Almond Board of California
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Project No.: 01-BL-01 Spur Dynamics and Almond Productivity

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Problem and its Significance:

In mature almond trees, yields reflect in large measure the number of fruit and fruit - bearing spurs. These spurs are perennial, i.e., persist for a number of years, but there are relatively few data concerning the renewal, regularity of fruitfulness and the reproductive longevity of almond spurs. Spur longeveity, how regularly they fruit and how these parameters are influenced by orchard management practices have not been addressed. We hypothesize that management variables such as N fertilization and irrigation rates influence the dynamics of spur renewal, fruitfulness and persistence and are likely to impact yield. These variables may exert both direct and indirect effects. Thus, growth may be a direct effect of adequate N availability and tree water status. Shading of lower or interior branches, which reduces spur survival, may be an indirect result of excessive vegetative growth. This study will increase our understanding of spur turnover and yield dynamics in 'Nonpareil' almond and how internal (i.e., alternate bearing) and external (management) variables influence productivity.

Objectives:

The objectives of the proposed study are to a) quantify the dynamics of spur renewal, fruitfulness and spur longevity and b) determine how those dynamics are influenced by important orchard management variables; specifically, N and irrigation application rates.

Plans and Procedures:

A. Plot establishment: The following treatments will be replicated four times:

1.) Low N* (withhold N fertilization) and moderate irrigation rates [irrigate at mid-day stem water potentials of -1.2Mpa (-12 bars)].
2.) Low N and high irrigation [irrigate to maintain mid-day stem water potentials in the range of -0.7 to -0.9 Mpa (-7 to -9 bars)].
3.) High N (200 pounds N/ acre) and high irrigation rates.
4.) High N and low irrigation rates.

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*Apply N at rate of 100 pounds N/ acre when July leaf N concentration gets as low as 2.0%. Apply 30 pounds with the last pre-harvest irrigation and 70 pounds during the period of shoot growth (mid-March).

B. Data collection. Two types of data will be collected:

1.) Productivity. The effects of treatments on orchard yields will be determined. We anticipate that treatments will influence yields significantly within three years.

2.)Spur dynamics. The dynamics of shoot growth, spur renewal, fruitfulness, and spur mortality will be quantified using annual assessment of previously-tagged spurs as well as by monitoring the generation of new spurs from previous year's growth. These analyses will be directed primarily at the treatment extremes (low N / low irrigation vs. high N / high irrigation). The rationale behind this strategy is that collection of these data is labor intensive, and differences will appear earliest at the treatment extremes. Because of tree-to tree variability, alternate bearing and pollination variables, etc., we will monitor 10 limbs per treatment.

C. Project duration. The proposed duration of the study is 6 years, but the time frame is subject to continuing review. The intent is that the study should be long enough to follow a cohort of spurs from formation to death.

Irrigation and nitrogen. In mid-March 2001, the two moderate irrigation treatments (T3, T4) were outfitted with sprinkler heads that output at 80% of the amount of the control sprinkler heads. Midday water potential was monitored by two different methods over the season. For irrigation scheduling purposes, one fully irrigated tree and one moderately irrigated tree was monitored on an approximately weekly basis through the season. For these measurements, two shaded leaves per tree were wrapped in damp cheesecloth and immediately placed in a pressure chamber for measurement. In order to get a larger picture of orchard water potential variability and validate treatment effects on monitored trees, a single leaf was bagged on each monitored tree (12 trees per treatment for a total of 48 trees) and left to equilibrate for at least 15 minutes before placing in the pressure chamber for reading.

Nitrogen fertilizer was applied through the drip irrigation system at a rate of 200 pounds per acre and application began in March and was continued throughout the season. Leaf samples were taken for nitrogen analysis in July. No nitrogen was applied to T3 or T4 in 2001.

Spur dynamics. The dynamics of shoot growth, spur renewal, fruitfulness, and spur mortality will be quantified using annual assessment of tagged spurs as well as by monitoring the generation of new spurs from previous year's growth. Although initial plans called for monitoring 10 limbs per treatment, due to difficulty in selecting 10 representative limbs of a manageable size, the procedures were changed. Instead, 2400 spurs were tagged with aluminum tags in late March and early April 2001. 12 spurs were selected on each of the north-east and north-west quadrants of the tree and 13 were selected on each of the south-east and south-west quadrants (see Fig. 1). The tags were placed on young spurs spanning from the most shaded portion of the canopy (near the trunk) to the more exposed outer canopy positions at a height of about 8 feet.

In July 2001, the number of leaves per tagged spur were counted and leaf sizes were rated. In addition a similar spur from a nearby location (but not so near as to be a direct influence on the tagged spur) with a similar light exposure was sampled for leaf area and leaf specific weight analysis. Leaves were kept under refrigeration wrapped in moist cloth within a plastic bag until leaf areas were measured. Leaf area was assessed by taking a digital photograph of all of the leaves on each spur. Leaves were then dried at 70°C for approximately 48 hours and weighed. Sigmascan image analysis software will be used to count the number of leaves and to calculate the leaf area for each spur from the digital photographs. The image analyses are partially completed. The leaf area and leaf dry weights will be used to calculate leaf specific weight. The leaf specific weight (dry weight per unit area) acts as an integrator of the total light exposure of the spur. In March 2002, number of flowers per tagged spur were assessed.

<u>Canopy light interception</u>
Canopy midday light interception was measured twice during July and twice during August using a Decagon Ceptometer (80 cm bar with light sensors mounted on it). Measurements were taken within 1 hour of the time the sun is directly overhead by making 100 measurements in a grid pattern covering the area between the Nonpareil and Monterey rows. Measurements were made near each tagged tree for a total of 48 measurements. Full sun measurements were taken periodically as a reference. In addition to these measurements, just before harvest, 20 measurements were taken directly beneath the canopy of each monitored tree in order. This measurement would show whether any changes in light interception by a treatment were due to changes in overall tree growth or to differences in canopy density.

<u>Leaf nitrogen</u>
Dried leaves from spurs used for leaf area assessment (see above) were sampled for total leaf nitrogen analysis.

<u>Yields</u>
Yield data for the first year of the study was collected as one composite sample for each treatment. The entire crop for each treatment and variety was collected and weighed in the field. Then, the entire yield for each treatment was followed through the hulling process to obtain a per acre kernel yield for each treatment and variety combination

Results and Discussion

<u>Irrigation</u>
Differential irrigation treatments began in early May. The control treatment midday stem water potentials were below (more negative than) the target values during much of the season due to problems with the water distribution system (see Table 1 and Fig.1). However, overall there was about a 1-3 bar difference between the fully irrigated and moderate irrigated treatments through the season. Although there was a tendency for the midday stem water potentials for the moderate irrigation treatments to be lower than the control, there were no significant treatment effects on midday stem water potential for the

large orchard sample until 25 July (the period when water was cutoff to prepare for harvest) when both of the water moderate treatments were significantly more stressed than the fully watered control (Table 1).

Part of the reason for the large variability in water potentials within a given irrigation treatment was due to the fact that the experiment encompasses three different irrigation sets. Therefore, on any given day, trees being monitored for water potential in any treatment had been irrigated anywhere from 0-4 days previous. The differences in midday water potential across the irrigation sets within one treatment tended to be fairly consistent over the course of the season (Fig. 2). These consistent differences were partially due to the differences in days since irrigation (since water potential measurements were generally done at the same point in an irrigation cycle) but there were also consistent differences across the irrigation sets most likely due to soil variability.

We will be able to factor the impacts of the irrigation variability into our data analysis since we have midday stem water potential data for each of our monitored trees throughout the season (see Table 1 for summary).

Canopy light interception

After late July, the two moderate irrigation treatments led to a significant decrease in canopy light interception (Fig. 2). This is probably because the water potentials in these treatments were consistently below –12 bars which is generally the level at which vegetative growth is impacted.

Measurements of light interception under the tree canopy indicated that some of the treatment differences could be due to increased light penetration through the tree canopy rather than decreased radial growth of the canopy (Table 2).

Spur dynamics

Leaf dry weight per spur increased from about 0.1 to almost 0.2 grams from the interior canopy spurs to the most exterior ones (Fig. 4). There were generally 5 to 6 leaves per spur and there were no significant treatment differences in leaf dry weight per spur at any canopy position in the 2001 season (Fig. 5). There were no significant treatment differences in number of leaves per spur although there was a tendency towards increasing number of leaves per spur as you move outward in the canopy.

Yields

Because the samples for all replications were lumped together, it was not possible to statistically analyze the data. There did not appear to be any treatment impacts on yield in the Nonpareil, but the trend towards lower yields in the moderate irrigation treatments in the Monterey and Wood Colony will have to be watched (Table 3). Future harvests will be separated out by replication to allow statistical analysis of yield data.

Nonpareil kernel weight for T4 (-N, -H_2O) was significantly lower than that for the control (see table 5). However, overall yields for Nonpareil were similar for T1 and T4 suggesting that either more nuts were maintained on the T4 trees or the sample size for the individual tree harvests (12 trees per treatment) were inadequate to realistically represent the variability in the orchard. Nonpareil kernel weight for T2 (+N, +H_2O) and T3 (+N, -H_2O) were not significantly different than the control.

Leaf nitrogen

All of the nitrogen and water deficit treatments had significantly lower leaf nitrogen at the July sampling date compared to the control (Table 5).

Kernel defects

There were no significant treatment effects on gumming, kernel blanks, worm damage, kernel doubles or kernel mold (Table 6). The only significant treatment effect on kernel quality was an increase in shriveled kernels in the low nitrogen treatments (Table 6).

Project duration

The proposed duration of the study is 6 years, but the time frame is subject to continuing review. The intent is that the study should be long enough to follow a cohort of spurs from formation to death.

Table 1. Midday stem water potential data through season by treatment. Data is for 2 trees per replication for a total of 48 trees. Leaves were bagged for at least 15 minutes before sampling.

		Midday stem water potential (bars)						
Treatment	Description	5-Jun	12-Jun	28-Jun	11-Jul	25-Jul	10-Aug	20-Oct
1	+N, +water	-11.3 a	-12.2 a	-8.6 a	-11.0 a	-10.3 a	-18.4 ab	-11.4 a
2	-N, +water	-12.2 a	-12.9 a	-8.1 a	-11.2 a	-10.0 a	-16.3 a	-10.4 a
3	+N, -water	-12.3 a	-13.9 a	-8.9 a	-11.9 a	-13.2 b	-19.9 b	-11.7 a
4	-N, -water	-13.1 a	-14.8 a	-9.3 a	-12.0 a	-12.0 ab	-23.5 ab	-10.5 a

		Difference from control						
Treatment	Description	5-Jun	12-Jun	28-Jun	11-Jul	25-Jul	10-Aug	20-Oct
1	+N, +water							
2	-N, +water	-0.9	-0.7	0.5	-0.2	0.3	2.1	1.0
3	+N, -water	-1.0	-1.7	-0.3	-0.9	-2.9	-1.5	-0.3
4	-N, -water	-1.8	-2.6	-0.7	-1.0	-1.7	-5.1	0.9

Table 2. Percent light interception under the tree canopy at midday on August 10, 2001.

Treatment	Description	PAR interception (%)
1	+nitrogen, +water	89.3a
2	-nitrogen, +water	87.7a
3	+nitrogen, -water	87.3a
4	-nitrogen, -water	84.8a

Table 3. Average pounds of kernel yield per acre by variety.

Treatment	Description	Nonpareil	Monterey	Wood Colony
1	+nitrogen, +water	1926	2380	1989
2	-nitrogen, +water	1898	2208	1874
3	+nitrogen, -water	1979	2073	1834
4	-nitrogen, -water	1992	2060	1714

Table 4. Kernel weight (g)

Treatment	Description	Nonpareil
1	+nitrogen, +water	1.20 a
2	-nitrogen, +water	1.17 a
3	+nitrogen, -water	1.14 ab
4	-nitrogen, -water	1.09 b

Table 5. Leaf nitrogen (July sampling date)

Treatment	Description	Leaf nitrogen
1	+nitrogen, +water	2.21 a
2	-nitrogen, +water	2.00 c
3	+nitrogen, -water	2.10 b
4	-nitrogen, -water	1.96 c

Table 6. Nut quality characteristics for Nonpareil.

Treatment	Description	Gum	Blank	Worm	Kernel doubles	Kernel shrivel	Mold
1	+N, +H_2O	0.21 a	0.14 a	0.43 a	0.5 a	9.6 c	27.5 a
2	-N, + H_2O	0.14 a	0.43 a	0.14 a	0.4 a	15.8 ab	30.5 a
3	+N, - H_2O	0.08 a	0.43 a	0.79 a	0.6 a	13.4 bc	27.1 a
4	-N, - H_2O	1.00 a	0.31 a	0.69 a	0.5 a	19.8 a	25.9 a

Fig. 1. Midday water potential over season for treatments 2 and 4 in irrigation set number 2. Leaves were sampled by wrapping a shaded leaf in damp cheesecloth and immediately taking a water potential reading.

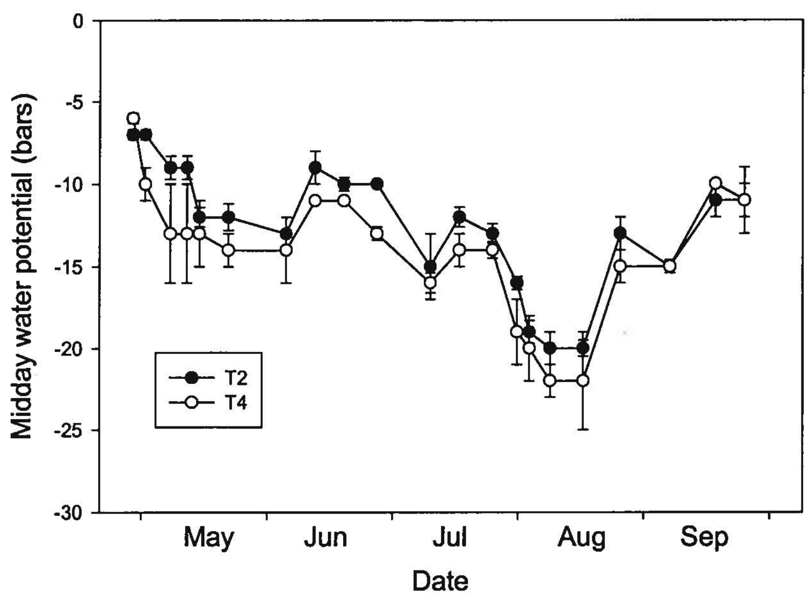

Fig. 2. Midday water potential over season for treatments 4 broken down by irrigation set. Leaves were sampled by wrapping a shaded leaf in damp cheesecloth and immediately taking a water potential reading.

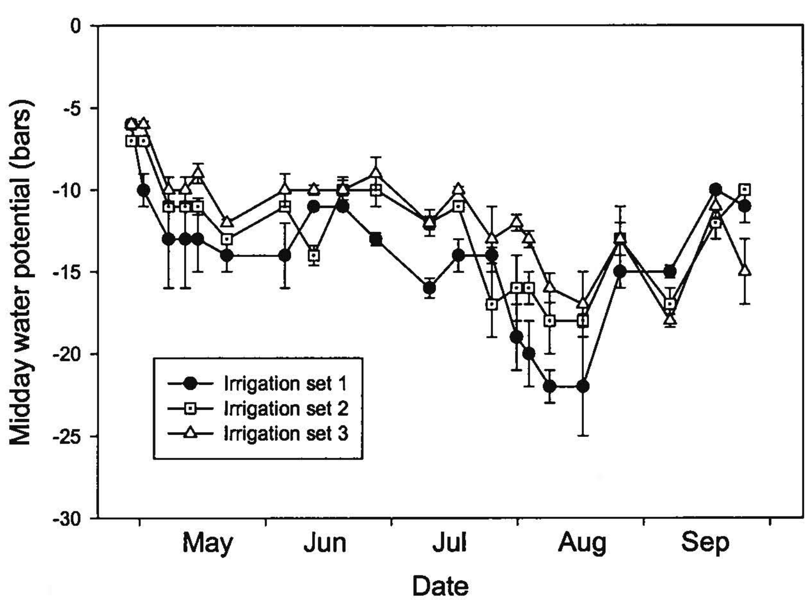

Fig. 3. Canopy light interception measured between the Nonpareil and Monterey rows by taking 100 measurements in a grid pattern. Asterisks indicate significant difference from T1.

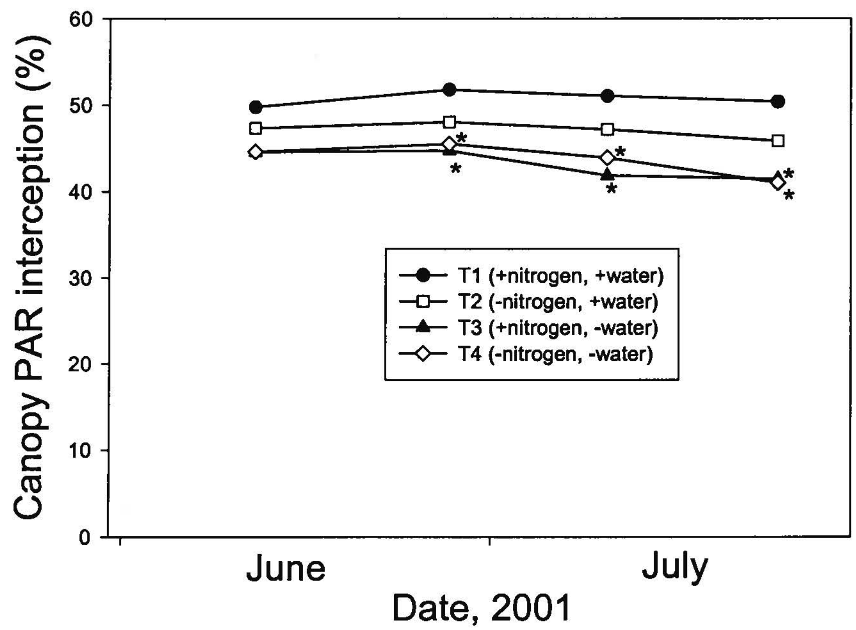

Fig. 4. Spur leaf dry weight as it varies by canopy position and treatment. Position 1 is the most interior and lowest on the tree and position 13 is the most outward and highest canopy location.

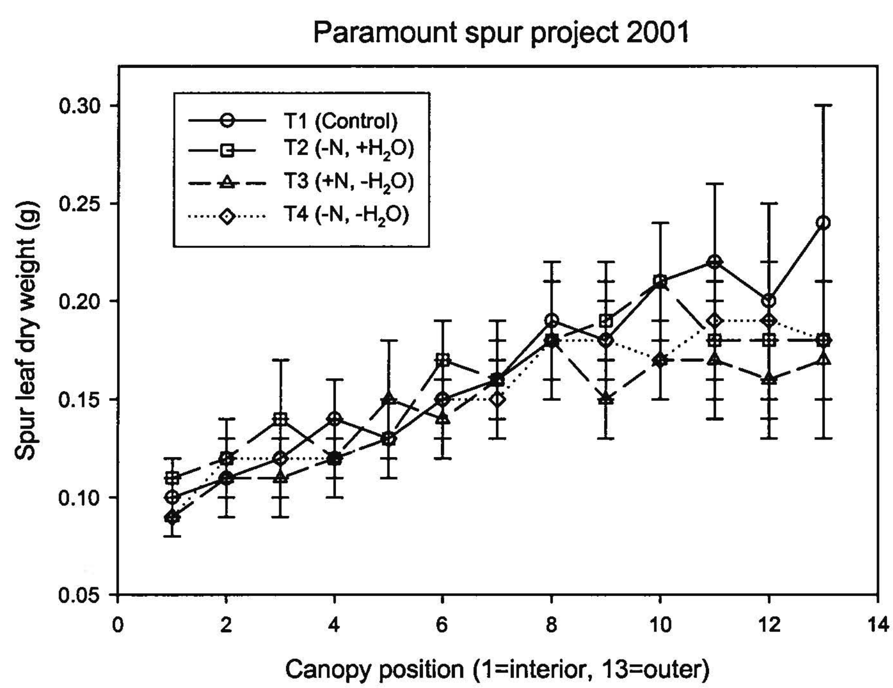

Fig. 5. Number of leaves per spur as it varies by canopy position and treatment. Position 1 is the most interior and lowest on the tree and position 13 is the most outward and highest canopy location