IRRIGATION MANAGEMENT SERIES

Irrigation Management for Alfalfa

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Alfalfa is a deep-rooted, drought-tolerant perennial with an extended growing season. As a consequence, as much as 40 inches of seasonal water are necessary to maintain healthy growth. The alfalfa growing season begins when the average temperature reaches 50 degrees Fahrenheit and continues until a harsh freeze occurs, usually in late fall. In deep, well-aerated soil, alfalfa roots may grow to a depth of 8 to 12 feet. When soil water is sufficient, alfalfa grows in direct relation to temperature and available sunlight.

Water-use Characteristics

Alfalfa requires more water than any other Kansas crop and the net irrigation requirement varies from 14 inches in Linn County in eastern Kansas to 27 inches in Morton County in southwest Kansas. During cooler parts of the growing season, alfalfa needs about 4 acre-inches of water per ton of production. During hot summer months, water use increases to 6 to 7 acre-inches per ton.

Alfalfa is considered drought-tolerant because it is able to use up to 70 percent of available soil water without undue stress or production loss. If the crop becomes stressed beyond this limit, plant growth stops until more soil water is available. Alfalfa can be considered as a crop choice for irrigators with limited water supplies because, water stress during one production cycle may cause loss of yield for that cycle but the crop can survive a dry period and recover during the next cutting for a good harvest if the water stress is removed.

A normal water-use rate for an alfalfa crop at mid-season is 0.35 inch per day, or about 1 inch of water every three days, though rates in excess of 0.35 inch per day have been recorded over several weeks. The water-use rate drops dramatically when the alfalfa leaf area is removed during harvest. As re-growth occurs, the use rate rapidly increases to that of a mature plant, generally reaching full use in a 10- to 12-day period.

Peak rates of 0.5 inch per day are not uncommon, but they seldom last more than a day or two. Because of a deep root system, alfalfa continues to grow through dry periods if enough soil-water storage is available. The combination of soil-water storage and irrigation system capacity must equal the long-term use rates if production is to be maintained.

Alfalfa is sensitive to excessive soil water or the lack of good aeration, so surface water should not be allowed to stand more than 24 hours during hot weather or 48 hours during cooler temperatures. The excess moisture causes root and crown diseases on the alfalfa crop. Shallow water tables also limit root growth. A deep, medium- to coarse-textured soil with adequate water is ideal.

Alfalfa does not have a critical stage of growth like many other crops. However, the seedling stage is sensitive to soil water because seeds are small, as are the reserves of energy and moisture. The period of re-growth after cutting is sensitive, so it is best to avoid surface irrigation, which may encourage weed competition. When the alfalfa canopy has been removed by harvest, ideally irrigation should not be applied in order to avoid surface-germinated weeds, such as grasses and pigweeds. A dry surface with adequate water below the top

12 to 18 inches of soil gives alfalfa an advantage over shallow-rooted grasses and other weeds because of its deep root system.

Irrigation Management

When irrigating alfalfa, only the top 3 to 4 feet of the root zone should be considered as the managed root zone in an irrigation scheduling analysis. Water is used below this depth, but the managed root zone contains more than a majority of the plant's roots, and approximately 80 percent of the water originates from this area. Research shows that if water is readily available to at least half of the roots, alfalfa plants experience little or no stress. Consequently, if water is available in the managed root zone, little water is used from the lower depths.

One method of limited irrigation involves exploiting the deeper soil water by not fully watering the upper root zone of the alfalfa. This method does not yield high production rates, but more soil-water storage is available for precipitation, and the production per unit of irrigation water increases. However, the economic benefits of this method are site-specific. Cost of pumping, crop value, and costs associated with the irrigation system and management must be considered. Even with a limited water supply, early- and late-season irrigations can be used because of alfalfa's long growing season and deep root zone.

End-of-season irrigation for alfalfa is important. The profile soil water should be in the readily plant-available water range when the crop goes dormant for the winter to reduce the chances of winter kill.

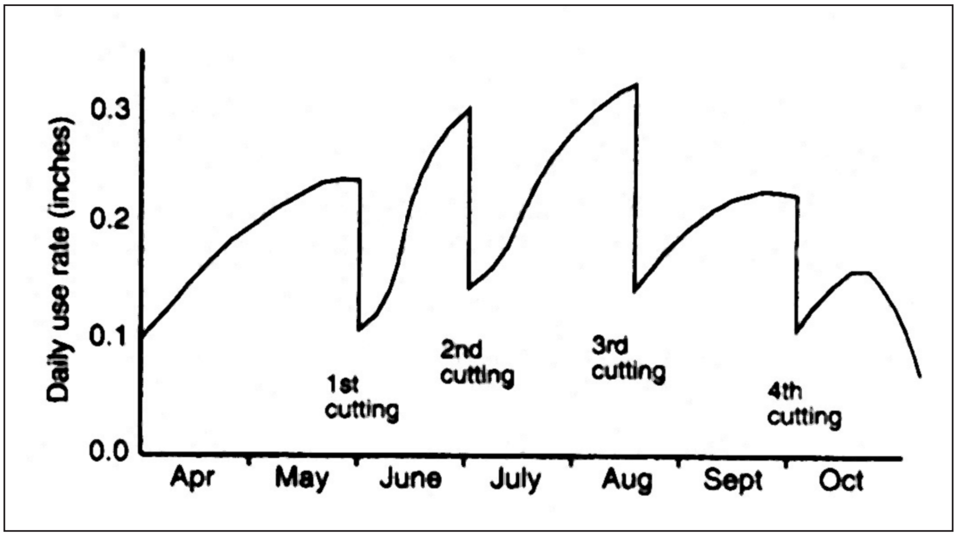

Figure 1: Normal water-use curve for alfalfa with four cuttings

Irrigation Timing

Alfalfa is sensitive to water stress at the time of harvest, and rapid re-growth depends on adequate soil water. Watering prior to harvest or immediately after is the best time to promote rapid growth. However, soil compaction may occur if the field is watered from above ground before harvesting. A firm, dry surface is best for harvest traffic and field-drying of hay. Also, because watering immediately after harvest stimulates the germination and growth of surface-germinated weeds it should be avoided when possible unless subsurface drip irrigation (SDI) systems are in use, which do not wet the soil surface during irrigation.

If the irrigation system has limited capacity, as most center pivots do during mid-season, irrigators may have very few options. The system is shut off during cutting and started again when the hay is removed. The harvest reduces the water-use rate for a time, but full water-use rates will occur in about 10 to 12 days after cutting. The best irrigation strategy during the alfalfa growing season is to irrigate until a few days to a week before harvest. The surface should be allowed to dry and stabilize for harvest, and then the root zone should be filled as soon after harvest as conditions allow. Usually, on medium-textured soils, 4 to 6 inches of water between cuttings is sufficient.

Irrigation Scheduling

An irrigation schedule should be developed for any irrigated crop because scheduling is a cost-effective way to improve irrigation management. The checkbook method is recommended because it allows flexibility in determining when and how much to irrigate. An initial estimate or measurement of root-zone soil water is needed, which usually requires the installation of soil-water measuring equipment or soil probing.

Soil-Based Scheduling Methods

Measuring soil water at frequent intervals is an excellent scheduling method. Measurement accuracy depends on the frequency, number, and location of measurements, though. Soil-water measuring equipment must be monitored frequently – at least twice a week at mid-season – and measurement

Table 1. Interpretation Chart for Table 1. Interpretation Chart for Soil Water

	Texture or appearance of soils			
Soil water remaining	**Very light**	**Light**	**Medium**	**Heavy and very heavy**
0%	Dry, loose, single-grained; flows through fingers.	Dry, loose; flows through fingers.	Powdery, dry; sometimes slightly crusted but easily breaks down into powdery condition.	Hard, baked, cracked; sometimes has loose crumbs on surface.
Less than 50%	Still appears to be dry; will not form a ball with pressure.	Still appears to be dry; will not form a ball[1].	Somewhat crumbly, but will hold together from pressure.	Somewhat pliable will ball[1] under pressure.
50% to 75%	Same as very light texture, with less than 50% moisture.	Tends to ball under pressure, but seldom will hold together.	Forms a ball, somewhat plastic; will sometimes stick slightly with pressure.	Forms a ball and is very pliable; sticks readily if relatively high in clay.
75% to field capacity	Tends to stick together slightly; sometimes forms a very weak ball under pressure.	Forms weak ball; breaks easily, will not stick.	Forms ball; will ribbon out between thumb and forefinger.	Easily ribbons out between fingers; has a slick feeling.
At field capacity (100%)	Upon squeezing, no free water appears on soil, but wet outline of ball is left on hand.	Same as very light texture.	Same as very light texture.	Same as very light texture.
Greater than field capacity	Free water appears when soil is bounced in hand.	Free water will be released with kneading.	Can squeeze out free water.	Puddles, and free water forms on surface.
[1]Ball is formed by squeezing a handful of soil firmly with fingers.				

records are necessary to guide irrigation timing.

Table 1 describes the visual "hand feel" method. This is the simplest procedure and, with experience, is generally adequate for irrigation management, especially for a deep-rooted and drought-tolerant crop like alfalfa.

The irrigator may install soil-water sensor blocks at various depths and field locations and determine soil water with a portable electric meter. The electric meters are good for medium- to fine-textured soils, and they eliminate guesswork while saving time and effort. A tensiometer may be used for sandy soils. These are easier to read and provide adequate information for most scheduling, but they lack the range to cover the soil-water-availability status of all soils.

The soil-water value obtained by either the hand probe or a soil sensor can be converted into the amount of water depleted from the crop root zone. The change in soil-water level between readings is an indication of the crop water-use and can therefore be used in a checkbook irrigation scheduling procedure. This method is described later.

Some irrigators check the irrigation application by using a simple steel probe. A probe consists of a steel rod 5/16 to 3/8 inch in diameter with a slightly larger ball welded to the end. A day after irrigation, the probe is pushed into the soil at several locations to check for easy penetration into wet soil or greater resistance into dry soil. In order for probing to be useful, time should be allowed for water to move downward, but too lengthy a time may cause confusion because of continued plant use.

Probing may need to be delayed until the second day after irrigation on fine-textured soils in order to get a better measure of the total depth of penetration from the irrigation application. While this does give useful information with regards to the depth of the irrigation wetting front and the uniformity of the infiltration, it provides little information with regards to the amount of water stored in the profile.

Other Scheduling Methods

Calendar-date scheduling is another scheduling procedure option which involves applying certain amounts of water based on the time of year. Alfalfa is one crop in Kansas where such scheduling has some utility because the deep-rooting habit and drought-tolerance of the plant does not make the irrigation schedule as critical as it is for other crops. However it is not a recommended practice. During particularly dry or wet years, crop production may be lost because the timing of the irrigation or the amount of irrigation water is not adjusted to the current conditions. As a result, the calendar-date scheduling procedure is not as efficient as other scheduling methods.

Some producers rely on crop-stress signs, such as color change due to depleted soil water. A careful observer notices a change in the crop's color as soil-water stress develops and the leaves become blue-green before wilting. If the irrigation system is capable of providing water rapidly, these color changes may be accurately used to schedule irrigation. Because color change takes several days to occur, relying on crop-stress signs for scheduling works if water is provided before wilting occurs. However, irrigation system capacity is a major difficulty with this method. From the time the color change becomes perceptible to alert the irrigator, only a few days remain until the onset of wilting. Few irrigation systems in Kansas have large enough capacities to cover the field before a yield loss occurs. If only crop-stress signs are used, knowing when to anticipate needed irrigation is difficult and this is not a recommended irrigation scheduling practice.

Checkbook Method

Checkbook irrigation scheduling is a recommended method of scheduling irrigation. The procedure uses crop water-use estimates to keep track of the available soil water in the managed root zone of the crop. The goal of the procedure is to provide the manager with current information on the amount of soil water depleted (or amount remaining) in the root zone. The checkbook method is similar to balancing a checkbook. The soil-water content is the balance in the check book. It moves up when deposits of rainfall or irrigation are added and moves down when the crop removes water. The irrigation manager tries to keep the balance within the readily available soil-water range for the crop. Unlike a bank balance, excess deposits are possible and occur when rain and/or irrigation have filled the root zone to beyond saturation.

Direct measurement of the soil-water content of the root zone can be used as described previously; however, climatic-based or ET-based irrigation scheduling is the recommended scheduling procedure.

Evapotranspiration (ET) is the term coined to describe the consumptive water use of crops; the amount of water used by a growing crop. K-State Research and Extension bulletin MF2389, *What is ET,* provides additional information on ET.

The amount of ET is influenced by climatological factors such as temperature, relative humidity, wind, and solar radiation. In addition, crop conditions such as stage of growth and plant health will affect the amount of ET that occurs.

ET information generated by climatological factors gathered at weather stations is generally referred to as reference ET or ETr. Values for ETr must be customized or modified by factors, called crop coefficients, to properly estimate crop ET or water-use of a specific crop for its particular growth stage. This modified ET value is referred to as either actual ET or crop ET or ETc.

ETr values are generated at a number of weather stations across Kansas. Some networks of stations are operated and maintained by local groundwater management districts and ETr data can be accessed via the Web or telephone. The Weather Data Library at K-State Research and Extension operates or has access to a number of weather stations throughout Kansas. While the data from some of these stations can be accessed locally, many can also be accessed via the Web at *www.ksre.ksu.edu/wdl*.

Irrigation scheduling can be accomplished by hand using charts, like those found in K-State Research and Extension bulletin L915, *Using Evapotranspiration Reports for Center Pivot Irrigation Scheduling*. The ETr information is assumed available via a weather station. The process of irrigation scheduling is then largely a series of simple additions and subtractions that calculates a soil-water balance for a given site in a field. While the math is simple, the number of repetitions required for a field throughout a growing season can become tedious. The scheduling process however, lends itself well to computerization.

Irrigation scheduling using ET data is the essence of KanSched, an ET-based irrigation scheduling software package available through Mobile Irrigation Lab (MIL) project of K-State Research and Extension. Contact your local county extension agent or check out *www.ksre.ksu.edu/mil* for more information or to download KanSched from the Web site. The newer versions of KanSched (KanSched2 or above) have had modifications to accommodate alfalfa cutting cycles within the program, making KanSched2 easy to use for scheduling irrigation on alfalfa.

Even irrigation systems with capacities that limit the irrigator's management flexibility can use ET information to benefit water management. The benefit can come from helping to determine when to start and end irrigation. This benefit generally translates into increased economic return, possibly through a lower fuel bill as a result of reduced over-watering, or as increased yield due to fewer periods of crop-water stress.

Irrigation Methods

Surface Irrigation

Surface systems usually have a large irrigation capacity. Irrigating alfalfa with a surface irrigation system often involves the use of border strips. These strips are long, narrow areas that are contained between low dikes along either side. The width is generally sized to efficiently accommodate the harvesting equipment. They are usually graded to a uniform grade of 0.3 to 3 percent along the length but are level across the slope. Water is rapidly introduced along the upper end of the strip and flows to the lower end. The alfalfa stand provides roughness to slow the water, help it spread across the strip, and prevent erosion. If properly designed, little runoff is produced, and the application efficiency is 75 to 85 percent. Because wind and low humidity have only minor effects, this system is relatively easy to manage.

Many irrigators who surface irrigate other crops also utilize corrugations and bedded-furrows for alfalfa, even though irrigation control is less precise than a well-designed border system. Corrugations are shallow furrows that help direct water flow in a certain direction. However, they are too shallow to prevent overtopping if the flow is too great and are often easily obstructed. Corrugations are an inexpensive method of gaining limited irrigation control. Furrows, or bedded furrows, offer additional control of the water through the system, but they create a rough surface to contend with at harvest.

Center Pivots

Center pivot systems irrigate the vast majority of crops in Kansas and are an effective method to apply irrigation water efficiently and uniformly for a wide variety of field topography and soil types. The major difficulty of irrigating alfalfa with center pivot systems is related to having dry soil surfaces for harvest and encouragement of weed germination with irrigation by center application before alfalfa regrowth reaches full cover. Harvesting interruption of irrigation also has an effect on the irrigation capacity for the field.

Subsurface Drip Irrigation (SDI)

Alfalfa needs plenty of water after each cutting to start regrowth. Subsurface drip irrigation (SDI) systems allow continuous irrigation right after harvest to encourage rapid regrowth and do not require irrigation suspension prior to harvest to allow for dry soil. According to studies done in California and Texas, SDI has shown increased alfalfa yield when compared to furrow irrigation. K-State findings for SDI in corn suggest it is a feasible technology and economically competitive for small or odd-shaped fields when center pivots are not feasible.

When surface wetting is reduced, evaporation loss and weed germination is also reduced. SDI greatly lessens the opportunity for deep percolation and surface evaporation loss. Research from K-State indicates that it is possible to save 25 percent of total water diverted in a season by using SDI compared to sprinklers. However, SDI systems, when used on permanent crops like alfalfa, may make additional management concerns, such as increased rodent pressure (see K-State Research and Extension Bulletin MF2867, *Subsurface Drip Irrigation for Alfalfa*).

Irrigation Capacity

The system irrigation capacity is the average application depth that would be applied if the entire field was watered in one day. Ideally, the irrigation capacity would be adequate to replenish the water at the peak rate of water use by the crop. Practically speaking, the typical irrigation capacity is less than the peak crop water-use rate and the water held in the root zone of the crop is decreased during periods when crop water-use rate exceeds irrigation capacity.

For summer-grown row crops in Kansas, a general rule of thumb is that an irrigation capacity of 0.25 inch/day is needed to serve a field with high water-holding capacity and would be considered a low risk system (unlikely to have yield-limiting water stress with proper operation). An irrigation capacity of 0.30 inch/day for a field with low water-holding capacity (sandy soils) would be a necessity. Since sandy soils have less water stored as reserve for crop use, the irrigation capacity must be closer to the peak water-use rate of the crop.

These rules of thumb however, are based on the assumption that the irrigation system can be operated continuously during the irrigation season – an assumption that is ineffective due to alfalfa harvest cycles within the growing season in case of surface flood and sprinkler irrigation systems. Because of harvesting needs, as many as seven days of irrigation may be missed for each harvest cycle of approximately 30 days. In essence, the alfalfa harvest interruptions on irrigation reduce the long-term irrigation capacity, as compared to grain crops.

Irrigation management responses could be maintained by increasing the flow rate to the field, reducing the number of irrigated acres, or accepting a lower yield when crop water-use exceeds irrigation supply. The latter is a common management strategy that works well because of multiple yearly harvests and the drought tolerance of alfalfa. Adjusting the acreage under irrigation is also an option so that irrigation can be shifted to another crop during alfalfa harvest for a given field. As irrigation capacity for a given system declines over time due to water table decline affecting well yield, this may be a management strategy to consider.

The Crop Water Allocator (CWA), designed for western Kansas production conditions, is a software program designed to assist irrigators in determining the optional acreage allocation for various crop combinations for a fixed water allocator. The CWA is available for download *www.ksre.ksu.edu/mil*.

Irrigation Water Quality

As for all crops grown under irrigation, the quality of the irrigation water should be considered as part of the system design and the irrigation management strategy, which would include the crop selection. Poor irrigation water quality can have adverse effects on plant productivity and soil quality. Alfalfa's rating, in terms of its tolerance to salinity, is moderately sensitive. For comparison, corn is also moderately sensitive, while grain sorghum, soybeans and wheat are moderately tolerant crops. Many factors have an influence on the salinity tolerance of the crop including the climatic conditions, soil, cultural practices, irrigation system type and irrigation management.

Summary

Successful irrigation of alfalfa is possible with surface, sprinkler and SDI systems with good management. Alfalfa can also be economical to grow with either full irrigation or limited irrigation strategies.

Additional References

Additional references are available from the K-State Irrigation Management Series:

L914, *Using Evapotranspiration Reports for Furrow Irrigation Scheduling*

L915, *Using Evapotranspiration Reports for Center Pivot Irrigation Scheduling*

L795, *Soil Water Measurements: An Aid to Irrigation Water Management*

L901, *Scheduling Irrigations by Electrical Resistance Blocks*

L796, *Tensiometer Use in Scheduling Irrigation*

MF2867, *Subsurface Drip Irrigation for Alfalfa*.

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