



SHORT COMMUNICATION

GIBBERELLIN INDUCED DIFFERENCES IN INTRINSIC WATER USE, CARBOXYLATION AND PHOTOCHEMICAL EFFICIENCIES IN A TEA (*CAMELLIA SINENSIS* L.) ACCESSION

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We demonstrate the plausible utility of gas exchange and fluorescence approaches for exploiting the variability in physiological traits such as water use, carboxylation and photochemical efficiencies in a tea accession (SA6) treated with different concentrations of gibberellin (GA₃).

Keywords: Gibberellin, intrinsic carboxylation efficiency, photochemical efficiency of PS II, photosynthetic rate.

The process of photosynthesis is often considered as a diffusive phenomenon (Farquhar *et al.* 1980, von Caemerrer and Farquhar 1981, Farquhar and von Caemerrer 1982) and the rate of diffusion of CO₂ is largely controlled by two factors - the stomatal conductance (g_s) and the CO₂ gradient between carboxylation site and the ambient air (Cousson 2000, El-Sharkawy and Cock 1983). Variation in g_s controls both the influx of CO₂ and efflux of water through the leaves (von Caemerrer and Farquhar 1996). The trade-off between g_s and mesophyll efficiency (g_m) largely influence the fate of intercellular CO₂ (C_i) levels and thereby photosynthetic efficiency (PE). The diffusivity of CO₂ into the leaf, therefore, is a reflection of intrinsic mesophyll carbon assimilatory capacity. Furthermore, the complication multiplies due to quantification methods. Unlike g_s, determination of mesophyll carbon assimilatory capacity is rather difficult and only indirect approaches have been used (Farquhar *et al.* 1980, von Caemerrer and Farquhar 1981, Farquhar and von Caemerrer 1982, Sheshshayee *et al.* 2003). A significant research

progress has been made to understand the implications of gas exchange approaches and relating this with biochemistry of photosynthesis (El-Sharkawy and Cock 1983). Gas exchange techniques have been used to quantify the relative stomatal and mesophyll limitations (Sheshshayee *et al.* 1996) and carboxylation efficiency (von Caemerrer and Farquhar 1996). Though snapshot, gas exchange measurements holds the prospective in preliminary screening of genotypes/accessions to identify photosynthetically efficient type/s in a given environmental conditions. The use of plant hormones has been well elucidated since mid 1920s and it continues to contribute largely in overall plants growth and development. Nevertheless, though, the formative effect of hormones is well studied (Taiz and Zeiger 2006), its implication (for instance GA₃) on intrinsic physiological traits was less understood in perennial tree species like tea.

In this background, the present study was aimed to examine the effect of GA₃ on CO₂ assimilation, intrinsic

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WUE (P_N/g_s), mesophyll efficiency (Ci/g_s) and carboxylation efficiency (dP_N/dCi) using gas exchange approach in a field grown tea accession. Further in recent years, the use of Chl *a* fluorescence has become routine in plant eco-physiology, to the extent that no investigation of the photosynthetic performance of plants growing in field conditions seems complete without this (Maxwell and Johnson 2000). Hence, Chl *a* fluorescence measurement was also made in the present investigation to examine the photochemical (PS II) efficiency in GA₃ treated plants.

The study was conducted in the tea gardens of Hindustan Lever Ltd., Tamil Nadu, India. Different concentrations of GA₃ (50, 100 and 150 ppm) were used to examine the variations in gas exchange traits along with untreated control in a leading tea accession, SA6 (which occupies more area under south India plantations). The average growth condition recorded using automatic weather station facility was as follows: RH, 70%; air temperature, 32°C; light intensity, 1100-1200 $\mu\text{mol m}^{-2}\text{s}^{-1}$; VPD, 12-14 mbars. Field-established five years old bush of SA6 tea accession was selected and GA₃ was sprayed on the foliage of these bushes two days prior to the measurement. From five such bushes, a healthy branch was selected and 3rd fully expanded foliage from the apex was used to measure gas exchange traits, using portable photosynthesis system (LICOR 6400, Licor Inc. Nebraska, USA) and intrinsic carboxylation efficiency by generating CO₂ response curves.

The built-in CO₂ dosing unit of the LICOR 6400 was employed to generate various CO₂ concentrations ranging from 50 to 1000 ppm. The net photosynthetic rate at each CO₂ concentration was plotted and a 2nd degree polynomial function was fit. The slope of the initial linear region of the curve (dP_N/dCi) is often considered as a reflection of the intrinsic carboxylation efficiency.

Chlorophyll (Chl) *a* fluorescence measurement [F_o (minimal fluorescence), F_m (maximal fluorescence), F_v (variable fluorescence)] was made non-invasively in the 1st to 5th leaf from the apex, immediately after keeping the leaves at least for 15 min in dark using PAM-2000 (Heinz Walz, GmbH, Germany). Here we present only

the ratio, F_v/F_m, which reflects the functional ability of photosystem PS II (Papageorgiou and Govindjee 2004). Analysis of variance (ANOVA) was done for each measurement for its significance using *mstatC* program.

In both control and GA₃-treated plants, gas exchange traits such as net photosynthetic rate (P_N), stomatal conductance (g_s) and transpiration rate (Trate), showed a significant variation across the treatments (Table 1). The ratios of net photosynthetic rate to stomatal conductance (P_N/g_s) and intercellular CO₂ (Ci) concentration to g_s (Ci/g_s) were computed as a measure of intrinsic water use and mesophyll efficiencies respectively.

An apparent increase in both intrinsic water use and carboxylation efficiencies was observed in the GA₃ treated plants. The increment in intrinsic WUE was to a tune of 15.5, 40.5 and 47.8 per cent in 50, 100 and 150 ppm respectively in GA₃-treated plants than control plants. Increase that observed in 50 ppm GA₃ was relatively low compared to rest of the treatments implying that 50 ppm, might be sub-optimum to induce any appreciable effect. Further, growth hormones have a differential response in different species and which is concentration dependent (Taiz and Zeiger 2006). The Ci/g_s values were low in all GA₃ treated plants than that of control (Table 1) suggesting that the hormone treated plants fix carbon efficiently at a given stomatal conductance, substantiating earlier findings in several other crops (Umoessien and Forward 1982, Tsai and Artega 1984, Salal 1995). The dP_N/dCi in control plant was 0.43 $\text{mmolCO}_2.\text{m}^{-2}\text{s}^{-1}\text{ppm}^{-1}$. However in 50, 100 and 150 ppm GA₃-treated plants, the dP_N/dCi was 0.51 (8.5%), 0.56 (18.8%) and 0.61 (29.5%) $\text{mmol CO}_2.\text{m}^{-2}\text{s}^{-1}\text{ppm}^{-1}$ respectively, indicating a steady improvement in intrinsic carboxylation efficiency due to GA₃ application.

The Ci/g_s showed a strong inverse relationship with dP_N/dCi in the present investigation (Fig. 1), which is in agreement with earlier reports in other crops like sunflower, groundnut and cowpea (Sheshshayee *et al.* 1996, Krishnaprasad *et al.* 1996, Sheshshayee *et al.* 2003, Bindumadhava *et al.* 2005, 2007b). A reduction in Ci levels can be expected either, when the g_s is low or when the efficiency of carbon assimilation by the

Table 1. Gas exchange traits, intrinsic water use, mesophyll, carboxylation and photochemical efficiencies in GA₃ treated tea clone (SA6)

GA ₃ -treatment	P_N	g_s	Ci	Trate	P_N/g_s	Ci/g_s	dP_N/dCi	Fv/Fm
Control	5.03	0.17	249	1.87	29.59	0.15	0.43	0.79
50 ppm	5.40	0.17	235	1.74	31.40	0.14	0.47	0.80
100 ppm	6.90	0.18	231	2.35	37.70	0.13	0.53	0.81
150 ppm	8.20	0.20	211	2.98	41.00	0.11	0.61	0.82
F-test	**	*	*	**	**	**	**	NS
CD at P=0.05	0.61	0.012	31.1	0.082	14.11	0.09	0.013	-

P_N - net photosynthetic rate ($\mu\text{mol m}^{-2} \text{s}^{-1}$), g_s – stomatal conductance ($\text{mol m}^{-2} \text{s}^{-1}$), Ci – intercellular CO₂ concentration (ppm), Trate- transpiration rate ($\text{mmol m}^{-2} \text{s}^{-1}$). P_N/g_s – intrinsic water use efficiency, Ci/g_s – intrinsic mesophyll efficiency, dP_N/dCi – intrinsic carboxylation efficiency, Fv/Fm – ratio of variable to maximum fluorescence, a reflection of PS II efficiency.

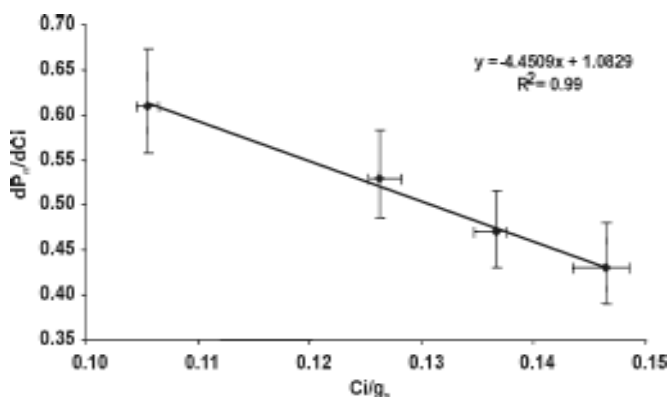


Fig. 1. Relationship between intrinsic mesophyll (Ci/g_s) and carboxylation (dA/dCi) efficiencies in GA₃-treated tea clone (SA6). Standard Error (SE) bar represents the spread in both the variables.

Rubisco is high (Debabrata Ray *et al.* 2003). At a given g_s , therefore, variations in Ci is predominantly a function of carbon assimilatory capacity (Sheshshayee *et al.* 2003, Bindumadhava *et al.* 2005, 2007a and 2007b).

The Fv/Fm of 1st to 4th leaf from the shoot apex of both GA₃-treated and control plants did not differ significantly (data not shown). On an average, the Fv/Fm of GA₃-treated leaves was 0.82 ± 0.03 compared to 0.79 ± 0.04 in control supporting our inference that the GA₃ (especially the concentration used in this study) is unable to modulate the PS II efficiency. The mean Fv/Fm of 5th leaf and maintenance leaf (*fish* leaf) of control and treated plants were 0.71 ± 0.05 , 0.76 ± 0.04 , 0.69 ± 0.06 and 0.73 ± 0.05 , respectively. The 3rd leaf which was used

for gas exchange, showed no difference in PS II efficiency in response to GA₃-treatment, suggesting that the GA₃ has no significant role to play in Chl fluorescence largely at the level of light harvesting by thylakoids system at least, in tea. Similarly, no or marginal difference in PS II efficiency in cowpea genotypes subjected to varied levels of water deficits was reported (Long *et al.* 1994). Further, it was shown that the changes in fluorescence kinetics may not be expected always whenever plants are treated with plant hormones (Souza *et al.* 2003). GA₃ treated plants showed considerable improvement in intrinsic carboxylation efficiency, indicating role of GA₃ is more pronounced in improving the enzyme driven photosynthetic efficiency rather than driving the initial photochemical efficiency (Bindumadhava *et al.* 2007). Therefore, it can be assumed that, GA₃ has very marginal or no effect on improving the PS II efficiency but has a role in improving the carboxylation efficiency (as evidenced by dP_N/dCi values).

As GA₃ induces cell growth and elongation thereby the cell turgidity (Tiaz and Zieger 2006), which thus facilitate an increased carbon exchange to water vapour ratio. In other words, to a given input of water, carbon assimilation increases, which inturn enhances the WUE (Sheshshayee *et al.* 2003, Bindumadhavha *et al.* 2005). Steady tissue water status also improves the activities of photosynthetic carbon assimilatory enzymes, leading to efficient carbon fixation (Sheshshayee *et al.* 1996, Krishnaprasad *et al.* 1996). In the present study, we

consider that the increased physiological efficiencies in GA₃-treated plants could be a result of either solitary or sum-effects of these metabolic functions.

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