Enhancement of Avocado Productivity.

II. Tree Phenology, Carbohydrate Cycling and Canopy Management

Continuing Project; Year 3 of 5 (of Revision)

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Benefit to the Industry

This project will supply the avocado industry with information regarding the growth and flowering behavior of the 'Hass' avocado under California conditions. Development of a phenology model for avocado will greatly enhance a grower's ability to plan management practices in relation to the events occurring within the tree and external to the tree such as temperature. Knowledge of the time of root and shoot growth, flowering and fruit set, and the relationships between these events and carbohydrate status within the tree will aid the grower in deciding the optimum time to undertake such cultural treatments as nutritional and root health treatments. It is also possible that an understanding of the carbohydrate status of 'Hass' avocado trees during successive seasons will lead to a better understanding of alternate bearing. We are committed to making the data from this project available to the industry in a timely manner. Data collected from this project will be available through the avocado home page (www.ucavo.ucr.edu) and other appropriate means.

Project Objectives

A. To collect information on root and shoot growth, flowering and fruit set, yield, and carbohydrate partitioning for 'Hass' trees on selected clonal rootstocks at the University of California (UC) South Coast Research and Extension Center (REC) in Irvine, CA. This information will be correlated with meteorological data collected at this site (air, soil temperature, irradiation and relative humidity).

B. To establish additional research sites throughout the California avocado industry to collect data pertaining to shoot and root growth, flowering, yield, and carbohydrate cycling. Meteorological data will also be collected and correlated to the timing of phenological events as in objective A.

C. To collect comparative data on 'Lamb Hass' as compared to 'Hass' on Duke 7 in relation to phenological events and carbohydrate cycling at the UC South Coast REC.

D. To collect comparative data on stumped (rejuvenated) 'Hass' trees as compared to non-stumped 'Hass' trees on Toro Canyon in relation to phenological events and carbohydrate cycling at the UC South Coast REC. (Data collection for this objective completed in 1999).

E. To establish a girdling project in a commercial grove and to follow fruit yield, size, and other tree characteristics over multiple years.

F. To establish a program to examine the relationship of canopy management (light distribution and microclimate effects within an avocado tree) to long term effects on productivity.

Summary

We have divided the highlights of our activities for the last year into four sections.

A. Phenology of 'Hass' avocado on four rootstocks at South Coast Research and Extension Center (SCREC)

P. Robinson, M. Mickelbart, X. Liu, M. Madore, C. Adams, W. Manor, M. L. Arpaia

We have analyzed the data collected at SCREC between 1992 and 1996. Figure 1 and Table 1 summarize our findings. A summary of the findings follows.

Mature 'Hass' avocado (Persea americana Mill.) trees on four rootstocks (Thomas, Topa Topa, Duke 7, or D9) were monitored from 1992 to 1996 to determine the relative timing of shoot and root growth, bloom, and carbohydrate levels, as well as the relationships between these variables and yield in southern California. Trees exhibited typical alternate bearing patterns with heavy and light crop loads ("on" and "off" years, respectively) alternating from year to year. Shoot growth occurred during two distinct flushes each year: one in spring and one in late summer. Although yield varied among rootstocks, neither the rate of shoot growth during flushes nor the total cumulative shoot growth over a season differed among rootstocks. The cumulative shoot growth did not differ between "on" or "off" years except in 1993, when yield was almost zero. The spring growth flush accounted for the majority of total shoot growth in most years; however, the summer growth flush accounted for most of the total shoot growth during 1993. Root growth did not exhibit dormant periods as shoot growth did, but in general, root growth was greatest when shoots were not actively growing. Crop load did not appear to affect root growth patterns or intensity. Bloom occurred each year from mid-March to mid-May. Bloom did not differ among rootstocks; however, bloom in "on" years occurred earlier and for a longer period than the bloom in "off" years. Shoot starch concentrations exhibited greater fluctuations during the year than trunk starch concentrations and were highest immediately before the spring shoot flush began. This information gives us insight into the relative timing of and relationships between growth events of avocado in southern California and will help growers determine the optimal timing of cultural practices.

We have reported previously our work on the 7 carbon (7C) sugars, D-Mannoheptulose and Perseitol, which are found in the avocado. In December 1999 we published two papers (J. Am. Soc. Hort. Sci., reprints available upon request) which summarized the seasonal changes in tree and fruit carbohydrate and the role of the 7C sugars. In summary, we found that the 7C sugars are the predominant soluble sugars found throughout the tree (with the sole exception of the seed). Additionally we provided preliminary evidence (which we have followed-up on) suggesting that these sugars provide the energy substrate for the respiratory rise associated with fruit ripening. This research provided us the preliminary data to use in a successful application for funding from USDA. This grant will begin in January 2001 and will explore the biochemistry and metabolism of the 7C sugars. This work will be done in conjunction with our on-going work outlined in (D) below.

B. Phenology of 'Hass' avocado on Duke 7 rootstock at various locations in California.
P. Robinson, M. Mickelbart, X. Liu, C. Adams, W. Manor, M. L. Arpaia

We are in the third year of a four-year study to examine the phenological patterns of growth in 'Hass' avocado growing in various parts of the state. We are currently analyzing the data collected thus far.

C. Photosynthetic characteristics of avocado leaves and relation to growth.
X. Liu, M. Mickelbart, C. Adams, R. Hofshi, M. L. Arpaia

Data collected by Xuan Liu has been analyzed and prepared for publication. In this work, developmental patterns of spring flush leaf area, color, chlorophyll concentration, and photosynthetic capacity were studied in relation to leaf abscission and fruit set on mature 'Hass' avocado (Persea americana Mill.) trees. The results are summarized in Figure 2. SPAD meter readings were linearly correlated with leaf chlorophyll concentrations determined by light spectroscopy of DMSO extracted samples and were therefore used to estimate leaf chlorophyll concentrations throughout the experiment. A flush from a single bud produced a shoot with 10 leaves that emerged over a 25-day period. Each leaf took 35 to 40 days to change from a red color at emergence to a light green color at full expansion, and another 14 to 21 days to develop a dark green color. Leaf color was correlated with leaf chlorophyll concentration. Leaves reached full photosynthetic capacity approximately 50 days after emergence. Fruit set occurred 30 days after shoot emergence, as the first newly formed leaves reached 20% of full expansion and attained a positive net CO_2 assimilation rate (P_n). By this time, 40% of the leaves produced in the previous season had abscised, but the leaves remaining on the tree maintained a high Pn. Rapid growth and increase in Pn of new leaves were simultaneous with fruitlet abscission, and decreased Pn and continued abscission of the previous season's leaves. Fruit abscission nearly ceased after all new leaves were fully expanded. Our results indicate that the predominant source of carbon for young developing avocado fruit is the previous season's leaves, and not the new spring flush.

D. Effect of environmental conditions and cultural practices on avocado leaf photosynthesis.

M. Mickelbart, R. Heath, M. Madore, M. L. Arpaia

In cooperation with Drs. Robert Heath and Monica Madore at UC Riverside, we are examining the effects of various environmental conditions and cultural practices on avocado leaf photosynthesis with the goal of increasing yields through extending the period of optimal photosynthesis in avocado. Dr. Liu's work has indicated that avocado leaf photosynthesis may be severely inhibited by low relative humidity and high temperatures. We are working toward establishing specific thresholds at which photosynthesis is inhibited so that management decisions can be made with this information in mind. We are also examining the effects of evaporative cooling on avocado leaf photosynthesis with the goal of determining if this cultural practice can extend the period of optimal photosynthesis and, in turn, increase yields.

Table 1. Shoot growth characteristics and yield of 'Hass' avocado trees growing on four clonal rootstocks. Trees were six years old in 1992. The percent of the total season's growth occurring in the spring or summer flush and the total season's growth and yield are shown for each rootstock.

Year	**Rootstock**[z]	**Spring (%)**	**Summer (%)**	**Total growth (mm·shoot $^{-1}$)**	**Yield (kg·tree $^{-1}$)**
1992	TH	59.5	40.5	86.1	79.8c
	TT	72.6	27.4	70.7	130.8ab
	D7	73.9	26.1	68.7	137.1a
	D9	80.8	19.2	58.3	115.4b
		ns	ns	ns	***
1993	TH	23.7	76.3	923.0	0.6
	TT	28.9	71.1	1249.3	0.1
	D7	26.5	73.5	1324.0	0.1
	D9	21.1	78.9	1598.9	1.3
		ns	ns	ns	‡
1994	TH	80.0	20.0	175.0	83.1^{b}
	TT	84.1	15.9	215.7	147.5^{a}
	D7	82.2	17.8	245.1	132.2^{a}
	D9	78.6	21.4	247.2	88.8^{b}
		ns	ns	ns	***
1995	TH	61.5	38.5	136.9	10.0^{c}
	TT	65.9	34.1	98.1	25.5^{bc}
	D7	55.9	44.1	161.1	41.9^{ab}
	D9	70.5	29.5	129.8	49.4^{a}
		ns	ns	ns	**
1996	TH	85.6	14.4	160.0	14.8
	TT	90.1	9.9	101.8	14.4
	D7	74.1	25.9	153.5	21.2
	D9	74.9	25.1	201.9	15.8
		ns	ns	ns	Ns

[z]TH=Thomas, TT=Topa Topa, D7=Duke 7, D9=D9

Means within a column and year with no letter(s) in common are significantly different based on Fisher's Protected L.S.D. test at P=0.05 (ns, *, **, ***: non-significant, or significant at P≤0.05, P≤0.01, or P≤0.001).

‡: data not suitable for ANOVA.

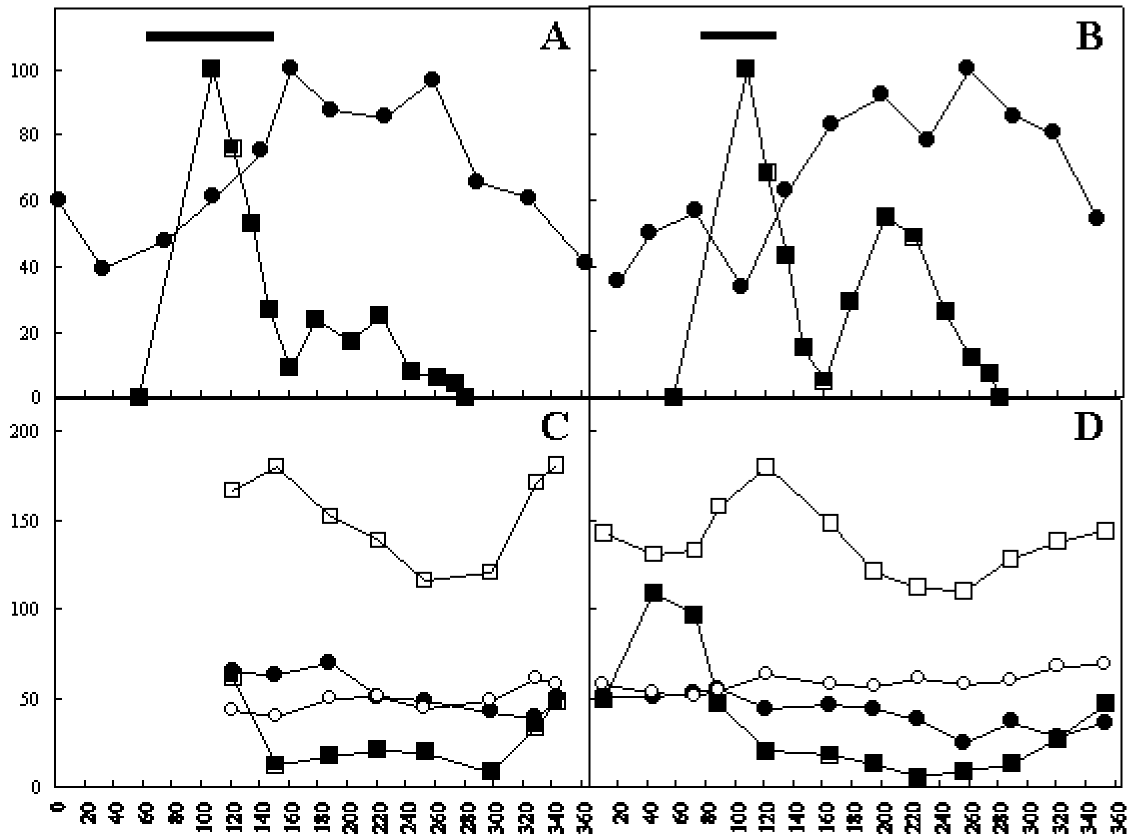

Figure 1. Graphical model of relative timing of phenological events of 'Hass' avocado in southern California. Relative shoot (■) and root (●) growth and bloom (bold line) in "on" (A) and "off" years (B) for 'Hass' on four clonal rootstocks. Growth is expressed as the percent of the maximum growth rate observed. Trunk concentrations of sugar (●) and starch (○) and shoot concentrations of sugar (■) and starch (□) in "on" (C) and "off" (D) years for 'Hass' on Duke 7 rootstock.

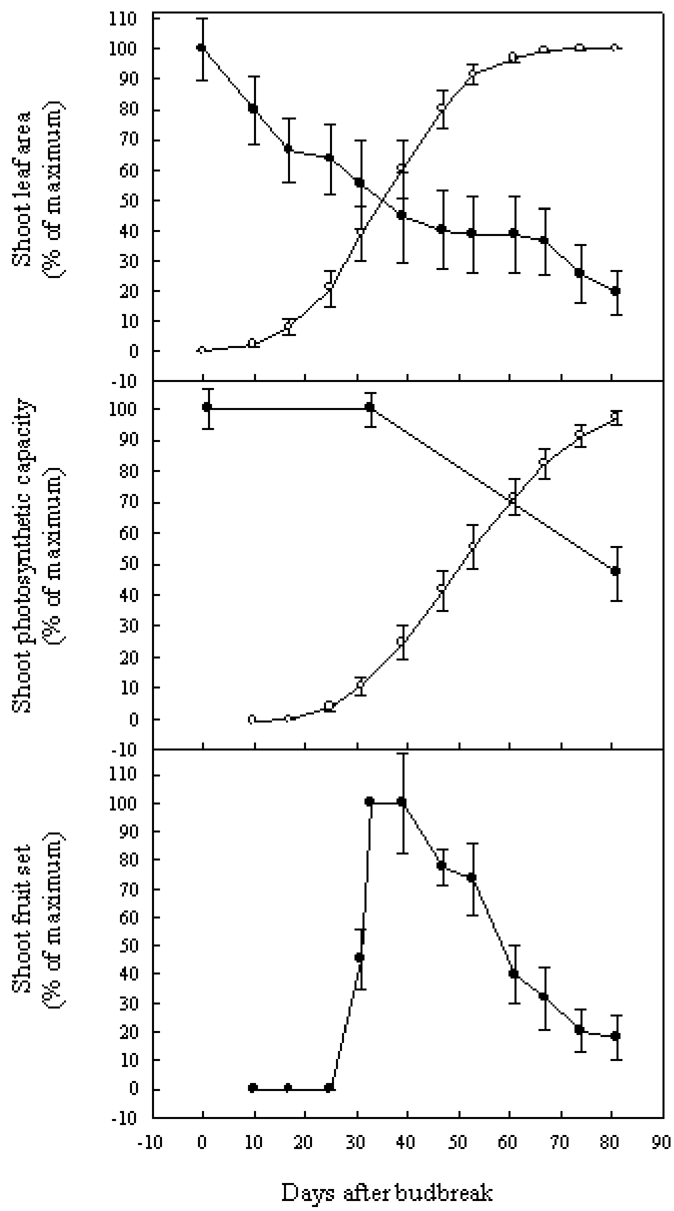

Figure 2. Relative timing of whole shoot leaf growth, leaf abscission, photosynthetic capacity, and fruit set and abscission. A. Current season's leaf growth (○) and previous season's leaf abscission (●) expressed as a percent of the maximum total new leaf area of current season's growth and of the maximum total leaf area of previous season's growth within the measurement period. Three trees growing in Irvine, California were used for measurements. Symbols represent the mean of 3 measurements per tree. Vertical bars represent standard error of the mean. B. Photosynthetic capacity of current (○) and previous (●) season's leaves expressed as a percent of the maximum total net CO_2 assimilation rate of the entire shoot integrated for all the new flushed leaves from a single bud, and for all previous season's growth. Five trees growing in Irvine, California were used for measurements on new leaves. Three trees growing in Irvine, California were used for measurements on old leaves. Measurement conditions for new leaves were the same as in Figure 4. Measurement conditions for previous season's leaves: T_a 30-31°C, T_l 31-

32°C, C_a 388-389 ppm, PPF 1451-1581 $\mu mol \cdot m^{-2} \cdot s^{-1}$, LVPD 3.4-3.5 kPa. Symbols represent the mean of 3 measurements per tree. Vertical bars represent standard error of the mean. C. Fruit set and retention (●) expressed as a percent of the maximum fruit number recorded on a shoot. Three trees growing in Irvine, California were used for measurements on old leaves. Symbols represent the mean of 3 branches per tree. Vertical bars represent standard error of the mean.