University of California
Agriculture and Natural Resources

ANR Publication 8551 | September 2015
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DROUGHT TIP

Managing Irrigated Corn during Drought

General Principles of Water Productivity under Water Deficits

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In California, corn is an irrigated summer crop. Because there is very little or no rainfall in the summer months, the amount of irrigation applied largely determines the amount of water available to the crop. At low to moderate yields, irrigation applied, crop water use (evapotranspiration, or ET), and yield are very closely coupled. That is, an increase in irrigation generally results in a linear increase in yield at low to moderate levels of productivity. However, at higher yield levels, more water is needed to get the same amount of yield increase. In other words, there is less "crop per drop" of water applied as the yield improves. This feature of diminishing returns at high levels of productivity is true for many resources in agricultural systems. When a resource such as water is scarce, it is preferable to optimize returns to that resource rather than maximizing productivity. In other words, it is better to accept a lower yield in order to achieve the greatest yield for the least amount of water.

Not every crop responds to water deficiency in the same way; unfortunately for growers of corn, even small deficiencies in water reduce overall productivity. Research has shown that water use efficiency and harvest index as a function of deficit irrigation are optimized at a water deficit of about 10% for corn (Farré and Faci 2006). Therefore, in a situation where water is scarce, a grower of corn might accept that applying about 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 evapotranspiration from a California corn crop can range from 23 to 29 inches of water. Note that this is not necessarily the amount of irrigation required (a crop planted into a field with a large supply of available soil water will need less irrigation than a crop planted into a field with little available soil water). What explains the difference between the high and low ends of 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 the crop is planted. Figure 1 shows that crops planted later in the season, when the weather is hotter, use less total water than crops planted earlier, which tend to develop more gradually under cooler temperatures and with access to more abundant soil water supplies (closer to the rainy season). This may result in less efficient use of water per unit of growth but also generally translates 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.

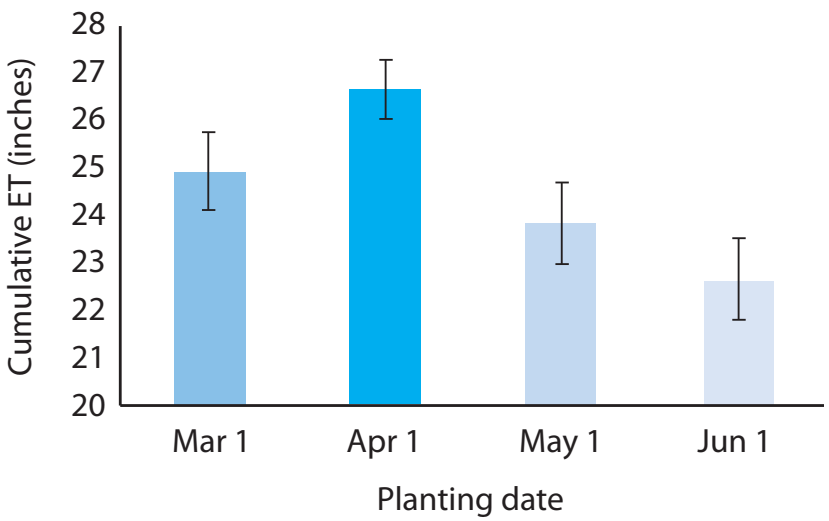

Figure 1. Planting date affects corn water use. Error bars represent the standard deviation of means across 6 (March 1) or 7 site-years. *Source:* Adapted *from Schwankl and Fulton 2015.*

A similar dynamic occurs between short- and long-duration varieties. 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 impact of planting date on yield depends on the variety selected (short versus long) (Tsimba et al. 2013). At early planting dates, long-duration varieties yield more than short-duration varieties. However, 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 (fig. 2). So, 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.

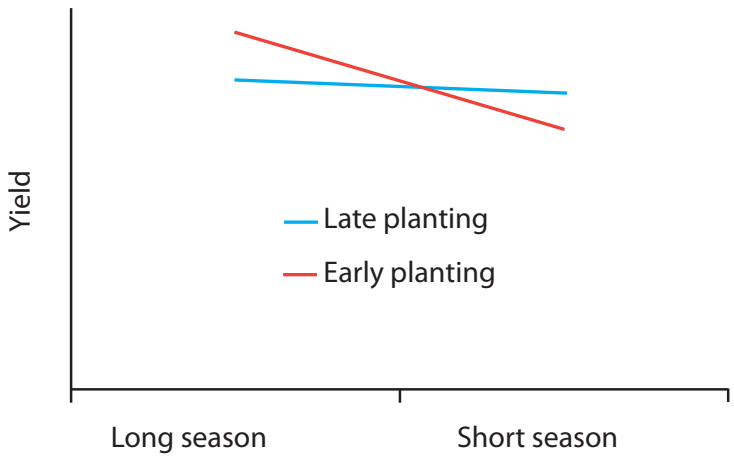

Figure 2. Effect of planting date and duration of variety on yield. Short-season varieties planted during the hotter portion of the season (when the cumulative seasonal ET demand is less) have proportionately less yield penalty and the best opportunity to achieve the most "crop per drop."

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, factors during this growth period 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. 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 reduces the volume of soil the crop can draw water from later in its development. Therefore, early weed control can be a water-saving strategy. Another early-season factor to keep in mind is salinity. During a drought there will be less surface water available for irrigation, resulting in greater groundwater use. Well water can 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 is advisable.

Late-Vegetative to Early-Reproductive

Tasseling marks the end of vegetative growth, and silking marks the start of reproductive growth. The 2 weeks prior to and following this transition are the worst times to stress corn. Relative to other periods of growth, stress during this period results in disproportionately large reductions in yield. Avoid water stress during this period.

Grain-Filling to Maturity

As with all other stages of growth, water stress during the grain-filling period reduces 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 can present 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 for maturity is when the white starch layer fills approximately 50% of the kernels (referred to as 50% milkline); for grain, the black abscission layer indicates that the grain is mature.

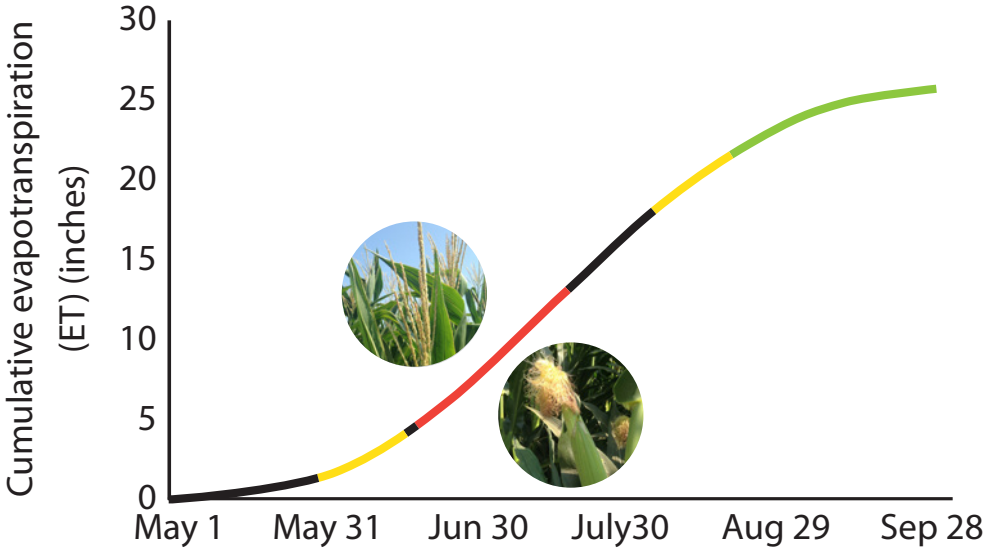

Figure 3. Crop water use as a function of the date. Periods of development when the crop is most sensitive to water stress are shown in red; periods when stress will have the least proportionate effect on yield are in yellow; and periods when irrigation is unnecessary are in green. *Photos:* M. Lundy

In-season Summary

Figure 3 summarizes these in-season management considerations for a California corn crop with average evapotranspiration planted on May 1. 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 corn is during the weeks leading up to and following tasseling and silking, when pollination is occurring. If you must water-stress a corn crop during its development, the mid-vegetative stage and the late stage of grain filling are when water stress will have the least yield consequence. Finally, irrigation after the crop reaches maturity is water wasted.

Other Management Considerations

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 from 20 to 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 irrigation. Overhead (center-pivot or wheel-line) low-flow systems can pinpoint the root zone in both space and time, resulting in less total water being 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, there is potential for substantial water savings using overhead versus furrow irrigation.
- Subsurface drip irrigation. Similarly, although subsurface drip irrigation (SDI) has not been widely used to grow corn in California, it 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 is much more costly to implement and operate than furrow irrigation. Nevertheless, as water becomes more limiting and expensive, economic incentives may become stronger for using these alternative irrigation systems to grow corn in California.

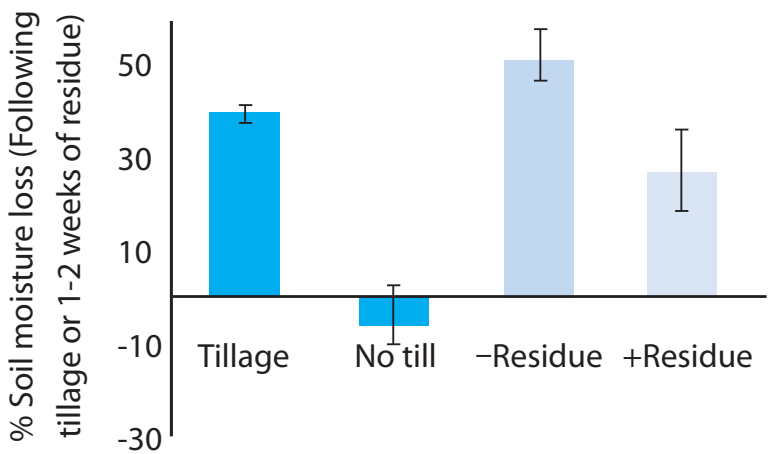

Figure 4. Effect of no-till and residue retention on early-season soil moisture loss. Error bars represent the standard deviations of means across 3 (till or no-till) and 5 (residue or no residue) site-years. *Source:* Adapted from Mitchell et al. 2012.

Conservation Agriculture

As with irrigation system design, conservation agriculture is a broader cropping system consideration that extends beyond the management of a specific crop. Nonetheless, recent work by Mitchell et al. (2012) demonstrated how elements of conservation agriculture can benefit water-limited crops in California. Specifically, in trials conducted in the San Joaquin Valley, eliminating tillage prior to planting and retaining residues from the previous crop help to retain soil moisture (fig. 4) by cooling the soil and reducing evaporation. Based on this, no-till was estimated to save 1/2 to 1 inch of water and residue retention was estimated to save 2 to 4 inches of water during the season (Mitchell et al. 2012). Given the sensitivity of corn to drought stress, these significant savings could greatly improve corn's resiliency to reduced water supplies in California.

Summary

Although water limitations 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 maximizes the productivity of the water that is applied. Key points include:

- Applying about 90% of the normal irrigation amount will yield the most amount of corn for the least amount of water.
- Planting a short-duration variety late in the growing season is likely to maximize the water productivity of the crop.
- Effective, early weed control can be a water saving strategy.
- Avoid water stress between tasseling and silking.
- Reducing irrigation at the tail end of a crop's maturation can save a little water with less consequence than at other growth stages.

References

Farré, I., and J. M. Faci. 2006. Comparative response of maize (Zea mays L.) and sorghum (Sorghum bicolor L. Moench) to deficit irrigation in a Mediterranean environment. Agricultural Water Management 83:135–143.

Lamm, F. R., and T. P. Trooien. 2003. Subsurface drip irrigation for corn production: A review of 10 years of research in Kansas. Irrigation Science 22:195–200.

Mitchell, J., P. Singh, W. Wallender, D. Munk, J. Wroble, W. Horwath, P. Hogan, R. Roy, and B. Hanson. 2012. No-tillage and high-residue practices reduce soil water evaporation. California Agriculture 66:55–61.

Schwankl, L., and A. Fulton. Corn ET estimates. 2015. University of California Drought Management website, http://ucanr.edu/sites/Drought/files/167003.pdf.

Tsimba, R., G. O. Edmeades, J. P. Millner, and P. D. Kemp. 2013. The effect of planting date on maize grain yields and yield components. Field Crops Research 150:135–144.

This publication was written and produced by the University of California Agriculture and Natural Resources under agreement with the California Department of Water Resources.

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Publication 8551

ISBN-13: 978-1-60107-949-7

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This publication has been anonymously peer reviewed for technical accuracy by University of California scientists and other qualified professionals. This review process was managed by ANR Associate Editor for Land, Air, and Water Sciences Allan Fulton.

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