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Terminal Report to Department of Energy

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Principal Investigator: Park S. Nobel

Grant Program: Program for Ecosystem Research: Fundamental (PERF)

Grant Title: Impact of Global Climate Change on Ecosystem-Level Interactions among Sympatric Plants from all Three Photosynthetic Pathways

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Original Abstract

The proposed research will determine biochemical and physiological responses to variations in environmental factors for plants of all three photosynthetic pathways under competitive situations in the field. These responses will be used to predict the effects of global climatic change on an ecosystem in the northwestern Sonoran Desert where the C₃ subshrub *Encelia farinosa*, the C₄ bunchgrass *Hilaria rigida*, and the CAM succulent *Agave deserti* are co-dominants. These perennials are relatively short (≤ 60 cm in height) with overlapping shallow roots (≤ 40 cm in depth), facilitating the experimental measurements as well as leading to competition for soil water.

Net CO₂ uptake over 24-h periods measured in the laboratory will be analyzed using an environmental productivity index (EPI) that can incorporate simultaneous effects of soil water, air temperature, and light. Based on EPI, net CO₂ uptake and hence plant productivity will be predicted for the three species in the field under various treatments. In particular, plots containing all three species will be exposed to the following five conditions at the field site: (1) control, (2) doubling the soil water availability, (3) halving the soil water availability, (4) increasing the temperature by 5°C, and (5) reducing the light by 30%. Activity of the two CO₂ fixation enzymes, Rubisco and PEPCase, will be determined for these various environmental conditions; also, partitioning of carbon to various organs will be measured based on ¹⁴CO₂ labeling and dry weight analysis. Thus, enzymatic and partitioning controls on competition among sympatric model plants representing all three photosynthetic pathways will be investigated. Whether net CO₂ uptake measured in the laboratory can predict long-term responses of plants in the field will be evaluated under various environmental conditions associated with global climatic change.

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Main Publications from DE-FG03-93ER61686:

- Zhang, H., M.R. Sharifi, and P.S. Nobel. 1995. Photosynthetic characteristics of sun versus shade plants of *Encelia farinosa* as affected by photosynthetic photon flux, intercellular CO₂ concentration, leaf water potential, and leaf temperature. *Australian Journal of Plant Physiology* **22**: 833-841.
- Graham, E.A. and P.S. Nobel. 1996. Long-term effects of a doubled atmospheric CO₂ concentration on the CAM species *Agave deserti*. *Journal of Experimental Botany* **47**: 61-69.
- Nobel, P.S. 1996. Ecophysiology of roots of desert plants, with special emphasis on agaves and cacti. In: Y. Waisel, A. Eshel, and U. Kafkafi (eds). *Plant Roots: The Hidden Half*, 2nd ed. Marcel Dekker, New York. Pp. 823-844.
- Zhang, H. and P.S. Nobel. 1996. Photosynthesis and carbohydrate partitioning for the C₃ desert shrub *Encelia farinosa* grown under current and doubled CO₂ concentrations. *Plant Physiology* **110**: 1361-1366.
- Drennan, P.M. and P.S. Nobel. 1996. Temperature influences on root growth for *Encelia farinosa* (Asteraceae), *Pleuraphis rigida* (Poaceae), and *Agave deserti* (Agavaceae) under current and doubled CO₂ concentrations. *American Journal of Botany* **83**: 133-139.
- Zhang, H. and P.S. Nobel. 1996. Dependency of c/c_a and leaf transpiration efficiency on the vapour pressure deficit. *Australian Journal of Plant Physiology* **23**: 561-568.
- Nobel, P.S. 1996. Responses of some North American CAM plants to freezing temperatures and doubled CO₂ concentrations: Implications of global climate change for extending cultivation. *Journal of Arid Environments* **34**: 187-196.
- Nobel, P.S. 1997. Root distribution and seasonal production in the northwestern Sonoran Desert for a C₃ subshrub, a C₄ bunchgrass, and a CAM leaf succulent. *American Journal of Botany* **84**: 949-955.
- Drennan, P.M. and P.S. Nobel. 1997. Frequencies of major C₃, C₄, and CAM perennials on different slopes in the northwestern Sonoran Desert. *Flora* **192**: 297-304.
- Nobel, P.S. and M.J. Linton. 1997. Frequencies, microclimate and root properties for three codominant perennials in the northwestern Sonoran Desert on north- vs. south-facing slopes. *Annals of Botany* **80**: 000-000.
- Nobel, P.S. and H. Zhang. 1997. Photosynthetic responses of three codominant species from the north-western Sonoran Desert — a C₃ deciduous sub-shrub, a C₄ deciduous bunchgrass, and a CAM evergreen leaf succulent. *Australian Journal of Plant Physiology* **24**, in press.
- Nobel, P.S. and M.E. Loik. 1998. Form and Function of Cacti. In: *Ecology of Sonoran Desert Plants and Plant Communities*, R.H. Robichaux, ed. University of Arizona Press, in press.
- Nobel, P.S., H. Zhang, R. Sharifi, M. Castañeda, and B. Greenhouse. 1997. Leaf expansion, net CO₂ uptake, Rubisco activity, and efficiency of long-term biomass gain for the common desert subshrub *Encelia farinosa*. Submitted.

Related Publications Acknowledging Partial Support:

- North, G.B. and P.S. Nobel. 1995. Hydraulic conductivity of concentric root tissues of *Agave deserti* Englem. under wet and drying conditions. *New Phytologist* **130**: 47-57.
- Israel, A.A. and P.S. Nobel. 1995. Growth temperature versus CO₂ uptake, Rubisco and PEPCase activities, and enzyme high-temperature sensitivities for a CAM plant. *Plant Physiology and Biochemistry* **33**: 345-351.
- Pimienta-Barrios, E. and P.S. Nobel. 1995. Monthly stem elongation for *Stenocereus queretaroensis*: relationships to environmental conditions, net CO₂ uptake and seasonal variations in sugar content. *Environmental and Experimental Biology* **35**: 17-24.
- Nobel, P.S., N. Wang, R.A. Balsamo, M.E. Loik, and M.A. Hawke. 1995. Low-temperature tolerance and acclimation of *Opuntia* spp. after injecting glucose or methylglucose. *International Journal of Plant Science* **156**: 496-504.
- North, G.B. and P.S. Nobel. 1996. Radial hydraulic conductivity of individual root tissues of *Opuntia ficus-indica* (L.) Miller as soil moisture varies. *Annals of Botany* **77**: 133-142.
- Wang, N. and P.S. Nobel. 1996. Doubling the CO₂ concentration enhanced the activity of carbohydrate-metabolism enzymes, source carbohydrate production, photoassimilate transport, and sink strength of *Opuntia ficus-indica*. *Plant Physiology* **110**: 893-902.
- Wang, N., H. Zhang, and P.S. Nobel. 1997. Phloem-xylem water flow in developing cladodes of *Opuntia ficus-indica* during sink-to-source transition. *Journal of Experimental Botany* **48**: 675-682.
- Wang, N. and P.S. Nobel. 1998. Phloem transport of fructans in the CAM species *Agave deserti*. *Plant Physiology*, in press.
- Wang, N., H. Zhang, and P.S. Nobel. 1998. Carbon flow and carbohydrate metabolism during sink-to-source transition for developing cladodes of *Opuntia ficus-indica*. Submitted.

Because the annual reports, including one recently submitted electronically, chart the yearly progress, the next comments will relate the above listed manuscripts to the original abstract. In particular, the major objectives were basically accomplished in the 13 main publications. One unexpected aspect was the great importance of root properties. For instance, the temperature dependence of root growth was found to be crucial for interpreting relative seasonal responses of *Agave deserti*, *Encelia farinosa*, and *Pleuraphis rigida* (formerly called *Hilaria rigida*). Moreover, variations of the relative abundance of these three sympatric codominants with slope also could be interpreted based primarily of thermal responses of the roots. Of the 9 publications acknowledging partial support from grant number DE-FG03-93ER61686, many dealt with root properties. Also, distribution of photosynthetic products was considered, especially with regard to specific phloem contents, about which little was previously known for the desert species considered.