Controlled Deficit Irrigation of Alfalfa (*Medicago sativa*): A Strategy for Addressing Water Scarcity in California

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Abstract

Alfalfa (*Medicago sativa*) uses approximately 18.7% of California's agricultural water, a larger percentage than any other single crop. Reduced water availability for agriculture is probable in the coming years, driven by urbanization and environmental demands. Therefore, examination of deficit irrigation strategies is warranted. More information is needed to determine the most profitable irrigation strategy to produce alfalfa with inadequate water supplies. Large-scale field trials were established in the Klamath Basin (California and southern Oregon) and the Sacramento Valley in 2003 to evaluate the effects of early-season irrigation cut-off (deficit irrigation) on yield, forage quality, stand persistence and economics. Results of these field trials showed severe yield loss when irrigation was halted in summer in some cases, but only slight losses in yield in other cases. There appeared to be little to no stand loss in these trials, but it was too early to make an accurate assessment. However, stand losses have been observed in other trials, particularly in the low desert. Research in this area is ongoing. Preliminary results suggest that the concept of temporary voluntary water transfers from alfalfa may have merit. The desirability of this practice from a grower's perspective will depend largely upon economic incentives and the potential for such strategies to sustain long-term alfalfa production on farms.

Media summary

Deficit irrigation of alfalfa—withdrawing irrigation water part way through the season—could provide a partial solution to water shortages in California during drought years.

Key Words

Irrigation management, water conservation, water transfers

Introduction

The "Achilles heel" of alfalfa production in California, and throughout most of the Western US, is unquestionably the crop's water use. Many outside the alfalfa industry criticize the crop for it high water use and even consider alfalfa production to be a misuse of this precious resource. Most don't understand or appreciate the value of alfalfa production which is inextricably linked to the multi-billion dollar dairy industry in California. Additionally, most critics do not realize that the water-use-efficiency of alfalfa is actually very high—higher than that of most other crops (Putnam et al., 2001).

In most years alfalfa receives more irrigation water than any other California crop. According to Department of Water Resources (DWR) 2000 estimates, 18.7% of the irrigation water used in the state is typically applied to alfalfa. The actual percentage varies depending on the watershed—in the major agricultural areas of the state, alfalfa's share of the irrigation water varies from approximately 8% to as high as 50% in the south Lahontan and Colorado River watersheds in the Low Desert. Irrigation water applications to alfalfa range from 610 to over 2540 mm per year, depending primarily on the region where the crop is grown (DWR estimates). A total of approximately 4.9 to 6.8 billion m^3 of water are applied to alfalfa in CA each year, depending on alfalfa acreage that year, weather patterns, and method of estimation. This amount of water is applied to alfalfa because of the number of hectares of alfalfa (typically over 400,000 ha in California) and its long growing season compared with other crops.

Short-Term Voluntary Water Transfers

Water transfers, from agriculture to urban use or for environmental mitigation are discussed by water agencies as the primary method to deal with droughts. Most discussions revolve around the complete fallowing of agricultural land with transfer of the agricultural water saved as a result. However, complete suspension of irrigation water by fallowing of large acreage can have devastating and long-lasting consequences on the farm economy of an area. An alternative approach could be to provide a mechanism so that interested alfalfa growers could voluntarily transfer some irrigation water (typically in summer and fall) for environmental uses in drought years and receive compensation. After a season of imposed deficit irrigation, they could resume full irrigation in normal or above normal precipitation years. While alfalfa requires full irrigation for maximum yield, it is relatively drought tolerant and can usually tolerate periods of drought. Spring cuttings would be harvested, which are typically higher in yield and forage quality than summer cuttings (http://alfalfa.ucdavis.edu/variety.html). This approach allows some forage production and economic viability of alfalfa in the face of drought and water transfers and avoids many of the problems associated with complete fallowing.

Methods

Field trials were established in the Klamath Basin and in the Sacramento Valley of California to provide answers to critical questions about the economic and agronomic viability of water savings resulting from deficit irrigation of alfalfa. Ongoing trials were established in the summer of 2003 to assess the effects of early season irrigation cut-off. Two trials were conducted in producer fields in each location. These sites differ dramatically in numbers of cuttings (3-4 for Klamath, 6-7 for Sacramento Valley) and climate.

The Klamath trial was conducted at two locations with vastly different soil types (a fine sandy loam and a silt loam with high organic matter content). Klamath Basin sites were sprinkler irrigated. There were three irrigation treatments: 1) normal full-season irrigation, 2) no irrigation after first cutting, and 3) no irrigation after second cutting. There were three cuttings at the sandy loam site and 4 cuttings at the silt loam site. The Sacramento Valley trials were conducted on two growers' fields in Yolo County (referred to as Sites 1 and 2), both clay loam soils susceptible to cracking. Both sites were flood irrigated and the irrigation treatments were applied to entire border strips. Treatments were: 1) normal full-season irrigation, 2) irrigation cut-off in mid summer (summer dry down), and 3) summer dry down with resumption of irrigation in fall.

Soil moisture content was assessed every 2 weeks after the first irrigation cut-off occurred (data not shown). Yield was measured for each cutting after the irrigation treatments were imposed with a flail-type forage harvester. Forage quality (ADF, NDF, and CP) was determined for all treatments at each harvest using near-infrared reflectance (NIR).

Results

Klamath Basin Studies Soil moisture showed a gradual decline after irrigation water was withdrawn (data not presented here). Both Klamath Basin locations had a relatively high water table—wet soil occurred at about 1 m at the sandy loam location and about 1.2 m at the silt loam location. Considerably more water was applied at the silt loam site than the sandy loam site, reflecting differences in grower irrigation practices. The sandy loam soil was irrigated once between cuttings with approximately 140 mm of water per irrigation. The silt loam site was irrigated one to two times per cutting and received an irrigation in mid-October after the harvest season was completed. Therefore, the water savings associated with the irrigation cut-off treatments varied considerably between the two locations. Two hundred eighty mm and 530 mm of water were saved with the irrigation cut-off after 1st cutting for the sandy loam and silt loam sites, respectively. This represents a considerable reduction in the total amount of applied water, as most alfalfa fields in the Klamath Basin are only irrigated one or two times before first cutting.

The yield reduction resulting from irrigation cut-off was not severe in the Intermountain (Malin) area (Table 1). The fine sandy loam site was an older field with lower yield potential. Irrigation termination after 1st cutting reduced yield by 1.35 Mg ha^{-1} over the 2nd and 3rd cuttings. Ceasing to irrigate after 2nd cutting reduced 3rd cutting yield by 0.65 Mg ha^{-1}. The silt loam site was a younger alfalfa stand with higher yield potential. Second cutting yield declined from 2.78 to 2.13 Mg ha^{-1} when irrigation was ceased. Third cutting yield was decreased from 3.05 Mg ha^{-1} to 2.53 and 2.69 Mg ha^{-1} when water was withdrawn before 2nd and 3rd cuttings, respectively. The total yield reduction from cutting water off at 1st cutting was 1.61 Mg ha^{-1} and cutting water off after 2nd cutting resulted in a yield reduction of 1.18 Mg ha^{-1}. For practical purposes the yield reduction may be more than that indicated in these studies. It may not be justified for a producer to harvest a cutting that is less than 1 Mg ha^{-1} because the income from such a small harvest may not cover harvesting costs.

This yield reduction is not severe considering the amount of water saved. The high water table probably supplied some of the water needs of the alfalfa during the latter half of the season in the deficit-irrigated treatments. These results may be typical for locations in the intermountain region with a relatively high water table. However, the yield reduction would probably be greater at sites without a high water table. The alfalfa from each of the cuttings was analysed to determine the effect of the deficit irrigation treatments on alfalfa forage quality. There was no statistically significant effect on forage quality at both intermountain locations (data not shown).

Table 1. The effect of irrigation cut-off on subsequent alfalfa yield on a fine sandy loam soil and a Capjac silt loam soil, Malin, OR and Tulelake, CA, respectively.

	Fine sandy loam Malin			Silt loam Tulelake			
	2nd Cut	3rd Cut		2nd Cut	3rd Cut	4th Cut	
Irrigation Treatment	7/22/03	8/30/03	Total	7/4/03	8/5/03	9/11/03	Total
	Mg/ha^{-1}						
Normal full-season irrigation	2.31	1.50	3.81	2.78	3.05	2.71	8.53
No irrigation after 1st cutting	1.97	0.49	2.46	2.13	2.53	2.26	6.92
No irrigation after 2nd cutting	2.31	0.85	3.16	2.73	2.69	1.93	7.35
LSD 0.05	NS	0.40	0.76	NS	NS	0.74	1.48

Sacramento Valley Studies Since these sites were surface irrigated using border-strip flood, irrigation treatments were imposed by preventing water entry into entire irrigation checks. Water application data from Site 1 were unavailable when this paper was submitted. At Site 2, a total of 850 mm of water were saved when no irrigation water was applied after the 3rd cutting. The treatment where irrigation resumed after 5th cutting resulted in a water savings of 600 mm. However, this is likely an over-estimate of the actual amount of water saved for this treatment. Application rates were calculated based on the amount of water applied to the entire field assuming that each check received the same amount of water. However, a larger quantity of water would be needed to rewet areas where water was withheld in mid-summer.

There was a much more dramatic yield response to irrigation cut-off at both of the Sacramento Valley sites than at the Intermountain sites. Yield for the harvest immediately after irrigation water was withdrawn decreased from 2.50 Mg ha^{-1} for normal irrigation to 0.85 Mg ha^{-1} without irrigation at Site 1 (Table 2). When irrigation resumed, yield rebounded somewhat for the following cutting (1.03 Mg ha^{-1} where irrigation resumed versus 0.52 Mg ha^{-1} without irrigation) but was still approximately half of that of the fully irrigated plots (1.90 Mg ha^{-1}). An even more severe drop in yield occurred at Site 2—yield decreased from 3.49 to 0.78 Mg ha^{-1} and from 3.02 to 0.56 Mg ha^{-1} for the 4th cutting and 5th cuttings, respectively, when irrigation water was withdrawn. At this site when irrigation was resumed yield fully recovered for the 6th cutting.

Table 2. The effect of deficit irrigation treatments on subsequent alfalfa yield on two clay loam sites in Yolo County, CA (Sacramento Valley).

	Clay loam Site 1			Clay loam Site 2			
	5th Cut	6th Cut		4th Cut	5th Cut	6th Cut	
Irrigation Treatment	8/29/03	10/6/03	Total	8/6/03	9/8/03	10/23/03	Total
Normal full-season irrigation	2.50	1.90	4.40	3.49	3.02	1.90	8.42
Irrigation cut-off in mid summer	0.85	0.52	1.37	0.78	0.56	0.94	2.28
Irrigation cut-off in mid summer with fall irrigation	0.83	1.03	1.86	0.60	0.36	2.15	3.11
LSD 0.05	0.43	1.37	1.75	0.63	0.38	1.39	1.25

The deficit irrigation treatments had a large effect on the forage quality at both Sacramento Valley locations. For every cutting except the 6th cutting at Site 2, the deficit irrigated plots averaged lower fiber (both ADF and NDF) than the normally irrigated plots. There was a major difference at some cuttings—often between 5 and 7 percentage points ADF or NDF. There was no increase in CP associated with deficit irrigation. While this reduction in fiber concentration with deficit irrigation is of interest, the yield decrease associated with the deficit irrigation treatments is excessive. The reason why there was a significant forage quality difference due to deficit irrigation at the Sacramento Valley locations and not the Intermountain locations may be due to the degree of the yield reduction.

Conclusion

The studies showed a yield reduction of 1.35 and 1.61 Mg/ha^{-1} at two Intermountain locations when irrigation was withdrawn after 1st cutting. In the Sacramento studies yield was reduced 3.03 and 6.14 Mg ha^{-1} when irrigation was completely withdrawn in August. While more research is clearly needed, analysis of the concept and initial results suggest that deficit irrigation of alfalfa could provide a partial solution to water shortages in drought years. Alfalfa growers are typically sceptical of proposed irrigation strategies which may result in water savings, since experience has taught them that urban and other elements may use such ideas in a ‘no holds barred’ effort to permanently transfer ag water for other uses. Under voluntary water transfer agreements, deficit irrigation strategies for alfalfa may provide opportunities for growers to provide relief for other uses and still maintain on-farm profitability and sustain agriculture and food production for the benefit of all communities.

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