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Evaluation of Eucalyptus Clones for Growth and Yield in Southern Region of Andhra Pradesh, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Eucalyptus is one of the most commonly planted forest species in the world due to its resilience to a variety of climatic and edaphic conditions as well as its use in the paper and pulp industry. The primary factor in the use of species at the farming and commercial levels in agroforestry is the higher productivity the species in a short time of 4-5 years. Superior clones are produced by Eucalyptus clonal trials at several areas, depending on the needs and performance. The present study was carried out to assess the growth and yield performance of Eucalyptus clones in southern region of Andhra Pradesh for identification of promising clones for the region. A clonal trial was established in the year 2012 with 49 clones to assess their suitability in the region. The results of growth performance on evaluation of these clones represents clone BCM-288 (13.9m) recorded higher tree height and the highest value of DBH belonged to clone BCM-23 (42.3 cm). The remaining clones had different ranks of DBH and height increments as compared to mean. The clone BCM-2169 recorded the maximum stem weight (125.8 kg/tree) and total above ground

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biomass (148.7 kg/tree) among the clones tested and clones BCM- 23 and BCM-571 recorded at par values. The clone BCM-27 recorded the least stem weight, foliage weight and above ground biomass proving to be a least performer among the clones tested. Therefore, in future, these promising clones (BCM-2169, BCM-23 and BCM-571) can be cloned for development and deployment of genetically superior clonal planting stock for reforestation, farming and Agroforestry projects in southern region of Andhra Pradesh.

Keywords: Eucalyptus clones; southern region; reforestation; mean annual increment; productivity.

1. INTRODUCTION

Eucalyptus sp. is distributed worldwide in various agroecological environments, from deserts to rainforests [1]. The Eucalyptus is one of the fast growing, evergreen genera of Myrtaceae family and native of Australia, but extensively cultivated in Brazil, India and China on a large scale on commercial plantations to produce raw materials for industry (pulp and paper, lumber, wood panels) and also on small plots for production of firewood and charcoal for domestic uses [2]. In India about 7.5 million hectares area is currently under eucalyptus plantations, which accounts for about 8% of the world's coverage [3]. The average annual productivity of natural forests in India is less than 2 m^3 ha^{-1}, while Eucalyptus plantations have an average annual productivity of 6-10 m^3 ha^{-1} in forests and 15-20 m^3 ha^{-1} in farmlands. The 7-year-old clonal trees have yielded 20 to 39 m^3 ha^{-1} yr^{-1} of wood, based on trials conducted in Andhra Pradesh [4]. Eucalyptus is the most suitable species for agroforestry plantations owing to its unpalatable characteristic, rapid growth rate, adaptation to extreme ecological situations including saline-alkali soil environment and drought [5,6]. Due to its versatility of providing huge income and stability of market price eucalypts is widely acceptance to grow by farmers [7]. Apart from that it is known for its carbon sequestration potential and for its higher organic matter production [8]. Due to its multiple benefits and adaptability farmers in coastal villages of Andhra Pradesh are increasingly opting for eucalyptus plantations, over traditional crops as they also struggle with water scarcity and groundwater salinity. Eucalyptus is being cultivated extensively on commercial lines in uplands of Nellore district in more than 50 thousand hectares. Due to the demand, different clones were introduced into the area. However, no clonal screening study has been conducted under this region for productivity. Hence present study was planned to evaluate the performance of different clones to assess their suitability to the southern region of Andhra Pradesh.

2. MATERIALS AND METHODS

This experiment was conducted at Agricultural Research station, Kavali in Nellore District, Andhra Pradesh, India. The field is located at 140.54'N latitude, 78^0.0'E longitude and at an altitude of 17 m above the mean sea level. The prevailing climate in Kavali region is known for its sub-humid climate with a mean annual rainfall of 1090 mm where 40% of rainfall occurs during June to September (South-West Monsoon) and 50% during the months of October-December (North East Monsoon) and rest during winter and summer months. The average temperature is 30.3°C, ranging from a maximum of 42.4°C to a minimum of 18.6°C. Kavali being coastal area experiences less seasonal variations in temperature though there is variation in rainfall pattern. The topography of the field was fairly uniform with a gentle slope. The soil in the area is red sandy loam and a composite representative soil sample was collected to study chemical properties of soil. The results of the soil analysis are given in Table 1.

The vegetation in the area includes kharif and rabi crops predominated with rice cultivation in agricultural land and the forests comprise deciduous, evergreen and degraded forest with less wasteland having scrub vegetationThe land was ploughed thoroughly to bring the soil to fine tilth and pits of 30 cm x 30cm x30 cm size were made in advance of planting. The clones were planted at a spacing of 2m x 2m. A uniform fertilizer dose of 30:50:80 g/plant of N: P205: K2O was applied at onset of monsoon during all the years. Irrigation was given as soon as the clones are planted in the main field and as per requirement depending upon the weather condition and soil moisture content. Weeding and Thinning was done manually during the initial stages of plant growth.To assess the suitable clones of Eucalyptus for this region a trial was conducted in the year 2012 at 2x 2 m spacing in a 10x 10 m plotwith forty-nine clones with planting of one seedling lot of eucalyptus following randomized block design having

Table 1. Result of chemical analysis of experimental field

Particulars	Values	Method of analysis
pH (1:2.5 soil: water)	6.4	pH meter method [10]
Organic carbon (%)	0.56	Rapid titration [11] as stated by Piper (1950) [12]
Available nitrogen (kg N ha^{-1})	170	Modified Kjeldahl's technique [10]
Available phosphorus (kg P ha^{-1})	17.4	Bray's method as stated by [10]
Available potassium (kg K ha^{-1})	162	Flame photometer method [10]

three replications. The Bhadrachalam (BCM) eucalyptus clones include viz., BCM– 571, BCM - 10, BCM - 147, BCM - 6, BCM - 271, BCM - 71, BCM - 99, BCM - 405, BCM - 286, BCM - 2169, BCM - 276, BCM - 404, BCM - 288, BCM -2154, BCM - 3, BCM - 128, BCM - 2070, BCM - 2135, BCM - 2145, BCM - 318, BCM - 2153, BCM - 274, BCM - 226, BCM -2170, BCM - 526, BCM - 290, BCM - 413, BCM - 266, BCM - 105, BCM - 2253, BCM - 7, BCM -23, BCM - 228, BCM - 406, BCM - 319, BCM - 2069, BCM -316, BCM - 206, BCM - 411, BCM - 285, BCM -2313, BCM - 2202, BCM - 2306, BCM - 27, BCM -273, BCM - 2045, BCM -272, BCM -130, BCM -132. The data on growth parameters and yield parameters were calculated based on the average data of 10 trees.The height of the clone was measured using a graduated Iron pole and expressed in metres. The DBH (Diameter at Breast Height) of the trees was measured using digital callipers and expressed in centimetres. The annual increment of height and girth of each clone was recorded at the end of each year. The data on final stem weight, foliage weight and total yield were recorded at the time of harvest after 4 years of study. The data were statistically analysed by standard ANOVA technique using outlined by Panse and Sukhatme [9] using the mean values to find out the significance.

3. RESULTS AND DISCUSSION

3.1 Plant Height

The height of Eucalyptus plantations has increased steadily over the ages from 2012 to 2014 and no further much increase in height of the tree were observed during 2015. The significant differences for tree height were observed among the clones (Table 2) during all the years of experimentation and the mean height of eucalyptus increased from 3.40m to 11.44 m from 1st year to 4th year. Among the 49 eucalyptus clones tested the height ranged in between 8.40 m and 13.9 m at the time of harvest. Among the clones BCM-2313 recorded consistently lower plant height during the four years of experimentation. The clone BCM-2154 (4.68m) and BCM-2070 (12.5m) recorded highest tree height during 1st and 2nd year respectively. During the 3rd and 4th year of experimentation it was clone BCM-288 which recorded significantly higher tree height of 13.7m and 13.9m respectively and most of the other treatments remained at par with higher values. Sharma et al. [13] and Ravula et al. [14] also made comparable observations regarding variations in plant height among the clones.

3.2 Diameter at Breast Height (DBH)

The significant differences for DBH were observed among the clones (Table 2) during all the years of experimentation and the mean DBH of eucalyptus increased from 9.69 cm to 31.84 cm from 1st year to 4th year. The DBH varied from 21.1 to 42.3 cm for different Eucalyptus clones evaluated at the time of harvest. Among the clones BCM-274 recorded lower DBH during the 1st year of experimentation and it was the clone BCM-27 which recorded lowest DBH during the remaining years of experimentation. Though different clones performed well during the initial years, it was clone BCM-23 (42.3 cm) which recorded significantly higher DBH over other clones being closely followed by BCM– 571 (41.9 cm), BCM - 288 (41.2 cm) and BCM - 2169 (41.1 cm). These results are in confirmation with results of Dhillon and Singh [15], Lal et al [16] and Singh and Dhillon [17] where they discovered that clones tested under the same conditions responded differently, which may be attributed to their genetic make-up.

3.3 Tree Biomass

In the present study, the data on stem weight, foliage weight and above ground biomass of tested clones were statistically analysed and presented in Table 2. The foliage weight of the eucalyptus clones ranged from 4.7 kg/tree to 26.0 kg/tree with an average of 12.05 kg/tree of foliage. Among the clones tested BCM-2202 recorded higher value of 26.0kg/tree, though recorded higher weight of foliage in BCM-2202 but its contribution for above ground biomass

Table 2. Effect of eucalyptus clone on tree height, DBH, stem weight, foliage weight and total biomass

Treatments	Plant Height (m)				DBH (cm)				Stem Weight (kg)	Foliage Weight (kg)	Total Biomass (kg)
	2012	2013	2014	2015	2012	2013	2014	2015	2015	2015	2015
BCM - 3	3.54	10.06	11.80	12.10	11.80	28.20	31.80	34.60	112.10	12.50	124.60
BCM - 6	3.76	7.77	10.23	10.32	13.30	22.20	24.00	26.60	33.20	8.40	41.60
BCM - 7	3.36	8.55	10.90	11.20	8.30	22.50	28.80	31.20	50.10	8.50	58.60
BCM - 10	3.92	8.50	10.83	10.88	10.40	25.80	30.00	33.30	69.30	12.60	81.90
BCM - 23	3.36	8.60	11.30	11.50	9.00	27.30	36.00	42.30	107.80	23.00	130.80
BCM - 27	3.72	7.10	10.90	11.00	8.50	16.50	19.00	21.10	30.60	4.70	35.30
BCM - 71	4.42	10.04	10.47	11.00	12.10	28.60	32.80	35.20	88.40	11.60	100.00
BCM - 99	4.10	10.00	11.50	11.80	11.80	26.40	30.80	33.00	75.20	6.70	81.90
BCM - 105	3.54	8.70	12.20	12.80	9.30	26.30	30.80	34.30	90.30	7.50	97.80
BCM - 128	3.96	10.10	11.70	11.90	10.10	20.50	32.50	37.40	112.00	13.50	125.50
BCM - 130	2.58	7.30	10.80	11.10	9.60	24.30	27.50	33.50	77.40	15.60	93.00
BCM - 132	2.33	7.40	11.00	11.30	8.80	24.00	30.70	36.30	80.80	8.70	89.50
BCM - 147	3.70	8.50	10.90	11.20	12.80	26.00	30.60	32.10	106.40	8.20	114.60
BCM - 206	2.22	7.50	10.53	10.60	9.30	22.20	25.30	26.50	94.20	10.20	104.40
BCM - 226	3.92	7.70	11.30	11.70	9.80	23.80	28.20	29.00	70.70	14.10	84.80
BCM - 228	2.78	7.40	11.50	11.90	6.60	24.50	30.00	35.90	92.80	14.10	106.90
BCM - 266	3.58	8.10	11.50	11.70	9.90	25.50	30.50	32.80	50.50	7.50	58.00
BCM - 271	3.78	9.00	10.50	10.90	11.30	23.00	27.60	28.80	44.50	5.80	50.30
BCM - 272	2.44	7.80	10.80	11.00	10.00	23.80	27.50	33.50	57.30	14.10	71.40
BCM - 273	3.22	7.10	10.53	10.60	8.00	18.30	22.30	26.00	35.50	7.60	43.10
BCM - 274	3.84	7.80	10.50	10.80	7.00	19.80	23.50	25.80	37.30	7.00	44.30
BCM - 276	3.22	8.00	10.50	10.70	7.70	21.00	24.80	28.30	63.70	11.10	74.80
BCM - 285	3.08	7.20	11.10	11.30	8.80	19.60	22.70	28.50	49.70	6.10	55.80
BCM - 286	3.86	9.60	10.93	10.98	9.80	23.50	25.30	27.50	77.10	6.50	83.60
BCM - 288	3.18	9.50	13.70	13.90	10.30	29.30	34.70	41.20	36.90	14.30	51.20
BCM - 290	4.04	10.00	11.00	11.40	9.60	25.80	29.80	32.20	68.50	8.30	76.80
BCM -316	2.50	7.60	11.00	11.30	8.60	19.00	21.00	25.00	82.50	8.50	91.00
BCM - 318	4.14	9.20	11.50	11.80	9.70	23.60	24.80	26.10	54.70	10.40	65.10
BCM - 319	3.22	7.10	11.20	11.40	8.00	19.00	22.50	24.70	53.80	14.30	68.10

Treatments	Plant Height (m)				DBH (cm)				Stem Weight (kg)	Foliage Weight (kg)	Total Biomass (kg)
	2012	2013	2014	2015	2012	2013	2014	2015	2015	2015	2015
BCM - 404	3.50	10.00	12.00	12.20	9.40	25.60	32.80	37.50	76.30	10.40	86.70
BCM - 405	3.80	10.60	11.10	11.50	10.90	28.20	32.40	35.20	78.80	12.40	91.20
BCM - 406	3.38	7.50	12.00	12.40	8.60	22.60	26.30	28.30	68.90	15.80	84.70
BCM - 411	3.04	7.90	11.00	11.30	9.80	21.00	23.50	27.70	56.60	7.10	63.70
BCM - 413	3.56	9.60	11.20	11.40	9.70	24.20	27.60	28.50	66.70	6.90	73.60
BCM - 526	3.44	10.00	12.40	12.90	10.90	26.80	31.20	33.90	76.60	5.90	82.50
BCM - 571	3.00	7.80	10.50	10.80	10.60	28.60	35.80	41.90	110.40	21.50	131.90
BCM -2045	3.42	6.80	10.73	10.80	9.10	17.80	21.00	26.50	75.20	18.50	93.70
BCM - 2069	2.76	8.60	11.80	12.10	8.60	24.80	28.30	33.30	98.80	17.90	116.70
BCM - 2070	3.98	12.50	11.80	12.20	10.60	26.80	31.20	34.10	78.00	13.80	91.80
BCM- 2135	3.88	11.00	11.10	11.50	10.00	25.40	29.20	32.00	87.00	9.60	96.60
BCM - 2145	3.58	10.20	11.40	11.80	10.70	25.40	29.80	31.70	81.50	12.50	94.00
BCM - 2153	3.14	10.60	12.50	12.70	10.90	27.60	34.20	36.70	88.00	25.90	113.90
BCM -2154	4.68	7.00	10.67	10.80	8.10	20.30	27.00	32.80	91.90	16.30	108.20
BCM - 2169	2.78	11.10	12.98	13.10	9.40	29.40	30.20	41.10	125.80	22.90	148.70
BCM -2170	4.40	9.40	11.40	11.70	10.40	27.20	28.00	33.40	75.90	7.00	82.90
BCM - 2202	2.56	8.10	11.70	12.00	10.70	25.30	28.50	33.30	94.60	26.00	120.60
BCM -2253	3.16	8.60	11.50	11.90	9.50	29.60	33.60	37.20	92.50	15.80	108.30
BCM - 2306	3.42	8.00	11.40	11.70	8.80	22.20	25.00	26.80	50.80	8.60	59.40
BCM -2313	1.88	7.10	7.33	8.40	8.30	18.00	21.50	26.00	38.20	14.70	52.90
Mean	3.40	8.68	11.14	11.44	9.69	24.0	28.22	31.84	73.79	12.05	85.85
F-Test	S	S	S	S	S	S	S	S	S	S	S
SEd(±)	0.18	0.52	0.88	0.80	0.97	3.07	3.65	3.20	6.90	1.96	7.08
CD(P=0.05)	0.51	1.46	2.48	2.23	2.71	8.62	10.24	8.97	19.37	5.50	19.87

was less. Similar observations of less contribution of leaf weight when compared to stem weight for total above ground biomass was also noticed by Saravanan [18] and Divya et al [19]. The average value of stem weight and total biomass recorded among the clones tested was 73.79 kg/tree and 85.85 kg/tree respectively. The treatment BCM-2169 recorded significantly higher stem weight (125.8 kg/tree) and total above ground biomass (148.7 kg/tree) being statistically at par with BCM-23 (107.8 and 130.8 kg/tree) and BCM-571(110.4 and 131.9 kg/tree) clones. However, the clones BCM-3(112.1 kg/tree) and BCM-128 (112.0kg/tree**)** also recorded at par stem weight with clone BCM-2169.The significant increase in above ground biomass in BCM-2169 may be attributed to higher stem weight of the tree and similar observation of higher contribution of stem weight to total above ground biomass was also reported by Saravanan 2019. Numerous research has documented the eucalyptus clones performance and those research' findings indicate that, considerable changes in growth and yield among eucalyptus clones may be attributed due to environmental and genetic variables [13,20].

4. CONCLUSION

Based on the performance of the tested clones, BCM-2169 was found to be the best performer and BCM-27 to be the least performer in terms of total biomass and stem weight. The top performer's clones, BCM-23 and BCM-571, also produced data on par with them. For the production and deployment of genetically superior clonal planting material for reforestation, agricultural, and agroforestry initiatives in the southern part of Andhra Pradesh, these promising clones (BCM-2169, BCM-23, and BCM-571) can be cloned.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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