Agropedology 2021, 30 (02), 105-112
doi.org/10.47114/j.agroped.2021.dec1

Evaluation of the Productivity Potential of Contemporary *G. arboreum* Cotton Genotypes on Vertic Haplustepts under Rainfed Conditions

M.V. Venugopalan[1], G.I. Ramkrushna[1], A.J. Bagadkar[1], M. Sabesh[2] and S.B. Giredkar[3]

[1] *ICAR-Central Institute for Cotton Research, Nagpur-441108*
[2] *ICAR-Central Institute for Cotton Research, Regional Station, Coimbatore-641003*
[3] *Ph. D Scholar, VNMKV, Parbhani- 43140*

Abstract: *Gossypium arboreum* L. (desi cotton) possesses several useful traits like high ginning percentage tolerance to drought and salinity, make more suitable for cultivation under low input conditions. Apart from being more resilient to climate change and the low cost of cultivation, the availability of new varieties with excellent fibre quality and good locule retention makes desi cotton more attractive and remunerative to farmers. A field experiment was conducted during the *Kharif* season of 2019-20 to evaluate the productivity potential of some promising contemporary *G. arboreum* genotypes and understand their response to sowing dates and planting density under rainfed conditions under dry sub-humid bio-climate.The soil was clayey in texture, moderately alkaline, moderately shallow, 60 cm in-depth, and is classified as a clayey, smectitic hyperthermic family of Vertic Haplustepts. Results indicated that the sowing date had a significant influence on seed cotton yield, days to first flower and boll weight. Plant density had a significant effect on boll weight, plant height, and boll number m^{-2} but not on seed cotton yield. The genotypes differed significantly with respect to days to first flower, plant height, boll number m^{-2}, boll weight and seed cotton yield. Genotypes PA-528 and PA-812 were the highest yielders. Genotypes PA-812 and PA- 760 were superior in terms of fibre quality. A delay in sowing by 15 days significantly reduced the yield of *G. arboreum* cultivars by 142 kg ha^{-1}. A significant interaction observed between plant density and genotypes necessitates a need to evaluate the elite *G. arboreum* cultivars at specific plant density to exploit their productivity potential.

Keywords: *Sowing date, planting diversity, fibre quality, weather parameters, rainfed cotton*

Introduction

India has the unique distinction of growing all the four cultivable species, *viz*. *Gossypium hirsutum, Gossypium arboreum, Gossypium barbadense and Gossypium herbaceum* of cotton. However, the area under the diploid species, *G. arboreum and G. herbaceum,* that accounted for 97% of the cotton grown in 1947, has drastically reduced to less than 5% (Kranthi 2015) and the area under *G. arboreum,* to less than 3% (DCD 2017). Nevertheless, *G. arboreum* cotton possesses several useful traits like high ginning percentage, tolerance to drought and salinity (Sethi *et al*. 2015; Dilnur *et al*. 2019), tolerance to sucking pests and nematodes (Yik and Berchfield 1984) *etc.* These qualities make *G. arboreum* cotton more suitable for

---

*Corresponding author: (Email: mvvenugopalan@gmail.com) cultivation under low input conditions (Venugopalan *et al.* 2018). Despite these advantages, *G. arboreum* cotton cultivars are not preferred by the farmers and the industry due to their lanky plant architecture, longer duration, inferior fibre quality, small boll size and poor locule retention (Manivannan 2015). In the last few decades, some of these drawbacks have been addressed by cotton breeders (Sethi *et al.* 2014). New varieties with excellent fibre quality and good locule retention are now available (Chandra *et al*. 2016;Chinchane and Baig 2018). In an era of climate change and spiralling production costs, it is imperative to climate-proof the cotton farmer without compromising the fibre quality required by the textile industry. An analysis by Romeu-Dalmau *et al*. (2015) indicated that under rainfed conditions of India, which are vulnerable to climatic variability, *G. arboreum* cotton could generate similar net revenue as that of Boll Gard (BG) *G. hirsutum* cotton.

Poor productivity has also been attributed to the low adoption of *G. arboreum* cotton (Giri and Gore 2016). Selection of appropriate cultivar, manipulation of sowing time and plant density are some low-cost techniques for improving productivity. A recent study by Sankaranarayanan *et al.* (2021) concluded that a delay in sowing resulted in a significant reduction in the yield of contemporary *G. arboreum* cultivars under winter-sown conditions of Coimbatore, Tamil Nadu. Venugopalan *et al.* (2013) advocated a high-density planting system as a technology for yield enhancement for semi-compact upland cultivars grown on shallow and medium-deep soils under rainfed conditions. Blaise *et al*. (2020) also advocated high-density planting for yield enhancement of *G. arboreum* variety, Phule Dhanwantary. At the same time, Yadav *et al.* (2021) concluded that 67.5 cm x30 cm was the optimum plant density for *G. arboreum* cotton. With this background, the present investigation was planned to evaluate the productivity potential of some promising contemporary *G. arboreum* genotypes, quantify the extent of yield reduction due to delay in planting, and comprehend if there is any differential response among genotypes to planting density.

Materials and Methods

A field experiment was conducted on the evaluation of contemporary *G. arboreum* genotypes during the *Kharif* (monsoon) season of 2019-20, at the research farm of ICAR-Central Institute for Cotton Research, Nagpur, Maharashtra (21° 04′N, 79° 04′E, 306 m above mean sea level) under rainfed conditions. The location is representative of Agro-eco sub-region 10.2, characterized by a hot, dry sub-humid bio-climate. Seven contemporary *G. arboreum* genotypes, developed under diverse ecological backgrounds, were evaluated across two plant densities and two dates of sowing in a split-split plot design with three replications. The main plots comprised two dates of sowing, *viz*. Timely sowing with the onset of monsoon on June 23, 2019, and late sowing, a fortnight after the first date, on July 8, 2019. Sub-plots comprised of two planting densities, *viz.* Normal (0.55 lakh plants ha^{-1}) and High Density (1.1 lakh plants ha^{-1}) plant population obtained by planting the crop at 60 cm x 30 cm and 60 cm x 15 cm spacing, respectively. In the sub-sub plots, there were seven genotypes – DLSa-17, PA-528, PA-402, PA-812, PA-760, CNA-1041 and Phule Dhanwantary.

The crop was raised following the recommended package of practices. The entire quantity of the recommended dose of P (30 kgP_2O_5ha^{-1}) and K (30 kgK_2O ha^{-1}) along with 1/3 dose of N (20 kg ha^{-1}) was applied at sowing, and the remaining N was applied in two equal splits of 20 kg Nha^{-1}at squaring (45 days after sowing, DAS) and flowering (70DAS). De-topping was done by mechanically clipping the top 10 cm when the crop was 90 days old to prevent apical dominance and reduce further vegetative growth. Six plants from each plot were tagged to obtain data on days to first flower, plant height at 85 DAS, boll number and boll weight. The last date on which 3 out of the 6 tagged plants had at least one flower was considered as onset of flowering, and the number of days from planting to that date was calculated to obtain days to the first flower.

At each picking, the total number of fully open bolls from the tagged plants were counted and averaged to give boll numbers per plant, and this was later expressed as bolls m^{-2}. Seed cotton from these open bolls from six tagged plants was weighed and divided by the number of bolls to obtain boll weight. Seed cotton from the net plots was handpicked thrice. Lint samples from the first pick were analyzed for fibre quality parameters using High Volume Instrument (HVI).

The data were subjected to statistical analysis using the ANOVA technique (Gomez and Gomez 1984). Wherever F values were significant, the least significant difference (LSD) values (P = 0.05) were used to determine the significance of the difference between treatment means.

Results and Discussion

Soil characteristics

Selected physical and chemical characteristics of the soil pedon at the experimental site are provided in table 1. The soil was clayey in texture, moderately alkaline, moderately shallow, 60 cm in-depth, and is classified as a clayey, smectitic hyperthermic family of Vertic Haplustepts. The BC layer had *murrum* with boulders in patches. The bulk density of the surface soil was 1.32 Mg $m^{-3,}$ and the bulk density increased with depth, which could be attributed to soil compaction due to repeated tillage and also due to clogging of pores by displaced clay particles. The surface soil had a saturated hydraulic conductivity (sHC) of 1.11 cmh^{-1} and organic carbon content of 7.6 g kg^{-1}. Both sHC and organic carbon content decreased with depth. The surface soil was low with respect to 0.5 *M* $NaHCO_3$ extractable P (5.6 mg kg^{-1}) but was high in ammonium acetate exchangeable K (276 mg kg^{-1}). The $CaCO_3$ content increased with depth from 2.2% in the surface soil to 26.0% in the BC horizon (40-60 cm), a common feature in soils of the semi-arid and dry sub-humid regions.

Table 1. Select physical and chemical properties of the soil pedon of the experimental site

Horizon	Depth (cm)	Clay (%)	Bulk density (Mg m^{-3})	sHC (cm h^{-1})	pH 1:2	Org. C (g kg^{-1})	$CaCO_3$ (%)
Ap	0 - 10	63.8	1.32	1.11	7.9	7.6	2.20
Bw1	10-20	66.4	1.44	0.54	7.9	6.1	5.38
Bw2	20-40	68.6	1.74	0.23	7.9	4.3	7.05
BC	40-60	68.6	-	1.79	7.9	3.5	25.99

Weather parameters

The study area is characterized by *ustic* soil moisture and hyperthermic soil temperature regimes (Soil Survey Staff 2014). The data on the monthly weather parameters during the cropping season (2019) along with the normal (1969-2010) values for these parameters (Nandankar *et al.* 2011) are shown in table 2. The weather parameters had a significant bearing on the performance of the crop. During the cropping season, rainfall of 1241 mm was received in 74 rainy days as against normal rainfall of 1002 mm in 48.8 rainy days. Thus, the rainfall was 24% higher than normal, and as per the norms of the India Meteorological Department, the season is characterized as 'excess rainfall season'

Table 2. Monthly average maximum, minimum temperature and total rainfall during the crop growing season (2019) *vis-a-vis* normal (1969-2010)

Parameter	Year	June	July	August	September	October	November	December
Max. temperature (°C)	2019	37.9	30.0	28.2	28.2	28.3	26.5	22.9
	Normal	37.8	31.7	30.6	32.2	33.6	30.9	28.8
Min. temperature (°C)	2019	29.0	25.1	24.9	24.4	22.4	17.3	13.1
	Normal	26.4	24.2	23.7	23.1	20.0	15.8	12.6
Monthly rainfall (mm)	2019	132.2	398.4	343.4	275.0	77.0	0	14.6
	Normal	163.4	304.0	275.0	170.1	61.2	16.8	11.7
Rainy days (number)	2019	8	20	20	19	4	0	3
	Normal	8.7	13.7	13.2	8.3	3.1	1.0	0.8

Effect of sowing date, plant density and genotype on growth, yield attributes and seed cotton yield

Results of ANOVA (Table 3) indicated that the date of sowing had a significant influence on seed cotton yield, days to first flower and boll weight. Likewise, plant density had a significant effect on boll weight, plant height at 85 DAS, and boll number m^{-2} but not on seed cotton yield. The genotypes differed significantly with respect to days to first flower, plant height, boll number m^{-2}, boll weight and seed cotton yield. The interaction effect between plant density and genotype was significant for seed cotton yield. All the other main plot, sub-plot and sub-sub plot effects were non-significant.

Table 3. Results of ANOVA (F values and significance) on the effect of spacing and MC on different growth and yield attributes, yield earliness and N uptake DAS

Effect	Days to first flower	Plant height at 85 DAS	Boll number m^{2}	Boll weight (g)	Seed cotton yield (kgha^{-1})
Sowing date (Sd)	29.6*	1.32 ^{ns}	0.10 ^{ns}	19.21 *	54.57 *
Plant density (Pd)	1.33 ^{ns}	92.69 *	9.39 *	10.09 *	2.66 ^{ns}
Genotype (G)	16.44*	34.54 *	3.76 *	8.24 *	12.87 *
Sd x Pd interaction	0.18 ^{ns}	3.97 ^{ns}	0.25 ^{ns}	0.01 ^{ns}	0.08 ^{ns}
Sd x G interaction	2.34 ^{ns}	1.84 ^{ns}	1.25 ^{ns}	0.94 ^{ns}	0.97 ^{ns}
Pd x G interaction	2.26 ^{ns}	0.27 ^{ns}	0.49 ^{ns}	0.42 ^{ns}	2.34 *
SdxPd x G interaction	1.15 ^{ns}	0.37 ^{ns}	2.11 ^{ns}	0.70 ^{ns}	0.64 ^{ns}

Averaged over genotypes and plant densities, a delay in sowing by 15 days hastened the time taken for the appearance of the first flower by 7.2 days, decreased the boll weight by 0.16g and reduced the seed cotton yield by 142 kgha^{-1} (Table 4). Earlier, Shah *et al*. (2017) also observed that late planting hastened flowering in cotton. Early-onset of reproductive phase, before the development of robust morphoframe, could be a reason for low productivity in late-planted cotton. The effect of delayed sowing on the bolls m^{-2} was not significant, but a significant decline in boll weight due to poor boll filling was another reason for low yield. Recently, Sankaranarayan *et al*. (2021) also reported a reduction in the yield of modern *G. arboreum* genotypes at Coimbatore, Tamilnadu. In a year of normal rainfall, Damahe *et al.*(2018) observed a 228 kgha^{-1} reduction in the yield of *G. arboreum* genotype AKA-8 at Akola, Maharashtra, when the sowing was delayed by 15 days. However, in the present study, the yield decline due to late planting was only 142 kgha^{-1}, probably because the season was characterized by excess and prolonged rainfall (Table 2). Adequate soil moisture partly offset the yield loss even in moderately shallow Vertic Haplustepts.

Under dense planting (1.11 lakh plants ha^{-1}), greater competition for resources reduced growth and the height at 85 DAS with 8.2 cm shorter plants than that planted at normal density (0.55 lakhs ha^{-1}). There was a significant increase in bolls m^{-2} at higher plant density, but its contribution to enhanced yield was counteracted by a significant reduction in boll weight. Consequently, the net increase in yield due to high-density planting (averaged over sowing date and genotypes) was only 88 kgha$^{-1,}$ and this increase was not significant. Several recent studies have reported higher yields under high-density planting (Venugopalan *et al.* 2018). However, Venugopalan *et al.* (2013) concluded that the benefit of high-density planting was more pronounced in a dry year than in a year of excess rainfall. Excess rainfall could be a reason for a marginal, non-significant yield improvement at high planting density in the present study conducted on Vertic Haplustepts.

Averaged over sowing dates and planting densities, among the contemporary *G. arboreum* genotypes evaluated, PA-528 (2683 kg ha^{-1}) followed by PA-812 (2537 kg ha^{-1}) were the top yielders, and the difference among their yields was not significant. The yield of Phule Dhanwantry was significantly lower than the rest. Incidentally, Phule Dhanwantary took the longest time for onset of flowering, was the shortest, had significantly lower bolls m^{-2} but slightly higher boll weight than the remaining genotypes. Earlier, Venugopalan *et al.* (2018) also observed significant yield differences among seventeen diverse *G. arboreum* genotypes evaluated on rainfed Typic Haplusterts at Nagpur, Maharashtra.

Table 4. Effect of sowing time, plant density and genotypes on growth, yield attributes and seed cotton yield under rainfed conditions on Vertic Haplustepts

Treatment	**Days to first flower**	**Plant height at 85 DAS**	**Boll number m^{-2}**	**Boll weight (g)**	**Seed cotton yield (kgha^{-1})**
Sowing date					
Timely (June 23)	71.4	134.9	70.3	2.90	2438
Late (July 8)	64.2	137.4	68.1	2.74	2296
LSD 0.05	5.70	NS	NS	0.140	82.2
Plant density (lakh plantsha^{-1})					
Normal (0.555)	67.4	140.3	62.2	2.85	2323
High density (1.110)	68.2	132.1	76.1	2.76	2411
LSD 0.05	NS	2.37	12.56	0.080	NS
Genotype					
DLSa-17	63.7	128.2	69.8	2.56	2455
PA-528	69.0	150.6	73.1	2.86	2683
PA-402	69.0	149.4	63.3	2.89	2447
PA-812	69.5	133.6	77.0	2.82	2537
PA-760	67.8	147.5	75.8	2.86	2426
CNA-1041	65.0	158.2	67.1	2.74	2396
PhuleDhanwantary	70.5	85.8	58.0	2.93	1629
LSD 0.05	1.83	12.43	10.09	0.133	224.9

The interaction between plant density and genotypes was significant for seed cotton yield (Table 5). All the genotypes except Phule Dhanwantary performed equally well both at normal (0.55 lakh plants ha^{-1}) and high density (1.11 lakh plants ha^{-1}). Being short (Table 4) and compact, Phule Dhanwantary yielded significantly higher at high plant density. At a density of 1.11 lakh plant ha^{-1}, it yielded 623 kgha^{-1} more than at 0.55 lakh plants ha^{-1} (1318 kgha^{-1}). Considering its compact stature, Blaise *et al.* (2020) recommended an optimum plant density of 2.21 lakh plants ha^{-1} for Phule Dhanwantary. The interaction effect observed in the present study necessitates the evaluation of elite *G. arboreum* cultivars at specific plant density to exploit their productivity potential.

Table 5. Interaction effect between plant density and genotype on seed cotton yield (kgha^{-1})

Genotype	**Normal (0.555 lakh plants ha^{-1})**	**High density (1.110 lakh plants ha^{-1})**
DLSa -17	2374	2535
PA - 528	2738	2628
PA - 402	2550	2344
PA - 812	2534	2541
PA - 760	2370	2481
CNA-1041	2379	2409
Phule Dhanwantary	1318	1941
LSD 0.05	449.7	

Fibre quality attributes of G. arboreum genotypes

Fibre quality is as important as yield in evaluating the performance of cotton genotypes, and the fibre parameters of the genotypes tested are presented in table 6. Both PA-760 and PA-812 were superior tothe remaining in terms of fibre length and uniformity. CNA-1041 has the strongest fibres with a Bundle Strength of 33.5 g tex^{-1}. As per standard fibre quality norms (Iyerand Iyer 1999), both PA-760 and PA-812, with fibre length in the range 27.5-32.0 mm, were classified as long-linted, Phule Dhanwantary with a fibre length of less than 20 mm as short and the remaining being in the range of 25 to 27 mm were classified as medium-long. Elongation Index was higher in Phule Dhanwantary compared to other genotypes.

Table 6. Mean fibre quality of *G. arboreum* cotton genotypes

Genotype	**Upper half mean length mm**	**Uniformity index %**	**Micronaire (microgrammes inch^{-1})**	**Bundle Strength (g/tex) at at 3.2mm gauge**	**Elongation Index %**
DLSa -17	26.9	80.3	4.8	29.2	4.4
PA -528	27.4	80.5	4.7	31.4	4.3
PA 402	26.0	80.5	5.1	31.2	4.5
PA 812	28.9	82.3	4.6	30.8	4.3
PA 760	29.5	82.5	4.9	29.8	4.2
CNA -1041	26.1	80.3	5.7	33.5	4.4
Phule Dhanwantary	19.6	73.8	6.3	23.9	5.1

Micronaire is an index of fineness of cotton, and *G. arboretums* are coarser than their *G. hirsutum* counterparts. Among the genotypes evaluated, PA- 760, PA-812, PA-528 and DLSa-17 with micronaire in the range of 4.0-4.9 microgrammes inch^{-1} were categorized as average, Phule Dhanwantary with a micronaire of >6.0 was categorized as very coarse, and the remaining genotypes PA-402 and CNA-1041 as coarse. The quality parameters of PA-812 and PA-760 reported in this study are in agreement with the values reported by Chinchane and Baig (2018) and are comparable to the quality attributes of contemporary intra hirsutum BGII hybrids grown in the region.

Conclusion

From the present investigation, it is concluded that among the seven *G. arboreum* cotton genotypes evaluated, both PA-528, PA-812 performed well in terms of yield under rainfed conditions on Vertic Inceptisols of AESR 10.2. Genotypes PA-812 and PA-760 were superior in terms of fibre quality. A delay in sowing by 15 days significantly reduced the yield of *G. arboreum* cultivars by 142 kg ha^{-1}. Further, in a year of excess rainfall, the benefit of high-density planting (1.1 lakh plants $^{-1}$) over normal density (0.55 lakh plants $^{-1}$) was only marginal. However, a significant interaction between plant density and genotypes necessitates a need to evaluate the genotypes at appropriate plant density to maximize their productivity.

Acknowledgment

The authors are grateful to the Director, ICAR-Central Institute for Cotton Research (CICR) and Head,Crop Production Division, ICAR-CICR, Nagpur, Maharashtra, for the encouragement and support during the course of the study. The help rendered by Head, Ginning and Training Centre, ICAR-CIRCOT, Nagpur, Maharashtra for analysis of fibre quality parameters is thankfully acknowledged.

References

Blaise, D., Kranthi, K.R., Ravindran, C.D. and Talal, K. (2020). High plant density can improve the productivity of rainfed Asiatic cotton (*Gossypium arboreum* L.). *Archives of Agronomy and Soil Science* **67**, 609-617.

Chandra, M. and Sreenivasan, S. (2011). Studies on improved *Gossypium arboretum* cotton: Part I - Fibre quality parameter. *Indian Journal of Fibre and Textile Research* **36,** 24-34.

Chinchane, V.N. and Baig, K.S. (2018). Performance of long linted desi cotton (*Gossypium arboreum*) genotypes for yield and fibre quality parameters under rainfed condition. *Journal of Pharmacognosy and Phytochemistry* **7,** 3409-3411.

Damahe, A.R., Satpute, S.B. and Parlawar, N.D. (2018). Growth and yield of cotton as influenced by different date of sowing and varieties. *International Journal of Current Microbiology and Applied Sciences* Special Issue **6,** 2622-2628.

DCD. (2017). Status paper of Indian cotton, Directorate of Cotton Development, Government of India Nagpur. *https://www.nfsm.gov.in/StatusPaper/Cotton2016.pdf*.

Dilnur, T., Peng, Z., Pan, Z., Palanga, K. K., Jia, Y., Gong, W., Du, X. (2019). Association analysis of salt tolerance in Asiatic cotton (*Gossypium arboretum*) with SNP Markers. *International Journal of Molecular Sciences* **20,** 2168. doi: 10.3390/ijms20092168. PMID: 31052464; PMCID: PMC6540053.

Giri, A.N. and Gore, S.B. (2006). Effect of plant densities and NPK levels on yield of newly released desi varieties of cotton (*Gossypium arboreum* L.). *Journal of Cotton Research* **20**, 77-79.

Gomez, K.A. and Gomez, A. A. (1984). Statistical Procedures for Agricultural Research. New York: John Wiley and Sons, p. 680.

Iyer, K.K.R. and Iyer, B. (1999). Cotton fibre quality evaluation. In' Handbook of Cotton in India'. (Eds. Sundaram, B., Basu, A.K.,Narayanan, S.S., Iyer, K.K.R and Rajendran, T.P.). Indian Society for Cotton Improvement, Mumbai pp. 303-337.

Kranthi, K.R. (2015). Desi Cotton - Returns? *Cotton Statistics and News*, 14th July, 2015, **No. 15,** pp 1-4.

Manivannan, V. (2015). Resurgence of desi cotton – A status of past, present and future. In "Future Technologies : Indian Cotton in the Next Decade" (Eds. R. S. Sangwan, M. S. Chauhan, Shiwani Mandhania, Omender Sangwan, S. Nimbal, S. R. Pundir, Neha Wadhwa and Ashish Jain) Cotton Research and Development Association, CCS Haryana Agricultural University, Hisar, pp. 204-213.

Nandankar, P. K., Dewangan, P. L. K. and Surpam, R. (2011). Climatic features of Nagpur, Regional Meteorological Centre, India Meteorological Department, Nagpur, India p. 5.

Romeu-Dalmau, C., Bonsall, M.B., Willis, K.J. and Dolan L. (2015). Asiatic cotton can generate similar economic benefits to Bt cotton under rainfed conditions. *Nature Plants* **1,** 15072. https://doi.org/10.1038/nplants.2015.72.

Sankaranarayanan, K., Venugopalan, M.V. and Kanjana, D. (2021). Assessment of production potential of long-linted *Gossypium arboretum L.* genotypes under different sowing times. *Bull Natl Res Cent* **45,** 106 https://doi.org/10.1186/s42269-021-00566-2.

Sethi, K., Siwach, P. and Verma, S. K. (2015). Assessing genetic diversity among six populations of Gossypium arboreum L. using microsatellites markers. *Physiology and Molecular Biology of Plants***21,** 531-539.

Sethi, K., Siwach, P. and Verma, S. K. (2014). Genetic improvement of *Gossypium arboreum* L. using molecular markers: Status and development needs. *African Journal of Agricultural Research* **9,** 2238-2249.

Shah, M.A., Farroq, M. and Shahzad, M. (2017). Yield and physiological response of Bt cotton to different sowing dates in semi-arid climate. *Pakistan Journal of Agricultural Research* **54**, 233 - 239.

Soil Survey Staff. (2014). Keys to Soil Taxonomy, United States Department of Agriculture, Natural Resource Conservation Service, Washington DC, 9th edn.

Venugopalan, M.V., Kranthi, K. R., Blaise, D., Lakade, S. and Sankaranarayanan, K. (2013). High density planting system in cotton – The Brazil experience and Indian initiatives. *Cotton Research Journal* **5,** 172–185.

Venugopalan, M.V., Blaise, D. and Lakde, S. (2018). Evaluation of diverse *G. arboreum* genotypes under high density planting system on rainfed Vertisols for earliness, productivity and fibre quality. *Cotton Research Journal* **9**, 64-69.

Yadav, S., Singh, H. and Kaur, M. (2021). Effect of plant spacing's and fertilizer levels on growth and productivity of *desi* cotton *(Gossypium arboreum* L.). *The Pharma Innovation Journal* **10**, 1975-1980.

Yik, C.P. and Berchfield, W. (1984). Resistant germplasm in Gossypium species and related plants to *Rotylenchulus reniformis*. *Journal of Nematology* **16,** 146-153.

Received: August, 2021 *Accepted: November, 2021*