DRIP IRRIGATION FREQUENCY FOR SUGARCANE IN THE TROPICS

By

R. CRUZ, J.S. TORRES, I.C. FRAGOSO,
H. MESA and D. DELVASTO

Cenicaña y Malimbu Sugarcane Plantation
jrcruz@cenicana.org

KEYWORDS: Drip Irrigation, Irrigation Schedule, Water Saving, Sugarcane Production, Colombia.

Abstract

DRIP IRRIGATION was a system initially developed for desert areas where the sandy soils have low water retention capacity and rainfall is limited. In the Cauca river valley, located in south-western Colombia, soils have a high water retention capacity and frequent irrigation results in excess moisture and poor root development, which affects crop development. The frequent application of water in the sugarcane soils of the Cauca River Valley results in excess soil water and little use of natural precipitation. The current study was conducted at the Malimbú Sugarcane Plantation, located in the driest area of the Cauca River Valley where annual precipitation is below 800 mm and soils are loamy to clayey in texture. The effect of irrigation frequency (daily, twice a week, weekly) was studied in drip-irrigated plots. A gravity irrigation system was used as check. In three consecutive cuts (plant crop and two ratoons), sugarcane production in drip-irrigated plots was 160 t/ha with daily irrigation (483 mm water applied), 165 t/ha when irrigated twice a week (356 mm water applied), and 166 t/ha when irrigated weekly (264 mm water applied). Gravity-irrigated cane produced 157 t/ha, with an average of 465 mm water applied. Average precipitation during the three cuts reached 984 mm. Results highlight the importance of taking advantage not only of the soil's capacity to store available water but also of actual precipitation, scheduling the weekly drip irrigation of sugarcane fields in the Cauca River Valley without adversely affecting cane production

Introduction

Given the shortage of water for irrigation and the increasing irrigation fees in the Cauca River Valley, located in south-western Colombia, sugarcane producers are now considering the possibility of investing in drip irrigation. They are, however, concerned because, in the past, they have had problems with hoses and emitters clogging up because of the build-up of iron and manganese (Franco *et al*., 1984) and because of the severe damage to hoses caused by harvest equipment (Cenicaña, 1984).

In parts of the sugarcane production areas where annual precipitation is below 1000 mm, the water supply is from deep wells drilled more than 15 years ago. Current flows from these wells range between 40–50 L/sec These low flows are not sufficient to apply gravity irrigation, which uses a flow of more than 60 L/s. The dilemma arises whether to invest in the building of new wells that could yield more than 60 L/s, at a cost of US $125 000 each, or to invest in drip irrigation to take advantage of the low flow of existing wells.

In 2003, a preliminary drip irrigation trial was conducted at the La Josepilla Sugarcane Plantation, located in a low-rainfall area (700 mm/year) of the Cauca River Valley where irrigation requirements are high and the availability of irrigation water is low (wells producing 40 L/sec). Trials consisted of three planting systems (two with double furrows and one with single furrows), two distances between emitters (0.5 and 0.7 m), and two emitter flows (1.2 and 1.6 L/h). While the water volumes used in drip irrigation were 48% less than those used in gravity irrigation, the production of drip-irrigated cane was 20–60 t/ha higher than that of furrow-irrigated cane.

The results of the preliminary trial carried out at the La Josepilla Sugarcane Plantation cannot be extrapolated to other areas because of the many mixed variables including planting configuration, spacing between emitters, emitter flows, fertiliser application rates and varieties. Therefore, in 2005, a new collaborative experiment was carried out by Cenicaña and the Malimbú Sugarcane Plantation, using emitters spaced at 0.5 m with a flow of 1.6 L/hour, three irrigation frequencies, and two planting arrangements (double and single furrows).

Materials and methods

The experimental site is representative of the driest area of the Cauca River Valley, with an average annual precipitation of 800 mm and two soil types: Río Paila (Fluventic Haplustolls, coarse loam texture) and Manuelita (Fluventic Haplustolls, fine loam texture), both characterised as being deep, well drained, and very fertile.

A split-plot experimental design was used with the irrigation frequency treatment assigned to the main plot and the spacing between furrows to the subplot.

The following irrigation frequencies were evaluated: (1) daily; (2) twice a week; and (3) weekly. Spacing between furrows was as follows:

(1) single furrow at 1.75 m;

(2) double furrow with 2.6 m between pairs and 0.6 m between furrows; and

(3) double furrow with 2.4 m between pairs and 0.4 m between furrows.

The check was a gravity-irrigated lot planted to sugarcane variety CC 85-92 spaced at 1.75 m. Irrigation was scheduled using the water balance method, with a K factor of 0.3 when the crop was 2–4 months old and one of 0.7 when the crop was 4–10 months old.

Forty soil samples were collected using an auger up to a depth of 1.2 m. To describe the soil profile, two sampling pits were dug and samples were collected to determine the soil's chemical and physical properties. Based on the chemical analysis of the soil, the recommended fertilisation for the plant crop was 80 kg N, 90 kg K_2O, and 7.5 kg Fe/ha.

Once soil preparation activities were completed, the drip irrigation system was installed. The system consists of a filter-and-control station where water is taken directly from a deep well and passed through a hydro cyclone filter, a gravel filter, and two ring filters. Fertilisation equipment consists of a 1.9 cm Venturi injector with a regulator and three 2000-L plastic tanks to mix the soluble fertilisers (N, P, K). Four control valves were installed in the field. These valves can be controlled by hand from the station and also by an automatic timer. The principal pipeline consists of a PVC tube, 10 and 8 cm in diameter, to which lateral hoses (internal diameter of 1.6 cm) are connected after. Emitters are located along these lateral hoses with a water flow of 1.6 L/hour.

The crop was planted on 3 August 2005 and, because the drip irrigation system had not yet been fully installed, sprinkler irrigation was performed immediately, applying a 45-mm water sheet, to enhance crop germination. During crop development, agronomic evaluations were made at 2, 4, 6, 8, and 10 months and then again at harvest.

Results and discussion

In the plant crop, drip-irrigated cane (variety CC 85-92) produced, on average, 162 t/ha, whereas the gravity-irrigated check produced 154 t/ha, a difference of 8 t/ha in favour of drip irrigation (Table 1). AS previously noted, in the drip irrigation experimental field, the first germination irrigation was applied by sprinkling because at that time the drip irrigation system had not yet been fully installed. The initial population in the drip-irrigated field was lower than that of the gravity-irrigated check because the germination irrigation by sprinkling was deficient—several areas presented water deficit and, at other sites, the water swept the seed away because of disconnections in the pipeline.

No significant differences were observed in other production indices—sugar yield, sugar production, tonnes of cane per hectare-month (TCHM), and tonnes of sugar per hectare-month (TAHM)—in relation to the irrigation system (drip versus gravity).

Table 1—Production of cane variety CC 85-92 on the Malimbú Sugarcane Plantation, located in the Cauca River Valley, South-western Colombia, using two different irrigation systems.

	Plant crop		First ratoon		Second ratoon		Average	
Production index	Gravity	Drip	Gravity	Drip	Gravity	Drip	Gravity	Drip
Cane production (t/ha)	154	162	150	147	168	190	157	166
Sugar yield (%)	13.4	13.1	11.88	12.38	12.40	11.81	12.6	12.4
Sugar production (t/ha)	20.7	21.2	17.8	18.2	20.8	22.4	19.8	20.6
Harvest age (months)	13.5	13.7	13.1	12.8	16.2	14.4	14.3	13.6
TCHM	11.4	11.8	11.5	11.5	10.4	13.2	11.1	12.2
TAHM	1.53	1.55	1.36	1.42	1.29	1.56	1.39	1.51
Total water applied (mm)*	148	207	690	334	240	194	465	264
Total precipitation		915		693		1345		984

The distribution of monthly precipitation between months two and nine of the cane crop (Figure 1) was satisfactory and, as a result, only one event of gravity irrigation (148 mm) was required during crop growth.

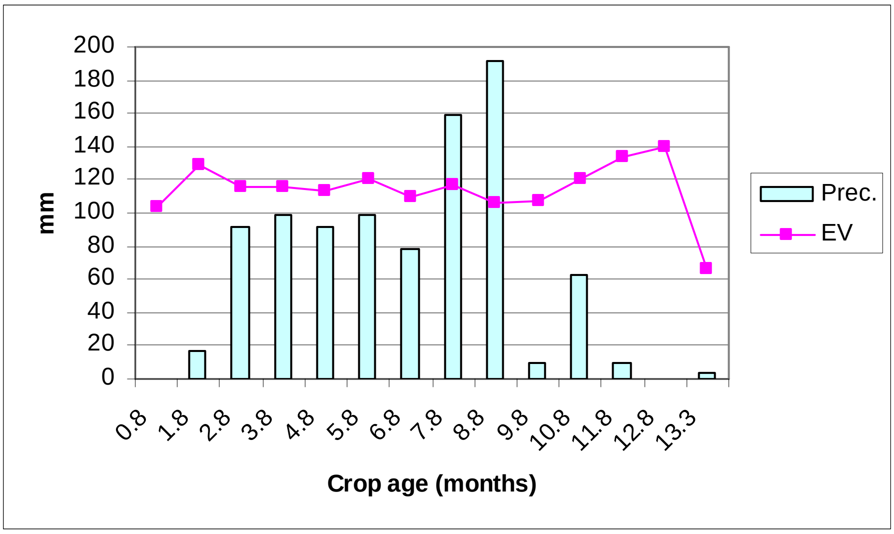

Fig. 1—Water conditions of the plant crop of sugarcane variety CC 84-92 during a drip irrigation experiment carried out at the Malimbú Sugarcane Plantation, located in south-western Colombia.

The number of irrigations in the case of drip irrigation was high: 63 for daily irrigation and 16 for twice-a-week irrigation. In the case of drip irrigation applied daily, the total water application was 319 mm, which was more than double (115%) that of gravity irrigation whereas, with the twice-a-week frequency, the total water application was 207 mm, 40% more than with gravity irrigation. In the case of the ratoons, the decision was made to test weekly drip irrigation to take advantage of the rains and the soil's water retention capacity.

In plant crops, the application of fertilisers using the drip irrigation system (fertigation) was carried out regardless of the irrigation schedule, which increased water consumption between 12% and 18%. For the first ratoon, fertilisation was synchronised with the drip irrigation schedule to avoid additional water use.

In the first ratoon, grown between 22 September 2006 and 2 October 2007 (12.3 months), the yield of drip-irrigated cane variety CC 85-92 was, on average, 147 t/ha, whereas the gravity-irrigated check yielded 150 t/ha, indicating that there was no significant differences in yield between drip irrigation and gravity irrigation (Table 1). Regarding the other production indexes (sugar yield, sugar production, TCHM, and TAHM), no significant differences were observed in relation to the irrigation system (drip versus gravity). It should be mentioned, however, that the skids of the lifters caused severe damage to the stools in drip-irrigated fields during the harvesting of the plant crop, especially in double-furrow planting. As a result, there was extensive replanting to replace the cane population.

The monthly precipitation during the first ratoon was deficient between 4–6 months and 8–10 months after planting (Figure 2). It was therefore necessary to apply five gravity irrigations for a total water application of 690 mm, whereas the total water application in the case of drip irrigation was 511 mm in the daily or conventional irrigation, 382 mm in the twice-a-week irrigation, and 334 mm in the weekly irrigation, which represents a saving of water of 26% in the daily frequency, 45% in the twice-a-week frequency, and 52% in the weekly frequency as compared with gravity irrigation.

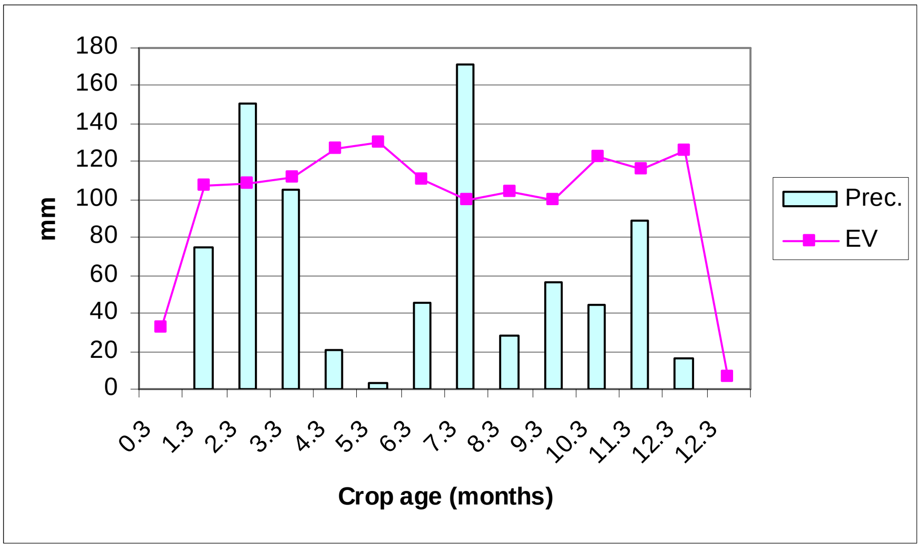

Fig. 2—Water conditions of the first ratoon crop of sugarcane variety CC 84-92 during a drip irrigation experiment carried out at the Malimbú Sugarcane Plantation, located in south-western Colombia.

In the first ratoon, in addition to the significant saving of water in the case of drip irrigation, the fertilisation carried out through this irrigation system was an added value for the sugarcane plantation because no expenditure was incurred for machinery and labour for conventional fertilisation. This represented a saving of US$30/ha. Specific drip fertigation trials should be carried out to evaluate the fertiliser efficiency and rates.

The second ratoon was grown on 2 October 2007 and harvested at 14.4 months (12 December 2008), in the case of the drip-irrigated cane, and at 16.2 months (7 February 2009) in the gravity-irrigated check. The yield of drip-irrigated cane variety CC 85-92 was, on average, 190 t/ha, whereas the gravity-irrigated check yielded 168 t/ha, a difference of 22 t/ha (13%) in favour of drip irrigation (Table 1). Sugar yield (11.81%) in drip-irrigated fields was slightly lower than in gravity-irrigated fields (12.4%), whereas sugar production was higher (22.4 t/ha versus 20.8 t/ha). Finally, the monthly production of drip-irrigated cane (13.2 t/ha per month) was higher than that of gravity-irrigated cane (10.4 t/ha per month); monthly sugar production under drip irrigation (1.56 t/ha per month) was also higher than under gravity irrigation (1.29 t/ha per month).

Precipitation during the second ratoon was 1345 mm, surpassing by 50% the average value for the area and well distributed throughout the crop cycle (Figure 3). Plantation administrators decided to apply irrigation up to 12 months after planting, taking into account the state mill's announcement to harvest between 14 and 15 months old because of delays in the harvest schedule. The gravity-irrigated check only required two irrigations, one at 10 and the other at 12 months, for a total water application of 240 mm. In drip irrigation, the total water application was 365 mm in daily or conventional irrigation, 329 mm in the twice-a-week irrigation, and 194 mm in the weekly irrigation. This means that there was a 19% saving in the amount of water used in the weekly drip irrigation alone as compared with gravity irrigation.

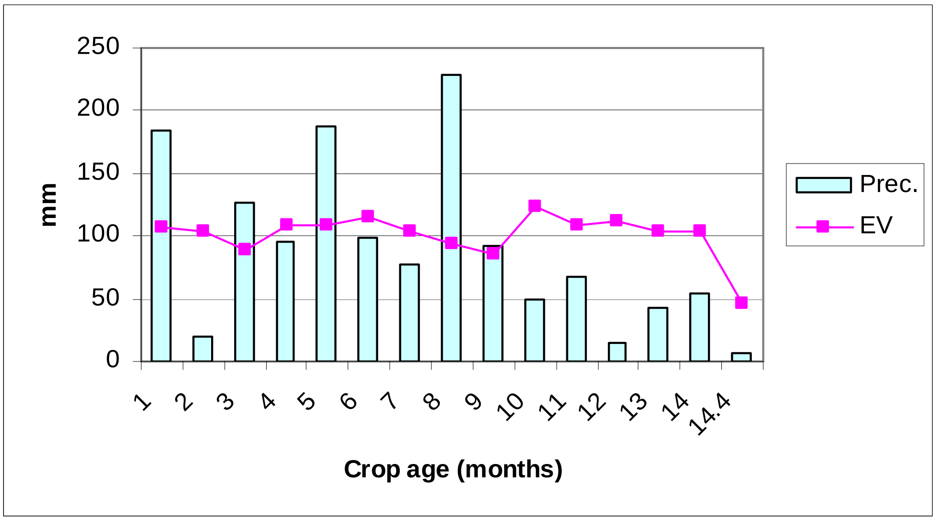

Fig. 3—Water conditions of the second ratoon of sugarcane variety CC 84-92 during a drip irrigation experiment carried out at the Malimbú Sugarcane Plantation, located in south-western Colombia

The average yield of drip-irrigated cane variety CC 85-92 for the three cuts was 166 t/ha, whereas the gravity-irrigated check yielded 157 t/ha, a 6% difference in favour of the former (Table 1). No difference was observed in sugar yield between drip irrigation (12.4%) and gravity irrigation (12.6%), whereas the sugar production of drip-irrigated cane was 20.6 t/ha as compared with gravity-irrigated cane with 19.8 t/ha, a 4% difference.

The TCHM index was 12.2 in the case of drip irrigation compared with 11.1 in the case of gravity irrigation (a 10% difference); the TAHM was 1.51 in drip irrigation and 1.39 in gravity irrigation, an 8% difference. In two of the three cuts (plant crop and the second ratoon), the monthly precipitation was above average for the area and only one gravity irrigation event (148 mm) was required in the plant crop and two gravity irrigations in the second ratoon during the period of crop growth. From 5 to 7 gravity irrigations are normally required in the area where the experiment was conducted. The average water application per crop cycle was 465 mm in gravity irrigation and 264 mm in weekly drip irrigation, representing a saving of 201 mm (43%) in the case of the latter.

Regarding the frequency of drip irrigation, no significant differences were observed in cane and sugar production over the three cuts **(**Table 2**)**. However**,** significant differences were detected regarding the amounts of water applied per crop cycle, especially in the first and second ratoons. In the first ratoon, these amounts were 511 mm for daily irrigation, 382 mm for twice-a-week irrigation, and 334 mm for weekly irrigation. In the second ratoon, the total water application was 365 mm for the daily drip irrigation, 329 mm for the twice-a-week irrigation, and 194 mm for the weekly irrigation. This indicates that, under these environmental conditions, drip irrigation should be scheduled based on the water balance and applied at a weekly frequency to obtain a significant saving in the amount of water used (46%) with respect to daily irrigation by taking advantage of the precipitation and the water storage capacity of soils in the Cauca River Valley.

Table 2—Production of cane variety CC 85-92 on the Malimbú Sugarcane Plantation, located in the Cauca River Valley, Southwestern Colombia, using three frequencies of drip irrigation.

	Plant crop		First ratoon			Second ratoon			Average		
Production index	Daily	Twice a week	Daily	Twice a week	Weekly	Daily	Twice a week	Weekly	Daily	Twice a week	Weekly
Cane production (t/ha)	158	162	142	145	146	180	187	184	160	165	165
Sugar yield (%)	13.4	12.6	12.5	12.2	12.1	13.4	12.8	11.8	13.1	12.5	11.9
Sugar production (t/ha)	21.1	20.5	17.7	17.7	17.7	24.1	24.0	21.7	21.0	20.7	19.7
Harvest age (months)	13.7	13.7	12.8	12.8	12.8	14.4	14.4	14.4	13.6	13.6	13.6
TCHM	11.5	11.9	11.1	11.3	11.4	12.5	13.0	12.8	11.7	12.1	12.1
TAHM	1.54	1.49	1.38	1.38	1.38	1.67	1.66	1.51	1.53	1.51	1.45
Total water applied (mm)*	319	223	511	382	334	365	329	194	438	356	264

Three inter-furrow distances were evaluated in drip irrigation: (1) double furrow with 2.6 m between pairs and 0.6 m between furrows, (2) double furrow with 2.4 m between pairs and 0.4 m between furrows; and (3) single-furrow check, spaced at 1.75 m. No differences were found in cane and sugar production **(**Table 3**).**

Table 3—Production of cane variety CC 85-92 on the Malimbú Sugarcane Plantation, located in the Cauca River Valley, Southwestern Colombia, using three planting systems.

	Plant crop			First ratoon			Second ratoon			Average		
Production index	Double furrows*	Double furrows**	Single furrow***	Double furrows*	Double furrows*	Single furrow**	Double furrow*	Double furrow*	Single furrow**	Double furrow*	Double furrow*	Single furrow**
Cane production (t/ha)	159	160	162	143	145	147	187	183	190	163	163	166
Sugar yield (%)	12.7	13.2	13.1	11.8	12.5	12.4	12.4	13.3	12.1	12.3	12.9	12.5
Sugar production (t/ha)	20.1	21.1	21.2	16.9	18.1	18.1	23.2	24.2	22.9	20.0	21.2	20.8
Harvest age (months)	13.7	13.7	13.7	12.8	12.8	12.8	14.4	14.4	14.4	13.6	13.6	13.6
TCHM	11.6	11.7	11.8	11.2	11.3	11.5	13.0	12.7	13.2	11.9	12.0	12.2
TAHM	1.5	1.5	1.6	1.3	1.4	1.4	1.6	1.7	1.6	1.5	1.6	1.5

*Double furrow with 2.6 m between pairs and 0.6 m between furrows
**Double furrow with 2.4 m between pairs and 0.4 m between furrows
***Single-furrow at 1.75 m

In double-furrow or paired-furrow planting systems, the skids of the lifters broke the drip hoses along several stretches and the wagons caused severe damage to the stools. Taking into account that planting in double furrows reduces the capital costs of lateral hoses by 32%, it would be worthwhile to purchase combine harvesters that adapt to this planting system.

In the second ratoon, differences in tonnes of cane per hectare (TCH) were detected which could be attributable to the frequency x spacing interaction ($\alpha = 5\%$). The highest response in terms of TCH (191 t/ha in variety CC 85-92) was found in the weekly drip irrigation in double furrows with 2.6 m between centres of the pair and 0.6 m between rows.

Conclusions

- In the three cuts, drip irrigation as compared with gravity irrigation generated a 43% saving in the amount of water used (2010 m^3/ha).
- Averaged over the three cuts (two receiving high precipitation and one low precipitation), the production of drip-irrigated cane variety CC 85-92 was 166 t/ha as compared with gravity-irrigated cane, which produced 157 t/ha, a difference of 9 t/ha (6%). Data will be more conclusive once the results of more dry years are available.
- At least five cuts should be included in the economic evaluation of drip irrigation.
- To adapt drip irrigation to the rainfall regime and the soils of the Cauca River Valley, it should be scheduled based on the criterion of a weekly irrigation to obtain significant water savings (40%) without adversely affecting cane production and sugar yields.
- In drip irrigation, the double-furrow planting system (2.6 m × 0.6 m) is economically favourable because the investment in lateral hoses would be reduced by 32%. Taking into account that the mechanical lifter causes damage to the stools and cuts hoses, it would be worthwhile to purchase a combine harvester that adapts to double-furrow planting because it would facilitate the adoption of drip irrigation.
- The fertilisation applied through drip irrigation (fertigation) represented a saving in terms of machinery and labour which should be evaluated in subsequent experiments to determine the system's efficiency and fertiliser doses and to quantify the added value of fertigation by dripping.

REFERENCES

CENICAÑA (Colombian Sugarcane Research Center). (1984). Informe Anual, 1983. Cali, Colombia. 88 p.

Franco, A.R., Holguín, A.F. and López, O. (1984). Evaluación de dos sistemas de riego, goteo y aspersión en caña de azúcar bajo condiciones comerciales en el Ingenio Mayagüez. In: Memorias Primer Congreso de la Sociedad Colombiana de Técnicos de la Caña de Azúcar. Edit. Buenaventura C., 1: 313–321.

FREQUENCE D'IRRIGATION GOUTTE A GOUTTE POUR LA CANNE A SUCRE SOUS LES TROPIQUES

Par

R. CRUZ, J.S. TORRES, I.C. FRAGOSO,
J.H. MESA et D. DELVASTO

Cenicaña et Plantation de canne à sucre de Malimbu
jrcruz@cenicana.org

MOTS-CLES: Irrigation Goutte à Goutte, Plan d'Irrigation, Economie d'Eau, Production de Canne à Sucre, Colombie.

Resume

L'irrigation goute à goutte était initialement conçue pour les endroits désertiques où les sols sablonneux ont une faible capacité de rétention d'eau et où la pluie est limitée. Dans la vallée de la rivière Cauca au sud-ouest de la Colombie, les sols ont une forte capacité de rétention et des irrigations fréquentes produisent un excédent d'humidité and un mauvais développement racinaire qui affectent le développement de la culture. L'application fréquente d'eau dans les sols de la vallée de la rivière Cauca est la cause d'un excédent d'eau dans le sol et d'une très faible utilisation des précipitations naturelles. Cette présente étude a été conduite à la plantation de canne à sucre Malimbú, située dans la partie la plus sèche de la vallée de la rivière Cauca où la pluviométrie annuelle est au dessous de 800 mm et où les sols ont une texture loamy à argileuse. L'effet de la fréquence d'irrigation (journalière, deux fois par semaine et hebdomadaire) a été étudiée dans des parcelles sous irrigation goute à goutte. Un système d'irrigation gravitaire été utilisé comme contrôle. Pour trois coupes successives, (une vierge et deux repousses), la production de canne à sucre dans les parcelles irriguées par goutte à goutte était de 160 t/ha avec l'irrigation journalière (application de 483 mm), 165 t/ha irrigué deux fois par semaine (application de 356 mm), et 166 t/ha irrigué chaque semaine (application de 264 mm). Pour l'irrigation gravitaire, la canne a produit 157 t/ha avec une application moyenne de 465 mm. La précipitation annuelle moyenne pendant ces trois coupes a atteint 984 mm. Les résultats indiquent l'importance de prendre avantage de non seulement de la capacité de rétention du sol pour stocker l'eau disponible mais aussi des pluies et de la planification de l'irrigation goutte à goutte hebdomadaire des champs de canne à sucre de la vallée de la rivière Cauca, sans affecter négativement la production de canne.

FRECUENCIA DE RIEGO POR GOTEO DE AÑA DE AZÚCAR EN LOS TRÓPICOS

Por

R. CRUZ, J.S. TORRES,
I.C. FRAGOSO, J.H. MESA y D. DELVASTO
jrcruz@cenicana.org

**PALABRAS CLAVE: Riego por Goteo, Lista de Riego,
Agua Almacenamiento, Producción de Caña de Azúcar, Colombia.**

Resumen

EL SISTEMA de riego por goteo fue desarrollado inicialmente para las zonas desérticas donde los suelos tienen bajas capacidades de retención de humedad (arenosos) y las lluvias son escasas. En el valle del Cauca los suelos son de alta capacidad de retención de humedad y la aplicación de riegos frecuentes resulta en excesos de humedad y en el desarrollo de un sistema radical reducido afectando el desarrollo del cultivo. La aplicación de riegos frecuentes en el trópico resulta en excesos de humedad en el suelo y en poco aprovechamiento de la precipitación natural. La presente investigación se realizó en la hacienda Malimbú, que está ubicada en la zona más seca del valle del río Cauca donde la precipitación anual es inferior a 800 mm y los suelos son de textura franca a arcillosa. Se evaluó el efecto de la frecuencia diaria, 2 veces por semana y una vez por semana en las parcelas regadas por goteo. El sistema de riego por gravedad fue tomado como un testigo de referencia. En tres cortes consecutivos (plantilla y dos socas) la producción de caña de las parcelas regadas por goteo con frecuencia diaria fue de 160 t/ha (lámina de riego 483mm), 165 t/ha para la frecuencia de 2 veces por semana (356 mm) y 166 t/ha para la frecuencia semanal (264 mm). La producción de la caña regada por gravedad fue de 157 t/ha con una lámina promedio aplicada de 465 mm. La precipitación promedio recibida durante los tres cortes alcanzó los 984 mm. Los resultados obtenidos indican la importancia de aprovechar la capacidad de almacenamiento de agua aprovechable de los suelos, la efectividad de la precipitación a partir de programar los riegos para la caña de azúcar en el valle del río Cauca siguiendo una frecuencia de riego semanal si afectar negativamente la producción.