Using Subsurface Drip Irrigation for Alfalfa

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Abstract

A trial on the suitability of using subsurface drip irrigation (SDI) for alfalfa (*Medicago sativa* L) was conducted on a producer's field. The soil is loam. The treatments included drip tape spacing of 60, 40, and 30 inches; placed at 18 and 12 inches depth. A nearby center pivot sprinkler irrigated plot was seeded to alfalfa and was used for comparison. Seedling emergence and yield was adversely affected at 60 inch spacing. The depth of placement of drip tapes (18 and 12 inches) showed no effect on yield. The site served for education and allowed comparison between SDI tape spacing and center pivot system.
Key Terms: Irrigation; water conservation; subsurface drip irrigation; alfalfa.

Background

Alfalfa acreage is increasing steadily in thirteen western states of the USA. The states with an increase are Arizona, Colorado, Idaho, Indiana, Kansas, Montana, Nevada, New Mexico, North and South Dakota, Texas, Utah, and Wyoming. More than a million acres have been added during the last decade (National Agricultural Statistics Service, USDA). Production agriculture in the arid western states predominantly depends on irrigation.

Alfalfa is a high water use crop. The consumptive use can exceed forty-six inches. Most of this amount is provided by irrigation and an irrigation diversion of 30 to 36 inches is common. These western states depend on both surface water diversions and/or groundwater from wells. Agriculture is by far the biggest water user at this time. Competition for limited water resources is increasing for other uses such as industry, municipality, recreation, aquatic and wildlife habitat maintenance.

The states depending on groundwater aquifers such as the Ogallala are experiencing declines in the water table. The cost of pumping also is going up due to rising energy costs. Thus, the efficient use of available water is needed to produce a high water use crops such as alfalfa.

Techniques like surge irrigation and sprinklers have improved efficiency and

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conserved water. Producers are constantly looking for new technology to improve irrigation efficiency and reduce operating costs. Drip irrigation for arid climates has reduced water loss from evaporation, runoff, and deep percolation.

Drip irrigation has proven to be most effective for high dollar cash crops like fruits and vegetables. In Kansas, subsurface drip irrigation (SDI) has been shown to be a feasible technology for the irrigation of field crops like corn (Lamm et al., 1995). Economic studies for irrigated corn have shown that SDI is economically competitive to flood and center pivot irrigation systems for small fields and potentially competitive for larger fields (O'Brien et al., 1998).

Subsurface drip irrigation is a viable alternative irrigation technology that offers the potential to reduce the amount of water used to irrigate alfalfa. Given the increased interest in alfalfa as a feed crop, research on SDI could provide needed information for irrigated alfalfa producers in the western United States. However, little information on the use of SDI for alfalfa is available in the scientific literature.

A previous study in California has shown increased alfalfa yields due to the use of SDI when compared to furrow irrigation (Hutmacher et al., 1992). One aspect of yield improvement is that the scalding of alfalfa leaves that can happen under sprinkler irrigation is reduced (Henggeler, 1995).

The critical stage to meet the water needs of alfalfa is after each cutting when the crop starts regrowth. SDI allows irrigation to continue during or right after harvest to encourage quick regrowth. There is no need to suspend irrigation for a soil dry down period before harvest or while the hay is curing, since the water is applied below the soil surface.

The lack of surface wetting eliminates evaporation loss and helps reduce the competition from annual weeds that may germinate with surface wetting from sprinkler or surface irrigation. The opportunity for deep percolation and surface evaporation losses are greatly reduced in SDI systems. Research from Kansas State University indicates that it is possible to save 25 percent of total water diverted in a season by using SDI in corn production (Lamm et al., 1995). The recommended optimum lateral spacing for installation of drip tape for row crops like corn in the Central Plains is 60 inches (Lamm et al, 1997). This spacing however has not been tested for alfalfa. With the influx of large-scale dairy industry in the area and the lower commodity price for corn the producers are considering to incorporate alfalfa in the crop rotation. Alfalfa hay price is holding well and the return from alfalfa hay is satisfactory. Producers are looking for information on the suitability of using SDI for alfalfa. Research on use of SDI for alfalfa is not forthcoming because a full-fledged replicated research for an expensive irrigation system like subsurface drip for alfalfa is time consuming and requires large funding which is difficult to come by. At the request of a producer a demonstration plus field study was initiated to answer frequently asked questions of producers.

Objectives

The objectives of this study were to:

- Demonstrate the feasibility of using SDI for alfalfa in a cooperator's field.
- Determine the optimum drip tape spacing and depth of placement for alfalfa production.
- Compare yields of SDI to a nearby sprinkler-irrigated field.
- Measure soil water content to observe the spread of water in the soil profile at various drip tape spacing.

Materials and Methods

The SDI system was installed in the corner of a center pivot sprinkler irrigated cornfield. The site is located south of Garden City, Kansas, south of the Arkansas River valley. The soil belongs to the Otero-Ulysses complex and has undulating slopes. The general textural group of this soil series is sandy loam. The soil textural analysis result for the field falls in loam category (sand: 36.3%, silt: 37.5%, and clay: 26.3%). The field was previously leveled for flood irrigation.

Drip tapes were plowed in using a deep shank ripper equipped with a tube guide in September 1998. The largest expense for an SDI system is the drip tape. The closer the spacing of the drip tapes, the more drip tapes are needed to irrigate a given area and thus the greater the cost for the system. The treatments for spacing of drip tapes, depth of placement, and control were as follows:

- 60 inches spacing at 18 inches depth
- 60 inches spacing at 12 inches depth
- 40 inches spacing at 18 inches depth
- 40 inches spacing at 12 inches depth
- 30 inches spacing at 18 inches depth, and
- A nearby center pivot irrigated field that served as control.

Nelson drip tape of 7/8th inch diameter and 24 inch emitter spacing was installed. The emitter flow rate is 0.372 gallons per hr per emitter at 8 psi. A 200-mesh disk filter system provided by Rain Bird[2] was installed to meet filtration requirements. Fluidyne vortex flow meters operated by 12-volt DC batteries were installed along with a solar panel for continuous recharging.

Alfalfa was seeded using 6-inch row spacing in the fall of 1998. Yield data was collected for 1999, 2000, and 2001. Four harvest samples were collected from each of the six treatment plots to obtain dry matter yield. An area of 11 ft^2 was harvested as a sample.

[2] Mention of product name or make is for the convenience of the reader. It does not imply endorsement or criticism of products or manufacturers not mentioned.

The harvest samples were hand clipped during the growing season. The harvest area was randomly selected across the block.

Gypsum block soil water sensors were installed at the midpoint between two drip tapes (laterals) to monitor the spread of water. The depth of placement of the gypsum block sensors was at 12, 24, and 36 inches below the soil surface. The soil water readings provided insight as to the distance of water movement away from the drip tape.

Results and Discussion

1999 started with a cool, wet spring, whereas the following years were hot and dry, Table 1. The irrigation period was prolonged in both 2000 and 2001. The information on irrigation period and water use is presented in Table 2.

Table 1. Weather data for the growing season of 1999, 2000, and 2001

Month	Average temperature oF			Rainfall in inches		
	1999	2000	2001	1999	2000	2001
April	51.1	53.4	55.5	1.23	0.32	1.37
May	61.7	65.5	63.3	3.26	3.17	3.9
June	70.0	73.7	72.8	4.16	0.97	2.6
July	78.5	77.3	82.0	2.63	3.15	2.37
August	77.6	80.2	76.3	2.46	0.82	1.11
September	63.8	69.6	69.8	1.76	0.07	1.0
			Total Rainfall	15.5	8.5	12.35

Table 2. Irrigation application

Year	Irrigation period	Ref ET inches	Irrigation, inches		Rainfall, inches
			SDI	Pivot	
1999	July 1 to Sept. 10	20.9	13.5	19.8	6.00
2000	May 10 to Sept. 21	41.9	21.0	25	5.51
2001	May 9 to Sept. 29	43.2	19.0	24	7.98

Dry matter yields are presented in Table 3. 1999 was the stand establishment year and the harvests were not consistent between subsurface drip irrigated and sprinkler irrigated fields. Total of four harvests from SDI fields are shown under column 1999 Total A and the last two harvests which were obtainable from the sprinkler irrigated field are shown under column 1999 Total B. The total yields for 2000 and 2001 were obtained from five cuttings. The results are non-replicated samples and therefore cannot be statistically compared.

Table 3. Alfalfa Yields: SDI and Sprinkler Irrigated Plots.

Treatment	Dry matter yield, ton/acre			
	1999		2000	2001
	Total A	Total B*		
60 inch spacing at 18 inch depth	4.60	2.08	7.98	6.56
60 inch spacing at 12 inch depth	4.73	2.30	7.18	6.81
40 inch spacing at 18 inch depth	5.16	2.45	8.65	8.60
40 inch spacing at 12 inch depth	5.04	2.28	9.02	8.50
30 inch spacing at 18 inch depth	4.46	1.98	8.46	7.48
Center Pivot (Sprinkler irrigation)	------	1.78	8.38	8.32

*Last two harvests out of total four.

Dry matter yield for the first year was lower for sprinkler-irrigated field compared to all drip treatments. Subsequently the yield for sprinkler irrigated field improved and was above the yield for drip with 60 inches spacing. The 40-inch spacing treatment gave a consistent higher yield. Drip tape spacing of 30 inches showed no yield advantage over 40-inch spacing.

The results of drip tape spacing and depth of placement are shown in Figure 1 and 2. The yield advantages from 40 inches drip tape spacing over 60 inches ranged from 0.44 to 1.9 tons per acre. The yield disadvantage for 60 inches spacing was greater for 2001.

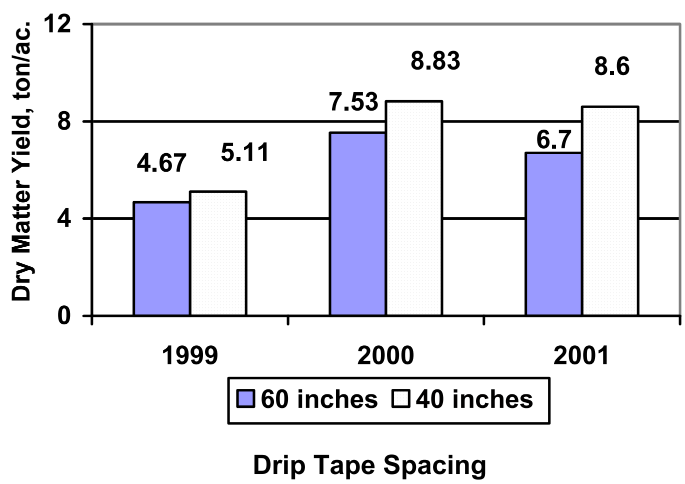

Figure 1. Dry Matter Yield as Affected by Drip tape Spacing

Hay quality analysis was done in an independent laboratory certified annually by the National Hay Testing Association. Four hay samples taken randomly from each block were ground to prepare a composite sample. A sub-sample taken from a composite was used for analysis. The average RFV (relative feed value) for 40-inch spacing was 164 (good dairy quality hay) compared to 134 (dairy quality hay) for 60-inch spacing. The RFV value for center pivot irrigated field was also 134. Although the samples were obtained randomly, the irrigation trial was on blocks and non-replicated and as such the results were not statistically compared.

The yields from two different depth of placement of the drip tapes showed similar dry matter yields (Figure 2). The depth of placement had a little effect on yield.

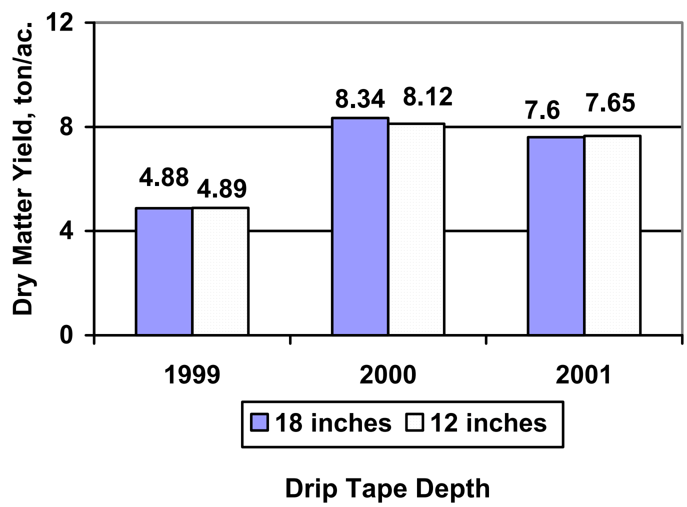

Figure 2. Dry Matter Yield as Affected by Depth of Drip tape Placement.

Gypsum block meter readings for the 60-inch spacing and 18-inch depth treatment in 1999 are presented in Figure 3. The gypsum blocks were buried at 12, 24, and 36 inches in the root-zone located at the midpoint between the drip tapes. Gypsum block reading of 99 to 95 indicates that available soil water is at 100 to 85 percent of availability. A reading of 60 indicated that the available soil water has fallen below 50 percent and needed replenishment by irrigation.

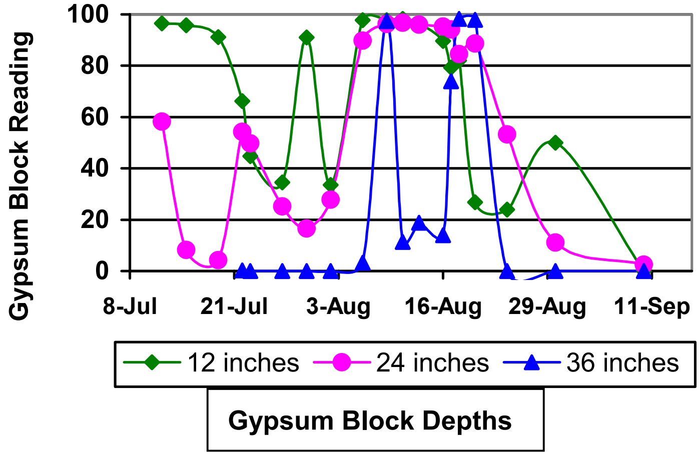

Figure 3. Gypsum Block Readings at the Midpoint for Drip tape at 60 inch Spacing.

The graphical representation of the meter readings in Figure 3 indicates that the available soil water status for the 60-inch spacing treatment remained below optimum. A "striping" appearance was visible during germination and later in the growing season during hot dry periods, Figure 4.

Figure 4. Picture showing alfalfa germination at 60 inches spacing of drip tapes.

Drip tape spacing of 40 inch placed at 12-inch depth below the soil surface provided a better water distribution for soils at 12 and 24 inches depths from the beginning of the season, Figure 5. Soil water at 36 inches depth came to 80 to 85 percent of available soil water level during fourth week of July.

Soil water distribution remained similar for the drip tape spacing in the following years, 2000 and 2001. Irrigation application amount was maintained at the same level for all treatments.

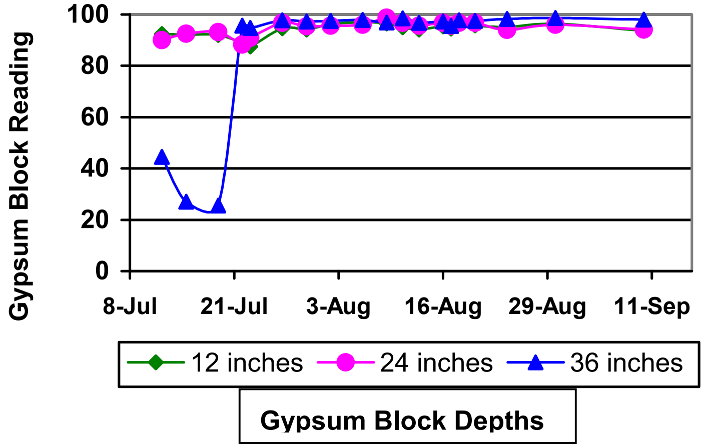

Figure 5. Gypsum Block Readings at the Midpoint for Drip tape at 40-inch Spacing.

Picture at Figure 6 shows improved germination of alfalfa seedlings at drip tape spacing of 40 inches.

Figure 6. Picture showing improved germination at 40 inches spacing of drip tapes

Economic Implications

A net present value (NPV) analysis was completed to determine which SDI spacing was the best investment alternative for alfalfa taking into account that SDI was economical to start with (O'Brien, et al., 1998). The major difference between the 40-inch and 60 inch drip tape spacing is the additional cost for closer spacing. Compared to the 60-inch spacing, the total length of drip tape required for the 40-inch spacing is increased by 4,356 ft per acre. The number of fittings required also increased. Consequently, the cost of the 40-inch spacing at $1,037 per acre is about $250 per acre more than the 60-inch spacing. However, yields were 0.44 to 1.9 ton per acre higher for the 40-inch spacing and the relative feed value (RFV) was 30 points higher.

Given the higher cost of the 40-inch spacing, the NPV analysis indicates that the 40-inch spacing would need to yield about 0.75 tons per acre higher than 60-inch spacing in order to have an equal NPV. This assumes a 15-year useful life of the system and an alfalfa price of $70 per ton. These assumed values are conservative. As the length of useful life and (or) alfalfa price increases, the additional yield needed for the 40-inch spacing to equal the NPV of the 60-inch spacing decreases.

It is expected that an SDI system will last for 20 years under good management. The SDI systems installed at the Kansas State University Southwest and Northwest Research-Extension Centers are 11 years old and functioning without any symptom of plugging or deterioration (Lamm and Trooien, 1999).

Studies done by Porter (Porter et al, 1997) for row spacing of corn has shown that 20-inch row corn always out produced the 30-inch row corn. The studies done by Kansas Sate Researchers has shown that increasing the plant population from 22500 to 34500 generally increases corn grain yields for SDI in this region and there was little penalty for increased plant population even when irrigation was limited (Lamm et al, 2001). The results of these two studies are significant from the standpoint that a drip system with 40 inches spacing will allow the producer to implement 20-inch row corn and there by increase the plant population. This is further significant because the producer will be able to rotate out of corn to grow alfalfa, as needed, resulting in a consistent higher yield of alfalfa compared to field where 60-inch spacing is implemented.

Conclusion

Alfalfa emergence was affected adversely at the 60-inch spacing for this site with loam soil. Some uneven emergence or "striping" was observed in the first year during the establishment period. Yields were reduced slightly for the drip tape spacing of 60 inch. Yields for 40-inch spacing treatment remained consistently higher. The spacing of 30 inch did not show any additional advantage over a spacing of 40 inches. Depth of placement of drip tapes did not affect the yields; they were similar for depths of 12 inch and 18 inch. Drip tape spacing of 40 inches may also prove to be economical when other agronomic factors, like narrow row corn for increased plant population and yield are considered after alfalfa in a crop rotation.

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