USE OF DRIP IRRIGATION ON ALFALFA

Joe Henggeler
Texas Agricultural Extension Service
PO Box 1298
Ft. Stockton, TX 79735

INTRODUCTION

Many farmers and/or researchers have experimented with the use of drip irrigation on cotton (notably in AZ, CA and TX) and on corn (notably in KS). Additionally, drip irrigation has also been successfully used in turf applications throughout the country. Very little work, however, has been done on the use of drip irrigation on alfalfa or other forage crops (see Appendix I for summaries of work done).

Alfalfa should particularly benefit, more than most other crops, from the use of drip irrigation for a variety of reasons:

1. Alfalfa consumes relatively large amounts of water. This is due both to its long growing season and its high in-seaon water use rate. Since one of the benefits of drip irrigation is that it conserves higher percentages of applied water, it makes sense that more water can be saved on crops that use higher amounts of water. In a similar vein, irrigation labor costs for any method of application is highly dependent on the number of irrigations applied per year. With alfalfa's long growing season and its high water use, alfalfa can be expected to receive higher than normal numbers of irrigation applications. In short, there is also higher potential for irrigation labor cost savings on alfalfa than in most other crops.

2. Alfalfa is sensitive to leaf burn from wind-drifted water, which occurs when sprinklers are used. Foliar burn can be caused when Na or Cl of the water > 10 to 20 meq/L (Maas, 1984). Alfalfa yield can also be greatly reduced from *scalding*, a condition that occurs when water remains ponded during hot weather. Drip irrigation eliminates both of

these problems.

3. Buried drip irrigation also adapts well to the harvesting needs of forage. Flood systems must be built around swather widths. Above ground equipment can be damaged by grazing animals. These problems are avoided with buried drip systems.

4. Alfalfa seed production, which is greatly influenced by soil moisture status at critical times, can be carefully managed.

5. Alfalfa growth is apparently reduced by water stress which occurs during the hay-cutting, hay-gathering and reposition of irrigation equipment (Hutmacher, 1992). Drip irrigation can decrease this off-time interval.

6. Weed infestation may be decreased, especially in arid areas (Bui and Osgood [1990]; Gibeault et al. [1985]).

ALFALFA YIELD VS. WATER USE

Yield of alfalfa is influenced by the length of growing season. For example, in the Trans-Pecos region of Texas six or seven cuttings are possible due to season length. In the valleys of Utah or Montana only two or three cuttings may be possible. Obviously, alfalfa grown in the Trans-Pecos region uses more water than that grown in Utah. However, Water Use Efficiency (WUE), which is the yield divided by the water used, of the two different areas is similar. In short, after irrigation losses are subtracted out, it takes about 5 or 6 inches of water to produce a ton of alfalfa, wherever you are.

DRIP SYSTEM COMPONENTS

Some of the critical components of the drip system are discussed below. Figure 1 is a diagram of a drip system.

Laterals

The key component of the drip irrigation system is the lateral. These are generally spaced 36 to 80 inches apart. There are two main types of laterals, ***tubes*** and ***tapes***. Tubes have heavier walls and are tubular in shape at all times. Tapes have thinner walls and are collapsed flat until pressurized, at which time they, too, become tubular in shape. The tapes can have inserted plastic emitters or they can have orifice outlets fabricated in the tape material during manufacture. Tubes cost more because of their heavier nature, but are thought to last longer. Some tubes have emitters impregnated with herbicide to reduce

The tubes/tapes are connected to the PVC manifold by a leader of polyethylene hose. Special ***fittings*** are used for the connections. Great improvements have been made in these fittings in recent years and leakage around the tie-in area has been eliminated. Besides being manifolded to the station's sub-main, the tubes/tapes should also be manifolded at the end of the field to ***flushing manifolds***. These flushing manifolds are used to periodically flush out the laterals. ***Vacuum relief valves*** should be installed on the flushing sub-mains to eliminate vacuum that might be created when the system is cut off. This prevents soil particles from being back-siphoned into the laterals. Since the flushing process requires adequate water, it is wise to manifold only about 25% of the laterals in a station together. These grouped laterals are flushed, the flushing manifold is closed back up and the next set of manifolded laterals are flushed, and so on.

Filters

All buried drip systems need to be filtered, even if the owner feels that the water is "clean". Cotton farmers in Texas who have matured through the learning curve of drip irrigation on field crops usually end up with automatic-flushing, ***sand media filters***. These filters cost more than sock or disk filters, but do a better job in safe-guarding the buried lateral lines. In cases where there is much sand in the water, a cyclone ***sand separator*** may be used in front of the filters.

Some Other System Components

It is a good idea to have ***chemigation injection equipment*** in the system to inject fertilizers, acid and chlorine for system maintenance, and registered pesticides. (Unfortunately, few pesticide products are currently labeled specifically for buried drip systems and this, in my view, is a serious concern.) Automation of the system is very important for two reasons. One is to reduce labor and the other is to help in managing the system so that water will not wet to the surface and hamper harvesting. Automation does not have to be expensive; the items required for automation are a ***timer, solenoid valves*** and ***wire***. Some systems use flushing ports (i.e., threaded caps) on the ends of the mains and sub-mains so that debris can be flushed out. Their main use is prior to hooking up the laterals so that the entire pipe network can be flushed out to remove dirt and PVC shavings that may have entered the pipes.

One extremely important piece of equipment is a ***water meter***. The reason that it is so important is that it can tell you if clogging is starting to occur. Flow rates of stations should not vary over time as long as the pressure remains the same. Install good pressure gauges and check and record flows and pressures over the life of the system. If the flow rate decreases by 5%, while the pressure has stayed the same or gone higher, than clogging is beginning to occur. Ascertain the problem and inject the appropriate chemical.

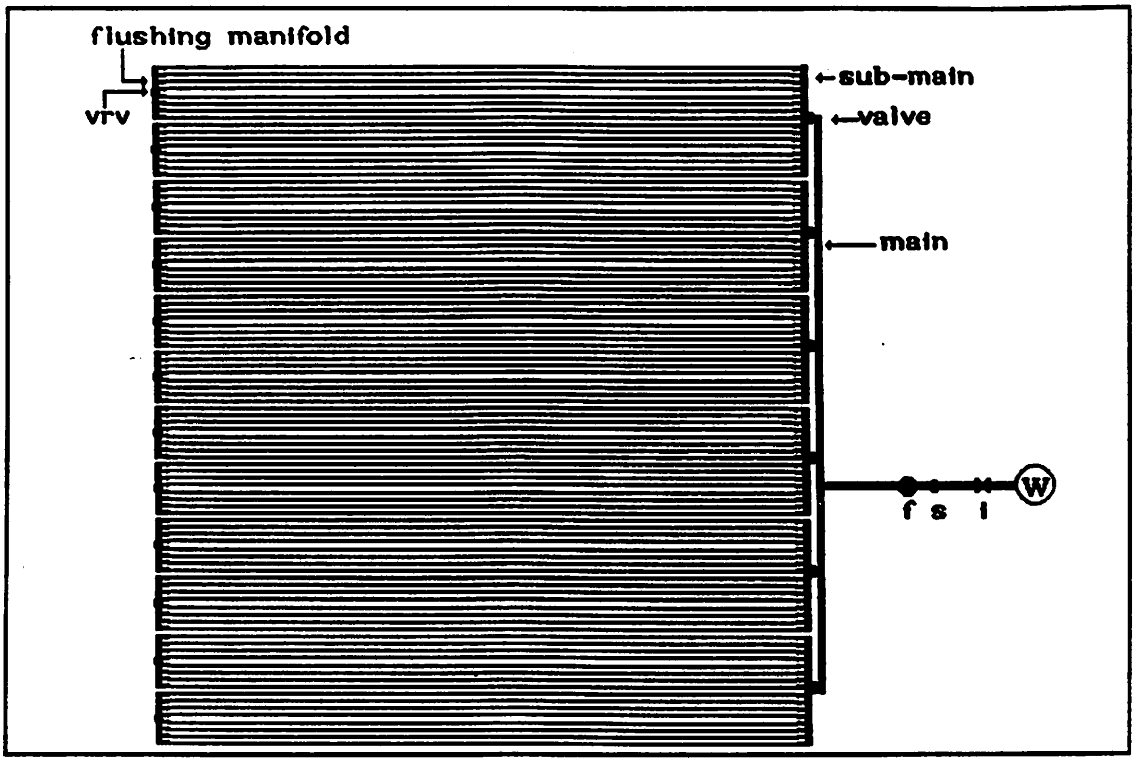

Figure 1. Diagram of a 6-station drip system showing well (W), injector (i), sand separator (s), filter (f), main, sub-mains, flushing manifolds and vacuum relief valves (vrv).

SYSTEM DESIGN

The steps in designing a drip irrigation system for alfalfa are as follows:

Water Requirements

First, determine water resources needed/available. In dry years in Texas we have found that the yield potential for center pivots is about a single ton per acre for each gallon per minute (gpm) per acre of system capacity. Thus, if the irrigation well makes 500 gpm and there are 100 acres, the expected yield would be 5 tons per acre; this converts to about 10 inches per ton of alfalfa. One may estimate that with drip irrigation, only about 5 to 7 inches of irrigation is needed per ton of production; this amount should be less in conditions where rainfall is more abundant. However, the supply of water should be adequate enough so that the alfalfa will not be stressed during the peak water use period. I would suggest having this capacity on hand:

1.00 of $\text{Reference}_{\text{alfalfa}}$ Evapo-transpiration (ET_r)
1.15 of $\text{Reference}_{\text{grass}}$ Evapo-transpiration (ET_o)
0.80 of Class A Pan Evaporation

Thus, if the peak summer month's ET_o is 0.28 inches per day (ipd), you should have 0.32 ipd capacity (0.28 ipd x 1.15 = 0.32 ipd). To convert ipd into gpm per acre, multiply ipd times 18.95. Then multiply this number times the acres to be irrigated to obtain the total amount of water required. For example given:

Field size:	40 acres
ET_o of peak month:	0.25 ipd

Water requirement needed:	0.25 ipd x 1.15 = 0.29 ipd
Capacity needed for each acre:	0.29 ipd x 18.95 = 5.4 GPM/acre
Total water needed:	5.4 GPM/acre x 40 ac = 218 GPM

Information on local historic ET_o, ET_r, and Pan Evaporation can be obtained from the local Cooperative Extension Service, SCS or other published sources, such as Toro (1966). Irrigation water source requirements determined from above can be reduced based on rainfall. It is wise, however, to error on having too much water. If this turns out to be the case, another station can be added later since drip systems are modular in nature.

Station Size

Next determine how big your stations will be. The area of each station is dependent on (1) the well flow rate, (2) the discharge rate of the tape/tubing and (3) the lateral spacing. If we use the previous example (218 gpm on 40 acres) and have selected a 40-inch lateral spacing and a tube/tape that has a discharge of 0.25 gpm/100' then there will be 87,200 feet of tape/tubing in each station. This corresponds to a station size of 6.67 acres. Divide this number into 40 acres and the result indicates that six stations will be required.

The distance that a lateral can run is about 600 to 800 feet. The length is dictated by what distribution is desired. *A good distribution is essential, even if water costs are low, since areas that get too much water will wet to the surface and impede harvesting.* Distribution itself is a function of discharge rate of the tube/tape (the less discharge, the better will be the distribution), whether pressure compensation emitters are used, the diameter of the tube/tape, and field slope. The mainline can be placed in the center with laterals going both directions if the field is too long.

ADDITIONAL NOTES

There are certain situations where drip-irrigated alfalfa might be more appropriate or successful than other methods of irrigation. The *economic potential of drip irrigation on alfalfa is higher as the growing season increases.* One niche alfalfa market for drip-irrigation is the small 3- to 20-acre ranchettes. Owners tend to be "week-end" farmers, often not accustomed to farming. The system also is a logical choice for odd shaped fields (e.g., pivot corners), or where slopes exist, or where labor/time is a premium (e.g., a person must commute 20 miles), or where quantities of water are scarce. As mentioned before, economic viability depends so much on the growing season, but, in most cases drip irrigation will be more profitable than side-rolls, hand-move and permanent set sprinklers and big guns. Viability vis-a-vis a center pivot or flood systems must be made on a case by case evaluation. One point to remember is that evapo-transpiration (ET) of a crop is the combination of plant transpiration (T) and evaporation (E) from the soil and plant surfaces. The latter, in general, offers little benefit to a crop. Modern equipment and new computer-driven models are giving us a better picture of what percentage of ET is made up of E and what is made up of T (previously we knew little about this). It is surprising that the E component is so large. Ham et al. (1990) showed that as late as the second week of August, E was 43% of the total. Other research has shown that E is also a large component of ET for bermudagrass and St. Augustinegrass turf. Buried drip irrigation greatly reduces E, leaving more water for plant transpiration.

Systems should have a long life, especially for tubes, and especially for products that have impregnated herbicide in the emitters. Systems should last from 10 to 20 years; it is always a good idea to use a shorter life cycle (say 5 to 7 years) to calculate feasibility, so that one is always on the safe side. Farmers must always be on guard for pests, such as gophers and ants, that can damage laterals.

Water transpires from a plant through the same gateway that CO_2, which is the building material for plant bio-mass, enters the plant. Thus, when transpiration decreases, largely in part to these gateways (called stomata) partially closing, CO_2 assimilation also decreases. It is not surprising that research from many quarters show that alfalfa yield is linearly related to ET. Transpiration potential in alfalfa is highest right before it is cut since the plant is taller and the leaf area index is the largest. However, it is at this time that irrigation is generally withheld, so that the crop can be cut, raked and baled. Hutmacher et al. (1992) showed that consumptive use of alfalfa was 36% higher on plots that did not have to water shut off to prepare the ground for vehicle traffic. Thus, an important goal of the drip system is to have this shut-down period be as small as possible, or ideally, to have no shut-down period.

The system can help do this when the distribution uniformity is high. It is also felt that deeper drip tube/tape installation will help. Another factor would be to increase the emission points in a field, so that the water is applied at more locations. For example, there are 5 times as many emission points in a 30-inch lateral row spacing with a tube/tape that has a 12-inch emitter spacing than a 40-inch row spacing with a product that has emitters spaced 40 inches apart. Another factor that may help to keep water from seeping to the surface is automation that will allow a block to be watered several times a day, rather than a manual system where the same quantity is applied once every day or two.

Lateral spacing is an important part of the irrigation design. However, the tube/tape is the most expensive component of the drip system. Obviously, decreasing the lateral spacing increases system costs. There are several other factors to think out when deciding on lateral spacing. What alternatives does one have to germinate the seed stand and irrigate young alfalfa that does not yet have a deep root system? Hutmacher et al. (1992) showed that 80-inch spacings yielded as much as 40-inch spacing in the second year, but had a 17% smaller yield in year one. There is also the already mentioned problem of wicking to the top; it probably would be reduced with narrower spacings. Also the compatibility of the lateral spacing to the row widths of the rest of the farm should be considered in the event that the field will later be rotated out to a row crop .

REFERENCES

Bui W. and R.V. Osgood. 1990. Subsurface irrigation trial for alfalfa in Hawaii. Proc. of the Third National Irrigation Symposium. Phoenix, AZ. Oct. 28-Nov. 1. pp. 658 - 659.

Gibeault, V.A., J.L. Meyer and V.B. Younger. 1985. Irrigation of turfgrass below replacement of evapotranspiration as a means of water conservation: weed invasion in three cool season turfgrasses. Proc. of the 5th International Turfgrass Research Conference. Avignon, France. July 1-5. pp 365-371.

Hagemann, R.W., L.S. Willardson, A.W. Marsh and C.F. Ehlig. 1974. Alfalfa seed (w/) underground drip irrigation. California Agriculture, April. p 22.

Ham, J.M., J.L. Heilman and R.J. Lascano. 1990. Determination of soil water evaporation and transpiration from energy balance and stem flow measurements. Agricultural and Forest Meteorology. 52: 287-306.

Henggeler, J. 1994. Personal communication from system owner, Warren Heagy.

Henggeler, J. and W. Multer. 1995. Drip irrigated alfalfa. TAEX District 6 Handbook (in preparation)

Hutmacher, R.B., C.J. Phene, R.M. Mead, D. Clark, P. Souse, S.S. Vail, R. Swain, M. van Genuchten, T. Donovan and J. Jobes. 1992. Subsurface drip irrigation of alfalfa in the Imperial Valley. Proc. 22nd California/Arizona Alfalfa Symposium. Un of CA and Univ of AZ Coop Ext, Dec 9-10, Heltville, CA. 22:20-22.

Maas, E.V. 1984. Salt tolerance of plants. In: B.R. Christie (ed.) The Handbook of plant science in agriculture. CRC Press Inc., Bica Raton, FL.

The Toro Company. 1966. Evapotranspiration data (for) United States and Canada. Minneapolis, Minnesota.

APPENDIX I.

HIGH LIGHTS FROM EXISTING DRIP IRRIGATED ALFALFA STUDIES

Texas

A.

-- Source: Henggeler, 1994.
-- a part time farmer installed 9 acres of drip irrigated alfalfa. It had alfalfa for 3 years and Brazos Coastal Bermudagrass for 3 years.
-- a bi-wall tubing was used.
-- no yield records were kept, but the owner said there was good yields; estimated at approximately 3.5 tons/ac harvested by machinery and 3 tons grazed by horses.
-- the system was abandoned after six years when the farm manager was transferred.
-- the owner felt the biggest draw backs were that sprinklers were needed to germinate the stand and phosphorous fertilizer was incompatible for injection.
-- lateral spacing was 40 inches, but he felt 30 inches would have been better.

B.

-- Source: Henggeler and Multer, 1995.
-- private owner who fall-planted 20 acres of drip irrigated alfalfa in 1990 followed by 16 additional acres in 1993.
-- produced 9 tons per acre the first year in production and 10 ½ tons/acre in subsequent years.
-- 40-inch spacing with emitters spaced every 12 inches.
-- system cost was about $550 per acre; annualized cost, including installation labor, was $106 per acre.
-- watered while he harvested hay at first, but ground surface became corrugated; now he cuts off several days before going in.
-- he would go in with 30-inch rows, but it doesn't fit his cotton spacing (he plans to rotate out into cotton).
-- the soil has cracked in the center parallel to the drip laterals, but this has not seemed to hurt anything.
-- worries about root intrusion; he had one line stop up, but thinks it was from a twisted lateral.
-- produces a ton of alfalfa on less than 6 inches of water.

APPENDIX I., cont.

HIGH LIGHTS FROM EXISTING DRIP IRRIGATED ALFALFA STUDIES, cont.

Hawaii

-- Source: Bui and Osgood, 1990.
-- 12 tons per acre produced; sprinkler-irrigated plots made nearly as much.
-- weed infestation was less in drip plots.
-- 59-inch spacing between laterals was sufficient.
-- little off time for harvesting compared to sprinkler-irrigated.
-- no plugging, root intrusion or mechanical failure of emitters after nearly two years when study was completed; evaluated to have least for "several more years" of life.

California

A.

-- Source: Hutmacher et al. 1992. Soil type: Holtville silty clay loam.
-- drip plots has 22% higher yields than flood (5.1 tons/ac vs 3.8 tons/ac in 1st year of spring-planted alfalfa; 8.9 tons/ac vs 7.7 tons/ac in 2nd year).
-- drip used 6% less water; however, flood system was much more efficient than would be found in a typical farm.
-- water required to produce one ton per acre was 5 inches for drip and 6 inches for furrow.
-- drip irrigation amounts had to be decreased below consumptive use during the 4 to 6 days prior to harvesting to allow the surface to be dry enough to drive on without compaction; laterals were placed at about 16 inches.
-- the 40-inch lateral spacing had nearly a 17% higher yield the first year; during the second year, yield on the 80-inch row was slightly higher.
-- water use in a small drip plot in a lysimeter was about 30% more than the drip fields since it application amounts were not decreased prior to harvesting; this would indicate that if the drip fields did not need the 5-day dry down cycle (e.g., tubes were deeper) they would have had even higher yields.
-- only 3% of the area had "wet" spots, but this was enough to cause the harvesting problem.

B.

-- Source: Hagemann et al. 1974.
-- alfalfa seed production appeared to be influenced by emitter spacing. Yields were: 1779, 1086, 831, 661, and 543 lbs of seed/ac for continuous, 8-inch, 24-inch, 24-inch and 36-inch spacings, respectively. (Nota bene: Water application rates were not discussed in this paper, and there may have been different rates applied).