Development and Testing of a Mobile Platform for Measuring Canopy Light Interception and Water Stress in Almond

Project No.: 09-HORT13-Lampinen

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Problem and Significance:

Data collected by the authors over the past several years has provided a rough upper limit to productivity in walnut and almond based on the percentage of the available midday canopy photosynthetically active radiation (PAR) that is intercepted and the age of trees. However, most of the data that was collected previously had limitations. The methods of measuring percent PAR interception using a handheld lightbar (Decagon Devices, Pullman, WA 99163) were relatively slow and labor intensive. For this reason, much of the lightbar data that was used to develop the relationship was based on sampling of relatively small samples of trees. Often the area for the yield and PAR interception data did not match (i.e. PAR data from 5 trees and yield data from either one tree or from an entire row). We have recently outfitted a Kawasaki Mule with a light bar that is able to measure light across an entire row (up to 28 feet wide). The data can be stored on a datalogger at intervals of less than 1 foot down the row at a travel speed of about 4.5 mph giving us a much better spatial resolution in much less time than was possible in the past.

Preliminary results suggest that measuring leaf temperature using an IR spot sensor or 2D imagery while accounting for windspeed, leaf orientation, and incident PAR can provide a potential means of detecting plant water status. Ondimu (2007) found that a combination of a thermal image with a RGB color image was able to account for moss temperature, texture and color, as well as predict water stress. We plan to use a sensor fusion technique to detect plant water stress in which we will look at the leaf temperature using an IR sensor, incident PAR using our PAR measurement system, color image (RGB) for leaf inclination information, and a wind speed sensor.

Objectives:

Objective 1. The first aspect of this proposal involves retrofitting the Mule (**Figure 1**) with sensors designed to develop the ability to detect water stress in trees.

Objective 2. The second component of this proposal involves using the Mule mounted lightbar setup (**Figure 1**) to measure light interception and corresponding yield in almond orchards throughout the almond growing area of California. The goal of this aspect of the work is to help establish the upper limit to the light interception/yield relationship for almond (shown in **Figure 2**).

These data are of use for any studies that aim to quantify the impact of treatments on yield. By measuring canopy light interception on a large scale, the impacts of differences in canopy development can be separated out from other treatment impacts allowing much more robust data interpretation.

Interpretive Summary:

Objective 1. Mule platform modification.

The existing Mule mounted lightbar setup has been modified in order to make it more robust. This included removing the cable support system and replacing them with supports underneath as well as adding a protective bumper to push low hanging branches up and over the lightbar (**Figure 1**). A sub-meter global positioning satellite (GPS) receiver and radar were added to provide accurate positional information. In addition, two infrared thermometers were added for measuring soil surface temperature under the tree canopy and in the middle of the drive row. Because the Almond Board funding for this project did not come in time to retrofit the Mule mounted lightbar for the 2009 season, this project concentrated on Objective 2 for the 2009 season. With repect to objective 1, the Mule mounted lightbar will be modified with additional canopy temperature and Light Detection and Ranging (LIDAR) sensors over the winter of 2010 for use in the 2010 field season.

Figure 1. Current design of Kawasaki Mule mounted lightbar after summer 2009 modifications showing adjustable end section and branch bumper on front designed to aid in pushing through orchards with many low overhanging branches.

Objective 2. Refine light interception/yield relationship in almond.

Nineteen almond orchard sites of varying ages and varieties from throughout the almond growing area of California were selected for measurements (**Table 1**). An emphasis was placed on orchards with Nonpareil but other varieties were also included. Light bar measurements were done in 10-20 rows (depending on orchard size and variability) in representative areas of the orchard during June to August. A portable weather station with temperature, relative humidity and photosynthetically active radiation sensors was set up outside of each orchard to provide reference data (on a one minute basis) during the time measurements were being taken. The photosynthetically active radiation data from this station was used to calibrate the sensors on the Mule lightbar throughout the measurement period. The data rows were then flagged and at harvest time, rough field weights were taken from the Nonpareil or other primary variety in the orchards. Subsamples from each variety were taken and dried and shelled to estimate kernel yield. In some cases measurements were done in orchards that are being used for other almond trials including sites from the area wide methyl bromide alternatives trials as well as projects funded under a federal SCRI grant. Other orchards were mapped from rootstock and pruning and training trials. Utilizing orchards from other studies allows us to utilize the data for multiple purposes.

Table 1. Orchards sites mapped with Mule lightbar during 2009 season.

Site #	County	Trial	Date mapped
1	Butte	Orchard removal	09/01/09
2	Colusa	SCRI- Arbuckle	06/18/09
3	Colusa	Nickels almond rootstock	07/31/09
4	Colusa	Nickels organic almond	07/30/09
5	Colusa	Nickels almond pruning/training trial	0730/09
6	Colusa	Shackel almond deficit trial	06/19/09, 06/24/09
7	Glenn	Almond light interception/yield	06/22/09
8	Glenn	Orchard removal	09/20/09
9	Kern	Billing Variety Trial	07/19/09, 07/20/09
10	Kern	SCRI- Belridge	07/21/09
11	Kern	Spur Dynamics	07/03/09, 07/04/09

Site #	County	Trial	Date mapped
12	Madera	Holtz almond surround trial	06/16/09, 06/17/09
13	Madera	Methyl bromide grower south orchard replant site	07/02/09
14	Madera	Paramount New Columbia fumigation/irrigation trial	06/30/09
15	Madera	Paramount New Columbia main fumigation trial	07/22/09
16	Sutter	DeJong almond model site	10/06/09
17	Stanislaus	SRCI- Salida	08/19/09
18	Stanislaus	Duncan almond pruning, spacing and training trial	08/12/09
19	Stanislaus	Duncan almond rootstock	08/17/09

The data for light interception and yield will be used to refine the relationship shown on the graph shown in **Figure 2**. Because the data in **Figure 2** was collected with a hand lightbar and the yield and light interception areas were not always equal, there is quite a bit of variability in the data. With a better estimate of the maximum productivity

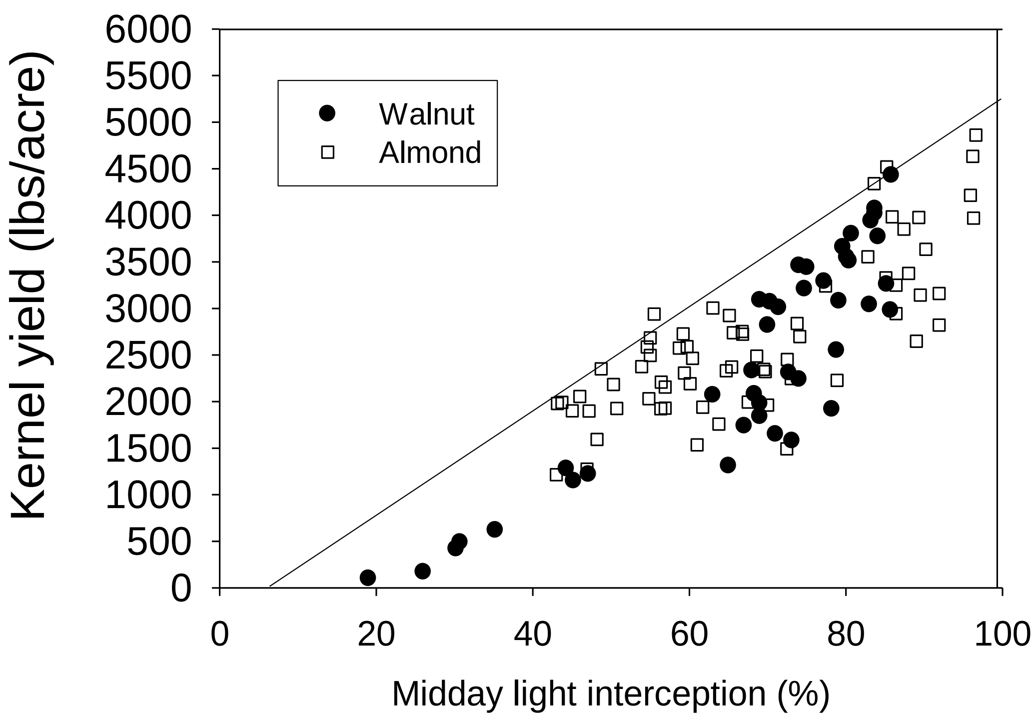

Figure 2. Midday canopy light interception versus yield relationship from various almond and walnut trials from throughout state.

unit light interception that can be obtained with harvesting equal areas to those measured with the Mule light bar, these data can be used to assess potential orchard yield and will allow us to separate out canopy light interception as a variable in other research projects. For example, if a pruning study is being conducted, this tool will allow the separation of the effect of the pruning treatment on overall canopy light interception as opposed to the effect of the pruning treatment on productivity per unit canopy. It will also allow block-to-block variability to be assessed before or after a research trial in initiated. These data will also allow us to look at how much of the variability in yields across an individual orchard is due to differences in canopy light interception as compared to other factors. These data can also be used to evaluate productivity of new almond selections compared to existing cultivars. Finally, these data will allow any orchard to be evaluated as to how well it is producing compared to other orchards of similar canopy cover. This will allow a grower to assess how current management practices are impacting productivity per unit canopy.

Sample positional data from the Mule mounted lightbar for orchard site number 6 (Shackel Nickels almond deficit trial, project 08-HORT13-Shackel) is shown in **Figure 3**. The circles with numbers at the end of each row represent a position where a full sun and GPS reading was taken. Distance down the row was measured with radar and the beginning and end of plot boundaries were marked in the datalogger file. **Figure 4** shows the percent light interception data (expressed as a decimal) for the left side of the Mule lightbar for the Nonpareil row that is the farthest left marked row in **Figure 3**. The data for the deficit irrigation and deficit irrigation plus canopy pruning plot as well as the fully irrigated control are shown on **Figure 4**. Midday canopy light interception averaged about 60, 40 and 20% in the control, deficit, and deficit plus pruning rows respectively,as shown in **Figure 4**.

At reporting time, harvest had been completed at all of the almond light interception/yield orchards but samples had not yet been analyzed so yield data are not available with this report. Final yield and light interception data will be provided in the Almond Board Annual Report for this project in July 2010.

Figure 3. Aerial image of Nickels Soil Lab orchard (Shackel almond deficit trial) mapped with the Mule lightbar. Numbers on image represent points at which full sun and GPS readings were taken.

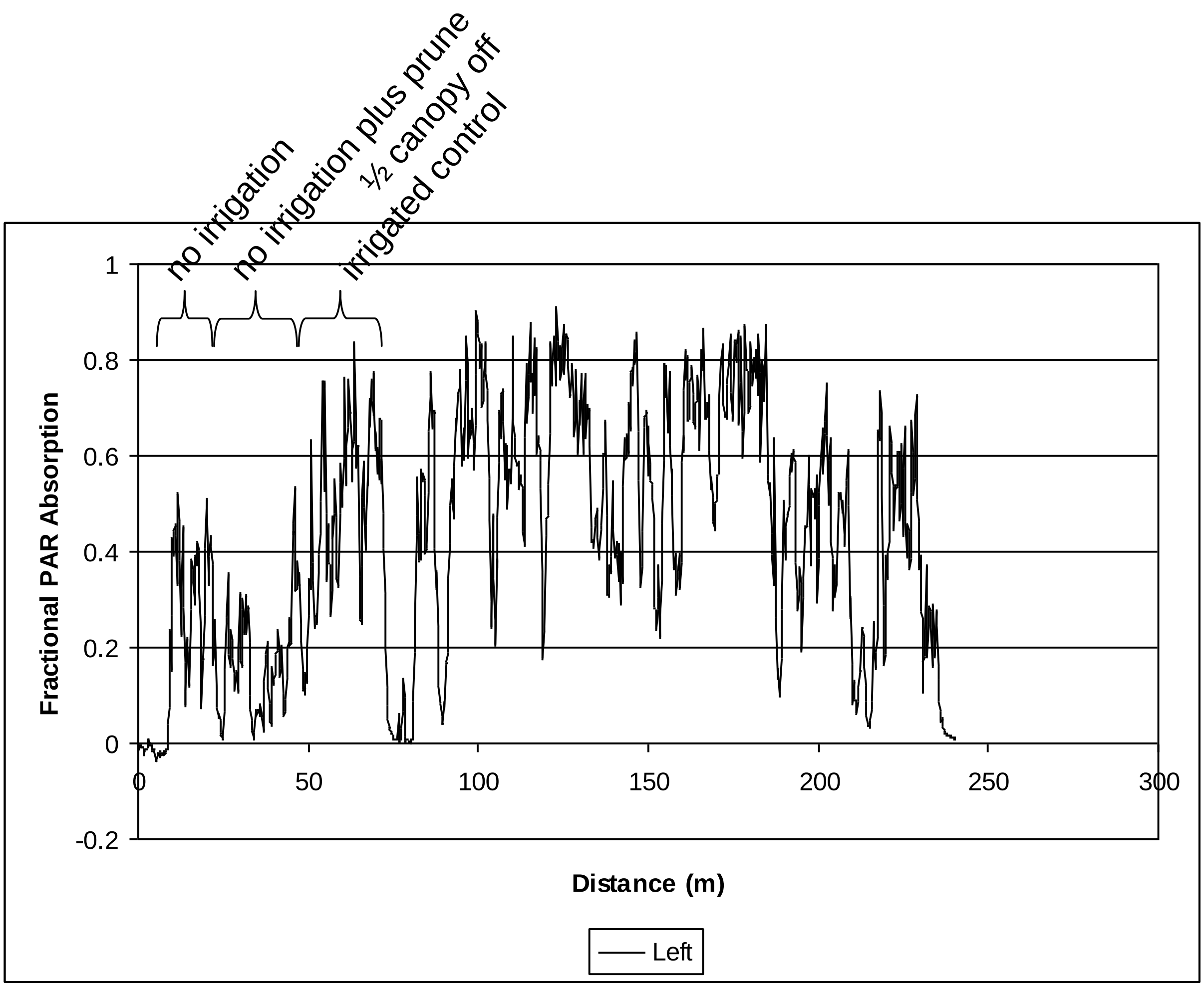

Figure 4. Fractional photosynthetically active radiation interception in transect across Nickels Soil Lab almond deficit trial orchard (transect farthest to left in **Figure 3** between the number 64 and 66 labels). Non-irrigated plot, non-irrigated plot plus ½ canopy pruned off plot, and irrigated control (non-pruned) plot are indicated. Data is for the left side of the lightbar only which was on the Nonpareil row.