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RESEARCH ARTICLE

Seasonal variation in physiology of *Eucalyptus* genotypes in relation to soil salinity

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Abstract

Expanding problems of soil salinity has become serious issues of concern as it affects productivity and threatens the sustainability of wood production by forest trees. An experiment was conducted to test the ability of *Eucalyptus* trees to grow under saline environment and to maintain their physiology. Saline irrigation treatment of five levels (Control, 5 dSm^{-1}, 10dSm^{-1}, 20 dSm^{-1}and 40 dSm^{-1}) were applied, eventually two highest levels viz., 20 dSm^{-1}and 40 dSm^{-1} leads to death of seedlings of three genotypes of *Eucalyptus tereticornis* (C-288), *E. camaldulensis* (C-413) and *Eucalyptus* hybrid (C-2070). As the salinity level increases, physiological processes were started declining more in all genotypes as compare to control condition. In general, genotype C-413 was found to be best for all physiological processes studied during winter season and water use efficiency and chlorophyll content during summer season, whereas, genotype C-2070 was best for photosynthesis, transpiration during summer season.

INTRODUCTION

Salt-affected soils, which are widespread in arid, semi-arid and coastal regions caused by excess accumulation of salts, typically most pronounced at the soil surface, reduce crop growth and yield (Allakhverdiev et al., 2000b). Soil salinity, one of the major abiotic stresses reducing plants productivity, affects large terrestrial areas of the world (Toshio and Eduardo, 2005). Currently, approximately 20% of the arable land, and nearly half of the irrigated land worldwide, is subjected to salt stress. In India, the salt affected soil is about 7167 sq km and (Kumar et al., 2013). In Punjab 6.4 per cent of total geographical area is affected by salinity (Sharma et al., 2011). In Southern Asia and the near East several million hectares of agricultural land are affected by salinity causing losses in food, fuel and industrial raw material production. Osmotic stress and ion toxicity present in saline soils result in low crop yields and negatively affect the growth of the agriculture and forestry industries (Alarcon et al., 1993). The reduced water potential at saline habitats creates in the plant a two-edged problem: a corresponding water and ion stress. The uptake of Na^+ and Cl^- into the different plant organs is highly controlled phenomenon (Hasegawa et al., 2000), salt-resistant species often possess special features to remove NaCl from the cytoplasm, e.g. by compartmentation in the vacuole (Muhling and Lauchli, 2002). In response to such stress conditions, many plants accumulate compatible metabolites in the cytoplasm of their cells in an attempt to combat the water problem (Munns, 2002).

Species and varieties of plants are, however, known to vary widely in their ability to tolerate salts (Craig et al. 1990, Minhas et al., 1997). Salt tolerance often varies widely in even closely related species (Dunn et al., 1994) and variations have also been observed among species provenances (Morabito et al., 1994). The relative tolerance of Eucalyptus species to salinity was investigated because the former is widely grown for production of wood-fuels and raw-materials for wood-based industries, and has a great potential in revegetating marginal and submarginal lands, and the latter has a wide range of economic utilization as fodder, fuelwood and furniture. As the species is of immense importance but little systematic work has been done on potential of Eucalyptus genotypes to survive and grow in the saline environments as well as seasonal variation in physiological process with respect to soil salinity so that the same is used in future reclamation of degraded saline soils and plantation programme. Hence, present study is a step in the direction to assess the effect of soil salinity on physiology of clonal Eucalyptus.

Materials and methods

The study was carried out at main experimental area of Department of Forestry and Natural Resources, Punjab Agricultural University, Ludhiana situated at 30° 45' N latitude, 75° 40' E longitude and 247 m altitude with mean annual rainfall 704 mm rainfall. Climate is sub-tropical to tropical with a long dry season from late September to early June and wet season from July to September. Soil was filled in iron containers of 60 cm height and 20 cm diameter, around 40 kilogram of soil is filled in each container by tapping 5 times after adding 5 kg soil for maintenance of uniform and normal bulk density, all the containers after weighing kept in trenches. Total 360 containers were filled for different treatment of salinity and three replications. Three different types of salts viz., Nacl, $MgSO_4$, $CaCl_2$ were used in different quantities following the method by Jackson (1967) to achieve desired salinity levels (control, 5, 10, 20 and 40 dsm^2). Three commercial genotypes viz., C-288 (*E. tereticornis*), C-413 (*E. camaldulensis*) and C-2070 (*Eucalyptus* hybrid) were collected from Prakrati Biotech Pvt. Ltd, Patiala (Punjab). Completely Randomized Design with three replications and plot size of eight plants was used. The observations on Photosynthesis (µmol m^{-2} s^{-1}), Transpiration (mmol m^{-2} s^{-1}), Physiological water-use efficiency (WUE) and Chlorophyll content (SPAD units) were recorded at two different season viz., December-2011 and May-2012 at the age of 1 year and 1.5 year.

An LI-6400 portable photosynthesis system (LI-COR Inc. Instruments U.S.A.) was used for measurement of net photosynthetic rate (µmol m^{-2} s^{-1}), transpiration rates (mmol m^{-2} s^{-1}) and water use efficiency (WUE) in the standing plants in field. Digital SPAD meter was used to calculate chlorophyll content (SPAD unit) of selected plants for all genotypes under study at each salinity level. Data recorded on plants raised in three treatments only viz., control, 5 dSm^{-1} and 10 dSm^{-1} were subjected to statistical analysis as per the procedure laid down for Completely Randomized Design (CRD) by Panse and Sukhatme (1989). Due to mortality, it was not possible to include highest level of salinity viz., 20 dSm^{-1} and 40 dSm^{-1}. Analysis of variance and least square difference (LSD) were calculated for the interpretation of results of the study.

Results

Saline irrigation treatment at five levels were applied (control, 5 dSm^{-1}, 10 dSm^{-1}, 20 dSm^{-1} and 40 dSm^{-1}) out of these five treatments eventually two highest salinity levels viz., 20 dSm^{-1} and 40 dSm^{-1} led to death of seedlings, these were lethal levels for Eucalyptus genotypes. The analysis of the variance showed significant differences among the genotypes and salinity treatments in respect of all characters. In general, the variations were recorded higher during summer than winter season except for water use efficiency. Different genotypes showed variations in physiological process at different level of salinity because all the genotypes are of different nature of genotype hence variations are due to genotypic effect and soil saline environment.

The data recorded during winter season (December-2011) revealed that C-413 had maximum photosynthetic rate among the genotypes in control condition and C-288 had lowest rate of photosynthesis rate (Table 1). When salinity level (EC) increases upto 5 dSm^{-1} and 10 dSm^{-1}, all the genotypes were started declining more as compared to controlled conditions and eventually C-413 holds maximum rate and C-288 had minimum among all genotypes studied. Similar trend for photosynthetic rate were recorded during summer season but assimilation rate was lesser than winter season for control condition as well as both salinity levels. During winter, the photosynthetic rate was recorded higher in C-413, whereas, C-2070 possessed higher rate of food assimilation in summer. However, the variations in rate of photosynthesis were more in summer among the genotypes (0.6%) and salinity levels (0.6%) than winter season (0.2%). Reduction in rate of photosynthesis was much higher in summer @ 10 dSm^{-1} salinity level in all genotypes.

Hysteresis was observed in both winter and summer seasons; however, the degree of hysteresis was larger during the dry season than during the winter season probably because of declining soil water availability (Table 2). It was observed that C-2070 transpired least water and C-288 transpired maximum among all three genotypes at control salinity level and but as salinity level (EC) increases (5 dSm^{-1} and 10 dSm^{-1}, respectively), all the genotypes were started transpiring more as compared to controlled conditions and specially C-413 transpired minimum water and C-2070 transpired maximum water among all genotypes studied. Similar pattern was recorded for summer season in control condition but as the salinity level increases C-288 transpired more water than C-2070 during summer season. When the salinity level increases from control to 5 dSm^{-1} there was enhancement in mean value across all the genotypes while further increment in salinity upto 10 dSm^{-1} leads to reduction for both seasons. However, increment in transpiration tare was much higher dry season. In general, C-413 was found to best in the view of transpiration rate for both seasons. The fluctuations in transpiration value in different genotypes and different salinity level is might be due to their varied genetic makeup and their differing ability to react at different saline conditions and sudden fluctuations also might be due to effect of their genotype.

The data on water use efficiency recorded in winter (December-2011) are given in Table 3. It was observed that C-2070 had maximum and C-288 had least WUE among all three genotypes grown in control salinity level but as salinity level (EC) increases (5 dSm^{-1}, 10 dSm^{-1}, respectively), all the genotypes were started declining more as compared to controlled conditions and eventually C-413 recorded maximum value of WUE and C-2070 had recorded minimum value among all genotypes studied. Similar pattern were recorded for summer season for all the genotypes. When the salinity level increases from control to 5 dSm-1 there was reduction in mean value across all the genotypes by 21 percent while further increment in salinity upto 10 dSm-1 leads to reduction in mean value of WUE across all the genotypes by 55 percent during winter season. Likewise, when the salinity level increases from control to 5 dSm^{-1} there was reduction in mean value across of WUE of all the genotypes by 35 percent while further increment in salinity upto 10 dSm^{-1} leads to reduction in mean value across all the genotypes by 31 percent during summer season. In general, C-413 was found to be best for winter season, and C-413 and C-2070 were best for summer season.

It was observed that C-413 had maximum chlorophyll content and C-2070 had least among all three genotypes at control condition level as well as all salinity levels (Table 4). However, as the salinity level (EC) increases chlorophyll content in all the genotypes were started declining as compared to controlled conditions. Similar pattern of chlorophyll content were recorded for summer season. All the genotypes and salinity levels were statistically significant and showed decreasing trend in chlorophyll content with increasing salinity level in the size. Interaction affects of genotype × Salinity levels were statistically significant for chlorophyll content. When the salinity level increases from control to 5 dSm^{-1} there was reduction in mean value across all the genotypes by 20 percent while further increment in salinity upto 10 dSm^{-1} leads to reduction in mean value across all the genotypes by 27 percent. Likewise, when the salinity level increases from control to 5 dSm^{-1} there was reduction in mean value of chlorophyll content across all the genotypes by 23 percent while further increment in salinity upto 10 dSm^{-1} leads to reduction in mean value of the same across all the genotypes by 29 percent.

Correlation studies were conducted to establish the relation between different traits, so that the suitability of different traits for indirect selection can be revealed. In general, the correlations among parameters studies were higher in summer season than winter (Table 5). Significant and positive correlation were recorded for all genotypes during summer season, however, transpiration rate had low non-significant correlation with WUE in C-288, and with WUE and chlorophyll content in C-2070. Similarly, high positive correlations were found in winter season; however, transpiration rate had a moderate correlation with chlorophyll content in C-288, and low with WUE and chlorophyll content in C-413. Transpiration rate had a negative correlation with photosynthesis, WUE and chlorophyll content in C-2070.

Table 1: Temporal effect of different levels of salinity on rate of photosynthesis (μ mol m^{-2} s^{-1}) of different genotypes of *Eucalyptus*

Genotype	December-2011				May-2012			
	Control	5 dSm^{-1}	10 dSm^{-1}	Mean	Control	5 dSm^{-1}	10 dSm^{-1}	Mean
C-288	9.4	8.9	3.9	7.4	8.1	6.5	1.5	5.4
C-413	9.7	9.2	4.3	7.8	8.9	7.9	1.8	6.2
C-2070	10.3	9.0	3.6	7.6	10.0	7.2	1.7	6.3
Mean	9.8	9.0	3.9		9.0	7.2	1.7	
L.S.D. @5%								
Genotype	0.2				0.6			
Salinity	0.2				0.6			
Interaction	0.3				1.2			

Table 2: Temporal effect of different levels of salinity on rate of transpiration (m mol m^{-2} s^{-1}) of different genotypes of *Eucalyptus*

Genotype	December-2011				May-2012			
	Control	5 dSm-1	10 dSm-1	Mean	Control	5 dSm-1	10 dSm-1	Mean
C-288	1.7	1.7	1.7	1.7	7.8	9.3	3.2	6.7

C-413	1.4	1.5	1.4	1.4	7.3	7.9	2.7	6.0
C-2070	1.3	1.9	1.8	1.6	6.1	8.4	3.0	5.8
Mean	1.5	1.7	1.6		7.0	8.5	2.9	
L.S.D. @5%								
Genotype	0.1				0.6			
Salinity	0.1				0.6			
Interaction	0.2				0.1			

Table 3: Temporal effect of different levels of salinity on water use efficiency of different genotypes of *Eucalyptus*

Genotypes	December-2011				May-2012			
	Control	**5 dSm-1**	**10 dSm-1**	**Mean**	**Control**	**5 dSm-1**	**10 dSm-1**	**Mean**
C-288	5.6	5.2	2.6	4.4	1.1	0.7	0.5	0.7
C-413	6.9	6.2	2.7	5.3	1.2	1.0	0.7	1.0
C-2070	8.1	4.8	2.1	5.0	1.7	0.9	0.6	1.0
Mean	6.9	5.4	2.5		1.3	0.9	0.6	
L.S.D. @5%								
Genotype	0.6				0.1			
Salinity	0.6				0.1			
Interaction	1.1				0.2			

Table 4: Temporal effect of different levels of salinity on Chlorophyll content (SPAD UNIT) of different genotypes of *Eucalyptus*

Genotypes	December-2011				May-2012			
	Control	**5 dSm^{-1}**	**10 dSm^{-1}**	**Mean**	**Control**	**5 dSm^{-1}**	**10 dSm^{-1}**	**Mean**
C-288	39.2	31.2	22.5	30.9	35.5	28.0	20.0	27.8
C-413	44.5	35.0	25.2	34.9	43.3	32.4	22.8	32.8
C-2070	34.8	27.3	19.9	27.3	33.4	25.2	17.7	25.4
Mean	39.5	31.2	22.5		37.4	28.5	20.1	
L.S.D. @5%								
Genotype	0.2				1.2			
Salinity	0.2				1.2			
Interaction	0.4				2.1			

Table 5: Correlation among physiological traits of *Eucalyptus* genotypes in different season

		C-288				C-413				C-2070			
		X_1	X_2	X_3	X_4	X_1	X_2	X_3	X_4	X_1	X_2	X_3	X_4
X_1	W	1.000				1.000				1.000			
	S	1.000				1.000				1.000			
X_2	W	0.822**	1.000			0.397	1.000			-0.519	1.000		
	S	0.890**	1.000			0.972**	1.000			0.714	1.000		
X_3	W	0.999**	0.798**	1.000		0.997**	0.336	1.000		0.922**	-0.806**	1.000	

	S	0.879**	0.577	1.000		0.958**	0.868**	1.000		0.901**	0.345	1.000	
X_4	W	0.914**	0.521	0.930**	1.000	0.909**	0.008	0.936**	1.000	0.942**	-0.003	0.999**	1.000
	S	0.964**	0.736	0.970**	1.000	0.909**	0.786	0.985**	1.000	0.978**	0.551	0.971**	1.000

* Significant at 5% level of significance
** Significant at 1% level of significance
X1 – Photosynthesis W – winter season
X2 – Transpiration rate S – summer season
X3 – Water use efficiency
X4 – Chlorophyll content

Discussion

Salt affected soil is a widespread soil type, and improving plant growth in this type of soil is urgently needed. Many methods have been used to improve plant growth in saline-alkali soils, the most effective of which are biological methods. However, plants seldom survive under high-salt conditions. In this study, we evaluated the physiological abilities of salt-tolerant Eucalyptus genotypes to adapt to high-salinity areas in North-western India. Photosynthetic rate is lower in salt-treated plants, but the photosynthetic potential is not greatly affected when rates are expressed with regard to chlorophyll or leaf area. Decreases in photosynthetic rate are due to several factors: (1) dehydration of cell membranes which reduce their permeability to CO_2, (2) salt toxicity, (3) reduction of CO_2 supply because of hydro-active closure of stomata, (4) enhanced senescence induced by salinity, (5) changes of enzyme activity induced by changes in cytoplasmic structure, and (6) negative feedback by reduced sink activity (Iyengar and Reddy, 1996). Suppression of photosynthesis was also reported under salt stress condition (Romeroaranda et al. 2001, Kao et al., 2001). In Acacia pseudoalhagi the leaf CO_2 assimilation rate increases at low salinity (50mM NaCl) but is not affected significantly by 100mM NaCl, while it is reduced to about 60% of the control in 200mM NaCl. In mulberry, net CO_2 assimilation rate decline under salt stress (Agastian et al., 2000). Similarly, net assimilation was higher at low salinity and decreases at high salinity in Bruguiera parviflora (Parida et al., 2004a).

The observed photosynthetic characteristics of the Eucalyptus genotypes indicate that salts induced salinity dissuade the rate of photosynthesis as increased salt concentration, which stands in agreement to the general finding that salinity reduces photosynthetic rate (Mickelbart, and Marler, 1996; Pezeshki and Chambers, 1986). However, this finding is in conformity with the work of Chavan and Karadge (1986) who reported stimulation in photosynthetic carbon assimilation in *Sesbania grandiflora*, respectively under saline conditions. The stimulation in the photosynthetic rate due to salt stress may be due to an increase in CO_2 absorption per unit leaf area as leaf succulence may increase the internal surface area per unit leaf surface (Shannon et al., 1994). Variation in rate of photosynthesis pattern in various genotypes clearly reveals role of salinity and the reaction of stress tolerance among genotypes which is controlled by their genotypic characters. Similar patterns were also reported in the findings of Farquhar and Sharkely (1982) and Pearcy et al., (1987). According to them genotype and stomatal CO_2 conductance was believed to be a major limiting factor for photosynthetic capacity. Leaf photosynthetic capacity is determined primarily by the amounts and catalytic activities of photosynthetic enzymes.

A clear seasonal variation in the temperature response to the photosynthesis was observed. The results showed a translational shift downwards of the photosynthetic response with increasing temperature and a shift in the temperature optimum of photosynthesis of 5-10°C between summer and winter. These results illustrate that the short-term temperature response of photosynthesis varies significantly on a seasonal basis. Medlyn et al., (2002), obtained similar results in *Pinus pinaster*. One mechanism appeared to be a shift in the temperature optimum of electron transport rate. Such a shift is generally ascribed to changing heat stability of the photosynthetic apparatus and has been clearly demonstrated for desert shrubs using in vitro methods (Armond et al., 1978). In accordance with the hypothesis that acclimation to low temperatures involves an increase in the capacity of temperature-limited enzymes such as Rubisco, however, Rubisco activity decreased with increasing ambient temperature (Berry and Bjorkman, 1980). A change in cell-wall conductance to CO_2 has also been implicated in plant acclimation to ambient temperature. Makino et al., (1994) formulated a hypothesis after finding that CO_2 limited photosynthesis per unit Rubisco varied with growth temperature.

In general, stomatal conductance and transpiration rates are higher in the wet season and decline during the dry season in response to increasing vapour pressure deficit (VPD) and declining soil water contents (Eamus and Cole, 1997). However, such patterns were not evident at the tree scale. Transpiration rates were higher during the dry season than during the wet/winter season. This result was contrary to expectations given the extended seasonal drought, and the decline in leaf stomatal conductance and predawn leaf water potential observed in many species within the area (Myers et al., 1997). Similarly stomatal conductance is consistent with the CO_2 assimilation rate and intercellular CO_2 concentration is lower in the NaCl treated plants than in the control (Kurban et al., 1999). The higher seasonal pattern in transpiration in the dry season compared with the winter season suggests that soil water availability did not become limiting during the extended dry season. Cook et al., (1998) found that there was sufficient soil water in the upper profile to maintain transpiration rates over the dry season. Increased evaporative demand over the dry season was larger than the magnitude of the decline in stomatal conductance resulting from increased VPD and reduced predawn leaf water potential (Prior et al., 1997b). This finding highlights the difficulties of extrapolating results at the leaf-scale (for example, reduced stomatal conductance in the dry season) to larger scales such as whole-tree or stand responses. Jarvis (1993) found that, in trees in aerodynamically rough forests, which are well coupled to the atmosphere, and not limited by soil water availability, transpiration will continue at the rate imposed by VPD in the *E. miniata* and *E. tetrodonta* open forests.

Simultaneous decreasing trend in rate of photosynthesis and transpiration had been observed earlier consequently the water use efficiency also decreased with increasing level of salinity as all three are interconnected because water use efficiency is ratio between Rate of Photosynthesis/ transpiration. Pereira and Kozlowski (1976) reported that closure of stomata in response to a decrease in plant water potential has also been observed in *E. camaldulensis* in pot experiments. Although the influence of environmental stress on stomatal closure varied among *E. camaldulensis* provenances (Roberts and Rosier, 1993). Water potential and osmotic potential of plants become more negative with an increase in salinity, whereas turgor pressure increases with increasing salinity (Morales et al., 1998; Khan, 2001; Meloni et al., 2001).

Leaf water and osmotic potentials and xylem tension increase with an increase in media salinity in *Rhizophora mucronata* (Aziz and Khan, 2001). Relative water content, leaf water potential, water uptake, transpiration rate, water retention, and water use efficiency decrease under short-term NaCl stress in jute (Chaudhuri and Choudhuri, 1997). Similarly, water potential, osmotic potential, and stomatal conductance become more negative with an increase in salinity, while pressure potential decreases with increasing salinity in the halophytic perennial grass *Urochondra setulosa* (Gulzar et al., 2003). With increasing salt concentration, leaf water potential and evaporation rate decrease significantly in the halophyte *Suaeda salsa* while there are no changes in leaf relative water content (Lu et al.,. 2002). Leaf water potential and osmotic potential decline depending on the osmotic potential of the rooting medium and the mode of stress imposition. A greater decline in osmotic potential compared with the total water potential led to turgor maintenance under progressive or prolonged NaCl stress (Rajasekaran et al., 2001).

Tree water use in each season could be determined solely by the prevailing soil water availability. If this is true, water use should decline substantially in the dry season, compared with the wet season. The results indicated that WUE was higher in winter season than dry season. However, water use increased in the dry season in trees. Low solar radiation and temperature limit water use to low values in winter season that’s why WUE was higher in winter season. Several studies suggest a hydraulic limit to water use. Leaf area/sapwood area ratio, sapwood area, leaf area and hydraulic conductivity are influenced by site differences in vapor pressure deficit (Whitehead, 1998). The hydraulic architecture of trees is structured such that runaway embolisms are just prevented (Tyree and Ewers, 1996). Hydraulic conductance of stems of *Pinus ponderosa* can limit stomatal conductance, and responses to soil and atmospheric water content can be explained by hydraulic architecture (Bond and Kavanagh, 1999).

The chlorophyll contents of leaves decrease in general under salt stress. The oldest leaves start to develop chlorosis and fall with prolonged period of salt stress (Hernandez et al., 1995, Agastian et al., 2000). Salt stress decreases the chlorophyll content in leaves of alfalfa plants (Khavarinejad and Chaparzadeh, 1998). However, in contrary to this, Wang and Nil (2000) have reported that chlorophyll content increases under conditions of salinity in *Amaranthus*. In Grevilea, chlorophyll content was significantly reduced under NaCl stress, but the rate of decline of protochlorophyll and chlorophyll is greater (Kennedy and De Fillippis, 1999). Gebauer et al., (2003) also reported that the increased salinity reduced the chlorophyll content and thus affects the photosynthetic rate, which leads to poor growth. Various genotypes exhibit different genetic combinations so variations in chlorophyll content of different genotypes at different salinity had already anticipated earlier. Similarly it was also observed in crops under salinity stress, leaf pigments studied in nine genotypes of rice reduce in general, but relatively high pigment levels are found in six genotypes (Alamgir and Ali, 1999).

Although physiological traits are clearly related, the relationship between these parameters is rather complex (Nasim et al., 2013). Estimates of correlations are necessary to assess whether selection based on low transpiration rate would significantly affect photosynthesis, water use efficiency and chlorophyll content also, and whether such a correlation will be observed at different genotypes and salinity levels. Due to phenotypic plasticity, variation always exists between genotypes of the same species grown in different salinity levels. It is therefore important for breeders to consider correlations of the same trait between different sites. In this study, we observed significant variation between parameters studied at different salinity and different seasons, and the correlations among parameters studied were significant as well. Therefore, selecting for one trait can affect the selection of another trait. Within the same salinity, the highest correlation coefficient was 0.999, which indicates that selecting trees with excellent WUE will probably lead to the selection of trees with excellent Chlorophyll content.

In conclusion, Large seasonal variations were recorded for rate of transpiration and water use efficiency, whereas, seasonal variations in rate of photosynthesis and chlorophyll content were very less. It is cleared that C-2070 was found to be best for photosynthesis, transpiration and WUE, whereas, C-413 showed higher chlorophyll content in control condition for both season. When the salinity level increases from control to 5 dSm^{-1} and 5 dSm^{-1} to 10 dSm^{-1}, C-413 was recorded best for all physiological parameters studied. The genotypes under study belong to three different species viz., C-288 (*E. tereticornis*), C-413 (*E. camaldulensis*) and C-2070 (*Eucalyptus* hybrid), these species are normally grown in wet habitats. The ratio of photosynthesis to transpiration, an instantaneous measure of intrinsic water-use efficiency, was highest in the species commonly found in the direst habitats and lowest in the species most common in the wettest habitats (Field et al., 1983). Improved WUE on the basis of reduced WU is expressed in improved yield under water-limited conditions only when there is need to balance crop water use against a limited and known soil moisture reserve. However, under most dryland situations where crops depend on unpredictable seasonal rainfall, the maximisation of soil moisture use is a crucial component of drought resistance (avoidance), which is generally expressed in lower WUE (Blum, 2005). Elevated photosynthetic rates were observed during two periods of the growing season and correlated with the fruiting process in apple (Fujii and Kennedy, 1985). However, in tree species where vegetative growth remains for longer period and in the presently study the observations were taken during first year of its age. Photosynthesis, WUE and chlorophyll content were observed higher in summer than winter due to high transpiration, which may have led to more water available for these physiological processes.

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