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FORESTRY

Dry Matter Production 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 for products that include pulp, paper fuel wood and solid wood products such as poles, furniture and construction timber. 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 MT 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 for better water and nutrient use efficiency 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 dry matter production and the present study gives an insight in to Clonal variation in with reference to dry matter production of above ground and below ground biomass.

Highlights

- This article will give an idea of biomass production of various Eucalyptus clones
- Biomass allocation will give better management idea for optimum use of natural resources
- Helps to recommend site-specific clones and future breeding programmes

Keywords: Eucalyptus clones, above ground biomass, below ground biomass, productivity

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} year^{-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} year^{-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} year^{-1}, respectively. The high biomass accumulation potential makes *Eucalyptus* sp. a good prospect for timber, wood products and carbon sequestration projects. 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.

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 M 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 better water and nutrient use efficiency study will help to overcome the natural calamities and proper management and optimum utilization of water and nutrients for wood production. Therefore the present study was undertaken to assess water and nutrient use efficiency of *Eucalyptus* clones along with the commercial clones available in the market at present and the seed origin seedlings for comparison purpose.

MATERIALS AND METHODS

Experimental Material

To carry out the dry matter allocation study, Eucalyptus clones are selected as the experimental material. This includes 24 clones and two seed origin seedlings. Among the 24 clones, 16 clones are 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.

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. Growth parameters and physiological parameters were taken annually. During the half rotation period, biomass sampling has been 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 analyzed for various major nutrients. Dry matter production, volume and commercial volume of different 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.

RESULTS AND DISCUSSION

Dry Matter Production of *Eucalyptus* Clones

Biomass is a complex mixture of organic materials such as carbohydrates, fats and proteins along with small amounts of minerals such as sodium, phosphorus, calcium and iron, etc. The main components of plant biomass are carbohydrates (approximately 75%, dry weight) and lignin (approximately 25%), which vary with plant type. Biomass is the total quantity of organic matter produced at a particular point of time in an ecosystem. Such biomass studies are important in clonal forestry, especially in *Eucalyptus* clones to generate base line data for future studies. Biomass production is usually expressed on over dry basis and the same is being followed in this study.

The data collected on above ground, below ground and total biomass has been analysed with the help of SPSS statistical package and the results are presented. It was found that, across the locations, there is a significant difference among the clones with reference to the above ground, below ground and total biomass production in different clones for three years period i.e. from first year to half rotation period.

Above Ground Biomass (AGB) of *Eucalyptus* Clones

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 1st, 2nd and the half rotation period (3 years). The AGB of the sampled *Eucalyptus* clones is ranged from 2.55 kg tree^{-1} (C-124) to 5.48 kg tree^{-1} in C-186, with the mean of 4.03 kg tree^{-1}, during the first year. In the second year, lowest of 3.36 kg tree^{-1} was registered in C-124 and maximum of 7.45 kg tree^{-1} in C-188 with the mean of 5.36 kg tree^{-1}. 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 and these clones are forming a single group. On the other hand, clones of C-124, check clones 7, 1 and 2 are recorded the lowest above ground biomass production.

Below Ground Biomass of *Eucalyptus* Clones

The below ground biomass was minimum in C-124 with 0.58 kg tree^{-1} and maximum in C-186 with 1.25 kg tree^{-1} during the first year with the mean of 0.93 kg tree^{-1}. During the second year, C-124 recorded the lowest BGB of 0.76 kg tree^{-1} and C-188 recorded maximum BGB of 1.72 kg tree^{-1} with the mean of 1.24 kg tree $^{-1}$. The same trend was noticed in the third year also like in second year and 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.

Total Biomass Production of *Eucalyptus* Clones

In the case of total biomass production in the first year, C-124 recorded the lowest total biomass of 3.13 kg tree^{-1} followed by 3.36 kg tree^{-1} in check clone 7 and 3.76 kg tree^{-1} in check clone 1. Clone C-186 recorded the maximum total biomass of 6.73 kg tree^{-1} followed by 6.61 kg tree^{-1} in C-188 and 6.32 kg tree^{-1} in C-19 with the mean of 4.96 kg tree^{-1}. During the 2nd year, C-124 recorded the lowest total biomass of 4.13 kg tree^{-1} followed by 4.67 kg tree^{-1} in check clone 7. Clone C-188 recorded the highest total biomass of 9.18 kg tree^{-1} followed by 9.08 kg tree^{-1} in C-186 with the mean of 6.61 kg tree^{-1}. In the third year, 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 1: Above Ground Biomass, Below Ground Biomass and total biomass (kg tree^{-1}) production of *Eucalyptus* clones across the location in one year old plantation

Clone	AGB	BGB	Total Biomass
C 7	5.06$^{f\text{-}g\text{-}h\text{-}i}$	1.18 $^{e\text{-}f\text{-}g\text{-}h}$	6.24$^{g\text{-}h\text{-}i}$
C 9	3.96$^{e\text{-}f\text{-}g}$	0.89 $^{d\text{-}e\text{-}f}$	4.86$^{e\text{-}f\text{-}g}$
C 10	5.11$^{i\text{-}j\text{-}k}$	1.15 $^{g\text{-}h\text{-}i}$	6.25$^{i\text{-}j\text{-}k}$
C 14	5.10$^{i\text{-}j\text{-}k}$	1.12$^{g\text{-}h\text{-}i}$	6.22$^{i\text{-}j\text{-}k}$
C 19	5.17$^{j\text{-}k}$	1.15 $^{g\text{-}h\text{-}i}$	6.32$^{j\text{-}k}$
C 63	4.08$^{f\text{-}g\text{-}h\text{-}i}$	0.91$^{e\text{-}f\text{-}g}$	4.98$^{f\text{-}g\text{-}hi}$
C 66	4.35$^{d\text{-}e\text{-}f}$	0.98$^{d\text{-}e}$	5.33$^{d\text{-}e\text{-}f}$
C 100	3.13^{a}	0.73^{a}	3.86^{a}
C 111	4.39$^{e\text{-}f\text{-}g}$	1.12$^{g\text{-}h\text{-}i}$	5.52$^{f\text{-}g\text{-}h}$
C 115	3.36$^{a\text{-}b\text{-}c}$	0.75$^{a\text{-}b\text{-}c}$	4.11$^{a\text{-}b\text{-}c}$
C 123	5.11$^{i\text{-}j\text{-}k}$	1.11$^{f\text{-}g\text{-}h}$	6.22$^{i\text{-}j\text{-}k}$
C 124	2.55^{a}	0.58^{a}	3.13^{a}
C 186	5.48$^{j\text{-}k}$	1.25$^{h\text{-}i}$	6.73$^{j\text{-}k}$
C 187	4.92$^{f\text{-}g\text{-}h}$	1.12$^{e\text{-}f\text{-}g}$	6.04$^{f\text{-}g\text{-}h}$
C 188	5.37^{k}	1.24^{i}	6.61^{k}
C 196	4.23$^{f\text{-}g\text{-}h\text{-}i}$	0.96$^{e\text{-}f\text{-}g\text{-}h}$	5.20$^{f\text{-}g\text{-}hi}$
Check 1	3.02^{a}	0.74$^{a\text{-}b\text{-}c}$	3.76^{a}
Check 2	3.09^{a}	0.75$^{a\text{-}b\text{-}c}$	3.85$^{a\text{-}b}$
Check 3	3.21$^{a\text{-}b}$	0.78$^{a\text{-}b\text{-}c}$	3.99$^{a\text{-}b}$
Check 4	3.82$^{b\text{-}c\text{-}d}$	0.87 $^{b\text{-}c\text{-}d}$	4.69$^{b\text{-}c\text{-}d}$
Check 5	3.73$^{c\text{-}d\text{-}e}$	0.84 $^{c\text{-}d\text{-}}$	4.57$^{c\text{-}d\text{-}e}$
Check 6	3.54$^{b\text{-}c\text{-}d}$	0.83$^{c\text{-}d}$	4.36$^{b\text{-}c\text{-}d}$

Check 7	2.73^{a}	0.63^{a-b}	3.36^{a}
Check 8	3.44^{d-e}	0.84^{d-e}	4.27^{d-e}
Check 9	3.32^{a-b}	0.81^{a-b-c}	4.13^{a-b}
Check 10	3.51^{a-b}	0.86^{a-b-c}	4.37^{a-b}
Mean	**4.03**	**0.93**	**4.96**

Table 2: Above Ground Biomass, Below Ground Biomass and total biomass (kg tree^{-1}) production of *Eucalyptus* clones across the location in two old plantation

Clone	AGB	BGB	Total Biomass
C 7	6.67$^{f-g-h-i}$	1.55$^{e-f-g-h}$	8.23^{g-h-I}
C 9	5.23^{e-f-g}	1.18^{d-e-f}	6.41^{e-f-g}
C 10	7.09^{i-j-k}	1.59^{g-h-i}	8.69^{i-j-k}
C 14	7.09^{i-j-k}	1.56^{g-h-i}	8.65^{i-j-k}
C 19	7.03^{j-k}	1.56^{g-h-i}	8.60^{j-k}
C 63	4.93$^{f-g-h-i}$	1.09^{e-f-g}	6.03$^{f-g-h-i}$
C 66	5.73^{d-e-f}	1.29^{d-e}	7.03^{d-e-f}
C 100	4.22^{a}	0.98^{a}	5.20^{a}
C 111	6.10^{e-f-g}	1.56^{g-h-i}	7.66^{f-g-h}
C 115	4.57^{a-b-c}	1.01^{a-b-c}	5.59^{a-b-c}
C 123	6.17^{i-j-k}	1.35^{f-g-h}	7.53^{i-j-k}
C 124	3.36^{a}	0.76^{a}	4.13^{a}
C 186	7.39^{j-k}	1.68^{h-i}	9.08^{j-k}
C 187	6.49^{f-g-h}	1.48^{e-f-g}	7.97^{f-g-h}
C 188	7.45^{k}	1.72^{i}	9.18^{k}
C 196	5.88$^{f-g-h-i}$	1.34$^{e-f-g-h}$	7.22$^{f-g-h-i}$
Check 1	4.10^{a}	1.00^{a-b-c}	5.11^{a}
Check 2	3.75^{a}	0.91^{a-b-c}	4.66^{a-b}
Check 3	4.24^{a-b}	1.03^{a-b-c}	5.27^{a-b}
Check 4	4.61^{b-c-d}	1.05^{b-c-d}	5.67^{b-c-d}
Check 5	5.03^{c-d-e}	1.13^{c-d-}	6.16^{c-d-e}
Check 6	4.67^{b-c-d}	1.09^{c-d}	5.76^{b-c-d}
Check 7	3.79^{a}	0.88^{a-b}	4.67^{a}
Check 8	4.63^{d-e}	1.13^{d-e}	5.76^{d-e}
Check 9	4.38^{a-b}	1.07^{a-b-c}	5.45^{a-b}
Check 10	4.88^{a-b}	1.19^{a-b-c}	6.07^{a-b}
Mean	5.36	1.24	6.61

Table 3: 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**

Biomass is a measure of biological accretion, customarily expressed in weight. The biomass in trees is subdivided into above and below ground components with further subdivision of each. Above ground biomass includes foliage, branches, stem and bark. It is the total quantity of organic matter accumulated at a particular point of time in an ecosystem. It is axiomatic that the above ground biomass (AGB) increased with increase in diameter and height growth of different *Eucalyptus* clones in different locations. Dry matter production on unit area basis (MT ha^{-1}) for the different clones was worked out based on the data from sample clone on hectare basis. The salient observations made with regard to dry matter production on per hectare basis are discussed here under.

The results on dry matter production (AGB) in the present study revealed that, the difference between the highest and the lowest AGB was 91.6% i.e. the clone C-188 registered more AGB (10.52 kg tree^{-1} or 26.3 MT ha^{-1}) compared to the clone C-100 (5.49 kg tree^{-1} or 13.7 MT ha^{-1}), the lowest AGB recorded clone during the half rotation period. Further, this study showed that, the clones registered the maximum dry matter production (74.2% higher) compared the seed origin seedlings (15.10 MT ha^{-1}). In the case of below ground biomass (BGB), the difference between the highest (2.44 kg tree^{-1} or 6.1 MT ha^{-1}in C-188) and the lowest (1.26 kg tree^{-1} or 3.15 MT ha^{-1} in C-124) was 93.7%. Here also, the clones are produced 64.9% more BGB when compared to the check clone 9 and 10.

The same trend was observed in the total biomass production as well. Clone C-188 recorded the highest total biomass of 12.99 kg tree^{-1} (32.5 MT ha^{-1}) and Clone C-100 recorded the lowest total biomass of 6.77 kg tree^{-1} (16.9 MT ha^{-1}) and the difference is 92.3% between the highest and the lowest total biomass production in the different Eucalyptus clones, across the location during the half rotation period (3 years). Results from the field and controlled environment experiments with several tree crops suggest a linear association between total dry matter production and total solar radiation intercepted by the leaves during the growing season (Pereira, 1990). Variation in total leaf area and specific leaf weight accounted for approximately 94% of the variance in total dry matter production in *E. globulus* clones.

The mean annual increment from these 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.

Percentage Contribution of Various Biomass Components to AGB in *Eucalyptus* Clones

The above ground biomass (AGB) of the sampled *Eucalyptus* clones ranged from 5.49 kg tree^{-1} (in C-100) to 10.52 kg tree^{-1} in C-188 clone during the half rotation period, across the location. Clone wise individual biomass components *viz*. leaf, branches, commercial wood and root (BGB) were worked out from the sampled trees in all the four locations. Variation was observed for individual biomass components in *Eucalyptus* clones. Leaf biomass ranged from 0.77 kg tree^{-1} to 1.49 kg tree^{-1}; branch biomass varied between 1.22 kg tree^{-1} and 2.36 kg tree^{-1}; commercial wood ranged from 3.48 kg tree^{-1} to 6.67 kg tree^{-1} and root biomass ranged from 1.26 kg tree^{-1} to 2.44 kg tree^{-1}, for the *Eucalyptus* clones across the location. From the present study, it was observed that the bole accumulated greater amount of dry matter in all the clones, across the location ranging from 8.7 MT ha^{-1} in C-100 to 16.68 MT ha^{-1} in C-188. This observed range in AGB is well within the range reported for *C. equisetifolia* plantations in west coast of Kerala (42.3 to 89.7 MT ha^{-1}) by Vidyasegran (2003). These results are also in tune with reported by Jambulingam (1989) in *C. equisetifolia*.

It was observed, however, that among different biomass components, stem contribution to AGB is ranged from 51.2 to 53.4% followed by BGB (18.1 to 19.2%), branch (17.6 to 18.3%) and leaves (11.1 to 13.6%) in different *Eucalyptus* clones, across the location. The foliage makes up a comparatively large portion of the biomass in the young trees in the study (8.9–9.0% of the AGB). This fraction usually decreases with increasing plantation age, since the woody biomass will increase while leaf mass may remain roughly constant in closed canopy stands or decrease slightly (Laclau *et al*. 2000; Judd 1996). The contribution of the leaf mass to the above-ground biomass in a 7-year-old stand of *E. grandis* was 3.8% (du Toit *et al*. 2000).

Job *et al*. (2003) reported that the bark plus branch fraction made up between 41% and 43% of the woody biomass. In an age-series study on the same plantation, showed that the bark plus branch fraction decreased from approximately 58% in a 1-year-old stand to 19% in an 11-year old stand of *E. grandis*. The stem wood mass makes up a comparatively small percentage of the AGB at this young age (between 52.1% and 53.8%). The stem mass of *E. grandis* plantations in other studies at comparable stages of development constituted between 58% and 68% of the total biomass.

The portion of biomass contained in each structural component remained remarkably similar across treatments in our study. Ranges for structural components were very narrowly distributed around the mean: foliage (0.1%) branches and bark (1.6%); stem wood (1.6%) and coarse roots (0.7%). The biomass contained in each component was strongly related to the tree size (represented by dbh), irrespective of treatment. The narrow ranges explain why the treatment effect in the allometric relationships developed for scaling-up purposes was non-significant in all cases. Birk and Turner (1992) studied the response of 9.25-year-old *E. grandis* plantations to fertilization (single or repeated applications), weeding and insecticide treatments. Their treatments resulted in significant differences in the biomass of individual tree components, however, the ratio between above-ground biomass components remained similar.

Hunter (2001) tested the effects of irrigation and fertilization on tree growth and biomass partitioning. The main effect of fertilization resulted in significant increases in stem, bark and branches, but the percentage of biomass allocated to woody tissues or foliage remained virtually constant. However, there are also a number of studies that demonstrated shifts in biomass ratio's following specific treatments. In Hunter's (2001) study, irrigation resulted in a substantial increase in stem wood and stem bark. In addition, there was a shift in the partitioning of AGB reserves; allocation to foliage increased from an average of 13.4% in two heavily irrigated treatments, up to 17.2% in the control treatment. However, it was observed that, among the different biomass components, stem contribution to the agb recorded the highest i.e. almost half of the agb (73.60% to 96.30%) to the total biomass followed by branch and leaf.

Similar results are also reported by Singh *et al*. (2010), 76.8% in *E. teriticornis* and 72.9% in *Pithecellobium dulce*, Karmacharya and Singh (1992) in Teak and Wang *et al*. (1995) in *Populus tremuloides*.

Below Ground Biomass

Eucalyptus clones displays a well developed root system, which goes to a depth of 1.2 to 1.8 m. the lateral roots become congested and interwoven together. Studies carried out on biomass production in root system have shown that not considerable variation occurs in BGB during the half rotation period. In the present study, roots of felled trees were excavated (dry excavation method) and dry weight of root samples was estimated on oven dry basis. The dry matter accumulated in roots of sample trees was calculated on individual tree basis.

The dry weight of root of sampled clones ranged from 1.26 kg tree^{-1} to 2.44 kg tree^{-1} Uma *et al.* (2011) reported the range of BGB of 3.35 kg tree^{-1} in 3 year old *C. equisetifolia*. Similar observations were also reported by Negi and Sharma (1984) in *E. globulus* and Kushalapa (1988) in *E. hybrid*.

The percentage of bgb to total biomass ranged from 18.1 to 19.3%. Vidyasegran (2003) reported similar percentage of root biomass of *C. equisetifolia* from 18.97 to 22.5%. Buvaneswaran (2004) reported that the percentage of 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. From the above study, it was noticed that, the proportion of bgb is almost same percentage in all the clones during the half rotation period, across the location.

The results on dry matter production in the present study revealed that, the difference in AGB in different clones ranged from 5.49 kg tree^{-1} to 10.52 kg tree^{-1} during the half rotation period. The same trend was noticed in the BGB and total biomass production of different clones of *Eucalyptus* across the location. As discussed earlier, such variations in dry matter production of different *Eucalyptus* clones within the location of same age can be attributed to inherent genetic variation existing in the plantations.

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