Fluctuating Asymmetry -- Summary

Fluctuating asymmetry (FA) is the terminology used to describe small variations from perfect symmetry in otherwise bilaterally-symmetrical characters in an organism (Moller and Swaddle, 1997). It is believed to arise in consequence of developmental instability experienced during ontogeny that is caused by various stresses, including both genetic and environmental factors (Martel *et al.*, 1999; Cornelissen and Stiling, 2005); and it has been studied extensively in animals but less so in plants (Moller and Shykoff, 1999).

In the first study to address the effects of atmospheric CO_2 enrichment on leaf asymmetry and how herbivores respond to these effects, Cornelissen *et al.* (2004) opened up a whole new window through which to view the world of the future in terms of the potential effects of the ongoing rise in the air's CO_2 content on the plant and animal components of the biosphere. The Cornelissen *et al.* study was conducted on a native scrub-oak community at the Kennedy Space Center, Titusville, Florida, USA, which is dominated by myrtle oak (*Quercus myrtifolia*) and sand live oak (*Quercus geminata*) under atmospheric CO_2 concentrations of approximately 370 and 700 ppm.

Based on measurements of (1) distances from the leaf midrib to the left and right edges of the leaf at its widest point and (2) leaf areas on the left and right sides of the leaf midrib, Cornelissen *et al.* determined that "asymmetric leaves were less frequent in elevated CO_2, and, when encountered, they were less asymmetric than leaves growing under ambient CO_2." In addition, they found that "*Q. myrtifolia* leaves under elevated CO_2 were 15.0% larger than in ambient CO_2 and *Q. geminata* leaves were 38.0% larger in elevated CO_2 conditions." As a bonus, they also determined that "elevated CO_2 significantly increased tannin concentration for both *Q. myrtifolia* and *Q. geminata* leaves" and that "asymmetric leaves contained significantly lower concentrations of tannins than symmetric leaves for both *Q. geminata* and *Q. myrtifolia*."

In commenting on their primary findings of *reduced percentages* of leaves experiencing asymmetry in the presence of elevated levels of atmospheric CO_2 and the *lesser degree* of asymmetry exhibited by affected leaves in the elevated CO_2 treatment, Cornelissen *et al.* say that "a possible explanation for this pattern is the fact that, in contrast to other environmental stresses, which can cause negative effects on plant growth, the predominant effect of elevated CO_2 on plants is to promote growth with consequent reallocation of resources (Docherty *et al.*, 1996)." Another possibility they discuss "is the fact that CO_2 acts as a plant fertilizer," and, as a result, that "elevated CO_2 ameliorates plant stress compared with ambient levels of CO_2," which is one of the well-documented biological benefits of atmospheric CO_2 enrichment (Idso and Idso, 1994).

With respect to the ancillary finding of CO_2-induced increases in tannin concentrations in the leaves of both oaks (a mean increase of approximately 35% for *Q. myrtifolia* and 43% for *Q. geminata*), it should be noted that this phenomenon may provide both species with greater protection against herbivores, and that part of that protection may be associated with the observed CO_2-induced reductions in the amount and degree of asymmetry in the leaves of the CO_2-enriched trees. Consistent with this hypothesis, for example, Stiling *et al.* (1999, 2003) found higher abundances of leaf miners in the leaves of the trees in the ambient CO_2 chambers, where asymmetric leaves were more abundant, while in the current study it was determined that leaf miners attacked asymmetric leaves more frequently than would be expected by chance alone in both CO_2 treatments.

In further support of this CO_2-induced benefit, Cornelissen and Stiling (2005) evaluated patterns of asymmetry in 40 leaves from each of 30 trees of each of two species of oak - sand live oak (*Quercus geminata*) and turkey oak (*Q. laevis*) - at the University of South Florida Botanical Garden in Tampa, Florida, USA, well before any herbivores had begun to attack the trees that growing season. Thereafter, patterns of leaf asymmetry, leaf quality and herbivory were examined for 30 individual trees of each of the two oak species from March to October of the same year.

The "before and after" measurements clearly indicated that differential herbivory patterns neither caused nor affected patterns of leaf FA. However, they revealed, in the words of the authors, that "herbivores may use asymmetry as a cue to plant quality and suitable oviposition sites," as plants with a higher percentage of asymmetric leaves were attacked more frequently by various leaf miners, as were leaves on the same plant that were more asymmetric. One of the reasons for these choices may have been, as Cornelissen and Stiling report, that "asymmetric leaves of both plant species exhibited better nutritional quality for herbivores than symmetric leaves," with asymmetric leaves possessing "significantly lower concentrations of tannins [-22% for *Q. geminata* and -36% for *Q. laevis*] and higher nitrogen content [+8% for both species]."

In one additional study, Kaligaric *et al.* (2008) measured the degree of FA in "undamaged (not grazed, not visibly attacked by herbivores or pathogens) fully developed leaves" of the Mediterranean shrub *Myrtus communis* L. growing along an atmospheric CO_2 gradient (570, 530, 490, 450, 410 and 370 ppm) moving away from a natural CO_2 spring

"I Borboi" near Lajatico (Pisa, Tuscany, Italy) at distances of 2, 18, 34, 50, 66 and 82 m, respectively, from the CO source.

The four researchers report they found "a significant and negative correlation between CO_2 concentration and leaf FA," such that "with increased CO_2 concentration the leaf FA decreased," which result, in their words, "confirms what was obtained by Cornelissen *et al.* (2004) on *Quercus myrtifolia* and *Quercus geminata* (in a short-term experiment)." In addition, they note that "*Myrtus communis*, grown under elevated CO_2 concentration at 'I Borboi,' showed a reduction in xylem embolism and an increase in hydraulic efficiency (Tognetti *et al.*, 2001)," stating that "improved water relations could represent a good explanation for the observed reduction in leaf FA [as the air's CO_2 content increased]."

In discussing their findings, Kaligaric *et al.* say that "adaptation and selection could explain the tendency towards decreased leaf FA in plants from the CO_2 spring relative to ambient conditions," since "the more symmetrical leaves under long-term elevated CO_2 concentration were more developmentally stable in these conditions."

In light of the results of the above studies, a reduction in leaf FA can be added to the ever-growing number of benefits plants will likely experience as the air's CO_2 concentration continues to rise.

References

Cornelissen, T. and Stiling, P. 2005. Perfect is best: low leaf fluctuating asymmetry reduces herbivory by leaf miners. *Oecologia* **142**: 46-56.

Cornelissen, T., Stiling, P. and Drake, B. 2004. Elevated CO_2 decreases leaf fluctuating asymmetry and herbivory by leaf miners on two oak species. *Global Change Biology* **10**: 27-36.

Docherty, M., Hurst, D.K., Holopainem, J.K., Whittaker, J.B., Lea, P.J. and Watt, A.D. 1996. Carbon dioxide-induced changes in beech foliage cause female beech weevil larvae to feed in a compensatory manner. *Global Change Biology* **2**: 335-341.

Idso, K.E. and Idso, S.B. 1994. Plant responses to atmospheric CO_2 enrichment in the face of environmental constraints: a review of the past 10 years' research. *Agricultural and Forest Meteorology* **69**: 153-203.

Kaligaric, M., Tognetti, R., Janzekovic, F. and Raschi, A. 2008. Leaf fluctuating asymmetry of Myrtus communis L., affected by increases in atmospheric CO_2 concentration: Evidence from a natural CO_2 spring. *Polish Journal of Environmental Studies* **17**: 503-508.

Martel, J., Lempa, K. and Haukioja, E. 1999. Effects of stress and rapid growth on fluctuating asymmetry and insect damage in birch leaves. *Oikos* **86**: 208-216.

Moller, A.P. and Swaddle, J.P. 1997. *Asymmetry, Developmental Stability and Evolution.* Oxford University Press, Oxford, UK.

Moller, A.P. and Shykoff, P. 1999. Morphological developmental stability in plants: patterns and causes. *International Journal of Plant Sciences* **160**: S135-S146.

Stiling, P., Moon, D.C., Hunter, M.D., Colson, J., Rossi, A.M., Hymus, G.J. and Drake, B.G. 2003. Elevated CO_2 lowers relative and absolute herbivore density across all species of a scrub-oak forest. *Oecologia* **134**: 82-87.

Stiling, P., Rossi, A.M., Hungate, B., Dijkstra, P., Hinkle, C.R., Knot III, W.M., and Drake, B. 1999. Decreased leaf-miner abundance in elevated CO_2: Reduced leaf quality and increased parasitoid attack. *Ecological Applications* **9**: 240-244.

Tognetti, R., Longobucco, A., Raschi, A. and Jones, M.B. 2001. Stem hydraulic properties and xylem vulnerability to embolism in three co-occurring Mediterranean shrubs at a natural CO_2 spring. *Australian Journal of Plant Physiology* **28**: 257-268.

Last updated 22 August 2012

Printer Friendly Version