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Clonal variation of *Dalbergia sissoo* genetic resources

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Abstract
Experiments were carried out in twenty clones of *Dalbergia sissoo* genetic resources in clonal evaluation trial at Forest College and Research Institute, Mettupalayam to elicit the information on the variability using biometric attributes. Among 20 clones evaluated the clone FCRIDS18 was found to be superior in respect of growth attributes and hence the clone FCRIDS18 could be exploited for further tree improvement programme.

Keywords: Sissoo, clonal evaluation, genetic resources, variability, biometric attributes

Introduction
Dalbergia sissoo belongs to the family of Leguminosae (Papilionioideae) and commonly known as Indian Rose wood, Shisham, Sissoo and Thali. Indian forests have undergone a tremendous change in the past few decades and are presently under a great threat. The human dependency on forests is complex and diverse (Tewari, 1994) [25]. The global forest area is over 4.0 billion hectares. The average per capita of the world forest works out to be 0.6 ha (GFRA, 2010) [6]. The mean annual increment (MAI) of Indian Forest is meager of 0.5 - 0.7 m^3 ha^{-1} compared to the global average of 2.1 m^3 ha^{-1} (Srivastava, 2005) [22]. The annual productivity of India's forests is only 3.18 m^3 ha^{-1} yr^{-1}, which is too low compared to other developed countries 8.20 m^3 ha^{-1} yr^{-1} (FSI, 2011) [4]. There is a growing demand for timber and timber products which ushered in a total mismatch between demand and supply. There has been a shift in the emphasis from utilization of often complex natural forests to plantation species which are relatively easy to manage and capable of producing large quantities of wood per unit area (Wilan, 1973) [28]. The demand for industrial wood raw material is also in the ascendancy due to expansion of various wood based industries. The National Forest Policy 1988 emphasized the wood based industries to raise their own raw material requirement without depending on forest and almost all industries in the country are in the process of establishment of captive industrial wood plantations (Lal, 2000) [15].
Despite being a species endowed with an amplitude of utilities and commanding extensive areas, yet it has received little research efforts in genetic improvement. A knowledge on magnitude, nature and type of variation is a pre-requisite for any tree improvement programme (Krishnakumar *et al*., 2017; Zobel and Talbert, 1984) [10, 11, 30]. The best gains can be made for characteristics that have a wide range of variation and are strongly under genetic control (Zobel, 1971; Lacase, 1978; Zobel and van Buijitenen, 1989) [29, 31]. Since Sissoo is extensively being planted for different purposes and plantations are very costly to establish, it is essential that the most productive plant material be used. A detailed knowledge of genetic variation within a species is thus a pre-requisite to select clones for developing efficient tree breeding strategies. Evidence accumulating on specific inter genetic variation in tree form and growth rate in *Dalbergia sissoo* gave significant difference among three geographic areas (Rehman and Hussain, 1986) [19]. However there is no systematic evaluation or improvement programme in order to utilize the existing genetic variation among broader genetic base population which warrants a systematic tree improvement programme in *Dalbergia sissoo* which will also address the shortage of suitable raw material to the different wood based industries.

Materials and Methods
The experimental materials for this study consisted of 20 clones of *Dalbergia sissoo* selected from various locations of Tamil Nadu and the details are presented in table 1. The clonal evaluation experiments were carried out in the field of Forest College and Research Institute, Tamil Nadu Agricultural University, Mettupalayam in a place having longitude and latitude of 11°19'N and 76°56'E and an altitude of 320.0 above MSL with the average rainfall of 922.0 mm in a soil having neutral in reaction (pH7.1).

Table 1: Details of *Dalbergia sissoo* clones genetic resources and locations

Location	Clones	Latitude	Longitude	Altitude (m)
Mudumalai	FCRIDS1	11°34'11.89"	76°36'00.22"	960
Singarapettai	FCRIDS2	12°15'20.05"	78°36'57.05"	345
Karamadai	FCRIDS3	11°`4'25.80"	76°57'27.70"	369
Mundanthurai	FCRIDS4	8°36'55.79"	77°23'01.12"	850
Gudalur	FCRIDS5	11°31'10.11"	76°28'54.01"	914
Coonnoor	FCRIDS6	11°20'00.76"	76°48'37.40"	1388
Thekkampatti	FCRIDS7	11°18'08.93"	76°55'58.89"	320
Kalakkadu	FCRIDS8	8°30'58.16"	77°33'24.84"	740
Kutralam	FCRIDS9	11°04'16.30"	79°33'43.72"	167
Barliyaru	FCRIDS10	11°20'09.21"	76°51'52.75"	800
Kunjappanai	FCRIDS11	11°21'44.94"	76°56'26.82"	1012
Melpattu	FCRIDS12	12°25'49.69"	78°48'50.82"	948
Siruvani	FCRIDS13	10°56'07.38"	76°41'16.29"	812
Pillur	FCRIDS14	11°14'07.99"	76°46'36.69"	443
Hasanur	FCRIDS15	11°40'23.56"	77°07'44.94"	930
Topslip	FCRIDS16	10°29'03.23"	76°51'00.67"	850
Ottanchathiram	FCRIDS17	10°48'00.00"	77°15'39.15"	302
Kallar	FCRIDS18	11°20'14.80"	76°53'01.34"	379
Harur	FCRIDS19	11°53'07.07"	78°56'26.10"	350
Megamalai	FCRIDS20	9°71'52.69"	77°40'87.02"	1650

A clonal evaluation trial has been laid at Forest College and Research Institute, Mettupalayam in 2010. Twenty different clones were planted in a randomized block design (RBD) replicated three times. The clones were planted at the espacement of 3 x 3 m. The observations were recorded at 24, 28 and 32 months after planting (MAP) as described below.

Plant Height
The plant height was measured from ground level to the tip of the stem and expressed in metres.

Diameter at breast height (DBH)
It is the diameter of the tree which is measured at the stem on 1.37 m (breast height) and expressed in centimetre.

Basal diameter
The basal diameter was measured at the base of the stem (near the ground level) and expressed in centimetre.

Number of branches
The number of branches was counted manually in number wise.

Clear bole height
The bole height was measured by the distance between the ground level and the crown point. It gives the height or length of the clear main stem of a tree and expressed in metres.

Crown height
The crown height was measured vertically from the tip to the point half way between the lowest green branches forming green crown all round and the lowest green branch on the bole and expressed in metres.

Volume
The volume was estimated using the formula prescribed by Chaturvedi and Khanna (1982) for standing trees.

$$\text{Volume} = (\pi r^2 h) \text{ X Form factor}$$

Statistical analysis
The data collected from the field experiments were analysed and tabulated. The estimates of mean, variance and standard error were worked out as per the procedure described by Panse and Sukhatme (1978). The significance test was carried out by referring to the standard 'F' table of Snedecor (1961).

Result
The results on biometric studies for plant attributes of *Dalbergia sissoo* under field condition over different growth periods are presented here under.

Tree height
The observations recorded on tree height at different intervals among the 20 clones evaluated are presented in the Table 2. The significant differences were observed among the clones tested. The tree height for 20 clones at 24 months after planting (MAP) had varied from 4.63 (FCRIDS6) to 7.30 m (FCRIDS18). Eight clones *viz.*, FCRIDS18 (7.30 m), and FCRIDS19 (6.64 m) FCRIDS7 (5.94 m), FCRIDS9 (5.84 m), FCRIDS10 (5.76 m), FCRIDS4 (5.63 m), FCRIDS1 (5.57 m) and FCRIDS3 (5.52 m), recorded significantly higher tree height compared to general mean (5.50 m). At 28 MAP, the tree height ranged from 5.54 m (FCRIDS20) to 8.58 m (FCRIDS18). The general mean for this trait was 6.78 m. Nine clones *viz*., FCRIDS18 (8.58 m), FCRIDS7 (8.15 m), FCRIDS11 (7.28 m), FCRIDS4 (7.28 m), FCRIDS17 (7.25 m), FCRIDS19 (7.19 m) FCRIDS3 (7.16 m), FCRIDS2 (6.94 m) and FCRIDS9 (6.84 m) recorded significantly higher tree height compared to grand mean. However, progressive increase in tree height was observed in all the clones. At 32 MAP, the tree height ranged from 6.11 m (FCRIDS20) to 9.16 m (FCRIDS18). Nine clones were identified and recorded higher significant value compared with grand mean (7.62) for tree height. The clones recorded higher significant values over grand mean are FCRIDS18 (9.16 m), FCRIDS7 (8.53 m), FCRIDS13 (8.32 m), FCRIDS3 (8.17 m), FCRIDS16 (8.02 m), FCRIDS17 (7.85m), FCRIDS5 (7.76m), FCRIDS19 (7.75 m) and FCRIDS6 (7.68 m).

Table 2: Clonal variations for tree height (m) in *Dalbergia sissoo*

Clone details/ Treatments	Tree height (m)		
	24 MAP	28 MAP	32 MAP
FCRIDS1	5.57	6.45	7.33
FCRIDS2	5.27	6.94	7.02
FCRIDS3	5.52	7.16	8.17
FCRIDS4	5.63	7.28	7.59
FCRIDS5	4.88	6.59	7.76
FCRIDS6	4.63	6.52	7.68
FCRIDS7	5.94*	8.15	8.53
FCRIDS8	5.42	6.42	6.68
FCRIDS9	5.84*	6.84	7.25
FCRIDS10	5.76*	5.76	7.15
FCRIDS11	5.50	7.28*	7.48
FCRIDS12	5.01	6.68	7.53
FCRIDS13	4.80	5.98	8.32
FCRIDS14	5.21	6.31	7.29
FCRIDS15	5.41	6.41	7.37
FCRIDS16	5.40	6.40	8.02
FCRIDS17	5.15	7.25	7.85
FCRIDS18	7.30	8.58	9.16
FCRIDS19	6.64	7.19	7.75
FCRIDS20	5.11	5.54	6.11
Mean	5.50	6.78	7.62
SEd	0.0694	0.0484	0.1313
CD (p= 0.05)	0.1404	0.0979	0.2658

* Significant at 5 per cent level

Diameter at breast height (DBH)

The observation on diameter at breast height (DBH) recorded among the 20 clones at various stages evaluated are presented in the Table 3. Significant differences were observed among the clones in respect of diameter at breast height evaluated. At 24 MAP, the diameter at breast height ranged between 4.06 cm (FCRIDS1) and 6.73 cm (FCRIDS18). Compared to general mean of 5.08 cm, only nine clones *viz.*, FCRIDS18 (6.73 cm), FCRIDS7 (5.98 cm), FCRIDS19 (5.77 cm), FCRIDS16 (5.56 cm), FCRIDS11 (5.50 cm), FCRIDS3 (5.46 cm), FCRIDS13 (5.35 cm), FCRIDS12 (5.28 cm) and FCRIDS17 (5.25 cm) recorded significantly higher values. At 28 MAP, the diameter at breast height (DBH) ranged from 5.06 cm (FCRIDS1) to 8.05 cm (FCRIDS18) and the general mean was 6.20 cm. Nine clones *viz.*, FCRIDS18 (8.05 cm), FCRIDS19 (7.09 cm), FCRIDS7 (6.98 cm), FCRIDS13 (6.95 cm), FCRIDS12 (6.76 cm), FCRIDS11 (6.60 cm), FCRIDS16 (6.58 cm), FCRIDS3 (6.46 cm) and FCRIDS17(6.25 cm) registered significantly higher values for diameter at breast height (DBH) compared to the general mean. At 32 months, the diameter at breast height (DBH) ranged from 5.75 cm (FCRIDS1) to 8.90 cm (FCRIDS18). The clones registered higher diameter at breast height (DBH) than the grand mean (6.95 cm) are FCRIDS18 (8.90 cm), FCRIDS19 (7.76 cm), FCRIDS7 (7.70 cm), FCRIDS13 (7.53 cm), FCRIDS12 (7.44 cm), FCRIDS11 (7.40 cm), FCRIDS3 (7.20 cm) and FCRIDS16 (7.00 cm).

Table 3: Clonal variations for DBH (cm) in *Dalbergia sissoo*

Clones details/ Treatments	Diameter at breast height (cm)		
	24 MAP	28 MAP	32 MAP
FCRIDS1	4.06	5.06	5.75
FCRIDS2	4.28	5.30	6.62
FCRIDS3	5.46	6.46	7.20
FCRIDS4	4.83	5.79	6.53
FCRIDS5	4.75	5.76	6.44
FCRIDS6	4.79	5.79	6.37
FCRIDS7	5.98	6.98	7.70
FCRIDS8	4.15	5.84	6.76
FCRIDS9	4.13	5.29	6.29
FCRIDS10	5.04	6.01	6.89
FCRIDS11	5.50	6.60	7.40
FCRIDS12	5.28	6.76	7.44
FCRIDS13	5.35	6.95	7.53
FCRIDS14	4.76	5.50	6.27
FCRIDS15	5.02	5.86	6.55
FCRIDS16	5.56	6.58	7.00
FCRIDS17	5.25	6.25	6.91
FCRIDS18	6.73	8.05	8.90
FCRIDS19	5.77	7.09	7.76
FCRIDS20	4.91	6.06	6.77

Mean	5.08	6.20	6.95
SED	0.0565	0.0312	0.0570
CD (p=0.05)	0.1144	0.0631	0.1155

* Significant at 5 per cent level

Number of branches

The observation on number of branches at different intervals among the 20 clones evaluated are presented in the Table 4. Among the clones, the number of braches evaluated at 24 MAP ranged between 4.47 (FCRIDS3) and 7.77 (FCRIDS16) and the general mean was (5.62). Eight clones *viz*., FCRIDS16 (7.77), FCRIDS18 (7.50), FCRIDS 7(6.47), FCRIDS20 (6.17), FCRIDS12 (6.12), FCRIDS8 (6.00), FCRIDS13 (5.87) and FCRIDS9 (5.73) performed above the mean value. At 28 MAP, the number of branches registered between 6.10 (FCRIDS17) and 9.53 (FCRIDS16) and the general mean was 7.69. The clones FCRIDS16 (9.53), FCRIDS18 (8.67), FCRIDS2 (8.67), FCRIDS7 (8.50), FCRIDS1 (8.50), FCRIDS15 (8.47), FCRIDS6 (8.43), FCRIDS4 (8.30), FCRIDS14 (8.03) and FCRIDS12 (7.93) recorded significantly higher values. At 32 MAP, the number of branches varied from 11.47 (FCRIDS2) to 14.87 (FCRIDS11). The clones FCRIDS11 (14.87), FCRIDS1 (14.67), FCRIDS4 (13.00), FCRIDS20 (13.00), FCRIDS14 (12.87), FCRIDS14 (12.87), FCRIDS10 (12.87), FCRIDS12 (12.73), FCRIDS13 (12.53), FCRIDS7 (12.50), FCRIDS15 (12.50), FCRIDS19 (12.38), FCRIDS18 (12.33) and FCRIDS5 (12.07) registered significantly higher number of branches.

Table 4: Clonal variations for number of branches in *Dalbergia sissoo*

Clone details/ Treatments	Number of Branches		
	24 MAP	28 MAP	32 MAP
FCRIDS1	5.40	8.50*	14.67
FCRIDS2	4.83	8.67*	11.47
FCRIDS3	4.47	6.50	12.00
FCRIDS4	4.80	8.30	13.00
FCRIDS5	5.17	6.67	12.07
FCRIDS6	4.87	8.43	12.00
FCRIDS7	6.47	8.50*	12.50
FCRIDS8	6.00*	7.53	11.33
FCRIDS9	5.73	7.53	11.67
FCRIDS10	5.13	6.63	12.87
FCRIDS11	5.40	6.50	14.87
FCRIDS12	6.12*	7.93	12.73
FCRIDS13	5.87	7.23	12.53
FCRIDS14	4.97	8.03	12.87
FCRIDS15	5.20	8.47	12.50
FCRIDS16	7.77	9.53	11.20
FCRIDS17	5.27	6.10	12.00
FCRIDS18	7.50	8.67*	12.33
FCRIDS19	5.33	6.57	12.38
FCRIDS20	6.17*	7.43	13.00
Mean	5.62	7.69	12
SED	0.2456	0.3976	0.8857
CD (p=0.05)	0.4971	0.8050	1.7931

* Significant at 5 per cent level

Basal diameter

The observation on basal diameter among the 20 clones evaluated at different intervals are presented in the Table 5. Significant differences were observed among the clones evaluated for basal diameter. At 24 MAP, the basal diameter ranged between 3.42 cm (FCRIDS 4) and 5.56 cm (FCRIDS18). Ten clones *viz*., FCRIDS18 (5.56 cm), FCRIDS14 (5.01 cm), FCRIDS8 (4.70 cm), FCRIDS13 (4.58 cm), FCRIDS9 (4.56 cm), FCRIDS20 (4.56 cm), FCRIDS16 (4.52 cm), FCRIDS7 (4.49 cm), FCRIDS11 (4.47 cm) and FCRIDS17 (4.33 cm) recorded significantly higher value than general mean (4.36 cm). At 28 MAP, the basal diameter ranged between 5.05 cm (FCRIDS 12) and 6.20cm (FCRIDS4) and the general mean was 5.59 cm. When compared to the average basal diameter at 28 MAP, nine clones FCRIDS4 (6.20 cm), FCRIDS18 (6.17 cm), FCRIDS16 (6.08 cm), FCRIDS7 (6.02 cm), FCRIDS19 (5.86 cm), FCRIDS14 (5.80 cm), FCRIDS1 (5.78 cm), FCRIDS13 (5.68 cm) and FCRIDS11 (5.67 cm) performed better over rest of the clones evaluated. At 32 MAP, the basal diameter ranged from 6.58 cm (FCRIDS17) to 10.17 cm (FCRIDS18) and the general mean was (7.72 cm). Ten clones *viz*., FCRIDS18 (10.17 cm), FCRIDS7 (8.50 cm), FCRIDS20 (8.13 cm), FCRIDS4 (8.12 cm), FCRIDS13 (8.10 cm), FCRIDS10 (8.04 cm), FCRIDS12 (8.00 cm), FCRIDS8 (7.82 cm), FCRIDS3 (7.77 cm) and FCRIDS19 (7.74 cm) registered higher values than mean basal diameter.

Table 5: Clonal variations for basal diameter (cm) in *Dalbergia sissoo*

Clone details/Treatments	Basal diameter (cm)		
	24 MAP	28 MAP	32 MAP
FCRIDS1	4.18	5.78	7.13
FCRIDS2	3.87	5.51	7.71
FCRIDS3	4.20	5.51	7.77
FCRIDS4	3.42	6.20	8.12
FCRIDS5	4.13	5.41	7.24
FCRIDS6	3.99	5.54	7.53
FCRIDS7	4.49	6.02	8.50
FCRIDS8	4.70	5.18	7.82
FCRIDS9	4.56	5.20	7.64
FCRIDS10	4.23	5.34	8.04
FCRIDS11	4.47	5.67*	6.91
FCRIDS12	4.05	5.05	8.00*
FCRIDS13	4.58	5.68*	8.10
FCRIDS14	5.01	5.80*	7.40
FCRIDS15	4.21	5.24	6.60
FCRIDS16	4.52	6.08	7.33
FCRIDS17	4.33	5.33	6.58
FCRIDS18	5.56	6.17	10.17
FCRIDS19	4.17	5.86*	7.74
FCRIDS20	4.56	5.18	8.13
Mean	4.36	5.59	7.72
SED	0.4123	0.0333	0.1188
CD (p= 0.05)	0.8347	0.674	0.2406

* Significant at 5 per cent level

Clear bole height

The observation on clear bole height among the 20 clones evaluated at different stages are presented in the Table 6. Among the 20 clones evaluated, significant differences were observed for bole height and their values varied from 0.74 m (FCRIDS1) to 2.00 m (FCRIDS18). Eight clones *viz*., FCRIDS18 (2.00 m), FCRIDS13 (1.67 m), FCRIDS3 (1.62 m), FCRIDS7 (1.54 m), FCRIDS5 (1.33 m), FCRIDS14 (1.28 m), FCRIDS9 (1.25 m) and FCRIDS17 (1.19 m) recorded higher bole height than the general mean (1.18 m). At 28 MAP, the bole height of tree ranged from 1.00 m (FCRIDS

15) to 2.41m (FCRIDS18). The general mean for bole height is 1.59 m. At this stage, the following clones FCRIDS18 (2.41 m), FCRIDS7 (2.10 m), FCRIDS3 (2.02 m), FCRIDS13 (1.95 m), FCRIDS9 (1.72 m), FCRIDS5 (1.71 m), FCRIDS14 (1.65 m), FCRIDS6 (1.62 m) and FCRIDS17 (1.60 m) recorded higher bole height than grand mean. However, progressive increase in bole height was observed in all the clones. At 32 months, the bole height ranged from 1.17 m (FCRIDS15) to 3.00 m (FCRIDS18). Compared to the average bole height of 1.87 m, the clones *viz*., FCRIDS18 (3.00 m), FCRIDS7 (2.30 m), FCRIDS13 (2.11m), FCRIDS20 (2.08 m), FCRIDS9 (2.07 m), FCRIDS3 (2.05 m), FCRIDS16 (1.99 m), FCRIDS8 (1.97 m), FCRIDS14 (1.90 m), FCRIDS5 (1.89 m) and FCRIDS2 (1.88 m) registered higher bole height (Table 6).

Table 6: Clonal variations for clear bole height (m) in *Dalbergia sissoo*

Clone details/Treatments	Clear bole height (m)		
	24 MAP	28 MAP	32 MAP
FCRIDS1	0.74	1.03	1.20
FCRIDS2	0.99	1.45	1.88
FCRDS3	1.62	2.02	2.05
FCRIDS4	1.12	1.54	1.71
FCRIDS5	1.33	1.71	1.89
FCRIDS6	1.05	1.62*	1.82
FCRIDS7	1.54	2.10	2.30
FCRIDS8	1.01	1.42	1.97
FCRIDS9	1.25*	1.72	2.07*
FCRIDS10	0.98	1.39	1.61
FCRIDS11	0.86	1.17	1.37
FCRIDS12	1.13	1.54	1.81
FCRIDS13	1.67	1.95	2.11*
FCRIDS14	1.28	1.65	1.90
FCRIDS15	0.76	1.00	1.17
FCRIDS16	1.05	1.52	1.99
FCRIDS17	1.19	1.60	1.85
FCRIDS18	2.00	2.41	3.00
FCRIDS19	1.02	1.45	1.70
FCRIDS20	1.09	1.52	2.08*
Mean	1.18	1.59	1.87
SEd	0.0325	0.2019	0.1041
CD (p= 0.05)	0.0658	0.0443	0.2018

* Significant at 5 per cent level

Crown height

The observation on crown height among the 20 clones evaluated at different intervals are presented in the Table 7. At 24 MAP, the clone FCRIDS11 registered the maximum value of 5.69 m, whereas the clone FCRIDS20 exhibited the minimum value (3.56 m) of crown height. The clones *viz*., FCRIDS11 (5.69 m), FCRIDS18 (5.44 m), FCRIDS16 (5.29 m), FCRIDS13 (5.26 m), FCRIDS1 (5.18 m), FCRID7 (5.06 m), FCRIDS19 (5.00 m), FCRIDS3 (4.99 m), FCRIDS15 (4.95 m), FCRIDS4 (4.78 m), FCRIDS9 (4.74 m), FCRIDS14 (4.71 m) and FCRIDS17 (4.71 m) recorded higher values in respect of crown height over grand mean of (4.67 m). At 28 MAP, the maximum crown height was exhibited by FCRIDS1 (6.19 m) and the minimum in FCRIDS12 (4.02 m). *Dalbergia sissoo* clones *viz*,. FCRIDS1 (6.19 m), FCRIDS11 (6.17 m), FCRIDS18 (5.79 m), FCRIDS13 (5.76 m), FCRIDS7 (5.69 m), FCRIDS16 (5.61 m), FCRIDS3 (5.38 m), FCRIDS4 (5.33 m), FCRIDS19 (5.31 m), FCRIDS15 (5.26 m) FCRIDS17 (5.18 m) and FCRIDS2 (5.16 m) performed well, among the selected clones taken for investigation compared to grand mean (5.13 m). At 32 MAP, the maximum crown height was observed in FCRIDS1 (7.20 m) and the minimum in FCRIDS20 (4.40 m). Compared to grand mean of 5.72 m, eleven clones *viz*., FCRIDS1(7.20 m), FCRIDS11 (7.10 m), FCRIDS7 (6.40 m), FCRIDS16 (6.03 m), FCRIDS15 (6.01 m), FCRIDS2 (6.00 m), FCRIDS13 (6.00 m), FCRIDS17 (5.99 m), FCRIDS4 (5.82 m), FCRIDS14 (5.80 m), and FCRIDS6 (5.75 m) performed well.

Table 7: Clonal variations for crown height (m) in *Dalbergia sissoo*

Clone details/ Treatments	Crown height (m)		
	24 MAP	28 MAP	32 MAP
FCRIDS1	5.18	6.19	7.20
FCRIDS2	4.50	5.16	6.00
FCRDS3	4.99	5.38	5.61
FCRIDS4	4.78*	5.33	5.82
FCRIDS5	3.80	4.13	4.50
FCRIDS6	4.20	4.81	5.75
FCRIDS7	5.06	5.69	6.40
FCRIDS8	4.08	4.49	5.18
FCRIDS9	4.74*	5.07	5.60
FCRIDS10	3.78	4.15	4.80
FCRIDS11	5.69	6.17	7.10
FCRIDS12	3.68	4.02	4.50
FCRIDS13	5.26	5.76	6.00
FCRIDS14	4.71	5.13	5.80
FCRIDS15	4.95	5.26	6.01*
FCRIDS16	5.29	5.61	6.03*
FCRIDS17	4.71	5.18*	5.99
FCRIDS18	5.44	5.79	6.00
FCRIDS19	5.00	5.31	5.70
FCRIDS20	3.56	3.99	4.40
Mean	4.67	5.13	5.72
SEd	0.0326	0.0273	0.1443
CD (p= 0.05)	0.0661	0.0552	0.2902

* Significant at 5 per cent level

Volume

The observation on volume arrived at different intervals among the 20 clones evaluated are presented in the Table 8. *Dalbergia sissoo* clones differed significantly in volume over the three growth periods. At 24 MAP, the maximum and minimum value ranged from 0.0156 m^3 (FCRIDS18) to 0.0043 m^3 (FCRIDS1). Six clones *viz*., FCRIDS18 (0.0156 m^3), FCRIDS19 (0.0104 m^3), FCRIDS7 (0.0100 m^3), FCRIDS11 (0.0078 m^3), FCRIDS16 (0.0079 m^3) and FCRIDS3 (0.0077 m^3) registered significantly higher volume than the general mean (0.0069 m^3). In case of 28 MAP, the clone FCRIDS18 recorded higher volume (0.0262 m^3) followed by FCRIDS 19 (0.01833 m^3), FCRIDS7 (0.01594 m^3), FCRIDS11 (0.01536 m^3), FCRIDS17 (0.01444 m^3), FCRIDS12 (0.01438 m^3), FCRIDS3 (0.01406 m^3), FCRIDS13 (0.01358 m^3) and FCRIDS16 (0.01305 m^3) and were registered significantly higher value than general mean (0.0127 m^3). At 32 MAP, FCRIDS18 recorded highest volume (0.0342 m^3) followed by FCRIDS7 (0.0240 m^3), FCRIDS13 (0.0223 m^3), FCRIDS19 (0.0205 m^3), FCRIDS3 (0.0201 m^3), FCRIDS12 (0.0199 m^3) and FCRIDS11 (0.0188 m^3) which were higher than general mean (0.0175 m^3). Considering volume at three growth periods, the clone FCRIDS18 consistently exhibited superior over other clones in clonal evaluation trial.

Table 8: Clonal variations for volume (m^3) in *Dalbergia sissoo*

Clone details/ Treatments	Volume (m^3)		
	24 MAP	28 MAP	32 MAP
FCRIDS1	0.0043	0.0077	0.0115
FCRIDS2	0.0045	0.0108	0.0148
FCRIDS3	0.0077	0.0140	0.0201
FCRIDS4	0.0062	0.0120	0.0146
FCRIDS5	0.0052	0.0103	0.0153
FCRIDS6	0.0050	0.0102	0.0148
FCRIDS7	0.0100	0.0159	0.0240
FCRIDS8	0.0044	0.0103	0.0144
FCRIDS9	0.0047	0.0090	0.0137
FCRIDS10	0.0069	0.0097	0.0160
FCRIDS11	0.0078	0.0153	0.0188
FCRIDS12	0.0066	0.0143	0.0199
FCRIDS13	0.0065	0.0135	0.0223*
FCRIDS14	0.0056	0.0089	0.0137
FCRIDS15	0.0064	0.0103*	0.0150
FCRIDS16	0.0079	0.0130*	0.0185
FCRIDS17	0.0067	0.0144	0.0164
FCRIDS18	0.0156	0.0262	0.0342
FCRIDS19	0.0104	0.0183	0.0205
FCRIDS20	0.0058	0.01056	0.0120
Mean	0.0069	0.0127	0.0175
SEd	0.0002	0.0002	0.0026
CD (p=0.05)	0.0004	0.0005	0.0053

* Significant at 5 per cent level

Discussion

In genetic improvement programme of trees, the selection of superior genotype is very important as it forms the very basis for any tree improvement. The success of any tree improvement programme depends on the amount of genetic variability in a tree species and it has got significant importance for developing effective tree improvement strategies (Vakshasya *et al.,* 1992) [27]. The largest, cheapest and fastest gains in most forestry tree improvement programme will accrue if use of suitable species and seed sources or clonal evolution within species is assured (Zobel and Talbert, 1984) [30]. Against this backdrop the current study has been designed to examine and evaluate the clones of *Dalbergia sissoo* in order to identify the superior clones for higher productivity for its utility.

The clonal evaluation trial conducted in the field showed significant differences among 20 clones of *Dalbergia sissoo* for the growth characteristics *viz.*, tree height, diameter at breast height (DBH), basal diameter, number of branches, clear bole height, crown height and volume at three growth stages

(24, 28, and 32 MAP). Significant variation was found observed in relation to all growth attributes studied *viz.*, tree height, diameter at breast height (DBH), basal diameter, number of branches, clear bole height, crown height and volume among 20 clones. Considering all the 20 clones, FCRIDS18 showed consistently superior performance in all the three different stages investigated. Current study was supported by plethora of workers who also reported the existence of significant differences and superiority of few seed sources, progenies and provenances in various tree like *Santalum album* (Krishnakumar *et al.*, 2018) [9], *Bambusa balcooa* and *Bambusa vulgaris* (Krishnakumar *et al.*, 2017) [10, 11], *Azadirachta indica* (Syed *et al.*, 2013) [24] *Populus deltoides* (Jha, 2012) [8], *Pongamia pinnata* (Divakara and Ramesh Das, 2011) [2], *Gmelina arborea* (Kumar, 2005) [13] *Eucalyptus tereticornis* (Ginwal *et al.*, 2004) [7], *Tamarindus indica* (Divakara, 2002) [3], *Ceiba pentandra* (Rajendran, 2001) [18], *Casuarina equisetifolia* and *Casuarina junghuhniana* (Kumar, 2001) [12], Teak (Parthiban, 2001), *Populus deltoides* (Singh *et al.*, 2001) [20] and *Dalbergia sissoo* (Tewari *et al*., 1996) [26]. Genetic selection of rapid juvenile growth rate was also advocated as a means of improving competitive ability of forest trees (Gall and Taft, 1973**;** Steiner, 1986) [5, 23] which extend the scope of selection of a clones in current study based on superiority during the period under evaluation.

Conclusion

Investigation was carried out on twenty clones of shisham (*Dalbergia sissoo*) assembled in clonal trial at Forest College and Research Institute, Mettupalayam to study variability using biometric attributes. Among the twenty clones evaluated in the field condition, the clone FCRIDS18 proved to be consistently superior for all the biometric traits investigated and this clone can be exploited for future tree improvement programme.

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