Spur Dynamics and Almond Productivity

Project No.: **09-HORT7-Lampinen**

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Objectives:

Almonds are produced on spurs, and we hypothesize those management variables such as nitrogen fertilization and irrigation rates, which are know to impact yield, influence the dynamics of spur renewal and fruitfulness. In turn, these dynamics of spur renewal and fruitfulness will likely impact overall orchard performance.

The original objectives of the proposed study were to: a) quantify the dynamics of spur renewal, fruitfulness and spur longevity, b) determine how those dynamics are influenced by important orchard management variables; specifically, nitrogen and irrigation application rates, and c) to assess the effects of the management variables on overall orchard development and productivity.

Because the canopy cover has now stabilized between 65-75 percent midday light interception in the various treatments, we are now dealing with the goal of maintaining productivity in the orchard. Previously, the canopy was still developing. In addition, because this orchard has gradients in water and light, it is becoming an important source of data related to food safety concerns including *Salmonella* and aflatoxin. Therefore, the current plan is to continue spur monitoring and expand canopy microclimate measurements.

Plot establishment: A 146-acre orchard that was planted in 1996 was chosen for the study. Tree spacing was 24 feet between and 21 feet within rows. Variety composition was 50% Nonpareil with 25% Monterey and 25% Wood Colony as pollenizers. Spur tagging and water potential measurements were performed only on the Nonpareil trees, but irrigation and nitrogen treatments were applied throughout the orchard, and yield data were taken for all three cultivars.

The treatments initially imposed were:

1. High N application rate (>200 pounds N/ acre) and high irrigation [maintain midday stem water potentials in the range of -0.7 to -0.9 MPa (-7 to -9 bars)]
2. Moderate N application rate (one-half normal rate when July leaf N concentration gets as low as 2.0%) and high irrigation
3. High N application rate and moderate irrigation rates
4. High N application rate and high irrigation rates

In 2008 and 2009, all treatments were returned to high levels of nitrogen and irrigation.

Interpretive Summary:

The 2007 season completed the seventh season of treatment imposition. For the 2008 season, with all treatments returned to the high water, high nitrogen regime, the goals were to 1) quantify the rapidity at which the deficit treatments respond to the changes and 2) observe the productivity per unit canopy to see if the more compact canopies on the deficit treatments (which will not require hedging as frequently as the original high water, high nitrogen treatment) are more productive per unit light intercepted.

With all treatments returned to the same nitrogen water regime in 2008 and 2009, the former deficit treatments appeared to be quickly adjusting. Seasonal average midday stem water potentials were not significantly different for any of the treatments in 2008 or 2009 (**Table 1**). Although the July leaf nitrogen levels increased in the entire deficit treatments in 2008, they were all still significantly lower than T1 (**Table 2**). In 2008, T1, T2 and T3 had similar leaf nitrogen levels while T4 had a significantly lower level (**Table 2**). However, all of the leaf nitrogen levels in 2008 and 2009, except T4 in 2009, were above the critical level of 2.2%. Kernel yields per acre and kernel yields per acre adjusted to similar levels of light interception were not significantly different between treatments in 2008 and 2009 (**Table 3**). Cumulative yields for T2, T3 and T4 are 85, 81 and 70% those of T1 for the eight years of the study (**Table 4**). However, if yields are adjusted to similar levels of light interception, T2, T3 and T4 had 90, 93 and 82% of the yield of T1 suggesting that more than one third of the decreased yield in T2 and T3 and one quarter of the decrease in T4 compared to T1 was likely due to the slower rate of canopy growth.

Within a given year, yields were closely coupled to canopy light interception, but between years, yields did not increase uniformly with increasing light interception (**Figure 2**). This suggests that factors besides water or nitrogen were determining the yield potential for any given level of light interception within any given year.

One of these factors may have been potassium deficiency. Potassium was added in 2008 and leaf levels in July were 1.40a, 1.52a, 1.10b, and 1.33ab percent respectively for T1 through T4. This would put T1 at the suggested critical value of 1.4% and T2 slightly above it. T3 and T4 were both below the critical value. This suggests that potassium deficiency may have occurred before the 2008 season. Leaf samples from the earlier years of the study were analyzed for potassium recently and results are shown in **Figure 3**. Results show that leaf potassium levels were in the adequate range for all treatments in all years except for T3 which was in the range between adequate and deficient for all years after 2003, except in 2006 (**Figure 3**) which was the year it yielded higher than all other treatments (**Table 3**). It is interesting that the highest leaf potassium levels occurred in 2006, which was one of the years with the lowest yields.

Active radiation intercepted below the tree canopy decreased in all treatments from 2004 to 2007 **(Figure 1b)**. In 2008, light interception below the tree canopy increased in all treatments **(Figure 1b)**. This could possibly be related canopy reduction resulting from potassium deficiency, since interception in all treatments increased in 2008. With adequate potassium in 2009, light interception has reached somewhat of a steady state, with all treatments declining moderately, except the low water, low nitrogen treatment, which increased slightly.

This study suggests that the impact of water deficits at the levels imposed in this trial were mainly reflected in decreased yields as a result of slower canopy development. The impact of nitrogen deficit also caused a reduction in production per unit canopy light intercepted and there was also an interaction between leaf nitrogen and potassium levels with high leaf nitrogen levels being associated with lower leaf potassium levels for both irrigation levels (**Figure 3**). The relationship between leaf nitrogen and potassium levels deserves further investigation.

Table 1. Average seasonal midday stem water potential by treatment for the 2001-2009 seasons. Measurements are for a total of 12 Nonpareil trees per treatment taken over the season.

Average midday stem water potential (bars)

Treatm.	2001	2002	2003	2004	2005	2006	2007	2008*	2009*	overall average.
T1-high water, high N	-11.9a	-9.8ab	-9.0a	-8.4 a	-9.1 a	-10.9 a	-9.6 a	-11.6 a	-13.2a	-10.4 a
T2-high water, mod. N	-11.6a	-9.7a	-8.8a	-9.2 a	-9.2 a	-11.0 a	-10.1 a	-12.3 a	-13.7a	-10.4 a
T3-mod. water, high N	-13.8b	-11.4c	-12.4b	-11.3 b	-11.7 b	-13.6 b	-11.9 b	-12.4 a	-15.2a	-12.6 b
T4-mod. water, mod. N	-13.0b	-11.0bc	-11.6b	-11.7 b	-11.8 b	-13.7 b	-12.0 b	-12.3 a	-14.4a	-12.3 b

* all treatments had same high water, high nitrogen applications in 2008 and 2009

Table 2. July leaf nitrogen for 2001-2009 seasons. Approximately 50 leaves were sampled from non-bearing spurs about half way up the canopy on 12 trees (same trees monitored for water potential) per treatment.

Treatment	2001	2002	2003*	2004	2005	2006	2007	2008**	2009**	Ave.
T1-high water, high N	2.20 a	2.02 a	2.39 a	2.48 a	2.55 a	2.59 a	2.75 a	2.90 a	2.38 a	2.48 a
T2-high water, mod. N	2.00 c	1.74 c	2.17 b	2.15 b	2.17 b	2.22 c	2.30 c	2.72** b	2.30** a	2.23 c
T3-mod. water, high N	2.11 b	1.91 b	2.19 b	2.23 b	2.25 b	2.38 b	2.50 b	2.76** b	2.29** a	2.32 b
T4-mod. Water, mod. N	1.96 c	1.67 c	2.00 c	1.96 c	1.99 c	2.03 d	2.06 d	2.61** c	2.17** b	2.08 d

*average of values from June 27th and August 9th sampling dates
** all treatments had same water and nitrogen in 2008 and 2009

Table 3. Average pounds of kernel yield per acre and kernel yield per acre of light intercepted for Nonpareil trees that were monitored for water potential over the season.

2004

Treatment Number	Treatment Description	Yield (lbs/acre)	Yield per acre light intercepted
1	+nitrogen, +water	2932 a	4022 a
2	-nitrogen, +water	2746 a	4142 a (102%)
3	+nitrogen, -water	2251 b	3789 a (94%)
4	-nitrogen, -water	1984 b	3511 b (87%)

2005

Treatment Number	Treatment Description	Yield (lbs/acre)	Yield per acre light intercepted
1	+nitrogen, +water	2255 a	2826 a
2	-nitrogen, +water	1624 b	2219 b (78%)
3	+nitrogen, -water	1571 b	2454 a (87%)
4	-nitrogen, -water	1422 b	2312 a (82%)

2006

Treatment Number	Treatment Description	Yield (lbs/acre)	Yield per acre light intercepted
1	+nitrogen, +water	1586 b	2129 b
2	-nitrogen, +water	1465 b	2078 b (97%)
3	+nitrogen, -water	1976 a	3167 a (149%)
4	-nitrogen, -water	1676 a	2775 a (130%)

2007

Treatment Number	Treatment Description	Yield (lbs/acre)	Yield per acre light intercepted
1	+nitrogen, +water	2770 a	3594 a
2	-nitrogen, +water	2504 ab	3384 a (94%)
3	+nitrogen, -water	2198 b	3402 a (95%)
4	-nitrogen, -water	1754 c	2749 b (77%)

2008

Treatment Number	Treatment Description	Yield (lbs/acre)	Yield per acre light intercepted
1	+nitrogen, +water	2731 a	3755 a
2	+nitrogen, +water	2671 a	3705 a (99%)
3	+nitrogen, +water	2364 a	3620 a (96%)
4	+nitrogen, +water	2565 a	3869 a (103%)

2009

Treatment Number	Treatment Description	Yield (lbs/acre)	Yield per acre light intercepted
1	+nitrogen, +water	2425 a	3235 a
2	+nitrogen, +water	2454 a	3340 a (103%)
3	+nitrogen, +water	2043 a	3300 a (102%)
4	+nitrogen, +water	2032 a	2914 a (90%)

Table 4. Cumulative yield and cumulative yield adjusted to 100% light interception for 2001 to 2009 seasons.

Treatment	Cumulative yield (pounds/acre)	Percent of T1 yield	Cumulative yield adjusted to 100% light interception	Percent of adjusted T1
T1 (high N, high water)	21,510 a		29,903 a	
T2 (mod. N, high water)	18,318 b	85	26,928 b	90
T3 (high N, mod. water)	17,348 b	81	27,951 a	93
T4 (mod. N, mod. water)	14,963 c	70	24,555 c	82

Figure 1. Seasonal average canopy light interception a) measured between the Nonpareil and Monterey rows for the 2001-2009 (100 measurements in a grid pattern) and b) under individual Nonpareil trees by taking 30 readings distributed evenly under canopy shaded area. Error bars indicate plus or minus one standard error.

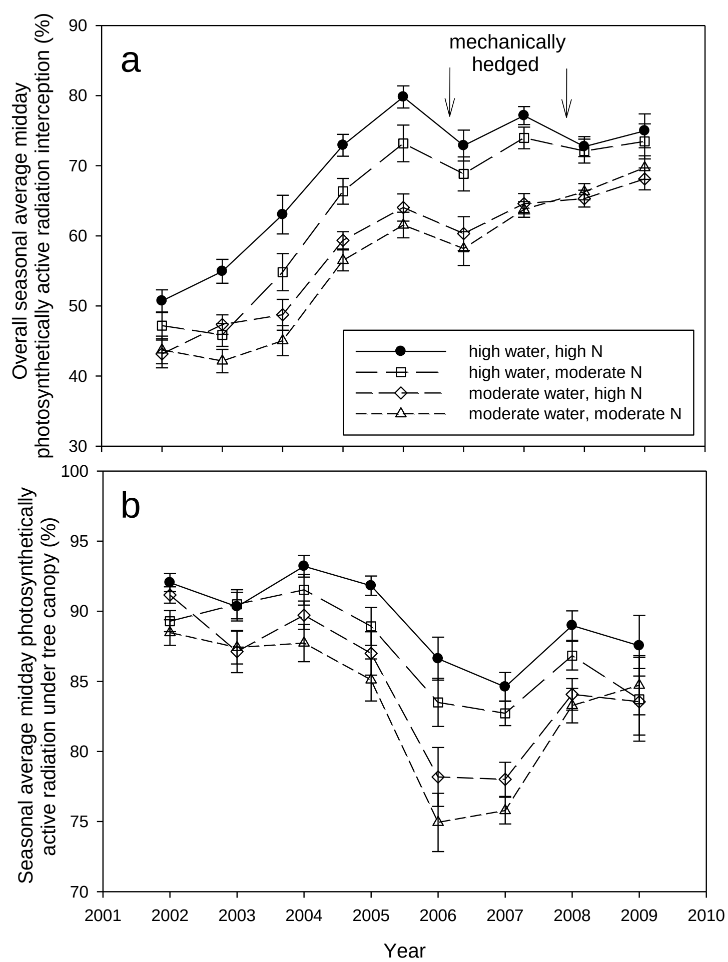

Figure 2. Annual treatment average midday canopy light interception versus yield by treatment for 2002 to 2009 seasons. Within a given year, treatments one to four are always from left to right except in 2009 when T1 and T2 were reversed.

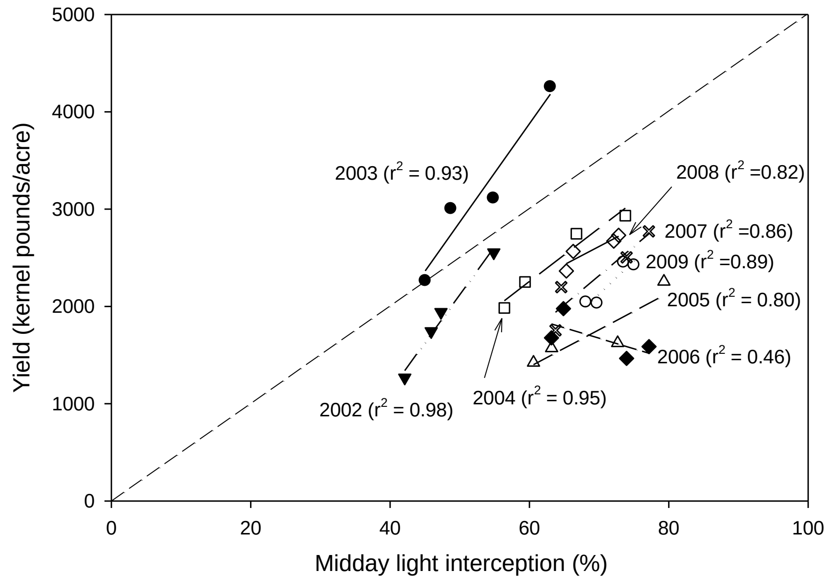

Figure 3. Leaf potassium level from 2002 to 2009 by treatment. Values above 1.4% are considered adequate and values below 1% are considered deficient.