GAS EXCHANGE CHARACTERISTICS IN CASUARINA CLONES

Kannan C.S. Warrier*, M. Ganesan and K.S. Venkataramanan

Institute of Forest Genetics and Tree Breeding
(Indian Council of Forestry Research and Education)
PB 1061, R.S. Puram Post, Coimbatore – 641 002, Tamil Nadu, India

* Author for correspondence
Email: kannan@ifgtb.res.in

GAS EXCHANGE CHARACTERISTICS IN CASUARINA CLONES

Kannan C.S. Warrier, M. Ganesan and K.S. Venkataramanan

Institute of Forest Genetics and Tree Breeding
(Indian Council of Forestry Research and Education)
PB 1061, R.S. Puram Post, Coimbatore – 641 002, Tamil Nadu, India

SUMMARY

Casuarina equisetifolia Forst. is a species of importance to the southern world. In India, it is extensively grown like a cash crop by farmers in southern peninsula due to its multiple utility values. However, this species is reported to show tremendous variation in tree form, growth parameters, tolerance to environmental stresses and adaptability to degraded lands. As drought is the main limiting factor influencing the productivity in semi-arid areas, water use efficiency (WUE) should be given due importance alongwith the yield parameters while selecting the trees. Studies conducted at the Institute of Forest Genetics and Tree Breeding, Coimbatore revealed considerable variation with respect to physiological parameters including WUE in 33 casuarina clones. Seven clones with superior growth performance and favourable physiological characteristics including high photosynthesis, carboxylation efficiency and water use efficiency were found.

KEY WORDS

Casuarina, clonal forestry, gas exchange parameters, water use efficiency.

INTRODUCTION

Casuarina equisetifolia is the most widely planted and domesticated species of *Casuarina* in India. Over a period of time since its introduction in India during the late 19th century, it has become a truly multipurpose species finding use in construction, pulpwood, fuelwood and for ecorestoration activities like sand dune stabilization and reclamation of degraded sites (Nicodemus *et al*., 2001). *C.*

equisetifolia has also gained considerable importance as an agroforestry species due to its nitrogen fixing ability and fast growth (Viswanath *et al*., 2001). However, this species is reported to show tremendous variation in tree form, growth parameters, tolerance to harsh environmental conditions and adaptability to degraded sites. As drought is the main limiting factor influencing the productivity in semi-arid zones, water use efficiency (WUE) should be given due importance alongwith the yield parameters while selecting the trees. A study was undertaken at the Institute of Forest Genetics and Tree Breeding (IFGTB), Coimbatore, Tamil Nadu to understand the variability with reference to various physiological parameters.

MATERIALS AND METHODS

Thirty-three clones of *C. equisetifolia* selected from Chidambaram / Chengalpet (CH/CP) region in Tamil Nadu and maintained in the clone bank of IFGTB were subjected to physiological studies at 4 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. 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 transpitaion (Pn/E). Intrinsic carboxylation efficiency was derived as the ratio of net photosynthetic rate to intercellular CO_2 concentration (Pn/Ci). Total height, diameter at breast height (DBH), collar diameter and biomass index were recorded to understand the growth performance (data not shown). The data were subjected to analysis of variance for randomized complete block design with three replications.

RESULTS AND DISCUSSION

Data on the primary physiological parameters including net photosynthetic rate, stomatal conductance, intercellular CO_2 concentration and transpiration rate recorded from the casuarina clones are given in Table 1. Table 2 gives information on intrinsic and instantaneous WUE and intrinsic carboxylation efficiency.

Photosynthesis is the key to dry matter production and increasing the photosynthetic efficiency is the most important way of increasing productivity (Gupta, 1994). Of all aspects of plant metabolism, photosynthesis shows the most prominent variation under the dictates of the immediate environment (Arora and Gupta, 1996). The net photosynthesis rate varied between 1.95 µmol m^{-2} s^{-1} (CP 1802) and 13.52 µmol m^{-2} s^{-1} (CH 2703) with a mean of 7.07 ± 3.19 µmol m^{-2} s^{-1}. Clones CH 3004 (13.15 µmol m^{-2} s^{-1}) and CH 0401 (11.26 µmol m^{-2} s^{-1}) were found on par with the top ranking clone. Six other clones shared the lower most position alongwith CP 1802. Stomatal conductance is of utmost importance when photosynthesis is concerned. The role of Stomates in determining the water use efficiency is also well understood (Li, 2000). The genotypes that can maintain higher water use efficiency will have an efficient stomatal regulatory capacity (Maroco *et al*., 1997). With reference to stomatal conductance, the minimum (0.064 mol m^{-2} s^{-1}) and the maximum (0.184 mol m^{-2} s^{-1}) values were recorded by CP 1802 and CH 2703 respectively (with mean 0.128 and standard deviation 0.032) for stomatal conductance. Clones CH 0401, CH 2803, CH 3004 and CP 0207 were on par with CH 2703 which showed the maximum value.

The values for intercellular CO_2 concentration (Ci) ranged between 96.35 and 242.50 µl l^{-1} with a mean of 207.87 ± 37.99. Clone CP 1802 registered the minimum value whereas, the maximum value was recorded by clone CP 3703. Around 80 per cent of the clones were on par with the top ranking clone with respect to this variable. Clone CP 1802 recorded the minimum value (9.72 mmol m^{-2} s^{-1}) and clone CH 2703 registered the maximum value (36.16 mmol m^{-2} s^{-1}) for transpiration rate. Clones CP 0207, CH 2803, CH 3004, CH 0401 and CH 1004 also registered superior values for transpiration rate. In general, it was observed that the values for these physiological parameters were found to decrease from high yielding to low yielding clones. When 52 clones of *Casuarina equisetifolia* were tested in a clonal trial, it was noticed that the various physiological characters like photosynthesis, transpiration, 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 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 WUE ranged from 21.90 (CH 1702) to 73.87 µmol mol^{-1} (CH 3004) with a coefficient of variation of 30 per cent among the clones. Around 58 per cent of the clones registered higher values for this ratio. The most productive clones, CH 3004, CH 0401 and CH 2703 recorded significantly superior values for intrinsic WUE and the ratio decreased gradually from high yielding to low yielding clones.

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. Similar to the observations on intrinsic WUE, productive clones exhibited superior values for this ratio in the present study. Instantaneous WUE ranged from 0.169 (CP 2401) to 0.477 µmol mmol^{-1} (CH 3004) with a coefficient of variation of 35 per cent. Clones CP 3702 and CP 1501 which were average performers for growth traits also recorded significantly higher instantaneous WUE. Tuomela (1997), studying the physiological and morphological responses of *Eucalyptus microtheca* provenances suggested that the efficient control of water loss 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. In the present study, higher intrinsic carboxylation efficiency was recorded by all the clones with superior growth characteristics. This ratio varied between 0.014 and 0.057 µmol m^{-2} s^{-1} (µl l^{-1})$^{-1}$ with a coefficient of variation of 39 per cent. Clones CH 1702 and CH 3004 recorded the minimum and the maximum values respectively. Fourteen clones were found on par with each other with respect to higher intrinsic carboxylation efficiency. Clones CH 3004, CH 2703, CH 0401, CP 0207 and CH 2803 recorded superior values for this ratio coupled with higher productivity.

Seven clones (CH 3004, CP 0207, CP 0203, CH 2703, CH 2803, CP 3903 and CH 0401) with superior growth and favourable physiological characteristics including high photosynthesis, carboxylation efficiency and water use efficiency were identified from the study. They could be used as potential candidates for special purpose clonal seed orchards for quality seed production.

REFERENCES

Ares, A. and Fownes, J.H. (1999). Water supply regulates structure, productivity, and water use efficiency of *Acacia koa* forest in Hawaii. *Oecologia* **121**: 458-466.

Arora, D.K. and Gupta, S. (1996). Advances in Plant Physiology Vol 8. Anmol Publications Pvt. Ltd., New Delhi, 416 p.

Balasubramanian, A. and Gurumurthi, K. (2001). Divergence studies in *Casuarina equisetifolia* for grouping of productive clones. In: K. Gurumurthi, A. Nicodemus and Siddappa (eds.), Casuarina Improvement and Utilization, pp. 57-62. Institute of Forest Genetics and Tree Breeding, Coimbatore.

Ceulemans, R.J., Impens, I. and Steenackers, V. (1988). Variations in photosynthetic, anatomical and enzymatic leaf traits and correlations with growth in recently selected *Populus* hybrid. *Can. J. For.Res*. **17**: 273-283.

Gupta, U.S. (1994). Improving photosynthetic efficiency and crop productivity. In: S.S. Purohit and M.P. Sahu (eds.), Agro's Annual Review of Plant Physiology (Basic and Applied) Volume I, pp. 1-50. Agro Botanical Publishers (India), Bikaner, India.

Hamerlynck, E.P., Huxman, T.E., Nowak, R.S., Redar, S., Loik, M.E., Jordan, D.N., Zitzer, S.F., Coleman, J.S., Seemann, J.R. and Smith, S.D. (2000). Photosynthetic responses of *Larrea tridentata* to a step-increase in atmospheric CO_2 at the Nevada desert FACE facility. *J. Arid Environ*. **44**: 425-436.

Lapido, D.O., Grace, J., Sandford, A.P. and Leakey, R.R.B. (1984). Clonal variation in photosynthetic and respiration rate and diffusion resistance in the tropical hard wood *Triplochiton scleroxylon* K. Schum. *Photosynthetica* **18**: 20-27.

Li, C.Y. (2000). Population differences in water-use efficiency of *Eucalyptus microtheca* seedlings under different watering regimes. *Physiologia Plantarum* **108**:134-139.

Maroco, J.P., Pereira, J.S. and Chaves, M.M. (1997). Stomatal response to leaf to air vapour pressure deficits in sahelian species*. Aust. J. Pl. Physiol.* **24**: 381-387.

Nicodemus, A., Varghese, M. and Nagarajan, B. (2001). Genetic improvement of *Casuarina equisetifolia* through selection and breeding. In: K. Gurumurthi, A. Nicodemus and Siddappa (eds.), Casuarina Improvement and Utilization, pp. 3-13. Institute of Forest Genetics and Tree Breeding, Coimbatore.

Petite, M.A., Moro, G.B., Murua, G.C., Lacuesta, M. and Rueda, M.A. (2000). Sequential effects of acidic precipitation and drought on photosynthesis and chlorophyll fluorescence parameters of *Pinus radiata* D. Don seedlings. *J. Pl. Physiol*.**156**: 84-92.

Tuomela, K. (1997). Physiological and Morphological Responses of Eucalyptus microtheca Provenances to Water Availability in Tropical Drylands. Tropical Forestry Reports No.13. University of Helsinki, Finland, 130 p.

Viswanath, S., Manivahakam, P. and George, M. (2001). *Casuarina equisetifolia* in agroforestry practices. In: K. Gurumurthi, A. Nicodemus and Siddappa (eds.), Casuarina Improvement and Utilization, pp. 187-192. Institute of Forest Genetics and Tree Breeding, Coimbatore.

Table 1. Net photosynthesis, stomatal conductance, intercellular CO_2 concentration and transpiration in casuarina clones

Sl No.	Clone No.	Net Photosynthetic Rate (Pn) (μmol m^{-2} s^{-1})	Stomatal Conductance (gs) (mol m^{-2} s^{-1})	Intercellular CO2 Concentration (Ci) (μl l^{-1})	Transpiration Rate (E) (mmol m^{-2} s^{-1})
1	CH 3004	13.15 ^{a}	0.178 ^{a}	235.00 ^{abc}	31.97 $^{a-d}$
2	CP 4305	3.76 $^{m-p}$	0.100 ^{hij}	188.50 $^{a-f}$	18.22 $^{g-j}$
3	CP 3703	8.87 $^{b-g}$	0.134 ^{bcd}	242.50 ^{a}	25.67 $^{b-g}$
4	CP 3702	7.66 $^{e-j}$	0.124 $^{c-g}$	237.60 ^{ab}	20.51 $^{e-j}$
5	CP 3901	5.83 $^{l-n}$	0.119 $^{c-h}$	216.30 $^{a-e}$	19.91 $^{e-j}$
6	CP 1501	9.97 $^{b-e}$	0.147 ^{b}	216.60 $^{a-e}$	24.70 $^{c-g}$
7	CP 1802	1.95 ^{p}	0.064 ^{k}	96.35 ^{g}	9.72 ^{k}
8	CP 4403	7.74 $^{e-j}$	0.127 $^{c-f}$	211.00 $^{a-e}$	23.43 $^{d-h}$
9	CP 4202	6.37 $^{g-l}$	0.123 $^{c-g}$	241.20 ^{a}	20.80 $^{e-j}$
10	CP 0301	7.08 $^{g-k}$	0.128 $^{c-f}$	212.00 $^{a-e}$	23.99 $^{c-g}$
11	CP 0110	4.42 $^{l-p}$	0.111 $^{f-i}$	183.50 $^{b-f}$	23.31 $^{d-h}$
12	CP 0207	10.44 ^{bcd}	0.175 ^{a}	223.70 $^{a-d}$	33.46 ^{ab}
13	CP 0108	5.21 $^{j-n}$	0.123 $^{c-g}$	199.20 $^{a-f}$	19.43 $^{f-j}$
14	CP 0203	9.71 $^{b-f}$	0.137 ^{bc}	231.50 $^{a-d}$	27.11 $^{b-g}$
15	CH 2703	13.52 ^{a}	0.184 ^{a}	242.30 ^{a}	36.16 ^{a}
16	CH 1802	3.45 ^{nop}	0.083 ^{j}	166.80 ^{ef}	13.94 $^{i-k}$
17	CH 3002	6.71 $^{g-l}$	0.132 $^{b-e}$	211.20 $^{a-e}$	22.11 $^{e-j}$
18	CH 2604	7.86 $^{e-i}$	0.126 $^{c-f}$	210.90 $^{a-e}$	21.56 $^{e-j}$
19	CH 2803	10.85 ^{bc}	0.181 ^{a}	237.40 ^{ab}	32.33 ^{abc}
20	CP 3501	6.11 $^{i-m}$	0.115 $^{d-i}$	198.10 $^{a-f}$	21.43 $^{e-j}$
21	CP 3101	4.96 $^{k-n}$	0.105 ^{ghi}	192.20 $^{a-f}$	14.85 $^{h-k}$
22	CP 3903	9.65 $^{b-f}$	0.148 ^{b}	227.20 $^{a-d}$	27.46 $^{b-f}$
23	CP 2401	2.10 ^{p}	0.113 $^{e-i}$	151.90 ^{f}	13.46 ^{jk}
24	CP 4805	8.70 $^{c-h}$	0.125 $^{c-f}$	233.70 $^{a-d}$	25.84 $^{b-g}$
25	CH 2602	7.23 $^{f-k}$	0.122 $^{c-g}$	210.40 $^{a-e}$	24.85 $^{b-g}$
26	CH 2303	4.30 $^{l-p}$	0.113 $^{e-i}$	217.60 $^{a-e}$	18.52 $^{f-j}$
27	CH 2002	4.92 $^{k-n}$	0.096 ^{ij}	186.70 $^{a-f}$	19.41 $^{f-j}$
28	CH 0401	11.26 ^{ab}	0.181 ^{a}	227.90 $^{a-d}$	31.93 $^{a-d}$
29	CH 0903	8.10 $^{d-i}$	0.136 ^{bc}	219.50 $^{a-e}$	23.30 $^{d-h}$
30	CH 1702	2.39 ^{op}	0.111 $^{f-i}$	180.40 $^{c-f}$	10.10 ^{k}
31	CH 0803	6.16 $^{h-m}$	0.109 $^{f-i}$	212.60 $^{a-e}$	20.74 $^{e-j}$
32	CH 1004	8.09 $^{d-i}$	0.148 ^{b}	219.10 $^{a-e}$	28.63 $^{a-e}$
33	CH 1002	4.70 $^{k-o}$	0.098 ^{ij}	178.90 ^{def}	22.57 $^{e-i}$
Mean		7.07	0.128	207.87	22.77
SD		3.19	0.032	37.99	7.36
SEM		0.321	0.003	3.819	0.740

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.

Table 2. Water use efficiency and carboxylation efficiency in casuarina clones

Sl No.	Clone No.	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})$^{-1}$
1	CH 3004	73.87 ^{a}	0.477 ^{a}	0.057 ^{a}
2	CP 4305	39.08 ^{hij}	0.227 $^{c\text{-}f}$	0.021 ^{fg}
3	CP 3703	66.83 $^{a\text{-}d}$	0.346 $^{a\text{-}f}$	0.037 $^{a\text{-}f}$
4	CP 3702	60.46 $^{a\text{-}f}$	0.388 ^{abc}	0.034 $^{b\text{-}f}$
5	CP 3901	47.00 $^{d\text{-}i}$	0.319 $^{a\text{-}f}$	0.028 $^{c\text{-}g}$
6	CP 1501	68.38 ^{abc}	0.420 ^{ab}	0.047 ^{abc}
7	CP 1802	30.93 ^{ij}	0.200 ^{def}	0.020 ^{fg}
8	CP 4403	60.07$^{a\text{-}g}$	0.330 $^{a\text{-}f}$	0.037 $^{a\text{-}f}$
9	CP 4202	52.54 $^{b\text{-}h}$	0.311 $^{a\text{-}f}$	0.027 $^{c\text{-}g}$
10	CP 0301	56.02 $^{a\text{-}h}$	0.295 $^{b\text{-}f}$	0.033 $^{b\text{-}g}$
11	CP 0110	40.22 $^{g\text{-}j}$	0.192 ^{ef}	0.024 ^{efg}
12	CP 0207	59.78 $^{a\text{-}g}$	0.313 $^{a\text{-}f}$	0.047 ^{abc}
13	CP 0108	42.90 $^{e\text{-}i}$	0.272 $^{b\text{-}f}$	0.026 $^{d\text{-}g}$
14	CP 0203	72.33 ^{ab}	0.359 $^{a\text{-}e}$	0.044 $^{a\text{-}e}$
15	CH 2703	73.34 ^{a}	0.374 $^{a\text{-}d}$	0.056 ^{a}
16	CH 1802	41.54 $^{f\text{-}i}$	0.272 $^{b\text{-}f}$	0.021 ^{fg}
17	CH 3002	51.00 $^{c\text{-}h}$	0.306 $^{a\text{-}f}$	0.032 $^{b\text{-}g}$
18	CH 2604	62.41 $^{a\text{-}e}$	0.385 ^{abc}	0.039 $^{a\text{-}f}$
19	CH 2803	60.04 $^{a\text{-}g}$	0.340 $^{a\text{-}f}$	0.046 $^{a\text{-}d}$
20	CP 3501	54.02 $^{a\text{-}h}$	0.289 $^{b\text{-}f}$	0.031 $^{b\text{-}g}$
21	CP 3101	48.08 $^{d\text{-}i}$	0.342 $^{a\text{-}f}$	0.026 $^{d\text{-}g}$
22	CP 3903	65.42 $^{a\text{-}d}$	0.361 $^{a\text{-}e}$	0.043 $^{a\text{-}e}$
23	CP 2401	22.92 ^{j}	0.169 ^{f}	0.014 ^{g}
24	CP 4805	70.02 ^{abc}	0.346 $^{a\text{-}f}$	0.037 $^{a\text{-}f}$
25	CH 2602	60.46 $^{a\text{-}f}$	0.296 $^{b\text{-}f}$	0.035 $^{b\text{-}f}$
26	CH 2303	38.03 ^{hij}	0.231 $^{c\text{-}f}$	0.020 ^{fg}
27	CH 2002	50.38 $^{c\text{-}h}$	0.254 $^{b\text{-}f}$	0.026 $^{d\text{-}g}$
28	CH 0401	61.79 $^{a\text{-}e}$	0.353 $^{a\text{-}e}$	0.049 ^{ab}
29	CH 0903	59.60 $^{a\text{-}g}$	0.372 $^{a\text{-}e}$	0.037 $^{a\text{-}f}$
30	CH 1702	21.90 ^{j}	0.239 $^{c\text{-}f}$	0.014 ^{g}
31	CH 0803	56.45 $^{a\text{-}h}$	0.297 $^{b\text{-}f}$	0.030 $^{b\text{-}g}$
32	CH 1004	55.07 $^{a\text{-}h}$	0.301 $^{a\text{-}f}$	0.037 $^{a\text{-}f}$
33	CH 1002	48.12 $^{d\text{-}i}$	0.224 $^{c\text{-}f}$	0.027 $^{d\text{-}g}$
Mean		53.67	0.309	0.033
SD		16.18	0.108	0.013
SEM		1.626	0.011	0.001

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.