The Response of Peanut Plants to Changes in Climate and Atmospheric CO_2

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THE RESPONSE OF PEANUT PLANTS TO CHANGES IN CLIMATE AND ATMOSPHERIC CO_2

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Nearly all agricultural crops respond to increases in the air's CO_2 content by displaying enhanced rates of photosynthesis and biomass production. In this brief summary, we review the results of some of the studies that have evaluated these effects and the effects of climate-model predicted changes in air temperature, precipitation and ozone pollution on peanut (*Arachis hypogaea* L.) plants.

In a study that was published at the turn of the century, Stanciel *et al*. (2000)[1] grew peanuts hydroponically for 110 days in controlled environment chambers maintained at atmospheric CO_2 concentrations of 400, 800 and 1200 ppm, finding that the net photosynthetic rates of plants grown at 800 ppm CO_2 were 29% greater than those of plants grown at 400 ppm CO_2, but that plants grown at 1200 ppm CO_2 displayed photosynthetic rates that were 24% *lower* than those exhibited by plants grown in 400-ppm CO_2 air. Nevertheless, the number of pods, pod weight and seed dry weight per unit area were all greater at 1200 ppm than at 400 ppm CO_2. Also, harvest index, which is the ratio of seed dry weight to pod dry weight, was 19 and 31% greater at 800 and 1200 ppm CO_2, respectively, than it was at 400 ppm CO_2. In addition, as the atmospheric CO_2 concentration increased, stomatal conductance decreased, becoming 44 and 50% lower at 800 and 1200 ppm than it was at 400 ppm CO_2. Thus, atmospheric CO_2 enrichment also reduced transpirational water loss, leading to a significant increase in plant *water use efficiency*.

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In another study, Prasad *et al*. (2003)[2] grew Virginia Runner (Georgia Green) peanuts from seed to maturity in sunlit growth chambers maintained at atmospheric CO_2 concentrations of 350 and 700 ppm and daytime-maximum/nighttime-minimum air temperatures of 32/22, 36/26, 40/30 and 44/34°C, while they assessed various aspects of vegetative and reproductive growth. In doing so, they found that leaf photosynthetic rates were unaffected by air temperature over the range investigated; but they rose by 27% in response to the experimental doubling of the air's CO_2 content.

Vegetative biomass, on the other hand, increased by 51% and 54% in the ambient and CO_2-enriched air, respectively, as air temperature rose from 32/22 to 40/30°C. A further air

[1] http://www.co2science.org/articles/V3/N17/B1.php
[2] http://www.co2science.org/articles/V7/N9/B1.php

temperature increase to 44/34°C, however, caused moderate to slight *decreases* in vegetative biomass in both the ambient and CO_2-enriched air, so that the final biomass increase over the entire temperature range investigated was 27% in ambient air and 53% in CO_2-enriched air. When going from the *lowest* temperature *ambient* CO_2 treatment to the *highest* temperature *elevated* CO_2 treatment, however, there was a whopping 106% increase in vegetative biomass.

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In contrast, seed yields in both the ambient and CO_2-enriched air dropped dramatically with each of the three temperature increases studied, declining at the highest temperature regime to but a small percentage of what they were at the lowest temperature regime. Nevertheless, Prasad *et al*. report that "seed yields at 36.4/26.4°C under elevated CO_2 were similar to those obtained at 32/22°C under ambient CO_2," the latter pair of which temperatures they describe as "present-day seasonal temperatures."

In light of these findings, it would appear that a warming of 4.4°C above present-day seasonal temperatures for peanut production would have essentially no effect on peanut seed yields, *as long as the atmosphere's CO_2 concentration rose concurrently*, by something on the order of 350 ppm. It is also important to note, according to Prasad *et al*., that "maximum/minimum air temperatures of 32/22°C *and higher* [italics added] are *common* [italics added] in *many* [italics added] peanut-producing countries across the globe." In fact, they note that "the Anantapur district in Andhra Pradesh, which is one of the largest peanut-producing regions in India, experiences season-long temperatures *considerably greater* [italics added] than 32/22°C *from planting to maturity* [italics added]."

In light of these real-world observations, i.e., that some of the best peanut-producing regions in the world currently experience air temperatures considerably greater than what Prasad *et al*. suggest is *optimum* for peanuts (something *less* than 32/22°C), it would appear that real-world declines in peanut seed yields in response to a degree or two of warming, even in air of *ambient* CO_2 concentration, must be very slight *or even non-existent* (for how else could the places that commonly experience these considerably higher temperatures remain some of the best peanut-producing areas in the world?), which in turn suggests that for more realistic values of CO_2-induced global warming, i.e., temperature increases on the order of 0.4°C for a doubling of the air's CO_2 content (Idso, 1998), there would likely be a significant *increase* in real-world peanut production.

In another pertinent study, Vu (2005)[3] grew peanut plants from seed to maturity in greenhouses maintained at atmospheric CO_2 concentrations of 360 and 720 ppm and at air temperatures that

[3] http://www.co2science.org/articles/V8/N8/B3.php

were 1.5 and 6.0°C above outdoor air temperatures, while he measured a number of parameters related to the plants' photosynthetic performance. His work revealed that although Rubisco protein content and activity were down-regulated by elevated CO_2, the Rubisco *photosynthetic efficiency* (the ratio of midday light-saturated carbon exchange rate to Rubisco initial or total activity) of the elevated-CO_2 plants "was 1.3- to 1.9-fold greater than that of the ambient-CO_2 plants at both growth temperatures." He also determined that "leaf soluble sugars and starch of plants grown at elevated CO_2 were 1.3- and 2-fold higher, respectively, than those of plants grown at ambient CO_2." In addition, he discovered that the leaf transpiration of the elevated-CO_2 plants relative to that of the ambient-CO_2 plants was 12% less at near-ambient temperatures and 17% less in the higher temperature regime, while the water use efficiency of the elevated-CO_2 plants relative to the ambient-CO_2 plants was 56% greater at near-ambient temperatures and 41% greater in the higher temperature environment.

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In commenting on his findings, Vu notes that because less Rubisco protein was required by the elevated-CO_2 plants, the subsequent redistribution of excess leaf nitrogen "would increase the efficiency of nitrogen use for peanut under elevated CO_2," just as the optimization of inorganic carbon acquisition and greater accumulation of the primary photosynthetic products in the CO_2-enriched plants "would be beneficial for peanut growth at elevated CO_2." Indeed, in the absence of other stresses, Vu's ultimate conclusion was that "peanut photosynthesis would perform well under rising atmospheric CO_2 and temperature predicted for this century."

In a somewhat different type of study, Alexandrov and Hoogenboom (2000)[4] studied how year-to-year changes in temperature, precipitation and solar radiation had influenced the yields of peanuts over a 30-year period in the southeastern United States, after which they used the results to predict future crop yields based on climate-change output from various global circulation models (GCMs) of the atmosphere. At ambient CO_2 concentrations, the GCM scenarios suggested a decrease in peanut yields by the year 2020, due in part to predicted changes in temperature and precipitation. However, when the yield-enhancing effects of a

[4] http://www.co2science.org/articles/V3/N34/B2.php

doubling of the atmospheric CO_2 concentration were included, a totally different result was obtained: a yield *increase*.

Although we have little faith in GCM scenarios (see, for example, the hundreds of model deficiencies that have been documented by various researchers posted in reviews found in our Subject Index under the heading Climate Models - Inadequacies[5]), it is interesting to note that their climate change predictions often result in positive outcomes for agricultural productivity *when the direct effects of elevated CO_2 on plant growth and development are included in the analyses*. These results support the findings of the voluminous Journal Reviews on the *CO_2 Science* website, which describe the stress-ameliorating effects of atmospheric CO_2 enrichment on plant growth and development under unfavorable growing conditions characterized by high air temperatures (see the categories under Temperature x CO_2 Interaction[6]) and inadequate soil moisture (see the categories under Water Stress x CO_2 Effects on Plants[7]).

Investigating another important aspect of CO_2 enrichment studies was Burkey et al. (2007)[8], who grew peanuts (*Arachis hypogaea* L., cv NC-V11) in a field near Raleigh, North Carolina (USA) using standard agricultural practices for two years in open-top chambers maintained at all combinations of three CO_2 treatments (375, 548 and 730 ppm) and three O_3 treatments -- charcoal-filtered air (CF, 22 ppb), non-filtered air (NF, 46 ppb) and O_3-enriched air (75 ppb) -- after which peanut seed yields and qualities were assessed.

In describing their findings, Burkey *et al*. report that "elevated CO_2 increased yield parameters 7 to 17% for plants grown in CF air and restored yield in NF air and elevated O_3 treatments to control *or higher* [italics added] levels," while "market grade characteristics and seed protein and oil contents were not affected by elevated O_3 and CO_2." Given such findings, the USDA Agricultural Research Service scientists concluded that, in the case of peanuts, "the major impacts of rising atmospheric O_3 and CO_2 will be on productivity, not product quality," and in the area of productivity, their data indicate that the positive effects of the ongoing rise in the air's CO_2 content should be able to compensate for concomitant future increases in tropospheric ozone concentrations. In fact, the continuing upward trend in atmospheric CO_2 concentration should ***more*** than compensate for any future increases in the air's O_3 content, because the latter will likely be relatively small due to the strong negative influence of elevated atmospheric CO_2 concentrations on vegetative isoprene emissions (Monson *et al*., 2007), which are responsible for increasing O_3 concentrations over land by perhaps 50% over what they would be in their absence (Poisson *et al*., 2000), as has been demonstrated by Arneth *et al*. (2007), who have calculated that when the effect of CO_2 on vegetative isoprene emissions is included, a properly-forced model "maintains global isoprene emissions within ± 15% of present values," which should significantly temper the future rate-of-rise of the troposphere's ozone concentration.

Working at the *same* site in North Carolina and under the *same* growing conditions, Tu *et al.* (2009)[9] also investigated the response of peanut plants to elevated CO_2. As with the work of

[5] http://www.co2science.org/subject/c/subject_c.php
[6] http://www.co2science.org/subject/t/subject_t.php
[7] http://www.co2science.org/subject/w/subject_w.php
[8] http://www.co2science.org/articles/V10/N52/B2.php
[9] http://www.co2science.org/articles/V12/N52/B3.php

Burkey *et al*., this new team of researchers found that "elevated CO_2 generally increased biomass production while O_3 suppressed it, and CO_2 ameliorated the O_3 effect." In terms of the season-long mean of *midday net photosynthesis*, for example, the 94% increase in the air's CO_2 concentration experienced in going from the lowest to the highest CO_2 treatment resulted in a 25% increase in net photosynthesis in the charcoal-filtered air, a 50% increase in the non-filtered air, and a 104% increase in the ozone-polluted air; while in terms of the final *aboveground biomass* produced, the corresponding CO_2-induced increases were 10%, 41% and 105%.

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On the other hand, Tu *et al*. report that "at mid-vegetative growth, elevated CO_2 significantly reduced leaf nitrogen concentrations by up to 44%," but they add that "plant nitrogen concentrations only differed by 8% among CO_2 treatments at harvest while N_2 fixation was increased," and they note that data from their experiment suggest that "symbiotic N_2 fixation is important for maintaining seed N concentrations and that CO_2 enhancement of symbiotic N_2 fixation may compensate for low soil N availability."

In discussing their findings, Tu *et al*. write that a number of experiments, like theirs, "have shown that elevated CO2 can offset the adverse effects of O_3 on crop biomass production and yield," citing the studies of Olszyk *et al*. (2000), Fuhrer (2003) and Fiscus *et al*. (2005). In addition, they note that "the protective effect of elevated CO_2 against O_3 injury has been observed in a number of C_3 plant species, including cotton, peanut, rice, soybean, and wheat, due in large part to a reduction in O_3 uptake from reduced stomatal conductance and possibly from increases in photoassimilation rates and antioxidant metabolism," citing the work of McKee *et al*. (2000), Booker and Fiscus (2005), Fiscus *et al*. (2005) and Booker *et al*. (2007).

In conclusion, considering all of the above findings, it would appear that even if the climate changes that are typically predicted to result from anticipated increases in the air's CO_2 content were to materialize (which we very strongly doubt will happen), the concurrent rise in the air's CO_2 concentration should *more than compensate* for any deleterious effects those changes in climate might otherwise have had on the growth and yield of peanuts. Furthermore, contrary to the blatantly false contention of the United States Environmental Protection Agency and others, CO_2 is *not* a pollutant; it is a pollution *fighter* that reduces the negative effects of true pollutants, such as ozone, and replaces them with positive effects that are of great worth to man and nature alike. In a world of the future, where atmospheric CO_2 concentrations will be higher than today, peanut plants will greatly benefit.

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