UNIVERSITY OF CALIFORNIA COOPERATIVE EXTENSION

COTTON MANAGEMENT GUIDELINES

Scheduling Final Irrigations

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With a combination of good early planting conditions and above normal heat accumulations during vegetative growth and early square growth stages, most fields progressed toward an earlier-than-normal cutout date in 2004. In some parts of the state, higher temperatures and windy conditions resulted in stand losses but few cases were severe enough to warrant replanting. In other years, there is usually a broader range of planting dates and a broad range of plant conditions in terms of boll retention patterns and dates expected for mature plants, cutout and open bolls. Final irrigation decisions, even under the best of conditions, are often better accomplished using a number of evaluations rather than just considering it a calendar date decision. A number of steps or considerations can help in making good decisions.

Setting a Harvest Date. Setting a desired harvest date is the primary step in determining final irrigation date. The field manager has to identify what flowering date corresponds with the last flower likely to be taken to maturity. In fields that progress toward cutout at early dates, proper timing of final irrigations can produce savings in applied water under some conditions without negative impacts on yield (particularly in lighter-textured soils with many in-season irrigations or where alternate furrow irrigation could be practiced in late season). Good decisions can also reduce problems with regrowth which can occur with excess soil water available after most boll maturation is complete.

With Good Retention: Use of NAWF Information. Plant mapping information on nodes above white flower (NAWF) can be used in making decisions on irrigation management. The data base for interpreting NAWF has been described in articles in the *California Cotton Review* newsletter (Volume 37) and is also thoroughly described in the UC publication *Cotton Production Manual.* The basic principles will be described here. Once plants are in bloom, the number of main stem nodes above the first position white flower is a better relative indicator of approaching vegetative cutout than other indicators such as height to node ratio. NAWF indicates the amount of terminal growth occurring from the time a square first appears in the terminal to when that flower blooms. To determine NAWF on a given plant, find the first position (location closest to the main stem node) white flower on a fruiting branch and count the number of main stem nodes above that bloom (node with the white bloom is counted as zero (0)). Include that node nearest the terminal with a main stem leaf at least one inch diameter.

Acala varieties not subjected to serious stress before early bloom will typically have eight to nine (sometimes even ten) main stem nodes above white flower at early bloom, and NAWF may typically decline to six or seven by three weeks after first bloom under conditions of well balanced vegetative and reproductive growth. NAWF generally will decrease to four or five by as early as late July to mid-August (depending upon planting date and growing season conditions). When an Acala crop reaches NAWF near four, this indicates that the crop has reached vegetative cutout and has set more than 90 percent of what is likely to be the final yield. Vegetative cutout is defined as the time when carbohydrate demand from developing bolls matches carbohydrate supply for boll growth plus plant maintenance, resulting in the near cessation of vegetative growth (main stem and lateral branch growth). In Acala varieties with very late cutout (white flowers after August 20), seldom are there enough degree-days to mature harvestable bolls from these late flowers.

In some fields and cotton varieties, cutout will come even earlier. Plants undergoing water stress or other stresses per-bloom or early-bloom have reduced vigor, reduced production of fruiting sites, and cutout early with a lower-than-expected boll load. In Acala varieties, NAWF of seven at early bloom and five by mid-bloom (mid-July in many years) indicates reduced vigor and less potential for a long boll production period. Water stress, nitrogen limits or unnecessary high rates of mepiquat chloride plant growth regulator may be involved in these responses. It is important to note that Pima varieties approach cutout at a slower rate than Acala varieties, and reach it at a lower NAYF (nodes above yellow flower for Pima), at about 3 to 3.5 NAYF.

Late Crops / Poor Early Retention. In fields with low early retention that depend on late-set bolls, it still is necessary to decide just how late a boll you are going to try to mature and open. Past experience suggests that extending irrigations, delaying defoliation and waiting to mature out most or all late bolls is a very risky operation that may strongly impact lint quality and increase chances of defoliation and weather-related problems during harvest. A long-standing recommendation in the San Joaquin Valley is that flowers through about August 20 have a good chance of producing mature bolls unless they are shed due to a large existing boll load. Flowers in late-season typically will require about 825 to as much as 900 heat units to reach full boll maturity (see separate web-site information in section titled "*Heat Units to Mature Late-Season Bolls*"). Under average weather conditions in late-August through October for Kern County, this would equal about 66 to 72 days (see Table 1 for estimates of maturity dates based on flowering dates, average heat units, and average time to mature bolls). If your production conditions require you to go for these late-season bolls, there are several approaches you can use to decide on timing of your last one or two irrigations.

Table 1. Percent of total yield produced by fruiting branches (FB) and average bloom, open boll dates in Acala cotton. Average of 100 fields (1981 to 1991, Kerby et al, 1992 as shown in UC/DANR publication No. 3352).

Fruiting Branch #	**Percent of Total Yield**		**Approximate Date for**	
	This Fruiting Branch	**Cumulative Total**	**Bloom**	**Open Boll**
1	7.4	7.4	July 1	August 26
2	10.3	17.7	July 4	August 29
3	11.5	29.2	July 7	Sept 1
4	11.4	40.6	July 10	Sept 4
5	10.8	51.4	July 13	Sept 7
6	9.8	61.2	July 16	Sept 11
7	8.9	70.1	July 19	Sept 15
8	8.0	78.1	July 23	Sept 19
9	6.6	84.7	July 26	Sept 24
10	5.5	90.2	July 29	Sept 29
11	4.1	94.2	August 2	Oct 4
12	2.4	96.6	August 6	Oct 9
13	1.6	98.2	August 10	Oct 15
14	0.8	99.0	August 14	Oct 22
15	0.5	99.5	August 19	Oct 29
16	0.3	99.8	August 24	Nov 6

Calculating Late-Season Water Needs. Work done during development of the California Cotton Manager program for the palmtop computers was developed to assist in estimating cutout and in determining an appropriate time for the final irrigation of the season. The basis for the calculations was to use an estimate of rooting depth (or wetted depth from late season irrigations) in combination with soil texture-based information on soil water holding capacity. These two estimates were used to estimate an amount of plant available water at a specific time period, such as at cutout. Plant monitoring data is used to estimate cutout and the timing of the last cracked (open) boll. This basic approach used in the palmtop program and its components will be described here and presented in table form where possible.

Using the last flower to mature and the average number of days (or heat units can also be used) required to mature a late-season bloom, the water requirements of the crop for the remainder of the growing season can be estimated. If heat unit accumulations are available, the open boll date for that last flower can be estimated using accumulated heat units and temperature forecasts. Calculate using the assumption that somewhere between 825 and 900 heat units are required to take an Acala or Upland varieties from late bloom to cracked open boll. If calendar days are used for estimating open boll dates for these late flowers, you must consider the effects of changing late summer / early fall weather conditions on heat unit accumulations. For example, under average weather conditions in the southern SJV, an August 2nd flower will take an average of 62 days until open boll, whereas an August 24 flower will take an average of 72 days until open boll. If the last harvestable boll was set on August 13, as reasonable estimate might be 67 days from flower until open boll.

In determining how long sufficient water is needed to mature out the last-set boll, Table 1 can also be used to estimate average boll maturation dates based upon flowering dates. The amount of water needed to carry a plant through that period, on the average, assuming average weather conditions for the SJV can be estimated using average daily crop evapotranspiration (ET) or crop water use values for that period. This information came from a collection of irrigation and total ET studies done in the SJV over a number of years (shown in Table 2). Table 1 also illustrates that if the crop has a good boll set on the first 10 to 12 fruiting branches, little additional yield would be gained by trying to mature out those upper fruiting positions. It also might be desirable to avoid prolonging the season and delaying final irrigation under many conditions (such as when irrigation water is in short supply or costly, or when late season insect pests are costly to control). As an example, Table 1 can be used to determine that an August 10th flower could mature to an open boll on about October 15. During that period, average water use (from Table 2) would be about 10.5 inches, determined as follows:

- August 10 to 31 = 21 days @ 0.29 inches / day = 6.1 inches
- September 1 to 30 = 30 days @ 0.13 inches / day = 3.9 inches
- October 1 to 15 = 15 days @ 0.03 inches / day = 0.45 inches

Table 2. Daily average water use (cotton plant evapotranspiration) for adequately watered Acala cotton during average year in the San Joaquin Valley of California (UC / DANR publication No. 3352).

Month	**Daily Water Use (inches / day)**
April	0.01
May	0.02
June	0.14
July	0.30
August	0.29
September	0.13
October	0.03

Once the amount of water necessary to mature out the crop is estimated, information on plant available water at a specific time such as cutout can be made using estimates of soil water holding capacity based on soil texture (values shown in Table 3) in combination with rooting depth, or depth wetted by the most recent irrigation if the full depth to which the plants root no longer represents depth of plant available water. In fields where deficit irrigation has occurred or where infiltration problems prevent deep water penetration during part of the growing season, a hand auger or other soil coring device can be used to verify the wetted depth and that roots are present to access deeper stored soil water. Correct determination or estimation of effective rooting depth (either by visual determination of the existence of roots or by assuming that rooting depth is equal to soil depth wetted by the most recent irrigation) is absolutely vital to making a good estimate for final irrigation timing.

The effective available soil water holding capacity usable by cotton plants can be estimated as the depth of soil that roots can access multiplied by the available water holding capacity per foot of soil. For example, if the effective rooting depth is four feet, with an available water holding capacity of 1.5 inches per foot (sandy loam soil in Table 3), the effective rooting depth can hold 6 inches of plant-available water. If we use the August 10th cutout date of the above example, more than one irrigation will be required to supply the full 10.5 inches of water needed after cutout. Similar calculations can be made for other cutout dates and soil / rooting depth combinations.

Table 3. Available soil water content averages for different major soil textural classes (from UC Public. No. 3352).

Soil Texture Description	**Available Soil Water Content (inches per foot of soil)**	
	Average	**Typical Range**
Coarse (fine sand, loamy sand)	1.0	0.7 to 1.2
Medium-coarse (sandy loam)	1.5	1.2 to 1.8
Medium (loam, silt loam, fine sandy loam)	2.0	1.6 to 2.4
Moderately fine (clay loam, silty clay loam, sandy clay loam)	2.2	1.8 to 2.5
Fine (silty clay, clay)	2.3	1.6 to 2.6

In addition, with surface irrigation methods, there is often limited control of the amount of water that can be applied each time, the amount being more a property of soil infiltration characteristics, field run lengths, and water delivery rates. In fine-textured, cracking soils with long irrigation runs, it may be difficult to apply less than 4 inches per irrigation without resorting to alternate furrow irrigation or other approaches. In soils with late-season infiltration problems, more than 2 inches of water per irrigation may be difficult to achieve and several irrigations may be required after vegetative cutout.

If more than one irrigation is required after cutout , depletion of available soil water prior to that first irrigation after cutout should probably not exceed 60 to 70 percent of the effective available water holding capacity within what you calculated as the "root zone" or effective wetted depth. If soil water depletion exceeds this range by much, water stress levels experienced by the plants may be too severe for proper development of fiber in late-set bolls. Confirm that depletions are not excessive by using leaf water potential measurements, if possible. For example, if a soil has an available water holding capacity of 1.8 inches per foot and an effective rooting depth of 3 feet, then the total available water would be approximately 5.4 inches (3 times 1.8 inches). If a desired limit of available water depletion is 60 percent, then 3.2 inches (0.60 times 5.4 inches) of water could be used between irrigations. Following the last irrigation of the growing season, the goal is to have plants only moderately water-stressed at the time of first harvest aid application, after which time plants can be allowed to gradually use up most available water holding capacity as they approach harvest.

Putting all these concepts together, after cutout dates, last bloom to carry to open boll, and plant available water estimates are made, Table 4 can be used to project an acceptable final irrigation date that will help save water while avoiding stress severe enough to damage yield or fiber quality. Again, these estimates are based on averages for amount of time required to mature late-season bolls and average heat unit accumulations expected during late summer and early fall. For a more in-depth discussion of heat units required to mature out late season bolls, please see "*Heat Units Required to Mature Late Season Bolls*" elsewhere on this website. As shown in that article, the time and heat units required to mature Pima bolls or thinner-walled Upland varieties differs somewhat from Acala, and estimates should be adjusted slightly based on those differences. It does matter that you put a good effort into the estimate of effective rooting depth in order to make a good estimate. ***The best use of tables shown in this article, including Table 4 … is to give you estimates of how sensitive the estimates of Final Irrigation Dates are to small changes in your assumed values for cutout date or available soil water. This can at least help in narrowing down final irrigation dates to consider.***

Table 4. Projected acceptable dates for final irrigation for Acala cotton, using estimates of plant available water (based on soil water content and wetted depth or rooting depth), average heat units required to mature out late-season blooms to open bolls (assume 850 degree-days base 60F), and average daily heat units and evapotranspiration (based on long-term averages for the Shafter Research Station, Kern County, CA). *Calculated using CA Cotton Manager Final Irrigation Module – University of CA.*

	Projected Final Irrigation Date as a function of plant available water and date of vegetative cutout					
Plant Available Water (inches)	**Date of Cutout**					
	7/16	**7/23**	**7/30**	**8/07**	**8/14**	**8/21**
2.5	8/17	8/24	8/28	9/06	9/13	9/19
3.5	8/14	8/21	8/24	8/30	9/06	9/10
4.5	8/11	8/17	8/21	8/26	8/30	9/02
5.5	8/08	8/14	8/18	8/22	8/27	8/28
6.5	8/05	8/11	8/15	8/19	8/24	8/26
7.5	8/01	8/07	8/11	8/15	8/20	8/22
8.5	7/28	8/04	8/08	8/12	8/16	8/18
9.5	7/25	8/01	8/05	8/09	8/13	8/15