Journal of Stress Physiology & Biochemistry, Vol. 9 No. 3 2013, pp. 333-344 ISSN 1997-0838
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ORIGINAL ARTICLE

Variation in Gas Exchange Characteristics in Clones of *Eucalyptus camaldulensis* Under Varying Conditions of CO_2

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Received April 14, 2013

The Institute of Forest Genetics and Tree Breeding, Coimbatore, India has a long term systematic tree improvement programme for *Eucalyptus* species aimed at enhancing productivity and breeding for trait specific clones. In the process, thirty high yielding clones of *Eucalyptus camaldulensis* Dehnh. were identified. Carbondioxide enrichment studies in special chambers help in understanding the changes at individual level, and also at physiological, biochemical and genetic level. It also provides valuable information for establishing plantations at different geographic locations. Considerable variations were observed when the selected 30 clones of *E. camaldulensis* were subjected to physiological studies under elevated CO_2 conditions (600 mol mol^{-1}). Ten clones exhibited superior growth coupled with favourable physiological characteristics including high photosynthetic rate, carboxylation and water use efficiency under elevated carbon di oxide levels. Clones with minimal variation in physiological characteristics under elevated levels of CO_2 suggest their ability to overcome physiological stresses and adapt to varying climatic conditions.

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Clonal forestry programmes operating on a large scale are mostly with several species in the genus Eucalyptus and a number of clones are being deployed to increase the productivity of this species in India. Eucalyptus are primarily used for making pulp/paper and for charcoal in India. It also finds use as fuel wood, poles, stakes, fence posts, mining timber and particleboard. There exists tremendous variation with reference to yield, tree form and physiological characteristics in clones of eucalypts. It is well understood that the cumulative growth of a tree is the result of genotypic and environmental effects and their interaction (Cornillon *et al.,* 2002). Use of physiological parameters to assist in the determination of superior genotypes for tree improvement has been in practice (Kramer, 1986).

Evaluation of the behavior of certain physiological parameters can effectively be used to assess the clonal performances under given environmental conditions. Net photosynthesis rate (Pn), transpiration rate (Tr) and total leaf area per plant are the important factors that determine the biomass production and Water Use Efficiency of a species. Variation in Pn, has been reported as determinant of plant productivity in rubber (Nataraja and Jacob, 1999). Significant differences in Pn and stomatal conductance (gs) have been reported to exist in different tree species (Zipperlen and Press, 1996), viz., *Eucalyptus camaldulensis* (Farrel *et al.,* 1996) *Populus* (Kalina and Ceulemans, 1997), *Azadirachta indica* (Kundu and Tigerstedt, 1998) and *Hevea brasiliensis* (Nataraja and Jacob, 1999).

As tree growth is the end result of the interactions of physiological processes that influences the availability of essential internal resources at meristematic sites, it is necessary to understand how these processes are affected by the environment to appreciate why trees grow differently under various environmental regimes (Kozlowski and Pallardy, 1997). Understanding the impacts of atmospheric CO_2 and its response to changes in temperature is critical to improve predictions of plant carbon-exchange with atmosphere (Crous *et al.,* 2011). Variations have been observed under tropical conditions in the responses of tree seedlings to elevated CO_2 levels (Varadharajan *et al.,* 2010).

Screening for genetic differences in ecophysiological traits such as net photosynthesis rates, respiration rates and nutritional attributes becomes imperative in a country with varied agro climatic and soil conditions, as the maximum performance potential of a tree species can be assessed only when data on these aspects are available (Warrier, 2010). Carbon enrichment studies in special chambers help in understanding the changes at individual level, and also at physiological, biochemical and genetic level. Reports on variations in responses of Eucalyptus species to carbon enrichment have been reported by Roden and Ball (1996) and Lima *et al.,* (2003). Considerable variation has been reported in clones of *Eucalyptus camaldulensis* Dehnh for important physiological characteristics including high photosynthesis, carboxylation efficiency and water use efficiency (Warrier *et al.,* 2009). The objective of the present study was to analyse differences with respect to leaf photosynthetic characteristics in *Eucalyptus camaldulensis* Dehnh. clones subjected to varying levels of CO_2 The information obtained would support designing further tree improvement and breeding strategies, to mitigate effects of climate change.

MATERIALS AND METHODS

The Institute of Forest Genetics and Tree Breeding, Coimbatore, Tamil Nadu ($11^0$16’ N and $76^0$58’21”E, 411m MSL) is working towards improvement of Eucalyptus species for the past two decades. First generation provenance trials were established in ten different locations and 100 candidate clones of *E. camaldulensis* were selected, based on individual tree superiority for height, diameter at breast height and straightness of stem through index selection method. The clonal trials were established in three different locations, viz., Coimbatore (Tamil Nadu), Sathyavedu (Andhra Pradesh) and Kulathupuzha (Kerala). Thirty three clones across all the three trials were selected after comparing them with 10 commercial clones and seed origin plants of *Eucalyptus camaldulensis* (3 entries) and *E. tereticornis* (2 entries) to prove clonal superiority for high productivity. These selected and tested superior clones of *E. camaldulensis* were subjected to elevated conditions of temperature and CO_2 and physiological observations at six months of age were recorded.

Methods: The selected clones were grown inside the open top chambers (OTCs) of 3 m diameter and 10 m height lined with transparent PVC sheets (0.125 mm thickness) with a CO_2 levels of 600 mol mol^{-1}. Pure CO_2 gas was used for the enrichment. Similarly OTCs were maintained at elevated temperatures (Ambient +4ºC) under ambient CO_2 (380 mol mol^{-1}). Controls were maintained in open field outside OTCs, with ambient CO_2 (380 mol mol^{-1}). CO_2 was provided throughout the day and night (24 h period). The experiments were laid in a Complete Randomized Design. The period of CO_2 enrichment was 180 days. A software facility called Supervisory Control and Data Acquisition (SCADA) was used to continuosly control, record and display the actual and desired CO_2 level, relative humidity and temperature in each OTC by feedback control loop passing through Programmable Logical Controllers (PLC) (Buvaneswaran *et al.,* 2010). The set that was maintained in the open served as the control under ambient conditions while the set maintained inside the chamber under ambient CO_2 conditions was used to eliminate the effects of the chamber on the response of the clones.

Measurements of photosynthesis and related parameters: Net photosynthesis rate (Pn), stomatal conductance (gs), intercellular CO_2 concentration (Ci) and transpiration rate (E) were measured using a Portable Photosynthesis System, LiCor-6400 (LiCor Instruments, USA). The measurements were taken between 9.30 am and 11.30 am under cloud free conditions at the end of six months. Observations were recorded from ten ramets per clone for all the physiological parameters. Water use Efficiency (WUE) was also estimated for the clones. Intrinsic water use efficiency was estimated as the ratio of net photosynthesis rate to stomatal conductance (Pn/gs) whereas instantaneous water use efficiency was estimated as the ratio of net photosynthesis rate to transpiration (Pn/E). Intrinsic carboxylation efficiency was derived as the ratio of net photosynthetic rate to intercellular CO_2 concentration (Pn/Ci). Intrinsic mesophyll efficiency was estimated as the ratio of intercellular CO_2 concentration to stomatal conductance (Ci/gs).

Statistical Analysis: The data were subjected to analysis of variance for completely randomsied design with five replications. A full-factorial multivariate general linear model (GLM) analysis was conducted using SPSS to determine whether there was significant variation in the different gas exchange characteristics between different CO_2 conditions within the clones. Post hoc range tests using Waller Duncan t-test was performed to group the significantly different clones.

RESULTS AND DISCUSSION

Table 1 shows the details of effects of elevated temperature and CO_2 on the gas exchange characteristics in Eucalyptus species. Information on the interclonal variation existing in net photosynthetic rate, stomatal conductance, intercellular CO_2 concentration and transpiration rate and the derived parameters namely intrinsic and instantaneous WUE, intrinsic carboxylation efficiency and intrinsic mesophyll efficiency are given in Tables 2 and 3 respectively.

Reports state that photosynthetic rate varies among the plants belonging to different taxa and also among the varieties within the same species (Arora and Gupta, 1996). Among the various parameters, though the primary physiological parameters were significantly higher for the clones maintained under control conditions, the clones subjected to elevated CO_2 showed higher values for the derived parameters under elevated conditions of temperature and CO_2 indicating the efficiency of the species to divert water and nutrients for photosynthesis than transpiration. The overall variation in various gas exchange characteristics in clones of Eucalyptus subjected to conditions of elevated CO_2 (Table 1) suggests the species' inherent ability to assimilate more of CO_2 and efficiency of photosynthesis under varying environmental conditions. Eucalyptus have been shown to precisely regulate transpiration rates, via stomatal movements (Bolhar- Nordenkampf, 1987), allowing this genus to take advantage of favourable conditions via enhanced CO_2 uptake (Fordyce et al.,1995), especially when exposed to significant seasonal fluctuations (Greenwood *et al.,* 2003).

Clone EC 52 ranked top with reference to the net photosynthesis rate followed by EC 70. Clones EC 9, 10, 19 and 111 exhibited poor photosynthetic rates. The Pn values varied from 0.204 to 7.94µmol m^{-2} s^{-1} with a mean of 3.01µmol m^{-2} s^{-1} under ambient conditions, 2.51µmol^{-2} s^{-1} in chamber control and 2.39 µmol^{-2} s^{-1} under elevated CO_2 levels. The photosynthetic rate was observed to reduce under elevated CO_2 levels except in clones EC 101, 94, 54, 207 and 75. Palanisamy (1999) reported increase in net photosynthetic rates in Eucalyptus seedlings after eight months of differential CO_2 exposure at 800 ppm CO_2. In the present study similar observations were recorded in the clonal responses to physiological stresses. Clones 207, 53, 94, 17,54,70,88 and 116 showed increased rates in chamber conditions under ambient CO_2 levels. Clone EC 52 showed the same trend under chamber conditions and under elevated CO_2. Clones EC 9, 10, 19 and 111 exhibited poor photosynthetic rates under the different conditions also.

Stomatal conductance varied between 0.008 to 0.264 mol^{-2} s^{-1} with a mean of 0.08 mol^{-2} s^{-1} under ambient conditions and there was a reduction in the stomatal conductance in eucalyptus when subjected to elevated CO_2 conditions. The minimum and the maximum values of gs were recorded by clones EC 52, 53 198, 207 and EC 66, 11 191 respectively. Clone 207 which showed higher gs under ambient and chamber control conditions, exhibited very poor response (almost 300 per cent low) under e CO_2 levels.

Among the 30 clones, EC 54, 75, 88 and 94 ranked higher for intercellular CO_2 concentration. Clones EC 14, 19, and 188 recorded low values. Both minimum (106.9 µl^{-1})and the maximum (436.6 µl^{-1}) values for transpiration rate (E) were registered under ambient conditions. The intercellular CO_2 concentration was 269.26 µl^{-1} for ambient, 275.68 µl^{-1} for chamber control and 239.22 µl^{-1} for eCO_2 conditions.

Clones EC 17, 52, 53, 54 and 207 exhibited high transpiration rates (E). Clones EC 9, 19, 66, 124 and 198 recorded low transpiration rates. The E values varied from 0.56 to 6.1 mmol m^{-2} s^{-1} with a mean of 2.44 mmol m^{-2} s^{-1} under ambient conditions, 1.97 mmol m^{-2} s^{-1} in chamber control and 1.66 mmol m^{-2} s^{-1} under elevated CO_2 . Carbondioxide is an essential substrate in the photosynthetic process and is incorporated in the light-independent reaction of photosynthesis to produce simple sugars (Kramer *et al.,* 2004). For photosynthesis to occur stomata must open to obtain CO_2 which produces an unavoidable trade-off: as CO_2 moves into the leaf, water from within the leaf is lost through the open staomata via transpiration (Gutschick,1999). In order to optimize photosynthetic returns the plant must balance CO_2 uptake with transpirational losses, thereby trying to maximize carbon gain while minimizing water loss (Givnish, 1978).

The water molecules lost per molecule of carbon fixed by the plant during photosynthesis, is referred to as water use efficiency (Ellsworth, 1999). Intrinsic water use efficiency (Pn/gs) implies the inherent ability of the plant to assimilate CO_2 (Ares and Fownes, 1999). A higher value indicates better ability of the plant for carbon assimilation. Intrinsic WUE ranged between 67.7 and 115.2 µmol mol^{-1} with a mean of 56.2 µmol mol^{-1} for ambient, 31.86 $µl^{-1}$ or chamber control and 43.89 $µl^{-1}$ for eCO_2 conditions.

The maximum values were observed in clones EC 14 and 19. About ten clones registered low values (Table 3). Li (2000) reported that measurement of WUE may be a useful trait for selecting genotypes with improved drought adaptation and biomass productivity under different environmental conditions. Net photosynthesis and related gas exchange parameters have been suggested as early selection criteria to improve the efficiency of tree breeding (Ceulemans et al. 1996). The values ranged from 5.8-330 under varying levels of CO_2. It was observed that water stressed *Pinus radiata* trees had higher WUE (Thompson and Wheeler 1992). Higher intrinsic WUE was associated with productivity in *Prosopis glandulosa* and *Acacia smallii* (Polley et al.1996). It is reported that long-term structural and growth adjustments as well as changes in intrinsic WUE are important mechanisms of *Acacia koa* to withstand water limitation (Ares and Fownes 1999).

Restricted stomatal opening will result in decreased stomatal conductance, lower transpiration rates and hence, increased plant water use efficiency (Tricker et al, 2005). As a result, the plant may reduce stomatal frequencies under elevated CO_2 concentration and maintain equal or increased carbon intake, so the relationship is of an inverse nature (Gregory, 1996; Fernandez *et al.,* 1998). Combined with reduced stomatal opening, conductance and transpiration rates, elevated CO_2 concentration also depresses dark respiration rates also leading to increased water use efficiency (Wullschleger *et al.,* 1992; Murray, 1995). Increase in water use efficiency has been found to increase drought tolerance in many plant species, which may allow increased plant distributions (Tyree and Alexander, 1993; Huxman *et al.,* 1998). Whether future increases in plant distribution are realized is dependent upon whether increased water use efficiency will be greater than enhanced transpiration, as a result of global warming (Houghton *et al.,* 1990 & 2001; Crowley, 2000).

Transpiration is one of the major gas exchange related traits associated with plant growth and productivity. In tree species stomatal transpiration contributes more than 90% of total transpiration (Taiz and Zeiger 2002). Instantaneous water use efficiency, the ratio of amount of carbon fixed per unit amount of water lost through transpiration, differed significantly amongst the clones studied (Table 3). Transpiration and photosynthesis are two major gas exchange parameters, which determine WUE of plants. Thirteen clones showed higher values under elevated CO_2 levels over ambient conditions. These clones could be the ideal clones for water limited conditions. Kannan Warrier et al.

(2007) found considerable variation with respect to physiological parameters including water use efficiency in 33 clones of *Casuarina equisetifolia*.

In the present study, clones EC 9,10,14,19,63,66,69,100,111,123,124,187,191 were found to exhibit low water use efficiency. The Pn/Ci ratio explained as the intrinsic carboxylation efficiency (CE) also differed significantly among the clones and the same clones which showed relatively higher WUE had high CE also. These clones might have greater dependency of photosynthesis on mesophyll characters than stomatal characters. This was evident from the comparatively higher intrinsic mesophyll efficiency values for these clones over those exhibiting higher WUE and CE. Similar observations have been made in rubber (*Hevea brasiliensis*) (Nataraja and Jacob, 1999) and sandal wood (Arunkumar *et al.,* 2009). Net photosynthesis and related physiological parameters have been suggested as early selection criteria to improve the efficiency of tree breeding (Balasubramanian and Gurumurthi, 2001). The selections made in the study could be potential candidates' for different agroclimatic zones due to their ability to adapt to varied climatic conditions and also for the development of site specific seed orchards.

Table 1. Various gas exchange characteristics in clones of *Eucalyptus* subjected to conditions of elevated temperature and CO_2 at the end of six months

S. No	Characteristics	Treatments		
		Control	Elevated Temperature	Elevated CO_2
1	Net Photosynthetic Rate (Pn) (µmol m^{-2} s^{-1})	3.01a	2.51ab	2.39b
2	Stomatal Conductance (gs) (mol m^{-2} s^{-1})	0.08a	0.05b	0.04b
3	Intercellular CO_2 Concentration (Ci) (µl l^{-1})	269.26a	275.68a	239.22b
4	Transpiration Rate (E) (mmol m^{-2} s^{-1})	2.44a	1.97b	1.66c
5	Intrinsic Water Use Efficiency (µmol mol^{-1})	56.2a	31.86c	43.89b
6	Instantaneous Water Use Efficiency (µmol $mmol^{-1}$)	11.4b	29.64a	37.33a
7	Intrinsic Carboxylation Efficiency (µmol m^{-2} s^{-1} (µl l^{-1})$^{-1}$	0.0145ab	0.0105b	0.0152a
8	Intrinsic Mesophyll Efficiency µl l^{-1} (mol m^{-2} s^{-1})$^{-1}$	5619.6b	9828.2a	8512.5a

Table 2. Net photosynthesis, stomatal conductance, intercellular CO_2 concentration and transpiration in *Eucalyptus* clones subjected to elevated temperature and CO_2 at the end of six months

Sl No.	Clone No.	Net Photosynthetic Rate (Pn) ($\mu mol\ m^{-2}\ s^{-1}$)			Sig.	Stomatal Conductance (gs) ($mol\ m^{-2}\ s^{-1}$)			Sig.	Intercellular CO_2 Concentration (Ci) ($\mu l\ l^{-1}$)			Sig.	Transpiration Rate (E) ($mmol\ m^{-2}\ s^{-1}$)			Sig.
		A	CC	EC		A	CC	EC		A	CC	EC		A	CC	EC	
1.	7	2.824	2.784	2.488	e-h	0.040	0.056	0.080	c-f	232.0	292.6	285.2	d-f	2.06	1.03	3.31	d-g
2.	9	1.486	1.234	1.148	i	0.020	0.016	0.016	i	213.0	211.3	215.4	ij	0.85	1.17	0.82	i
3.	10	1.502	0.420	1.076	i	0.020	0.044	0.014	g-i	223.4	338.2	221.6	d-g	0.91	1.90	0.78	hi
4.	14	3.230	0.108	2.072	hi	0.022	0.040	0.014	hi	106.9	346.8	116.9	j	1.04	1.74	0.89	hi
5.	17	4.098	5.292	4.312	bc	0.146	0.054	0.048	a-c	370.7	245.4	233.7	b-e	5.11	2.08	2.24	a-c
6.	19	1.874	0.204	1.858	i	0.012	0.058	0.014	g-i	112.4	356.3	134.4	j	0.61	1.74	0.94	i
7.	52	7.550	7.940	4.614	a	0.138	0.082	0.038	ab	335.8	240.9	206.4	d-g	4.60	3.29	1.55	a-c
8.	53	3.022	3.838	2.504	d-g	0.160	0.086	0.014	ab	391.8	356.6	137.2	a-d	4.74	3.73	0.64	a-c
9.	54	2.884	5.746	4.348	b-d	0.078	0.116	0.058	a-c	349.5	311.3	284.0	ab	2.96	4.20	2.49	ab
10.	63	3.230	0.204	2.864	g-i	0.046	0.036	0.052	e-i	232.7	340.3	246.2	c-f	1.95	1.69	2.87	d-g
11.	66	2.390	1.066	1.218	hi	0.018	0.034	0.016	i	128.0	308.7	202.3	ij	0.86	1.31	0.98	i
12.	69	4.306	2.040	1.820	e-h	0.072	0.024	0.024	f-i	244.3	193.8	217.2	h-j	2.32	1.60	1.20	f-i
13.	70	4.346	6.920	3.822	b	0.176	0.044	0.038	ab	391.4	164.7	250.2	def	4.57	1.70	1.73	b-e
14.	75	1.792	3.664	5.552	c-e	0.164	0.070	0.050	ab	404.1	348.3	225.6	a	3.44	2.57	2.19	b-d
15.	88	3.354	7.024	2.762	b-d	0.100	0.080	0.050	a-d	377.1	270.4	326.3	a	2.98	3.44	2.10	b-d
16.	94	1.590	4.524	4.116	c-f	0.264	0.062	0.058	d-h	436.6	308.0	245.9	a	3.51	2.46	2.60	b-d
17.	100	4.150	0.976	0.982	g-i	0.062	0.036	0.056	e-i	225.5	301.3	317.8	b-e	2.74	1.91	2.46	c-f
18.	101	2.288	1.752	2.388	g-i	0.042	0.042	0.052	f-i	274.0	240.6	282.8	d-g	1.26	2.64	1.91	e-h
19.	111	2.062	0.796	1.006	i	0.016	0.048	0.036	f-i	142.7	321.5	289.3	e-i	0.82	2.27	2.18	f-i
20.	115	2.470	0.272	1.662	hi	0.044	0.050	0.018	b-e	247.0	362.9	173.6	d-g	2.07	1.13	1.07	g-i
21.	116	2.748	7.388	1.604	b-e	0.102	0.064	0.046	f-i	381.7	206.1	260.1	b-e	3.67	2.71	2.24	b-d
22.	123	2.506	0.164	2.072	hi	0.032	0.046	0.028	f-i	208.3	342.6	212.4	d-i	1.54	2.11	1.58	f-i
23.	124	2.912	0.890	0.716	hi	0.050	0.008	0.034	f-i	264.4	173.8	318.3	d-i	1.24	0.58	1.38	i
24.	186	3.544	1.934	1.556	f-i	0.082	0.024	0.020	f-i	278.7	198.2	216.2	f-j	2.32	1.86	0.96	f-i
25.	187	2.818	0.916	1.390	hi	0.020	0.048	0.024	f-i	107.8	332.7	236.0	g-j	0.95	1.49	1.56	hi
26.	188	3.334	0.872	1.950	g-i	0.078	0.010	0.020	d-g	262.7	155.1	158.1	j	2.85	0.56	1.10	g-i
27.	191	3.878	1.316	1.398	f-i	0.066	0.016	0.080	f-i	255.3	188.0	332.6	d-h	2.06	0.90	2.03	f-i
28.	196	1.528	0.562	2.474	hi	0.040	0.016	0.064	g-i	269.5	279.4	302.6	b-e	1.48	1.22	1.26	hi
29.	198	3.832	1.258	0.536	g-i	0.044	0.014	0.030	a	209.8	186.1	337.6	e-i	1.68	0.92	0.80	i
30.	207	2.764	3.116	5.310	c-e	0.176	0.088	0.040	a	400.7	348.7	191.1	a-c	6.10	3.03	1.82	a

Means with atleast one letter common in a column do not differ significantly as per Duncan's Multiple Range Test at 5 per cent level of significance. A – Control; CC - Elevated Temperature; EC - Elevated CO_2

Table 3. Water use efficiency, carboxylation efficiency and mesophyll efficiency in *Eucalyptus* clones subjected to elevated temperature and CO_2 at the end of six months

Sl No.	Clone No.	Intrinsic Water Use Efficiency (µmol mol^{-1})			Sig.	Instantaneous Water Use Efficiency (µmol mmol^{-1})			Sig.	Intrinsic Carboxylation Efficiency (µmol m^{-2} s^{-1} (µl l^{-1})$^{-1}$			Sig.	Intrinsic Mesophyll Efficiency µl l^{-1} (mol m^{-2} s^{-1})$^{-1}$			Sig.
		A	CC	EC		A	CC	EC		A	CC	EC		A	CC	EC	
1.	7	67.6	54.7	30.6	g-j	1.40	3.10	0.70	c	0.012	0.012	0.008	e	541.4	598.7	453.2	d-g
2.	9	83.5	77.1	78.2	b-d	1.80	1.10	1.40	c	0.010	0.006	0.004	e	1220	1390.4	1441.7	b
3.	10	76.0	92.5	73.8	f-i	1.70	0.20	1.40	c	0.006	0.001	0.004	e	1137.4	749.3	1790.5	bc
4.	14	148.6	275.0	139.9	A	3.10	0.10	2.40	c	0.056	0.001	0.028	de	475.1	878.9	793.8	c-g
5.	17	97.0	279.0	107.7	K	3.70	10.90	9.60	c	0.010	0.022	0.028	de	342.1	535.9	505.2	e-g
6.	19	146.9	330.0	125.7	Ab	3.10	0.10	2.00	c	0.022	0.001	0.016	de	833.5	761.1	923.6	b-g
7.	52	16.6	26.2	33.4	K	5.60	10.80	13.40	c	0.024	0.034	0.034	de	250.3	332	525	g
8.	53	79.0	88.0	38.2	K	2.60	3.80	1.80	c	0.010	0.012	0.026	de	352.8	462.1	1185.8	c-g
9.	54	120.0	171.0	190.0	K	4.90	6.70	8.20	c	0.010	0.022	0.016	de	555.4	319.4	499.8	e-g
10.	63	67.9	60.9	55.3	h-j	1.70	0.10	1.00	c	0.016	0.001	0.014	de	598.1	1001.5	512.8	c-g
11.	66	136.9	30.3	80.9	a-c	3.10	0.80	1.30	c	0.020	0.004	0.010	de	682.6	991.5	1327.4	b-f
12.	69	62.0	90.9	78.6	Cd	1.80	1.20	1.50	c	0.020	0.014	0.008	de	436.1	861.7	2056.6	b-d
13.	70	100.0	41.6	22.7	K	2.70	16.20	10.60	c	0.012	0.044	0.040	de	235.4	386.8	740.9	e-g
14.	75	84.0	12.3	26.7	K	2.00	4.70	12.00	c	0.004	0.010	0.028	de	379.3	772.1	461	d-g
15.	88	12.6	20.9	13.8	K	3.50	9.00	5.80	c	0.010	0.024	0.012	de	405.2	341.5	691.7	e-g
16.	94	52.0	79.0	23.5	K	0.70	7.30	11.10	c	0.004	0.016	0.028	de	182.9	584.4	510.3	fg
17.	100	70.5	27.2	17.8	J	1.50	0.50	0.40	c	0.020	0.001	0.001	de	396.3	843.5	597	c-g
18.	101	51.6	59.8	44.5	g-j	1.70	0.90	1.20	c	0.008	0.006	0.008	de	745.6	1320.7	550.2	b-g
19.	111	126.2	16.5	26.9	e-h	2.60	0.30	0.50	c	0.016	0.001	0.002	de	899.2	691.6	903.4	b-g
20.	115	57.8	5.8	101.2	f-i	1.20	0.20	1.60	c	0.008	0.001	0.012	c-e	876.7	745.6	1008	b-g
21.	116	79.0	29.5	12.3	K	2.90	13.20	6.40	b	0.008	0.038	0.040	b-e	421.5	386.8	615.6	e-g
22.	123	82.8	35.1	77.5	f-i	1.70	0.10	1.40	b	0.012	0.001	0.012	b-e	789.6	758.5	776.4	b-g
23.	124	60.5	103.7	20.8	e-g	2.40	1.50	0.50	b	0.010	0.004	0.001	b-e	598.7	4006	973	a
24.	186	42.4	85.7	81.0	c-e	1.40	1.10	1.60	b	0.012	0.012	0.010	b-e	501	1038.1	1131.8	b-g
25.	187	148.5	19.7	60.0	Cd	3.20	0.60	1.00	b	0.038	0.002	0.004	b-e	478.1	704.7	1147.9	b-g
26.	188	50.5	114.7	115.6	A	1.30	1.50	2.10	b	0.012	0.006	0.018	a-d	512.3	2193.4	815	bc
27.	191	60.2	94.9	17.4	e-g	1.90	1.40	0.70	ab	0.016	0.006	0.002	a-c	429.1	1871.4	469.5	b-g
28.	196	48.9	32.9	41.7	Ij	1.20	0.50	2.20	ab	0.006	0.001	0.010	ab	854.9	1799.7	512.8	b-e
29.	198	86.8	95.3	16.8	d-f	2.30	1.40	0.70	a	0.018	0.008	0.001	a	493	1538.7	1143.5	b-e
30.	207	50.0	127.0	311.0	K	1.80	4.70	14.20	a	0.004	0.008	0.034	a	235.2	618.8	474.4	e-g

Means with atleast one letter common in a column do not differ significantly as per Duncan's Multiple Range Test at 5 per cent level of significance. A – Control; CC - Elevated Temperature; EC - Elevated CO_2

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