MEETING ET WITH CENTER PIVOTS

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INTRODUCTION

Large acreages of alfalfa are grown under center pivot irrigation in the western U.S. In most areas, center pivots have become the dominant sprinkler system, due to a number of factors: low labor requirements; allowing individual farmers to irrigate large numbers of acres with high uniformity of water application, remote system monitoring and control ability; and the ability to cover more acres with the same volume of supply water due to high application efficiencies.

However, many farmers have found that alfalfa yield from center pivots may be less than from solid set or set-move systems. To examine possible reasons for the difference in yield, and modifications necessary to center pivot design and operation to improve yield, we need to first examine several characteristics of the alfalfa plant.

IRRIGATION-RELATED PLANT CHARACTERISTICS

Alfalfa is a deep-rooted crop with a tap root structure. As a result, a mature stand on a deep well-drained soil can extract water from depths up to 10 feet as shown in Figure 1. Because of the differences in root structure, alfalfa roots can extract water somewhat uniformly from all depths, as opposed to a fibrous root system where the typical extraction pattern is 40%, 30%, 20% and 10 % in the top to bottom quarters of the active rooting depth (Isrealsen and Hansen, 1962). In a uniform soil with no confining layers, root depth is assumed to be 4 feet for many deep soils in the western U.S. (Ashley et al., 1996). Although roots can extend deeper, the majority of the water appears to come from the top 4 feet of soil. Root depth can be reduced due to the presence of a hardpan layer, rock or a seasonally high water table. If this is the case, sprinkler design and operation must be modified to accommodate these restrictions.

Alfalfa responds linearly to ET within reasonable growing conditions. For example, at Kimberly, ID, approximately 5 inches of ET are required to produce one ton of dry hay (Wright, 1988). Similar relationships have been found for Utah (Hill et al.,1982). Water applied in excess of seasonal ET does not produce increased yields.

As a forage crop, alfalfa is cut several times during the season. After cutting, leaf area is dramatically reduced, thus reducing ET to essentially that from soil evaporation for several days until re-growth starts. ET increases back to maximum over about a 1-2 week period as leaf area increases to a threshold level. Following harvest when leaf area is very low, the crop should not

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be water stressed since the driving force for water movement from soil to plant is by tension forces generated by leaf area. Therefore, smaller leaf area requires more moist soil to avoid water stress. Low leaf area occurs in early spring and following each harvest.

IMPORTANCE OF PROPER DESIGN

One reason for lower yields on pivots when compared to other sprinkler systems or surface irrigation is that the typical design capacity is selected to minimize system cost and stretch water over as many acres as possible. As a result, most pivots are designed to deliver only about 80% of peak ET, as shown in Figure 2. The mid-season water application deficit must be supplied by soil moisture storage, requiring that the entire root zone be filled to field capacity before deficit conditions begin. Although ET is lower following cutting (Figure 2), irrigation must be stopped for a minimum of two weeks, causing the system to fall further behind ET, or at best, just maintain the deficit.

A second and equally important reason deals with the constraints on water application by center pivots. In many soils, application per revolution is limited to about 1 inch to avoid runoff or excess tower tire rutting. Water content between irrigations ranges from field capacity down to about 75 -85 % available water with most pivots. As shown in Table 1, on silt loams or other relatively high water holding capacity soils, 1 inch of net water application can re-wet only to a depth of about 14-20 inches. As a result, deeper wetting is very difficult with a pivot, and rooting depth stops at about 1.5 feet, even on deeper soils unless winter precipitation can fill the root zone deeper.

If pivot capacity can be increased to 8 gpm/ac, as shown in the top horizontal line in Figure 2, the system can meet the average peak ET and therefore be able to catch up at any point during the season. This gives considerable flexibility in system operation, and allows deeper wetting and better utilization of the deep water extraction pattern of alfalfa, allowing access to a larger pool of water, macro and micro nutrients.

Alfalfa ET and several pivot management strategies are shown in Figure 4. All three pivot scenarios start the year with about half the usable moisture that could be stored in a 4-foot root zone. The 6.5 gpm pivot is operated as much as possible (3-day interval at 0.81 inches per revolution) from April 15 until it is stopped for the first cutting of hay the last week in May. The combination of water in the profile and running as much as possible allows the pivot to meet ET for the first and second cuttings. By the third cutting, the alfalfa is under about a 2 inch deficit and by fourth cutting under a 3-inch deficit. By entering first cutting with 5 inches of stored water, the crop yield should be minimally affected. However, the pivot is not able to completely re-fill the root zone until mid-October.

The 6.5 gpm line with no early “water banking” was operated to just match ET until the first cutting and then run as much as possible. As a result of not filling the soil profile before first cutting, the deficits are about 2 inches for the second cutting, 5 for third and 7 for fourth. This illustrates the importance of filling the soil profile before the peak part of the water use season if the pivot cannot keep up during peak use. The pivot cannot re-fill the profile by the end of the season. Ending moisture deficit is about 3 inches even with continuous operation since June 1.

The 8gpm/ac pivot had sufficient capacity that irrigation above ET to bank water was not started until May 1. The soil profile was still full at first cutting and the pivot kept up with ET throughout the season. After 4 th cutting, it was run only half as much as the two other pivots and was able to completely re-fill the root zone before the end of the season.

IMPORTANCE OF MAINTAINING HIGH WATER APPLICATION EFFICIENCY

Maintaining high pivot water application uniformity through attention to detail will give more effective use of water applied and will help meet ET over a larger portion of the irrigated field as shown in Figure 3. Irrigation industry experience has shown that after somewhere around 10,000 hours, pressure regulators on low-pressure pivots tend to stick in one position or suffer serious hysteresis problems and should be replaced. If not replaced, some will give significantly less than design pressure output and some more, creating poor application uniformity. New nozzle packages should always be checked to assure that nozzles are installed in the correct location. As simple as this sounds, it has been a problem in a significant number of cases and produces poor application uniformity until corrected.

PIVOT MANAGEMENT

Even with proper pivot design, correct season-long system management is critical for optimum production. Proper early season management has two major benefits. The first is that initial alfalfa growth is more rapid, with differences apparent all season when adequate water is available as the crop breaks dormancy. Therefore, assure adequate soil moisture at break dormancy.

Also check soil moisture to the maximum anticipated rooting depth before the first spring irrigation. This identifies the presence and extent of any dry soil layers. Soil texture and moisture content then determine the depth of irrigation required to refill the entire rooting depth. Because most pivots cannot “keep up” in mid season, the soil profile must be filled before then. Since wet soil stays cool longer than dry soil, do not completely fill the soil profile until the crop is growing well. The time when extra irrigation should be started depends upon pivot design capacity and the depth of “extra” water to be added, as shown in the above discussion of Figure 4. An added benefit to filling the root zone early is that evaporation losses are lower at this point in the season.

With proper pivot design and management, alfalfa production under a center pivot can be equal, or perhaps better than under solid set or set-move systems. Given the other benefits of center pivots, uniform quality, high-yielding alfalfa can be produced at a bottom-line profit competitive with that of other sprinkler systems.

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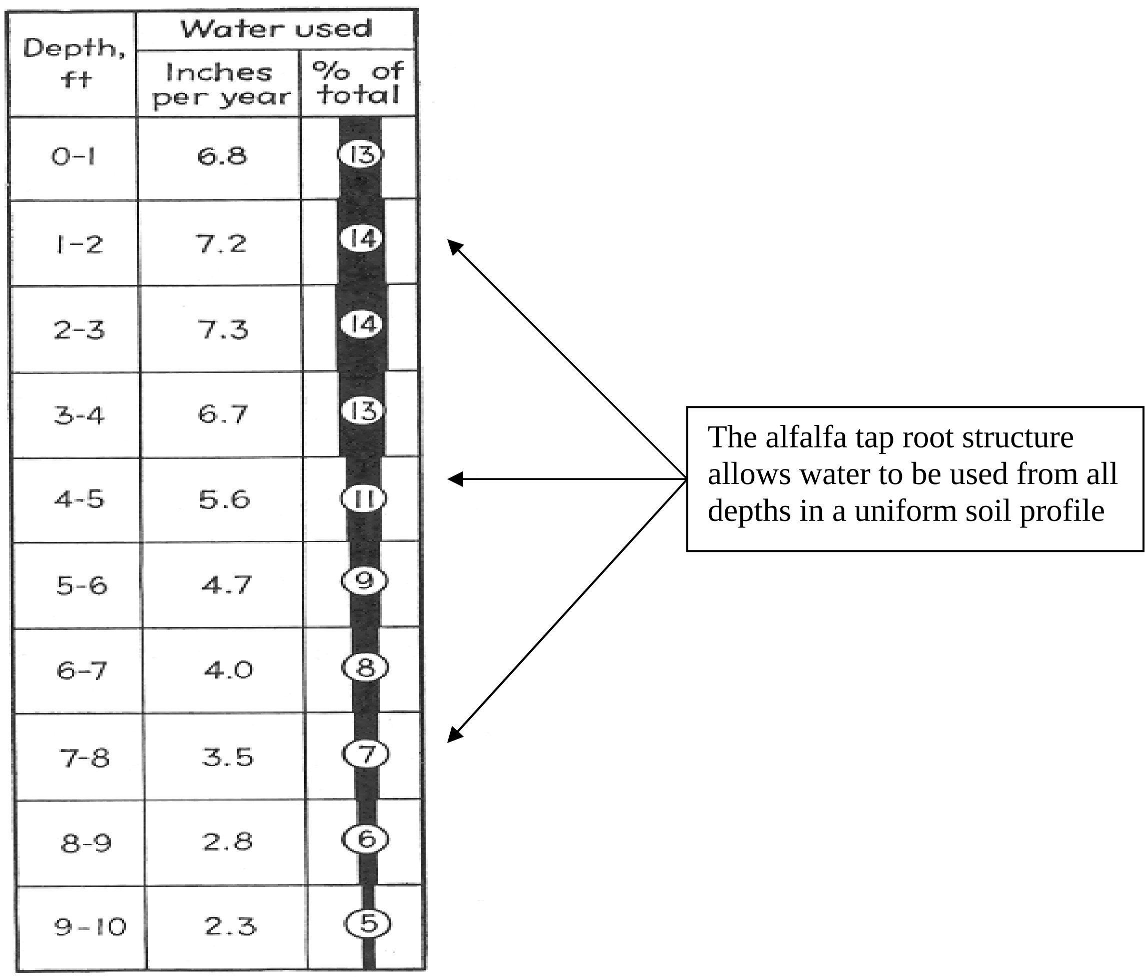

Depth, ft	Water used	
	Inches per year	% of total
0-1	6.8	13
1-2	7.2	14
2-3	7.3	14
3-4	6.7	13
4-5	5.6	11
5-6	4.7	9
6-7	4.0	8
7-8	3.5	7
8-9	2.8	6
9-10	2.3	5

Figure 1. Use of water by alfalfa in Arizona from each foot of the root zone soil (Isrealson & Hansen, 1963).

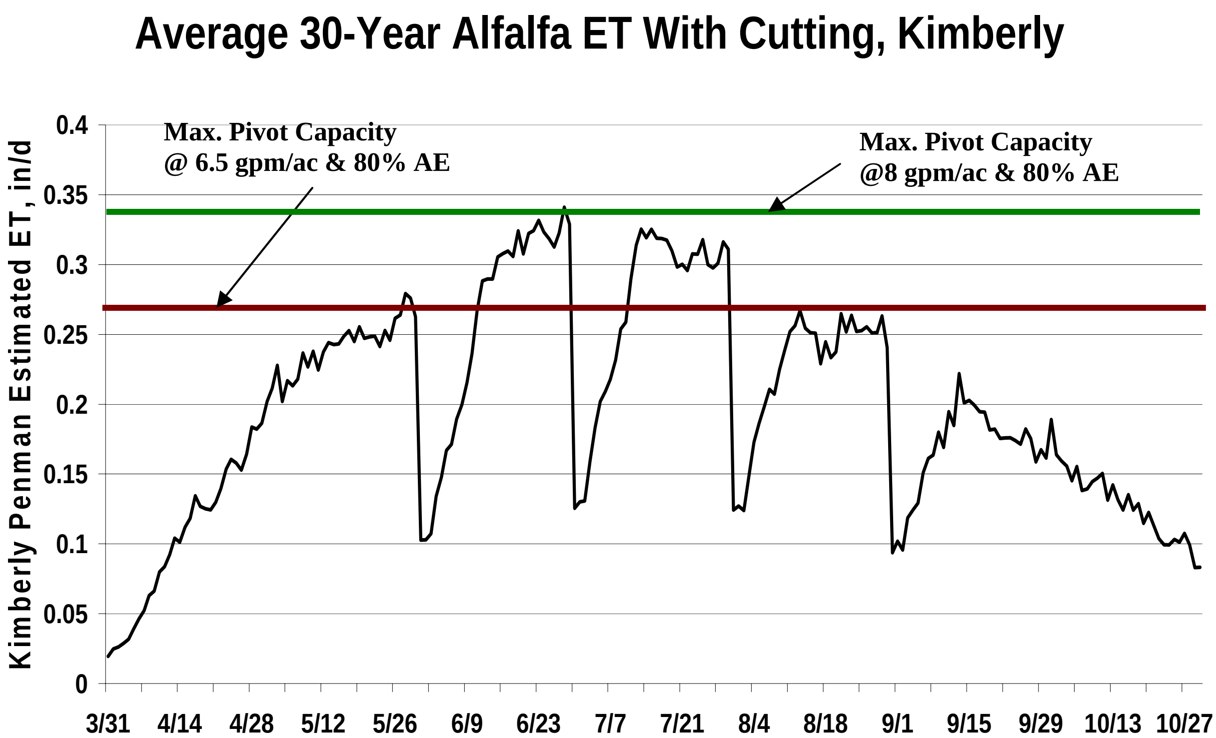

Figure 2. Penman – Wright estimated alfalfa ET for a typical 4-cut system in Southern Idaho.

	Sand	Sandy Loam	Silt Loam	Clay
Average Water Holding Capacity (in/ft)	1.0	1.7	2.1-2.4	2.2
Moisture Content (% depleted)	**Soil Depth (inches)**			
25	48	28	20	22
35	34	20	14	16
50	24	14	10	11
75	16	9	7	7
100	12	7	5	5

Table 1. Depth Penetrated by a 1-inch Net Water Application (assuming uniform soil properties and uniform initial soil moisture with depth) (Neibling and Smith, 1997)

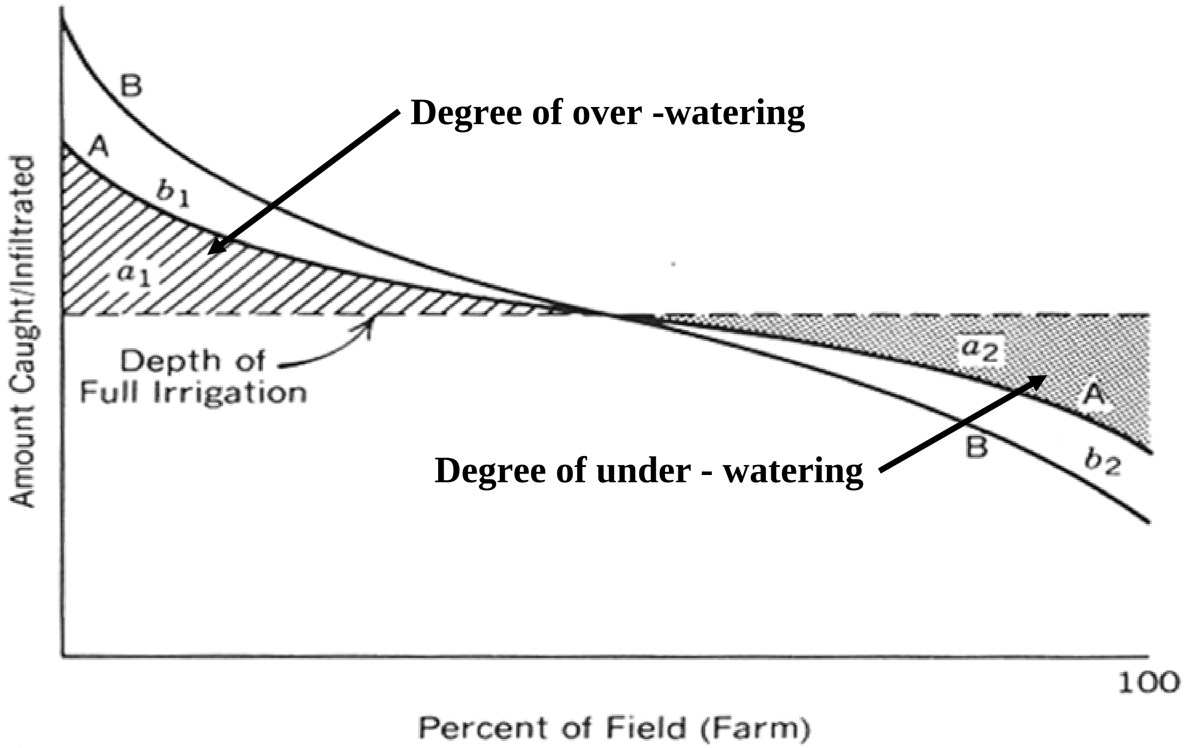

Figure 3. High application uniformity reduces the amount of over and under – watering.

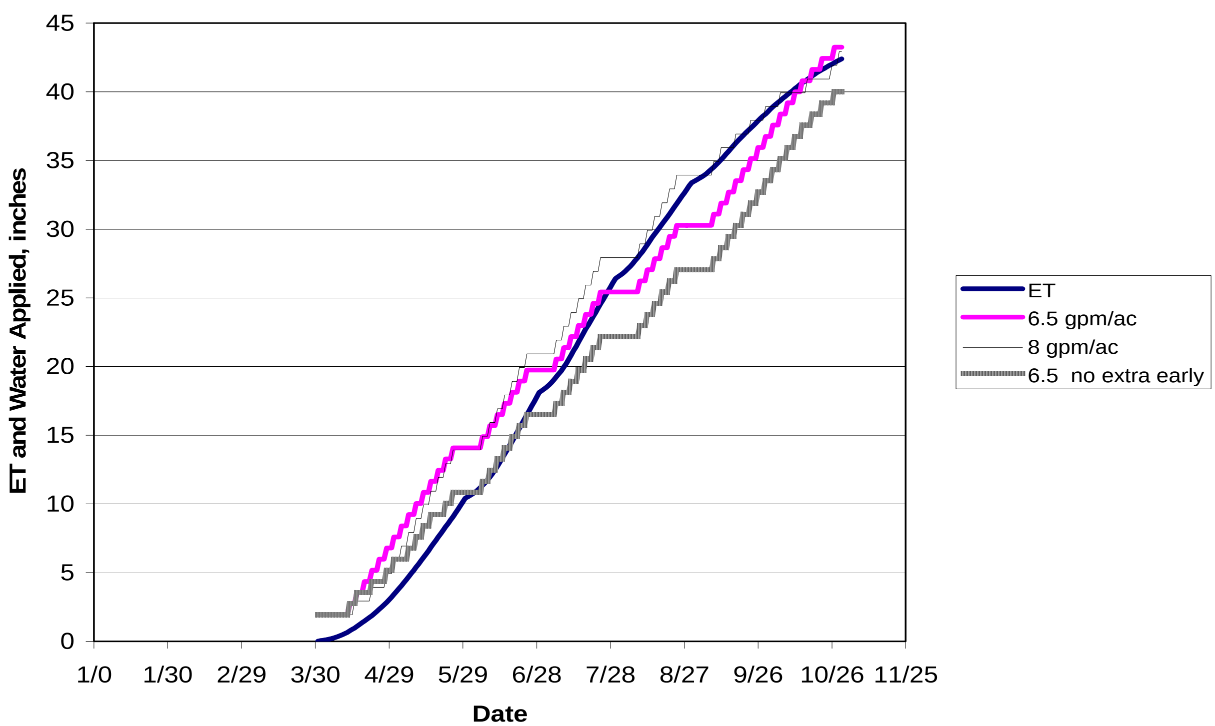

Figure 4. Cumulative 30-year average Penman-Wright ET for Kimberly, ID and cumulative water added by different pivot management strategies.