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Effect of diameter and plant spacing on growth of *Acrocarpus fraxinifolius* under mid hill conditions of Himachal Pradesh

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ABSTRACT

The data were collected from randomly selected trees at three sites with plant spacing, viz. 1.5m ×1.5m, 1.0m × 3.5m and 3.0m × 3.0m (namely S-I, II and III, respectively) of *Acrocarpus fraxinifolius* (20 years old) in mid hill conditions of Himachal Pradesh. The effect of plant spacing and diameter class on growth characteristics, viz. diameter at breast height (dbh), tree height, bole height, form factor, basal area, stem volume and crown parameters was assessed. Stem volume was positively and highly correlated with all growth parameters and showed highest correlation (0.95) with dbh. The tree height, bole height, basal area, stem volume, crown height, crown width and crown area increased significantly with increase in diameter as well as with spacing. Study regarding fiber length and specific gravity also contributed to growth behaviour of pink cedar at different spacing, where, specific gravity of wood showed an erratic behaviour with slight variation from 0.66 to 0.88, while stem and branch fiber length increased (1.05 to 1.11mm and 0.78 to 0.95mm, respectively) with increasing plant spacing. The overall growth performance of the species was best at 3m × 3m spacing.

Key words : *Acrocarpus fraxinifolius*, Crown characteristics, dbh, Spacing, Stem volume

Acrocarpus fraxinifolius, a member of sub-family Caesalpinioideae of Fabaceae family, is a large deciduous, fast growing species (Nath *et al*. 2012), commonly known as Mundani, pink cedar and shingle tree, the only species of genus *Acrocarpus* in India, having its natural habitat in the evergreen forests of Western Ghats, chiefly on hill slopes up to 1220m (Troup 1921). This species is also distributed in some other tropical countries of Asia in the tropical evergreen and sub-evergreen forests. The literature reveals some attempts to explore seedling growth at different spacing and altitudes but studies on crown parameters, wood specific gravity and fiber length in relation to planting density are lacking. Such information is of vital concern as this species is widely used for packing cases, shingles, honey bee boxes, plywood manufacture (Shukla *et al.* 1993), particleboards (Trianoski *et al.* 2011) and construction purposes (Mandang and Artistien 2003). *A. fraxinifolius* have potential for timber production and shade tree under coffee (Nath *et al.* 2011) and cardamom plantations (Radhakrishnan *et al.* 2010) in Southern India. Pink cedar is suitable for social forestry (Ghildyal 1989) and agroforestry (Nath *et al*. 2011) so the studies on stem and crown behaviour in relation to spacing are of vital concern under agroforestry interventions where maximization of stem growth without impairing the agriculture production forms an important pre-requisite.

The interaction between the trees and crops or grasses for shade, nutrients, moisture, soil fertility and their compatibility are the basic issues in agroforestry (Solanki 1998). Information on tree crown characteristics has been used in forestry to assess tree and ecosystem health and productivity (Goodale *et al.* 2009) and the increment of trees depends, primarily, on the size of the assimilation apparatus of the crown and its efficiency to produce organic matter (Turski *et al.* 2008).

MATERIALS AND METHODS

Three plantations of *Acrocarpus fraxinifolius* were selected for the study (Table 1) in the mid hill zone of Himachal Pradesh between 30°50′30″ to 30°52′0″ N and 77°8′30″ to 77°11′30″ E. The data were collected for different growth parameters, i.e. diameter at breast height or dbh (cm) and tree height, crown height, crown width and crown length in metres during 2008-10 from randomly selected trees which were classified into 5cm diameter interval.

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Table 1 Details of study sites

Spacing	Slope	Density (Trees/ha)	Aspect	Altitude (m)
S-I (1.5m x 1.5m)	Moderate	4 444	North-eastern	About 1205m
S-II (1.0m x 3.5m)	Moderate to steep	2 857	Eastern	About 1230m
S-III (3.0m x 3.0m)	Moderate	1 111	Southern	About 1255m

Karl Pearson's coefficient of correlation was worked out for all the growth parameters including number of branches and stem volume for all the sites. Thereafter, Z-transformation was applied to get pooled estimates of correlation coefficient. Diameter class-wise observations were recorded for crown length, crown height and crown width in all sites. The calculations were done for crown per cent, crown fullness ratio, crown projection ratio and crown quotient to ground cover area by the following formulae:

$$\text{Crown per cent} = \frac{l}{h} \quad 100$$

$$\text{Crown fullness ratio} = \frac{w}{l}$$

$$\text{Crown projection ratio} = \frac{w}{dbh}$$

$$\text{and, Crown quotient to ground cover area} = \frac{w^2}{(dbh)^2}$$

where l, w, h and dbh represents crown length, crown width, tree height and diameter at breast height, respectively.

The fiber length of stem wood and branches was determined by macerating the shavings of wood in Jaffery's fluid (chromic acid and nitric acid @ 10%) for 48 hours (Pandeya *et al*. 1968). After staining with safranine, fiber length was measured with the help of ocular micrometer after standardizing with stage micrometer. The specific gravity was estimated for main stem wood using maximum moisture method (Smith 1954), by taking 5-8cm thick discs from different heights of stem. The fresh and dry weight (constant weight) of samples were used to find out the specific gravity of each sample by applying the formula;

$$\frac{1}{\frac{(M_m \quad M_0)}{M_0} + \frac{1}{GS_0}}$$

where, M_m is the fresh weight of sample at maximum moisture content, M_o is the oven dry (constant) weight of sample and GS_o is the average density of wood, a constant having value of 1.53.

RESULTS AND DISCUSSION

Stem and crown growth parameters

The results of correlation study after Z-transformation (Table 2) reveals that stem volume was positively and significantly correlated with all growth parameters in the descending order as with dbh (0.95) > tree height (0.84) > crown length (0.66) > crown height (0.60) > crown width (0.54) > crown area (0.53) > number of branches (0.44). The dbh was also showing positive and significant relationship with height (0.79). Similar trends were obtained for *Pinus roxburghii* (Sharma 1999), *Casuarina* species (Chavan *et al.* 2011) and *Dalbergia sissoo* (Rizvi *et al.* 2008). Ozdemir and Donoghue (2013) also found the positive correlations between tree height and dbh.

The data pertaining to the stem growth parameters is presented in Table 3. The dbh, tree height, bole height, basal area and stem volume/tree were showing increasing trend from 10.10cm to 25.54cm, 9.94m to 18.66m, 5.22m to 11.38m, 99.48cm^2 to 572.58cm^2 and 0.05m^3 to 0.43m^3, respectively, with increase in spacing, and with respect to

Table 2 Correlation between different growth parameters of pink cedar

	Volume	dbh	Tree height	Crown height	Crown width	Crown length	Crown area	No. of branches
Volume	1							
dbh	0.95**	1						
Tree height	0.84**	0.79**	1					
Crown height	0.60**	0.57**	0.68**	1				
Crown width	0.54**	0.60**	0.44**	0.38**	1			
Crown length	0.66**	0.62**	0.83**	0.12	0.28	1		
Crown area	0.53**	0.59**	0.41**	0.39**	0.94**	0.24	1	
No. of branches	0.44**	0.52**	0.41**	0.16	0.33**	0.41**	0.28	1

**Significant at 1% level of significance diameter classes. The similar trend was observed by Khan and Chaudhry (2007) in *Populus deltoides*. While, the form factor decreased from 0.42 to 0.38 with increased spacing and also with increased diameter in all spacings except S-I. Similar results were found by Gabhane *et al*. (1997) for *Eucalyptus tereticornis* and *Casuarina equisetifolia* and Mostafanezhad and Dastmalchi (2004) for redwood. Nogueira *et al*. (2008) also observed lower form factor with increasing tree size in Amazonian forest.

The effect of dbh and plant spacing on various crown characteristics, viz. crown height, crown length, crown width and crown area (Table 4) which increased with increasing dbh in all spacings. Average crown height, crown width and crown area increased (5.22m to 11.38m, 2.80m to 3.88m and 7.31m^2 to 15.07m^2, respectively) with increased spacing, in general, crown length was also better at higher plant spacing. *Acrocarpus fraxinifolius* is a moderately light demanding species (Luna 2005) so these findings support the findings of Hart (1991) that most light-demanding species require more space for proper crown development. Khan and Chaudhry (2007) also found significantly better crown development in lower density in *Populus deltoides.* Sobachkin and Sobachkin (2011) found crown height and crown length dependent on stand density in *Larix sibirica* plantations.

Crown per cent (Table 5) generally increased (from 29.73% to 48.52% and 48.51% to 58.42%, respectively) with increasing tree diameter in S-I and S-II, whereas in S-III it decreased (from 54.17% to 30.23%). Generally, crown fullness ratio increased, with increasing tree diameter except at lowest plant spacing. Crown projection ratio and crown quotient of ground cover area decreased with increasing dbh in S-I and S-II, while it showed an increasing trend with increasing dbh at S-III. Crown per cent showed an erratic behaviour with increasing plant spacing and maximum (52.80%) was found in S-II. While, Honghui and Guijie (2004) found decreased crown per cent with increased planting density of *Pinus massoniana.* Crown fullness ratio, crown projection ratio and crown quotient of ground cover area decreased (from 0.82 to 0.55, 31.94 to 14.60 and 1354.91 to 230.99, respectively) with increasing plant spacing. However, Walter and Maguire (2004) in Douglas-fir did not found any significant difference in crown fullness between silvicultural treatments (group-selection cuts, two-story regeneration harvests and clearcuts). Generally, larger ratios are indicative of healthier, faster growing trees and as the base of the live crown progresses toward the top of a tree, the crown per cent declines. Several studies have reported increasing crown efficiency with more dominant crown classes in some species (O'Hara 1988) and others have found the opposite pattern (Reid *et al*. 2004).

Wood quality parameters

An erratic behaviour was observed for specific gravity of stem wood (Table 6) in all the sites with increase in

Table 3 Diameter class-wise stem growth parameters of pink cedar at different spacing

Diameter Class (cm)	Diameter at breast height (cm)			Tree height (m)			Bole height (m)			Form factor			Basal area (cm^2)			Stem volume (m^3/tree)		
	S-I	S-II	S-III	S-I	S-II	S-III	S-I	S-II	S-III	S-I	S-II	S-III	S-I	S-II	S-III	S-I	S-II	S-III
0-5	3.93			5.34			3.66			0.42			12.21			0.01		
5-10	7.32	8.21		7.87	9.14		4.36	4.69		0.41	0.43		43.75	53.33		0.01	0.02	
10-15	12.51	12.17	13.70	11.98	11.30	12.00	5.37	5.30	5.50	0.41	0.39	0.44	124.23	117.40	147.34	0.06	0.05	0.08
15-20	16.65	17.18	17.83	14.58	14.22	16.33	7.50	6.78	9.42	0.42	0.39	0.38	217.72	232.76	251.28	0.13	0.13	0.16
20-25		20.80	22.81		19.00	18.57		7.90	10.97		0.37	0.38		339.62	410.12		0.24	0.29
25-30			26.60			20.83			13.00			0.37			557.34			0.43
30-35			32.68			22.75			14.38			0.35			838.37			0.67
35-40			39.60			21.50			15.00			0.35			1231.01			0.94
Mean	10.10	14.59	25.54	9.94	13.42	18.66	5.22	6.17	11.38	0.42	0.40	0.38	99.48	185.78	572.58	0.05	0.11	0.43
SE	2.80	2.77	3.90	2.06	2.13	1.63	0.84	0.73	1.45	0.01	0.01	0.02	45.93	63.31	164.81	0.03	0.05	0.13
CV (%)	55.45	37.97	34.40	40.79	31.74	21.40	32.03	23.52	31.27	1.19	5.00	10.53	92.34	68.15	70.51	111.36	87.14	75.99

Table 4 Diameter class-wise crown characteristics of *Acrocarpus fraxinifolius* under different spacing

Diameter	Crown height (m)			Crown length (m)			Crown width (m)			Crown area (m^2)		
class(cm)	S-I	S-II	S-III	S-I	S-II	S-III	S-I	S-II	S-III	S-I	S-II	S-III
0-5	3.66			1.68			1.70			2.78		
5-10	4.36	4.69		3.51	4.45		2.43	2.23		5.62	4.21	
10-15	5.37	5.30	5.50	6.62	6.00	6.50	3.35	3.02	1.52	9.32	7.48	1.81
15-20	7.50	6.78	9.42	7.08	7.77	6.91	3.72	4.15	2.38	11.52	12.21	4.85
20-25		7.90	10.97		11.10	7.60		4.25	3.03		14.18	8.83
25-30			13.00			7.83			4.24			14.78
30-35			14.38			8.38			4.85			19.09
35-40			15.00			6.50			7.23			41.03
Mean	5.22	6.17	11.38	4.72	7.33	7.29	2.80	3.41	3.88	7.31	9.52	15.07
SE	0.84	0.73	1.45	1.29	1.43	0.31	0.46	0.48	0.83	1.94	2.26	5.80
CV (%)	32.03	23.52	31.27	54.52	38.96	10.57	32.58	28.3	52.68	53.07	47.49	94.31

Table 5 Diameter class-wise crown ratios of *Acrocarpus fraxinifolius* under different spacing

Diameter class (cm)	Crown per cent			Crown fullness ratio			Crown projection ratio			Crown quotient of ground cover area		
	S-I	S-II	S-III	S-I	S-II	S-III	S-I	S-II	S-III	S-I	S-II	S-III
0-5	29.73			1.29			45.58			2823.88		
5-10	42.78	48.51		0.89	0.51		33.23	27.41		1292.96	815.51	
10-15	54.50	52.75	54.17	0.55	0.56	0.23	26.74	24.96	11.09	747.26	654.21	123.10
15-20	48.52	51.51	42.45	0.54	0.62	0.35	22.20	24.34	13.49	519.53	623.51	201.93
20-25		58.42	41.84		0.58	0.42		11.54	13.13		133.14	205.15
25-30			37.36			0.58			15.82			256.80
30-35			36.13			0.63			15.81			265.61
35-40			30.23			1.11			18.26			333.34
Mean	43.88	52.80	40.36	0.82	0.57	0.55	31.94	22.06	14.60	1354.91	470.29	230.99
SE	5.29	2.07	3.30	0.18	0.02	0.13	5.08	3.57	1.03	518.69	146.19	29.15
CV (%)	24.11	7.86	20.03	43.37	8.06	56.00	31.81	32.36	17.34	77.08	62.17	30.91

Table 6 Stem wood specific gravity and fiber length of pink cedar in different diameter classes and spacing

Diameter	Stem wood specific gravity			Stem fiber length (mm)			Branch fiber length (mm)		
class (cm)	S-I	S-II	S-III	S-I	S-II	S-III	S-I	S-II	S-III
0-5	0.67			1.01			0.81		
5-10	0.67	0.77		1.01	1.08		0.76	0.89	
10-15	0.79	0.71	0.88	1.04	1.04	1.13	0.71	0.89	0.91
15-20	0.80	0.75	0.87	1.12	1.05	1.10	0.83	0.94	0.96
20-25		0.68	0.79		1.09	1.03		0.95	0.97
25-30			0.66			1.11			0.96
30-35			0.79			1.11			0.95
35-40			0.73			1.16			0.97
Mean	0.73	0.73	0.79	1.05	1.07	1.11	0.78	0.92	0.95
SE	0.04	0.02	0.03	0.03	0.01	0.02	0.02	0.04	0.01
CV (%)	9.90	5.52	10.63	4.97	2.28	3.90	6.06	3.28	2.36

diameter. However, in general it decreased with increase in diameter except at lowest plant spacing (S-I). Specific gravity of wood was similar (0.73) for first two spacing; however, it increased (0.79) with increase in spacing. Some workers like Peszlen (1998) for poplar clones and Bhardwaj *et al*. (2001) for *Populus deltoides* did not found any significant effect of spacing on specific gravity. While, in poplar hybrids Pliura *et al.* (2007) found moderately significant effect of different sites on wood density.

The fiber length increased from 1.05mm to 1.11mm in stem and 0.78mm to 0.95mm in branches with increase in plant spacing. In general, the fiber length also showed an increasing trend with increase in diameter of the trees. Stem fibers were found to be longer than the branch fibers. These findings are in agreement with those of Sharma (1997) in *Robinia pseudoacacia*, where spacing had a significant effect on fiber length. Huang *et al.* (2000) found that wood density and fibre length of *Eucalyptus urophylla* were not much affected by stand density. However, Chauhan *et al*. (2001) found increase in fiber length in closer spacing in *Populus deltoides.* The overall growth performance of the species was best at 3m × 3m spacing.

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