IRRIGATION MANAGEMENT FOR WHEAT

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SUMMARY

In the Central Valley of California, water use for wheat is about 22 inches for a grain crop, 16 inches for a forage crop cut at soft dough, and 9 inches for a forage crop cut at boot. The amount of irrigation water required to meet this water use depends on rainfall and the efficiency of the irrigation system. The first post-emergence irrigation for wheat is usually not needed until the boot stage with normal rainfall in the Central Valley. Thereafter, irrigations in the Central Valley can be spaced about 12 to 18 days apart until soft dough, when the last irrigation is needed on most soils.

Key Words: Wheat, water use, irrigation, soil texture, root growth, water stress

CROP WATER USE

Water use by the wheat crop primarily depends on the location, planting date, variety, and weather during the growing season. In the Central Valley of California, water use for wheat is about 22 inches for a grain crop, 16 inches for a forage crop cut at soft dough, and 9 inches for a forage crop cut at boot (Fulton et al., 2006). Water use for wheat in the Central Valley is low during early development from December through February, increases rapidly during jointing in March and April, peaks during grain fill in May, and falls steeply during senescence in June as the crop turns color (Fig. 1). The steep rise in water use during jointing is due to the rapid growth of the crop covering the soil, with less water evaporating from bare soil than what is transpired by a vigorously growing crop. The decrease in water use during senescence occurs as a result of the disappearance of green leaves as a conduit for water loss. Otherwise, water use increases steadily as the season progresses due to increased solar radiation and temperature. Daily water use can be much greater than the long-term average would indicate, especially on windy days, and irrigation is needed sooner.

Total water use and the water-use pattern for wheat in other regions of California are actually very similar to those cited for the Central Valley. The primary difference is the growing season, or difference in planting and harvesting times, which shifts the dates when the water is used. For example, wheat grown for grain in the Intermountain region is typically planted in late March through April and harvested in August to early September whereas, wheat in the Imperial Valley is typically planted in December and January and harvested in late May and early June.

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IRRIGATION REQUIREMENT

The irrigation requirement is different from water use since water is "gained" from rainfall or "lost" from inefficiencies in irrigation water application. Irrigation efficiency, or water used divided by water applied, varies from 70-90% depending on the irrigation system (Hansen et al., 2004). So, the irrigation requirement can be greater than water use depending on the contribution of rainfall. In the absence of rainfall, wheat grown on a loam soil in the Central Valley would require six irrigations (Table 1). However, due to the contribution of rainfall, the number of border flood irrigations typically required is 1-3 for the Sacramento Valley, 3-6 for the San Joaquin Valley, and 5-7 for the Imperial Valley (Fulton et al., 2006). In the Intermountain Region, the number or irrigations varies tremendously depending on soil type, irrigation method and precipitation pattern. Even with sprinkler irrigation, the number of irrigations can range from 3 to 4 for wheel-line irrigated fields to over 15 passes with a center pivot irrigation system. Keep in mind that not all rainfall on wheat is effective since some can be lost due to evaporation, runoff, and deep percolation.

IRRIGATION SYSTEMS

Wheat can be produced successfully with a variety of irrigation systems. Drip and sprinkler irrigation systems can apply smaller amounts of water than surface flood systems, and therefore, less applied water moves past the root zone. Frequent irrigation with sprinkler systems can result in rapid disease development. Surface flood systems are more efficient at leaching salts, which is important if salts are a problem. Flood irrigation is most common in the Central Valley and Low Desert regions of California, whereas, sprinklers are more common in the Intermountain Region. Wheat can be grown equally well on beds or flat ground. Beds have an advantage if infiltration or drainage is a problem, the field has substantial side-fall, or a sufficient head of water cannot be delivered. However, growing wheat plants in furrows in a bed system slows the advance of surface irrigation water, increases water infiltration, and can result in less efficient irrigation.

IRRIGATION SCHEDULING METHODS

Irrigations can be scheduled using predetermined calendar dates or days between irrigations, methods that directly measure soil moisture or crop stress, or the soil water balance (checkbook) method using evapotranspiration data. Predetermined calendar dates or days between irrigations can be useful for scheduling irrigations under average conditions, but requires adjustment for weather conditions that vary from normal. Soil moisture and crop water stress can be measured in a variety of ways (Hanson et al., 2004) and calibrated at certain critical levels to trigger irrigation. However, these techniques are more often used in higher value crops than wheat. The soil water balance method can estimate soil moisture and impending crop stress without the investment in sensors and collection of the data they provide, but some accuracy may be lost compared to direct measurements.

IRRIGATION TIMING

Soil texture. The amount of water available from the soil is a function of the soil texture. Coarse textured soils such as sands hold less plant available water than finer textured soils such as clays (Table 2). Soil textures are broad categories, and the amount of water a particular soil will hold can vary by a few tenths of an inch per foot from the average of the category. Also, soil texture can change with depth, so the soil texture of the surface soil does not always accurately reflect the texture of the entire soil profile.

Rooting depth. Plant available water is also a function of effective rooting depth, sometimes defined as the depth where 80 to 90% of water extraction occurs. Wheat roots can be found at a depth of 8 ft, but the maximum effective rooting depth is much less than that. Rooting depth increases steadily until about the watery kernel stage when a depth of about 4 ft is reached on deep-well drained soils (Table 3). On soils with restrictive layers or in other situations, the effective rooting depth may be in the range of 2.5 to 3.5 ft. With sprinkler irrigation, due to frequency of water application, the effective rooting depth for irrigation scheduling purposes may be considered to be 2 ft.

Germination irrigation. Wheat may be planted into pre-irrigated soil or into dry soil and the seed germinated with an irrigation or impending rainfall. Pre-irrigation has the advantage of germinating weed seeds and allowing a dry soil mulch to be made at planting that provides a favorable environment for wheat seed germination and emergence. The disadvantage of pre-irrigation is increased turnaround time between crops, the window when the soil is in condition for planting is narrow, and rainfall can delay planting. Irrigating up has the advantage of convenience but the disadvantage of the possibility of forming a soil crust (with flood irrigation) and cooling the soil which leads to delayed emergence. Relying on rainfall can be a risky practice if precipitation is not received during the optimum time for crop establishment, but otherwise can save irrigation water for later in the season.

First post-emergence irrigation. The first post-emergence irrigation for wheat is usually not needed until boot with normal rainfall in the Central Valley (Fulton et al. 2006). Applying the first irrigation earlier may temporarily increase crop growth but not increase grain yield. The first irrigation may be applied early to help in the germination of the seed if the soil crusts or to prevent seedling desiccation in cracking soils. Applying the first irrigation too early can result in loss of soil nitrogen by leaching or denitrification (loss as a gas). Waterlogged conditions also hinder nitrogen uptake from the soil since plant roots need oxygen to take up nitrogen. The plant symptoms of waterlogged soil conditions are yellowing and lack of growth of the plants. Plant wilting is a sign the first irrigation should have been applied sometime earlier. Delaying the first irrigation as long as possible with the intention of promoting root development and improving the ability of the crop to extract deep moisture in the future, is a dubious practice (Ottman et al., 1997).

Last irrigation. The last irrigation should be applied at the beginning of soft dough for most loamy soils, earlier for heavier soils and later for lighter soils. The soft dough stage begins about 3-4 weeks after heading and 2 weeks before physiological maturity, at which point the yield has been made. Water use between soft dough and physiological maturity is about 4 inches. An additional 2 inches of water will be used in the dry down process between physiological maturity and harvest, and water use during this period has no effect on grain yield. Applying an unnecessary irrigation at the end of the season wastes water, contributes to lodging, and may delay harvest. Conversely, water stress at the end of the season may result in smaller and shriveled kernels, accompanied by reduced kernel weight, test weight, and yield. Depending on available soil moisture and the water holding capacity of the soil, the last irrigation is needed 1-3 weeks before the heads have completely turned color from green to tan, since the crop is physiologically mature at this point and the kernels cease to accumulate dry weight. It usually is not economical to apply a final irrigation to benefit a few green tillers in a mature crop As seen in the northern Central Valley during 2012, low winter rainfall does not provide the typical deeper soil moisture for use in the spring, so the last irrigation will be later than most years unless previous irrigation recharged soil moisture in the rooting zone.

WATER STRESS

Critical soil moisture depletion. Wheat should generally be irrigated when 50% of the available water is depleted. However, in the low elevation deserts or other areas where daily water use may exceed 0.3 inches per day, the crop may benefit from irrigating more frequently or when less than 50% of the plant available water is depleted. In a study conducted at Maricopa, AZ, irrigating at 35 rather than 50% depletion increased grain yield by 14% (Ottman and Husman, 2003). The cost of producing this additional grain yield includes one or two additional surface flood irrigations, an additional 34 lbs N/acre, and increased harvesting and hauling costs. Whether irrigating at 35% instead of 50% depletion is economical is very site specific and largely depends on soil type, irrigation method and grain prices. This practice is most likely to be economical with drip or sprinkler irrigation, since irrigating more frequently does not require as much additional labor and water compared to flood irrigation.

Critical growth stages. Water stress at any stage can reduce wheat yield. Yield is reduced by water stress during tillering by reduced head number, primarily. Water stress during jointing reduces kernels per head. Water stress during pollination can cause sterility and reduce kernel number. Water stress during grain fill can reduce kernel weight and result in unacceptable grain test weights. There is some evidence that wheat is most susceptible to water stress (or lack of irrigation) during jointing, least susceptible during grain fill, and intermediate in susceptibility during tillering (Day and Intalap, 1970). A key to achieving maximum grain yields is to avoid water stress to the greatest extent possible.

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Table 1. Date water is required from irrigation or rainfall for wheat in the Central Valley using the example of a December 15 sowing date on a **loam soil**. The dates are calculated based on 50% depletion of the plant available water in the root zone and a final rooting depth of 4 ft (see Table 3). The amount water required from irrigation or rainfall to replenish the soil water supply is greater than the crop water use due to inefficiencies in irrigation water application or losses of rainfall in evaporation, runoff, or deep percolation.

Stage	Irrigation or rainfall date	Crop water use between successive dates
		inches
Planting	Dec 15	0
Tillering	Feb 28	1.75
Jointing	Mar 26	2.75
Boot	Apr 15	3.50
Kernel watery	May 01	4.00
Soft dough	May 16	4.00

Table 2. Average available water holding capacity for various soil textures. Actual values for a particular soil texture can vary depending on soil type. (Adapted from Fulton et al., 2006).

Soil texture	Available water holding capacity
	inches/foot
Sand	0.7
Sandy loam	1.4
Loam	2.0
Clay	2.3

Table 3. Rooting depth of wheat at various growth stages. (From Ottman, 2004)

Rooting Depth	Growth stage
0.5	Emergence
1.0	2 leaf
1.5	4 leaf
2.0	6 leaf
2.5	2 node
3.0	Flag leaf collar visible
3.5	Heading
4.0	Kernel watery

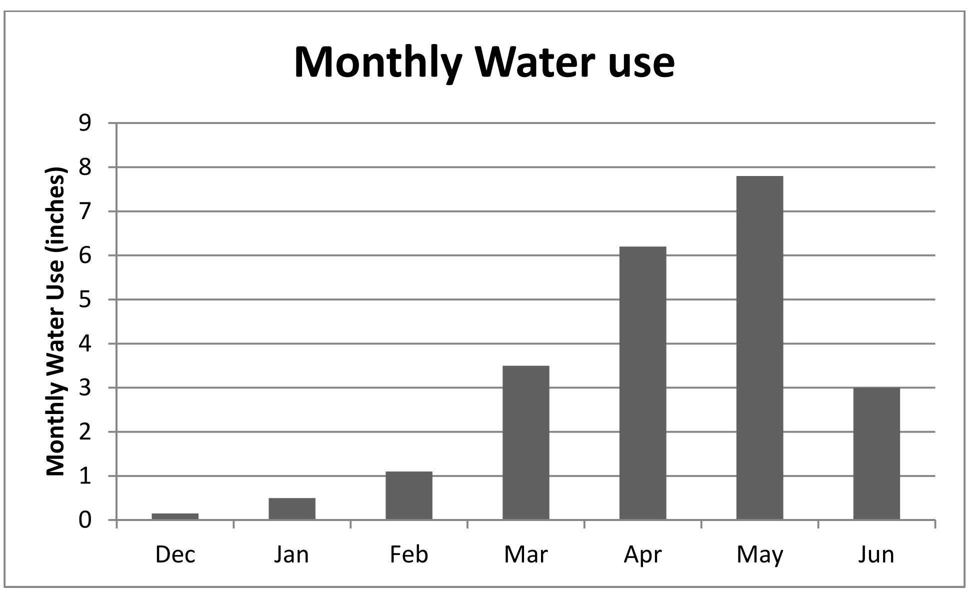

Fig. 1. Average monthly water use of wheat planted on December 15 in the San Joaquin and Sacramento Valleys (adapted from Fulton et al., 2006).