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Growth, Productivity, and Genetic Variability of Some *Melia dubia* Cav. Open Pollinated Families in Gujarat, India

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Abstract: The growth, productivity, and genetic variability among 17 open pollinated *Melia dubia* families was estimated for 5 years in Gujarat, India. There was significant variation in tree height and DBH growth among families from 1^{st} till 5^{th} year of evaluation. In 4^{th} and 5^{th} year, GJ09 (local family from Northern most tip of Western Ghats, parts falling in Gujarat) achieved significantly maximum height (11.20 and 13.33 m, respectively) and DBH (15.26 and 18.00 cm, respectively) compared other families. Overall, at the age of 5 years, family GJ09, attained highest fresh biomass (30.35 tonne $ha^{-1} year^{-1}$) and volume productivity (29.63 $m^3 ha^{-1} year^{-1}$). The highest GCV, PCV and genetic gain was for tree volume and biomass. All the growth traits recorded maximum heritability values and varied from 60.20 to 74.73 per cent. Among all growth parameters, tree biomass resulted in higher broad sense heritability and genetic gain. There was a strong positive genetic and phenotypic correlation among studied growth traits in *M. dubia*. Values of r_g (0.835 to 0.939) and r_p (0.689 to 0.943) were within the permissible limit for tree height, DBH and volume. Tree biomass was strongly associated with height, diameter and volume.

Keywords: *Melia dubia*, Tree growth, Volume, biomass, Productivity, Genetic variability, Heritability, Genetic advance, Paper pulp

The total forest and tree cover of the country is 80.73 million hectare which is 24.56 percent of the geographical area of the country. Indian forests are having very poor productivity. Against the global average productivity of 2.1 m^3 $hectare^{-1}$ $year^{-1}$, the productivity of Indian Forest is only 0.5 to 0.7 m^3 $hectare^{-1}$ $year^{-1}$ (FSI 2017), while TOFs are producing nearly 3.06 cum per ha per year. Roundwood demand forecast by 2030 in pulp and paper, furniture, plywood and other wood-based industries and construction sector is 12.5, 13.34, 57.49 and 14.48 million m^3 (roundwood equivalent), respectively. These estimates indicate a jump of nearly 70% in demand for roundwood in India in the next decade, from 57 million m^3 in 2020 to 98 million m^3 in 2030, driven largely by the construction sector (Kant and Nautiyal, 2021). Particularly, paper industry in India has an immense potential. Paper consumption in India is projected to grow by 6-7 % per annum in the next five years so as to reach 30 million tonnes by FY 2026 -27 making it the fastest growing paper market in the world (Gupta, 2022). In this backdrop, many efforts have been made to meet wood deficiency by implementing programmes and schemes like agroforestry, social forestry, setting up of state Forest Development Corporations (FDCs) and mission oriented to supply sustain wood to various wood-based industries. Species like Eucalypts, Poplars, Acacias, Casuarinas, *etc*., were introduced, and to some extent, raw material supply was assured. Still inadequate availability of wood for wood-based industries in India is major constraint (Luna et al 2009, 2011, Agarwal and Saxena 2017). Although proven species, may be indigenous or exotic, are relied on vigorously; however, their multipurpose nature is quite limited (Luna et al 2014. Lodhiyal 2014, Chaturvedi et al 2016). In recent years diversified the industries from plywood, paper and pulp, bioenergy, timber for construction, railway, *etc*. Hence, there is very need to look for species which could be utilized for most of the industries at various stages of development.

Melia dubia Cav., an important multipurpose tree, indigenous to Western Ghats region of India, and is common in moist deciduous forests of the Indian. It is also found in Bangladesh, Myanmar, Thailand, Mexico, Sri Lanka, Malaysia, Java, China, America, Philippines and Australia (Mohanty et al 2019). It is short rotation species having multiple uses like very good raw material for ply and pulp wood, plywood industries, high-quality timber for various purposes (Kumar et al 2017, Parthiban et al 2019, Sinha et al 2019) and many other uses like drupe pulp as animal feed (Sukhadiya et al 2019, 2020). It is also considered as an excellent agroforestry species (Jilariya et al 2017, Mohanty et al 2019, Thakur et al 2019, 2020, Prajapati et al 2020) without any allelopathic effect (Kumar et al 2017, Thakur et al 2017, Parmar et al 2020). However, attempts to test progenies of this valuable species are still in infancy stage to develop high yielding varieties/clones in various parts of the country which are limited to North (Kumar et al 2017) and South India (Parthiban et al 2019). Selection of superior genotypes based on higher values in terms of growth and productivity are generally practiced for large scale multiplication and plantation programme. Therefore, for the first time, we evaluated performance of some open pollinated progenies of *M. dubia* in the Western Indian state Gujarat. The present paper presents the performance of progenies in terms growth, biomass and volume productivity at the age of 5 years as it can be harvested within 4 to 5 years for paper-pulp and for plywood if it has attained minimum diameter (log mid diameter) of 10 cm (Sinha et al 2019, Deepika et al 2019).

MATERIAL AND METHODS

Edapho-climatic conditions of site: The investigation was carried out at the College of Forestry, Navsari Agricultural University, Navsari (20.95°N latitude, 75.90°E longitude with an altitude of 10 m amsl), Gujarat, India, during 2014-2019. Climate of area is characterized humid and warm with monsoon rainfall of around 1500 mm (June-September), moderately cold in winter (November-February) and fairly hot and humid in summer (March-May). Soils of experimental site is deep black originated from old alluvium of basaltic material, taxonomically placed under the group of *Ustochrepts*, sub group of *verti Ustochrepts*, sub order of *orchrepts* and order of *inceptisols*, characterized by clay, deep, moderately drained with good water holding capacity. The soil cracks heavily on drying and expands on wetting and predominant clay mineral found to be montmorillonite. Soil pH and average available nitrogen, phosphorus, potassium, and organic carbon of experimental site was 225.79 kg ha^{-1}, 32.81 kg ha^{-1}, 310.34 kg ha^{-1}, 7.67 and 0.87%, respectively. The average minimum and maximum temperature from 2014 to 2019 was 20.0 and 32.0°C, respectively and average relative humidity and rainfall was 85% and 1570 mm, respectively.

Experimental details: Experiment was conducted in randomized block design with 17 open pollinated *Melia dubia* families as treatments with three replication (three individuals in each replication). The seeds of 16 families were supplied by Division of Genetics and Tree Improvement, Forest Research Institute Dehradun, Uttarakhand, India and family named GJ09 was local source (collected from Northern most tip of Western Ghats), which were collected from South Gujarat, India (Table 1). Planting was carried out in January, 2014 at 3x3 m spacing with boundary row to avoid edge effect. Normal tree management practices were followed to maintain experimental trial. No additional fertilizer (organic or inorganic) was applied throughout the period and trees were allowed to natural pruning after 2nd year onwards.

The tree height and diameter at breast height (DBH; at 1.37 cm above ground) from 2015 to 2019 (1stto 5th years of age) were recorded periodically following standard methods of each family. Standing tree fresh biomass and over bark volume was calculated following regression equations

Table 1. Geographical location of *M. dubia* families tested in the present study

Family No.	Area/Location	Latitude (N)	Longitude (E)	Elevation (ft.)
24	Central Nursery, Forest Research Institute, Dehradun, Uttarakhand, India	30°20'43.3"	78°00'44.2"	2116
28	Central Nursery, Forest Research Institute, Dehradun, Uttarakhand, India	30°20'43.3"	78°00'43.6"	2175
32	Central Nursery, FRI, Dehradun, Uttarakhand, India	30°20'43.6"	78°00'43.7"	2175
69	Forest Area, Dehradun, Uttarakhand, India	30°20'44.6"	78°00'42.1"	2185
75	Central Nursery, Forest Research Institute, Dehradun, Uttarakhand, India	30°20'44.7"	78°00'42.3"	2201
114	Forest Area, Dehradun, Uttarakhand, India	30°20'55.9"	77°59'44.8"	2165
159	Chemistry Division, Forest Research Institute, Dehradun, Uttarakhand, India	30°20'40.1"	78°00'11.6"	2286
195	Forest Area, Dehradun, Uttarakhand, India	30°20'57.3"	77°59'40.2"	2125
233	Forest Area, Dehradun, Uttarakhand, India	30°20'25.4"	78°00'16.9"	2152
263	Forest Area, Dehradun, Uttarakhand, India	30°'20'00.70"	78°00'22.9"	2952
259	Forest Area, Dehradun, Uttarakhand, India	30°'20'31.4"	77°59'33.9"	2180
260	Forest Area, Dehradun, Uttarakhand, India	30°'20'59.4"	77°59'53.6"	2194
261	Forest Area, Dehradun, Uttarakhand, India	31°'32'19.4"	75°53'22.7"	2020
262	Forest Area, Dehradun, Uttarakhand, India	30°'20'00.64"	78°00'22.9"	2134
64	Central Nursery, Forest Research Institute, Dehradun, Uttarakhand, India	30°'24'44.7"	78°00'43.1"	2185
270	Forest Area, Dehradun, Uttarakhand, India	30°'20'04.80"	78°00'29.05"	2270
GJ 09	Nanapodha, Gujarat, India	20˚26.075	73˚ 08.975′	207

$B=0.0299(HD^2)+7.48$ and $V=0.003+0.00003(HD^2)$, respectively (Thakur et al 2021), Where, B =total tree fresh biomass, V=Log volume (Over bark), H=height (m) of the tree and D= DBH (cm). Finally, fresh biomass productivity potential at 5 years age was worked out.

Variability studies: The biometrical analysis was carried out according to the estimation of genotypic and phenotypic coefficients of variation following the method used by Burton and Devane (1953).

Genotypic Variance (GV): $\sigma^2 g = (\sigma^2 g - \sigma^2 e)/r$

r = the number of replications

Phenotypic Variance (PV): $\sigma^2 p = (\sigma^2 g - \sigma^2 e)$

Phenotypic coefficient of variance (PCV): PCV (%) = $\sqrt{\sigma^2 p}/\mu \times 100$

Where, $\sigma^2 p$ = Phenotypic variance, μ = population mean of the character

Genotypic coefficient of variability (GCV): GCV (%) = $\sqrt{\sigma^2 g}/\mu \times 100$

Where, $\sigma^2 g$ = Genotypic variance, μ = population mean of the character

Heritability: Heritability in broad sense was calculated according to Lush in 1949.

$h^2 = (\sigma^2 g / \sigma^2 p)$

Genetic advance: Genetic advance is calculated according to Johnson et al (1955).

Genetic Advance (GA) = $h^2 \times \sqrt{\sigma^2 p} \times K$

K is the selection differential at selection intensity (K= 2.06).

Statistical analysis: The data generated were subjected to the statistical analysis following Duncan's multiple range test (DMRT) was used to compare the sets of means of each treatment following Sheoran et al (1998).

RESULTS AND DISCUSSION

Height (m) and DBH (diameter at breast height, cm) growth: There was a significant variation in height and DBH growth among studied families from 1st year till 5th year of observation (Table 2). Family 259 attained maximum height from 1st to 3rd year (5.83, 7.90 and9.27 m, respectively). In 1styear, family 75 and in 2nd and 3rd year, family 75 and GJ09 were statistically at par with family 259. In 4th year, family 260 out crossed for height (11.37m) which was at par with GJ09. However, in 5th year, GJ09 achieved significantly maximum height (13.33 m) which was at par with family 260 with height growth of 12.46 m. Family 270 put minimum growth throughout the study period. Results indicated that family 259 attained significantly maximum DBH during 1st to 3rd year (6.26, 11.46 and 13.59 m, respectively). However, at 4th and 5th year, family GJ09 excelled with higher DBH of 15.26 and 18.00 cm, respectively than other families. Family 233

Table 2. Variation in growth of *M. dubia* families at different age gradations in Gujarat, India

Family	Tree height (m)					DBH (cm)				
	Age (Years)									
	1	2	3	4	5	1	2	3	4	5
24	4.73^{bc}	6.97^{abcd}	8.57^{ab}	9.08^{bc}	9.93^{cd}	4.99^{b}	9.71^{bc}	11.35^{bcd}	12.23^{cdefgh}	13.91^{cde}
28	4.12^{cd}	6.19^{bcdef}	7.30^{bcd}	8.55^{cde}	9.92^{cd}	3.29^{efgh}	7.54^{de}	9.74^{defg}	11.27^{fgh}	12.53^{de}
32	2.88^{efg}	5.48^{efgh}	6.81^{def}	7.72^{ef}	8.20^{efg}	2.71^{fghij}	7.06^{def}	9.02^{efg}	10.07^{ghi}	12.63^{de}
69	3.77^{cde}	5.10^{fghi}	6.85^{cdef}	8.88^{bcd}	10.07^{cd}	3.46^{defg}	6.53^{efg}	10.46^{cdef}	11.37^{efgh}	12.00^{ef}
75	5.54^{ab}	6.33^{abcde}	8.60^{ab}	9.83^{b}	11.82^{ab}	4.99^{b}	9.50^{c}	12.00^{abc}	13.15^{abcdef}	15.71^{abc}
114	2.44^{fg}	5.01^{fghi}	6.83^{cdef}	9.40^{bc}	9.97^{cd}	2.59^{fghij}	6.37^{efg}	12.31^{ab}	14.08^{abcd}	15.56^{abc}
159	3.95^{cd}	4.60^{ghi}	6.42^{def}	7.32^{fg}	8.63^{def}	3.50^{def}	7.18^{def}	10.67^{bcdef}	11.49^{efgh}	15.39^{bc}
195	4.33^{c}	7.60^{ab}	8.27^{abc}	9.80^{b}	10.35^{bc}	5.09^{b}	10.40^{abc}	12.21^{abc}	13.82^{abcde}	15.08^{bcd}
233	2.37^{fg}	4.68^{ghi}	5.57^{efg}	8.80^{bcd}	9.58^{cde}	2.07^{j}	5.89^{fg}	8.00^{gh}	10.32^{ghi}	13.69^{cde}
263	4.68^{bc}	5.93^{cdefg}	6.96^{cde}	8.02^{def}	8.53^{def}	3.80^{cde}	8.13^{d}	10.86^{bcde}	12.44^{bcdefg}	13.80^{cde}
259	5.83^{a}	7.90^{a}	9.27^{a}	9.50^{bc}	10.27^{bc}	6.26^{a}	11.46^{a}	13.59^{a}	14.35^{abc}	16.14^{abc}
260	4.53^{bc}	7.43^{ab}	8.48^{ab}	11.37^{a}	12.46^{a}	4.46^{bcd}	11.04^{ab}	13.19^{a}	14.84^{ab}	16.90^{ab}
261	3.30^{def}	5.13^{fgh}	5.50^{fg}	6.40^{gh}	7.17^{fg}	3.18^{efghi}	7.22^{def}	8.92^{fg}	9.82^{hi}	12.74^{de}
262	1.93^{g}	4.14^{hi}	5.53^{efg}	9.27^{bc}	9.62^{cde}	2.23^{ij}	5.41^{g}	9.34^{efg}	11.68^{defgh}	12.04^{ef}
64	2.10^{g}	5.77^{defg}	5.80^{efg}	9.03^{bcd}	10.47^{bc}	2.34^{hij}	6.80^{def}	9.55^{defg}	11.79^{defgh}	13.80^{cde}
270	1.88^{g}	3.67^{i}	4.92^{g}	6.18^{h}	6.80^{g}	2.41^{ghij}	5.25^{g}	6.71^{h}	8.06^{i}	9.64^{f}
GJ 09	4.03^{cd}	7.33^{abc}	8.40^{ab}	11.20^{a}	13.33^{a}	4.62^{bc}	10.83^{abc}	13.27^{a}	15.26^{a}	18.00^{a}

Means with different superscript letter in the same column indicate significant difference ($p<0.05$) according to Duncan's Multiple Range Test attained minimum DBH in 1st year, however, from 2nd till 5th year family 270 attained minimum DBH (Table 2).

Fresh biomass (kg tree^{-1} or tonne^{-1}) and over bark volume (m^3 tree^{-1} and m^3 ha^{-1}): Study expressed that, fresh biomass per tree and per hectare differed significantly among the 17 open pollinated families (Table 3). Per tree and per hectare biomass, from 1st to 3rd year, was maximum (14.36, 38.57 and 58.73 kg tree^{-1}, and 15.96, 42.86 and 65.25 tonne ha^{-1}, respectively) among individuals of family 259. However, at 4th and 5th year, individuals of family GJ09put up maximum individual tree fresh biomass (85.48 and 136.60 kg tree^{-1}, respectively) and per hectare as well (94.97 and 151.76 tonne ha^{-1}, respectively). Similarly, per tree and per hectare over bark volume varied significantly among the tested families (Table 4). From 1st to 3rd year, individual tree volume (0.011, 0.035, and 0.055 m^3 tree^{-1}, respectively) as well on hectare basis (11.89, 38.88 and 61.35 m^3 ha^{-1}, respectively) was recorded among individuals of family 259. Whereas, in 4th and 5th year, individuals of family GJ09 achieved maximum over bark volume at individual tree level (0.082 and 0.134 m^3 tree^{-1}, respectively) and per hectare basis (91.17 and 148.15 m^3 ha^{-1}, respectively).

Fresh biomass (tonne ha^{-1} year^{-1}) and over bark volume (m^3 ha^{-1} year^{-1}) productivity: There was a significant variation in productivity potential in terms of fresh biomass (tonne ha^{-1} year^{-1}; Fig. 1) and volume (m^3 ha^{-1} year^{-1}; Fig. 3) of *M. dubia* open pollinated families estimated during 5 years growth period. Since, over 5 years period, family GJ09 put

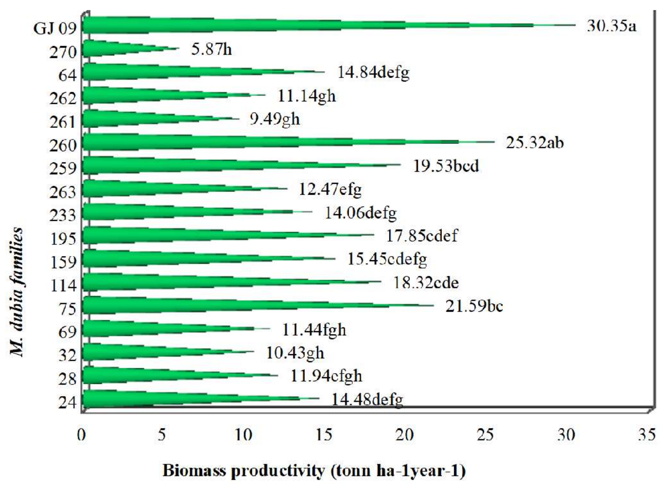

Fig. 1. Variation in biomass (tonne ha^{-1}year^{-1}) productivity potential of *M. dubia* families at the age of 5 years (means with different superscript letter in the same bar indicate significant difference (p<0.05) according to Duncan's Multiple Range Test)

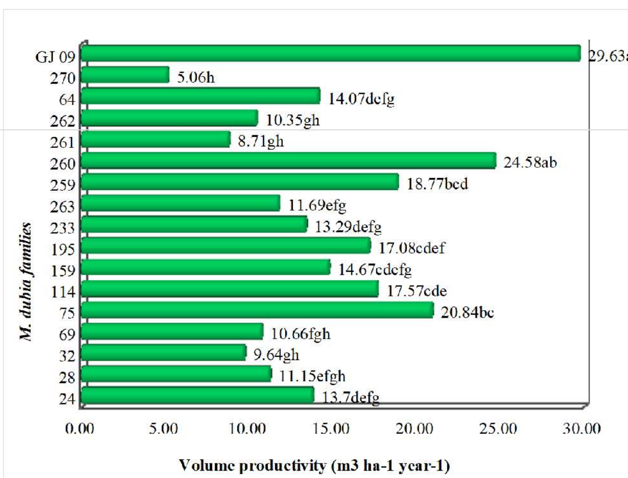

Fig. 2. Variation in volume (m^3 ha^{-1}year^{-1}) productivity potential of *M. dubia* families at the age of 5 years (means with different superscript letter in the same bar indicate significant difference (p<0.05) according to Duncan's Multiple Range Test)

Table 3. Variation in fresh biomass production (kg tree^{-1} and tonne ha^{-1}) of *M. dubia* families at different age gradations in Gujarat, India

Family	Fresh biomass (kg tree^{-1})					Fresh biomass (tonne ha^{-1})				
	Age (Years)									
	1	2	3	4	5	1	2	3	4	5
24	11.01^{bcd}	27.20^{bc}	40.43^{bcd}	48.25^{bcde}	65.15^{defg}	12.23^{bcd}	30.22^{bc}	44.92^{bcd}	53.61^{bcde}	72.38^{defg}
28	8.94^{defg}	18.14^{e}	28.40^{def}	39.97^{defg}	53.72^{efgh}	9.94^{defg}	20.15^{e}	31.55^{def}	44.41^{defg}	59.69^{efgh}
32	8.12^{fg}	16.15^{ef}	24.93^{efg}	31.70^{efg}	46.92^{gh}	9.02^{fg}	17.95^{ef}	27.70^{efg}	35.21^{efg}	52.13^{gh}
69	8.85^{efg}	14.16^{ef}	29.88^{def}	42.29^{def}	51.50^{fgh}	9.83^{efg}	15.7^{ef}	33.19^{def}	46.98^{def}	57.21^{fgh}
75	11.81^{b}	26.09^{cd}	45.19^{bc}	59.38^{bcd}	97.17^{bc}	13.12^{b}	28.99^{cd}	50.20^{bc}	65.97^{bcd}	107.95^{bc}
114	7.97^{g}	13.57^{ef}	39.44^{cd}	67.09^{ab}	82.48^{cde}	8.85^{g}	15.08^{ef}	43.81^{cd}	74.54^{ab}	91.63^{cde}
159	8.99^{defg}	14.80^{ef}	29.48^{def}	36.34^{efg}	69.50^{cdefg}	9.99^{defg}	16.44^{ef}	32.75^{def}	40.37^{efg}	77.22^{cdefg}
195	11.57^{bc}	32.82^{abc}	45.09^{bc}	64.65^{abc}	80.32^{cdef}	12.86^{bc}	36.46^{abc}	50.10^{bc}	71.83^{abc}	89.24^{cdef}
233	7.79^{g}	12.42^{ef}	18.13^{fg}	35.67^{efg}	63.29^{defg}	8.65^{g}	13.80^{ef}	20.14^{fg}	39.63^{efg}	70.3^{defg}
263	9.51^{cdefg}	19.27^{de}	32.22^{de}	44.74^{cdef}	56.14^{efg}	10.57^{cdefg}	21.41^{de}	35.80^{de}	49.70^{cdef}	62.37^{efg}
259	14.36^{a}	38.57^{a}	58.73^{a}	66.14^{ab}	87.89^{bcd}	15.96^{a}	42.86^{a}	65.25^{a}	73.48^{ab}	97.65^{bcd}
260	10.26^{bcde}	34.65^{a}	51.76^{ab}	82.67^{a}	113.95^{ab}	11.40^{bcde}	38.49^{a}	57.50^{ab}	91.84^{a}	126.59^{ab}
261	8.54^{efg}	15.71^{ef}	21.47^{efg}	27.03^{fg}	42.74^{gh}	9.49^{efg}	17.46^{ef}	23.85^{efg}	30.03^{fg}	47.48^{gh}
262	7.79^{g}	11.11^{f}	22.73^{efg}	46.40^{bcdef}	50.14^{gh}	8.65^{g}	12.34^{f}	25.25^{efg}	51.54^{bcdef}	55.71^{gh}
64	7.83^{g}	15.54^{ef}	23.31^{efg}	45.23^{cdef}	66.79^{defg}	8.70^{g}	17.26^{ef}	25.90^{efg}	50.25^{cdef}	74.20^{defg}
270	7.81^{g}	10.53^{f}	14.07^{g}	19.55^{g}	26.39^{h}	8.67^{g}	11.70^{f}	15.64^{g}	21.72^{g}	29.32^{h}
GJ 09	10.09^{bcdef}	33.22^{ab}	51.86^{ab}	85.48^{a}	136.60^{a}	11.21^{bcdef}	36.91^{ab}	57.62^{ab}	94.97^{a}	151.76^{a}

Means with different superscript letter in the same column indicate significant difference (p<0.05) according to Duncan's Multiple Range Test

Table 4. Variation in volume production (m^3 tree^{-1} and m^3 ha^{-1}) of *M. dubia* families at different age gradations in Gujarat, India

Family	Volume (m^3 tree^{-1})					Volume (m^3 ha^{-1})				
	Age (Years)									
	1	2	3	4	5	1	2	3	4	5
24	0.007^{bcd}	0.024^{bc}	0.037^{bcd}	0.045^{bcdef}	0.062^{defg}	8.16^{bcd}	26.21^{bc}	40.95^{bcd}	49.67^{bcde}	68.51^{defg}
28	0.005^{defg}	0.014^{ef}	0.025^{def}	0.036^{efg}	0.050^{efgh}	5.86^{defg}	16.11^{e}	27.54^{def}	40.44^{defg}	55.77^{efgh}
32	0.004^{fg}	0.013^{efg}	0.021^{efg}	0.028^{fg}	0.043^{gh}	4.94^{fg}	13.89^{ef}	23.67^{efg}	31.21^{efg}	48.19^{gh}
69	0.005^{efg}	0.011^{efg}	0.027^{de}	0.039^{ef}	0.048^{fgh}	5.75^{efg}	11.67^{ef}	29.18^{def}	43.02^{def}	53.29^{fgh}
75	0.008^{b}	0.022^{cd}	0.041^{bc}	0.056^{bcde}	0.094^{bc}	9.05^{b}	24.97^{cd}	46.25^{bc}	62.08^{bcd}	104.19^{bc}
114	0.004^{g}	0.010^{efg}	0.036^{cd}	0.064^{ab}	0.079^{cde}	4.77^{g}	11.01^{ef}	39.84^{cd}	70.67^{ab}	87.82^{cde}
159	0.005^{defg}	0.011^{efg}	0.026^{def}	0.033^{fg}	0.066^{cdefg}	5.91^{defg}	12.38^{ef}	28.74^{def}	36.39^{efg}	73.36^{cdefg}
195	0.008^{bc}	0.029^{abc}	0.041^{bc}	0.061^{abcd}	0.077^{cdef}	8.79^{bc}	32.47^{abc}	46.15^{bc}	67.95^{abc}	85.42^{cdef}
233	0.004^{g}	0.009^{efg}	0.014^{fg}	0.032^{fg}	0.060^{defg}	4.57^{g}	9.73^{ef}	16.09^{fg}	35.65^{efg}	66.43^{defg}
263	0.006^{cdefg}	0.016^{de}	0.029^{de}	0.041^{def}	0.053^{efg}	6.49^{cdefg}	17.36^{de}	31.81^{de}	45.75^{cdef}	58.46^{efg}
259	0.011^{a}	0.035^{a}	0.055^{a}	0.063^{a}	0.085^{bcd}	11.89^{a}	38.88^{a}	61.35^{a}	69.61^{ab}	93.86^{bcd}
260	0.007^{bcde}	0.031^{a}	0.048^{ab}	0.079^{a}	0.111^{ab}	7.32^{bcde}	34.51^{a}	53.58^{ab}	88.03^{a}	122.90^{ab}
261	0.005^{efg}	0.012^{efg}	0.018^{efg}	0.024^{fg}	0.039^{gh}	5.40^{efg}	13.40^{ef}	19.81^{efg}	26.02^{fg}	43.52^{gh}
262	0.004^{g}	0.024^{fg}	0.019^{efg}	0.043^{bcdef}	0.047^{gh}	4.56^{g}	8.27^{f}	21.21^{efg}	47.60^{bcdef}	51.78^{gh}
64	0.004^{g}	0.014^{efg}	0.020^{efg}	0.042^{cdef}	0.063^{defg}	4.61^{g}	13.20^{ef}	21.87^{efg}	46.30^{cdef}	70.33^{defg}
270	0.004^{g}	0.013^{g}	0.010^{g}	0.016^{g}	0.023^{h}	4.58^{g}	7.62^{f}	11.58^{g}	17.68^{g}	25.30^{h}
GJ 09	0.006^{bcdef}	0.011^{ab}	0.049^{ab}	0.082^{a}	0.134^{a}	7.13^{bcdef}	32.92^{ab}	53.70^{ab}	91.17^{a}	148.15^{a}

Means with different superscript letter in the same column indicate significant difference (p<0.05) according to Duncan's Multiple Range Test up maximum growth, volume and biomass production; hence, showed highest fresh biomass (30.35 tonne ha^{-1} $year^{-1}$) and volume (29.63m^3 ha^{-1} $year^{-1}$) productivity potential, which was followed by family 260 (fresh biomass 25.32 tonne ha^{-1} $year^{-1}$ and over bark volume 24.58 m^3 ha^{-1} $year^{-1}$). However, family 270 showed minimum productivity potential. Growth and development of tree species is primarily controlled by several factors such as growth, climatic and edaphic conditions, age and genetic constituent (Khanna, 2015). The study indicated that amongst evaluated open pollinated families, family 259 from 1^{st} year to 3^{rd} year had significantly higher values for tree height and DBH. Finally, at 4^{th} and 5^{th} year, GJ09 gained significantly higher DBH and maximum height at 5^{th} year. Hence, the fresh biomass and over bark volume and productivity potential was highest among the evaluated families in the study. In Northern Indian states of Punjab, Haryana and Uttarakhand, at 3x3 m spacing (at the age of 7 years), *M. dubia* families attained tree height of 9.67 to 16.19 m and DBH of 17.20 to 25.73 cm, individual tree stem under bark volume of 0.104 to 0.255 m^3 and productivity of 23.19 to 55.83 $m^3ha^{-1}year^{-1}$(Kumar et al 2017). The growth and productivity evaluated at the age of 5 years of same families by these workers is higher as compared to that achieved in 7 years. However, family GJ09 out crossed the same family in our study as well as productivity achieved in Punjab, Haryana and Uttarakhand. The variation in growth and productivity of tree species varies from location to location due to edapho-climatic attributes and genetic worth of material (Lodhiyal et al 2002). The better growth and productivity of GJ09 is also attributed to the fact it is local source and well adapted to local edapho-climatic conditions.

The clonal eucalyptus grown in Punjab, India, at 5 years of age (1250 trees/ha) attained height of 19.59 m, DBH of 13.40 cm, individual tree volume of 0.135 m^3tree^{-1} and volume of 168.50 m^3ha^{-1}. Similarly, Luna et al (2009) also reported that eucalyptus clones (12 clones), in 3 years (1666 trees ha^{-1}), acquired height of 10.29-13.97 m, DBH of 7.87-9.82 cm, volume of 0.027-0.052 m^3 $tree^{-1}$, and volume of 44.25-86.41 m^3ha^{-1}. Poplar clones (12 clones) evaluated in Punjab (India) by Luna et al. (2011), at 3 years of age with at 5x4 m spacing, gained the height of 13.50-14.42 m, DBH of 11.58-14.74 cm, individual tree volume of 0.0653-0.1040 m^3tree^{-1}. The above ground biomass for *Eucalyptus* at the age of 5 years (2500 tree ha^{-1}) was estimated to be 52.93 tonne ha^{-1} (Lodhiyal, 2014). Thus, the productivity potential of most of the *M. dubia* families investigated in our study is higher as compared to some of above mentioned industrially important tree species which, in fact, are improved clones.

Tree height and DBH are very important characteristics which indicates the vertical growth and development, and also contributes overall volume and biomass production of the tree (Beck 2010). Height is a good indicator of the adaptability of trees to various growing environmental condition (Kundu 2000). Tree height is one of the important criteria while selection of trees for large scale multiplication (Zobel and Talbert 1984). DBH mainly depends on cambial growth (Spicer and Groove 2010). Selection of superior genotypes based on their higher values in terms of growth, and productivity potential are generally practiced for large scale multiplication and plantation programme. Hence, based on the significant superior growth and productivity of GJ09 can be propagated and further tested for commercial cultivation to achieve higher productivity.

Variability studies: Genotypic variance (σ^2g), Phenotypic variance (σ^2p**)**, Genotypic coefficient of variability (GCV), Phenotypic coefficient of variability (PCV), Heritability (bs) and Genetic advance for growth traits are given in Table 5. In the study, PCV was slightly higher than GCV for height, DBH, volume and biomass. The maximum highest GCV, PCV and genetic gain was recorded by tree volume and biomass than tree height and DBH (Table 6). All the growth traits recorded maximum heritability values and it varied from 60.20 to 74.73 per cent. Such higher heritability values for height, basal diameter and volume index was also recorded in *M. dubia* clones at initial age of growth at field condition (Sathya and

Table 5. Estimates of variance and genetic parameters for growth traits in *M. dubia*

Growth parameter	Height	DBH	Volume	Biomass
σ^2g	2.60	3.58	0.005	1003.50
σ^2p	3.48	5.95	0.007	1462.75
GCV (%)	16.41	13.43	41.01	41.01
PCV (%)	18.98	17.31	49.51	49.51
Heritability (%)	74.73	60.20	68.60	68.60
Genetic advance	2.87	3.03	0.12	54.05
Genetic gain (%)	29.22	21.47	69.97	69.97

N=51 (17 families x 3 replications); DBH, Diameter at Breast Height

Table 6. Phenotypic (above diagonal) and genotypic (below diagonal) correlation among growth traits in *M. dubia*

Growth parameter	Tree height	DBH	Tree volume	Tree biomass
Tree height	-	0.689**	0.851**	0.851**
DBH	0.835**	-	0.943**	0.943**
Tree volume	0.939**	0.946**	-	1.000**
Tree biomass	0.939**	0.946**	1.000**	-

**P ≤ 0.01; DBH, Diameter at Breast Height

Parthiban 2018). In case of *Eucalyptus* clones of 10 years old, the heritability values for height, DBH and volume ranged between 26 to 52 per cent (Behera et al 2017). Therefore, in the study, among all growth parameters, tree biomass resulted in higher broad sense heritability and genetic gain. Hence, this trait may be used while selection best genotypes in *M. dubia.*

Phenotypic (r_p) and genotypic (r_g) correlation coefficient are worked out to understand the relationship between tree height, DBH with volume and biomass in *Melia dubia* (Table 6). There was a strong positive genetic and phenotypic correlation among studied growth traits in *M. dubia.* Values of r_g (0.835 to 0.939) and r_p (0.689 to 0.943) were within the permissible limit for tree height, DBH and volume. The tree biomass was strongly associated with height, diameter and volume. Therefore, maximum tree biomass can be obtained by trees with more height and diameter. Hence, this trait may be considered for selection of genotypes to achieve higher productive potential in *M. dubia.* Such positive relationship among growth traits was also recorded in *M. dubia* (Chauhan and Kumar, 2014), *M. azedarach* (Meena et al 2014) and *Leucaena* (Sangram and Keerthika 2013).

CONCLUSION

There was significant variation in height and DBH growth among families from 1st year till 5th year of observation. In 4th and 5th year, GJ09 resulted in significantly maximum height, DBH, fresh biomass and over bark volume (kg tree^{-1} as well as ha^{-1}) than other families. Thus, family GJ09 put up maximum growth, volume and biomass production; hence, it showed highest fresh biomass and volume productivity potential at age of 5 years. Genetic variability study indicated that PCV was slightly higher than GCV for height, DBH, volume and biomass. Interestingly highest GCV, PCV and genetic gain was recorded by tree volume and biomass than tree height and DBH. All the growth traits recorded maximum heritability values. Therefore among all growth parameters, tree biomass resulted in higher broad sense heritability and genetic gain. Hence, this trait may be used while selection best genotypes in *M. dubia*.

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