Selection of site specific *Eucalyptus camaldulensis* and *Eucalyptus tereticornis* clones for Ariyalur region (Tamil Nadu) based on its higher Productivity

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Abstract

Eucalyptus camaldulensis clones were shortlisted based on individual tree superiority observed in the multi-location clonal trials for growth attributes like height, girth at breast height and volume through Index selection method. These clones were planted along with commercially planted clones in southern peninsular India , seedlings raised from improved seed orchard source and genetically poor seedlings procured locally during the year 2009. The above clones and seedlings were planted near Nachiarpettai located near Ariyalur (Tamil Nadu) to identify the best performing site specific clones in Tamil Nadu. It falls in the range of 11° 07’45.91’’N latitude to 79°13’15.94’’E longitude. The growth parameters like height, girth at breast height and its volume were recorded up to 3 years. The results confirm that the clones are best selected and tested in environments similar to those where they will be deployed. Ranking of the 33 commonly planted clones and two seed lots showed that Clone C31, C9, C196 and C17 were consistently superior in their growth performance when compared to all other clones, seed lots and some of the commercially cultivated clones with respect to height, girth and volume although the sequence changed for each characters. Based on the study it was concluded that the clones viz., Clone C31, C9, C17 and C196 are best

suitable for the area in and around Nachiarpettai (Ariyalur) having the same soil property (Sandy loam) and climatic conditions.

Key words: *Eucalyptus camaldulensis,Eucalyptus tereticornis*, clone, site specific, repeatability, deployment

1. 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 $35m^{-3}ha^{-1}year^{-1}$ 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 timber construction. Being endemic to Australia, Southeast Asia, and the Pacific, eucalypts are grown mainly as exotic species (Davidson, 1995; Stape *et al.*, 2010; Stape, 2002; Liu and Li, 2010; ICFRE, 2010).

Eucalyptus, in India, is believed to be introduced in 1790 and growing them as plantations started in the latter half of the nineteenth century (Wilson, 1973). Some 170 species, varieties and provenances of eucalyptus were tried in India (Bhatia, 1984). Of which, *Eucalyptus camaldulensis* and *Eucalyptus tereticornis* were found to be well suited for arid low elevation regions of India and these two species account for around 90% eucalypts grown in the country. Worldwide, Eucalyptus species are being planted for pulp and paper production. India is one of the world leaders in Eucalyptus plantations with an area of 3.94 million hectares (Chezhian *et al.*, 2010). Furthermore, clonal forestry has improved productivity in terms of increased volume of wood (Lal 2003). Mean annual increments of clone plantations of *Eucalyptus sp*. with no fertilization, with fertilization and fertilization combined with irrigation are 33, 46 and 62 $m^3ha^{-1}year^{-1}$, respectively (Stape *et al*., 2010). However, clones selected for improved morphological traits such as fast growth, have been found to display a significant variation within and between clones in their intrinsic wood quality traits (Gomide 2009; Rao *et al.*, 2002; Raymond *et al.*, 2009).

In South India especially in Tamil Nadu, Puducherry and Karnataka until 1999, the Eucalyptus plantations were raised mainly through seedlings of *Eucalyptus tereticornis* and

Eucalyptus camaldulensis with high variability results in low yield. In order to increase the yield per unit area, clonal technology was developed in Eucalyptus through shoot cutting methods which would yield 3 to 4 times more than the present yield that is from 6-10 m^3 /ha/yr to 20 -58 m^3 /ha/yr.

The clonal approach to plantation improvement is to identify a number of individual trees, by replicated tests in target environments conducted over several years, that are superior in one or more desired combination of traits such as tree form, wood quality, rate of growth, tolerance to drought, salinity, etc., and to reproduce them vegetatively. Clones are essentially vegetative propagules and the ramets produced by rooted cuttings will be identical to the parent material. High genetic gain in a shortest possible period of time is achieved through development of clone in tree improvement programme**.** This leads to creation of clonal plantation with superior traits as that of their parent material.

Considering the importance of clonal technology, Institute of Forest Genetics and Tree Breeding (IFGTB) has raised three clonal trials of *E. camaldulensis* and *E. tereticornis* at Sathyavedu in Andhra Pradesh, at Karunya in Tamil Nadu and Panampally in Kerala using 126 clones selected from seed orchards established since 1995. Out of the 126 clones, 31 best clones have been short listed and selected for future development. Some of these clones are performing far better than the commercial clones presently planted by various user agencies. These short listed 31 IFGTB clones, two commercial clones and also seedlings (both from IFGTB seed orchard and local seed source) need to be tested for their performance to identify the clones suitable for particular location. This will help SFDs, forest corporations, wood based industries and farmers to improve the productivity. Hence this study aims at

development of site specific clones/progeny for the area in and around Nachiarpettai located in Ariyalur (Tamil Nadu).

2. Materials and Methods

As a part of the breeding program, 31 superior clones were selected from first generation provenance trials and seed production areas established during 1996 using the seeds received from CSIRO. The selections were carried out basically through index selection method. The height and diameter at breast height and straightness were given more importance during the selection process. These selected clones were multiplied during 2009 and clonal trial was established at Nachiarpettai, Ariyalur district of Tamil Nadu (11° 07'45.91''N; 79°13'15.94''E) during September 2010. The soil texture is sandy loam soil having the pH of 5.6, EC 0.03ds/m, organic carbon 1.5, Bulk density 0.8, N-202.6 kg/ha,P-21.7 kg/ha and K -111.6 kg/ha.

All the selected 31 Clones viz.,C7, C9, C10, C14, C16, C17, C19, C23, C26, C31, C52, C53, C63, C66, C69, C70, C86, C100, C101, C111, C115, C118, C123, C124, C131, C186, C187, C188, C191, C196, C198 were tested along with two of the commercially planted clones viz., ITC- 3, ITC-7 and two seed lots 301 (Orchard seeds) and 302 (local seed source). Trial was laid in Randomized Block Design with about four replications and 16 ramets (4 x 4 blocks) in each replication in the trial (Fig-1).

Sufficient care was taken in selection of site for establishment of the trial. The rainfall and temperature data was recorded and soil characters tested for the selected site. At the same time, uniformity within the trials plot was ensured.

Trees were planted at 3 x 2 meter spacing after a disc plough using heavy duty tractor. Weeding was carried out twice a year before rain. Watering was restricted to planting and

initial period of establishment. Fertilization and soil amendments were also restricted to initial planting season.

Every year, growth traits were recorded before rain. Periodic inspections were carried out once in six months for observing any other pest and disease incidence.

Table 1: Pedigree details of the clones

Clone ID	Source population	Species
C7, C9, C10, C14, C16, C17, C19, C23, C26 & C31	Satyavedu SSO	*Eucalyptus camaldulensis*
C52 & C53	Progeny Trial, Puducherry	*Eucalyptus camaldulensis*
C63, C66, C69, C70 & C86	SPA, Pudukkotai	*Eucalyptus camaldulensis*
C100, C101, C111, C115, C118, C123, C124 & C131	PRS, Pudukkotai	*Eucalyptus camaldulensis*
C154	Pudukkottai SSO	*Eucalyptus camaldulensis*
C186, C187, C188, C191 & C196	Panampally SSO	*Eucalyptus camaldulensis*
301	IFGTB seed origin	*Eucalyptus camaldulensis*
302	Local seed origin	*Eucalyptus camaldulensis*
303	ITC3	*Eucalyptus camaldulensis*
307	ITC7	*Eucalyptus camaldulensis*

3. Results

3.1. Analysis of Variance

The growth characters like height and girth at breast height were recorded at every 12 months interval. The first growth measurement was taken 12 months after planting followed by 24 and 36 months. Height was measured using haga altimeter and girth was measured using measuring tape. Volume was estimated using the measured height and the girth at breast height. The cross section area was calculated and multiplied with height to calculate cylindrical volume and further multiplied with form factor to arrive at the actual volume. In the present case, 0.55 was kept as form factor value based on earlier studies conducted. The

data was analysed using GENSTAT 5. Variance for replication, ramet and clonal spectrum was calculated for all the three traits.

The trial was analyzed separately for every year growth traits. Clone mean was calculated and statistical significance was tested. Standard error of mean and least significant difference were also calculated for all three years and given in table from 3 to 4.

The clones were significantly different among themselves for all the traits and years. Clones with high mean values and their relative superiority over other clones can be compared using LSD values given in each tables (2 & 3).

ANOVA for growth traits
Table -2

Locality	df	Treatment SS	Treatment MS	EMS	F Value	F Pro.
Girth (I year)	34	2303.398	67.747	2.398	28.25	<.001
Girth (II year)	34	21023.13	618.33	18.66	33.13	<.001
Girth (III year)	34	51402.39	1511.83	48.79	30.99	<.001
Height (I year)	34	347.0031	10.2060	0.2869	35.57	<.001
Height (II year)	34	1593.214	46.859	1.324	35.38	<.001
Height (III year)	34	5149.229	151.448	4.852	31.21	<.001
Volume (I year)	34	0.770E-04	0.226E-05	0.162E-06	13.94	<.001
Volume (II year)	34	0.03277527	0.00096398	0.00003609	26.71	<.001
Volume (III year)	34	0.6420057	0.0188825	0.0007539	25.05	<.001

Table-3. Growth attributes of Eucalyptus Clonal Trial at **Ariyalur**

Clone	Height 1 (m)			Girth (cm)			Volume (Cu. m).		
	I year	II Year	III Year	I year	II Year	III Year	I year	II Year	III Year
C7	1.97	6.22	11.23	5.68	17.05	27.00	0.0003	0.009	0.039
C9	2.83	7.15	12.89	7.35	21.72	**33.83**	0.0007	0.016	**0.072**
C10	1.29	4.88	8.80	3.88	11.32	17.78	0.0001	0.005	0.020
C14	1.63	5.24	9.34	4.72	14.26	21.89	0.0002	0.006	0.024
C16	2.18	5.60	10.23	5.13	15.18	23.68	0.0003	0.007	0.029
C17	2.20	7.35	**13.15**	6.87	20.06	31.17	0.0005	0.015	**0.068**
C19	2.24	6.89	12.28	6.69	20.54	31.80	0.0004	0.013	0.057
C23	2.36	7.01	12.81	6.43	19.50	30.42	0.0005	0.014	**0.062**
C26	2.21	6.35	11.38	5.43	15.85	24.56	0.0003	0.008	0.034
C31	2.82	7.62	**13.68**	7.71	23.47	**36.68**	0.0008	0.020	**0.089**
C52	2.24	6.76	11.97	6.69	19.75	30.93	0.0005	0.012	0.054
C53	2.34	6.84	12.25	5.74	17.42	27.65	0.0004	0.010	0.045
C63	2.46	6.25	11.17	5.13	15.48	24.42	0.0004	0.009	0.039
C66	2.57	6.73	12.05	5.77	17.30	26.92	0.0005	0.011	0.046
C69	1.88	5.48	9.72	3.99	12.03	18.90	0.0002	0.004	0.019
C70	1.88	6.28	11.26	5.28	15.82	24.69	0.0003	0.008	0.035
C86	1.68	4.74	8.34	3.76	11.13	17.41	0.0002	0.004	0.017
C100	1.99	5.56	9.88	4.64	14.06	22.20	0.0002	0.006	0.026
C101	2.28	6.08	10.91	5.28	15.94	24.96	0.0004	0.009	0.040
C111	2.08	5.31	9.51	4.91	14.49	22.59	0.0003	0.007	0.030
C115	2.08	5.71	10.39	4.78	14.25	22.15	0.0003	0.006	0.028
C118	2.71	6.96	12.50	6.29	18.73	29.59	0.0005	0.011	0.050
C123	1.83	5.44	9.73	4.75	14.23	22.27	0.0002	0.006	0.026
C124	2.29	6.46	11.67	5.45	16.30	25.62	0.0003	0.008	0.036
C131	1.81	5.70	10.21	5.05	14.95	23.62	0.0003	0.007	0.033
C186	2.17	6.84	12.25	6.09	18.32	28.58	0.0004	0.011	0.048
C187	2.11	5.71	10.20	5.10	15.35	24.03	0.0003	0.007	0.030
C188	1.63	5.93	10.74	5.10	15.20	23.74	0.0002	0.007	0.032
C191	2.46	7.23	12.99	6.44	19.27	30.53	0.0005	0.013	0.057
C196	2.49	7.65	**13.56**	6.61	19.50	30.49	0.0005	0.014	**0.062**
C198	1.71	6.49	11.52	5.70	17.01	26.16	0.0003	0.009	0.039
301	2.40	6.62	11.97	6.17	18.73	29.21	0.0004	0.011	0.049
302	1.72	5.55	9.98	4.65	13.93	21.50	0.0002	0.006	0.024
303	2.40	7.01	12.54	5.87	17.40	27.49	0.0004	0.010	0.045
307	1.06	3.98	7.15	3.08	9.09	14.23	0.0001	0.002	0.011
Total	2.13	6.26	11.23	5.54	16.57	25.91	0.0004	0.009	0.041
SEd	0.09	0.20	0.39	0.27	0.76	1.24	0.00008	0.001	0.005
LSD	0.19	0.40	0.76	0.54	1.50	2.42	0.0002	0.002	0.010

The result revealed that clone no 31,9, 19 and 17 are having maximum girth at breast height (gbh) ie., 36.68 cm , 33.83 cm, 31.80 and 31.17 respectively compared to all other clones in this location. As far as height is concerned clone no 31, 196 and 17 are having maximum height growth than all other clones. Considering the volume production as major criteria clone no 31, 9 , 17 and 196 are best suitable clones to plant in sandy loam soil in Nachiarpettai, Ariyalur area as they recorded maximum volume of about 0.089, 0.072, 0.068 and 0.062cubic meter respectively.

3.2. Analysis of different Genetic Tests

Clonal repeatability is used to estimate gain possible from clonal selection. Knowing these estimates helps to set up selection criteria for visual evaluation, which increases selection efficiency and reduces the risk of losing superior genotypes. The repeatability was calculated for height, diameter and volume using third year growth parameters.

The genotypic, phenotypic and error variance components were calculated based on the plot mean values using SPAR 2.0 .The results are given below.

Phenotypic and genotypic co –variance values and repeatability values for height, girth and volume

Traits	**PCV**	**GCV**	**Repeatability**
Height	15.83	10.53	0.442
GBH	20.75	13.98	0.454
Volume	50.26	32.86	0.427

The repeatability values were found to be high for all the studied traits viz., height, diameter and, volume.

4. Discussion

The proportion of improved genetic material to the total planting material used for raising new plantations in India is meagre. Clonal plantations promise vigorously growing plants with high levels of uniformity in growth. New clones have to be regularly developed through selection and testing to sustain and improve the current productivity of eucalypt plantations. The present study is an effort in that direction and is one involving large number of clones of *E.camaldulensis* and *E.tereticornis* from a broad genetic base deployed in the field trial may account for the substantial number of superior new clones identified.

Although plantation companies and other organizations have identified many clones suitable for planting, availability of plants and user preference has resulted in use of only a few clones. It is common to come across hundreds of hectares planted with a single clone. The widespread damage due to gall incidence caused by *Leptoceyba invasa* Fisher & La Salle (Jacob *et al*., 2007), especially in clonal nurseries and plantations has made planters to realize the necessity to have sufficient genetic diversity in the planting material used. In this context, even those clones which were found to be on par with the commercial clones or slightly inferior to them will be preferred to increase the number of clones deployed in clonal plantings.

Significant differences in wood quality among clones provide an opportunity to select superior clones for solid wood production that combine superior growth with desirable wood traits which can be used in further breeding programmes. Higher genetic gains can be achieved when selected clones are deployed in the field. The selection of clones with low growth strain and volumetric shrinkage could be an important step (Sakthi Chauhan and Pankaj Aggarwal, 2011).

Wei Zhongmian *et al.*, (2009) evaluated the growth comparison of eight year old *Eucalyptus* clones **(***Eucalyptus urophylla* × *E. grandis* clones 3229, 30-1 and *E. urophylla* clone U6) and revealed that, *Eucalyptus* clones showed high growth rate during the first three years. There were significant differences amongst the 3 Eucalyptus clones in plant height, diameter and volume growth. These indexes were positively correlated with the increasing age. Clone 3229 showed best growth followed by 30-1, while the U6 grew worst.

The significant G x E interaction observed among clones/seed origin on test site in the present study indicates that clones have to be tested in target environments before deploying in plantations (Oballa *et al*., 2005). Twenty four commercially available clones tested in three contrasting sites in Haryana State, India showed site-depended differences among clones for growth trait (Karur and Saxena, 2002). In the present study, most of the clones outperformed the local seedlots and commercial clones at comparatively dry environment (Ariyalur).

The regression coefficients obtained from joint regression analysis for volume indicated the differential behaviour of the clones in the test site. This technique proved to be very effective in emphasizing the trend of the family responses to range of environments (Finaly and Wilkinson, 1963; Barnes *et al*., 1994). In Colombia, the variation caused by site effect was very high in *E. grandis* (Osorio *et al.*, 2001). On account of the clone × site interactions, adopting a site-specific selection and deployment strategy was estimated to provide 15% greater wood mass yield across the region compared with a generalised selection and deployment strategy (Luo JZ *et al.*, 2012). Among the 22 clones of *Eucalyptus camaldulensis* planted in the clonal trial at Badami (Karnataka) clones Clone C- 10,19,188 are performing better than all other clone planted in that particular location having same soil property (sandy loam) and climatic conditions (Vijayaraghavan *et al.*, 2015). The fact that

most clones outperformed the provenance seedlots at comparatively waterlogged condition (Karaikkal); whereas some clones were inferior to the best provenance seedlot demonstrates that clonal selections should not be transferred to contrasting environments without thorough testing (Vijayaraghavan *et al.*, 2016).

4.1. Selection and Genetic Gain

There are few reports on genetic parameters from clonal trials in Eucalypts in general and in particular *E.camaldulensis* and *E.tereticornis*. The clonal repeatability values obtained for growth and wood density in the present study are comparable to those reported for *E.grandis* clones (Osorio *et al*., 2001). They are also higher than narrow sense heritabilities reported for eucalypts from progeny tests (Malan, 1991; Wei and Borralho, 1998; Hedge, 2002; Apiolaza *et al*., 2005) indicating presence of considerable non-additive genetic variation.

Clonal repeatability increased over years consistent with previous reports on heritability for Eucalyptus species (Wei and Borralho, 1998; Osorio *et al*., 2001). Wood density had a higher clonal repeatability at the age of 3 years than 6 years. This may be due to genotypic instability to the change in environments or the differences in the sampled clones. Since the increase was slower after third year compared to previous years, this age which is half-rotation age for eucalypt plantations in India is suitable for selecting clones and predicting genetic gain through their deployment. This is also supported by the strong age-age correlation between growth in 3 and later years. Osorio *et al*., (2001) also recommended 3 years as the optimal selection age for *E. grandis* clones based on age-age and trait-trait correlations. Superior clones of *E. camaldulensis* identified in the trial reported here are likely to play an important role in future breeding programme.

5. Conclusion

This study has clearly shown that selection of clones for a particular site is very important to get maximum productivity of clonal eucalypt plantations in and around Nachiarpettai of Ariyalur district (Tamil Nadu). In addition, this study demonstrated that there would be clear benefits, with respect to productivity of a large eucalypt plantation to pursuing site-specific selection and deployment strategies for the high productive clones. Although implementing such a strategy could require significant investments in field trials, for larger growers with plantations spread across site types, the benefits with respect to increased clonal plantation with site specific clones would be more beneficial. In the present study, ranking of the 33 commonly planted clones showed that Clone C31, C9, C196 and C17 were consistently superior with respect to height, girth and volume although the sequence changed for each character. All these clones viz., C31, C9, C196 and C17 are observed to be superior in their growth performance when compared to commercially cultivated clones. The results confirm that the clones are best selected and tested in particular environment and they will be deployed in larger area having similar environmental conditions.

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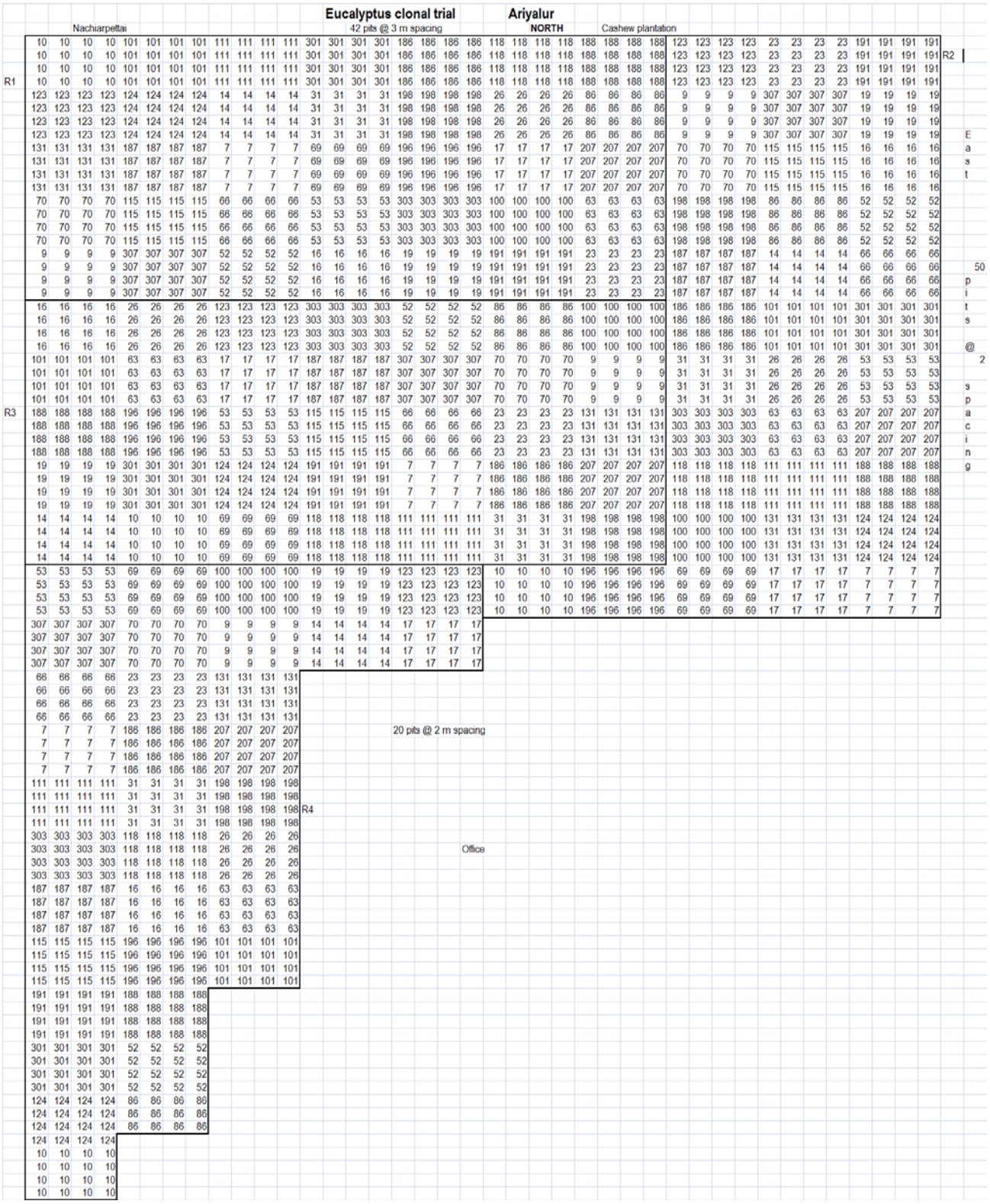
Fig. 1. RBD Design(four replications)of Eucalyptus clonal trial established at Ariyalur during September, 2010



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