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In This Issue

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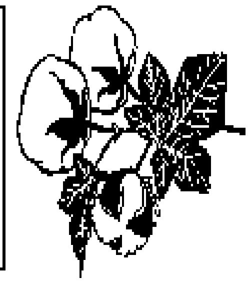

LATE SEASON IRRIGATION MANAGEMENT FOR COTTON

Dan Munk, Bob Hutmacher, Bruce Roberts, Steve Wright, Jon Wroble

Determining the best date to terminate irrigation on a cotton crop is not a simple matter since several factors must be considered simultaneously to help with this decision. This is sometimes further complicated by unpredictable late season weather patterns. This climatic uncertainty means irrigation termination will always be somewhat imprecise, but good estimates of final irrigation timing remain important decisions in achieving timely and effective crop termination.

There are several indicators in each field that can be useful and bring about more consistent results, thereby minimizing risks of income loss due to improper late season water application. Developing a systematic approach to irrigation termination in cotton requires some time and expense to evaluate; but, when done properly, can result in input cost savings, improved yield and consistent high-quality cotton. In most production settings, the combination of benefits achieved by following these procedures will far outweigh the additional input costs for the evaluation.

Considerable information has been collected over the past decade that confirms the value of using a water budget approach (Munk and Munier, 1992; Hake et al., 1996; Hutmacher and Munk, 1997). This article will discuss current and past approaches used, describe the well tested water budget approach, and provide farm site data that demonstrates the ability of this approach to minimize risks to the farmer. Some varietal characteristic's impact on termination will be discussed as well as the problems encountered from a yield and quality perspective when imprecise crop termination occurs.

Past Decision Making Principles

Growers of cotton in the San Joaquin Valley have long recognized the existence of significant variations both within the field and from field to field in factors influencing the timing and uniformity of crop maturation. Intuitively, the timing of management practices to move toward termination have been based on past experience and a basic understanding of late season crop senescence. Many have adopted calendar date methods that often also integrate soil moisture storage principles.

During the late 1960's and early 1970's, ground breaking work was being conducted in the SJV that would demonstrate the value of recognizing individual field characteristics in irrigation termination decisions (Grimes and Dickens, 1974). In this approach, optimal irrigation termination dates were determined based upon soil type and soil water storage estimates. This work correctly pointed out that the amount of soil water available to the plant following the final irrigation varied from location to location and was closely related to soil texture and rooting depth. It was observed that in a high water holding capacity soil (ie. Panoche clay loam, Fig. 1), the best yield and quality would be achieved with irrigation termination in the first week of August. In a lighter, sandy loam soil, best results were with late August irrigation termination. These general principles were incorporated into SJV farming systems practices and continue to be exercised on many San Joaquin Valley farms today.

One of the difficulties in using soil based approaches to schedule final irrigation events is the fact that each

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season and each field differs in its maturity and therefore, the time it takes to set the late season crop. While some crops have early fruit set and early cutout based on management, site and genetic potential, still others may have poor early fruit set, followed by rapid vegetative growth and a large late set crop. Slimming and sometimes absent profit margins will require the manager to identify early cutout fields and develop an early irrigation termination approach. Alternatively there is an increasing need to identify late maturing fields that may require additional late-season water resources while also setting the plant up for effective defoliation and harvest.

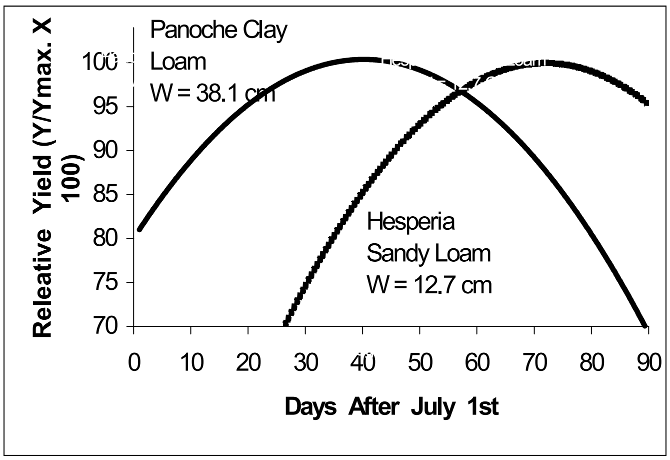


Figure 1. Relative cotton lint yield (yield divided by maximum yield for each specific soil in experiment, expressed as a percent) as a function of date of final irrigation in two SJV soils (from Grimes and Dickens, 1974).

Newer Approaches in Water Management

During the late 1980's and throughout the 1990's, considerable progress was being made in California on the development and incorporation of plant monitoring information for individual cotton fields, Kerby and Hake (1996). Recognizing the wide range of cotton maturity dates has led us to terminate fields based on our knowledge of individual field and season crop development. The Nodes Above White Flower (NAWF) approach came into common usage to identify the last harvestable boll, while Nodes Above Cracked Boll (NACB) became useful in determining late season crop maturity and in timing defoliation.

During the 1990's, changes in the types of cotton grown and in the production systems resulted in a wider range in timing of field maturity. The maturity classes of Acala and Upland cotton saw expansion, increases in indeterminate Pima cotton acreage were seen, and more varied irrigation systems and management were employed that influenced cotton termination decisions. In today's production systems, it is evident that there are benefits in evaluating better approaches to the estimate of optimal irrigation termination dates.

Water Budget Approach

a) Establish crop maturity date

Late season crop monitoring in fields is of great value in establishing proper crop termination procedures. The first step is to identify the last bloom that you plan to take to harvest. The observance of crop cutout finds utility for this purpose and is defined as approximately 5 NAWF for Acala/Upland cotton types and 3.5 NAYF for Pima cotton types (Kerby and Hake, 1996). The established goal for late season irrigation management is for the last harvestable boll to be provided adequate plant resources to reach full physiological maturity, thereby lowering the risk of decreased yield and/or quality.

Once the cutout date is established for a field, determine a maturity date for this last set boll. A general rule for late season bolls is that approximately 850 (Upland) to 950 (Pima) heat units are needed to take the crop from last set flower to open boll. Further subtracting 100 heat units from this value, we approximate the maturity date since about 100 of the last heat units are used to desiccate the carpel wall prior to boll crack. Table 1 can be used to estimate either boll maturity date or cracked boll for most central and southern SJV locations.

Table 1. Long-term averages and ranges of daily heat units (DD60F) from Shafter REC weather station between 1974 and 1999 (unpublished data of Hutmacher).

	Degree Days (60F) (in DD_{60} per day)		
Time Period	**Average Daily DD**	**Range in Daily DD**	**Total DD60 For Time Period**
July 1-15	18.3	14 – 21	274
July 16-31	18.6	13 – 22	297
Aug. 1-15	18.7	15 – 22	281
Aug. 16-31	16.3	11 – 19	262
Sept. 1-15	15.1	10 – 22	227
Sept. 16-30	11.6	5 – 17	175
Oct. 1-15	8.2	5 – 15	122
Oct. 16-31	5.6	2 – 8	90
Nov.1-15	2.3	1 – 5	34

As an example, we use an Acala field cutout date of July 26 in which field maturity is established as follows:

7/26 to 7/31	8/01 to 8/15	8/16 to 8/31	9/ 01 to 9/ 08
6 days @ 18.6	16 days @ 18.7	15 days @ 16.3 days	8 days @ 15.1
= 110 HU	+299 HU	+244 HU	+120 HU

= 773 heat units (HU)

Boll maturity for this field is now estimated to occur about September 8. Establishing a maturity date for this field allows us to calculate crop water needs up to this date. If this had been an early cutout Pima field, 100 additional heat units would be required, thereby extending the maturity date by about 9 days (assuming average heat units during September).

b) Estimate crop water use to maturity

To estimate crop water use that would allow the last harvestable boll to mature, we use long-term crop water use data. Surprisingly, the year to year differences in late season water use are not large when averaged over the duration of final boll maturation. Late season crop water use averages are identified in Table 2 and depict the decrease in crop water use for post cutout cotton fields. Using methods similar to that for calculating heat units, crop water use from cutout to maturity is projected.

Table 2. Average cotton evapotranspiration (ET) for an early April planting of cotton in the San Joaquin Valley (from Hake et al, 1996—UC Publication # 3352).

Week Ending	ET (weekly total)	ET (daily average)
July 22	2.25	0.32
July 29	2.20	0.31
Aug. 5	2.11	0.30
Aug. 12	2.02	0.29
Aug. 19	1.90	0.27
Aug. 26	1.78	0.25
Sept. 2	1.60	0.23
Sept. 9	1.39	0.20
Sept. 16	1.16	0.17
Sept. 23	0.92	0.13
Sept. 30	0.71	0.10

Example Calculations: Using the previous example of July 26th cutout and September 8th maturity:

July Water Use	Aug. Water Use	Sept. Water Use
6 days @ 0.31”	16 days @ 0.3 “ + 15 days @ 0.26”	8 days @ 0.21”

= 1.9” + 4.8” + 3.9” + 1.7” = 12. 3 ”

We now have a good estimate of late season crop water needs in this field during the stated period (about 12 inches). Providing sufficient moisture during this post cutout period with about 12-acre inches water use will take the crop to maturity while avoiding damaging water stress. Restricting the plants access to water beyond this time will assist in getting the crop set up physiologically for good activity of harvest aids. The final step, and perhaps the most important, is to identify plant available water (PAW) following final irrigation.

c) Estimate available crop water supply

Soils differ in their ability to store moisture for subsequent use by the crop. Clay soils, because of their high content of fine soil particles that attract water molecules, have the highest water retention characteristics. Sandy soils, due to their low percentage of fine particles, have the least water retention (See insets pages 6 and 7). Plant available water (PAW) can be estimated in soils by determining the soil texture of the site (see table 3) and conducting field based tests to estimate the effective rooting depth. Multiplying the available water per foot of soil, by effective rooting depth, yields reasonable estimates of PAW. More precise measures of PAW using accurate soil moisture measuring devises are also appropriate to use in this step.

Table 3. Available soil water content for different major soil textural classes.

Soil Texture	Available Soil Water Content (inches of water per foot of soil)	
	Average	**Range**
Coarse (fine sand, loamy sand)	1.0	0.7 to 1.2
Medium-coarse (sandy loam)	1.2	0.9 to 1.8
Medium (loam, silt loam, fine sandy loam)	2.0	1.6 to 2.4
Moderately fine (clay loam, silty cl. loam, sandy cl. loam)	2.2	1.8 to 2.5
Fine (silty clay, clays)	2.3	1.6 to 2.6

Example Calculations: A soil auger was used to collect soil samples used in estimating PAW in a sandy loam soil overlaying a loamy sand. The irrigation manager evaluated the field about one week prior to his or her decision to terminate the crop in our example (with a cutout date of July 26). The top two feet of soil consisted of sandy loam, while the next three feet was a coarse loamy sand. Indications of some limited rooting were observed in the fifth foot, but no evidence of significant water extraction was seen at that depth. The following estimate of plant available water was then made:

sandy loam soil		loamy sand soil		Total
2 feet @ 1.5" / ft	+	2 feet @ 1.0" / ft	=	5 inches

On this very light soil type, 5 inches of plant available water will be available for uptake before severe water stress will occur in most of the field. Using this estimate to calculate the last irrigation date, work from the maturity date (calculated on page 3 as September 8) backward in time to identify final irrigation date. Again, this is based upon how many August and September days will equal about 5 inches of crop water use:

September Water Use	August Water Use
8 days @	13 days @
0.21" = 1.7"	0.26" = 3.3 "

Irrigation termination (final irrigation) on this early-maturing field should, therefore, occur about August 18.

Will this approach work in my field?

Favorable results were achieved when using the water budget approach on large scale Acala fields in the late 1990's. In replicated trials over a three-year period, nine locations with contrasting soil characteristics were evaluated to confirm the water budget approach method. There were no examples observed that resulted in increased yields when compared to irrigation termination dates conducted either before or after the optimum date established by this method. To increase the speed at which the calculation could be made, the California Cotton Manager's Irrigation Termination Module was used to estimate optimum irrigation termination dates, Munier et al. (1995). Table 4 shows cooperator yield data for three distinctly different soil types as found in trials conducted in Tulare, Kings and Fresno counties.

It remains a good idea, however, to keep in mind that there are some instances in which the irrigation termination date calculations can potentially be problematic.

Case I: Soils with poor late season water infiltration.
Some sealing soils make it difficult to refill the soil moisture profile on the final irrigation. In these poorly permeable soils, water penetration is slow and may only allow three acre-inches or less of water uptake. In this event, the best option is to forego the soil storage estimate outlined above and simply use the water application amount of the final irrigation event plus any residual soil storage that may be contributed to provide your estimate of plant available soil water.

Table 4. Cotton lint yields (lbs lint/acre) as a function of different irrigation termination dates (Munk et al, 1997) Select results from larger cotton field study supported by Cotton Incorporated State Support.

*Irrigation Termination Date (top) And Lint Yield (bottom) for each site *letters show statistical mean separation* Early	Medium	Late	Crop and Site Description
August 9 1315 c	August 22 1400 a	*Sept. 4* *1355 b*	Maxxa 1997 Silty Clay
July 21 1946 a	August 8 1975 a	August 29 1932 a	Maxxa 1997 Clay Loam
July 21 1438 a	August 8 1353 b	August 29 1145 c	GC-510 1997 Clay Loam
August 15 865 b	August 26 930 a	Sept. 8 885 b	Maxxa 1995 Sandy Loam

Case II: Restricted or limited root systems.
If a shallow root system exists, it is of particular importance to develop good estimates of effective rooting depth. Under- or over-estimating rooting depth can have a big impact on plant responses to irrigation termination dates. This is most problematic on clay soils as they often have high available water content per soil volume and under some circumstances can also produce shallow root systems. If for example a four-foot rooting depth is used rather than a three-foot rooting depth, a difference of perhaps 2.2 inches could be observed, which could translate to a 9 to 14 day miscalculation of your optimum irrigation termination date. This could have significant consequences in terms of yield, quality, and crop production costs. Best rooting depth estimates can often be made just a few days prior to any irrigation event near or at plant cutout.

There are certainly other special production conditions that can impact some of the assumptions with the approach just described. These situations can make it less precise and less useful. Crops grown under conditions with highly saline soil can not only be exposed to water availability problems associated with poor infiltration and limited root systems as described in Cases I and II above, but they can also result in stunted plants and less canopy cover, resulting in lower ET than in the original assumptions. Another example would be crop production in the presence of groundwater shallow enough and of a quality that plants can access it in the mid and late-season. This situation can reduce the level of control the irrigation manager has over the timing when soil water becomes limiting to plant growth. The basic approach described here can still be useful, but more in-field evaluation will be needed to adjust ET and soil water estimates.

Impacts of Variety and Types of Cotton

The effects of the timing of late season water stress on Acala cottons have been found to be variety dependent (Munk et al., 1994). Results from early 1990's irrigation management trials found that the timing of late-season crop water stress strongly influenced crop yield (Figure 2) . Further evaluations in the mid- to late-1990's also demonstrated varietal differences in impacts

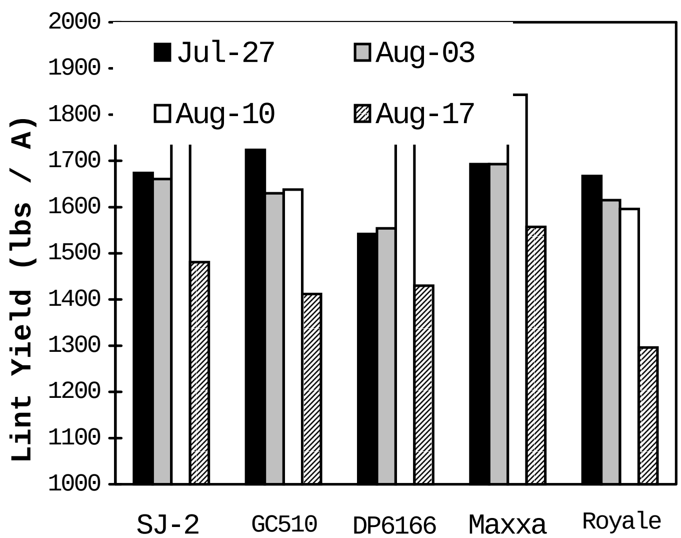


Figure 2. Average yield response of 5 Acala varieties to 4 irrigation termination dates across 1991 and 1992 studies in a clay loam soil at the West Side REC.

on maturity, as demonstrated by Figure 3 which shows impacts of irrigation termination timing on nodes above cracked boll (NACB) (an indication of readiness for harvest aid applications).

It was generally observed that more determinate varieties experienced the most sensitivity to the timing of water stress with yields severely declining when sustained water stress levels below –22 bars occurred shortly after crop cutout. Moderately indeterminate to indeterminate varieties were affected least by exposure to late season water stress imposed during the period between cutout and last mature boll.

Several San Joaquin Valley studies have also been conducted on late-season crop water use for Acala cotton varieties. Most of the data collected suggest that although crops may have different maturity levels, if

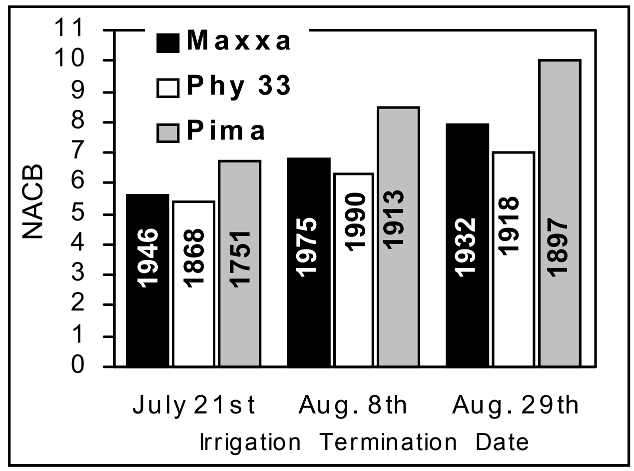


Figure 3. Irrigation termination date influence on nodes above cracked boll (NACB) measured on September 12, 1997 and final lint yield (lbs/acre) in each treatment (shown as number printed within each column).

irrigated using similar irrigation regimes, total season crop water use will not be significantly different between varieties. The story may be different, however, in comparing Acala with Pima or true shorter-season Uplands. For instance, long-term studies at the West Side Research and Extension Center and more recently in grower fields during the 2000 and 2001 season are consistently finding Pima cotton to have higher water use late-season than current Acala varieties. Recent data suggests that during the period just after through boll maturation, one to two inch higher ET occurs with Pima. This should be considered when using the water budget approach outlined in this guide.

References

Grimes, D.W. and W.L. Dickens. 1974. Dating termination of cotton irrigation from soil water retention characteristics. Agron. J. 66:403-404.

Grimes, D.W. and K. M. El-Zik. 1982. Water management for cotton. Berkeley, University of California, DANR, Bulletin 1904.

Hake, S.J., D.W. Grimes, K.D. Hake, T. A. Kerby, D. J. Munier and L.J. Zelinski. 1996. Irrigation Scheduling. In S. J. Hake, T. A. Kerby, and K. D. Hake (eds) Cotton Production Manual. UC publ. 3352, pp. 228-247.

Hutmacher, R.B. and D.S. Munk. 1997. Scheduling final irrigations in 1997. California Cotton Review Vol. 44.

Hutmacher, R.B. 1997. High temperatures and square, boll loss. California Cotton Review, Vol. 44.

Kerby, T.A. and K.D. Hake. 1996. Monitoring cotton's growth. In S. J. Hake, T. A. Kerby, and K. D. Hake (eds) Cotton Production Manual. University of California publication 3352, pp. 324-334.

Munier, D.W., T.A. Kerby, J. Young, R.E. Plant, P.B. Goodell, D.S. Munk, W. Wright, B. Roberts, R.N. Vargas and B. Weir. 1995. California Cotton Manager Version 2.2.

Munk, D.S., D.W. Grimes and T.A. Kerby. 1995. Plant responses to late season water deficits in cotton. 1st International Cotton Production Research Conference. Brisbane, Australia.

Munk, D.S. and S.D. Wright. 1995. Irrigation management that minimizes crop losses. California Cotton Review Vol. 36.

Munk, D.S. 1996. Mid-season water management for cotton. California Cotton Review, Vol. 40.

Munk, D.S., J.Wroble and S.Wright. 1997. Establishing a model for irrigation termination in cotton. Beltwide Cotton Conference: 1406-1409.

Munk, D.S., R.B. Hutmacher, B. Weir, and J. Wroble. 1999. Irrigation scheduling that aids crop termination. California Cotton Review Vol. 52

State of California Department of Water Resources. 1986. Crop water use in California. Sacramento DWR Bulletin 113-4.

The aim of a timely termination is to provide the plant enough water to mature the last pickable boll, and simultaneously reduce stored soil water reserves. This will allow a crop physiological response that promotes effective defoliation and boll-cracking following boll maturity. Across a wide range of production conditions, then, we can summarize the steps in making final irrigation decisions as :

1. **Establish cutout date to identify last set flowers**
2. **Calculate date of last pickable boll to carry to maturity**
3. **Estimate crop water use during the period leading up to maturing that last boll**
4. **Estimate plant available water in field**

Soil texture alone doesn't fully describe characteristics important in making irrigation management decisions, but some general characteristics have been found over years of studies that can apply to broad areas of SJV soils in which cotton is grown. These are summarized briefly in the section that follows, along with some field data describing patterns of soil water use with depth from studies in some soils representative of these categories.

Fine Textured Soils

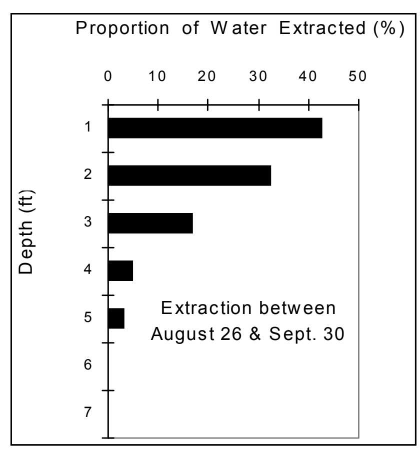
Soils in this category have high clay content but can vary in their ability to take up water during irrigations and in plant available water. Clay contents of these types of soils in the SJV typically range from 40-50 percent clay although unusual soils can have even 55 percent clay. The mineralogy of these soils varies, but most are found to have moderate to high shrink–swell potential.

What this means for cotton producers is that during irrigation, water will move rapidly into the soil initially, primarily through large cracks in the soil surface; but, once the cracks are filled, infiltration rates decline rapidly. If irrigation water continues to be applied, a saturated surface soil may take many days to drain thereby affecting soil gas exchange and aeration.

These soils are often impacted early season by some degree of anoxic conditions, which are thought to compromise root system development and restrict the rooting depth. Commonly, rooting activity is confined to the top 36 to 42 inches of soil, which is the zone in which crop water removal occurs in late season.

Fortunate for the cotton irrigation manager, these soils are highly buffered with respect to water management as a result of the high soil water retention characteristics. Plant available water for the top three feet of soil ranges from 5 to 7.0 inches. Optimum irrigation termination dates range from August 12 to August 22.

Table 5. Late season crop water use expressed as a proportion of total water use in one foot increments with a fine-textured soil .



Medium & Medium Fine Textures

Medium textured soils include the loams and clay loams. Clay loams, in particular, dominate the sloping grounds of the SJV west site. The clay content of these soils commonly ranges between 28 and 38 percent and tend to have well-drained characteristics following an irrigation event. Clay content and fine particle mineralogy are low enough not to pose significant risks of anaerobic conditions and associated potential for damage to the crops.

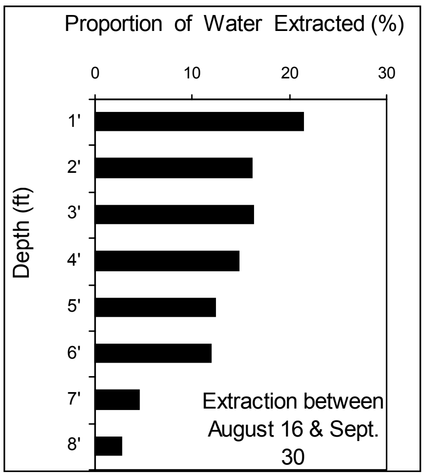


Table 6. Late season crop water use expressed as proportion of total water use in one foot increments of a medium to medium-fine textured soil.

Yet, clay contents are relatively high, so these soils exhibit high water retention. These soils don't compact easily, and often plants can take up water to the six and seven foot depth. The combination of high water retention and a deep rooting profile in the late season create a condition of high plant available water following a final irrigation event. Plant available water mid-season in these soils often ranges from 8 to 12 inches, allowing final irrigation dates to range from July 25 through August 12.

Light and Medium-Textured Soils

These soils include the sands, loamy sands and sandy loams, which often occur in fields that also exhibit significant soil textural variation. In the San Joaquin Valley, these soils are most common on the Eastside alluvial fans, whose river sources originate in the Sierra Nevada mountain range. The high river flow variation over the years can help explain the high variation in textural deposition and soil variability that can make water management a real challenge. Clay content in these soils varies from about 2 to over 10 percent, but the sandy loam group that dominates these soil types typically ranges from 5 to 10 percent clay content.

Some of the distinguishing characteristics of these soils are that they can easily "seal" (develop reduced water infiltration rates) after several irrigation cycles. Less deep water penetration can reduce mid and late-season effective rooting depth (Fig. 7). These soils are also more prone to compaction problems and often have only moderate water retention properties. Because of these characteristics, these soils often require more frequent irrigation, and, in some extreme cases, may require irrigation intervals of 8 to 10 days in late-season. Recommended final irrigation dates in these soils typically range from about August 12 to September 5 for most cotton crops.

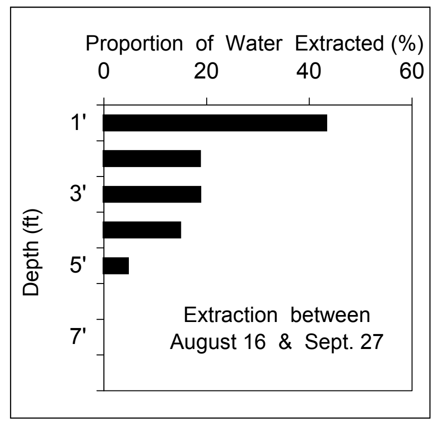


Table 7. Late season crop water use expressed as proportion of total water use in one foot increments of a light to medium-textured soil.

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HARVEST AID RESEARCH TRIAL INFORMATION:

A summary of information regarding the research results from the past several years of research trials with harvest aids will be summarized by the end of August on the University of CA Cotton Website: **http://cottoninfo.ucdavis.edu**

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COTTON FIELD DAYS - 2001

University of CA, USDA-ARS & CA Dept. of Food and Agriculture participating

- UC Shafter Research and Extension Center - Tuesday**, September 18, 2001**
  (contact Brian Marsh (661) 868-6210 or Bob Hutmacher (661) 746-8020 for more information)
- UC West Side Research and Extension Center - Thursday**, September 20, 2001**
  (contact Dan Munk (559) 456-7561 for more information)