ALFALFA PRODUCTION USING SUBSURFACE DRIP IRRIGATION

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Abstract

The studied was established in a medium textured soil in a arid region of northern Mexico (Comarca Lagunera). Yearly average precipitation of the region is 250 mm having annual evaporation of 2500 mm. The overall objectives of the study were to evaluate dry matter production and to determine under which irrigation criteria the highest water use efficiency (WUE) index is obtained as well as to compare buried drip irrigation with traditional (surface) and sprinkler (center pivot) irrigation systems in alfalfa cropping system.

Five irrigation treatments were evaluated using subsurface drip (tape) with alfalfa. These treatments where: to replenish soil water using 100, 90, 80, 70, and 60% of Eto estimated as the pan evaporation times a coefficient , Kt = 0.8. From this, effective rainfall was subtracted for obtaining the water depth to be applied according the treatment. Buried (30 cm depth) tape (0.375 mm wall tick) laterals space was 70 cm with emitters each 20 cm. The flow of the tape was 2.5 lph with operating pressure of 10 PSI.

After two years of evaluation, the treatment of replenishing water using 80% of Eto under buried drip irrigation showed the highest yield of green forage, 64% (with 15 % of humidity) compared with traditional surface irrigation system and increases of 23% compared with sprinkler irrigation (center pivot). The highest WUE of 1.9 kg of dry matter per cubic meter was obtained with the treatment of 70% of Eto.

Key words: buried drip irrigation, water use efficiency, dry matter, alfalfa

Introduction

The Comarca Lagunera Region in Northern Mexico, it is one of the most important dairy industries in the country. Annually 36,000 hectares of alfalfa are grown for feeding cows with average yield of 73.5 $ton.ha^{-1}.yr^{-1}$ of green forage (SAGARPA, 2001). The main issues with this crop are the length of the productive life (about 3 years), low yields and high water demand. It is estimated a yearly water depth ranging from 170 to 210 cm depending of the level of irrigation technology used, (Rodríguez and Orona, 1991).

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One strategy for increasing water use efficiency of crops is the use of advanced irrigation methods like subsurface drip irrigation. Recent research results have shown that this irrigation method in alfalfa may increase dry matter production in about 28.3% compared with surface irrigation (Phene, 1999), also, Godoy *et al* obtained an increase of dry matter yield of 16 to 23%. Increase ranging from 37 to 74% in seed production is reported by Neufeld, 2001. On the other hand, an increase of 47% of green forage (with 15% of humidity) may be obtained with this irrigation method (Rivera *et al,* 2001).

The objectives of this research were: a) to evaluate the response of alfalfa (dry matter) to different irrigation criteria using subsurface drip, b) to evaluate the water use efficiency (WUE) of all irrigation criteria studied and c) to compare subsurface drip irrigation method with sprinkler (center pivot) and traditional (surface) irrigation methods.

Materials and methods

Yearly average (20 years) precipitation in the experimental site is 250 $mm.yr^{-1}$ and 2500 mm of yearly evaporation (relation 1:10). Soil texture of the site was medium with electrical conductivity of 3.1 $dS.m^{-1}$. Five irrigation criteria were evaluated consisting in replenishing water to the soil in amounts of 100, 90, 80, 70 and 60% of reference evapotranspiration (Eto) computed as daily pan evaporation times a coefficient Kt = 0.80 subtracting effective rainfall, Ppe (Aguilera 1980).

Irrigations were applied twice a week. Hydraulic characteristics of the irrigation system are shown in table 1. Green forage and dry matter were evaluated harvesting one square meter in three sits of the experimental plot: at the beginning, in the middle and at the end. Samples of forage were oven dried at 70°C for 72 hr.

Table 1: Hydraulic characteristics of the irrigation system

Characteristics	Description
Tape	T-Tape
Wall tick	15 mil(0.375 mm)
Operating pressure	10 PSI
Emitter flow	0.5 lph
Flow per meter	2.5 lph
Space between emitters	20 cm.
Space between laterals	70 cm.
Buried depth	30 cm.
Irrigation intervals	Twice a week (monday and thursday)
Irrigation treatments	100, 90, 80, 70 y 60 % of Eto -Ppe

Results

Green forage and dry matter yields

Table 2 shows average yearly yields of green forage and dry matter for two years of study; this implies 10 and 12 cuts per year for the first and second year respectively. Meaningful statistical difference was obtained among treatments being statistically equal irrigation treatments of 100, 90, 80 and 70% of ETo. Nevertheless, replenishing water to the soil with 80% of evaporation showed the highest annual yields of both green forage and dry matter (114.7 and 21.2 tons per hectare respectively). For the second year also statistical difference was obtained with the same trend.

Table 2.- Yearly average of green forage and dry mater yields (tons per hectare).

Irrigation treatments (% ETo)	Years			
	2000		2001	
	Green forage	Dry matter	Green forage	Dry matter
100	107.8 a	20.4 a	109.3 b	20.7 b
90	106.8 a	19.9 a	125.8 ab	23.4 ab
80	**114.7 a**	**21.2 a**	**134.9 a**	**24.9 a**
70	107.3 a	20.1 a	126.6 ab	23.7 ab
60	83.2 b	16.2 b	108.1 b	21.1 ab

Different letters indicate statistical difference (DMS, 95 %)

Water consumption

Table 3 shows yearly average water depths applied and water use efficiencies (WUE). WUE is the ratio of yearly dry matter yield (kg.ha.year $^{-1}$) and water volume available for consumption [(Lr + Ppe) *10,000 m ^{2}], where Lr is the water depth applied and Ppe is the effective rainfall. During the first year WUE ranged from 1.1 to 1.5 kg dry matter per cubic meter showing the highest efficiency the treatment of 70% of Eto. For the second year, WUE was higher fluctuating from 1.1 to 1.9 kg dry matter per cubic meter used; for this year the treatments of 70 and 60% of Eto showed the highest values of WUE (1.9 kg dry matter per cubic meter used). This finding is similar to tht reported by Somohano, 2003 but less than the data reported by Godoy, *et al* (2003) and Figueroa *et al* (2003) (3.13 and 3.35 kg dry matter per cubic meter used respectively). Nevertheless the WUE reported by this authors are average of three and five cuts during the first year and do not specify if they took in to account the irrigation for establishment of the crop and if they considered effective rainfall.

Table 3.- Yearly water depths (Lr), effective rainfall (Ppe), available water (Ad) and WUE.

Year	Variables	Irrigation treatment (% de ETo)				
		100	**90**	**80**	**70**	**60**
2000	Lr (cm)	160.1	144.1	128.1	112.1	96.1
	PPe (cm)	18.9	18.9	18.9	18.9	18.9
	Ad (cm)	179	163	147	131	115
	WUE (kg/m3)	1.1 c	1.2 bc	1.4 ab	**1.5 a**	1.4 ab
2001	Lr (cm)	172.5	155.2	138	120.7	103.7
	PPe (cm)	6.6	6.6	6.6	6.6	6.6
	Ad (cm)	179.1	161.8	144.6	127.3	110.3
	WUE (kg/m3)	1.1 c	1.4 b	1.7 a	**1.9 a**	**1.9 a**

Different letters indicate statistical difference (DMS, 95 %)

Table 4 shows a comparative analysis of different variables for three different irrigation methods. Variables for the surface irrigation method correspond to regional averages; in this way, regional yield average is 77 tons .ha $^{-1}$ of green forage with water depth of 170 cm. On the other hand, variables for center pivot were obtained from a typical farmer using this type of irrigation system (property Nuevo Leon). WUE and yields correspond to averages of two years with this irrigation method.

Table 4.- Comparison among irrigation methods

Variables	Irrigation method		
	Surface	**Center pivot**	**Subsurface drip (tape)**
Green forage (ton/ha) (15% de H.)	16.7	22.4	27.4
Water depth (cm.)	170	146.2	133
WUE (kg/m^3)	0.98	1.53	2.1
Yield increase respect to traditional irrigation method		34.1%	64%

From table 4 it can be computed water savings of 3,700 and 2, 380 m^3 . ha $^{-1}$. year $^{-1}$ for drip and center pivot respectively.

Forage quality

Table 5 shows some variables indicating forage quality. Statistical analysis did not detect differences among treatments. Nevertheless a trend was detected related with higher quality on those treatments where more water was applied. No differences were detected between drip and surface irrigation methods for this variable, nevertheless, Phene (1999) obtained increments in raw protein contents of about 18 to 100%. Probably these findings in our study were due to the crop variety used, WL 711, which has been rated as highly nutritive quality (HQ).

Table 5.- Forage quality for the treatments studied

Variables	Drip irrigation			Surface irrigation
	100% ETo.	80% ETo.	60% ETo.	
Raw Protein (%)	25.5	24.9	24.9	24.5
Digestible protein (%)	18.2	17.8	17.7	16.9
Acid detergent fiber (ADF %)	27.3	27.6	27.8	26.8
Neutral detergent fiber (NADF %)	36.8	36.9	36.7	38.8
Net energy, ENPL (Mc/kg)	1.58	1.56	1.56	1.6
Total digestible nutrients (%)	69.5	69.2	68.9	69.9

High quality (HQ) alfalfa varieties may have more digestibility and net energy. This differences are equivalent to 100 kg of milk for each ton of dry matter in comparison to normal alfalfa varieties according to computations with the computer program Milk 95 (Nuñez *et al* 2000).

Conclusions

- The irrigation treatment of 80% of Eto showed the highest green forage and dry matter yields (124.8, and 23 ton.ha $^{-1}$ respectivelly).
- Over the two years of evaluation the highest WUE was obtained by the 70% of Eto treatment (1.5 and 1.9 kg dry matter m^{-3} for the first and second year respectively).
- Subsurface drip irrigation showed yield increases (green forage) up to 64% higher than traditional surface irrigation method and 23% higher than sprinkler irrigation (center pivot).

Recommendations

Water use efficiencies should be the paradigm of agricultural areas under rainfall uncertainty where forage production is important. This may be achieved by some strategies as:

- To shift to less demanding water varieties
- To change to pressurized irrigation systems
- To use as irrigation criteria to replenish a percentage of Eto or pan evaporation as shown in this paper.
- To irrigate as frequent as possible but with low water depths
- If traditional irrigation systems are to be used, to level the field and make irrigation runs according the available flow (lps), texture and to use a irrigation calendar accordingly.

- To maintain the irrigation system as operational as possible performing frequent hydraulic evaluations.
- No matter how efficient the irrigation system might be…good management practices are important too.

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