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Growth, Biomass Production and Components Variation in Eucalyptus Clones

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ABSTRACT

Eucalypts are among the most widely cultivated forest trees in the world under a range of different climates. Productivity and profitability of plantations of Eucalyptus have been revolutionized with the development of genetically improved, fast growing and high yielding clonal planting stock of Eucalypts. Eucalypts clonal planting has been said to have advantages which includes quick provision of benefits associates with fast growth, short rotation for production of pulp wood (of around 70 t ha^{-1} in 6 years) ready marketing and easy establishment and less maintenance needs. Clonal planting one among the approach for management of water and nutrients compared to the other conventional strategies. Studies relating to clonal difference and evaluation for dry matter production will help to overcome productivity loss due to deficit rainfall and optimum utilization of available natural resources for higher wood production. The present study was carried out to test the hypothesis that there exists a clonal variation in growth, biomass production and components and the present study gives an insight in to clonal variation with reference to growth, biomass production and components. Clone188 registered higher growth rate, total dry matter production, above and below ground biomass compared to other clones and seed source seedlings.

Key Words:

Biomass, Components, Eucalyptus Clones and Growth

INTRODUCTION

Eucalypts are among the most widely cultivated forest trees in the world. The major Eucalyptus growing countries are China, India and Brazil. Growth rates that routinely exceed 35 m^3 ha^{-1} yr^{-1}. These fast-growing plantations can be grown under a range of different climates for products that include pulp and paper, charcoal, fuel wood, and solid wood products such as poles, furniture, and construction timber. Being endemic to Australia, Southeast Asia, and the Pacific, eucalypts are grown mainly as exotic species (Davidson 1995; Stape 2002; 2010; ICFRE 2010). Eucalyptus shows a broad productivity response depending on species, clones and soil factors (Onyekwelu et al. 2011). Eucalyptus sp. has some of the highest net primary productivity rates up to 49 m^3 ha^{-1} yr^{-1} (Hubbard et al. 2010). Mean annual increments of clone plantation of Eucalyptus sp. with no fertilization, with fertilization and fertilization combined with irrigation are 33, 46 and 62 m^3 ha^{-1} yr^{-1} respectively. Some 170 species, varieties and provenances of eucalypt were tried in India (Bhatia 1984), out of which the most outstanding and favoured has been the *Eucalyptus hybrid*. *Eucalyptus tereticornis* and a form of *E. tereticornis* known as Mysore gum (thought to be a hybrid) are the most widely planted eucalypts in India. There are several reasons for raising eucalypts under large scale plantations in India; some are common and some are specific to the region. The most important common reason is production of wood for fuel, poles, construction and pulp.

The high biomass accumulation potential makes Eucalyptus sp. a good prospect for timber, wood products and carbon sequestration projects (Bhardwaj et al. 2000. Clonal selection and deployment in Eucalyptus is receiving attention as an intensive forest management tool for increased wood production. Many pulp and paper and other wood based industries are now establishing clonal forestry programme after the promulgation of 1988 National Forest Policy. The National Forest Policy has given clear cut indication that the forest based industries must prefer to raise required raw materials by themselves. The industries should establish direct relationship with individual growers of raw material by providing them credit, technical advice, harvesting and transport services. The policy also indicated that small and marginal farmers have to be encouraged to grow wood species required in forest based industries in their marginal and sub-marginal lands. The early introduction of *E. camaldulensis* and *E. tereticornis* to India was from southern temperate localities in Australia rather than the northern tropical regions where the climatic conditions closely resemble the areas available in India because of the inaccessibility and difficulties in collecting seeds (Boland 1981).

Eucalyptus clonal planting has been said to have advantages includes quick provision of benefits associated with fast growth, short rotation for production of pulp wood (about 70 t ha^{-1}), ready marketing and other reasons. It is an important industrial species and now popularized among the farmers due to varies reasons especially climatic vagaries (erratic and shortage of total rainfall, variation in the distribution, etc.) and shortage of irrigation to agriculture. The clonal plantations are the one among the best option to meet out the ever increasing demand for paper and pulp wood. But there is a continuous depletion of the natural resources especially various nutrients from the soil due to its repeated rotation and fast growth in nature. Information on consumption of natural resources mainly water and nutrients for production of biomass and stem wood are not well documented especially in Eucalyptus clones.

Clonal planting is one among the approach for management of water and nutrients compared to the other conventional strategies. The clonal evaluation for growth, biomass production and components variation study will help to selection of site specific clones based on climatic and edaphic factors for obtaining optimum yield. Therefore the present study was undertaken to assess growth, biomass production and components variation in Eucalyptus clones along with the commercial clones available in the market at present and the seed origin seedlings for comparison purpose.

MATERIALS AND METHODS

To carry out the dry matter allocation study, 24 clones and two seed origin seedlings were selected. Among 24 clones, 16 clones were shortlisted by IFGTB and these clones are numbered from C-7 to C-196. For comparison purpose, 8 clones (6 ITC clones and 2 TNPL clones) and two seed origin seedlings (each one from Tamil Nadu Forest Plantation Corporation and IFGTB) are selected and named as check clone 1 to 10. The present study was conducted in four locations of Tamil Nadu *viz*, Coimbatore district falling in the Western zone and the Pudukottai, Karaikudi and Tirunelveli falling in the Southern zone.

Establishment of field trials

The Clonal field trials have been established and in total, 49 ramets were planted in a block per clone and 26 clones were planted in three replications in the espacement of 3 × 1.5 m established in four locations of Tamil Nadu *viz*, Coimbatore district falling in the Western zone and the Pudukottai, Karaikudi and Tirunelveli falling in the Southern zone. The details of the above four locations including the climatic and edaphic factors are given in the Table1.

Pudukottai

The clonal trial established at Pudukottai situated between 10^{o}20'020" N and 76^{o}53'539" E with the elevation of 124 m above MSL. This place received an average annual rainfall of 919 mm during the study period. The minimum and maximum temperature recorded in the trial plot was 19.6 - 24.7^{o} C and 25.0 - 38.7^{o} C. The major soil type is red soil. The status of the soil nutrients for 0-15 cm and 15-30 cm were analysed.

Karaikudi

The clonal trial established at Karaikudi situated between 09^{o}54'749" N and 78^{o}39'064"E with the elevation of 80 m above MSL. This place received an average annual rainfall of 336 mm during the study period. The minimum and maximum temperature recorded in the trial plot was 20.5 - 25.6 ^{o} C and 31.10 - 39.40 ^{o} C. The major soil type is red soil. The status of the soil nutrients for 0-15 cm and 15-30 cm were analysed.

Tirunelveli

The clonal trial established at Tirunelveli situated between 08^{o}56'291" N and 77^{o}39'102"E with the elevation of 101 m above MSL. This place received an average annual rainfall of 336 mm during the study period. The minimum and maximum temperature recorded in the trial plot was 18.0 - 29.0^{o} C and 31.6 - 41.8^{o} C. The major soil type is red soil with gravels. The status of the soil nutrients for 0-15 cm and 15-30 cm were analysed.

Coimbatore

The clonal trial established at Coimbatore situated between 11^{o}02'592" N and 76^{o}53'539" E with the elevation of 471 m above MSL. This place received an average annual rainfall of 336 mm during the study period. The minimum and maximum temperature recorded in the trial plot was 18.0 - 29.0^{o} C and 31.6 - 41.8^{o} C. The major soil type is red soil. The status of the soil nutrients for 0-15 cm and 15-30 cm were analysed.

Table 1. Details of plantations established in four locations.

Sl. No	Location	Latitude	Longitude	Elevation (in m)	Area (in ha)	No. of clones	Spacing (in m)
1.	Coimbatore	11^{o}02'592"	76^{o}53'539"	471	2.0	26	3 x 1.5
2.	Pudukottai	10^{o}20'020"	78^{o}38'412"	124	2.0	26	3 x 1.5
3.	Karaikudi	09^{o}54'749"	78^{o}39'064"	80	2.0	26	3 x 1.5
4.	Tirunelveli	08^{o}56'291"	77^{o}39'102"	101	2.0	26	3 x 1.5

Growth parameters and physiological parameters were taken annually. During the half rotation period, biomass sampling was carried out by adopting the stratified average tree technique. Samples from different components of Eucalyptus clones such as leaves, branches, twigs, stem and root were collected and Eucalyptus clones were worked out on single tree basis and converted to hectare (ha) basis. The sampling technique adopted in the present study was 'Stratified average tree technique' as proposed by Art and Marks (1971). In this technique, the girth at breast height of each tree in the replication was recorded. The whole girth class was grouped by frequency distribution method and an average tree of each replication was selected for sampling. Thus, the average trees were felled from each replication and estimated the above and below ground biomass. The data obtained on growth parameters were analysed by GENSTAT 3.2.0 version and other statistical analysis using SPSS® 21.0 version and Microsoft® Excel 2007

RESULTS AND DISCUSSIONS

Growth parameters

For selection of high productive clones from the established clonal trials, the collected height values were analysed across the location (Table 2). The height (grand mean) of the Eucalyptus clones across the location was 7.3 m, while the average height varies from 5.0 to 9.3 m across the locations. At the half rotation period, C-188 registered highest average height growth of 9.3 m followed by C-19 (8.9 m), C-63 (8.7 m) and C-186 (8.6 m). The least height growth of 5.0 m was recorded in C-115 followed by 5.7 m in check clone 1 and 5.9 m in check clone 8. Though various clones registered variation in height parameters in different locations, clones C-188, C-186, C-123, C-14, C-10 and C-19 registered the maximum height of above 8.50 m and these clones registered greater grand mean height with low standard error values which implies that, within and across the trials, these are the preferable stable clones for large scale planting with reference to the total height, across the locations.

The grand mean girth of the Eucalyptus clones across the location was 19.5 cm. From the clonal trials established in four locations, C-19 registered the maximum girth of 25. 9 cm followed by C-188 (25.6 cm) C-14 (24.6 cm), C-186 (24.4 cm), C-10 (23.6 cm) and C-123 (23.7 cm). When compared to the grand mean across the trial (19.5 cm) which is lower than the grand mean in Pudukottai, Karaikudi and Coimbatore, except in Tirunelveli. Clones of C-14, C-19, C-186 and C-188 recorded greater girth measurement more than 23.5 cm (Table 3).

Kumar et al. (2010) also reported that, significant variations were recorded for height, diameter at breast height (DBH) and clear bole height (CBH) for eighteen clones of *E. tereticornis* for various growth parameters. The average genetic gain for three years was recorded maximum for height (159.60%) followed by DBH (110.97%) and CBH (70.34%). Clone 17 attained maximum DBH over other genotypes for second and third year followed by clones 14 and 11. There were significant differences between clones and sites for height and circumference and there were significant effect of interaction clone x site for circumference and height (Paulo Ricardo Gherardi Hein et al. 2010). Ginwal (2009) studied the Provenance and family variation in growth performance of *E. tereticornis* and reported that, significant variation in plant height, clean stem height, girth at breast height (GBH). Within provenance individual tree heritability estimates for height, clean stem length, GBH and number of branches at age 3 years were 0.318, 0.215, 0.269 and 0.231, respectively (assuming a coefficient of relationship of 0.4 for open-pollinated families of *E. tereticornis*). Similarly significant differences in different Eucalyptus species have been reported by various workers. Lal (2005) conducted a study to assess the comparative growth performance of various Eucalyptus species. Kumar and Bangawa (2006) observed significant differences for growth attributes among seven species of Eucalyptus species. Xiaoyong Mo et al. (2003) studied the important traits and combined evaluation of Eucalyptus clones and revealed that, 17 clones were significantly taller than the mean of 27 clones by the average of 20.3%. The mean superiority in dbh of 17 clones was 18.4%. The minimum height and dbh were 6.5 m and 6.14, respectively.

Table 2. Average height grand mean girth of Eucalyptus clones in different clonal trials

Clone ID	Average height of Eucalyptus clones (m)				Grand mean (m)
	Pudukottai	Karaikudi	Tirunelveli	Coimbatore	
C 7	10.0 ± 0.5	7.8 ± 0.5	7.6 ± 0.2	7.9 ± 0.1	8.3 ± 0.6
C 9	5.9 ± 0.5	6.6 ± 0.5	5.8 ± 0.2	6.5 ± 0.1	6.2 ± 0.2
C 10	10.7 ± 0.5	7.8 ± 0.5	7.1 ± 0.3	8.1 ± 0.3	8.7 ± 0.8
C 14	7.5 ± 0.4	8.6 ± 0.4	7.3 ± 0.1	10.0 ± 0.2	8.7 ± 0.6
C 19	9.2 ± 0.5	10.0 ± 0.5	7.9 ± 0.2	8.4 ± 0.2	8.9 ± 0.5
C 63	8.4 ± 0.5	7.9 ± 0.5	8.0 ± 0.1	8.3 ± 0.1	8.6 ± 0.6
C 66	7.6 ± 0.5	7.0 ± 0.5	6.4 ± 0.1	6.8 ± 0.2	6.9 ± 0.3
C 100	7.1 ± 0.4	7.4 ± 0.5	6.7 ± 0.1	7.1 ± 0.3	7.1 ± 0.1
C 111	8.9 ± 0.4	9.1 ± 0.4	7.6 ± 0.2	8.1 ± 0.1	8.4 ± 0.4
C 115	4.4 ± 0.2	5.4 ± 0.2	4.6 ± 0.3	5.5 ± 0.4	5.0 ± 0.3
C 123	7.9 ± 0.4	8.0 ± 0.4	9.2 ± 0.3	8.4 ± 0.2	8.4 ± 0.3
C 124	8.4 ± 0.6	7.3 ± 0.6	6.7 ± 0.1	7.0 ± 0.1	7.4 ± 0.4
C 186	8.9 ± 0.7	8.8 ± 0.5	7.7 ± 0.2	9.2 ± 0.2	8.6 ± 0.3
C 187	8.4 ± 0.4	8.1 ± 0.4	7.2 ± 0.2	7.9 ± 0.3	7.9 ± 0.3
C 188	11.6 ± 0.2	8.7 ± 0.2	8.3 ± 0.2	8.4 ± 0.2	9.3 ± 0.3
C 196	8.6 ± 0.4	8.0 ± 0.4	7.7 ± 0.1	8.7 ± 0.3	8.4 ± 0.4
Check 1	5.9 ± 0.4	5.5 ± 0.4	5.3 ± 0.2	6.0 ± 0.2	5.7 ± 0.2
Check 2	6.3 ± 0.4	6.0 ± 0.4	5.5 ± 0.1	6.4 ± 0.2	6.0 ± 0.2
Check 3	6.5 ± 0.4	5.9 ± 0.4	6.2 ± 0.1	6.8 ± 0.2	6.4 ± 0.2
Check 4	8.3 ± 0.6	7.4 ± 0.6	7.1 ± 0.1	7.3 ± 0.4	7.5 ± 1.3
Check 5	7.5 ± 0.4	6.6 ± 0.4	6.8 ± 0.2	7.2 ± 0.2	7.0 ± 0.2
Check 6	6. 7 ± 0.7	6.1 ± 0.7	6.2 ± 0.13	6.1 ± 0.4	6.3 ± 0.1
Check 7	7.6 ± 0.2	6.4 ± 0.2	6.0 ± 0.1	7.6 ± 0.2	6.9 ± 0.4
Check 8	6.4 ± 0.2	5.4 ± 0.2	5.8 ± 0.2	6.1 ± 0.1	5.9 ± 0.2
Check 9	6.8 ± 0.2	5.5 ± 0.4	5.4 ± 0.2	6.1 ± 0.3	6.0 ± 0.3
Check 10	5.8 ± 0.4	5.5 ± 0.4	5.5 ± 0.1	6.3 ± 0.1	6.0 ± 0.2
Grand Mean	7.8	7.2	6.6	7.4	7.3
SED	0.59	0.42	0.26	0.33	0.46

* Mean height value with ± Standard Error.

Table 3. Average Girth at breast height grand mean girth of Eucalyptus clones in different clonal trials

Clone ID	Average girth of Eucalyptus clones (cm)				Grand mean girth (cm)
	Pudukottai	Karaikudi	Tirunelveli	Coimbatore	
C 7	25.3 ± 0.9	22.7 ± 1.5	16.3 ± 0.7	22.5 ± 1.5	22.0 ± 1.7
C 9	20.7 ± 1.2	20.7 ± 1.5	15.6 ± 0.3	20.7 ± 1.2	19.8± 0.9
C 10	28.3 ± 1.2	24.8 ± 1.5	20.3 ± 0.7	22.6 ± 0.9	23.6 ± 2.0
C 14	23.6 ± 1.9	23.3 ± 0.7	21.6 ± 0.3	30.7 ± 1.8	24.6 ± 2.2
C 19	24.7 ± 1.5	32.2 ± 1.9	19.6 ± 1.7	26.0 ± 1.2	25.9 ± 2.6
C 63	18.5 ± 1.5	16.6 ± 1.2	23.3 ± 2.3	22.0 ± 1.5	19.5 ± 1.2
C 66	17.3 ± 1.8	18.0 ± 2.1	14.0 ± 1.0	17.3 ± 1.2	17.1 ± 0.5
C 100	13.6 ± 1.8	15.0 ± 1.7	12.3 ± 0.3	14.0 ± 1.1	14.0 ± 0.4
C 111	23.0 ± 1.5	27.3 ± 1.8	20.0 ± 1.0	22.6 ± 0.9	16.6 ± 1.7
C 115	16.2 ± 1.5	17.6 ± 0.9	15.0 ± 1.0	17.7 ± 1.2	15.7 ± 0.8
C 123	22.6 ± 1.2	22.5 ± 0.9	28.0 ± 1.0	22.7 ± 0.7	23.7 ± 1.0
C 124	14.8 ± 1.5	16.5 ± 1.2	12.6 ± 0.7	17.8 ± 1.5	15.4 ± 0.9
C 186	23.7 ± 1.5	25.0 ± 1.5	17.6 ± 0.3	29.0 ± 0.6	24.4 ± 2.1
C 187	21.6 ± 1.5	22.3 ± 1.2	18.3 ± 0.7	21.7 ± 0.9	20.6 ± 1.7
C 188	32.7 ± 0.9	23.6 ± 1.5	25.0 ± 1.0	23.3 ± 0.9	25.6 ± 2.3
C 196	20.6 ± 1.2	20.6 ± 1.5	17.3 ± 0.3	27.6 ± 0.9	16.2 ± 2.4
Check 1	13.6 ± 1.8	15.6 ± 1.5	12.3 ± 1.3	16.7 ± 0.9	14.8 ± 0.8
Check 2	15.3 ± 1.8	17.0 ± 1.0	15.4 ± 0.3	17.7 ± 1.2	18.3 ± 0.7
Check 3	15.7 ± 1.8	13.3 ± 1.3	12.7 ± 0.7	16.3 ± 0.9	15.6 ± 0.7

Check 4	23.6 ± 1.3	21.3 ± 1.6	19.6 ± 0.7	21.6 ± 1.5	21.4 ± 1.0
Check 5	22.6 ± 0.9	21.3 ± 0.9	19.7 ± 0.3	21.0 ± 1.5	20.8 ± 1.0
Check 6	19.6 ± 1.5	20.6 ± 1.2	16.3 ± 0.3	15.3 ± 0.9	16.0 ± 1.2
Check 7	14.3 ± 1.2	15.5 ± 0.7	13.4 ± 0.7	16.7 ± 1.2	15.0 ± 0.7
Check 8	16.1 ± 1.5	14.3 ± 1.2	14.0 ± 1. 0	15.3 ± 1.2	16.2 ± 0.7
Check 9	17.0 ± 1.7	15.6 ± 1.2	14.3 ± 1.3	16.0 ± 0.6	15.6 ± 0.5
Check 10	15.5 ± 1.5	17.6 ± 1.2	12.7 ± 0.3	16.7 ± 0.5	15.5 ± 0.9
Grand Mean	20.1	20.1	17.1	20.5	19.5
SED	2.12	1.91	1.31	1.56	1.64

* Mean height value with ± Standard Error.

Biomass production

The difference in the AGB between the highest and the lowest in various clones in different clonal trials was worked out and the results were presented for across the location for the half rotation period (3 years). In the half rotation period (3rd year), the lowest AGB was recorded 5.55 kg tree^{-1} in C-124 and the highest AGB of 10.52 kg tree^{-1} in C-188. The highest above ground biomass was recorded in C-188, C-10, C-14, C-19, C-123 and C-186. On the other hand, in the third year C-124 recorded the lowest BGB of 1.26 kg tree^{-1} and C-188 recorded the highest BGB of 2.44 kg tree^{-1} with the mean of 1.51 kg tree $^{-1}$. The clones of C-188, C-10, C-14, C-19, C-111 and C-186 are forming a single group and recorded the highest below ground biomass production among the different clones. Among the clones, C-124 registered the lowest below ground biomass followed by C-100 and check clone 7. In the case of total dry matter production C-100 registered the lowest total biomass production of 6.77 kg tree^{-1} and C-188 registered the highest total biomass of 12.99 kg tree^{-1} with the mean of 9.54 kg tree^{-1}.The clones C-188, C-186, C-19, C-10 and C-14 are forming a single group and registered the higher production of total biomass among the Eucalyptus clones. Clone C-100 registered the lowest total biomass of 6.77 kg tree^{-1} followed by C-124 (6.80 kg tree^{-1}) and check clone 1 (7.23 kg tree^{-1}) compared to the mean (Table 4).

MAI from plantations of selected clones after six years was recorded to 35 m^3 ha^{-1} yr^{-1} as compared to 20-25 m^3 ha^{-1} yr^{-1} from selected provenance and about 12 m^3 ha^{-1} yr^{-1} from unselected seed lots reported by Praveen et al. (2010) in Eucalyptus hybrids. Dry matter production is directly related to the growth parameters and the clones are recorded higher production of the dry matter content compared to the seedling origin seedlings. Pugazhendhi et al. 2018 reported that various eucalyptus clones have significant different net photosynthetic rates which is reflected in their biomass production.

Biomass partitioning

In third year, the leaf biomass ranged from 0.79 kg tree^{-1} in C-124 to 1.49 kg tree^{-1} in C-188 followed by 1.42 kg tree^{-1} in C-186 with the mean of 1.11 kg tree^{-1}; branch biomass ranged from 1.22 kg tree^{-1} in C-100 to 2.36 kg tree^{-1} in C-188 followed by 2.23 kg tree^{-1} in C-186 and C-19 with the mean of 1.73 kg tree^{-1}. In the case of stem wood biomass, C-124 registered the lowest biomass of 3.50 kg tree^{-1} and C-188 recorded the highest biomass of 6.67 kg tree^{-1} followed by C-19 (6.38 kg tree^{-1}) with the mean of 4.86 kg tree^{-1}. Clone C-124 recorded the lowest root biomass of 1.26 kg tree^{-1} and C-188 recorded the highest root biomass of 2.44 kg tree^{-1} followed by 2.27 kg tree^{-1} in C-186 with the mean of 1.79 kg tree^{-1} in the case of root biomass production (Table 5).

Studies in *C. equisetifolia* in Puerto Rico revealed that, the percentage contribution of stem wood was highest (76%) when compared to other components. Relatively higher percentage of bole was reported in *C. equisetifolia* by Verma (1987), Jambulingam (1989) and Srivastava (1994). Similar results are also reported by Singh et al. (2010), 76.8% in *E. teriticornis* and 72.9% in *Pithecellobium dulce* and Wang et al. (1995) in *Populus tremuloides*. Vidyasegran (2003) reported similar percentage of root biomass of *C. equisetifolia* from 18.97 to 22.5%.

Buvaneswaran (2004) reported that root biomass to total biomass increased from 17.0 to 30.0% for teak in Southern dry and western moist agro-climatic zones of Tamil Nadu. With regard to review of bgb in different species, Zabek and Prescott (2006) reported 13-26% of root biomass to total plant biomass in Hybrid poplar. Dhyani et al. (1990) found that root weight ranged from 22% (*L. leucocephala*) to 29% (*E. teriticornis*) of total tree biomass in a comparison of five tree species at 2 years of age.

Table 4. Above Ground Biomass, Below Ground Biomass and total biomass (kg tree^{-1}) production of Eucalyptus clones across the location in three year old plantation.

Clone	AGB	BGB	Total Biomass
C 7	8.87 $^{f-g-h-i}$	2.07 $^{e-f-g-h}$	10.94 $^{g-h-i}$
C 9	8.26 $^{e-f-g}$	1.87 $^{d-e-f}$	10.14 $^{e-f-g}$
C 10	9.82 $^{i-j-k}$	2.21 $^{g-h-i}$	11.73 $^{i-j-k}$
C 14	9.81 $^{i-j-k}$	2.16 $^{g-h-i}$	11.98 $^{i-j-k}$
C 19	9.95 $^{j-k}$	2.22 $^{g-h-i}$	12.16 $^{j-k}$
C 63	8.87 $^{f-g-h-i}$	1.97 $^{e-f-g}$	10.84 $^{f-g-h-i}$
C 66	7.90 $^{d-e-f}$	1.79 $^{d-e}$	9.63 $^{d-e-f}$
C 100	5.49 ^{a}	1.28 ^{a}	6.77 ^{a}
C 111	8.45 $^{e-f-g}$	2.16 $^{g-h-i}$	10.61 $^{f-g-h}$
C 115	6.47 $^{a-b-c}$	1.44 $^{a-b-c}$	7.91 $^{a-b-c}$
C 123	9.82 $^{i-j-k}$	2.15 $^{f-g-h}$	11.97 $^{i-j-k}$
C 124	5.55 ^{a}	1.26 ^{a}	6.80 ^{a}
C 186	9.96 $^{j-k}$	2.27 $^{h-i}$	12.24 $^{j-k}$
C 187	8.63 $^{f-g-h}$	1.97 $^{e-f-g}$	10.60 $^{f-g-h}$
C 188	10.52 ^{k}	2.44 ^{i}	12.99 ^{k}
C 196	8.82 $^{f-g-h-i}$	2.01 $^{e-f-g-h}$	10.83 $^{f-g-h-i}$
Check 1	5.81 ^{a}	1.42 $^{a-b-c}$	7.23 ^{a}
Check 2	5.96 ^{a}	1.45 $^{a-b-c}$	7.41 $^{a-b}$
Check 3	6.18 $^{a-b}$	1.51 $^{a-b-c}$	7.69 $^{a-b}$
Check 4	6.94 $^{b-c-d}$	1.59 $^{b-c-d}$	8.53 $^{b-c-d}$
Check 5	7.31 $^{c-d-e}$	1.65 $^{c-d-}$	8.97 $^{c-d-e}$
Check 6	6.94 $^{b-c-d}$	1.62 $^{c-d}$	8.56 $^{b-c-d}$
Check 7	5.69 ^{a}	1.32 $^{a-b}$	7.02 ^{a}
Check 8	7.47 $^{d-e}$	1.82 $^{d-e}$	9.30 $^{d-e}$
Check 9	6.04 $^{a-b}$	1.48 $^{a-b-c}$	7.52 $^{a-b}$
Check 10	6.16 $^{a-b}$	1.51 $^{a-b-c}$	7.67 $^{a-b}$
Mean	7.76	1.79	9.54

Table 5. Mean dry matter production (kg tree^{-1}) of various biomass components in Eucalyptus clones during 3rd year of growth across four locations of study.

	Dry matter production (kg tree^{-1})			
Clones	Leaf	Branch	wood	Root
C 7	1.29 ^{g}	2.02b $^{g-h-I-j}$	5.56 $^{g-h-I-j}$	2.07 $^{e-f-g-h}$
C 9	1.14 $^{e-f}$	1.84 $^{e-f-g}$	5.28 $^{e-f-g}$	1.87 $^{d-e-f}$
C 10	1.36 $^{g-h-i}$	2.12 $^{h-I-j}$	6.34 $^{h-I-j-k}$	2.21 $^{g-h-i}$
C 14	1.43 $^{i-j}$	2.20 $^{I-j-k}$	6.18 $^{I-j-k}$	2.16 $^{g-h-i}$
C 19	1.34 $^{g-h-i}$	2.23 $^{j-k}$	6.38 $^{j-k}$	2.22 $^{g-h-i}$
C 63	1.30 $^{g-h}$	1.98 $^{g-h-i}$	5.59 $^{f-g-h.i}$	1.97 $^{e-f-g}$
C 66	1.16 $^{e-f}$	1.76 $^{d-e-f}$	4.98 $^{d-e-f}$	1.79 $^{d-e}$
C 100	0.77 ^{a}	1.22 ^{a}	3.5 ^{a}	1.28 ^{a}
C 111	1.35 $^{g-h-i}$	2.15 $^{I-j-k}$	4.95 $^{I-j-k}$	2.16 $^{g-h-i}$
C 115	0.92 $^{b-c}$	1.45 $^{a-b-c}$	4.1 $^{a-b-c}$	1.44 $^{a-b-c}$
C 123	1.43 $^{I-j}$	2.19 $^{I-j-k}$	6.2 $^{I-j-k}$	2.15 $^{f-g-h}$
C 124	0.79 $^{a-b}$	1.24 ^{a}	3.5 ^{a}	1.26 ^{a}
C 186	1.42 $^{h-I-j}$	2.23 $^{j-k}$	6.31 $^{j-k}$	2.27 $^{h-i}$
C 187	1.24 $^{f-g}$	1.93 $^{f-g-h}$	5.46 $^{f-g-h}$	1.97 $^{e-f-g}$
C 188	1.49 ^{j}	2.36 ^{k}	6.67 ^{k}	2.44 ^{i}
C 196	1.24 $^{f-g}$	1.98 $^{f-g-h-i}$	5.6 $^{f-g-h-i}$	2.01 $^{e-f-g-h}$
Check 1	0.82 $^{a-b}$	1.30 ^{a}	3.69 ^{a}	1.42 $^{a-b-c}$
Check 2	0.84 $^{a-b}$	1.33 $^{a-b}$	3.79 $^{a-b}$	1.45 $^{a-b-c}$

Check 3	0.87^{a-b-c}	1.38^{a-b}	3.93^{a-b}	1.51^{a-b-c}
Check 4	0.97^{c-d}	1.55^{b-c-d}	4.42^{b-c-d}	1.59^{b-c-d}
Check 5	1.08^{d-e}	1.63^{c-d-e}	4.6^{c-d-e}	1.65^{c-d-}
Check 6	0.97^{c-d}	1.55^{b-c-d}	4.42^{b-c-d}	1.62^{c-d}
Check 7	0.82^{a-b}	1.27^{a}	3.6^{a}	1.32^{a-b}
Check 8	1.08^{d-e}	1.67^{d-e}	4.72^{d-e}	1.82^{d-e}
Check 9	0.86^{a-b-c}	1.35^{a-b}	3.83^{a-b}	1.48^{a-b-c}
Check 10	0.87^{a-b-c}	1.38^{a-b}	3.91^{a-b}	1.51^{a-b-c}
Mean	1.11	1.73	4.86	1.79

***Values having same alphabets as superscript are statistically at par with each other**

CONCLUSION

Genetic variation and environmental heterogeneity fundamentally shape the interactions between plants of the same species. Many authors reported that, significant differences between clones and sites for height, GBH, dry matter production and yield. There were significant effect of interaction between clones x site for height, GBH, dry matter production and yield. These findings can be useful for screenings, classifications, or preliminary selections in breeding programs of Eucalyptus. This disparity could also reflect in high variability in height, GBH, dry matter production and yield of clones in the same age. Further, this study confirms that, the clonal material exhibits better growth performance in terms of height as well as in girth, compared to the seedlings of seed origins, mainly due to the genetic characters of the materials.

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