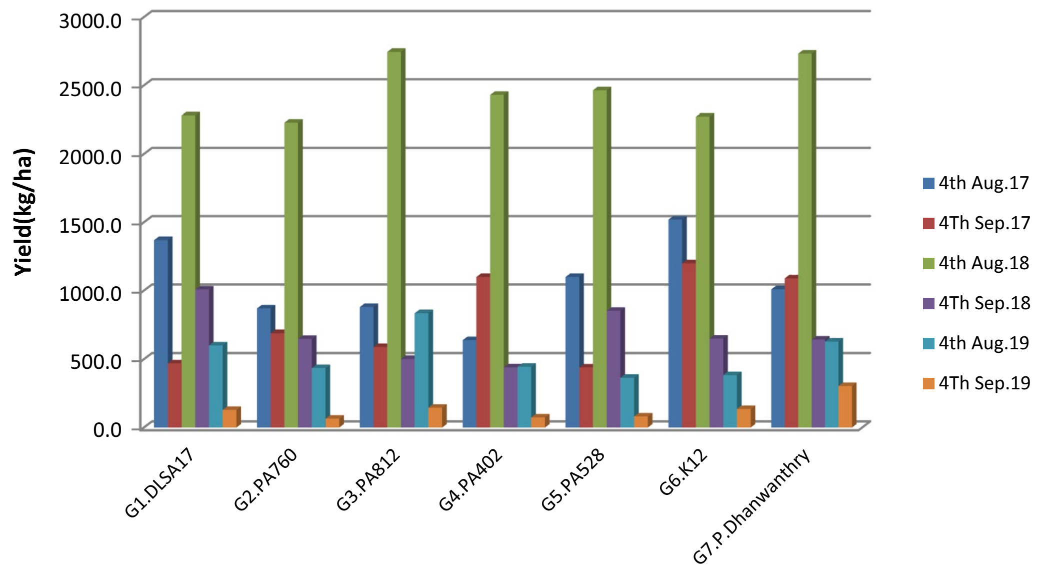

Fig. 1 Seed cotton yield (kg/ha) by genotypes and times of sowing

indicated the maximum temperature (°C) of 30.8 and 29.9, minimum temperature (°C) of 22.4 and 21.6 and, SSH of 5.02 and 4.6, respectively. The climate variables reported in 4 August were more favourable for cotton production. Minimum temperature decreased in late sowing which does not favour proper boll maturation of seed cotton (Ali et al. 2004). Yeates et al. (2013) reported that cooler night temperature might be detrimental to boll retention and growth. Reduction in yield parameters in later sowing dates might be due to poor environmental conditions particularly minimum temperature falling at the time of reproductive stage (Manjeet et al. 2019). The gradual reduction in boll weight by late sowing was reported by Sankaranarayanan et al. (2020).

Seed cotton yield

The pooled analysis found that Phule Dhanwanthry, K-12, DLSA 17 and PA 812 are high performing genotypes. The genotypes had higher number of bursted bolls/plant which in turn registered higher seed cotton yield. Manivannan et al. (2018) reported that number of bolls/plant was the major contributor towards the seed cotton yield.

The effect of sowing time was consistent across genotypes and years of experimentation and higher yield was recorded with 4 August planting than 4 September. In 4 August planting, the prevalence of congenial weather conditions resulted an improved and balanced vegetative and reproductive growth thus ultimately resulted as higher seed cotton yield. The optimum time planted cotton had accumulated more of its resources and assimilates into higher reproductive growth. Presumably, the early planted cotton is able to take advantage of more favourable weather conditions than late planted cotton as observed by Pettigrew and Adamczyk (2006). Early sown crops had 32% more bursted bolls than the late-sown crops due to easy access of available resources early in the season (Khan et al. 2017). Pettigrew (2002) also observed that the early planted cotton yielded 10% more lint than that produced by the late planted cotton. Ali et al. (2009) showed that the maximum seed cotton yield of 2039 kg ha^{-1} was obtained with early sowing. The reproductive development in late sown crop was affected by cooler temperature and low light, which reduced photosynthetic activity and transport of carbohydrates to fruit structures (Gormus and Yucel 2002; Liu et al. 2015; Zhang et al. 2014). The lesser yield was due to sub-optimal weather conditions in late sowing date as reported by Gormus and Yucel (2002) and Sankaranarayanan et al (2020)

Amongst years of experimentation, 2018–19 resulted as higher performance of *G. arboreum*, despite the fact that the genotypes were repeated following similar management practices in all three years. The analysis of weather parameters found that seasonal rainfall received were 472.3, 396.8 and 686.6 mm during 2017–18, 2018–19 and 2019–20, respectively. *G. arboreum* is known for its suitability in low rainfall region and the less rainfall balanced the vegetative and reproductive growth and led to realization of higher yield. Venugopalan and Pundarikakshudu (1999) indicated that mono-cultured *G. arboreum* was superior to *G. hirsutum* in nine out of eleven years except in years experiencing heavy rainfall.

Table 6 Interaction effect of Seed cotton Yield (kg/ha) of *G. arboreum* genotypes as influenced by different dates of sowing recorded in different years and ANOVA table of pooled analysis

Genotypes × times of sowing	4 Aug	4 Sep	Genotypes (Grand mean)	2017–18	2018–19	2019–20	Year × times of sowing	4 Aug	4 Sep	Year (Grand Mean)	Source	DF	Sum of Square	Mean Square	F Value	Pr > F
G1.DLSA17	1418	536	977	920	1645	365	2017–18	1060	800	930	Y	2	32,006,666	16,003,333	441.19	< .0001
G2.PA760	1178	468	823	780	1440	250	2018–19	2451	678	1565	Y(B)	6	14,457	2409	0.07	0.9988
G3.PA812	1487	412	951	740	1624	490	2019–20	528	134	331	T	1	20,553,654	20,553,654	566.64	< .0001
G4.PA402	1172	538	855	870	1436	260	Mean	1346	537	942	Y*T	2	14,778,184	7,389,092	203.71	< .0001
G5.PA528	1310	458	883	770	1658	222					G	6	899,235	149,872	4.13	0.0012
G6.K12	1392	663	1027	1360	1462	260					Y*G	12	1,760,539	146,712	4.04	< .0001
G7.P.Dhanwanthry	1457	679	1069	1050	1689	467					G*T	6	579,496	96,583	2.66	0.0211
Mean	1345	536	941	927	1565	331					Y*G*T	12	2,507,096	208,925	5.76	< .0001
ANOVA	G	T	Y	GxT	YxG	YxT	YxGxxT									
SEd	63.8	33.9	41.6	89.8	109.9	58.8	155.5				R-Square	Coeff Var	Root MSE			
CD (5%)	126.9	67.8	81.5	175.9	215.5	115.2	304.8				0.9414	24.508	191.26			

G, Genotypes; T, Times of Sowing; Y, Year; B, Replication

Table 7 Seed cotton Yield (kg/ha) and N uptake (kg/ha) of *G. arboreum* genotypes as influenced by different dates of sowing at harvest

Genotypes	Seed Cotton Yield (kg/ha)									Nitrogen Uptake (kg/ha)								
	2017–18			2018–19			2019–20			2017–18			2018–19			2019–20		
	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean
G1.DLSA17	1370	470	920	2282	1008	1645	601	129	365	105.5	39.1	72.3	173.5	142.4	157.9	114.7	33.2	74.0
G2.PA760	870	690	780	2230	649	1440	435	65	250	67.9	44.7	56.3	132.2	120.1	126.2	57.7	44.6	51.1
G3.PA812	880	590	740	2746	502	1624	835	145	490	71.8	39.8	55.8	128.5	112.3	120.4	68.1	37.7	52.9
G4.PA402	640	1100	870	2431	441	1436	445	74	260	54.4	79.9	67.1	174.0	115.5	144.7	50.5	88.7	69.6
G5.PA528	1100	440	770	2465	852	1658	364	81	222	77.0	30.9	53.9	154.2	138.9	146.5	68.7	28.1	48.4
G6.K12	1520	1200	1360	2273	652	1462	384	136	260	122.5	100.8	111.7	164.5	88.6	126.6	112.7	96.5	104.6
G7.P.Dhanwanthry	1010	1090	1050	2733	644	1689	629	304	467	83.3	93.5	88.4	175.5	124.3	149.9	79.7	79.5	79.6
Mean	1060	800	0	2451	678	1565	528	134		83.2	61.2	72.2	157.5	120.3	138.9	78.9	58.3	68.6
ANOVA	G	T	GxT	G	T	GXT	G	T	GXT	G	T	G xT	G	T	GXT	G	T	G xT
SEd	93	50	131	178.6	95.5	252.6	46	24	65	2.9	3.3	4.2	5.1	2.7	7.2	3.4	1.8	4.9
CD (5%)	191	102	NS	NS	196.3	519.3	94	50	133	6.0	6.9	8.6	10.4	5.6	15.2	7.0	3.8	10.2

Table 8 Phosphorus and potassium uptake (kg/ha) of *G. arboreum* genotypes as influenced by different dates of sowing at harvest

Genotypes	Phosphorus uptake (kg/ha)									Potassium uptake (kg/ha)								
	2017–18			2018–19			2019–20			2017–18			2018–19			2019–20		
	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean
G1.DLSA17	23.50	7.22	15.36	34.2	27.7	30.9	22.2	11.7	17.0	100.7	34.6	67.64	147.4	122.2	134.8	124.7	44.2	84.5
G2.PA760	12.27	8.38	10.33	27.2	23.4	25.3	15.3	16.6	16.0	62.6	44.7	53.68	116.5	103.5	110.0	62.1	69.9	66.0
G3.PA812	14.06	7.17	10.62	24.6	22.7	23.7	18.1	12.3	15.2	62.8	33.5	48.14	109.1	94.7	101.9	79.1	59.3	69.2
G4.PA402	10.66	17.06	13.86	32.1	21.9	27.0	16.0	21.1	18.6	50.0	83.5	66.77	147.6	97.8	122.7	51.9	103.8	77.8
G5.PA528	14.17	5.35	9.76	29.9	25.5	27.7	17.3	12.0	14.7	64.7	28.5	46.60	129.3	119.2	124.3	79.9	41.4	60.6
G6.K12	21.68	20.58	21.13	30.4	16.5	23.5	19.9	24.6	22.3	103.7	92.4	98.03	138.4	73.8	106.1	95.0	101.3	98.1
G7.P.Dhanwanthry	16.00	16.19	16.09	33.5	22.9	28.2	19.2	22.4	20.8	76.7	82.7	79.70	147.5	97.8	122.7	75.0	111.7	93.4
Mean	16.0	11.7	13.9	30.3	23.0	26.6	18.3	17.3	17.8	74.5	57.1	65.8	133.7	101.3	117.5	81.1	75.9	78.5
ANOVA	G	T	G xT	G	T	GXT	G	T	G xT	G	T	G xT	G	T	GXT	G	T	G xT
SEd	0.7	0.8	1.0	1.4	0.8	2.0	1.0	0.5	1.4	3.1	3.6	4.5	5.2	2.8	7.4	3.5	1.9	5.0
CD (5%)	1.5	1.7	2.1	2.9	1.6	4.3	2.0	1.1	2.9	6.4	7.4	9.2	10.7	5.8	15.6	7.3	3.9	10.6

Thus, *G. arboreum* is better adapted to drier conditions. The high variation of seed cotton yield in different experimental years has been reported by many workers (Singh et al. 2012, Tuteja 2006 and Singh et al. 2014). Even though *G. arboreum* is our land races and existing in the local environment since so many years, because of high genotype × environment interaction, the species showed high variation in yield.

Nutrient uptake

The genotypes viz., K-12, DLSA 17 and PA 528 were estimated higher nutrient uptake of major nutrients in different years. The superior plant growth characteristics registered with the genotype might be attributed for the increased nutrient uptake. The boosted growth parameters enabled the increased uptake of nutrients (Sankaranarayanan and Nalayini 2015). Ramakal et al. (1988) reported that higher nutrient uptake might be due to genetic richness of that variety resulted in high dry matter production and uptake was a positive function of dry matter yield. The genotype, which uptake more nitrogen, naturally boosted the uptake of other nutrients including phosphorus and potassium (Nanjundappa et al. 1994). The major nutrients uptake (kg/ha) was the highest with 4 August planting. The conducive climate prevailed in 4 August planting resulted higher growth characters and dry matter production and ultimately resulted in higher nutrient uptake.

Quality parameters

The genotypes are varying with respect to quality parameters because of different genetic background. Phule Dhanwanthry is not grouped under long-linted *G. arboreum*, which registered less quality parameters and fibre quality index. Amongst long-linted *G. arboreum* genotypes tested, PA 760 recorded higher quality parameters and fibre quality index. The results of better performance of PA 760 are in agreement with the reports of Deshpande et al. (2003), Sakhare et al. (2005), Bolek et al. (2010) and Patil et al. (2015). Planting times had not influenced quality parameters significantly. The similar result was reported by Sankaranarayanan et al. (2011).

Growth characters VS Seed cotton yield

Studying the relationship between growth and yield characters versus seed cotton yield is necessary which will facilitate to select better varieties with desirable characteristics by Chinchane et al. (2018). Number of monopodial branches per plant ($r = 0.748$) and number of bursted bolls ($r = 0.975$). were significantly and positively correlated with seed cotton yield. Jan et al. (2017) reported that monopodia and seed cotton yield were significantly and positively correlated with each other. Phenotypic and genotypic association of number of monopodial branches and seed cotton yield reported by Ahuja et al. (2016) and Alkuddsi et al. (2013). However, the findings observed by the author in present research work are not in agreement to the results found by Killi (1995). This may be due to different genetic makeup of the experimental materials. The positive correlation of bursted bolls and seed cotton yield was reported by Ahuja et al. (2016), Salahuddin et al. (2010) and Yehia and El-Hashash (2019).

Plant height has significant negative correlation with number of bursted bolls and seed cotton yield. *G. arboreum* is known for putting rank vegetative growth, higher plant height with lesser yield attributes and seed cotton yield under high (more than optimum) rainfall situation. The productivity of different species of cotton under rainfed condition, high rainfall year normally favours *G. hirsutum over G. arboreum/G. herbaceum* and the reverse is true for a low or scanty rainfall year as reported by Sankaranarayanan et al.(2010).

The growth characters include number of sympodia, number of nodes, H/N ratio, boll weight and dry matter production that were not influenced the seed cotton yield significantly. These results are in agreement with those of Afiah and Ghoneim (2000) as they found a very low direct effect of sympodia on seed cotton yield. *G. arboreum* due to its negative association with high rainfall (more than optimum) thus leads to uncontrollable vegetative growth resulted in higher dry matter production with less reproductive growth. Cotton often produces more vegetative growth than is needed for maximum boll production and yield especially when climatic conditions favour vegetative growth (Nawalkar et al.2015).

Yield model

Plant growths mostly rely on environmental factors, management practices and genotypes characteristics. Weather is the foremost feature of crop growth and yield (Manjunatha et al.2010). The yield model based on regression was developed (Y = -17,711.4 + 617.32 Max. Temp. (46–90 DAS) + 1.72SSH (90–120 DAS)-1.525RF (mm) (1–150 DAS)) and validated (r^2 value of 0.806). The cotton crop is cultivated during winter season (August-Feb) in that experimental zone. The higher contribution of maximum temperature is reported in the equation (coefficient of 617.32). The mean maximum temperatures (^{0}C) recorded during cropping periods were ranged from 29.1 to 32.2 at critical period of 46–90 DAS which was less than optimum required for cotton growth; hence, recorded maximum temperature was positively and linearly contributed for yield. Mauney (1986) stated that all processes leading to square, blossom and boll initiation and maturation are temperature-dependent. Manjeet et al. (2019) reported that documented that sub-optimum

Table 9 Quality parameters of *G. arboreum* genotypes as influenced by different dates of sowing

Genotypes	UHL (mm)			Mean length (mm)			Uniformity Index			Fibre Strength (g/tex)			Micronaire (μ/inch)			FQI		
	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean	4 Aug	4 Sep	Mean
G1.DLSA17	27.2	27.8	27.5	22.5	23.1	22.8	82.3	83.0	82.7	25.1	25.9	25.5	5.5	6.1	5.8	289.5	290.8	290.1
G2.PA760	29.4	30.4	29.9	24.4	25.4	24.9	82.7	83.0	82.8	26.5	27.4	27.0	5.4	5.3	5.3	335.7	363.8	349.7
G3.PA812	28.7	26.3	27.5	23.8	21.2	22.5	83.0	80.3	81.7	26.1	24.0	25.1	5.6	5.9	5.7	317.9	260.3	289.1
G4.PA402	26.4	27.5	27.0	22.0	23.0	22.5	83.3	83.3	83.3	24.0	25.3	24.6	5.5	6.0	5.8	269.8	284.0	276.9
G5.PA528	24.8	28.3	26.5	19.9	23.4	21.6	80.3	83.0	81.7	23.2	26.2	24.7	6.3	5.8	6.1	228.3	308.4	268.4
G6.K12	26.9	26.5	26.7	22.1	21.9	22.0	82.3	82.0	82.2	24.8	24.2	24.5	5.8	5.4	5.6	278.2	275.6	276.9
G7.P.Dhanwanthry	22.4	24.4	23.4	16.2	19.5	17.9	72.7	79.3	76.0	20.8	22.8	21.8	6.3	6.7	6.5	186.2	214.4	200.3
Mean	26.5	27.3	26.9	21.6	22.5	22.0	81.0	82.0	81.5	24.4	25.1	24.7	5.8	5.9	5.8	269.2	282.8	276.0
ANOVA	G	T	GXT	G	T	GXT	G	T	GXT	G	T	GXT	G	T	GXT			
SEd	1.28	0.68	1.81	1.4	0.7	1.9	1.6	0.9	2.3	1.2	0.6	1.7	0.3	0.2	0.5			
CD (5%)	2.63	NS	NS	2.8	NS	NS	3.4	NS	NS	2.5	NS	NS	NS	NS	NS			

Table 10 Correlation (r = value) of growth characters, yield attributes and seed cotton yield (kg/ha) of *G. arboreum* genotypes

	Plant height (cm)	No of Nodes	H/N	No of Monopodia	No of Sympodia	LAI	No of Bolls	Boll weight (g)	DMP (Kg/ha)	Times of sowing	Actual Yield (kg/ha)	Predicted yield (kg/ha)
Plant height (cm)	1.000									4 Aug.17	1060	956
No. of Nodes	**0.517**	1.000								4 Sep.17	800	737
H/N	**0.847**	− 0.011	1.000							4 Aug.18	2451	2068
No of monopodia	− 0.028	− 0.277	0.148	1.000						4 Sep.18	678	1271
No of Sympodia	0.032	**0.791**	**− 0.447**	**− 0.327**	1.000					4 Aug.19	528	735
LAI	− 0.117	− 0.273	0.067	**0.681**	− 0.271	1.000				4 Sep.19	134	118
No of Bolls	**− 0.316**	− 0.172	− 0.239	**0.724**	− 0.045	0.684	1.000			Chi-square Value	1.6E−89	
Boll weight (g)	0.004	0.024	− 0.005	− 0.052	0.004	− 0.155	− 0.269	1.000		(Y = − 17,711.4 + 617.32 Max.Temp(46–90 DAS) + 1.72SSH(90–120 DAS)-1.525RF(mm)(1–150 DAS)) and validated(r^2 value of0.806)		
DMP (Kg/ha)	0.250	0.009	0.299	0.256	− 0.168	0.141	0.183	**− 0.318**	1.000			
Yield (kg/ha)	**− 0.334**	− 0.202	− 0.240	**0.748**	− 0.077	**0.660**	**0.975**	− 0.120	0.180			

Bold letter indicates significant correlation at 5% level temperatures retarded growth and fibre development. Seed cotton yield per plant was greatly influenced by climatic factors, especially temperature in various cultivation times (Jan et al. (2017) and Ali et al. (2003). The positive coefficient (1.7238) of sun shine hours (90-120DAS) is reported in the equation. The sunshine hours reported in the range of 4.6 to 9.5 recorded during the different years of crop growth periods of 90–120 DAS; the variation in SSH influence seed cotton yield positively and significantly. Plants with the higher boll load are the most sensitive to low light intensity due to their increased requirements of photosynthate (Guinn 1998). The lint yield reduction resulting from low light situations is primarily due to fewer bolls being produced on the plants (Pettigrew 1994). High rainfall had negative contribution as reported in the equation (coefficient of -1.525), and the similar result was reported by Venugopalan and Pundarikakshudu (1999). Balasubramaniyan (1987) found that *G. arboreum* cotton produced excess vegetative growth with less seed cotton yield (40% less) as compared to *G. hirsutum* when excess rainfall (692 mm) was received at early stage of crop growth (48%) as compared to deficit rainfall year (363 mm) with 33% at early growth stage. Rainfall and temperatures are effective variables for G. hirsutum cotton, while it is rainfall alone for G. arboreum cotton (Mangat 1985). The study indicated that less rainfall, optimum temperature and sunshine hours have positive influence on *G. arboreum.*

Conclusions

The results concluded that the significantly highest mean seed cotton yield was recorded with Phule Dhanwanthry (1069 kg/ha) which was on par with K12 (1027 kg/ha), DLSA 17 (977 kg/ha) and PA 812 (951 kg/ha). Planting at 4 August found that the significantly higher seed cotton yield (1345 kg/ha) in comparison with 4 September sowing (536 kg/ha). Amongst long-linted genotypes, PA 760 recorded the significantly higher fibre quality index (349.7).

Abbreviations

HVI: High Volume Instrument; DTPA: Diethylene Triamine Penta Acetic acid; EC: Electrical conductivity; RH: Relative humidity; CD: Critical Difference; SSH: Sun Shine Hours; N: Nitrogen; P: Phosphorus; K: Potassium; dSm^{-1}: DesiSiemens per meter; LAI: Leaf Area Index; Y: Yield; FQI: Fibre Quality index; H/N ratio: Height to node ratio; DAS: Days after Sowing; SEd: Standard error of difference.

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Authors' contributions

KSN—first author, involved in planning, execution of field experiments, data collection on biometric, analysis of quality parameters, reporting the data and article preparation; MVG—second author, involved in interpretation of results. KNJ—third author, involved in analysis on nutrients in plants. All the author read and approved for final manuscript.

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Availability of data and materials

Weather data of experimental periods and data of different experimental years are available with us.

Declarations

Ethical approval and consent to participate

The project is aimed to find out performance of ***G. arboreum*** genotypes with sowing window. The experiment does not involve any component related to ethical and animal welfare issues. The bio-safety is not applicable here.

Consent for publication

Not Applicable.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]ICAR-Central Institute for Cotton Research, Regional Station, Coimbatore, Tamil Nadu 641003, India. [2]ICAR-Central Institute for Cotton Research, Nagpur, Maharashtra, India.

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