CLONAL VARIATION IN GROWTH, FLOWERING AND SEED PRODUCTION OF *DALBERGIA SISSOO* IN A CLONAL SEED ORCHARD

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NAUTIYAL, S., PAL, M., SAGTA, H. C., RAWAT, R. S. & NEGI, D. S. 2003. Clonal variation in growth, flowering and seed production of *Dalbergia sissoo* in a clonal seed orchard. Thirty-eight clones of *Dalbergia sissoo* (Leguminoceae) were, over a period of four years, evaluated for their flowering and growth behaviour at the Forest Research Institute, Dehra Dun, India. Data on plant height, collar diameter, flowering and seedpod production were collected annually. All the plant characters exhibited highly significant variations ($p<0.01$) among clones, years of observation and their interaction effects. From the average growth of clones in four years of measurement, clone C018 (Khanpur, Shahmansoorpur, Uttar Pradesh) attained the maximum height, followed by clone C045 (Trilokpur, Gonda, U.P.). The average collar diameter in all the four years was largest for clone C045, followed by clone C097 (Lakhawali, Hanumangarh, Rajasthan). Initially relatively slow growth was observed in clones C129 (Ghaire, Domukha, Jhapa, Nepal) and C124 (Chakarghati, Mahandra Nagar, Nepal) in the first two years. This increased rapidly in subsequent years. Clones from Suratgarh, Hanumangarh, Rajasthan (C099 and C100) exhibited higher seed production; however, no seed setting was observed in clones C023 and C043 (from Bareilly and Gonda, U.P., respectively) till the last observation. Clones from more northern latitudes had higher seedpod production. Clear bole of mother tree, longitude and rainfall of the area from where clones were collected had a significant effect on the growth of clones.

Key words: Clonal seed orchard - seedpod - geographical variation - clonal variation - *Dalbergia sissoo*

NAUTIYAL, S., PAL, M., SAGTA, H. C., RAWAT, R. S. & NEGI, D. S. 2003. Variasi klon dalam pertumbuhan, pembungaan dan pengeluaran biji benih *Dalbergia sissoo* di kebun biji benih klon. Tiga puluh lapan klon *Dalbergia sissoo* (Leguminoceae) dinilai kelakuan pembungaan dan pertumbuhannya selama empat tahun di Forest Research Institute, Dehra Dun, India. Data tentang tinggi pokok, diameter kolar, pembungaan dan pengeluaran lenggai biji benih dikumpul setahun sekali. Kesemua ciri pokok mempamerkan variasi yang sangat bererti ($p< 0.01$) pada klon, tahun cerapan dan kesan interaksinya. Daripada purata pertumbuhan klon sepanjang empat tahun itu, klon C018 (Khanpur, Shahmansoorpur, Uttar Pradesh, U.P.) mencapai tinggi maksimum, diikuti dengan klon C045 (Trilokpur, Gonda, U.P.). Purata diameter kolar di sepanjang empat tahun adalah paling besar bagi klon C045, diikuti dengan klon C097 (Lakhawali, Hanumangarh, Rajasthan). Pertumbuhan perlahan secara relatif dicerap dalam klon C129 (Ghaire, Domukha, Jhapa, Nepal) dan C124 (Chakarghati, Mahandra Nagar, Nepal) pada dua tahun pertama. Pertumbuhan meningkat dengan pantas pada tahun-tahun berikutnya. Klon daripada Suratgarh, Hanumangarh,

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Rajasthan (C099 dan C100) mempamerkan pengeluaran biji benih yang lebih tinggi; bagaimanapun, tiada biji benih dicerap dalam klon C023 dan C043 (masing-masing dari Bareilly dan Gonda, U.P.) sehinggalah cerapan yang terakhir. Klon dari latitud yang lebih ke utara mempunyai pengeluaran lenggai biji benih lebih tinggi. Batang pokok induk yang lurus, longitud dan hujan di kawasan klon diambil mempunyai pengaruh bererti terhadap pertumbuhan klon.

Introduction

Dalbergia sissoo Roxb. (shisham) is one of the best timber species of India. It has been planted in tropical countries, especially in arid and semi-arid regions, for timber, fuelwood, fodder, shade and stabilization of eroding landscape. Being a moderately fast-growing multipurpose tree species, it has been widely used in forestry and tree planting programmes throughout India. Poor stem form with a generally crooked and forked bole is the major drawback of this species.

It is possible to improve this species, however, by clonal selection and multiplication. If tree clones are grown in several environments, the observed variation in the phenotype of a particular character will be entirely due to the effect of environment (Banagarwa 1996). Also there is genetic variation in some physiological traits (Blum 1988). Stem straightness in *D. sissoo* is strongly under genetic control. Bangarwa (1993), Vidakovic and Siddiqui (1968), and Rehman and Hussain (1986) studied heritability for stem straightness. Vakshasya and Rawat (1986) reported flowering initiation at the age of nine months in *D. sissoo* and 90% pollen fertility was observed by Haques *et al.* (1982). Some studies have assumed that *D. sissoo* is a predominantly/strictly self-pollinated species (Vakshasya & Rawat 1986, Bangarwa & Singh 1994). However, the clone preserves the superiority of its characters once obtained (Chaudhari 1971, Hartmann & Kestor 1976). There is a little information available on clonal evaluation trials for selecting site-specific clones for large-scale plantations.

Tree improvement work on *D. sissoo* has been undertaken by ICFRE (Indian Council of Forestry Research and Education), involving selection of plus trees/superior clones, clonal multiplication, evaluation and establishment of clonal seed orchards. A large number of clones have been selected and assembled in a clonal bank. A part of this activity was the establishment of a clonal evaluation trial/clonal seed orchard at the Forest Research Institute, Dehra Dun, in 1993 to assess relative performance of different clones. The results based on the data collected so far are presented in this paper.

Table 1 Geographical location, rainfall and morphology of the mother trees of the clones (CPTs)

S. No.	Clone No.	Range	Division	State	Geographical location and rainfall				Morphology of the mother tree			
					Latitude	Longitude	Altitude (m)	Rainfall (cm)	Height (m)	GBH (cm)	Age (year)	Clear bole (m)
1	C004	Sabalgarh	Chiryapur	Uttar Pradesh (U.P.)	29°36'N	78°30'E	460	1166	19.0	175	60	8
2	C018	Khanpur	Shahmansoorpur	U.P.	29°41'N	78°1'E	274	1164	30.0	195	59	12
3	C019	Khanpur	Shahmansoorpur	U.P.	"	"	"	"	34.0	178	-	15
4	C020	Khanpur	Shahmansoorpur	U.P.	"	"	"	"	20.0	168	-	12
5	C021	Khanpur	Shahmansoorpur	U.P.	"	"	"	"	33.5	195	58	14
6	C022	C.B.Gunj	Bareilly	U.P.	28°13'N	79°14'E	173	1068	34.5	196	58	15
7	C023	C.B.Gunj	Bareilly	U.P.	"	"	"	"	34.0	143	58	20
8	C034	Bhainsasur	Tulsipur, Gonda	U.P.	26°22'N	82°2'E	115	1280	35.0	274	21	12
9	C036	Hasanapur	Tulsipur, Gonda	U.P.	"	"	"	"	25.0	128	21	10
10	C041	Hasanapur	Tulsipur, Gonda	U.P.	"	"	"	"	28.0	109	21	12
11	C043	Trilokpur	Tulsipur, Gonda	U.P.	27°6'N	81°54'E	110	1294	25.0	122	21	12
12	C045	Trilokpur	Tulsipur, Gonda	U.P.	"	"	"	"	25.0	99	21	12
13	C078	12A, Kola	Hanumangarh	Rajasthan	29°20'N	74°12'E	177	296	22.0	127	-	9
14	C079	12A, Kola	Hanumangarh	Rajasthan	"	"	"	"	23.0	116	-	9
15	C080	12A, Kola	Hanumangarh	Rajasthan	"	"	"	"	25.0	114	-	12
16	C082	12A, Kola	Hanumangarh	Rajasthan	"	"	"	"	25.0	108	-	7.2
17	C083	12A, Kola	Hanumangarh	Rajasthan	"	"	"	"	27.0	128	-	9
18	C085	12A, Kola	Hanumangarh	Rajasthan	"	"	"	"	22.0	101	-	6
19	C086	Naurand, Shergarh	Hanumangarh	Rajasthan	29°21'N	74°13'E	177	296	26.0	157	-	9
20	C087	Naurand, Shergarh	Hanumangarh	Rajasthan	"	"	"	"	20.0	108	-	6

continued

Table 1 (continued)

21	C090	Lakhawali	Hanumangarh	Rajasthan	"	"	"	"	25.0	91	-	9
22	C091	Lakhawali	Hanumangarh	Rajasthan	"	"	"	"	23.0	103	-	9
23	C092	Lakhawali	Hanumangarh	Rajasthan	"	"	"	"	30.0	180		9
24	C093	Lakhawali	Hanumangarh	Rajasthan	"	"	"	"	25.0	100	-	7.5
25	C094	Lakhawali	Hanumangarh	Rajasthan	"	"	"	"	22.0	150	-	4.5
26	C095	Lakhawali	Hanumangarh	Rajasthan	"	"	"	"	25.0	95	-	9
27	C097	Lakhawali	Hanumangarh	Rajasthan	"	"	"	"	32.0	122	-	9
28	C099	Lakhawali	Hanumangarh	Rajasthan	"	"	"	"	40.0	135	-	12
29	C100	Suratgarh	Hanumangarh	Rajasthan	"	"	"	"	24.0	145	-	6.6
30	C101	Suratgarh	Hanumangarh	Rajasthan	"	"	"	"	22.0	125	-	9
31	C102	Suratgarh	Hanumangarh	Rajasthan	"	"	"	"	22.0	155	-	6
32	C103	Suratgarh	Hanumangarh	Rajasthan	"	"	"	"	25.0	118	-	9
33	C104	Suratgarh	Hanumangarh	Rajasthan	"	"	"	"	25.0	120	-	6
34	C105	Suratgarh	Hanumangarh	Rajasthan	"	"	"	"	26.0	132	-	6
35	C108	Birdwal	Hanumangarh	Rajasthan	"	"	"	"	31.0	132	-	6.6
36	C109	Birdwal	Hanumangarh	Rajasthan	"	"	"	"	26.0	136	-	4.5
37	C124	Chakarghati	Mahandra Nagar	Hetawda (Nepal)	26° 25'N	87° 31'E	121	2491	24.0	118	-	9.2
38	C129	Ghaire, Domukha	Jhapa	Hetawda (Nepal)	"	"	"	"	32.0	115	22	13.4

Materials and methods

The trial included a selection of 38 clones of *Dalbergia sissoo* after identification of phenotypically superior trees from its natural distribution range in Uttar Pradesh and Rajasthan States, India, and some parts of Nepal by a team of scientists from the Forest Research Institute (F.R.I.), Dehra Dun. Morphological characters of the mother trees, viz. tree height, girth at breast height (GBH), age, and length of clear bole, were noted together with site details of the plus trees. These details are presented in Table 1.

Mature branch cuttings collected from candidate plus trees (CPTs) were rooted in a mist chamber in July 1993. Six-month-old ramets were planted at 5 × 3 m spacing following randomized single tree plot design with 10 replications of each clone at New Forest, F.R.I., Dehra Dun. Height, collar diameter, flowering and seed production were recorded annually for four years, from 1995 to 1998. The data were subjected to analysis of variance and Pearson simple correlation coefficient for the growth characters, geographical location, rainfall and form of mother tree. Critical difference was calculated by Scheffe's formula, which is based on F-statistics.

Results and discussion

Data pertaining to growth and pod weight are presented in Table 2. The survival percentage was almost 100% in all 38 clones. Significant differences exist within the clones and years at $p<0.01$ level. However, variation among years also revealed significant differences among each other at $p<0.05$ level (Table 2). Clones C018, C045, C034, C041 and C004 showed significant variations ($p<0.05$) among themselves and all the others in height. In all the four years of measurement, maximum height was noted for clone number C018, followed by C045 and C034. These results are supported by Kamaluddin and Ali (1995), who suggest that *D. sissoo* clones with better height and strong apical dominance are good for field plantation. Clones C108 and C105 were the shortest.

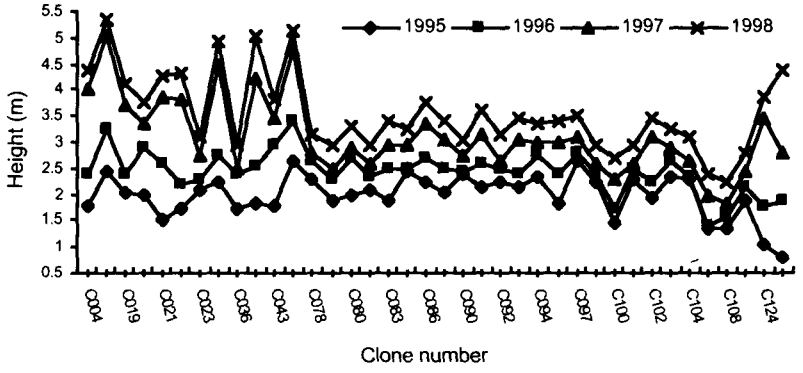

Figure 1 Height variation of clones in different years

Table 2 Height, collar diameter and pod weight of the clones recorded in different years and their standard errors (given in parentheses)

S. No.	Clone No.	Height (m)					Collar diameter (mm)					Pod weight (g)				
		1995	1996	1997	1998	Mean	1995	1996	1997	1998	Mean	1995	1996	1997	1998	Mean
1.	C004	1.80 (±0.06)	2.40 (±0.04)	4.02 (±0.22)	4.40 (±0.21)	3.16 d	21.74 (±0.82)	30.41 (±1.95)	43.98 (±4.26)	57.47 (±3.49)	38.40 a	00.00	5.00 (±0.71)	00.00	00.00	1.25 a
2.	C018	2.46 (±0.12)	3.25 (±0.13)	5.06 (±0.05)	5.34 (±0.05)	4.03 h	12.81 (±0.82)	17.14 (±0.95)	23.30 (±1.30)	79.26 (±1.02)	33.13 a	00.00	00.00	48.35 (±0.88)	75.03 (±0.60)	30.85 f
3.	C019	2.01 (±0.13)	2.41 (±0.14)	3.70 (±0.16)	4.11 (±0.14)	3.06 c	17.80 (±1.29)	23.92 (±1.76)	52.73 (±3.84)	67.65 (±3.24)	40.53 a	00.00	52.00 (±0.55)	30.00 (±0.71)	50.00 (±0.71)	33.00 g
4.	C020	1.98 (±0.08)	2.88 (±0.15)	3.35 (±0.26)	3.74 (±0.24)	2.99 c	28.96 (±1.95)	36.53 (±3.71)	74.10 (±3.84)	86.72 (±2.87)	56.58 g	00.00	175.00 (±3.36)	00.00	190.29 (±3.27)	91.32 s
5.	C021	1.52 (±0.09)	2.61 (±0.11)	3.85 (±0.14)	4.26 (±0.15)	3.06 c	27.03 (±1.69)	57.87 (±1.77)	63.16 (±1.58)	75.83 (±1.64)	55.97 f	00.00	10.50 (±0.31)	35.00 (±1.14)	95.03 (±0.18)	35.13 g
6.	C022	1.75 (±0.02)	2.17 (±0.03)	3.80 (±0.04)	4.32 (±0.04)	3.01 c	22.27 (±0.09)	29.54 (±1.14)	39.85 (±1.24)	54.81 (±0.56)	36.62 a	00.00	00.00	15.35 (±00.38)	57.12 (±0.55)	18.12 e
7.	C023	2.08 (±0.02)	2.30 (±0.02)	2.73 (±0.08)	3.10 (±0.04)	2.55 a	21.58 (±1.25)	24.47 (±1.93)	65.33 (±3.15)	84.13 (±3.04)	48.88 d	00.00	00.00	00.00	00.00	00.00
8.	C034	2.25 (±0.02)	2.75 (±0.03)	4.50 (±0.29)	4.92 (±0.14)	3.61 f	18.00 (±1.54)	22.92 (±2.08)	45.54 (±2.62)	62.52 (±2.95)	37.25 a	00.00	00.00	37.78 (±0.59)	00.00	9.45 d
9.	C036	1.70 (±0.06)	2.40 (±0.09)	2.50 (±0.07)	2.95 (±0.09)	2.39 a	24.57 (±0.44)	31.18 (±0.61)	60.74 (±1.27)	76.70 (±2.07)	48.30 c	00.00	00.00	30.00 (±0.71)	00.00	7.50 b
10.	C041	1.85 (±0.10)	2.53 (±0.13)	4.22 (±0.15)	5.05 (±0.17)	3.41 e	24.13 (±1.89)	38.33 (±1.67)	59.07 (±3.86)	74.98 (±3.02)	49.13 d	00.00	00.00	56.00 (±0.57)	78.12 (±0.94)	33.53 g
11.	C043	1.80 (±0.08)	2.97 (±0.14)	3.45 (±0.14)	3.83 (±0.15)	3.01 c	25.03 (±1.53)	37.83 (±2.93)	73.97 (±3.82)	89.02 (±4.41)	56.46 g	00.00	00.00	00.00	00.00	0.00
12.	C045	2.62 (±0.05)	3.42 (±0.01)	4.80 (±0.03)	5.15 (±0.03)	4.00 g	29.94 (±2.35)	48.87 (±0.44)	90.05 (±0.23)	101.7 (±0.73)	67.65 h	00.00	00.00	00.00	35.26 (±0.56)	8.82 c
13.	C078	2.30 (±0.12)	2.63 (±0.14)	2.78 (±0.30)	3.14 (±0.17)	2.71 a	19.18 (±1.31)	21.43 (±1.62)	42.40 (±4.39)	61.74 (±1.36)	36.19 a	00.00	80.35 (±1.02)	00.00	95.56 (±0.68)	43.98 m
14.	C079	1.86 (±0.08)	2.31 (±0.17)	2.50 (±0.25)	2.94 (±0.26)	2.40 b	17.27 (±1.28)	20.66 (±1.94)	38.00 (±2.98)	53.76 (±1.02)	32.42 a	25.00 (±1.14)	5.00 (±0.45)	00.00	00.00	7.50 b
15.	C080	2.00 (±0.11)	2.71 (±0.16)	2.90 (±0.18)	3.33 (±0.18)	2.74 a	21.26 (±0.82)	23.96 (±1.05)	49.77 (±3.61)	67.97 (±4.16)	40.74 a	0000	82.50 (±0.82)	40.00 (±0.72)	95.65 (±0.78)	55.79 o

continued

Table 2 (continued)

16.	C082	2.09 (±0.70)	2.36 (±0.06)	2.60 (±0.07)	2.94 (±0.08)	2.50 a	20.65 (±0.92)	23.47 (±1.22)	45.06 (±1.54)	59.51 (±0.64)	37.17 a	20.00 (±0.95)	110.00 (±1.65)	70.85 (±1.26)	00.00	50.21 n
17.	C083	1.90 (±0.07)	2.47 (±0.08)	2.95 (±0.16)	3.41 (±0.16)	2.69 a	18.31 (±0.86)	23.56 (±0.82)	49.98 (±2.73)	61.04 (±0.40)	38.22 a	00.00	15.15 (±0.80)	00.00	00.00	4.79 a
18.	C085	2.44 (±0.07)	2.47 (±0.12)	2.95 (±0.21)	3.28 (±0.21)	2.79 b	22.71 (±1.25)	23.56 (±1.53)	49.98 (±5.41)	60.49 (±0.54)	39.18 a	25.00 (±1.58)	20.25 (±0.33)	49.25 (±0.68)	72.18 (±1.41)	41.67 l
19.	C086	2.23 (±0.19)	2.68 (±0.20)	3.34 (±0.16)	3.75 (±0.16)	3.00 c	20.27 (±1.80)	25.65 (±2.03)	51.67 (±5.45)	55.97 (±3.67)	38.39 a	00.00	60.20 (±2.64)	40.25 (±0.88)	70.00 (±1.37)	42.61 l
20.	C087	2.03 (±0.04)	2.51 (±0.06)	3.07 (±0.34)	3.41 (±0.32)	2.76 a	18.78 (±0.74)	22.76 (±1.35)	47.33 (±2.17)	61.88 (±2.45)	37.69 a	40.65 (±0.88)	200.00 (±1.92)	00.00	21.00 (±1.30)	65.41 r
21.	C090	2.37 (±0.15)	2.42 (±0.18)	2.72 (±0.37)	3.06 (±0.28)	2.64 a	22.19 (±2.29)	24.21 (±2.25)	56.35 (±8.11)	70.80 (±7.11)	43.39 a	38.15 (±0.77)	65.15 (±0.85)	20.00 (±0.84)	36.00 (±0.71)	39.83 k
22.	C091	2.15 (±0.10)	2.61 (±0.09)	3.17 (±0.26)	3.62 (±0.24)	2.89 c	20.38 (±1.33)	27.44 (±1.02)	58.82 (±3.42)	70.48 (±1.77)	44.28 a	5.00 (±0.84)	50.35 (±1.39)	40.72 (±0.81)	57.21 (±0.73)	38.32 j
23.	C092	2.26 (±0.14)	2.51 (±0.17)	2.66 (±0.26)	3.15 (±0.25)	2.65 a	21.46 (±2.20)	24.08 (±2.13)	47.29 (±4.14)	60.38 (±0.63)	38.30 a	00.00	55.30 (±0.97)	25.35 (±0.58)	62.89 (±0.63)	35.89 h
24.	C093	2.15 (±0.09)	2.40 (±0.10)	3.06 (±0.30)	3.45 (±0.31)	2.77 a	22.07 (±1.05)	24.10 (±1.78)	57.77 (±5.79)	74.34 (±5.53)	44.57 a	00.00	30.10 (±1.04)	00.00	00.00	7.53 b
25.	C094	2.33 (±0.06)	2.75 (±0.14)	3.00 (±0.32)	3.34 (±0.32)	2.86 b	24.34 (±0.94)	29.44 (±1.40)	60.26 (±5.52)	78.81 (±3.92)	48.21 c	00.00	105.00 (±0.74)	69.32 (±0.69)	69.32 (±0.59)	60.91 q
26.	C095	1.82 (±0.13)	2.37 (±0.14)	3.01 (±0.28)	3.43 (±0.28)	2.66 a	18.46 (±1.41)	22.54 (±2.02)	49.97 (±6.17)	65.56 (±6.00)	39.13 a	00.00	00.00	40.28 (±1.34)	20.25 (±1.18)	15.13 e
27.	C097	2.62 (±0.09)	2.78 (±0.02)	3.11 (±0.06)	3.50 (±0.07)	3.00 c	25.58 (±1.09)	41.47 (±3.40)	74.78 (±6.22)	92.30 (±4.26)	58.53 g	25.15 (±0.98)	95.25 (±1.23)	00.00	72.00 (±1.30)	48.10 m
28.	C099	2.25 (±0.06)	2.41 (±0.06)	2.61 (±0.05)	2.96 (±0.05)	2.56 a	23.03 (±0.88)	29.40 (±1.30)	55.31 (±5.68)	71.24 (±3.50)	44.75 a	30.45 (±1.04)	225.45 (±1.58)	14.00 (±1.00)	280.00 (±0.05)	137.48 u
29.	C100	1.47 (±0.13)	1.75 (±0.09)	2.30 (±0.30)	2.69 (±0.30)	2.05 a	17.20 (±0.57)	20.59 (±1.15)	46.21 (±4.89)	61.75 (±4.45)	36.44 a	00.00	130.65 (±1.86)	120.00 (±1.13)	195.00 (±1.38)	111.41 t
30.	C101	2.30 (±0.10)	2.48 (±0.10)	2.60 (±0.27)	2.97 (±0.28)	2.59 a	22.71 (±1.44)	25.51 (±1.70)	47.89 (±4.85)	63.71 (±3.72)	39.96 a	00.00	75.00 (±1.81)	60.25 (±1.77)	92.67 (±2.32)	56.98 p
31.	C102	1.95 (±0.11)	2.26 (±0.12)	3.08 (±0.12)	3.44 (±0.13)	2.68 a	20.27 (±1.17)	24.48 (±1.66)	55.13 (±4.49)	63.18 (±3.57)	40.77 a	00.00	130.15 (±1.38)	50.00 (±0.71)	77.56 (±1.67)	64.43 r
32.	C103	2.33 (±0.09)	2.63 (±0.09)	2.90 (±0.12)	3.27 (±0.13)	2.78 a	20.63 (±1.24)	26.30 (±2.26)	55.48 (±2.66)	65.28 (±1.04)	41.92 a	25.65 (±1.57)	40.00 (±1.47)	00.00	40.00 (±1.70)	26.41 f

continued

Table 2 (continued)

33.	C104	2.27 (±0.15)	2.35 (±0.12)	2.63 (±0.14)	3.09 (±0.16)	2.59 a	24.29 (±1.38)	29.96 (±2.03)	54.53 (±6.24)	72.65 (±3.88)	45.36 a	15.65 (±0.77)	20.25 (±1.17)	00.00	42.89 (±1.66)	19.70 e
34.	C105	1.37 (±0.10)	1.40 (±0.06)	1.98 (±0.17)	2.38 (±0.18)	1.78 a	15.38 (±0.60)	16.76 (±0.74)	40.90 (±3.54)	54.41 (±1.89)	31.86 a	00.00	60.25 (±1.93)	25.26 (±1.74)	38.90 (±0.97)	31.10 f
35.	C108	1.38 (±0.15)	1.55 (±0.15)	1.83 (±0.17)	2.25 (±0.17)	1.75 a	19.39 (±1.15)	20.88 (±1.96)	37.56 (±4.83)	54.68 (±2.75)	33.13 a	10.15 (±1.03)	35.15 (±1.36)	00.00	30.26 (±1.40)	18.89 e
36.	C109	1.88 (±0.06)	2.12 (±0.10)	2.46 (±0.22)	2.82 (±0.23)	2.32 a	17.28 (±1.14)	21.17 (±0.75)	40.40 (±2.50)	54.67 (±2.91)	33.38 a	50.85 (±2.03)	25.20 (±1.06)	25.10 (±1.32)	50.00 (±1.02)	37.79 i
37.	C124	1.06 (±0.07)	1.76 (±0.09)	3.45 (±0.03)	3.85 (±0.03)	2.53 a	30.08 (±0.26)	34.93 (±0.72)	66.04 (±0.86)	70.46 (±0.05)	50.38 e	00.00	00.00	00.00	15.00 (±1.07)	3.75 a
38.	C129	0.80 (±0.01)	1.89 (±0.01)	2.82 (±0.02)	4.40 (±0.03)	2.48 c	14.91 (±0.24)	35.17 (±1.73)	54.67 (±0.07)	66.08 (±0.43)	42.71 b	00.00	00.00	00.00	10.26 (±0.65)	2.57 a
Mean of Year		1.99 a	2.44 b	3.12 c	3.55 d	2.77	21.37 a	27.96 b	53.30 c	68.53 d	42.79	8.44 a	51.56 c	24.82 b	55.93 d	35.19

Probability	Critical differences								
	Height			Collar diameter			Pod weight		
	Clone	Year	Clone* Year	Clone	Year	Clone*Year	Clone	Year	Clone *Year
CD 5%	2.98	0.37	9.65	10.21	1.28	33.05	3.55	0.44	11.55
CD 1%	3.19	0.45	Not significant	10.91	1.54	34.61	3.82	0.54	12.01

Interaction effect of year and clones revealed significant variation only at $p \leq 0.05$ level. As represented by Figure 1, the best height values were given in 1998 by clones C018 (5.34 m), C045 (5.15 m) and C041 (5.05 m). Growth variations in natural populations of *D. sissoo* were also observed by Vidakovic and Siddiqui (1968) and Vidakovic and Ahsan (1970).

Over the years the highest collar diameter (67.65 mm) was shown by clone C045, followed by clone C097 (58.53mm) (Table 2). These clones also showed maximum collar diameter (101.75 and 92.30 mm respectively) in 1998 (Figure 2). Collar diameter was highly significantly different for clones, years and their interaction effect at $p \leq 0.01$ level. Clones C124, C021 and C045 showed significant differences in collar diameter at $p < 0.05$ level among themselves and the other clones. The two clones of Hetaunda, Nepal, exhibited a sudden increase in growth in the third and fourth years. Despited such irregular growth, White (1990) reported that it is possible to detect vigour in *D. sissoo* at an early age (1–2 years) and assessment of stem form can be made within five years of planting. The slow-growing clones were C108, C100 and C082.

Maximum (100%) flowering was observed in clones C020, C082, C086, C087 and C100 in 1996, while clone number C085 showed maximum (88%) flowering in 1995; clones C018, C078, C092, C093, C095, C100, C101, C102 and C105 did not flower until 1995. Clone C091showed the lowest flowering (40%) in 1995 and clone C093 (50%) in 1996. However, clones C018 and C095 did not flower until 1997. It is clear from the observations that flowering behaviour and subsequently seed setting are aspects of a rhythmic phenomenon in this species. The flowering pattern keeps changing from year to year. Generally a clone will flower poorly in the following year after flowering well in one year. This will accordingly influence the seed production of the clone.

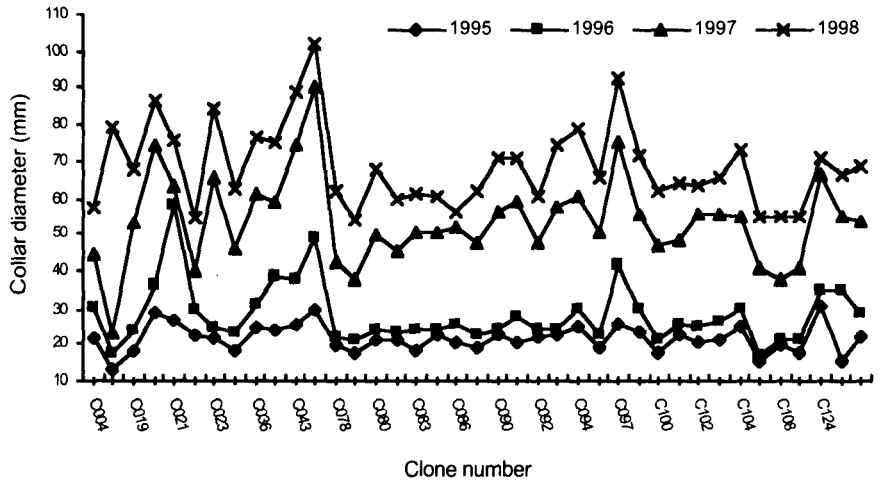

Figure 2 Variation in collar diameter of clones in different years

Seed production

The seed production of the 38 clones over the 4 years is shown in Figure 3 and Table 2. Flowering and seed set occurred in the first year in many clones. At one year after transplantation about one third of the clones flowered and set seeds; a similar finding was reported by Matziris (1997) in Aleppo pine. Highly significant ($p<0.01$) variation was observed among clones, years and their interaction effect for seed production. A lot of variation was observed for pod weight and 21 homogenous groups were made among the clones at $p<0.05$ level of significance. Pod weights among the years were significantly different ($p<0.05$) from each other. The highest average pod weights of 137.48 g and 111.41 g were exhibited by clones C099 and C100. However, no seed set was observed in clones C023 and C043 until 1998. The yearly seed production shows that in the first year (1995) seedpod weight was low, increasing in the next year (1996), decreasing again in 1997 and increasing in 1998. This reflects a sigmoid pattern of bad and good seed years. The highest seed production (280.00 g) per plant was given by clone C099 in 1998, followed by the same clone (225.85 g) in 1996. In the second year after transplanting most of the clones flowered and two-thirds of them set seeds.

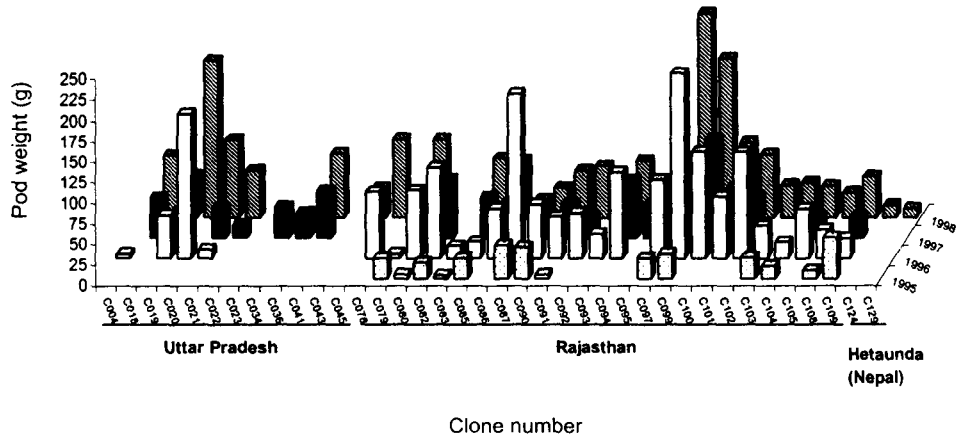

Figure 3 Pod weight of clones in different years

The best seed producer clones as represented by Rajasthan State could be an indication that clones from drier zones having stressed sites and poor tree forms set more seed due to water stress condition prevailing throughout the year, as it is well known that water stress induces more flowering. That could be a genetic phenomenon of the arid zone clones. On the other hand, the best growth was shown by the Gonda clones. Gonda is the best shisham growing area in the country, where trees are found to be good in growth, form, and timber quality. Thus the trees growing in Gonda areas are genetically more superior, having a high potential of expressing good tree growth and form.

The proposed clonal evaluation trial plot will be converted into a clonal seed orchard after removing the poor performing clones and will be the source of quality seed for growing large-scale plantations. The two or three high yielding clones, which have been selected here, will be recommended for large-scale plantations by growing them in a separate vegetative multiplication garden.

Correlation matrix

Pearson simple correlation was conducted among the growth characters and pod weight with the geographical location, rainfall and morphology of the mother tree (Table 3). Height exhibited positive significant correlation ($p \leq 0.05$) with collar diameter, GBH, clear bole, longitude and rainfall, while no positive or negative correlation was observed with other parameters. This shows that geographical parameters and morphology of the mother tree have a partial effect on plant height. A given geographical area can sometimes contain sites with vast differences. These tree morphological properties are not genetically fixed and only represent the effects of varied environments. Individual trees of a species often vary a great deal from one another even when growing in the same stand. This is the major type of genetic variation the tree breeder uses in a selection and breeding programme. Many individual tree differences in *D. sissoo* such as stem form and apical dominance are strongly under genetic control (Bangarwa 1993).

Table 3 Pearson's simple correlation coefficient among the plant characters and geographical parameters

Parameter	Height	Collar diameter	Pod weight
Height	1		
Collar diameter	0.410*	1	
Pod weight	-0.156	-0.042	1
Mother tree height	0.103	0.038	-0.006
Girth at breast height (GBH)	0.349*	-0.163	0.007
Tree age	0.013	-0.394*	0.246
Clear bole	0.395*	0.348*	-0.210
Latitude	-0.214	-0.364*	0.438**
Longitude	0.328*	0.417**	-0.453**
Altitude	0.157	-0.169	0.092
Rainfall	0.328*	0.387*	-0.414

* = significant at 5%, ** = significant at 1%.

Collar diameter showed negative significant correlation ($p \leq 0.05$) with mother tree age and latitude; positive significant correlation was observed with clear bole and rainfall at $p \leq 0.05$ level and with longitude at $p \leq 0.01$ level. Pod weight exhibited only two significant correlations, which were positive with latitude and negative with longitude, both significant at $p \leq 0.01$ level. This indicates that clones from latitudinally more northern sites and longitudinally less eastern sites have better seedpod production capacity.

Based on the 4-y data it is concluded that clone C045 of Trilokpur, Gonda (U.P.) and C018 of Khanpur, Shahmansoorpur (U.P.) show the best growth and form; however, the best seed producer clones were C099 and C087 from the dry zone (Rajasthan). These clones may be considered for a large-scale plantation and establishment of a F2 generation seed orchard.

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