Almond ET/Yield Production Function

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Problem and its Significance:

Water is a critical resource for Californian agriculture and much of California suffers from periodic shortages and persistent threats of reduced allocations. Water is also the primary means of delivery of nitrogen and the primary driver for nitrogen loss. One of the major challenges faced by irrigated agriculture is to optimize the use of water with respect to production (i.e., more "crop per drop"). It is well known in almonds and most other crops that production increases with increasing water availability up to a point, but for almonds a relation between water availability and crop production, the "Water Production Function" (WPF), has not been established. It has long been assumed that production will be maximized by applying water to match orchard evapotranspiration (ETc), but we do not know the shape of this relation, and the shape of the relation is an important basis for determining the optimum irrigation approach. It is imperative that the almond industry have the best available information on the relation of almond tree yield to different levels of irrigation in mature orchards.

Objective:

- Develop a water production function (WPF) for almonds grown in California that will relate potential yield to water applied, accounting for the site-specific effects of orchard cover, soils, varieties, and physiological level of stress experienced by the tree.

Background:

Previous irrigation research in almond has suggested that there is a maximum possible yield for any given level of irrigation, corresponding to about 70 kernel pounds per inch of water (solid line, Fig. 1). In any particular orchard however, an increase in applied water may not give this level of yield response if there are other factors limiting yield. For instance, in the Goldhamer 1991 study (red dots in Fig. 1), the increase in yield was only about 23 kernel pounds per inch of water. Further research by Lampinen has shown that in order to be on the 70 kernel pounds per inch of water line, it is necessary to have a correspondingly high level of orchard shaded area (PAR interception, Fig. 1, lower x-axis). Lampinen has also shown that almond orchards can be divided into classes (great to poor, Fig. 2), with the majority of high yielding orchards showing a yield of about 50 kernel pounds per percent of PAR (Fig. 2). A water production function (WPF) project was established in three commercial orchards across the state (Fig. 3), in order to determine the response of yield to applied water in the context of these findings. The target levels of applied water ranged from about 70% ET to 110%ET, but the actual level of applied was determined for each treatment as the sum of irrigation, rain, and soil moisture depletion.

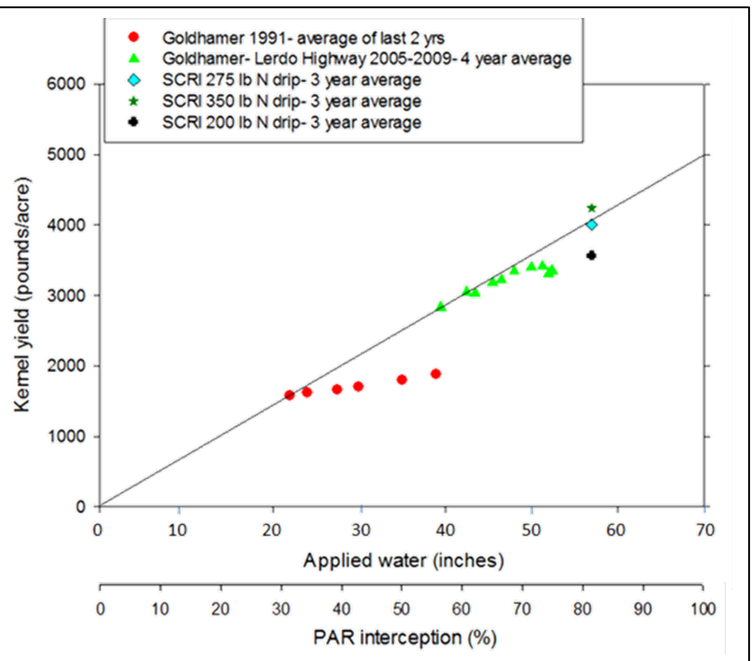

Figure 1. Summary of previous almond research results showing a linear increase in yield with increases in either applied irrigation water or canopy light interception (PAR).

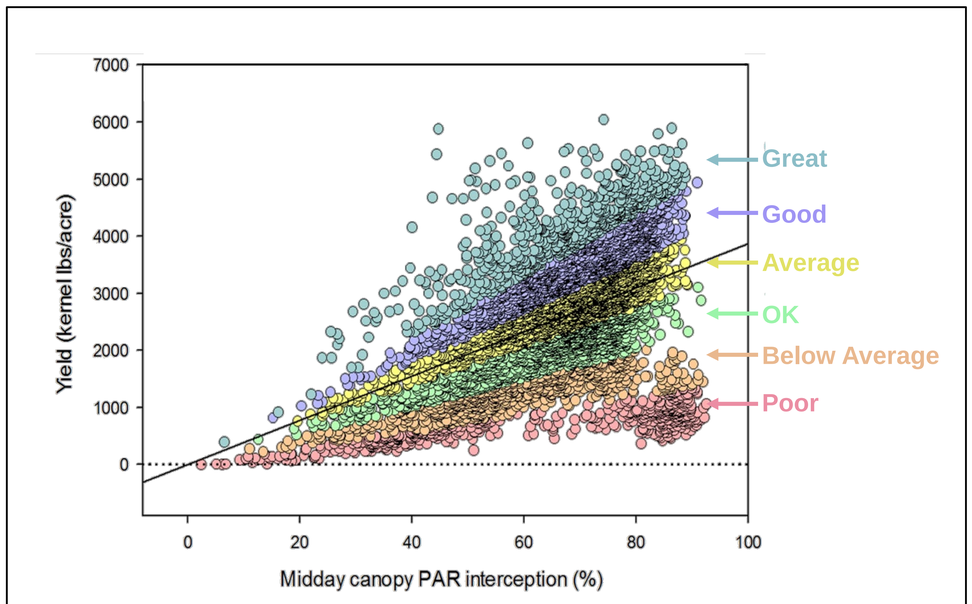

Figure 2. Summary of multi-year/multi-location yield and PAR measurements in almond orchards, showing different classes of orchard productivity, with the best orchards having the highest yields for a given level of PAR.

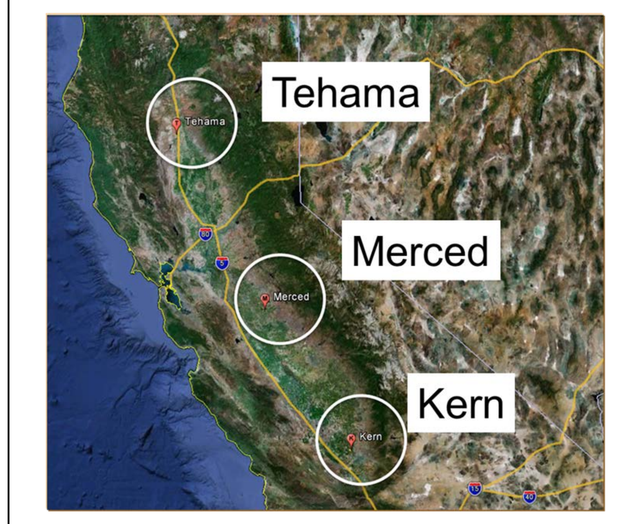

Figure 3. Map showing the location of the three commercial orchard water production function sites.

Results and Discussion:

Treatment average yields have been variable over time, but at the Kern and Merced site, higher yields have been associated with increased irrigation from 2014-2016 (Fig. 4). The Nonpareil yields in Tehama have been relatively unresponsive to water (Fig. 4), but yields of one of the pollinizers (Monterey) at this site have shown responses similar to the Nonpareil in the other sites (data not shown). This indicates that another factor (possibly the use of an interstem) is limiting the Nonpareil yield at the Tehama site. The response of yield and PAR to irrigation at each site was similar in each of the 2014-2016 years (data not shown) , and so the 3 year average values were used to compare yield and PAR responses to water across sites (Fig. 5). Yields at all sites were somewhat below the expected levels (Fig. 5A), with Merced and Kern showing a small but consistent difference in yield for the same level of water availability. However, both Merced and Kern showed a parallel yield response of about 35 kernel pounds per acre for each additional inch of water. Tehama yield showed no response to water (Fig. 5A), but both the response (slope) as well as the overall level of PAR at a given level of applied water was identical across all sites (Fig. 5B). Unlike the yield results, most of the PAR values were also above the expected level (above the dashed line in Fig. 5B), indicating that canopy development and maintenance were generally not limiting yield at these sites.

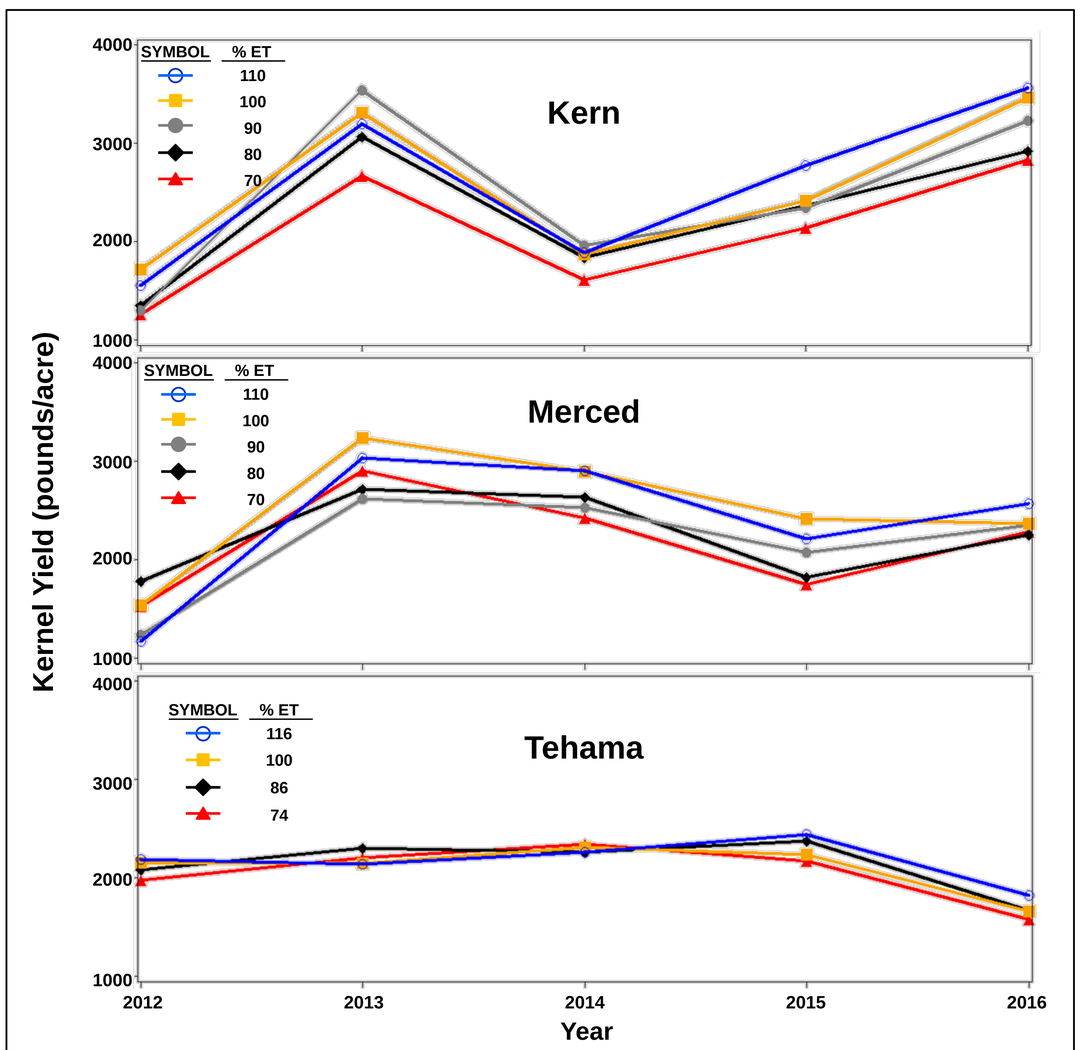

Figure 4. Average kernel yields at each site for each irrigation level prior to (2012) and following (2013-2016) the imposition of irrigation treatments (% ET).

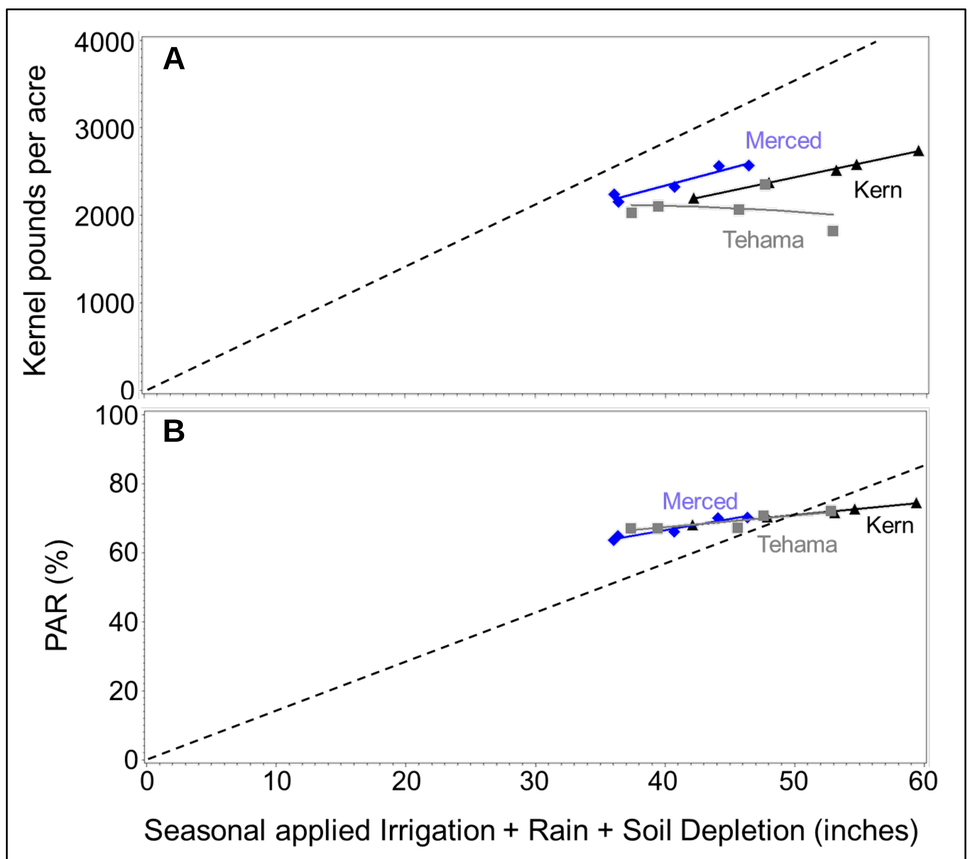

Figure 5. Comparison of the 2014-2016 average response of orchard yield (A) and PAR (B) to the sum of applied irrigation, rain, and soil water use (depletion), in each irrigation treatment (each point) of the 3 study sites. Dashed lines are the expected values based on the literature, summarized in Fig. 1 (solid line).

Conclusions:

1. At all sites, the trees have consistently responded to irrigation in terms of their physiological water stress levels starting on the first year of irrigation treatments (see previous almond reports).
2. Despite this, across a relatively wide range of seasonal water regimes (35" to 60") we have only seen modest increases in yield, on average giving about 35 kernel pounds of additional yield per acre for every additional inch of water.
3. Nonpareil yield at the Tehama site has been largely unresponsive to water, but the Monterey yield at that location has shown a similar response to Nonpareil at the other sites.
4. Together, these indicate that a factor/s other than water stress may be preventing yields from reaching their potential, and identifying these factors should lead to substantial gains in almond orchard productivity per unit of water.