WATER SAVING AND GROWTH OF ALFALFA (Medicago sativa L.) USING SUBSURFACE DRIP IRRIGATION

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ABSTRACT

La Laguna region, which is located at the Northern part of Mexico at 26° N latitude and 103° W longitude, undergoes an important water scarcity due to the amount of water extracted from the subsurface aquifer is around 40 % higher of that entering into the aquifer. In turn, this causes a decreasing in water availability for different uses, such as domestic, industry and agriculture. It is in the last use where around 85 % of water extracted is applied. However, the level of irrigation efficiency is not as high as needed for preserving this important natural resource. Based on this problem, a field experiment was carried out in order to obtain information regarding to irrigation water saving using subsurface drip irrigation (SSDI) in comparison to the traditional surface irrigation method; and about growth and yield of alfalfa (*Medicago sativa* L.) under SSDI conditions. Four irrigation depths were evaluated, which were calculated from pan evaporation readings (EV) using four percentages, 50, 65, 80, and 100 %. Treatments were allocated in the field and statistically analyzed based on a randomized complete block design with four replications. Specific differences between treatments were calculated using the Duncan method (p= 0.05). Irrigation was applied twice per week using the SSDI method. Accumulated dry matter in six harvests of alfalfa (cv. Excelente) was analyzed. Likewise, two plant growth variables, leaf area index (LAI) and crop growth rate (CGR) were measured. Both, total irrigation water applied and water saving in comparison to the surface irrigation method, were also measured. Water saving was obtained from the treatments that received less than 100 % of the EV at levels of 43.9, 32.0 y 19.4 % for the 50, 65 y 80 % EV treatments, respectively. CGR resulted higher in the treatment that received the highest irrigation depth, whereas the level of LAI did not vary throughout the range of irrigation depth studied. Crop dry matter was higher at the most irrigated treatment (20.82 t ha^{-1}). As compared to the average commercial dry forage yield with surface irrigation in the Comarca Lagunera, all the treatments produced a higher value.

Key words: Irrigation water saving, alfalfa dry forage yield, water depth, LAI,CGR.

INTRODUCTION

Water scarcity for agriculture and other uses is one of the most important problems in La Laguna region, which is located at the Northern part of Mexico, with an evaporation ten times bigger than rain. Likewise, this is the most important dairy region in the country, being the forage crops which occupy most of the irrigated land in this region (Delgado, 2000). However, the practice of the irrigation is carried out using the traditional and most worldwide used, surface method, which due to the nature of its characteristics, water is unavoidably wasted in levels that may reach 60 to 15% depending principally on soil texture, water flow

level, surface slope, and type of user. Furthermore, alfalfa (*Medicago sativa* L.) is the forage crop with the major sowed land and it consumes the highest water depth among all the crops sowed in this region with around 2.1 m per year. As a result of the above, water extraction from the aubsurface aquifer is 40% bigger than that recharging the aquifer, which, in turn, provokes an deplation of this water source of 2 m annually (CONAGUA, 2001).

An alternative to reduce this problem is to minimize water wasting during irrigation, which can be achieved improving the irrigation efficiency. Drip irrigation reaches the highest efficiency, but its use in alfalfa has been reduced due to its high cost. The invention of the tape-type drip irrigation that is a flattened tube with a thinner wall than the traditional tube, is significantly cheaper than this, allowing, economically speaking, its use in crops like alfalfa that requires too many irrigation tubes.

Despite this, drip irrigation is more expensive than the other two alternatives, surface and sprinkler irrigation. The performance of studies that show the advantages of drip irrigation can increase the use of this irrigation method. Based on this fact, a study was carried out with the main objective of determining the level of water saving using drip irrigation in alfalfa, as well as the growth behavior of this crop under this irrigation method with different water depths.

MATERIALS AN METHODS

The study was carried out at the experimental field of the Facultad de Agricultura y Zootecnia de la Universidad Juarez del Estado de Durango in the Comarca Lagunera region located at the 26° 46' North latitude and the 103° 21' West meridian. Mean temperature is 21 °C, with an evaporation of 2,200 mm and a precipitation of 200 mm yearly. Four irrigation depths were evaluated which were based on percentages of pan evaporation, 50, 65, 80, and 100%. These were allocated in the field based on a randomized complete block design with four replications. Experimental units consisted of 12 irrigation lines 0.7 m apart each other and 10 m long, these were buried 35 cm deep. Irrigation was applied twice per week to alfalfa Var. "Excelente". Irrigation duration (ID) was calculated using the following equation:

$$ID=((EV*Aeu)/Ief) / Qeu \qquad \text{Eq. 1}$$

Where:

EV: evaporation (mm).

Aeu: area of the experimental unit (m^2).

Ief: irrigation efficiency.

Qeu: water flow in the experimental unit ($m^3 \, h^{-1}$).

Water saving, alfalfa dry matter yield, leaf area index (LAI), and crop growth rate (CGR) were measured as a response-variables. Water saving was calculated resting the water depth resulted from each of the treatments (50, 65, 80, and 100% EV) from 2.1 m that is the mean irrigation depth applied with surface irrigation in the Comarca Lagunera region. Dry forage yield was measured in six harvests from one m^2 in each experimental unit. To determine dry matter yield, fresh forage was placed in an oven to 65° C until a even weight was reached between two consecutive measurements. Leaf area index (LAI) was calculated as the quotient of leaf area and soil surface area. LAI was measured at the second harvest (273 days after sowing, DAS) from an area of 625 cm^2 and using an electronic device LI-COR 3100 (LI-COR, Inc., Lincoln, NE, USA). Crop growth rate (CGR) was calculated from two measurements of dry matter weight made seven days before the second harvest (266 DAS) and at the second harvest (273 DAS) using the following equation:

$$CGR = (1 / Ga) \times (dw / dt) \qquad Eq. \ 2$$

Where:

Ga: ground area (cm^2).

dw: difference in plant weight between two consecutive
measurements (g).

dt: difference in time between two consecutive
measurements (days).

Data from the response variables was analyzed through an analysis of variance and the specific differences between treatments were calculated using the Duncan method ($p = 0.05$) (Steel and Torrie, 1980).

RESULTS

Water saving

Total water depth applied in six harvests, including 25 cm applied using surface irrigation during the crop stablishment, varied from 87 cm (50 % EV) to 155 cm (100 % EV)

(Table 1). Taking into account that the 100% of the evaporation in this region is equivalent to the water depth applied yearly to alfalfa (around 2.1 m), the three treatments that received less than 100% EV generated water saving at levels of 43.9, 32.0 y 19.4 % for 50, 65, and 80 % EV. This agrees with findings in other studies carried out in this region in alfalfa with SSDI (Rivera *et al*., 2001; Godoy *et al*., 2003). Likewise, these levels of water saving have been observed in other crops like corn (*Zea mays* L.) (Lamm, 1995).

Table 1. Total water depth and dry alfalfa forage yield per harvest and total under four water depths applied with subsurface drip irrigation. DEP-FAZ-UJED. Comarca Lagunera, Mexico.

Treatment (% EV)	Water depth (cm)	Dry forage yield (t ha^{-1})						Total yield (t ha^{-1})
		First	Second	Third	Fourth	Fifth	Sixth	
100	155	3.9 a[1]	3.6 a	3.2 a	3.4 ab	3.8 a	3.1 a	20.8 a
80	128	3.1 b	3.0 a	3.2 a	2.6 b	3.2 b	2.7 a	17.9 b
65	108	3.3 ab	3.2 a	3.3 a	3.6 a	3.1 b	2.8 a	19.2 ab
50	87	3.9 a	3.2 a	2.9 a	2.9 b	2.9 b	2.9 a	18.1 b

[1]Within columns, means followed by different letters are significantly different (Duncan, 0.05).

Leaf area index (LAI)

There was not significant difference in LAI in response to the levels of water depth (WD) evaluated (Table 2). The range of LAI values varied from 5.8 (WD= 128 cm) to 7.7 (WD= 155 cm), which indicates that the treatment that received the highest WD generated a LAI value considered as optimum (the optimum range is 8 to 10) (Gardner *et al*., 1985). This means that the highest amount of water produced an amount of leaf area that allows for a better interception of solar radiation and therefore, a better production of dry matter by the crop (Davies and Castro-Jimenez, 1989). A high value of LAI can generate a high value in CGR and therefore in dry matter, as occurred in this study. The positive effect of a higher water depth on the level of LAI has been observed in other crops like chile (*Capsicum annuum* L.) (Horton *et al*., 1982).

Crop growth rate (CGR)

The unique difference in CGR occurred between the highest WD (155 cm) and the lowest one (87 cm), which was equivalent to 138% (Table 2). This was reflected in the

amount of dry matter where this statistical difference also occurred. As compared to the CGR value considered as acceptable for alfalfa under surface irrigation (23 g m^{-2} day^{-1}) (Grimes *et al*., 1992), excepting the treatment that received the lowest WD, the rest of them reached higher values, which indicates that the WD recommended for alfalfa to get an optimum gain of dry matter per unit of ground per unit of time (CGR) must be higher than the derived from 50% of evaporation.

Table 2. Leaf area index (LAI) and crop growth rate (CGR) in alfalfa under four water depths applied with subsurface drip irrigation. DEP-FAZ-UJED. Comarca Lagunera, Mexico.

Treatment (% of EV)	Growth variable	
	LAI	CGR (g m^{-2} day^{-1})
100	7.7 a	38.97 a
80	5.8 a	28.91 ab
65	6.2 a	25.71 ab
50	6.1 a	16.28 b

In the columns of growth variable, means followed by the same letter are not significantly different (Duncan, 0.05)

Dry matter yield

Total alfalfa dry matter yield was significantly affected by the range of WD evaluated in this study (Table 1). The highest WD (155 cm) generated a higher level of dry matter in comparison to the rest of the treatments excepting the equivalent to 65%EV (108 cm). In the rest of the comparisons there was not significant difference. This agrees with the behavior observed in CGR. Even though the highest WD produced the highest yield, it is better to recommend a lower WD because of the Comarca Lagunera region undergoes a severe water scarcity problem; therefore, a WD equivalent to 50 to 80% EV must be used in order to save water. This recommendation is done based on the fact that all the treatments in this study produced a higher yield in comparison to the average yield in this region using the surface irrigation method. Other authors have recommended between 50-65% EV (Rivera *et al*., 2001; Godoy *et al*., 2003).

CONCLUSIONS

Subsurface drip irrigation (SSDI) in alfalfa in the Comarca Lagunera region generated water saving from 19.4 to 43.9 % in comparison to surface irrigation.

Leaf area index (LAI) in the wettest treatment reached a value considered as optimum. A similar behavior occurred in crop growth rate (CGR), which, in turn, affected positively to dry matter yield.

Even though the highest WD produced the highest yield, it is better to recommend a lower WD because of the Comarca Lagunera region undergoes a severe water scarcity problem; therefore, a WD equivalent to 50 to 80% EV must be used in order to save water. This recommendation is done based on the fact that all the treatments in this study produced a higher yield in comparison to the average yield in this region using surface irrigation.

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