GAS EXCHANGE CHARACTERISTICS IN *EUCALYPTUS* CLONES

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SUMMARY

The largest operational clonal forestry programmes are with several species in the genus *Eucalyptus* and a number of clones are being deployed to increase the productivity of this species in India. There exists tremendous variation with reference to yield and tree form in clones of eucalypts. Studies on photosynthesis and related physiological parameters of various clones shall provide valuable information for establishing plantations at different geographic locations. Considerable variations were observed when 59 clones of *Eucalyptus camaldulensis* Dehnh. were subjected to physiological studies at the Institute of Forest Genetics and Tree Breeding (IFGTB), Coimbatore. Five clones exhibited superior growth coupled with favourable physiological characteristics including high photosynthesis, carboxylation efficiency and water use efficiency.

Key words: **Clonal forestry, eucalypts, physiological studies, water use efficiency**

INTRODUCTION

Eucalypts constitute the majority of the World's exotic hardwood forest and one of the world's main sources of biomass. It is one of the fast growing species with its unique adaptability to withstand a variety of environmental conditions. In India, eucalypts are primarily used for making pulp/paper and for charcoal. It also finds use as fuel wood, poles, stakes, fence posts, mining timber and particleboard. Though India is the largest planter of eucalypts in the tropics (Davidson 1998), the productivity is much less when compared to other countries. One of the major reasons for the low productivity is the non-availability of genetically improved planting material. Therefore, genetic improvement programmes of this species attract utmost attention. Clonal forestry has contributed substantially to improve the productivity of this species. There exists tremendous variation with reference to yield and tree form 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). Various physiological parameters play vital roles in growth and development of a selected clone. As tree growth is the end result of the interactions of physiological processes that influence 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). A study was undertaken at the Institute of Forest Genetics and Tree Breeding (IFGTB), Coimbatore, Tamil Nadu to understand the variability with respect to various physiological parameters in clones of *Eucalyptus camaldulensis* Dehnh.

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MATERIALS AND METHODS

Fifty-nine clones of *E. camaldulensis* selected by IFGTB were subjected to physiological studies at 3.5 years of age. 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 (LiCor Instruments, USA). The measurements were taken between 9.30 AM and 11.30 AM under cloud free conditions during August - September. Three observations each from three ramets per clone were recorded for all the physiological parameters. Water Use Efficiency (WUE) was also estimated from the clones. 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 (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). The data were subjected to analysis of variance for randomized complete block design with three replications.

RESULTS AND DISCUSSION

Table 1 shows the details of data on the primary physiological parameters including net photosynthetic rate, stomatal conductance, intercellular CO_2 concentration and transpiration rate. Information on intrinsic and instantaneous WUE, intrinsic carboxylation efficiency and intrinsic mesophyll efficiency are given in Table 2.

The photosynthetic rate varies among the plants belonging to different taxa and also among the varieties within the same species (Arora and Gupta 1996). Clone EC 130 ranked first (number one) with reference to the net photosynthetic rate followed by EC 17-1, EC 286, EC 404 and EC 1-7. The Pn values varied from 10.05 to 37.80 µmol m^{-2} s^{-1} with a mean of 18.45 ± 6.70 µmol m^{-2} s^{-1}. The minimum value was recorded by clone EC 12-11. Enhancing the photosynthetic efficiency is the most important way of increasing productivity (Gupta 1994). Photosynthetic rate of any species is a direct indicator of plant growth and metabolism. Therefore, selection of a variety or species for a given geographical location could also be on the basis of its photosynthetic activities.

Stomatal conductance is of utmost importance when photosynthesis is concerned. Stomata play a pivotal role in controlling the balance between assimilation and transpiration (Beadle *et al*. 1981). Several researchers have explained the variation in the rate of photosynthesis with reference to stomatal conductance (Balasimha *et al*. 1991, Eamus *et al*. 1993, Rodriguez *et al*. 1999). The role of stomata in determining the water use efficiency is also well understood (Leverenz *et al*. 1999, Li 2000). Kallarackal and Somen (1998) observed significant variations among different species of *Eucalyptus* viz. *E. tereticornis, E. camaldulensis, E. urophylla, E. brassiana, E. pellita* and *E. deglupta* in stomatal conductance. It was lowest in *E. urophylla* and highest in *E.camaldulensis*. Stomatal conductance varied between 0.120 to 0.474 mol m^{-2} s^{-1} with a mean of 0.22 ± 0.1. The minimum and the maximum values of gs were recorded by clones EC 10-6 and EC 130 respectively. Clones EC 17-1 and EC 71 occupied the second and third positions (from the top) in the list. Sixteen other clones were found to share the bottom position alongwith clone EC 10-6.

Among the 59 clones, EC 130 ranked first (197.30 µl l^{-1}) for intercellular CO_2 concentration. Clone EC 148 recorded the lowest value (92.58 µl l^{-1}). The mean and standard deviation were 125.34 and 26.45 µl l^{-1} respectively. The minimum (10.63 mmol m^{-2} s^{-1}) and the maximum 32.15 (mmol m^{-2} s^{-1}) values for transpiration rate (E) were registered by clones EC 242 and EC 404 respectively. The values for this parameter varied with a mean of 19.32 ± 5.27. Clones EC 130, EC 71, EC 132 and EC 286 also recorded high 'E'. Clones EC 17-1, EC 1-7, EC 404, EC 286, EC 72 and EC 130 which exhibited superior growth characteristics (data not shown) also registered higher rate of transpiration.

The ratio of net photosynthetic rate (Pn) to stomatal conductance (gs) is referred as intrinsic water use efficiency (Ares and Fownes 1999) and it implies the inherent ability of the plant to assimilate CO_2. Higher the ratio, better the ability for carbon assimilation. Intrinsic

Table 1. Net photosynthesis (Pn), stomatal conductance (gs), intercellular CO_2 concentration (Ci) and transpiration (E) in *Eucalyptus* clones.

Sl. No.	Clone No.	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	EC 1-5	15.48 p-u	0.157 op	119.90 l-p	12.85 q-t
2	EC 1-27	12.52 w-z	0.127 s-v	113.80 o-t	21.80 e-i
3	EC 2-1	19.16 h-l	0.283 g	138.20 f-h	21.27 f-j
4	EC 2-3	18.57 i-m	0.196 kl	108.10 r-v	19.56 g-l
5	EC 5-7	13.69 t-y	0.129 r-v	135.60 g-i	22.06 e-h
6	EC 10-2	13.45 t-y	0.140 p-v	104.20 t-x	15.58 n-q
7	EC 10-4	17.78 i-o	0.174 m-o	96.65 w-y	16.28 l-q
8	EC 13-4	29.46 cd	0.352 e	182.60 bc	20.51 f-k
9	EC 16-4	11.50 yz	0.121 uv	97.43 v-y	20.57 f-k
10	EC 19-2	10.80 yz	0.128 r-v	104.50 t-x	10.87 st
11	EC 20-1	22.26 fg	0.323 f	141.60 fg	18.35 h-n
12	EC 21-1	13.34 u-z	0.129 r-v	118.50 m-r	14.34 o-s
13	EC 1-6	11.37 yz	0.124 uv	103.60 t-x	11.68 r-t
14	EC 14-1	15.74 o-t	0.156 pq	129.20 h-l	13.14 q-t
15	EC 20-2	19.75 h-j	0.253 h	128.60 h-m	18.14 i-n
16	EC 5-3	18.45 i-m	0.176 mn	108.20 r-v	15.02 n-r
17	EC 4-5	11.44 yz	0.137 q-v	109.10 q-u	17.60 j-o
18	EC 12-11	10.05 yz	0.129 r-v	101.10 u-y	13.10 q-t
19	EC 13-3	13.50 t-y	0.130 r-v	119.50 l-q	20.59 f-k
20	EC 17-1	35.54 b	0.423 b	179.90 bc	25.90 cd
21	EC 12-9	23.31 f	0.328 f	146.20 ef	15.23n-r
22	EC 10-6	11.07 yz	0.120 v	109.50 p-u	17.45 k-p
23	EC 1-7	30.29 c	0.398 cd	175.80 c	25.31 c-e
24	EC 99	16.45 m-s	0.191 k-m	99.66 u-y	17.92 j-o
25	EC 259	16.94 l-q	0.159 n-p	105.20 t-x	22.78 d-g
26	EC 404	30.34 c	0.397 cd	187.90 b	32.15 a
27	EC 251	13.34 u-z	0.141 p-u	117.80 n-r	11.35 st
28	EC 250	14.92 q-v	0.141 p-u	109.90 p-u	21.17 f-k
29	EC 286	30.46 c	0.388 cd	179.20 bc	27.19 bc
30	EC 228	19.69 h-k	0.279 g	141.90 fg	21.97 e-h
31	EC 268	21.04 gh	0.273 g	129.70 h-l	22.11 e-h
32	EC 290	28.02 de	0.383 d	157.40 d	22.11 e-h
33	EC 419	20.07 hi	0.275 g	130.80 h-k	22.72 d-g
34	EC 10	26.23 e	0.382 d	156.50 d	19.53 g-l
35	EC 7	14.58 r-w	0.146 p-s	116.20 n-s	13.85 p-t
36	EC 71	29.72 cd	0.403 c	155.90 d	30.11 ab

Sl. No.	Clone No.	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})
37	EC 158	18.33 i-n	0.226 j	113.80 o-t	16.10 l-q
38	EC 128	17.51 j-p	0.181 lm	109.10 q-u	22.89 d-g
39	EC 148	13.89 t-x	0.147 p-r	92.58 y	17.71 j-o
40	EC 72	29.18 cd	0.394 cd	152.60 de	25.41 c-e
41	EC 264	13.67 t-y	0.146 p-s	102.90 u-y	19.68 g-l
42	EC 242	11.68 x-z	0.123 uv	99.28 u-y	10.63 t
43	EC 132	18.00 i-o	0.229 j	126.20 i-n	28.68 bc
44	EC 130	37.80 a	0.474 a	197.30 a	30.33 ab
45	EC 231	15.45 p-u	0.154 pq	109.60 p-u	18.70 h-n
46	EC 285	13.49 t-y	0.144 p-t	114.10 o-t	13.70 q-t
47	EC 27	28.33 cd	0.385 cd	156.10 d	21.38 f-j
48	EC 8	12.81 v-z	0.132 r-v	119.80 l-p	10.72 st
49	EC 26	14.29 s-w	0.134 r-v	94.72 xy	15.57 n-q
50	EC 16	12.85 v-z	0.127 w-v	105.20 t-x	19.53 g-l
51	EC 261	17.80 i-o	0.199 k	104.40 t-x	19.42 g-m
52	EC 3	12.56 w-z	0.126 t-v	99.34 u-y	18.72 h-n
53	EC 52	16.81 m-r	0.178 m	105.70 s-w	16.28 l-q
54	EC 399	19.49 h-k	0.283 g	125.40 i-n	17.57 j-o
55	EC 116	16.15 n-s	0.141 p-u	98.24 v-y	15.74 m-q
56	EC 1	12.8 v-z	0.128 r-v	122.90 j-o	20.76 f-k
57	EC 122	18.55 i-m	0.247 hi	122.00 k-o	25.38 c-e
58	EC 6	17.39 k-p	0.235 lj	131.40 h-k	23.54 d-f
59	EC 351	19.50 h-k	0.278 g	133.00 g-j	19.46 g-m
Mean	18.451	0.220	125.339	19.323	
SD	6.703	0.102	26.448	5.266	
SEM	0.504	0.008	1.988	0.396	

Means with the same letter in a column do not differ significantly as per Duncan's Multiple Range Test at 5 per cent level of significance.

WUE ranged between 67.7 and 115.2 µmol mol^{-1} with a mean of 88.2 ± 14.1 µmol mol^{-1}. The maximum value was estimated in clone EC 116 and eight other clones were found to be at par with it. Clone EC 2-1 registered the minimum value (Table 2). The most productive and promising eucalypts clones did not record high values for intrinsic WUE. 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).

Instantaneous WUE is estimated as the ratio of net photosynthetic rate to transpiration (Petite *et al*. 2000). Higher the value, better the efficiency of the plant to divert water for photosynthesis than transpiration. Clones EC 17-1, EC 1-7 and EC 130 recorded higher values for instantaneous WUE coupled with superior growth traits. They may be suited for drier and water deficit

Table 2. Water use efficiency (WUE), carboxylation efficiency and mesophyll efficiency in *Eucalyptus* clones.

Sl. No.	Clone No.	IntrinsicWater 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	EC 1-5	98.62 b-f	1.21 b-j	0.129 p-v	764.50 g-j
2	EC 1-27	98.23 f-g	0.58 z	0.110 v-z	895.10 b-f
3	EC 2-1	67.66 p	0.91 n-y	0.139 l-r	488.00 q-v
4	EC 2-3	94.73 b-i	0.95 k-w	0.172 c-f	551.70 n-r
5	EC 5-7	106.70 ab	0.63 z	0.101 z	1054.00 a
6	EC 10-2	96.06 b-h	0.86 q-z	0.130 p-u	749.60 g-k
7	EC 10-4	102.50 a-e	1.10 d-q	0.184 a-c	557.20 n-q
8	EC 13-4	83.69 h-o	1.44 ab	0.161 e-j	519.20 o-s
9	EC 16-4	94.70 b-i	0.56	0.119 s-z	803.40 g
10	EC 19-2	84.54 g-n	1.00 h-t	0.104 yz	817.90 fg
11	EC 20-1	69.05 p	1.22 b-j	0.157 f-l	439.10 s-w
12	EC 21-1	103.60 a-e	0.93 m-x	0.113 u-z	919.50 b-d
13	EC 1-6	91.54 d-k	0.98 j-v	0.110 v-z	836.40 d-g
14	EC 14-1	101.10 b-e	1.20 b-k	0.122 r-y	832.10 d-g
15	EC 20-2	77.97 k-p	1.09 e-q	0.154 f-m	508.10 p-t
16	EC 5-3	105.20 a-d	1.24 b-i	0.171 c-g	616.30 mn
17	EC 4-5	83.81 h-o	0.65 z	0.105 x-z	799.70 gh
18	EC 12-11	77.75 l-p	0.77 t-z	0.100 z	781.90 g-j
19	EC 13-3	104.20 a-d	0.66 z	0.113 u-z	923.30 bc
20	EC 17-1	83.99 h-o	1.37 a-c	0.198 a	425.00 t-w
21	EC 12-9	71.04 n-p	1.53 a	0.160 e-k	445.20 s-w
22	EC 10-6	92.35 c-j	0.64 z	0.101 z	912.30 b-e
23	EC 1-7	76.10 l-p	1.24 b-i	0.172 c-f	441.70 s-w
24	EC 99	86.01 f-m	0.92 n-y	0.165 c-i	521.00 o-s
25	EC 259	107.30 ab	0.75 t-z	0.161 e-j	666.30 k-m
26	EC 404	76.46 l-p	0.95 l-x	0.162 e-j	473.70 q-w
27	EC 251	94.66 b-i	1.18 c-m	0.114 t-z	835.90 c-g
28	EC 250	106.40 a-c	0.71 w-z	0.137 m-s	782.70 g-j
29	EC 286	78.53 k-p	1.16 c-n	0.170 c-h	461.60 r-w
30	EC 228	70.60 n-p	0.91 o-y	0.139 l-r	508.60 p-t
31	EC 268	76.96 l-p	0.96 k-w	0.162 e-j	474.10 q-w
32	EC 290	73.30 m-p	1.27 b-f	0.178 b-e	411.80 u-w
33	EC 419	73.18 m-p	0.89 p-z	0.153 f-m	476.60 q-w
34	EC 10	68.74 p	1.34 a-d	0.168 c-h	409.60 vw
35	EC 7	100.00 b-f	1.06 f-r	0.126 q-w	794.40 g-i
36	EC 71	73.81 m-p	0.99 i-u	0.191 ab	387.20 w

Sl. No.	Clone No.	IntrinsicWater 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})$^{-1}$
37	EC 158	81.05 i-p	1.14 c-p	0.161 e-j	504.00 q-u
38	EC 128	97.05 b-h	0.76 t-z	0.161 e-j	602.20 m-o
39	EC 148	94.44 b-i	0.79 s-z	0.150 h-o	628.30 l-n
40	EC 72	74.10 m-p	1.15 c-o	0.191 ab	387.30 w
41	EC 264	93.40 b-i	0.70 x-z	0.133 n-t	704.60 i-l
42	EC 242	94.65 b-i	1.10 d-q	0.118 s-z	805.00 g
43	EC 132	78.63 k-p	0.63 z	0.143 j-q	550.90 n-r
44	EC 130	79.74 j-p	1.25 b-h	0.192 ab	416.30 t-w
45	EC 231	100.20 b-e	0.83 r-z	0.141 k-r	710.80 h-l
46	EC 285	93.60 b-i	0.99 i-u	0.118 s-z	792.90 g-i
47	EC 27	73.75 m-p	1.33 a-e	0.182 a-d	405.80 vw
48	EC 8	96.74 b-h	1.20 b-l	0.107 w-z	905.80 b-f
49	EC 26	107.10 ab	0.92 n-y	0.151 h-o	709.10 h-l
50	EC 16	100.90 b-e	0.66 z	0.124 q-x	828.30 e-g
51	EC 261	89.44 e-l	0.92 n-y	0.171 c-g	524.30 o-s
52	EC 3	99.52 b-f	0.67 yz	0.126 q-w	787.70 g-j
53	EC 52	94.68 b-i	1.05 f-r	0.160 e-k	596.00 m-p
54	EC 399	68.93 p	1.25 b-g	0.155 f-m	443.50 s-w
55	EC 116	115.20 a	1.03 f-s	0.164 d-i	699.80 j-l
56	EC 1	99.67 b-f	0.62 z	0.104 yz	959.30 b
57	EC 122	75.05 m-p	0.73 v-z	0.152 g-n	493.50 q-v
58	EC 6	73.83 m-p	0.74 u-z	0.132 o-u	559.10 n-q
59	EC 351	70.25 op	1.00 g-t	0.147 i-p	479.40 q-w
Mean	88.187	0.971	0.145	640.319	
SD	14.061	0.264	0.029	184.555	
SEM	1.057	0.020	0.002	13.872	

Means with the same letter in a column do not differ significantly as per Duncan's Multiple Range Test at 5 per cent level of significance.

locations. This ratio varied between 0.56 µmol $mmol^{-1}$ (EC 16-4) and 1.53 µmol $mmol^{-1}$ (ET 12-9) with a coefficient of variation (CV) of 27 per cent. Genotypic differences in long-term measures of instantaneous WUE among the native populations of *Larix occidentalis* have been reported (Zhang and Marshall 1994). Though relatively higher WUE (average long-term WUE – 6.3 g dry weight biomass per kg of transpired water) was noticed in *Salix viminalis* (Lindroth *et al*. 1996), water availability was identified as the critical factor in short rotation willow forestry. Studying the physiological and morphological responses of *Eucalyptus microtheca* provenances it was suggested that the faster growth of selected provenances was related to their prodigal water use (Tuomela 1997). The efficient control of water loss through stomatal regulation was indicated by high instantaneous WUE. Measurement of WUE might be a useful trait for selecting genotypes with improved drought adaptation and biomass productivity under different environmental conditions (Li 2000).

The ratio of net photosynthesis rate to intercellular CO_2 concentration is termed as intrinsic carboxylation efficiency (Hamerlynck *et al*. 2000). Higher the ratio, better the efficiency for carboxylation. Among the eucalypt clones, EC 17-1, EC 1-7, EC 71, EC 72 and EC 130 recorded higher values for intrinsic carboxylation efficiency coupled with superior growth when compared to others. This ratio varied from 0.100 (EC 12-11) to 0.198 $\mu mol\ m^{-2}\ s^{-1}\ (\mu l\ l^{-1})^{-1}$ (EC 17-1) with a coefficient of variation of 20 per cent.

The ratio of intercellular CO_2 concentration (Ci) to stomatal conductance (gs) represents the intrinsic mesophyll efficiency (Sheshshayee *et al*. 1996). At a given stomatal conductance, lower Ci indicated better mesophyll efficiency and better draw down rate of the substrate CO_2. It has been reported that drought tolerant cultivars of *Morus alba* exhibited greater mesophyll efficiency than the drought sensitive genotypes (Ramanjulu *et al*. 1998). In the present study, clone EC 71 recorded the minimum value (387.20 $\mu l\ l^{-1}\ (mol\ m^{-2}\ s^{-1})^{-1}$ whereas, EC 5-7 estimated the maximum value (1054.00 $\mu l\ l^{-1}\ (mol\ m^{-2}\ s^{-1})^{-1}$). The mean and the standard deviation for this ratio were 640.32 and 184.56 $\mu l\ l^{-1}\ (mol\ m^{-2}\ s^{-1})^{-1}$, respectively.

Many researchers have studied on the physiological adaptations of eucalypts. Srivastava (1993) reported that *Eucalyptus* has high water holding capacity in the soil. There was more soil moisture under *Eucalyptus* than a nearby open area even after three consecutive drought years. Osorio and Pereira (1993) studied the effect of drought on productivity and WUE in *E. globulus* clones and reported that WUE significantly increased by water deficit. Abbasi and Vinithan (1997) have established that *Eucalyptus* hybrid plantations do not deplete soil moisture. Kumar (1984) has refuted the point that *Eucalyptus* has a high transpiration rate. According to him, *Eucalyptus* has a low transpiration rate and it controls stomatal openings according to water availability without serious reduction in biomass production. *Eucalyptus* has the inherent capacity for luxury consumption of water when moisture is abundantly available. The high rate of transpiration reported in certain physiological studies on *Eucalyptus* is thus an adaptability mechanism operative under adequate soil moisture only (Srivastava *et al*. 2003). Leaf shedding of eucalypts reduces water demand by reducing leaf area. It also reduces heat load under dry conditions when transpiration is reduced (Roberts 2001).

In the present study, five clones namely, EC 1-7, EC 17-1, EC 71, EC 72 and EC 130 exhibited superior growth coupled with favourable physiological characteristics including high photosynthesis, carboxylation efficiency and water use efficiency. The genotypes maintaining higher WUE have an efficient stomatal regulatory capacity (Maroco *et al*. 1997). The best way to conserve soil water is to select and plant genotypes having higher WUE so that the transpirational water loss can be optimized. Such genotypes should also be able to tolerate drought stress. Hence, the above listed clones may be suited for arid locations and could be used as potential candidates for special purpose clonal seed orchards for quality seed production.

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