University of California Hansen Trust
Research Competitive Grants Funded 2007-2008
Carbon Dioxide Applied to Raspberries

Final report

Cover Page

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Title: Carbon dioxide application for enhanced raspberry production in Ventura County

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Location of Work: Hueneme Rd, Camarillo, CA (Ventura County)

Commodity: Raspberries

Funding: 2006/2007 - $19,980; 2007/2008 - $24,375

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Objectives

The primary objective is to optimize a CO_2 delivery system to increase photosynthesis and fruit yield. We will identify ambient CO_2 levels required for maximum photosynthesis and the amount of CO_2 sequestered by the plants.

A secondary objective is to disseminate the results of this research:

1) to engage local growers by demonstrating the potential benefits of this technology to environmental quality and production, and

2) to provide incentive to industrial producers of CO_2 for continued optimization of the CO_2 sequestration and recycling.

Site description

A 10-ton tank measuring 20 feet in length by 8 feet in width and height rests atop four thick planks 8 feet in length by 12 inches in width and height. The tank is filled to its capacity by an 18-wheeler truck about every 45 days. The liquid carbon dioxide travels through a vaporizer to warm and vaporize the gas before it moves through the piping system that regulates its pressure and flow. The gas continues through 550 feet of PVC pipe to three separate raspberry hoops. At each hoop entrance, the PVC connects to black plastic tubing and then to low-flow drip tape suspended within the raspberry canopy. The drip tape extends the entire length of the commercial raspberry hoop delivering carbon dioxide to the plants for 300 feet on each of three rows for 8 hours per day.

Summary of methods

The trial was established with three replications of CO_2 and control (no CO_2) in a randomized complete block design. Before beginning CO_2 application, we measured stomatal conductance, CO_2 assimilation and florescence of leaves in lower, mid and upper plant canopy from sunrise to sunset. We also measured plant height, counted fruiting canes, and monitored yield and pruned biomass to establish baseline plant conditions. The CO_2 delivery system was assembled in May 2007; CO_2 was applied 8-12 hours per day for 4 months prior and during the harvest in Sept. to Oct. CO_2 concentrations inside the hoop were continuously monitored using two gas analyzers connected to a datalogger. Photosynthesis measures were taken twice more during the season, in June and Sept. Yield and fruit size data from the full tunnel and from 20 ft. sub-plots established in the tunnels was monitored for the duration of the fall harvest.

Summary of results

Objective: to optimize CO_2 delivery system. The delivery system was successfully designed and installed, applying a total of about 60 tons of CO_2 to specific hoops during the four-month trial. Diurnal measurements of leaf stomatal conductance, CO_2 assimilation, and fluorescence showed a mid-day depression (Fig. 1), enabling us to make an informed decision about optimum application time. We avoided application at the time of the day where plants would be unable to take up the applied CO_2, thereby minimizing waste. We found CO_2 concentration in the hoops where gas was applied were 20-25% higher than ambient CO_2 concentration during delivery periods (8 h/day; Fig. 2), generally returning to ambient levels during hours when gas was not applied. We also found that leaves in the middle and lower

canopy, rather than the top, were the most active (Table 1), prompting us to place our CO_2 drip tape for delivery at about 90 cm above ground level.

Objective: to increase photosynthesis and yield. The number of baskets from the full hoops, in which CO_2 was applied, increased by 36% compared to 16% for control hoops (Table 2) in comparing the harvests before and after CO_2 application. Berry weight also increased 0.1% per berry in the CO_2 hoops (Table 2). Cane height, number, and diameter as well as photosynthesis measures were all similar after CO_2 application. Carbohydrate content of fruit is currently being analyzed by the ANR lab.

Objective: to engage local growers and industrial producers. In August 2007, we showed our delivery system and trial setup to a UCCE farm advisor from another raspberry-producing county. In September 2007, we organized a tour for six industry representatives and investors interested in CO_2 recycling from ethanol production in the Santa Maria and Los Angeles regions. They were very interested in our work and showed a willingness to support further research. In February 2008, we presented our results at the UC Annual Caneberry meeting in Watsonville, CA. Several attendees mentioned they came specifically for our presentation. We discussed future experiments with other UC Farm Advisors and researchers, raspberry growers and researchers from Driscoll's and other companies, and ethanol industry representatives and investors. We submitted a paper describing this study and its results to *HortTechnology* and it has been accepted for publication, pending response to comments. These comments have been addressed and the paper was resubmitted on September 1, 2009.

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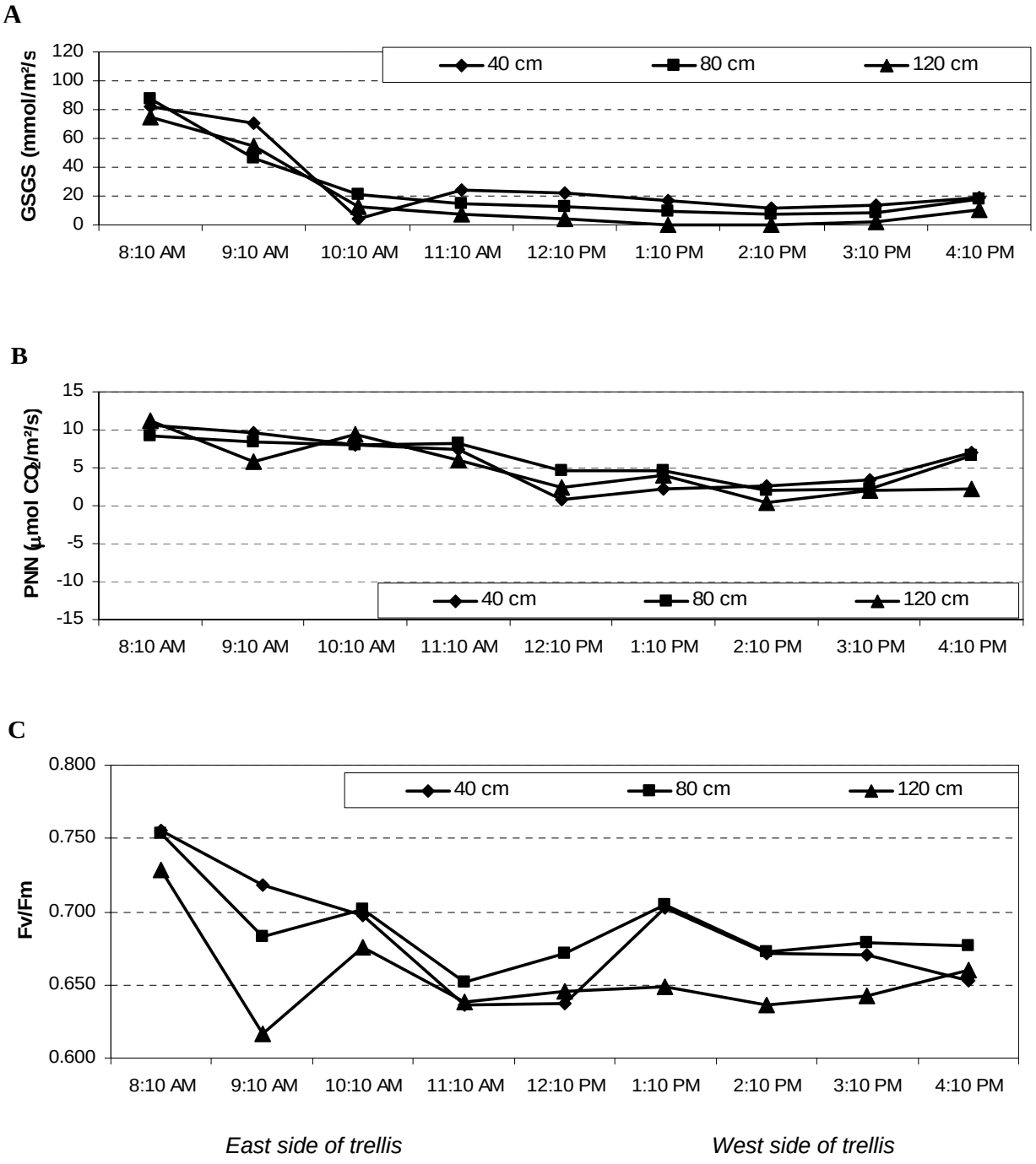

Fig. 1. Stomatal conductance rate (A), CO_2 assimilation rate (B), and fluorescence (C) for raspberry leaves at three heights in the plant canopy on 29 Mar. 2007 near Camarillo, CA.

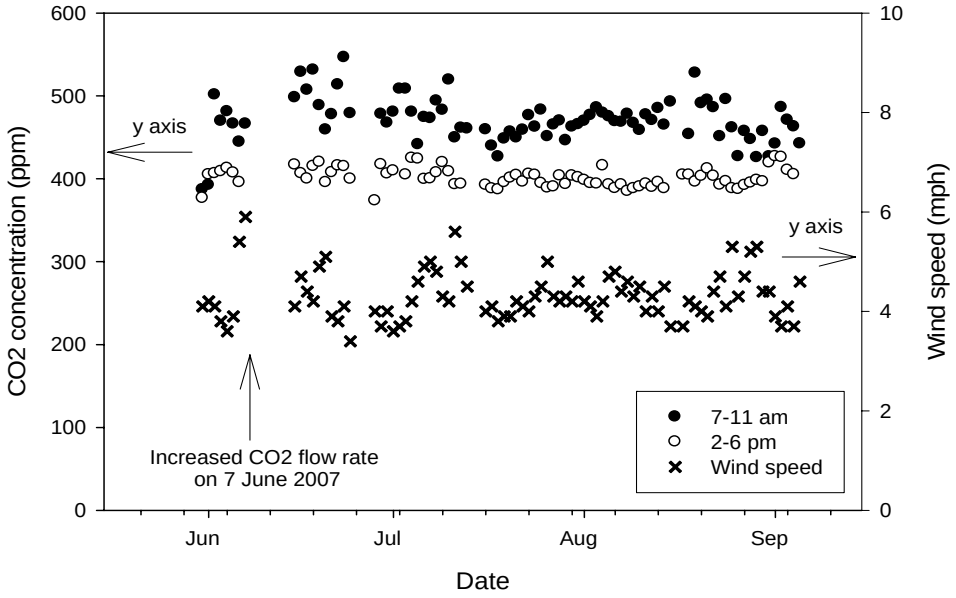

Fig. 2. Average CO_2 concentration and wind speed in a raspberry tunnel near Camarillo, CA during morning and afternoon CO_2 application hours from June to Sept. 2007.

Table 1. Raspberry leaf fluorescence (F_v/F_m or variable fluorescence over maximum fluorescence), CO_2 assimilation (µmol CO_2/ m^2/s), stomatal conductance (mmol/m^2/s) at three heights in the plant canopy.

Leaf height (cm)	Leaf fluorescence	CO_2 assimilation	Stomatal conductance
40	0.69 a	5.7	29.4
80	0.70 a	6	25.2
120	0.65 b	4.8	18.4
P-value	0.0001	0.43	0.17

Table 2. Percent increase in yield from baseline harvest before CO_2 application (May-June) to after 4 months of CO_2 application (Sept.-Oct.).

Leaf height (cm)	Number of baskets (full hoop)	Total ounces (small plots)	Avg. weight per berry (small plots)
CO_2	36% a	6%	0.08% a
Control	16% b	16%	-0.04% b
P-value	0.02	0.44	<0.0001