IMPROVING IRRIGATION EFFICIENCIES THROUGH IRRIGATION CUTOFF STRATEGIES

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ABSTRACT

Alfalfa irrigation water has been diverted to other crops and urban areas in the past. The purpose of this report is to review alfalfa irrigation cutoff studies and to evaluate the economic feasibility of sub-optimal irrigation strategies for alfalfa. Irrigation cutoff studies conducted in Arizona and California have generally shown that skipping irrigations for a few cuttings during the summer have had no long term negative effect, except for one or two cuttings after irrigations are resumed. Stand damage or permanent yield loss was observed in some studies if irrigations were terminated for more than two cuttings or if the study was conducted on a sandy soil. Negative effects of salt buildup or weeds have also been observed. Irrigation cutoff strategies for the August or March cutting become more profitable than normal irrigation when water cost is $20 per acre foot or greater. Irrigating only once per cutting instead of twice for the August and March cutting is not as profitable as not irrigating at all during these cutting cycles.

Key Words: Alfalfa, irrigation, termination, cutoff, stand, yield, water use, irrigation efficiency, profitability.

INTRODUCTION

Irrigated agriculture in general, and irrigated alfalfa production in particular has been criticized as not sustainable or wasteful by those not well informed on the subject. First, irrigated agricultural systems are the most sustainable in the world and have been productive for thousands of years where water and salinity have been managed properly (Jensen et al., 1990). Agriculture and human civilization itself began with irrigated systems. Irrigated agriculture occupies about 24% of the arable land and about 50% of the crop production in the world (Jensen et al., 1990). Irrigated agriculture has a greater relative importance in developing countries than in industrialized nations. Higher productivity from irrigated land may prevent food shortages in developing

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countries in the future. Second, although alfalfa requires about 80% more water than other crops grown in the desert (Erie et al., 1965), this irrigation water is not wasted due to the value of alfalfa as a feed. Animal nutrition and performance is enhanced by alfalfa which is considered the highest quality feed available. The major markets for alfalfa in the desert southwest are the dairy and horse markets. Desert alfalfa production will at least be stable or even increase in the future to meet the expanding demand of the local dairy and horse markets, which is driven by increased population.

Alternatively, alfalfa acreage or the amount of water applied to alfalfa may decrease in the future due to increased water costs or municipal water demand. For many years, irrigation water intended for alfalfa has often been diverted by farmers to other crops such as cotton or vegetables since alfalfa can withstand some water stress due to its perennial and deep rooted nature. Recently, alfalfa irrigation water has also been diverted to municipalities during the summer. Alfalfa irrigation practices have been studied in the past and should continue to be studied in the future for economic and water conservation considerations.

The purpose of this paper is to review previous research on irrigation cutoff strategies and to suggest how these strategies may be economical with increasing water costs.

IRRIGATION CUTOFF STUDIES

Alfalfa irrigation strategies have been the subject of research for several decades. Sub-optimal irrigation strategies for alfalfa include irrigating with less water each cutting or not irrigating at certain cuttings. These type of studies have been conducted in western states and in the Mediterranean area. I will concentrate on irrigation cutoff studies, rather than deficit irrigation studies, conducted in Arizona and California in the review that follows.

Arizona

Some of the earliest research on alfalfa irrigation cutoff during the summer was conducted at Mesa, AZ, by Schonhorst et al. (1963). In this study, stands were actually enhanced if alfalfa irrigation was cutoff during the summer for two cuttings. Yields recovered when irrigations were resumed. Schneiter (1973) conducted a similar study in Tucson, AZ and found that stands and subsequent yields were not damaged by withholding irrigation water during the summer. Ottman et al (1996) conducted irrigation cutoff studies at Maricopa and Yuma, AZ. Two irrigation cutoff strategies were imposed at the Maricopa location: 1) Summer termination - irrigation terminated from August through September and 2) Summer, fall, and winter termination - irrigation terminated from August through March. Neither of these termination strategies affected stand. Yields following the summer termination treatment were not affected the first year but, in the second year, were 67% of the control the first cutting after irrigations were resumed and 85% of the control the second, and similar thereafter. The summer, fall, and winter termination strategy resulted in reduced yields for most cuttings even after irrigations were resumed. Summer irrigation termination (July through October) at the Yuma location resulted in severe stand loss (33% of the control) and permanent productivity damage. Winter irrigation termination (November through February) had no effect on stand and reduced yield 41%. Stand loss occurs when crown moisture content drops below 40% according to Wissuwa (1996) and can be used as an guideline of when to re-irrigate alfalfa to avoid permanent damage.

California

Frate et al (1988) conducted an irrigation cutoff study in the San Joaquin Valley where treatments included irrigating once per cutting, skipping irrigations in July and August, and terminating irrigation in July until the following year. Irrigating only once per cutting resulted in 87% of the yield of the control averaged over years. For both the July/August irrigation skip and the July termination, yields recovered the second cutting after irrigations were resumed. Robinson et al. (1995) recently conducted on excellent study on irrigation cutoff strategies in the Imperial Valley. The treatments included one instead of two irrigations during August and September (minimum), no irrigations during August and September (short), and no irrigations in July through September (long). Stands were not affected by cutoff strategy the first and second years presumably due to reliance on subsoil moisture during the termination period, but were severely reduced the third year. Hay yields generally rebounded by the second cutting after irrigations were resumed except the during the third year where modest yield reductions were noted. Soil salt buildup occurred with the irrigation cutoff treatments (short and long) that were not corrected until after a sudangrass crop following the alfalfa. The irrigation cutoff treatments also experienced increased weed pressure.

IRRIGATION AND WATER USE EFFICIENCY

Irrigation cutoff strategies have resulted in greater irrigation efficiency or more forage produced per unit of water applied (Schonhorst et al., 1963; Frate et al., 1988; Ottman et al., 1996). However, irrigation efficiencies have also been decreased by irrigation cutoff strategies if yields after irrigations are resumed are permanently damaged (Ottman et al., 1996). Reduced irrigation can increase irrigation efficiencies since in typical systems, some parts of the field are overwatered so other parts can receive sufficient water amounts due to field non-uniformity.

Water use efficiency is generally reduced by irrigation cutoff strategies (Grimes, 1992; Robinson et al., 1995). Water use efficiency is the amount of forage produced by a certain amount of water consumed by the plant (as opposed to applied as irrigation water mentioned above). Alfalfa yields increase proportionately to water consumption (Grimes, 1992) but a certain amount of water is required before any forage is produced at all. Therefore, water use efficiencies will always be greater at higher water consumption levels.

PROFITABILITY OF IRRIGATION CUTOFF

Revenue from alfalfa production in the low elevation desert based on average yields and historical prices is $181 per acre (Table 1). The yield assumed of 8 tons per acre per year is an average yield of Yuma, LaPaz and Maricopa Counties in Arizona from 1989-1993 (Sherman et al., 1994). The hay price is based on monthly prices from Yuma County averaged over 16 years from 1980-1995. The variable costs are custom rates from Arizona Field Crop Budgets (Wade et al., 1995). Establishment, fertilizer, and weed control (treflan) costs are distributed over all cuttings. Ownership and fixed costs are about $192 per acre so that total return is close to zero. This analysis assumes that water cost is $10 per acre foot, which is typical of the lower Colorado River area but low compared to other project water and pump water. Water costs in other areas can be as high as $50 per acre foot, but alfalfa production becomes marginal if water costs exceed $30 per acre foot. The spring cuttings are most profitable as expected because of higher yields and hay prices compared to other times of the year.

The economics of not irrigating the August cutting is presented in Table 2. In this scenario, we assume the alfalfa will not grow without irrigation water (Ottman et al., 1996), no harvesting is necessary, spraying for the beet armyworm or other insects in August is not necessary, and that no yield loss is incurred in the subsequent cutting when irrigation is resumed. In this case, $14 per acre is lost instead of $7 per acre if irrigated and water costs $10 per acre foot. Even though there are no growing expenses in this example, the $14 loss is from establishment, weed control, and fertilizer costs.

If irrigations are cutoff in the winter from December to March, a gain of $1 is realized for the March 1 cutting instead of a gain of $4 per acre if irrigated (Table 3). This analysis assumes that rainfall and subsoil moisture will supply enough water for yield to be 59% of the fully irrigated yield (Ottman et al., 1996), winter broadleaf weed control will not be necessary, control of the Egyptian alfalfa weevil will not be required, the hay will be discounted $19 per ton due to poor quality from weeds and weevil feeding, and that yields will recover in subsequent cuttings once reirrigated. Harvest costs are incurred in this example, but no other growing costs such as irrigation or chemical application. Water cost is assumed to be $10 per acre foot.

In the third example, one instead of two irrigations are applied for the August cutting and for the March cutting. This is the least economical strategy since returns are $19 per acre less than if two irrigations were applied at these cuttings assuming water costs $10 per acre foot (Table 4). In this example, all production costs of full irrigation are incurred and hay yield is assumed to be 72% of normal in the August cutting (Robinson et al., 1995) and 80% of normal in the March cutting (Frate et al., 1988; Ottman et al., 1996).

Water costs have a big influence on the profitability of these irrigation cutoff strategies (Table 5). Suboptimal irrigation becomes more profitable as water costs rise. Summer or winter cutoff is more profitable than normal irrigation using our assumptions if water costs are $20 per acre foot or greater. Irrigating once instead of twice for the August cutting and the March cutting was more profitable than normal irrigation only if water cost is $30 per acre foot or more. The profitability of irrigation cutoff strategies is also influenced by yield, hay price, growing costs, or other assumptions. In these examples, we have considered profitability to be return over operating costs. The outlook for hay production is more grim if we consider return over total cost including fixed cost, in which case irrigation cutoff strategies would still lose less money as irrigation costs increase compared to normal irrigation.

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Table 1. *No irrigation cutoff*: Revenue, variable costs, and return.

Item	01 Mar	15 Apr	21 May	21 Jun	21 Jul	21 Aug	01 Oct	01 Dec	Sum
<u>Revenue</u>									
Yield (T/A)	0.89	1.10	1.35	1.49	1.08	0.81	0.65	0.63	8.00
Price ($/T)	99	99	91	77	71	70	79	95	---
Value($/A)	88	109	123	115	77	57	51	60	680
<u>Variable Costs</u>									
Irrigate	10	10	10	10	10	10	10	10	80
Harvest	31	33	37	39	33	29	27	27	256
Insect	14	11	0	0	0	11	0	0	36
Herbicide	15	0	0	0	0	0	0	0	15
Other	14	14	14	14	14	14	14	14	112
Total	84	68	61	63	57	64	51	51	499
Return ($/A)	4	41	62	52	20	-7	0	9	181

Yield is calculated from eight alfalfa trials conducted by the University of Arizona. Price is the average hay price from 1980-1995 in Yuma County, AZ. The irrigation cost of $10 per acre is assumed and can be variable. Harvest costs include swathing ($15/A), raking ($3/A), baling ($10/T), and roadsiding ($4/T). Insecticide applications are for Egyptian alfalfa weevil (01 Mar), aphids (15 April), and beet armyworm (21 Aug). Herbicide application for the 01 Mar cutting is for broadleaf weeds. The other category includes establishment, fertilizer, and herbicide (treflan) costs. Fixed costs are $24 per cutting.

Table 2. *Summer cutoff* (21 Jul to 21 Aug): Revenue, variable costs, and return.

Item	01 Mar	15 Apr	21 May	21 Jun	21 Jul	*21 Aug*	01 Oct	01 Dec	Sum
<u>Revenue</u>									
Yield (T/A)	0.89	1.10	1.35	1.49	1.08	*0.00*	0.65	0.63	7.19
Price ($/T)	99	99	91	77	71	*70*	79	95	---
Value($/A)	88	109	123	115	77	*0*	51	60	623
<u>Variable Costs</u>									
Irrigate	10	10	10	10	10	*0*	10	10	70
Harvest	31	33	37	39	33	*0*	27	27	227
Insecticide	14	11	0	0	0	*0*	0	0	25
Herbicide	15	0	0	0	0	*0*	0	0	15
Other	14	14	14	14	14	*14*	14	14	112
Total	84	68	61	63	57	*14*	51	51	449
Return ($/A)	4	41	62	52	20	*-14*	0	9	174

Assumptions: The alfalfa will not grow without irrigation water (Ottman et al., 1996), no harvesting is necessary, spraying for the beet armyworm or other insects in August is not necessary, and that no yield loss is incurred in the subsequent cuttings when irrigation resumes.

Table 3. *Winter cutoff* (01 Dec to 01 Aug): Revenue, variable costs, and return.

Item	*01 Mar*	15 Apr	21 May	21 Jun	21 Jul	21 Aug	01 Oct	01 Dec	Sum
Revenue									
Yield (T/A)	*0.52*	1.10	1.35	1.49	1.08	0.81	0.65	0.63	7.63
Price ($/T)	*80*	99	91	77	71	70	79	95	---
Value($/A)	*42*	109	123	115	77	57	51	60	634
Variable Costs									
Irrigate	*0*	10	10	10	10	10	10	10	70
Harvest	*27*	33	37	39	33	29	27	27	252
Insecticide	*0*	11	0	0	0	11	0	0	22
Herbicide	*0*	0	0	0	0	0	0	0	0
Other	*14*	14	14	14	14	14	14	14	112
Total	*41*	68	61	63	57	64	51	51	456
Return ($/A)	*1*	41	62	52	20	-7	0	9	178

Assumptions: Rainfall and subsoil moisture will supply enough water for yield to be 59% of the fully irrigated yield (Ottman et al., 1996), winter broadleaf weed control will not be necessary, control of the Egyptian alfalfa weevil will not be required, the hay will be discounted $19 per ton due to poor quality from weeds and weevil feeding, and that yields will recover in subsequent cuttings once reirrigated.

Table 4. *One irrigation per cut summer (21 Jul - 21 Aug) and winter (01 Dec - 01 Mar)*: Revenue, variable costs, and return:

Item	*01 Mar*	15 Apr	21 May	21 Jun	21 Jul	*21 Aug*	01 Oct	01 Dec	Sum
Revenue									
Yield (T/A)	*0.71*	1.10	1.35	1.49	1.08	*0.58*	0.65	0.63	
Price ($/T)	*99*	99	91	77	71	*70*	79	95	
Value($/A)	*70*	109	123	115	77	*41*	51	60	
Variable Costs									
Irrigate	*5*	10	10	10	10	*5*	10	10	70
Harvest	*29*	33	37	39	33	*26*	27	27	251
Insecticide	*14*	11	0	0	0	*11*	0	0	36
Herbicide	*15*	0	0	0	0	*0*	0	0	15
Other	*14*	14	14	14	14	*14*	14	14	112
Total	*77*	68	61	63	57	*56*	51	51	484
Return ($/A)	*-7*	41	62	52	20	*-15*	0	9	162

Assumptions: All production costs of full irrigation are incurred and hay yield is 72% of normal in the August cutting (Robinson et al., 1995) and 80% of normal in the March cutting (Frate et al., 1988; Ottman et al., 1996).

Table 5. Influence of irrigation water cost on return over variable cost for various irrigation strategies.

Irrigation strategy	Cost of Irrigation water ($/acre-foot)				
	10	20	30	40	50
	---------- Return over variable cost ($/acre) ----------				
No cutoff	181	101	21	-59	-139
Summer cutoff	174	104	34	-36	-106
Winter cutoff	178	108	38	-32	-102
One irrigation per cut in Aug and Mar	162	92	22	-48	-118