Using carbon isotope discrimination to predict water-use efficiency

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The process of photosynthetic CO_2 uptake "costs" transpiration water. For a plant, transpiration efficiency, the ratio of dry matter accumulation to water lost is, in part, a function of p_i/p_a, the ratio of the CO_2 pressure inside leaves, p_i, to that around the leaves, p_a. Transpiration efficiency, W, of leaves and whole plants is negatively related to pi/pa. For a crop, water-use efficiency, which includes all sources of water loss in addition to transpiration, will also be related to p_i/p_a if there is no genetic variation in parameters such as early growth when the soil evaporation component of evapotranspiration is relatively large, or crop architecture which can create significant aerodynamic resistances to heat and vapour transfer.

There is also a relationship (positive, in this case) between carbon isotope discrimination and p_i/p_a in C_3 species. Figure 1 shows the relationship between carbon isotope discrimination, Δ, and p_i/p_a in leaves of different peanut genotypes. At any instant in time, different genotypes tended to have different values of pi/p_a and of Δ. The genetic control of Δ is strong in leaf or stem material of peanut, cowpea, barley, and wheat (2). Genotypic ranking of A tends to be maintained in these species when they have been grown at different sites with different water availability. The broad sense heritabilities (proportion of total variance of Δ which can be ascribed to genotype, rather than to environment or to interactions between the two) ranges between 60% and 90%. Discrimination may be a good predictor of yield in wheat (1).

Because transpiration efficiency is related (negatively) to pi/pa and carbon isotope discrimination is related (positively) to p_i/p_a, we expect a negative relationship between W and Δ. This has been shown to be true in the following C3 species: wheat, peanut, barley, cotton, and tomato (2). Figure 2 shows a plot of the negative relationship between W and Δ in pot-grown plants of barley cultivars. This has also been shown in field-grown peanut cultivars (3,4). The results to date show promise for the use of A as a predictor of water-use efficiency.

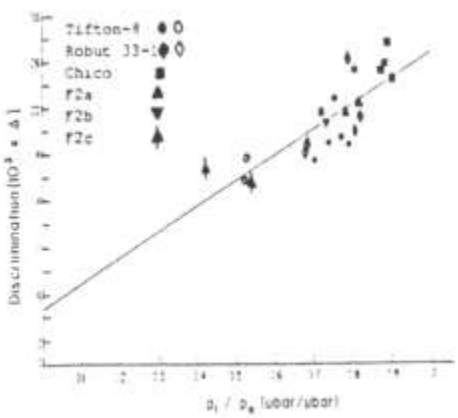

Figure 1

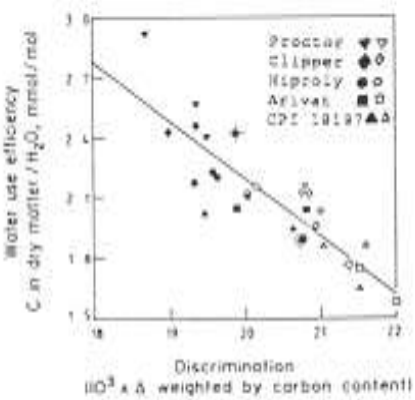

Figure 2

1. Condon, A.G., Richards, R.A., and Farquhar, G.D. 1987. Crop Science 27, 996-1001.

2. Farquhar, G.D., Ehleringer, J.R., and Hubick, K.T. 1989. Annual Review Plant Physiology Plant Molecular Biology 40, 503-537.

3. Wright, G.C., Hubick, K.T., and Farquhar, G.D. 1988. Australian Journal of Plant Physiology 15, 815-925. ibid. Proc. 5th Aust. Agron. Conf. Perth.