ALFALFA IRRIGATION AND DROUGHT

University of Idaho
College of Agricultural and Life Sciences

Glenn E. Shewmaker[1], Richard G. Allen[2], and W. Howard Neibling[3]

[1]Extension Forage Specialist, [2]Professor of Water Resources Engineering, and [3]Water Management Engineer, Kimberly Research and Extension Center, University of Idaho

Water use is high in alfalfa because it has a long growing season, a deep root system, and a dense canopy of vegetation. The amount of water needed for alfalfa production is a function of temperature, wind, humidity, and the amount and intensity of light. The irrigation requirement for alfalfa is determined by rainfall and the water holding capacity of the soils growing the crop. Commonly cited ranges in water requirements for alfalfa are 20 to 46 inches of water per season, depending on climate, elevation, growing season, number of cuttings, latitude, and fall dormancy rating of the alfalfa variety.

Not much water is exported with alfalfa hay. Potential irrigated alfalfa hay yield at elevations near 4000 feet is about 7.5 tons/acre. Hay harvested at 12% moisture removes 240 lbs water/ton hay, or 1,800 lbs/acre for a normal crop of alfalfa hay per year.

Evapotranspiration (ET) is the primary use of water by alfalfa and averages about 36 inches/year (900 mm) at Kimberly. The ET at peak periods of 0.4 inches/day (10 mm/day) can reach 4080 tons of water per acre and 45 tons per acre per day. As shown in Figure 1, adequate center pivot irrigation system capacity is critical for maintaining acceptable soil moisture levels (and yield potential) later in the season. Systems designed and operated to apply less than 7 gallons per minute are not able to match ET and must rely on soil water bank to supply the deficit.

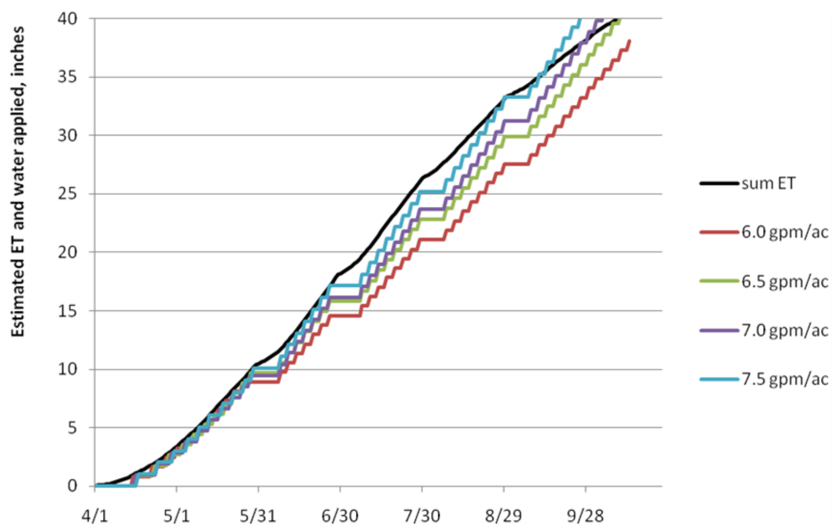

Figure 1. Cumulative estimated ET averaged over 30 years, including cutting effects and irrigation water applied by center pivot at 4 irrigation system capacities for Kimberly, ID conditions. The four horizontal "stair steps" where ET is level result from the harvest periods when it takes a few days for the alfalfa to form new leaves and ET to resume significantly.

Yield response to water applied is linear for alfalfa. Research with non-stressed alfalfa at Kimberly (Wright 1988) suggested a requirement of about 5 inches of water to produce each ton of alfalfa. Figure 2 shows similar effects of ET on yield from several sources. Averaged across sites and cuttings at Oakes, ND (Bauder et al. 1978), Israel (Kipnis et al. 1989), and Las Cruses, NM (Sammis 1981) research suggests 6.6 inches of ET to produce 1 ton of alfalfa hay at 12% moisture (M.E. Jensen, personal communication). Lindenmayer et al. (2011) reviewed 9 studies done in the west and Midwest and concluded that it takes 7.4 inches of ET to produce 1 ton of alfalfa. Some of these studies used older varieties of alfalfa and had less frequent cutting schedules than present. Newer varieties may have different root architecture and growth potential.

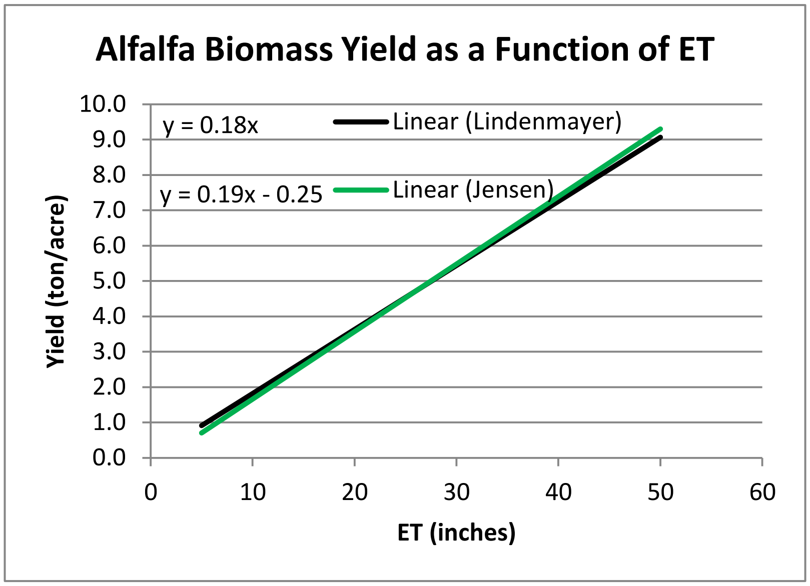

Figure 2. Season-long alfalfa hay yield at 12% moisture as a function of ET from irrigation studies reviewed by Lindenmayer et al. (2011) and Jensen (2001, personal communication).

In some heavier soils, moisture accumulation from previous fall irrigation and normal or better winter and spring precipitation may be sufficient to produce a normal yield for the first cutting, assuming rooting depth is adequate. Sandy soils generally have too little water-holding capacity to produce a full first cutting under Idaho rainfall patterns. In northern California, Hansen (1989) found little response of alfalfa hay yield to applied water for the first cutting because of stored moisture in soil from normal winter and spring precipitation.

Forage yield expressed in tons per acre per inch of water applied is generally higher for the first cutting than other times of the year. In a 4-cut system, the first cutting usually makes up about 35-38% of the year's total forage yield (Fransen et al. 2001), and in a 5-cut system the first cutting contributes about 27% to the total year yield.

Plant stress can occur when available soil moisture decreases below 50% in mid-summer. Water stress results in reduced ET and reduced yield because of reduced carbon dioxide conductance into the leaves. This opportunity can never be "made up" by irrigating more than necessary following the stress! Water applied in excess of ET does not produce extra yield! Under moderate moisture stress, alfalfa plants have the ability to go into a drought-induced dormancy. If the plant has adequate carbohydrate reserves, the plant should survive until moisture is returned. Net photosynthesis (Pn) typically declines with drought due to plants closing stomata and other physiological factors (Boyer, 1976).

Forage yield expressed in tons per acre per inch of ET is highest when the total water supplied to plants via irrigation, precipitation, or shallow ground water approximates evapotranspiration. Application rates vary substantially and should be limited to re-filling the active root zone. Roots can develop and extract water to depths of more than 5 feet in mature alfalfa stands if soil depth and water management strategies allow. Root zone irrigation storage capacity for several soil depths and soil textures is shown in Table 1. Surface irrigation can add several inches per irrigation (about 3 inches on average), depending on furrow flow, row spacing, and set time. Set-move systems commonly apply about 1.5 to 3 inches net per irrigation. Center pivots and linear moves apply about 0.5 to 1 inch per revolution, with depth limited by rate of water infiltration into the soil, water holding capacity, or soil depth. In most soils, center pivot application per revolution is limited to one inch or less to minimize surface runoff and excess wheel track rutting. Given typical soil water holding capacities, this results in re-wetting depths of 12-18 inches in silt loam soils and 20-30 inches in sandy loam soils. Depth of re-wetting can be greater in set or set-move systems because the water application rate is usually less than the infiltration rate of the soil.

Table 1. Maximum irrigation water that can be stored in the active root zone assuming half the available water can be used without water stress (maximum allowable depletion or MAD= 0.5).

Sandy loam (1.7 in/ft * 0.5 = 0.85 in/ft that can be used and refilled)
1 ft→ 0.8 in
2 ft→1.7 in
3 ft→2.6 in
4 ft→3.4 in
Silt loam (2.4 in/ft * 0.5 = 1.2 in/ft that can be used and refilled)
1 ft→1.2 in
2 ft→2.4 in
3 ft→3.6 in
4 ft→4.8 in

Genetics and Varietal Differences

In several studies, the cultivar or variety used had no effect on yield for a given amount of water (Grimes et al., 1992; Donavan and Meek, 1983; Hattendorf et al., 1990; Undersander, 1987). In contrast, yield differences were found among cultivars in the Imperial Valley (Robinson et al., 1994), however, water use data were not available in that study. The listed studies evaluated varieties having a range of fall dormancy ratings from 3 to 9 and found no significant differences in tons per acre per inch of ET for season-long production, although there appears to be some difference in late fall. There is some potential to select varieties with higher production per unit of water use. Varieties with higher yields are commonly taller and have lower leaf to stem ratios than varieties with lower yields under water-stressed conditions at Las Cruces, NM (Ray et al. 1999). Several studies reported that cultivars with the longest roots have lower plant water potentials under moisture stress and produce more herbage than cultivars with shorter roots. The ability to extract water from a larger volume of soil is certainly an advantage in drought; however, rooting depth must be established by proper irrigation water management before the drought occurs.

Deficit Irrigation

Discontinuing irrigation during the hot summer period has been considered as an option to conserve water and increase profitability of alfalfa production in a hot environment having water scarcity (Peterson, 1990; Frate et al., 1991; Ottman et al., 1992). However, studies have shown that termination of irrigation during summer may be associated with permanent reduction in forage yield in alfalfa (Wron, 1992), particularly on sandy soils or if irrigation termination is extended to 12 or more weeks (Ottman et al., 1996). Intolerant alfalfa plants died in the period from 42 to 60 days after irrigation termination near Tuscon, AZ (Wissua and Smith, 1997). Water stress for 60 days during summer caused significant yield loss and death of plants. Wissua and Smith concluded that the drought- tolerant plants were able to maintain a higher sucrose concentration which may have improved the ability to retain water in leaves when under stress. They found that the higher the sucrose and total nonstructural carbohydrate concentrations the lower the crown mortality. Heat stress from 99 °F average air temperatures during the termination period and high respiration rates in the Arizona environment are more severe than conditions at higher elevations and at latitudes having lower air temperatures.

Deficit irrigation imposed after the first cutting reduced yields by 0.6 to 2.2 ton/acre in the Klamath Basin of N. California, while no irrigation after the second cutting reduced yields by 0.31 to 1.23 ton/acre (Orloff and Hanson, 2008).

Lindenmayer et al. (2011) reviewed literature on deficit irrigation and concluded that relative ET declines 30% faster than relative biomass yield under deficit irrigation or dryland management. Because early season harvests often have greater yield to ET ratios, combining full irrigation in spring with no irrigation during less efficient water-use growth periods may be more effective in saving water than continuous, season-long deficit irrigation. Management practices that can influence yield/ET ratios under deficit irrigation include stand age, growth stage at harvest, previous water management, and alfalfa variety.

High ET and Drought in 2013

The weather has been hot and dry during the summer of 2013. Alfalfa peak ET has been above the 23-year average at Kimberly (Figure 3). Alfalfa peak ET exceeded 0.35 inches/day for 22 days by August 14, and on 5 days exceeded 0.4 inches/day (Figure 2). Few pivot sprinkler designs can keep up with ET rates above 0.25 inches/day.

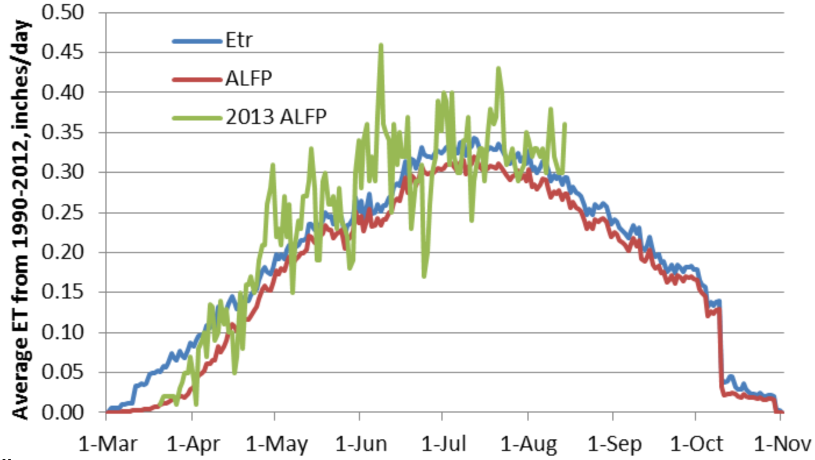

Figure 3. Kimberly Penman ET data from the Twin Falls (Kimberly) AgriMet station. ETr = reference evapotranspiration averaged for 1990 through 2012; (Kimberly-Penman alfalfa reference) from lush, well-irrigated alfalfa at least 1-foot tall. ALFP = alfalfa peak ET averaged for 1990 through 2012, or the "maximum" daily consumptive use for "mature" (uncut) stages of alfalfa growth. 2013 ALFP = alfalfa peak ET for 2013.

Alfalfa Irrigation Recommendations

1. Irrigate early, if the root zone can hold it, during April and May, so that the root zone is nearly full by the end of that period. Pivots should be slowed to the point where the application depth causes a little runoff at the outer span. This will maximize the depth per irrigation, reduce the number of irrigations and therefore, reduce the amount of wasted evaporation from wet leaves and wet soil. Deep irrigations can promote healthy roots in deep soil to take advantage of the soil's water holding capacity. A deep soil capacity can sustain alfalfa growth when irrigation is halted for harvest or when the irrigation application rate does not keep up with ET.
2. Yield response to water application is generally linear, but varies with climate. It takes about 6.6 inches of applied water to produce each ton in arid climates.
3. Maintain the irrigation equipment to eliminate leaks and poor distribution.
4. Use the estimated water consumption provided by the AGRIMET data for irrigation scheduling where possible. http://www.usbr.gov/pn/agrimet/
5. Monitor soil moisture with a soil probe and soil moisture monitoring instruments to determine the water availability in all alfalfa fields on a weekly basis. Continuous monitoring in the effective root zone will indicate soil moisture trends and allow prompt adjustment of irrigation management and avoid costly dry soil conditions.
6. Transpiration through the crop creates yield, not evaporation from water droplets or soil.
7. Dry harvested hay quickly by having a wide windrow, rake at 40% moisture, bale and remove as soon as possible. Weak, yellow and stunted alfalfa plants have lost several days production from photosynthesis while covered with the windrow or bale.

When Irrigation Water is Limited

1. The general recommendation is to provide adequate water until the water is gone, allow the crop to be mature and dry at the time of the last cutting so that the plants will go into dormancy. However, if irrigation water is reduced but available all of the growing season,

deferring irrigation until the temperatures cool in late August and September may be a good strategy (see earlier discussion).

2. Use moderate irrigation rates on fewer acres rather than lightly irrigating all acres. Spreading water on more acres results in lower average tons of hay per inch of water efficiency because a larger percentage of water is evaporated from the soil as compared to what is transpired through the plant. Thus more total alfalfa yield is produced on fewer acres with deficit irrigation.
3. Apply water to the best soils and dry up shallow or marginal irrigation sets.
4. Severe drought and plant death are more likely in sandy soils. Plants will resume growth if the roots and crowns have not dried out. Avoid irrigating drought-induced dormant alfalfa until late in the fall, when lower temperatures will maintain dormancy. This will preserve stored root reserves for winter maintenance and spring growth (Fransen 2001).
5. Replace worn nozzles which can apply up to 50% excess water. Repair leaks which can result in unproductive water losses of up to 30% of system capacity, and shut off inefficient equipment, such as end guns.

Strategies for Applying Less Water

1. Prevent over-irrigation through better management of irrigation water.
   a. Irrigation scheduling helps determine when to irrigate and how much to apply.
   b. For set and set-move irrigation systems: the water balance approach consists of estimating crop evapotranspiration and applying irrigation when accumulated ET is equal to the allowable soil moisture depletion. Amount applied is determined by ET corrected by the irrigation inefficiency.
   c. For pivot and linear systems, the design is probably limiting the system from over-application, and you cannot wait for 50% depletion before irrigating.
   d. The cutting schedule is the major constraint in irrigation scheduling. The soil surface should be dried several days prior to cutting, and then it may be a week before bales are removed. This leaves about a 2-week interval for irrigation between cuttings.
2. Improve the uniformity of distribution and the efficiency of irrigation systems.
   a. No irrigation system can apply water at 100% uniformity. Too much water in one place will increase disease potential, and cause run off or drainage below the root zone.
3. Perform deficit irrigation.
   a. Late fall irrigation may be desirable on low water holding soils because dry soils even during winter may cause stand declines.
   b. Delaying irrigation until a canopy is formed will reduce the evaporation component from the soil and can convert more of the water into transpiration through the plant (Romanko, 2001).
   c. The first cutting has relatively low ET rates coupled with fast growth rates. Mid-summer cuttings occur at maximum growth rates but also with near maximum ET rates. Autumn growth rates are moderate and ET rates are moderate.

Summary

When irrigation water is limited, producers must consider whether short-term yield or long-term stand may be more important. If the goal is to maintain a stand, then soil moisture and plant non-structural carbohydrates must be balanced. Alfalfa plants may die from low soil moisture, or desiccation after 60 days in the heat of the summer, or from low non-structural carbohydrates during late fall and winter. Low non-structural carbohydrates may allow the plant to starve from lack of energy as plant respiration uses the sugars, or the plant could die from lack of cold-hardiness.

Should growers irrigate in the fall after the alfalfa has been dry and dormant during late summer? How much and when? These are questions that will require more research for us to be able to answer. With high hay prices and uncertainty of weather predictions, it may be the most economical to use the water while it is available and plan to rotate crops sooner than normal if the stand declines.

Definitions and Glossary

evapo-	evaporated water from the soil surface
transpiration	water taken up by the roots and evaporated from plant surfaces (primarily leaves)
ET	evapotranspiration, the combined evaporated water from soil and plant surfaces

alfalfa reference ET (ETr) reference evapotranspiration (Kimberly-Penman alfalfa reference); ET from lush, well-irrigated alfalfa at least 1-foot tall
water use efficiency (WUE) dry matter produced divided by the amount of water consumed
ETr - reference evapotranspiration (Kimberly-Penman alfalfa reference)
ALFM - ALFALFA (MEAN)*
ALFN - ALFALFA (NEW PLANT)
ALFP - ALFALFA (PEAK)*
"Peak" chart values represent the "maximum" daily consumptive use for "mature" (uncut) stages of alfalfa and grass hay growth. "Mean" values represent "average" daily use that takes seasonal cuttings into consideration.

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