Managing Irrigated Corn under Drought Conditions

General principles of water productivity under conditions of water-deficits

In the California context, corn is an irrigated, summer crop. As such, the amount of irrigation applied will largely determine how much water is available to the crop. At low to moderate yield levels, irrigation applied and crop water use [i.e. evapotranspiration (ET)] are very closely coupled. That is, an increase in irrigation will generally result in a linear increase in yield at moderate-to-low levels of productivity. However, at higher yield levels more and more water is needed to get the same amount of yield increase. In other words, you start to get “less crop per drop” of water applied as your yield gets better. This feature of diminishing returns at high levels of productivity is true for many resources in agricultural systems. So, when a resource, like water, is scare, we want to manage our system to optimize the returns to that resource rather than maximizing productivity. In other words, we have to accept a lower yield so that we can instead achieve the greatest yield for the least amount of water.

Not every crop will respond to water deficiency in the same way, and, unfortunately for growers of corn, even small deficiencies in water will reduce overall productivity. Previous research has shown that water use efficiency and harvest index as a function of deficit irrigation are optimized at around a 10% water deficit for corn (Farre and Faci, 2006). Therefore, in a water scarce situation, a grower of corn might accept that applying around 90% of their normal irrigation amount will result in the most amount of crop for the least amount of water.

How much water does a California corn crop require?

Cumulative ET from a California corn crop will range between 23 and 29 inches of water over the course of the season[1]. What explains the difference in this range? While there will always be some variation from site-to-site and year-to-year, there is a measurable difference in crop water use based on when it is planted. Figure 1 shows that crops planted later in the season, when the weather is hotter, use less total water than earlier-

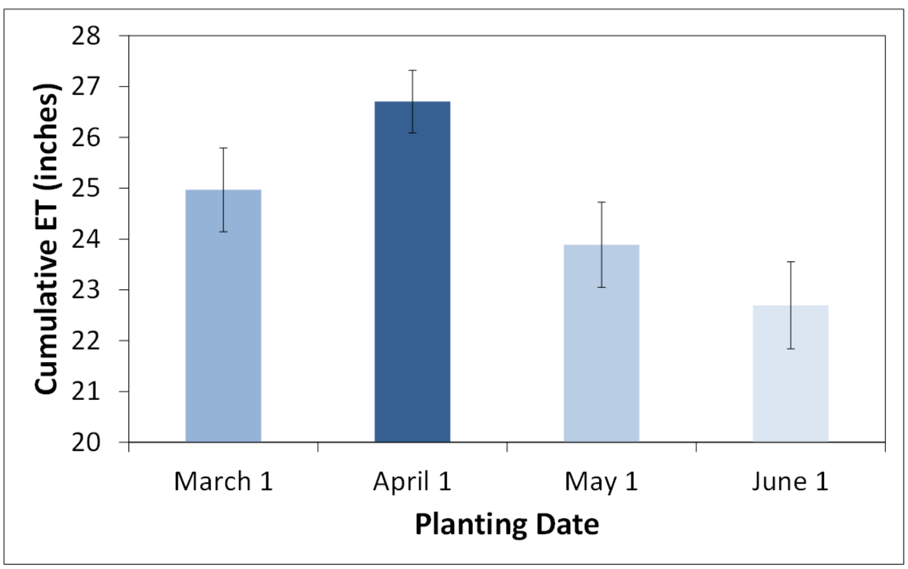

Figure 1. Planting date affects corn water use. Error bars represent the standard deviation of means across 6 (March 1) or 7 site-years. Data adapted from Schwankle and Fulton.

[1] This is not necessarily the amount of irrigation required. A crop planted into a field with a supply of soil available water will need less irrigation than a crop planted into a field with little soil available water. General principles of determining soil available water and irrigation scheduling are covered elsewhere (see Drought Tips: XXX).

planted crops. Crops planted earlier in the season tend to develop more gradually, under cooler temperatures and with access to more abundant soil water supplies (closer temporal proximity to the rainy season). This may result in less efficient use of water per unit of growth but will also generally translate to greater overall productivity. In contrast, a late-planted crop uses less water by developing more quickly during the hotter portion of the season. Yet, the quicker development leaves less time to produce yield components and generally results in lower overall productivity.

There is a similar dynamic that occurs between short or long duration varieties. That is, long duration varieties are generally higher yielding than short duration varieties. However, because they require more days in the ground, they also use more water. Recent work has demonstrated that the duration of the variety selected and the date the crop is planted interact (Tsimba et al. 2013). At early planting dates, long duration varieties yield more than short duration varieties. Whereas, at later planting dates, the reverse is true because there is less of a penalty for the quicker development associated with the short duration variety. So, <u>in a water-limited situation planting a short duration variety late in the growing season is likely to maximize the water productivity of the crop</u>.

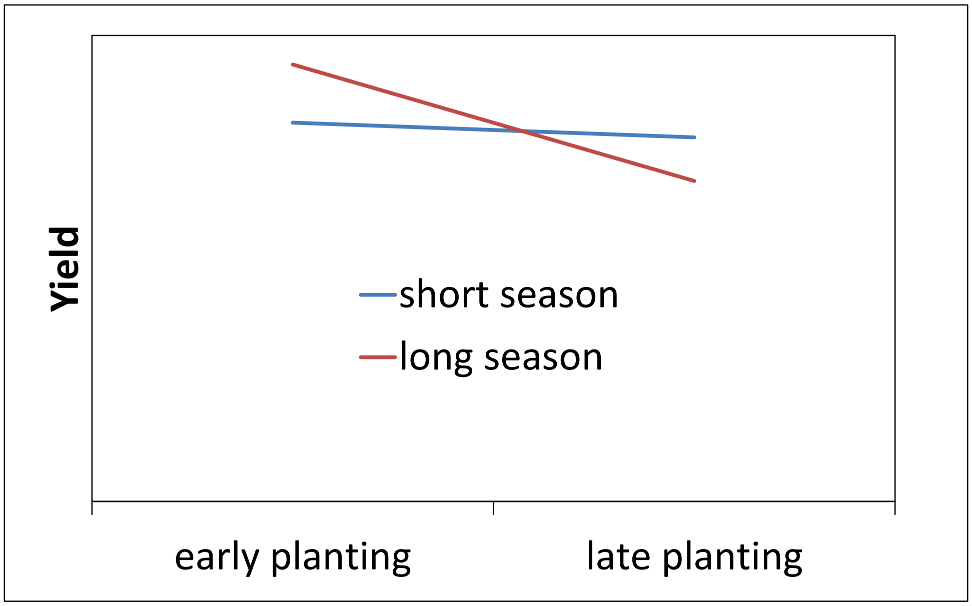

Figure 2. Interaction between planting date and duration of variety. Short season varieties planted during the hotter portion of the season (when the cumulative seasonal ET demand is less) will have proportionately less yield penalty and have the best opportunity to achieve the "most crop per drop".

In-season considerations

Emergence to V5 (Vegetative growth stage, 5-leaves):

There is not much absolute demand for water during the early vegetative growth stage. However there are a couple of factors during this period of growth that can have a lasting effect on the water productivity of a crop. The first is weed competition. Weeds can directly deduct water from the soil profile, making it unavailable to the crop itself. They can also force the crop to devote more resources to aboveground growth (since they're competing with the weeds for light). As a result, the crop has fewer resources to allocate to its developing root system, which impacts the volume of soil the crop can draw water from later in its development. Therefore, <u>early weed control can be a water saving strategy</u>. Another early-season factor to keep in mind is salinity. During a drought there will be less surface water available, resulting in greater groundwater use. Well water tends to have higher salt concentrations. Because the effects of salinity are most detrimental to the corn plant early in its development, if a grower has multiple sources of water, using the higher quality water early in the season would be advisable.

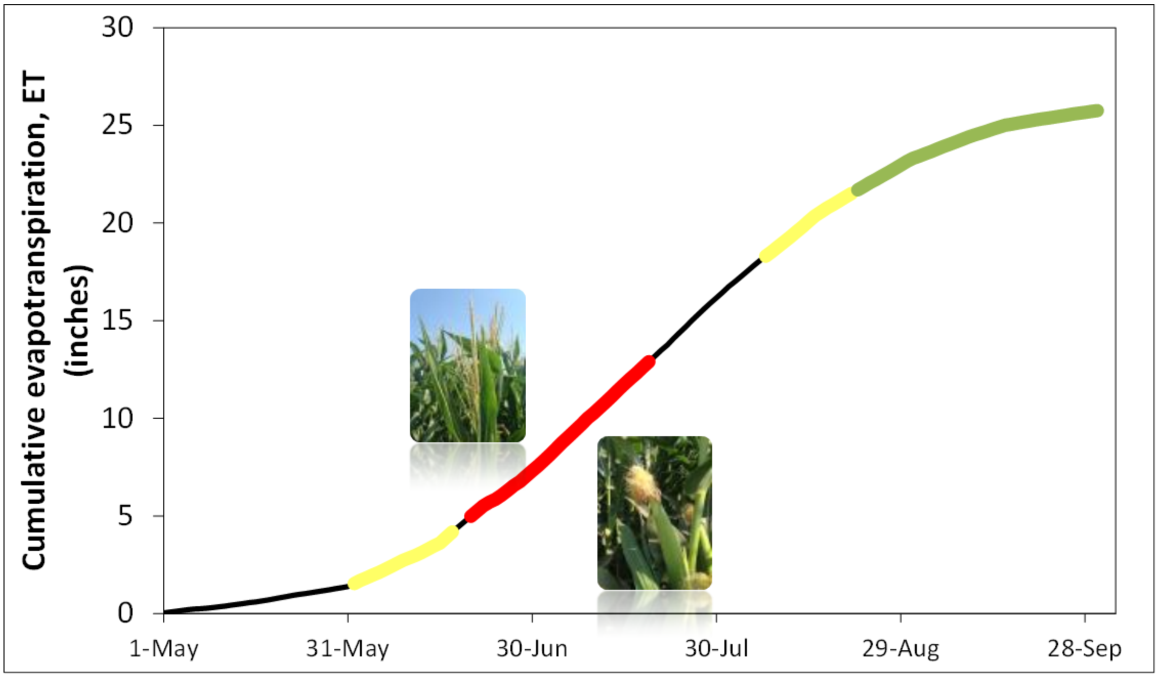

Figure 3. Depicts periods of crop development when crop is most sensitive to water stress (red) as well as periods when stress will have the least proportionate effect on yield (yellow) and when irrigation is unnecessary (green).

Late-vegetative to early-reproductive:

Tasseling marks the end of vegetative growth period and silking marks the start of reproductive growth. The two weeks prior to and following this transition are the worst times to stress corn. Relative to other periods of growth, stress during this developmental period will result in disproportionately large reductions in yield. Avoid water stress during this period!

Grain-filling to maturity

Like with all other stages of growth, water stress during the grain-filling period will reduce yields. However, at this point, the crop's root system is fully developed and it can translocate water to grain. Avoiding stress as long as possible is best. However, the tail-end of the crop's maturation might be an opportunity to save a little water with less consequence than at other stages. To take advantage of this opportunity it is important to know when the crop has reached maturity. For a silage crop, the rule of thumb is about 50% milkline; for grain, the black abscission layer indicates that the grain is mature.

In-season summary

Figure 3 summarizes these in-season management considerations for a California corn crop with average ET planted on May 1st. The underlying message is that, while there is never a good time to water-stress corn, some periods are worse than others. The worst developmental stage to water-stress the crop is during the weeks leading up to and following tassling and silking, when pollination is occurring. If you must water-stress a corn crop during its development, the mid-vegetative and late stages of grain filling are the times that will probably have the least yield consequence. Finally, irrigation after the crop reaches maturity is irrigation wasted.

Other management considerations of relevance

Irrigation system design

Because corn is a low-value crop relative to others in California, it generally supports limited capital investment. Since furrow irrigation is one of the cheapest irrigation systems to implement, it is often used to irrigate corn. However, even a highly efficient furrow irrigation system will lose between 20% and 30% of its water below the root zone due to differential soil saturation between the head and tail of a field.

What are some alternatives to furrow irrigation? Overhead (center-pivot or wheel-line) low-flow systems can pinpoint the root zone more precisely in both space and time resulting in less total water applied. In one example from the Westside Research and Extension Center in 2009, an overhead system provided 20 inches of water to a corn crop in 57 irrigation events; whereas, furrow irrigation required almost 33 inches in 11 events to achieve a similar crop (J. Mitchell, personal communication). Based on this evidence, there is the potential for substantial water savings using overhead versus furrow irrigation. Likewise, although subsurface drip irrigation (SDI) has not been widely used to grow corn in California, SDI has been widely adopted in crops that commonly rotate with corn such as tomatoes. Water savings using SDI in corn have been demonstrated in other parts of the country (Lamm and Trooien, 2003). However, as with overhead irrigation, SDI systems are much more costly to implement and operate than furrow irrigation. Nevertheless, as water becomes more limiting and expensive, we might start to see stronger economic incentives for using these alternative irrigation systems to grow corn in California.

Conservation Agriculture

As with irrigation system design, the topic of Conservation Agriculture (CA) is a broader, cropping system consideration that extends beyond the management of a specific crop. Nonetheless, some recent work by Mitchell et al. (2012) demonstrated how elements of CA can benefit water-limited crops in the California context. Specifically, in trials conducted in the San

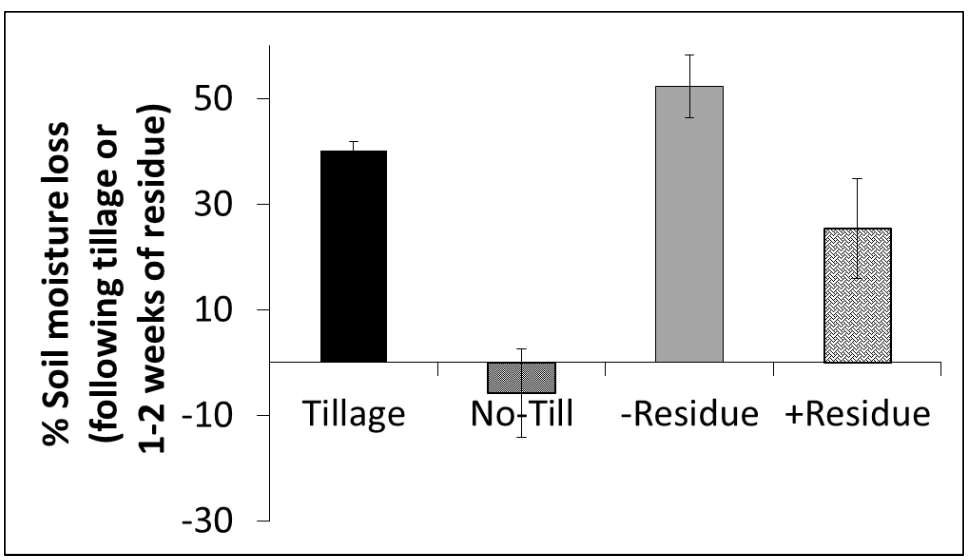

Figure 4. Effect of no-till and residue retention on early-season soil moisture loss. Error bars represent the standard deviations of means across 3 (till/no-till) and 5 (residue/no residue) site-years. Adapted from Mitchell et al. (2012).

Joaquin Valley, eliminating tillage prior to planting and retaining residues from the previous crop help to retain soil moisture (Figure 4) by cooling the soil and reducing evaporation. Extrapolated out, no-till was estimated to save around ½ to 1 inch of water and residue retention around 2-4 inches of water across the season (Mitchell et al., 2012). Given the sensitivity of corn to drought stress, these are significant savings that could greatly improve its resiliency to reduced water supplies in California.

Summary

Although water limitations will reduce the productivity of a corn crop, careful consideration of variety choice, planting date, tillage practices, residue management, in-season agronomic practices, and irrigation system design and performance will maximize the productivity of the water that is applied.

References

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