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Irrigation Management and Crop Characteristics of Alfalfa

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Alfalfa is relatively drought-tolerant, but irrigation makes it possible to grow high-quality alfalfa in Nebraska, on a wide range of soils, producing yields almost proportional to water available.

Alfalfa (*Medicago sativa*) is the most important forage legume in Nebraska. Irrigation makes it possible to grow high quality alfalfa throughout Nebraska on a wide range of soils. While alfalfa is relatively drought-tolerant, it responds favorably to irrigation and will produce yields almost proportional to the amount of water available to the crop.

Special Alfalfa Irrigation Characteristics

A number of important factors cause alfalfa irrigation to differ from other crops normally irrigated in Nebraska. These factors include:

1. Alfalfa is a perennial crop with a potential deep-root system that can use moisture deep within the soil profile.
2. Multiple harvests prevent irrigation for about 7 to 10 days per growth cycle.
3. Frequent heavy equipment traffic across an alfalfa field causes soil compaction and often forms a crust on the soil surface. This crust could result in reduced soil water infiltration rates as stands age.
4. Over-irrigation can quickly injure alfalfa plants and encourage weed invasion, especially right after harvest.
5. Water use efficiency is greatest during cool to moderate temperatures, especially during spring.

Alfalfa Water Use Characteristics

Because it has a longer growing season, alfalfa can use more water annually than other crops. Irrigation management must consider characteristics such as water requirements (including seasonal, total and daily water use), root system development, and critical stages of growth as well as soil characteristics, the irrigation system, and the available water supply.

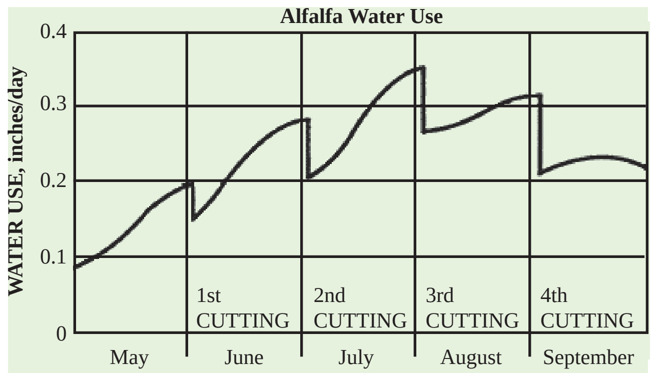

Figure 1. Seasonal water use pattern for alfalfa in Nebraska.

A water-use pattern for alfalfa in Nebraska is shown in *Figure 1*. This pattern shows typical daily crop evapotranspiration (ET) throughout the growing season. Evapotranspiration is the combination of water transpired by the crop and water evaporating directly from the soil and plant surfaces. The amount of water used by alfalfa varies from season to season and location to location, but will follow this same general pattern. The primary climatic factors affecting the magnitude of water use are air temperature (greater with higher temperatures and less with cooler temperatures), solar radiation and wind speed. Availability of soil water also will directly affect crop water use.

Alfalfa begins using water when plant growth starts in the spring. For Nebraska conditions, growth typically begins in early to mid-April. Initial crop water use is small because growth is slow and temperatures are cool. As temperatures rise and the rate of growth increases, daily water use increases. The water use rate rises sharply and reaches a peak at canopy closure near the pre-bud stage at 10-12 inches in height.

Water use may drop slightly as harvest approaches, but it drops sharply when alfalfa is cut because transpiration is minimal when most of the leaf area has been removed. After harvest, alfalfa re-growth begins and the water use cycle begins again. This cycle is repeated for each cutting (i.e., every 30 to 40 days).

The active roots of the alfalfa plant can penetrate 8 to 12 feet in deep, well-drained soils. However, alfalfa will obtain 75 to 90 percent of its moisture from the upper four feet of soil. Water in the lower portion of the root zone is especially important if the crop's water demand cannot be totally supplied by the irrigation system during peak water use periods.

During the growing season, irrigation normally will not supply water any deeper than four feet in the soil profile. Irrigation and precipitation in the fall or early spring can supply water to the deeper portions of the soil profile for use during the growing season. A clay pan or other restrictive soil layers can limit the effective root zone depth. Shallow root zones require smaller and more frequent irrigations.

Alfalfa does not have a stage of growth that is extremely critical or less sensitive to water stress. If water is not available, the plant will slow or stop growing and go dormant. When water becomes available, growth will resume. However, lack of moisture will reduce crop ET and yield. Drought-stressed alfalfa matures earlier, thus forage quality will peak earlier and degrade more rapidly than under normal conditions. In Nebraska, precipitation and stored soil moisture normally will be adequate for the first cutting. Thus, when the irrigation water supply is limited, irrigation will probably be most beneficial just before the second cutting and during the third and fourth cutting growth periods.

Although alfalfa responds well to irrigation, too much water can damage it. Alfalfa is susceptible to damage from over-irrigation, ponding of water, and high water tables, especially on fine-textured soils with low permeability. Subirrigation from high water tables can effectively meet the water requirements of alfalfa.

In general, serious damage may occur when the water table is at a depth of three to four feet or less. Crop damage results from poor aeration and diseases such as crown and root rots. Damage will be more extensive during periods of high temperatures. In general, the alfalfa plant should not be submerged in water for more than 24 to 48 hours to prevent reduced growth and stand loss.

The peak daily water use of alfalfa in Nebraska normally will range from 0.3 to 0.35 inch per day in July and August, but may be as high as 0.5 inch during hot, windy, and dry days. During the peak water use period in July and August, the alfalfa crop will use about 5 to 6 inches of water for each ton of field-dry hay produced.

If yields of 1.5 tons per acre per cutting are expected, 7.5 to 9.0 inches of water will be required for each of the third and fourth cuttings. If all of this water must be supplied to the crop by irrigation, 8.8 to 10.6 inches of water will need to be applied (assuming an irrigation application efficiency of 85 percent) to meet the net irrigation water requirement of 8.8 to 10.6 inches.

In most cases, some of the water requirement will be supplied by precipitation and moisture stored in the soil from the spring, so the net irrigation requirement for the third or fourth cutting will typically be 6 to 7 inches. The corresponding gross irrigation requirement will be 7.1 to 8.2 inches (85 percent efficiency). If sufficient water is available for irrigation after the first harvest, use it early in the season since water use efficiency is higher during cooler weather.

Water Application

Alfalfa responds well to water application regardless of the type of irrigation system used. With surface irrigation systems, have good land preparation before seeding. The topography and degree of water control desired will determine the extent of land preparation required. After the stand is established, no further preparation can be done. The most common surface irrigation systems used for irrigating alfalfa are border strips, furrows or corrugations, although basin irrigation may also be used.

Furrow irrigation can be effective for alfalfa if adequate slope, proper stream sizes, and proper lengths of run are used. Furrow spacing normally will vary from 30 to 60 inches. Spacings greater than 60 inches will not provide adequate lateral movement in most soils. Match furrow spacing to the wheel spacing of harvest equipment. Make the furrow size adequate to carry the recommended water flow in the furrow, but not so large that considerable growth is left in the furrow at harvest time. Small furrows or corrugations spaced 15 to 30 inches apart to direct the water across the field also may be used. With small furrows, the length of run must be shorter and furrow flow size will be smaller. The Natural Resources Conservation Service can provide design guidelines for surface irrigation systems. Surface irrigation normally adds several inches per irrigation (about 3 inches on average), depending on the furrow flow, row spacing, and set time.

When properly designed, sprinkler systems can be adapted to most soil and topographic conditions to irrigate alfalfa. Sprinkler systems capable of frequent light irrigations can be used to establish an alfalfa stand. Center pivots and linear (lateral) move systems apply about 0.5 to 1 inch of water, depending on the water infiltration rate of the soil, water-holding capacity, depth, and speed of the system. Light and frequent irrigations of less than 1 inch tend to encourage shallow rooting, reducing one of alfalfa's advantages — a potentially deep root system and its resultant expanded soil profile. Irrigation should encourage deep rooting; applying greater amounts at each irrigation, if infiltration rates permit, are more desirable.

Irrigation Management

Irrigation management includes deciding when and how much water to apply. The decision must be based on the available irrigation water supply, the available water-holding capacity and intake rate of the soil, the water needs of alfalfa for a given period and the irrigation system capacity. The management objective normally will be to meet the crop water needs to provide for optimum plant growth. The success in meeting crop needs will depend upon the size of the available water supply. The timing of harvest and other time factors also must be considered. Criteria to help determine when to irrigate include soil water monitoring and water use prediction based on climatic data.

Crop Appearance and Proportion of Growth

The appearance of alfalfa can indicate soil water status. When adequate water is available, alfalfa usually will be light green. As moisture stress develops, the color darkens. Apply water when the plant has turned dark green, before wilting occurs, otherwise yield and quality will be reduced. Wilting generally will occur when about 25 to 30 percent of the available water capacity remains in the root zone. Drought-stressed alfalfa matures earlier, thus forage quality will peak earlier and degrade more rapidly than under normal conditions.

In Nebraska, precipitation and stored soil water will normally be adequate for the first cutting. If not, irrigate during the first cutting because this is when water is used most efficiently to produce increased yield. It is suggested that adequate soil moisture (i.e., 80-90% of the field capacity) be maintained in the soil profile to a 4-ft depth at the time of first cutting.

Estimate the irrigation water requirement based on crop water requirements, soil characteristics, and proportion of crop growth that has occurred. Also consider weather conditions and precipitation. For example, if a yield of one ton per acre is expected, about six inches of water will be required for the cutting. To estimate how much water is needed to refill the profile at any given time, estimate the proportion of growth that has been made. If 50% of the growth has occurred, 3.0 inches of water will have been consumed (0.50 × 6.0). The net application amount will be 3.0 inches which will require a gross application of 3.5 inches if the system efficiency is 85 percent (3.0 in. ÷ 0.85).

Calendar Method

To determine a calendar schedule, use an estimated water-use rate and soil water-holding capacity. For example, if the average water use rate is 0.35 inch per day and the available water capacity is 1.75 inches per foot, the following schedule could be developed:

Effective root zone = 3.0 ft.
Available water capacity = 3.0 ft. × 1.75 in./ft. = 5.25 in.
Minimum allowable balance = 35%
Available water at minimum allowable balance = 0.35 × 5.25 = 1.84 in.
Usable water = 5.25 in. - 1.84 in. = 3.41 in.
System application efficiency = 85%
Gross irrigation application = 3.41 in. ÷ 0.85 = 4.0 in.
Irrigation frequency = 4.0 in. ÷ 0.35 in./day = 11.4 days

Do not overlook weather conditions, irrigation system capacity, and other factors when using either the proportion of growth or calendar schedule. Without consideration of all the factors involved, it will be easy to over- or under-irrigate.

Crop Water Use and Monitoring Soil Water Status

Daily weather data can be used to estimate crop water use. Estimated crop water use can be calculated using data from a series of automated weather stations across Nebraska. Get weather data and estimated crop water use from the High Plains Regional Climate Center (*http://www.hprcc.unl.ed*) for many locations in Nebraska.

Crop water use estimates can help calculate the current soil water status of a given field. One of the oldest procedures is called "checkbook irrigation management." The soil acts as a "bank" or reservoir to store water for crop uptake. Rain and irrigation are deposits to the bank and the crop water use is a withdrawal. Like a checking account, a weekly (or any other interval) balance of these deposits and withdrawals will give the amount of water remaining in the root zone.

Alfalfa will maintain optimum growth when the soil water is maintained between 70 to 50 percent of the water-holding capacity. As long as water remains in this range, there will be little difference in yield and water use. However, for highest yield, the soil water balance in the root zone should not drop below 40 percent of the available water capacity.

Start irrigation before soil water in any part of the field drops below 40 percent of the available water holding capacity (40 percent depletion). From a practical standpoint, and especially for coarse-textured (sandy) soils, start irrigation when 50 percent of the available water capacity has been used. Plant stress can occur when available soil water drops below 50 percent.

Monitoring soil water is critical for an effective irrigation management, so you know when to irrigate and how much water to apply. Several methods can be used. The calculated soil water balance can be checked periodically by using some type of soil water monitoring. Measuring the irrigation water applied to a field will improve the accuracy of the soil water balance calculation.

Watermark sensors can be used to monitor soil matric potential for irrigation management. Detailed information on how to use these sensors for irrigation management can be found in *Watermark Granular Matrix Sensor to Measure Soil Matric Potential for Irrigation Management,* UNL Extension Circular EC783.

Watermark sensors measure soil matric potential, which is an indication of the energy plants must exert to extract water from soil. The soil matric potential reading at which irrigation is necessary depends on soil texture (see *Table I*). Sandy soils retain far less water than soils with a high clay, silt, or organic matter content, so irrigation on sandy soils should occur more frequently and at a lower soil matric potential value (negative sign of the matric potential is omitted).

The matric potential reading will increase as the soil becomes drier. After the field is irrigated, the matric potential readings typically return to lower values (i.e., 0 to 10 kPa). These wetting and drying cycles continue throughout the season as the crop is irrigated and the soil dries with crop water use and surface soil evaporation. The key to proper irrigation management using soil water sensors is to monitor the sensors regularly, track the soil water level, and irrigate when the kilopascal (1 kPa = 1 cbar) readings are in the desired range for your soil type (See *Table I*; Orloff et al., 2001). Irrigating when the soil water readings exceed the desired range may result in crop stress and yield loss. Irrigation before the readings reach the desired range may result in excessive irrigation, water wastage or runoff.

Table I. Suggested values of soil matric potential at which irrigations should be applied for alfalfa for different soil types.

Soil type	*Average soil matric potential reading of top three sensors (kPa)*
Sand or loamy sand	40-50
Sandy loam	50-70
Loam	60-90
Silt loam	80-100
Clay loam or clay	100-120

Other Considerations

A major consideration when timing irrigation is interference with harvest. Irrigate as close to harvest as possible to meet the peak needs of the crop and have adequate moisture available to start re-growth. Give the soil surface enough time to dry to prevent excess soil compaction during harvest and to prevent hay on the soil surface from absorbing excess water and delaying the drying process. If the surface is too wet at harvest, the soil will be compacted by the harvesting equipment, seriously reducing the soil intake rate for future applications of water.

Although surface irrigation may be easiest just after cutting, the alfalfa plant is most vulnerable to excess water at this time. Irrigating immediately after harvest also may stimulate weed growth. As a general rule, complete irrigation several days before cutting and do not start again until alfalfa re-growth has begun. This full interval may not be possible on soils with low available water-holding capacity or when the irrigation system capacity is limited. During these situations, stop irrigation 2-3 days before the cutting and begin again as soon as hay is removed.

Fall irrigation can be an important management tool on deep, medium-textured soils in the drier areas of the state. Fall irrigation provides good growing conditions prior to winter dormancy and helps the plant build its reserves in the root system, and gives vigorous spring re-growth. The deeper portion of the soil profile can be refilled in this off-season period because peak water use is not placing a demand on the system capacity. Water placed in the deeper portion of the profile will be available during the peak water use period. When water is applied in the fall, avoid excessive applications which can cause water to percolate below the root zone or ponding which, in turn, will cause crop loss.

Because of its deep, well-developed root system, alfalfa can allow the irrigator to use rainfall efficiently. To maintain the best growing conditions and receive the greatest benefit from rainfall, irrigation applications should not exceed three inches (when surface irrigation is used) except for a fall or spring irrigation on deep, medium-textured soils. In eastern Nebraska it is possible to utilize rainfall more effectively if the soil profile is not completely refilled by irrigation. This leaves water-holding capacity in the soil to store rain occurring immediately after irrigation.

For surface irrigation systems using applications of about four inches and two irrigations per cutting will normally be required. Start the first application about five days after cutting and finish the second about five days before cutting. This type of schedule must be adjusted to reflect soil moisture status, crop needs and system capacity. For sprinkler systems, the size of application often will be smaller. Because of the lower application amounts, the irrigation frequency likely will range from three to seven days. However, after crop re-growth has begun to use higher amounts, use up to 3 inches per application if soil infiltration rates will allow, to prevent development of shallow root systems.

Summary

- Alfalfa can be grown on a variety of soils, but deep, uniform, well-drained, medium-textured soils are easiest to manage. Most irrigation systems can be used on alfalfa if designed properly for the site.
- Seasonal water use in Nebraska ranges from 30 to 38 inches, including precipitation, depending on location and weather conditions. The peak daily water use rate of alfalfa will normally range from 0.30 to 0.35 inches during the peak ET month(s) (July and August). The water requirement averages approximately six inches for each ton of hay produced but varies during the growing season.
- For optimum growth, maintain soil water content in the effective root zone between 50 to 70% of the available water holding capacity. Manage irrigations so that the soil is not excessively wet at harvest. For effective irrigation management, monitor soil water status and couple this information with crop water needs and system capacity.
- Excess water causes diseases, reduced growth rate, and loss of stand.
- Effective irrigation management through measurement of soil water status in the soil profile coupled with monitoring crop water use will help to increase crop yield quantity and quality and will help to save water and energy.

References

Orloff, S., B. Hanson, and D.H. Putnam. 2001. Soil Moisture Monitoring: A simple method to improve alfalfa and pasture management. University of California Cooperative Extension.

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Index: Irrigation Engineering
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