Correction to Appendix C (February 2019)

The purpose of this correction is to point out a couple of typos that were found in Appendix C and present a new and more correct derivation for C4 plants, thus revising Eqs. (C23) and (C24). As shown at the end of this supplemental file (Supplemental Figures S5-10), this new and also simpler derivation does not change the main results and conclusions of the original paper.

New derivation for C_4 plants

The original solution for C_4 plants was found by combining Eqs. (C22), (C17) and (1). Equation (C17) was needed to express the respiratory term F_r as a function of $\varepsilon_{ci} = p_{CA}/(p_i - p_{CA})$. However, this expression for F_r assumes that the CO_2 mixing ratio relevant for photorespiration can be approximated by p_{CA}/P. Such an assumption may be justified for C_3 plants but is not justified in C_4 plants because of the spatial separation between mesophyll and bundle sheath cells and the CO_2 concentration mechanism operating in the bundle sheath. For C_4 plants, it is probably more correct to assume that photorespiration is negligible so that $F_r \approx V_r/A$ becomes independent of ε_{ci}. In this case, the set of equations simplifies greatly. Combining Eqs. (C22) and (1) with the approximation $F_r \approx V_r/A$ leads to a quadratic equation, whose positive solution is ε_{ci}:

$$b_3\varepsilon_{ci}^2 + b_2\varepsilon_{ci} + b_1 = 0\,, \qquad \text{(C23')}$$

with:

$$\begin{cases} b_3 = \Delta_i - \left[\phi_r \frac{V_r}{A}\left(\delta_{es} - \delta_{trans}\right) + a_{cb}\left(1 + \frac{V_r}{A}\right) + \Delta_{ei}\left(\frac{V_r}{A} + \frac{1}{3\rho_i}\right)\right]\left(1 + \Delta_i\right) \\ b_2 = \Delta_i - \left[\phi_r \frac{V_r}{A}\left(\delta_{es} - \delta_{trans}\right) + a_{cb}\left(1 + \frac{V_r}{A}\right) + \Delta_{ei}\frac{V_r}{A}\right]\left(1 + \Delta_i\right) + \left(\Delta_i - a_w\right)\left[\left(1 + \frac{V_r}{A}\right)\left(1 - a_{cb}\right) + \frac{1}{3\rho_i}\right], \\ b_1 = \left(\Delta_i - a_w\right)\left(1 + \frac{V_r}{A}\right)\left(1 - a_{cb}\right) \end{cases} \qquad \text{(C24')}$$

where δ_{es} and δ_{trans} represent the water isotope compositions of leaf water at the evaporative site and of transpired water vapour, respectively. As in Appendix C, we made the approximation $\Delta_{ei} - \Delta'_{ei} \approx \delta_{es} - \delta_{trans}$ and set $\phi_r = 0.5$ and $a_{cb} = 9.5‰$. For two individual *Z. mays* leaves (*i.e.*, 2% of the entire C_4 dataset), Eq. (C23') has only negative roots, unless the ratio V_r/A takes unrealistic values (> 0.5). This was already the case with the original derivation [Eq. (C23)] and the reasons for this behaviour have been discussed (see Appendix C). For all the other leaf measurements, a solution to Eq. (C23') could be found and the retrieved values for ε_{ci}, g_m, p_{CA}, θ and ρ were all very similar to those presented in the different figures of the original study (see Supplemental Figures S5-10 at the end of this correction). Thus, despite this new derivation, all the conclusions of the study remain unchanged, even for C_4 plants.

Typographical errors

Symbols t and F in Eqs. (C27) and (C28) should be read as t_a and F_r, i.e., these equations should be written as:

$$R_A = \frac{R_a p_a - R_{i0} p_i - t_a\left(R_a p_a + R_{i0} p_i\right)}{\left(1 + \overline{a}'\right)\left(p_a - p_i\right) - t_a\left(p_a + p_i\right)}\,, \qquad \text{(C27')}$$

and:

$$\frac{R_{\text{CA0}}}{R_{\text{a}}} = \frac{(1-t_{\text{a}})p_{\text{a}} + F_{\text{r}}\left[(1+\overline{a}')(p_{\text{a}}-p_{\text{i}}) - t_{\text{a}}(p_{\text{a}}+p_{\text{i}}) + (1+a_{\text{w}})(1+t_{\text{a}})(p_{\text{i}}-p_{\text{CA}})\right]}{(1+F_{\text{r}})\left[(1+\overline{a}')(p_{\text{a}}-p_{\text{i}}) - t_{\text{a}}(p_{\text{a}}+p_{\text{i}}) + (1+t_{\text{a}})(1+a_{\text{w}})(p_{\text{i}}-p_{\text{CA}})\right] + (1+t_{\text{a}})p_{\text{CA}}}. \tag{C28'}$$

Also, although not relevant anymore with the new derivation for C_4 plants provided below, the term $(C_1Z' - A_1'X)$ appearing in the expressions for b_0, b_1 and b_2 [Eq. (C24)] should have been written as $(C_1Z' + A_1'X)$.

Errors in the code

A first error was found to be very minor and related to the way the fractionation factor $\overline{a}'$ was computed. By definition, $\overline{a}'$ represents the "weighted-mean isotope fractionation factor during CO_2 diffusion through the leaf boundary layer and the stomata" (see Appendix D). The weighing however was originally performed using resistances to CO_2 diffusion through the stomatal pores and leaf boundary layer [as in Eq. 15 in Lee *et al.* (2009)]. A more correct way to perform the weighing is to use CO_2 mixing ratios [see for example $\overline{a_{\text{Ci}}}^{18}$ in Table 4 of Ubierna *et al.* (2017)]. The two expressions give the same fractionation factor $\overline{a}'$ when ternary corrections are negligible and thus $g_{sc} = A/(C_s - C_i)$ where C_s is the CO_2 mixing ratio at the leaf surface. When ternary corrections are not negligible, the error on the fractionation factor $\overline{a}'$ remains very small (a few percent) and leads to even smaller differences on the final mesophyll conductance estimates (i.e. well below the uncertainty on this parameter).
Another error, not relevant anymore with the new derivation for C_4 plants provided here, was related to the way the fractionation factor a_{cb} was taken care of in the expression for A_1'' [Eq. (C25)]. The latter was taken as 0.0095, instead of 9.5‰. Should a new, more correct, and simpler solution had not been derived, this error may have had significant consequences on the final values of mesophyll conductance for C_4 species.

References

Lee X, Griffis TJ, Baker JM, Billmark KA, Kim K, Welp LR (2009) Canopy-scale kinetic fractionation of atmospheric carbon dioxide and water vapor isotopes. Global Biogeochemical Cycles **23**: GB1002

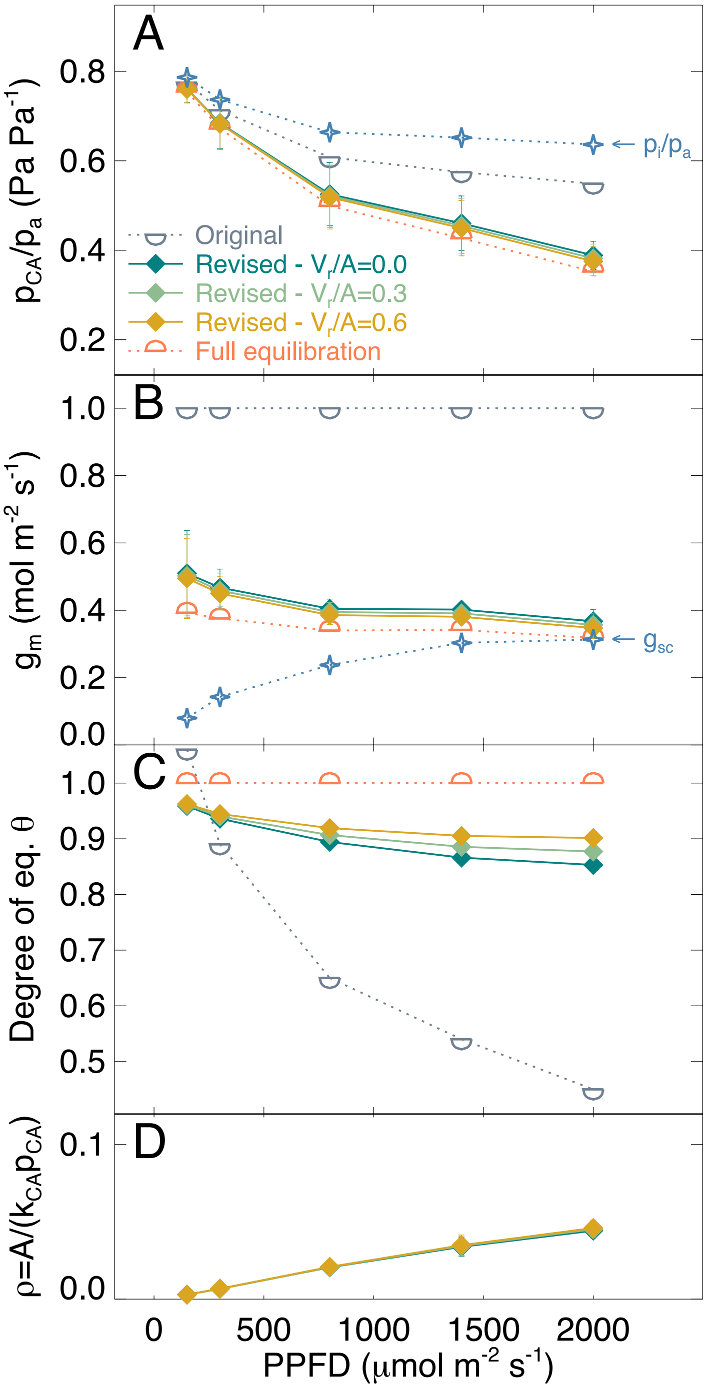
Ubierna N, Gandin A, Boyd RA, Cousins AB (2017) Temperature response of mesophyll conductance in three C_4 species calculated with two methods: ^{18}O discrimination and *in vitro* V_{pmax}. New Phytol **214**: 66–80

Acknowledgements

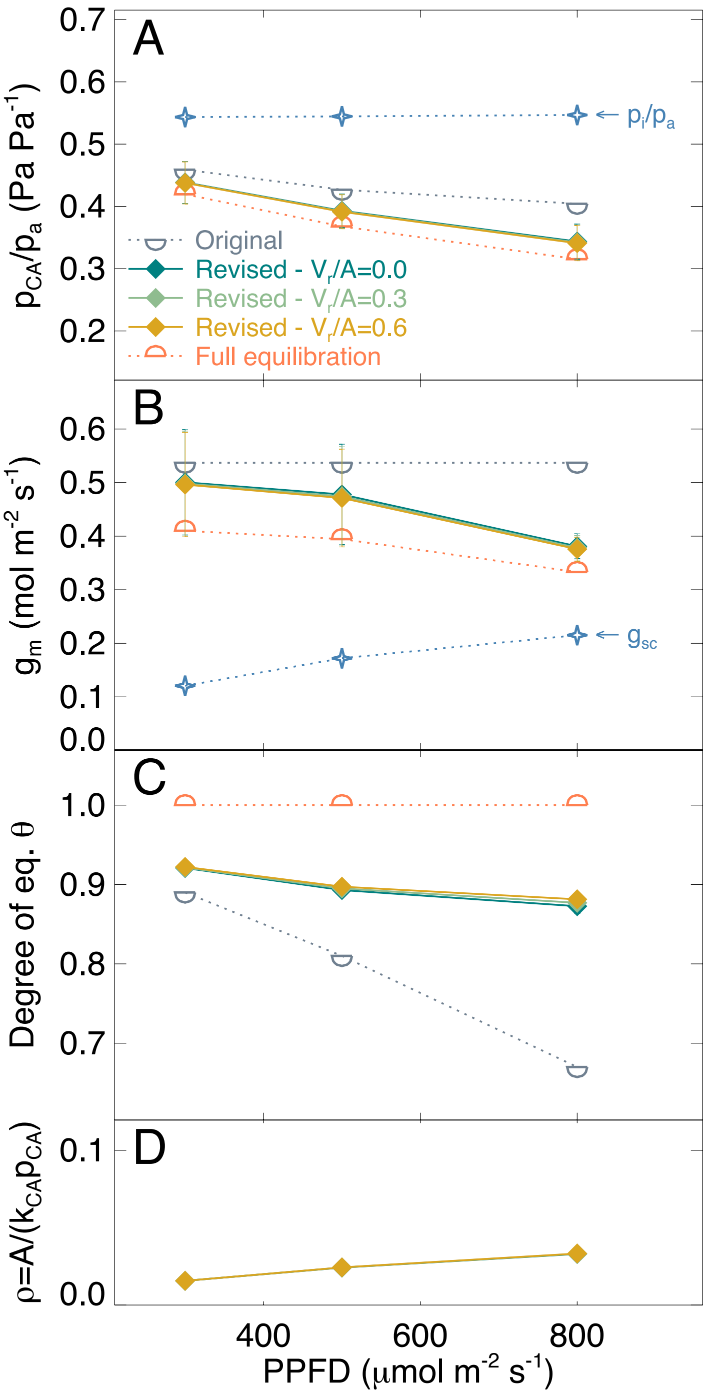
We would like to thank Dr. Nerea Ubierna for pointing out the typos in Appendix C and the errors in our code, which led to us finding this simpler derivation for C_4 species.

Supplemental Figures S5-10

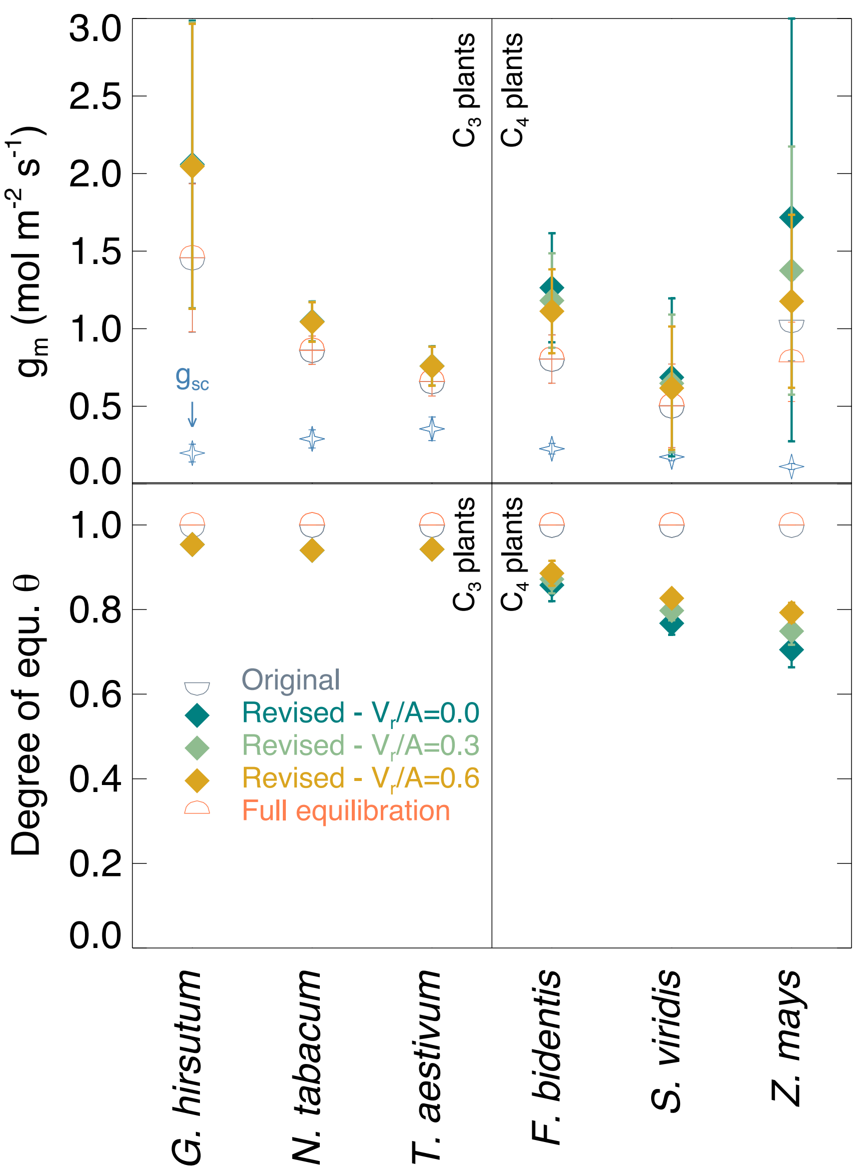
Supplemental Figure S5. Same figure as Fig. 2 in the main text, but using the correct calculation of fractionation factor $\overline{a}'$ and Eq. (C23') instead of Eq. (C23).



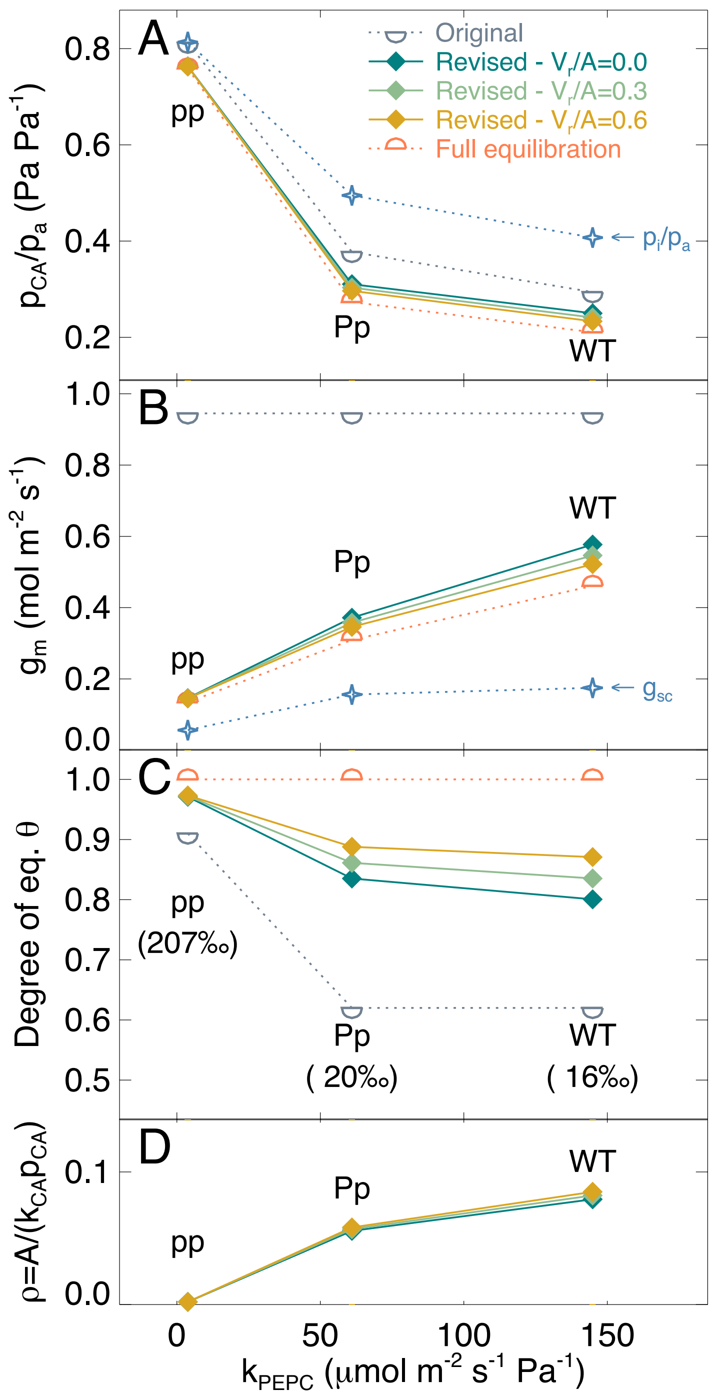
Supplemental Figure S6. Same figure as Fig. 3 in the main text, but using the correct calculation of fractionation factor $\bar{a}'$.



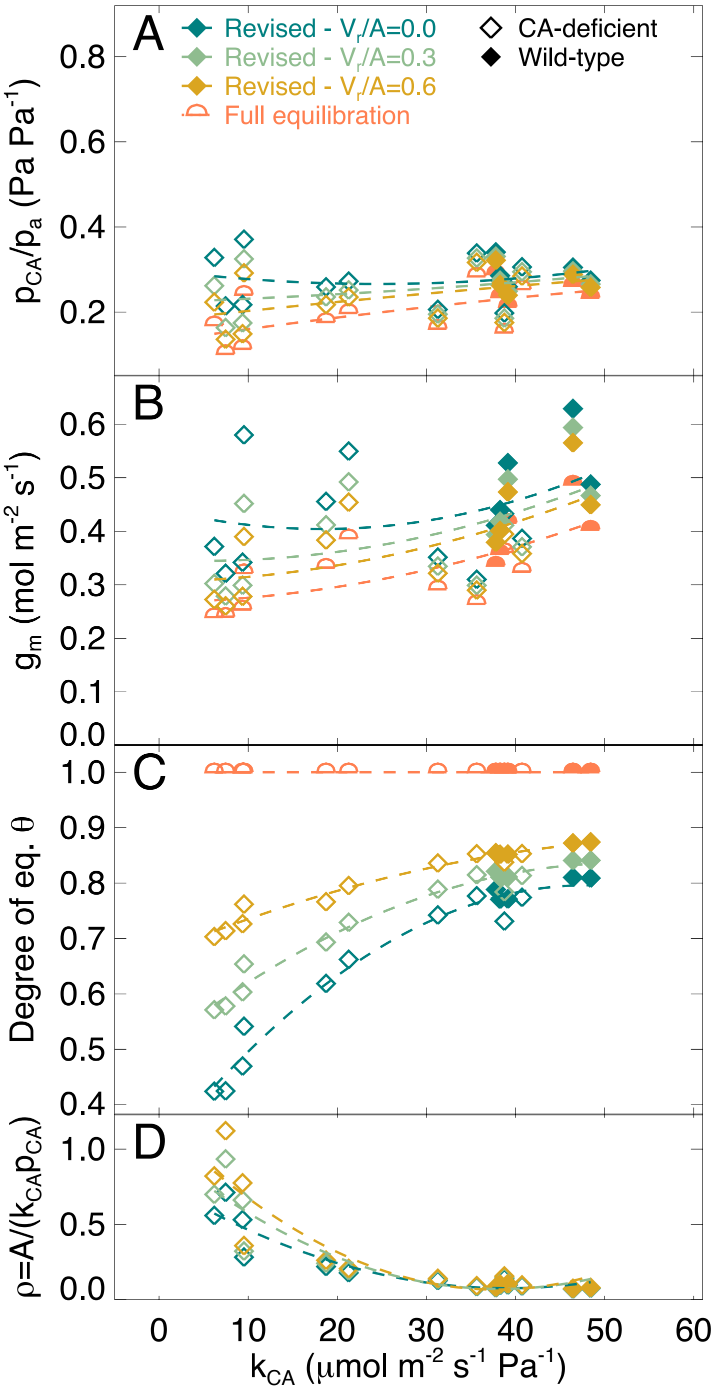
Supplemental Figure S7. Same figure as Fig. 4 in the main text, but using the correct calculation of fractionation factor $\overline{a}'$ and, for C_4 species, Eq. (C23') instead of Eq. (C23).



Supplemental Figure S8. Same figure as Fig. 5 in the main text, but using the correct calculation of fractionation factor $\bar{a}'$ and Eq. (C23') instead of Eq. (C23).



Supplemental Figure S9. Same figure as Fig. 6 in the main text, but using the correct calculation of fractionation factor $\overline{a}'$ and Eq. (C23') instead of Eq. (C23).



Supplemental Figure S10. Same figure as Fig. 7 in the main text, but using the correct calculation of fractionation factor $\overline{a}'$ and Eq. (C23') instead of Eq. (C23).