Annual Report

I. Project Title: Whole-vine measurements of photosynthesis to determine physiological effects of regulated deficit irrigation and crop load in *Vitis vinifera* cv. Cabernet Sauvignon.

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III. Summary:

Our goals for 2001 were to design and build a properly engineered chamber for measuring photosynthesis on mature grapevines in the vineyard, and to adequately test the prototype. This preparatory effort was necessary to ensure the success of a large field experiment during 2002 and 2003 in which several large chambers will be used to measure photosynthesis in deficit-irrigated 'Cabernet Sauvignon' vines in a commercial vineyard.

Photosynthesis is the process by which plants use energy from sunlight to transform carbon dioxide (CO_2) into simple sugar molecules for subsequent use in growth, development, and energy storage. Sugars that accumulate in grape berries are products of photosynthesis. Carbon dioxide, the substrate for photosynthesis, diffuses into the leaf through stomates, tiny pores on the underside of the leaf. Water molecules simultaneously diffuse out of the stomate into the atmosphere as water vapor, a process called transpiration. When a vineyard manager adopts 'regulated deficit irrigation,' he or she attempts to withhold water from the vine to the point that the vine becomes water stressed. Generally this results in some stomates closing, thereby reducing transpiration. Because CO_2 diffuses into the leaf through the same pores that water vapor diffuses out, water stress may limit CO_2 for photosynthesis. The most appropriate way to collect dynamic measurements of photosynthesis that reflect the integrated response of the entire vine canopy is through the use of a whole-vine chamber.

A whole-vine chamber must accommodate the trellis, be lightweight, robust enough to withstand high wind, and easy to remove for vineyard operations. Because the vineyard does not have electricity, the system must be run by generator. In 2001, prototypes of large, open-top chambers were constructed and tested. Horticultural, agronomic, and ecological literature were consulted for guidelines on design and operation so that our measurements would be valid. The final design incorporates an aluminum frame in a circular chamber built in halves (see diagram under "Research Accomplishments"). The air delivery system also is modular to facilitate rapid

setup. Because photosynthesis is highly dependent on temperature, the chamber was designed to minimize the difference in temperature between inside and outside without artificially raising transpiration. The chamber's covering material maximizes transmission of both sunlight and the radiant energy emitted by the vine. The vertical temperature distribution inside the chamber closely matched that of a vine outside, with the largest difference between inside and outside at 2 °C (4 °F) on sunny days. Air blown into the chamber was delivered through perforated tubes to increase mixing and to avoid pockets of CO_2-depleted air. Tests with smoke bombs showed that air entering the chamber mixed in less than 10 seconds. Humidity in the chamber (vine included) was close to that outside. High winds destroyed the first prototype, so structural changes were made and the new chamber survived 50-mph gusts. Construction of 6 chambers currently is underway for the 2002-2003 experiment. Other necessary equipment was secured during 2001 by purchase or on loan from USDA-ARS: CO_2 analyzer and solenoid unit; laptop PC and data logging hardware; travel trailer for housing computer-controlled equipment and a 5000-W gas generator; intake fans, pressure sensors, radiation sensors, and humidity probes.

IV. Objectives and Experiments Conducted to Meet Stated Objectives:

This proposal addressed the 2001 AVF Viticulture survey categories "*influence of plant water status on productivity and fruit composition*" (2.57) and "*regulation of photosynthesis and carbon partitioning*" (2.04).

1. To construct and test a field-portable, whole-vine photosynthesis system with multiple chambers (2001)
2. To determine the effects of high and low crop loads, and the effects of early-season (fruit set) or late-season (post-veraison) deficit irrigation on rates of photosynthesis in *Vitis vinifera* cv. Cabernet Sauvignon (2002, 2003)

Objective 1 required extensive engineering and design work, including system testing, rather than classical field experiments. *Objective 2, as proposed, will be addressed in 2002 and 2003.*

IV. Experiments Conducted to Meet Stated Objectives and V. Summary of Major Research Accomplishments and Results

During the summer of 2001, a field-portable photosynthesis system was constructed for enclosing entire grapevines in the vineyard. Modifications were made to rigorous designs of open-top chambers (e.g., Bugbee, 1992; Garcia et al., 1990; Ham et al., 1993; Leadley and Drake, 1993) and chambers developed for use with trees and potted grapevines (e.g., Corelli-Grappadelli and Magnanini 1993; Poni et al., 1997).

Structural considerations

Because of high winds at the experimental site, a rigid frame was constructed and modified several times to balance strength with surface area. About four feet of 'headspace' were incorporated into the chamber's height to minimize elevated temperatures within the vine canopy. The completed chamber is round, framed with aluminum, and constructed of independent halves weighing only several pounds each. Total volume is 7.34 m^3 (260 ft^3). Adjacent modules are sealed with closed-cell foam gaskets and hand-tightened hardware. The

ventilation system also is modular. The chamber requires only two people for setup and removal. Incursion of outside air into the top of the chamber was minimized by including a frustum.

A number of plastic films were tested for optical properties, strength, and resistance to abrasion. The best compromise was in a material that transmits about 99% of incident sunlight and near-infrared radiation. The film is nearly impermeable to CO_2, O_2, and water vapor. Over the course of a day, a vine inside the chamber received between 90 and 95% of incident solar radiation. The difference between the optical properties of the film and the radiation environment inside the chamber is due to solar angle and intermittent shading by the chamber frame.

Air flow and delivery

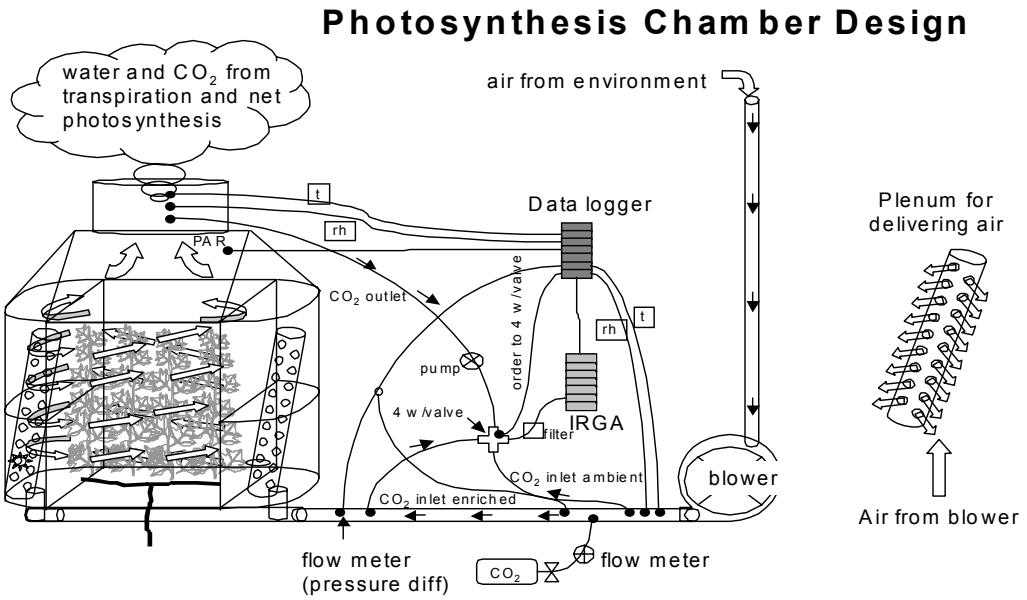
Techniques for delivering air and accurately measuring air flow rates, critical to the calculation of photosynthesis, followed the protocols of Garcia et al. (1990) and Ham et al. (1993). A 1-HP blower was dedicated to each chamber. Several plenum designs were tested. The most rapid and even mixing was produced by a bilateral plenum with a vertical gradient in orifice diameter (after Buwalda et al., 1992). Mixing was assessed visually from video recorded during the release of smoke bombs. Air flow rates were estimated three ways: from velocity measurements with a hot-wire anemometer; from pressure differences in the delivery duct; and by CO_2 injection into the duct. Typically, an air exchange rate of at least 1.5 chamber volumes per minute is acceptable (R. Garcia, J. Ham, personal communication). At an exchange rate of 2.5 chamber volumes per minute, air temperature in the canopy was no more than 2° C (4° F) higher inside the chamber than in a vine outside. This flow rate also maintained humidity within the chamber near that of the air in an unchambered canopy.

CO_2 measurement

Differences in CO_2 between inlet and outlet of the chamber were measured with an infrared gas analyzer (IRGA; model 225, ADC, Hoddesdon, UK) having a cell volume of 5 cm^3 and a resolution of 0.1 ppm at CO_2 concentrations in air of 350 ppm. Prior to harvest, differences in CO_2 between inlet and outlet averaged 12 ppm, well above the instrument's limits of detection. Air samples were drawn from the chamber inlet at 50 ml min^{-1} and from the outlet at 15 L min^{-1} with a vacuum pump. Excess sample gas was shunted off. For the multiple-chamber experiment, a series of solenoid valves will switch airstreams to the IRGA sample cell at 1-min intervals. The solenoid system was tested in the laboratory. All tubing that carried sample gas to the IRGA was polyethylene-lined EVA (Bev-A-Line).

Data acquisition and control

Analog signals from the IRGA were recorded by data logger (CR-7, Campbell Scientific, Logan, UT) which also recorded environmental measurements (temperature, humidity, solar radiation, air pressure). Software was written for recording and processing data so that rates of photosynthesis were calculated and displayed real time.



VI. Outside Presentations of Research:

J. Perez Peña. *Research Proposal Seminar*. Nov. 2001. Presented to faculty and staff of Washington State Univ., Prosser Research Station. Also presented to faculty and students, Department of Horticulture and Landscape Architecture, Washington State Univ., Pullman.

J. Perez Peña and J. Tarara. *Program Overview Seminar*. Dec. 2001. Presented to Horticultural Crops Research Unit, USDA-ARS, Corvallis, OR.

J. Perez Peña and J. Tarara. *Design and testing of a chamber system for measuring whole-vine photosynthesis in the vineyard.* Abstract to be submitted to ASEV for 2002 annual meeting.

VII. Research Success Statements:

The engineering and design work that was proposed for 2001 was completed and has produced an experimental system for the investigators to collect measurements of whole-vine photosynthesis during the upcoming growing seasons. The application of this research equipment to the study of regulated deficit irrigation (RDI) will produce information on physiological effects of RDI and its timing, which will be valuable to the industry in arid areas where RDI is being considered or already is practiced.

VIII. Funds Status:

On November 28, 2001, an invoice was sent from ARS to AVF for agreement #58-5358-1-440 (AVF #V113) in the amount $4,000. AVF released the funds and they have been received by ARS, but as of this writing are not available to the PI through the ARS accounting system.