16th Annual

IRRIGATION CONFERENCE

FEBRUARY 9, 1984
Columbia, Missouri

PROCEEDINGS

OF

THE SIXTEENTH ANNUAL IRRIGATION CONFERENCE

FEBRUARY 9, 1984

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COLUMBIA, MISSOURI

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FOREWORD

We wish to thank the following co-sponsors for their financial contribution to the 1984 Irrigation Conference:

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Thanks to their contributions, the 1984 registration fees were not increased over the previous year's; thus, the participants were the beneficiaries of the industry and association contributions (approximately $10 savings for each registrant).

Thanks, also, to the exhibitors, whose fees help support the Conference plus contributing to the educational aspects of the Conference.

Missouri's irrigators and irrigation equipment suppliers have now endured four years of floods, drought, high interest rates and relatively low prices for agricultural products. Even though irrigation produced much greater yields than dryland in the unusually hot and dry years of 1980 and 1983, many irrigators were unable to recoup all the costs of production.

Thus, the theme "PLANNING FOR PROFIT" was chosen for the Sixteenth Irrigation Conference. Planning for profit should include a systematic scheduling procedure plus available water and equipment capacity to apply water at a rate sufficient to prevent undue crop stress. Also, water should not be applied when benefits will not exceed the cost of application or actually cause a reduced yield, e.g., soybeans may be irrigated at a stage when excessive growth and decreased yields result.

We hope you will find useful information in this Proceedings.

CONFERENCE PLANNING COMMITTEE

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MANAGING IRRIGATED ALFALFA

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The acreage of alfalfa is again increasing in Missouri following several years during the mid-1970s when it reached a low of about 0.5 million acres. The increase is due, in part, to learning to cope with and control the alfalfa weevil. In general, however, those farmers that were diligent in producing alfalfa also learned that improvement of other management practices such as phosphorus and potassium fertilization, leaf-hopper control, weed control, and cutting frequency was also beneficial. Today the economic analyses for Missouri show alfalfa is ranked second behind soybeans in monetary return per acre. This ranking occurs due to the high yield, and especially the premium paid for the high quality forage that is produced by this perennial forage crop.

When managing a crop such as alfalfa in Missouri one needs to consider the relative impact of each management decision on yield of forage, quality of the forage produced, and especially persistence of the stand. In general, there has been a lot of emphasis on yield and quality, which is good, but there is a growing concern in the lower corn belt about placing more management emphasis on persistence. This is especially the case because of the high cost of establishing crops such as alfalfa. Persistence is also of greater importance when alfalfa is grown on sloping sites that are subject to erosion when tilled, and on shallow, rocky soils where seedlings are subject to drought stress during the early establishment period.

Managing alfalfa that is irrigated is quite similar to managing alfalfa that is not irrigated except that yields are higher, fertilizer needs are greater, and the plants may need to be harvested more frequently. Forage quality is probably improved somewhat by irrigation because leaf retention is improved and the air and soil temperatures in the immediate vicinity of the plants are reduced.

Harvesting the First Cutting

Management systems for harvesting the first two cuttings in Missouri tend to be similar, whether or not the field is irrigated. Recommendations for date or stage of growth for cutting the first crop show a great deal of variation from state to state, and need to be fine-tuned relative to the intended use of the forage. It is generally recognized that forage quality decreases during the growth period (Table 1) such that *in vitro* dry matter digestibility decreases as temperature in spring increases and the plants mature. On the other hand, ability of the plants to recover quickly after cutting improves when the plants are allowed to become more mature before

Table 1. Relationship of calendar date to stage of growth for alfalfa at the Southwest Center near Mt. Vernon, and at the Agronomy Research Center near Columbia. Data for *in vitro* dry matter disappearance (digestibility) are for the Columbia dates.

Southwest Center		Agronomy Research Center		
Date	Stage	Date	Stage	IVDMD
May 1	Vegetative	May 7	Vegetative	65.2%
May 9	Mid-bud	May 14	Vegetative	65.1%
May 14	First bloom	May 20	Mid-bud	62.5%
May 21	25% bloom	May 27	First bloom	61.2%
May 28	75% bloom	June 4	Half bloom	56.2%
June 4	Full bloom	June 10	Full bloom	53.9%
June 11	Green seed	June 19	Green seed	51.7%

cutting. A reasonable compromise is to harvest the first cutting when the plants are in the late bud to first-bloom stage. There is a wide variation across Missouri as to the date that plants reach various growth stages (Table 1), so a universal date cannot be used. Further, even within a region of the state the date will vary from year-to-year depending upon the climate, especially the air temperature during April and early May. The best method is to let the plants be the guide to taking the first cutting.

Harvesting the Last Cutting

Alfalfa needs to have about 6 weeks of uninterrupted growth in the fall to become properly winter hardy. Most often this can be accomplished by allowing about 4 weeks of regrowth before the first frost (27-28°F) that kills back the tops, plus the next 2 weeks before a true killing frost occurs. Since the average date of the frost in Missouri is usually about October 15, but differs from year-to-year, research was conducted to evaluate the response to date of last cutting (Table 2).

Table 2. Effect of cutting in fall on yield in the subsequent spring. Spring harvests were made at the late bud stage. Data is the average for 3 years at the Southwest Center near Mt. Vernon, and for 1 year at the North Missouri Center near Spickard. Yield is in tons/acre.

Southwest Center		North Missouri Center	
Fall Cut Date	Spring Yield	Fall Cut Date	Spring Yield
Sept. 9	1.20	Sept. 6	1.36
Sept. 18	1.10	Sept. 18	0.99
Sept. 28	1.05	Sept. 26	0.99
Oct. 8	1.10	Oct. 6	1.12
Oct. 18	1.12	Oct. 20	1.09
Nov. 3	1.21	Nov. 8	1.26
Nov. 12	1.19		
L.S.D. 0.05	0.12		0.19

Note that yields the following spring were high when alfalfa was cut in early September at both locations, but yields were markedly reduced when the last cut in fall was between mid-September and late October. Later research showed the response was not always due to death of plants, but occurred largely due to reduced vigor of the plants the following spring because they were not hardened properly during the previous fall. Thus, the present recommendation is to take the final cut before September 15. On well-drained soil sites alfalfa can be harvested again in early November, as by that time the plants are fully hardened and vigor will be good the following spring. The plants are hardened and will not regrow again in fall to lose hardiness. This late cutting would not be recommended on soil sites that are not well-drained. The short stubble in the field would provide minimal shade of the soil during winter, therefore allowing freezing and thawing to contribute to frost heaving of alfalfa. Frost-heaved plants are desiccated over winter and young buds on the crown are frozen so the entire plant dies.

Management During the Summer

The second cutting is normally made about 35 days after the first, and during most years in Missouri this cutting does not suffer markedly from water stress. Temperatures for growth during late May and throughout June are nearly ideal for alfalfa. The days are long to give good radiation, and rains usually occur at frequent intervals as June is the wettest month in Missouri. The stage of growth at 35 days will often be early bloom, but quality of forage does not decrease as rapidly with maturity during summer growth as it does in the spring, probably because temperatures are already high. Allowing for 35 days between cuttings usually will give sufficient time for recovery of carbohydrates in the roots to support rapid regrowth after cutting and to maintain a good stand.

Normally, the third and fourth cuttings of alfalfa are low yielding without irrigation. Our research at the Southwest Center showed that without irrigation about 65 to 70% of the total seasonal yield occurred in the first two cuttings of a four-cut system. In fact, the third and fourth cuttings usually each yielded only about 0.5 tons/acre. Thus, a convenient way to manage dryland alfalfa is to divide the time interval between the first cutting date and September 15 into three increments. That will give four cuttings before September 15. For example, if the first cutting is made on May 20, then subsequent cuttings could be made about every 40 days such that the fourth cutting occurs just prior to September 15.

With irrigation during summer, however, cutting may be done more frequently. Since a major objective is to obtain high quality forage, the first cutting could be taken at the late bud stage near the middle of May, allowing about 120 days until September 15. This would permit four more cuts at about 30-day intervals, with irrigation playing an important role in the last three cuttings. One could expect to cut irrigated alfalfa somewhat more frequently than dryland alfalfa because the environmental stress is lessened so the plants can be "worked" a bit harder. It is still critical, however, to maintain the proper cutting schedule in fall, i.e., the last cut made before September 15, with a late cutting after November 1 if soil drainage is good.

Influence of Irrigation on Yield

The major effect of irrigation is that it decreases water stress on the plant, but it does not eliminate water stress. With adequate water the plant is able to keep the stomata open to allow CO_2 to enter the leaf to be built into sugars via photosynthesis. In addition, the cells that comprise the leaf and stem tissue are able to expand more, giving rise to longer and thicker stems, and especially larger and thicker leaves. The larger and thicker leaves are a real bonus for irrigation as they add to the quality of the forage.

Water stress improves both the ability of the present leaves to fix sugars for growth and the growth of new leaf area. Thus, two processes become additive (or perhaps multiplicative) to yield. For example, we are evaluating growth responses of alfalfa in plots at the Claypan Research Farm east of Columbia where we irrigated during late July and August. Yield during summer of 1983 was 2.5 times more than the unirrigated control. Plants per acre and stems per plant were similar for both treatments indicating that the yield increase occurred due to more weight per individual stem, probably because stems were longer and leaves were larger.

Several experiments have been conducted in the Midwest regarding irrigation and yield of alfalfa (e.g. Carter and Schaeffer, 1983a). In almost all cases the major response occurred when water was added between mid June and late August. It is also critical to irrigate such that the alfalfa plants gradually draw down the soil-water supply reaching a low level in late August, and then letting rainfall bring it back to a full profile. Similar to corn (Woodruff et al., 1973) alfalfa responds best in terms of both yield and water-use efficiency (Carter and Schaeffer, 1983a) if the soil is allowed to gradually become depleted of water during summer. Fall rains in September after the last cutting will restore the water in the soil profile.

In some experiments, where the soil profile has been kept at a high water content (greater than 75% of capacity) , actual yield reductions have occurred due to stand thinning (Donovan and Meek, 1983). Alfalfa is not well adapted to persist in wet soils, with only a few varieties being resistant to phytophthora root rot, a severe disease of alfalfa that is stimulated in wet soils.

Influence of Irrigation on Forage Quality

Brown and Tanner (1983) evaluated alfalfa growth under irrigated and non-irrigated conditions on a droughty soil in Wisconsin. Irrigation during late June and early July caused a 67% increase in summer yield. Stressed plants had 39% less leaf area and 48% shorter internode lengths than did irrigated plants. Number of internodes and number of leaves on the stems of irrigated alfalfa were only slightly higher than for stressed alfalfa. These data suggest that the rate of leaf initiation was much less affected by drought or irrigation than was leaf size or internode length which are controlled largely by cell expansion. These data suggest that irrigation may influence forage quality.

Ironically, most of the data suggest that unirrigated alfalfa in summer may actually produce a higher quality forage than irrigated alfalfa. Brown and Tanner (1983) tried to understand the response, and suggested that shorter alfalfa stems of unirrigated plants are often leafier than the taller ones that would be produced by irrigation. Thus, just due to the fact yield is increased by irrigation may cause a decrease in leafiness. Even so, there is good evidence (Onstad and Fick, 1983) that the lower canopy temperature of irrigated alfalfa should lead to better quality forage to partially offset the less favorable leaf:stem ratio. Carter and Shaeffer (1983a) also noticed that lower leaves dropped off the plants much earlier in stressed than in irrigated alfalfa. When leaves are dropped the quality drops quickly.

Influence on Canopy Temperature

Several researchers have shown that on midsummer days when air temperature is 95 to 100°F the canopy (leaf) temperature of irrigated alfalfa may be 3 to 6°F cooler than the air temperature due to evaporative cooling. Conversely, with water-stressed alfalfa the canopy temperature on the same day would be 3 to 6°F hotter than the air temperature which may lead to heat stress and sunscald of leaves. Alfalfa leaves of stressed plants tend to "cup" during the mid-day on high stress days to try to decrease the heat load from the radiation (Travis and Reed, 1983). However, this reduces their photosynthetic output and limits growth..

When air temperatures are 75 to 80°F during the day the canopy temperature of stressed alfalfa plants is only about 2 F° hotter, and that of irrigated plants about 2°F cooler than the air temperature (Carter and Shaeffer, 1983b; Donovan and Meek, 1983; Sharratt et al., 1983). Alfalfa grows best at a temperature of 80 to 85°F (Bula and Massengale, 1972) so the cooler temperature of irrigated alfalfa on hot days would be beneficial. However, even on most hot days the temperature is above the optimum for only about 4 to 6 hours near midday, but that could have a great influence on yield and quality.

Improving Water-Use Efficiency by Irrigation

It is generally recognized that alfalfa is responsive to irrigation, but it is also regarded as a crop that is extravagant in terms of water use since seasonal evapotranspiration (ET) rates are higher than many other crops. Thus, irrigation scheduling becomes critical, especially in order to allow a gradual soil water draw-down, and at the same time to keep the plant from becoming overly stressed.

Daily ET rates have been reported to be as high as 0.5 inches/day for alfalfa during June when radiation and temperatures are high and soil water is abundant. Most often in summer when temperatures and radiation are high, but soil water is decreasing, ET rates are reported as 0.30 to 0.35

inches/day (Blad and Rosenberg, 1974). In our studies at the Claypan Research Farm we found that an alfalfa yield of 1.25 tons/acre for a seedling stand had an average ET of about 0.33 inches/day during the late July and August period (Fig. 1). Treatments with a yield of 0.5 tons/acre had an ET of only about 0.22 inches/day as there was less soil water for growth and growth was reduced. However, not only did the irrigated alfalfa yield more but the three areas that had ET 0.28 inches/day also had noticeably higher water use efficiency (tons of dry matter per inch of water used). The maximum possible water use efficiency has not been reached in this study but will probably occur when ET is greater than 0.3 inches/day. It was estimated that soil evaporation alone (no alfalfa present to transpire) would have been near 0.15 inches/day (Figure 1). Between July 15 and September 2 the alfalfa withdrew about 8.5 inches of water from the available supply in the soil, in addition to the 2.0 inches that was added through precipitation.

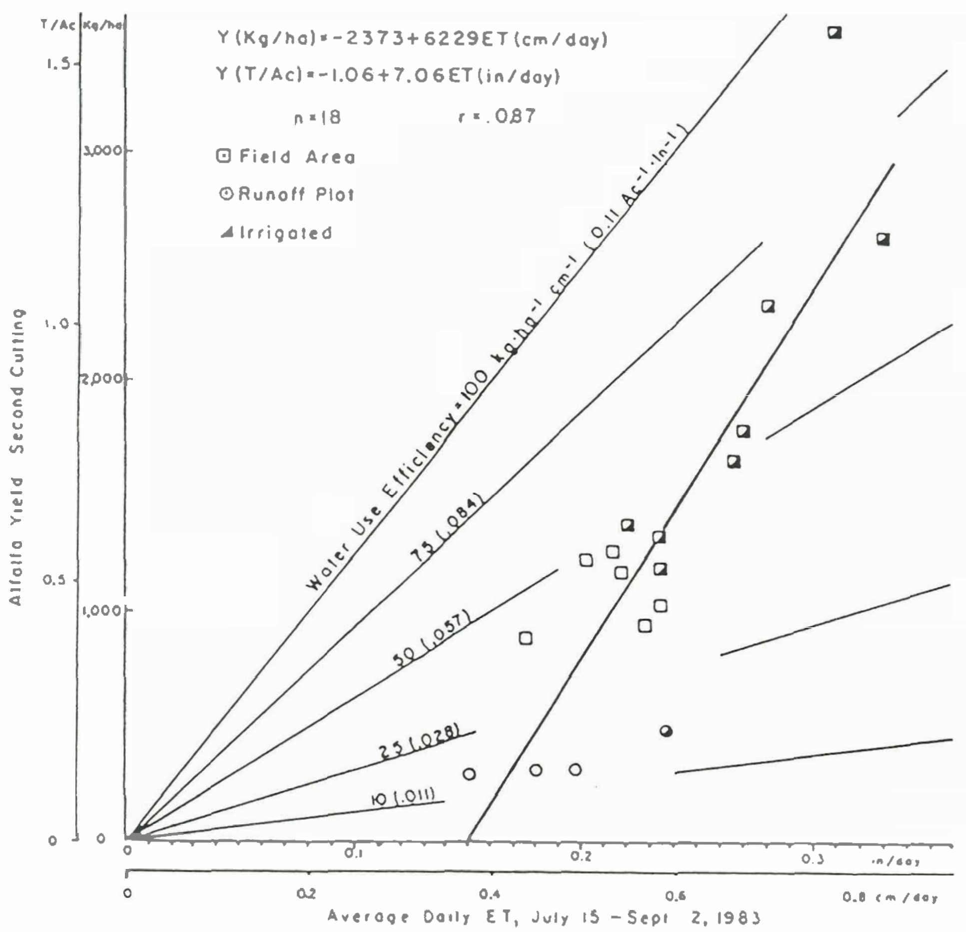

Figure 1. Relationship between alfalfa yield (T/Ac) during summer and average daily evapotranspiration rate (ET, in/day). Lines at angles from the origin (o,o) are calculated lines for fixed water-use efficiencies assuming that yield and water use are direct functions. Since the line through the experimental data points does not pass through the origin, it is clear that water is used more efficiently as alfalfa yield is increased.

Influence on Insect Management

The life cycle of the alfalfa weevil is such that eggs hatch into larva in the base of the alfalfa stem in late winter and early spring. The larva climb to the top of the stem and begin to feed on the young developing leaves. The weevil larva will probably need to be sprayed at least once during the first growth period. A few adults and larva may still be around for a short time and will feed on the new regrowth after cutting. Little damage from the weevil occurs to alfalfa after the second cutting begins active regrowth.

Potato leafhoppers are blown in from southern states on upper air currents during early summer. The potato leafhopper can be a serious problem in the second, and especially the third, fourth and fifth cuttings. The nymphs (immature adults) suck juices from the stem and inject a toxin into the plant that decreases the growth. The stem tips of damaged plants often have a yellowish or reddish cast similar to boron deficiency. In dryland alfalfa production leafhopper control with insecticides is generally economical, and it would be more economical on irrigated alfalfa where the summer yields are critical. Leafhoppers are less troublesome in fall as temperatures decrease after the last cutting in mid-September.

Influence on Nitrogen Fixation

One of the main reasons for using alfalfa in crop rotations is to exploit its ability to fix large amounts of nitrogen. Alfalfa is one of the most effective crops for nitrogen fixation, being able to fix upwards of 200 lbs/acre/year. Carter and Sheaffer (1983c) compared fixation rates (acetylene reduction) during summer of irrigated and nonirrigated alfalfa. Irrigated plants had forage yields that were nearly double their non-irrigated counterparts. Nitrogen fixation for both treatments was maximum just before harvest, decreased rapidly after harvest then gradually increased again during regrowth. However, nitrogen fixation was always lower for the non-irrigated plants, and was nearly stopped when plants were severely stressed. Alfalfa nodules subjected to severe drought stress recovered partially when soil moisture was restored.

From the data presented in the above and other studies, it is difficult to determine exactly the increased amount of nitrogen fixed due to irrigation. However, one could estimate that an increase of about 30 to 50 lbs/acre due to irrigation may be reasonable for the summer period.

Influence of Irrigation on P and K Fertilization Needs

A large input into alfalfa management is fertilization, especially with phosphorus (P) and potassium (K) as alfalfa fixes abundant supplies of nitrogen. A good guide to fertilization is to base applications on nutrient removal. Alfalfa removes about 12 lbs of P and 50 lbs of K per ton of hay (15% moisture), so requirements with high yields due to irrigation are going to be very high. With high yields expected from irrigation it is critical to split the K application, but the P application can be applied at one time. A good way is to apply all the P and half the K after the first cutting. The other half of the K should be applied in late August or early September after the last cutting. Potassium is beneficial for developing maximum winterhardiness of alfalfa.

Alfalfa, especially with high yields, also needs boron application. About 1 lb/acre annually is necessary for high yielding management systems. Again, it is best to apply the boron after the first cutting along with the P and K or to apply 2 lbs/acre every other year.

Summary and Conclusions

Alfalfa is a valuable crop for production of large amounts of high quality forage. In addition it works effectively in rotations to fix a large amount of nitrogen that is available for subsequent crop use. There is good demand for high quality alfalfa hay that warrants a premium on the market.

Irrigation will increase alfalfa yields during summer in Missouri and is a logical management step for those persons who are already doing a good job in terms of cutting management, fertilization, insect control, and harvesting. Special emphasis will need to be placed on selecting varieties for good disease resistance. The yield increase from irrigation at the Claypan Research Farm in 1983 occurred due to increased weight and length of each stem, which is consistent with other data.

The long-term responses of alfalfa to irrigation have not been researched. One of our objectives is to evaluate persistence of the stands at the Claypan Research Farm. At the end of the seedling year the stand averaged about 25 plants/square foot for both irrigated and stressed areas. For both treatments plants averaged 5 stems/plant. Our plan is to follow the decrease in plants/acre as they begin to die, and at the same time follow the increase in stems/plant of the remaining plants as they try to compensate. That data will allow us to assess the role of soil water availability (irrigation) on plant persistence and compensation.

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