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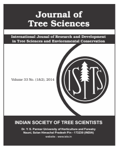

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Characterization of Physiological Efficiency and Gall Tolerance of Eucalyptus Clones Under Field Conditions

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Arid, Clonal variation, Eucalyptus, Gall infestation, ITC, Photosynthesis

ABSTRACT

Twenty five commercial clones of Eucalyptus, planted by farmers in different parts of the country were screened for their physiological parameters and gall infestation under field conditions. Twenty clones showed high water use efficiency while clones ITC 122, 228 and 248 were free from attack of gall. Clone ITC 227 was found suitable for improved yield in arid areas. These clones are recommended for further breeding and development of new varieties in clonal forestry.

INTRODUCTION

Eucalyptus, one of the most widely planted trees in many tropical countries occupies about 13 million hectares in India. They have rapid growth rates, less suspectibility to diseases and can adapt to a wide range of climatic and edaphic conditions. *Eucalyptus* trees have wide adaptation to adverse environments and occur naturally within or near coastal or inland sites, where soils are generally nutrient poor. Depending on the provenances, *Eucalyptus* exhibits good tolerance to stress such as drought, salinity, low temperature and prolonged inundation (Butt et al. 2013).

Clonal materials help in developing individuals true to type, uniform and with all the superior desirable characteristics of the elite mother trees. Gains can be made from existing natural variations and genetic superiority of trees through cloning. Clones can be developed and large scale commercial plantations can be raised aimed at higher productivity or adaptability to specific sites including problematic soils. Productivity of clonal Eucalyptus plantations is 2 to 3 times higher compared to normal seedlings on comparable sites and a very large number of farmers have harvested more than 250 tonnes per ha at 5 year rotation with mean annual increments around 50 $m^3ha^{-1}y^{-1}$ (Lal 2007). High yielding clonal Eucalyptus plantations on marginal agricultural lands have helped farmers earn substantial income and also provided high quality poles and pulpwood to the wood based pulp paper units (Lal 2008).

The estimated annual production of wood from forests in India is 3.17 million cum (FSI 2011). Contribution of wood supplies from trees outside forests, comprising largely of agroforestry plantations, is many times larger with potential production of wood estimated at 42.77 million cum per year.

According to industry sources, the projected demand for paper will increase to 24 million tonnes per year by 2025 and domestic production is likely to contribute 22 million tonnes annually. Assuming similar trends in growth of all the three sectors of paper industry, wood based production during 2025 is projected at 6.1 million tonnes. That will require nearly 24.4 million tonnes of freshly harvested debarked pulpwood annually (Kulkarni 2014). Due to low productivity of the seedling raised plantations, clonal forestry has been adopted for Eucalyptus, a major raw material of the paper industry, in India, and a large number of clones have been developed for commercial planting (Jayaraj et al. 2014). There are more than 1000 clones now available in the market, planted and promoted by the pulp and paper industries. Clonal farming of the species is highly remunerative yielding 70-100 MT ha^{-1} on a 5-year rotation, currently fetching about Rs. 1,50,000 ha^{-1}.

The demand for genetically superior clonal planting stock of *Eucalyptus* is, therefore, continuously growing and extent of area under clonal Eucalyptus plantations is expected to expand very fast. Majority of the *Eucalyptus* plantations in India will be based on genetically improved clonal planting stock .Therefore, the economic stakes in clonal plantations will continue to grow and with that the challenges / opportunities before the scientists for continuously developing and testing new and still better clones will also multiply. Eucalyptus clones like 3, 6, 7, 10 and 27 developed at Bhadrachalam formed the basis of initial clonal plantations since 1992. These clones are still popular with the farmers (Lal et al. 1997) Presently the most important commercial clones are - 3, 6, 7, 10, 27, 71, 72, 99, 105, 115, 122, 128, 130, 223, 265, 266, 271, 272, 273, 274, 175, 277, 284, 285, 286, 288, 290, 292, 316, 319, 405, 411, 412, 413, 417, 439 and 470. The most adaptable clones for alkaline soils are - 1, 10, 27, 71, 99, 105, 115, 116, 122, 128, 130, 158, 223, 266, 271, 272, 273, 274, 277, 290, 316, 318, 328, 410, 411, 412, 413 and 417. The plastic clones are - 27, 71, 83, 99, 105, 116, 128, 130, 147, 271 and 285. The outbreak of diseases caused by various fungi on *Eucalyptus* in nursery and field revealed main pathogens as *Cylindrocladium* spp. and *Alternaria* spp. The fungal disease resistant clones short-listed are 1, 3, 6, 7, 288 and 316.

Eucalyptus has a very satisfactory health record in India concerning insect pests. However, *Leptocybe invasa* Fisher and La Salle, a gall inducing insect (Mendel et al. 2007) attack on *Eucalyptus* was reported in 2002 is posing a great threat to *Eucalyptus* clonal forestry. *Eucalyptus* gall (Jacob et al. 2007) caused by L. invasa created havoc in nursery and plantations in the year 2008-09. ITC clones 1, 6, 7, 320, 411, 413, 513, 612, 2008, 2145, 2253, 2254, 2306 and 2313 are found free of gall attack amongst 107 Bhadrachalam clones of *Eucalyptus.* Clones such as ITC 10 and 27 are found to be highly susceptible (Kulkarni, 2014). The aim of the paper was to characterize selected commercial clones of *Eucalyptus* in terms of their growth parameters, photosynthesis, stomatal conductance, chlorophyll content and response to gall infestation.

MATERIALS AND METHODS

Twenty five commercial clones of *Eucalyptus* (Table 1) assembled at the clone bank of Institute of Forest Genetics and Tree Breeding, Coimbatore, India were selected for characterization of physiological efficiency and gall tolerance. Gas exchange characteristics viz., net photosynthetic rate (Pn), stomatal conductance (gs), intercellular CO_2 concentration (Ci) and transpiration rate (E) were measured using a Portable Photosynthesis System, LiCOR 6200. The measurements were taken between 9.30 am and 11.30 am under cloud-free conditions. Three observations each from three ramets per clone were recorded for all the physiological parameters. Intrinsic water use efficiency was estimated as the ratio of net photosynthetic rate to stomatal conductance (Pn/gs), whereas, instantaneous water use efficiency was estimated as the ratio of net photosynthetic rate to transpiration rate

(Pn/E). Intrinsic carboxylation efficiency was derived as the ratio of net photosynthetic rate to intercellular CO_2 concentration (Pn/Ci). For chlorophyll estimation, 100 mg of needles freshly collected, were ground in 80 per cent acetone and absorption of the clear supernatant measured at 645 nm and 663 nm. Calculations were made as described in Arnon (1949). Total height, collar diameter and biomass index were recorded to understand the growth performance.

The variation in gall infestation was assessed in terms of number of leaves affected, number of galls, number of galls / leaf, size of the gall and the stage of the gall. The clones were graded using point grading method assigning a score to each of the assessed character (Jayaraj et al. 2014).

All experiments had a complete randomized design. Data obtained was subjected to Analysis of variance (ANOVA) and means separation done by Duncan's Multiple Range mean separation test (DMRT) using the SPSS Ver.10.0 package wherever significant. Cluster analysis based on the different biochemical parameters in relation to height, diameter and volume was done to find linear combinations to discriminate between the groups.

RESULTS AND DISCUSSION

ANOVA revealed that there were no significant variation among the clones in Net photosynthetic rate (Pn), Stomatal conductance (Gs), Intercellular CO_2 concentration (Ci) and Transpiration rate (E). Table 1 revealed that photosynthetic rate ranged from 13.32 To 23.67 μmol m^{-2} s^{-1} Stomatal conductance ranged from 90.43 To 189.50 mol m^{-2} s^{-1}. Intercellular CO_2 concentration ranged from 111.43 To 215.70 μl l^{-1} while transpiration rate ranged from 2.61 To 3.78 mmol m^{-2} s^{-1}.

Table 1: Gas exchange parameters of 25 Eucalyptus clones

S.No	Clone	Net photosynthetic rate (Pn) (μmol m^{-2} s^{-1})	Stomatal conductance (Gs) (mol m^{-2} s^{-1})	Intercellular CO_2 concentration(Ci) (μl l^{-1})	Transpiration rate (E) (mmol m^{-2} s^{-1})
1.	ITC 1	23.67	103.97	215.70	2.89
2.	ITC3	16.35	107.37	149.83	3.03
3.	ITC 4	16.11	90.43	152.87	2.61
4.	ITC 6	15.91	160.70	180.47	3.19
5.	ITC 7	16.17	164.78	174.27	2.82
6.	ITC 8	15.71	149.90	170.40	2.91
7.	ITC 10	17.39	152.67	163.00	2.79
8.	ITC 71	15.70	144.67	111.43	3.25
9.	ITC 99	19.18	166.60	178.07	3.50
10.	ITC116	17.40	183.53	139.63	3.53
11.	ITC122	13.32	173.90	150.83	3.71
12.	ITC128	14.79	156.17	146.60	3.66
13.	ITC130	14.31	152.70	193.97	3.71
14.	ITC132	16.31	163.70	132.75	3.70
15.	ITC148	16.84	151.23	194.57	2.98
16.	ITC161	14.08	189.50	154.77	3.42
17.	ITC227	20.43	166.07	168.97	3.68
18.	ITC228	19.29	161.43	178.23	3.66

S.No	Clone	Net photosynthetic rate (Pn) (µmol m^{-2} s^{-1})	Stomatal conductance (Gs) (mol m^{-2} s^{-1})	Intercellular CO_2 concentration(Ci) (µl l^{-1})	Transpiration rate (E) (mmol m^{-2} s^{-1})
19.	ITC231	16.86	172.10	166.00	3.70
20.	ITC242	14.31	167.50	186.40	3.78
21.	ITC248	14.06	132.27	161.43	3.45
22.	ITC251	16.65	166.37	153.63	3.36
23.	ITC256	17.02	151.27	176.53	3.60
24.	ITC259	16.76	118.50	160.93	3.29
25.	ITC264	17.91	140.77	129.57	3.68
	Mean	16.66	151.52	163.63	3.36
	S.Ed	2.25	24.50	22.86	0.36
	CV	0.14	0.16	0.14	0.11

Table 2 revealed a significant variation among the clones in terms of intrinsic water use efficiency, Mesophyll efficiency while CE and SWUE did not show any significant variation. The Intrinsic water use efficiency (TWUE) varied from 0.076 to 0.232 µmol mol^{-1}; Instantaneous water use efficiency (SWUE) showed a range of 3.59 to 8.648 µmol mmol^{-1}. Carboxylation efficiency (CE) ranged between 0.075 and 0.143 (µmol m^{-2} s^{-1} (µl l^{-1})$^{-1}$ while Mesophyll efficiency (ME) was in the range of 0.78 to 2.119 µl l^{-1} (mol m^{-2} s^{-1})$^{-1}$.

Table 2: Physiological parameters of Eucalyptus clones

S.No	Clone	Intrinsic Water Use Efficiency (µmol mol^{-1})	Instantaneous Water Use Efficiency (µmol mmol^{-1})	Intrinsic Carboxylation Efficiency (µmol m^{-2} s^{-1} (µl l^{-1})$^{-1}$	Intrinsic Mesophyll Efficiency µl l^{-1} (mol m^{-2} s^{-1})$^{-1}$
1.	ITC 1	0.232^{c}	8.648	0.123	2.119^{c}
2.	ITC3	0.155^{ab}	5.563	0.110	1.404^{ab}
3.	ITC 4	0.205^{bc}	6.157	0.105	1.856^{bc}
4.	ITC 6	0.101^{a}	5.260	0.089	1.124^{ab}
5.	ITC 7	0.102^{a}	5.741	0.094	1.139^{ab}
6.	ITC 8	0.108^{a}	5.516	0.092	1.153^{ab}
7.	ITC 10	0.123^{a}	6.497	0.112	1.196^{ab}
8.	ITC 71	0.109^{a}	4.829	0.143	0.809^{a}
9.	ITC 99	0.123^{a}	5.651	0.111	1.129^{ab}
10.	ITC 116	0.098^{a}	5.034	0.126	0.780^{a}
11.	ITC 122	0.080^{a}	3.590	0.089	0.918^{a}
12.	ITC 128	0.104^{a}	4.128	0.102	1.046^{a}
13.	ITC 130	0.095^{a}	3.865	0.075	1.280^{ab}
14.	ITC 132	0.105^{a}	4.481	0.127	0.814^{a}
15.	ITC 148	0.119^{a}	5.836	0.087	1.387^{ab}
16.	ITC 161	0.076^{a}	4.110	0.091	0.827^{a}
17.	ITC 227	0.125^{a}	5.545	0.124	1.018^{a}
18.	ITC 228	0.121^{a}	5.273	0.109	1.158^{ab}
19.	ITC 231	0.098^{a}	4.583	0.103	0.969^{a}
20.	ITC 242	0.086^{a}	3.763	0.077	1.125^{ab}

S.No	Clone	Intrinsic Water Use Efficiency (µmol mol^{-1})	Instantaneous Water Use Efficiency (µmol mmol^{-1})	Intrinsic Carboxylation Efficiency (µmol m^{-2} s^{-1} (µl l^{-1})$^{-1}$	Intrinsic Mesophyll Efficiency µl l^{-1} (mol m^{-2} s^{-1})$^{-1}$
21.	ITC 248	0.108[a]	4.102	0.092	1.242[ab]
22.	ITC 251	0.104[a]	4.963	0.107	1.005[a]
23.	ITC 256	0.113[a]	4.708	0.100	1.220[ab]
24.	ITC 259	0.143[ab]	5.277	0.107	1.371[ab]
25.	ITC 264	0.137[ab]	4.997	0.140	0.968[a]
	Mean	0.119	5.12	0.105	1.16
	S.Ed	0.04	1.06	0.02	0.31
	CV	0.30	0.21	0.17	0.27

*Values sharing the same superscripts do not significantly vary from each other

In general, it has been observed in the earlier studies that the values for these physiological parameters decrease from high yielding to low yielding clones. When 25 clones of Eucalyptus were tested in a clonal trial, it was noticed that various physiological characters like photosynthesis, transpiration rate, stomatal conductance and intercellular CO_2 concentration were related to productivity (Balasubramanian and Gurumurthi 2001). The most productive clones showed higher physiological activities compared to other clones. Net photosynthesis and related physiological parameters have been suggested as early selection criteria to improve the efficiency of tree breeding (Lapido et al. 1984, Ceulemans et al. 1988).

The ratio of net photosynthetic rate to stomatal conductance is referred to as intrinsic water use efficiency (Ares and Fownes 1999) and it implies the inherent ability of the plant to assimilate CO_2. Instantaneous water use efficiency is estimated as the ratio of net photosynthetic rate to transpiration rate (Petite et al. 2000). Higher the value, better the efficiency of the plant to direct water for photosynthesis than transpiration. Tumomela (1997), studying the physiological and morphological responses of Eucalyptus provenances suggested that the efficient control of water loss was indicated by high instantaneous water use efficiency. The ratio of net photosynthesis rate to intercellular CO_2 concentration is termed as intrinsic carboxylation efficiency (Hamerlynck et al. 2000).

Photosynthesis is the key to dry matter production and increasing the Photosynthetic efficiency is the most important way of increasing productivity (Gupta 1996). Of all aspects of plant metabolism, photosynthesis shows the most prominent variation under the dictates of the immediate environment (Arora and Gupta 1996). Physiological parameters including water-use efficiency in Casuarina indicated superior growth performance and favourable physiological characteristics including high photosynthesis, Carboxylation efficiency and water-use efficiency (Warrier et al. 2007).

Table 3: Chlorophyll content of Eucalyptus clones

S.No	Clone ID	Chlorophyll a (mg g^{-1})		Chlorophyll b (mg g^{-1})		Total chlorophyll (mg g^{-1})		Chlorophyll a:b	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
1.	ITC 1	1.456^{bcde}	0.244	0.414^{abc}	0.071	1.870^{b}	0.289	3.541^{cde}	0.547
2.	ITC3	0.826^{a}	0.171	0.156^{a}	0.071	0.981^{a}	0.241	5.971^{f}	2.203
3.	ITC 4	1.438^{bcd}	0.167	0.357^{ab}	0.068	1.794^{b}	0.232	4.071^{de}	0.351
4.	ITC 6	1.633^{bcdefg}	0.318	0.514^{bcd}	0.249	2.147^{bcd}	0.567	3.452^{bcde}	0.853
5.	ITC 7	$1.668^{bcdefgh}$	0.280	0.404^{abc}	0.145	2.070^{bcd}	0.422	4.388^{e}	1.069
6.	ITC 8	1.526^{bcde}	0.103	0.419^{abc}	0.218	1.945^{bcd}	0.264	4.538^{e}	2.629
7.	ITC 10	1.345^{b}	0.146	0.573^{bcd}	0.048	1.918^{bc}	0.192	2.345^{abc}	0.087
8.	ITC 71	$1.681^{bcdefgh}$	0.206	0.710^{cdefg}	0.101	2.390^{bcdef}	0.307	2.373^{abc}	0.050
9.	ITC 99	1.374^{bc}	0.076	0.505^{bcd}	0.077	1.877^{b}	0.153	2.749^{abcd}	0.257
10.	ITC 116	1.277^{b}	0.153	0.543^{bcd}	0.081	1.820^{b}	0.234	2.361^{abc}	0.102
11.	ITC 122	1.610^{bcdef}	0.359	0.696^{cdef}	0.169	2.306^{bcde}	0.525	2.321^{abc}	0.141
12.	ITC 128	$1.669^{bcdefgh}$	0.155	0.631^{bcde}	0.075	2.299^{bcde}	0.223	2.654^{abcd}	0.151
13.	ITC 130	1.918^{efgh}	0.558	1.097^{hi}	0.459	3.014^{efg}	1.013	1.814^{a}	0.236
14.	ITC 132	2.517^{ij}	0.081	1.271^{ij}	0.139	3.787^{hi}	0.210	1.994^{abc}	0.181
15.	ITC 148	1.834^{cdefgh}	0.501	0.957^{efghi}	0.241	2.790^{defg}	0.741	1.909^{ab}	0.060
16.	ITC 161	2.561^{j}	0.012	1.414^{j}	0.219	3.974^{i}	0.231	1.841^{a}	0.283
17.	ITC 227	2.034^{fgh}	0.149	0.974^{fghi}	0.162	3.007^{efg}	0.310	2.109^{abc}	0.181
18.	ITC 228	2.106^{ghi}	0.282	0.975^{fghi}	0.255	3.080^{fg}	0.536	2.219^{abc}	0.350
19.	ITC 231	1.330^{b}	0.146	0.535^{bcd}	0.023	1.865^{b}	0.150	2.489^{abc}	0.273
20.	ITC 242	1.653^{bcdefg}	0.088	0.797^{defgh}	0.188	2.311^{bcde}	0.052	2.147^{abc}	0.494
21.	ITC 248	$1.725^{bcdefgh}$	0.120	0.729^{cdefg}	0.044	2.453^{bcdefg}	0.164	2.366^{abc}	0.024
22.	ITC 251	$1.686^{bcdefgh}$	0.351	0.664^{bcdef}	0.118	2.350^{bcdef}	0.453	2.545^{abc}	0.340
23.	ITC 256	2.140^{hi}	0.187	0.914^{efgh}	0.052	3.054^{efg}	0.228	2.341^{abc}	0.135
24.	ITC 259	1.882^{defgh}	0.185	0.793^{defgh}	0.103	2.674^{cdef}	0.262	2.387^{abc}	0.259
25.	ITC 264	2.098^{ghi}	0.111	1.033^{ghi}	0.207	3.150^{gh}	0.261	2.082^{abc}	0.399
	Mean	1.719		0.723		2.44		2.76	
	S.Ed	0.39		0.30		0.68		1.02	
	CV	0.23		0.42		0.28		0.37	

*Values sharing the same superscripts do not significantly vary from each other

Significant variation among the clones was observed in terms of Chlorophyll a, Chlorophyll b, Total chlorophyll and Chlorophyll a : Chlorophyll b ratio (Table 3). ITC 161 showed maximum chlorophyll content. The chlorophylls, Chl a and Chl b, are virtually essential pigments for the conversion of light energy to stored chemical energy. The amount of solar radiation absorbed by a leaf is a function of the photosynthetic pigment content; thus, chlorophyll content can directly determine photosynthetic potential and primary production (Filella et al. 1995). In addition, Chl gives an indirect estimation of the nutrient status because much of leaf nitrogen is incorporated in chlorophyll (Moran et al. 2000). Furthermore, leaf chlorophyll content is closely related to plant stress and senescence (Merzlyak et al. 1999).

Significant variation among the clones was observed in terms of Height, Collar Diameter and Biomass (Table 4). The details of gall infection and the score attained by each clone are provided in Table 5.

Table 4: Growth parameters of Eucalyptus clones

S.no	Clone	Height (H) (cm)		Collar diameter (CD) (cm)		Biomass	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
1.	ITC 1	130.5^{bcdefg}	10.39	31.090^{abc}	3.013	1282.0^{ab}	327.9
2.	ITC3	202.8^{j}	3.06	41.910^{cdefg}	4.043	3591.3^{defg}	749.2
3.	ITC 4	161.7^{fghi}	47.78	39.863^{cdefg}	10.049	2914.7^{bcdef}	1787.4
4.	ITC 6	126.7^{bcdef}	36.75	30.597^{abc}	7.097	1326.0^{abc}	989.5
5.	ITC 7	101.7^{ab}	20.65	23.567^{a}	9.265	687.3^{a}	658.7
6.	ITC 8	174.2^{hij}	19.37	41.137^{cdefg}	7.082	2941.3^{bcdef}	762.1
7.	ITC 10	164.0^{fghi}	10.39	50.233^{gh}	6.108	4220.0^{fg}	1200.3
8.	ITC 71	146.2^{cdefgh}	23.10	37.537^{bcde}	14.769	2399.7^{abcde}	2015.7
9.	ITC 99	131.0^{bcdefg}	17.06	35.517^{bcd}	3.870	1695.0^{abc}	537.9
10.	ITC 116	190.8^{ij}	1.04	46.830^{defgh}	2.231	4191.7^{fg}	397.9
11.	ITC 122	164.8^{fghi}	30.52	42.150^{cdefg}	3.975	2979.3^{bcdef}	886.8
12.	ITC 128	145.0^{cdefgh}	13.23	49.900^{fgh}	3.660	3655.3^{defg}	879.3
13.	ITC 130	168.7^{ghij}	24.58	49.103^{efgh}	2.274	4043.0^{efg}	377.7
14.	ITC 132	164.0^{fghi}	3.61	54.493^{h}	1.037	4871.0^{g}	208.3
15.	ITC 148	157.0^{efghi}	2.65	47.113^{defgh}	2.471	3493.7^{defg}	398.6
16.	ITC 161	156.8^{efghi}	17.48	49.097^{efgh}	5.553	3865.0^{efg}	1170.8
17.	ITC 227	85.0^{a}	14.29	26.710^{ab}	3.823	630.3^{a}	281.5
18.	ITC 228	120.0^{abcde}	19.52	40.310^{cdefg}	3.138	1927.7^{abcd}	121.2
19.	ITC 231	150.0^{defgh}	8.66	45.410^{defgh}	3.207	3119.7^{cdef}	592.7
20.	ITC 242	143.3^{cdefgh}	7.57	40.383^{cdefg}	6.013	2394.0^{abcd}	841.3
21.	ITC 248	132.0^{bcdefg}	10.58	38.323^{cde}	2.882	1961.3^{abcd}	433.1
22.	ITC 251	116.0^{abcd}	17.35	37.383^{bcde}	6.102	1683.0^{abc}	710.5
23.	ITC 256	108.3^{abc}	12.58	42.073^{cdefg}	4.688	1924.7^{abcd}	441.7
24.	ITC 259	130.0^{bcdefg}	22.61	44.567^{defgh}	3.961	2647.0^{bcdef}	920.1
25.	ITC 264	131.5^{bcdefg}	28.08	44.350^{defgh}	8.240	2786.3^{bcdef}	1691.1
	Mean	144.08		41.1859		2689.21	
	S.Ed	27.50		7.57		1142.31	
	CV	0.19		0.18		0.42	

*Values sharing the same superscripts do not significantly vary from each other

Nair et al (1986) made a comprehensive review of pests of eucalyptus in India. 20 species of root feeding termites damaging eucalypts was recorded by Nair and Varma (1985). Jacob et al (2007) reported the outbreak of invasive eulophid wasp L. invasa in India. This gall is spreading fast in many eucalypts growing areas around the world (Protasov et al. 2004). Based on all the characters studied, Mahalanobis D2 analysis was done followed by Tocher's method to cluster the clones using average linkage. The clones fell into five distinct clusters. Cluster five was distinct comprising only clone (ITC 132). Cluster three comprised maximum clones of (8) followed by clusters I and IV (7). The dendrogram is given below.

Table 5: Variation in gall infestation of the clones

S.No	Clone ID	No. of leaves affected	No. of Galls	No. of gall/leaf	Size of galls	Stage	Total score
1	ITC 1	2	2	1	0.12	OPD	20
2	ITC3	2	3	2	0.54	OPD+GALL	15
3	ITC 4	1	1	1	0.02	OPD	20
4	ITC 6	3	2	2	0.10	OPD+GALL	18
5	ITC 7	4	7	4	0.08	OPD+GALL + RED	13
6	ITC 8	3	5	4	0.40	OPD	15
7	ITC 10	1	0	0	0	OPD	23
8	ITC 71	3	7	1	0.08	OPD+GALL3	16
9	ITC 99	2	5	5	0.34	GALL	15
10	ITC 116	2	5	3	0.10	OPD+GALL	17
11	ITC 122	0	0	0	0	CLEAR	25
12	ITC 128	0	1	1	0.04	OPD+GALL	20
13	ITC 130	5	4	1	0.02	OPD+GALL +RED	14
14	ITC 132	3	7	4	0.32	OPD+GALL	14
15	ITC 148	0	0	0	0	OPD+GALL	23
16	ITC 161	3	2	2	0.02	OPD	19
17	ITC 227	0	0	0	0	OPD	24
18	ITC 228	0	0	0	0	CLEAR	25
19	ITC 231	0	0	0	0	OPD	24
20	ITC 242	5	9	4	0.26	OPD+GALL +RED	10
21	ITC 248	0	0	0	0	CLEAR	25
22	ITC 251	4	8	4	0.14	OPD+GALL +RED	13
23	ITC 256	3	3	4	0.16	OPD+GALL +RED	15
24	ITC 259	3	9	7	0.18	OPD+GALL +RED	10
25	ITC 264	3	9	4	0.12	OPD+GALL +RED	13

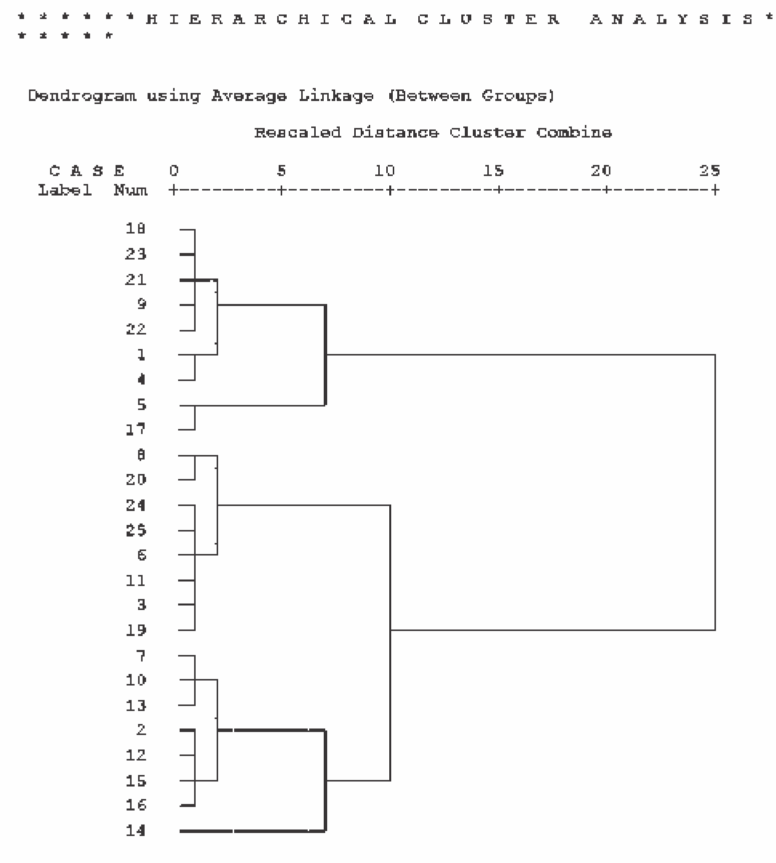

Fig. 1 Dendrogram showing the clusters of ITC clones

Table 7: Good performing clones of ITC in terms of selected parameters.

Parameters	Good performers
Intrinsic water use efficiency	ITC6,7,8,10,71,99,116,122,128,130,132,148,161,227,228,231,242,248,251,256
Mesophyll efficiency	ITC71,116,122,128,132,161,227,231,251,265
Gall free	ITC122,228,248
Biomass	ITC7,227

Table 7 shows clones suitable for planting in arid zones based on the physiological parameters. ITC 122, 228 and 248 was found to have high intrinsic water use efficiency and was free from attack of gall. These clones could be recommended for further screening and development in clonal forestry. Further they could also be planted in arid areas. The clone ITC 227 was high in Mesophyll efficiency, intrinsic water use efficiency with high biomass and would be suitable when selecting clones for high yield. The highly productive and gall free clones were also grouped together during the cluster analysis (Fig. 1).

CONCLUSION

Photosynthetic efficiency and Water use efficiency are important physiological characteristics while going in for large scale plantation in arid and semi-arid areas. Parameters that can be assessed to identify water stress include changes in photosynthetic rate, transpiration rate, stomatal conductance and chlorophyll. The response to gall infestation among several clones of Eucalyptus enables deciding on clones to be deployed for large scale planting programmes. With changing climatic conditions, identification of clones suited for dry conditions, with pest tolerance can contribute to environmental amelioration and help conservation of precious soil and water resources.

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