

TOWARDS THE IMPROVEMENT OF FURROW IRRIGATION FOR SUGAR CANE CROPS IN COLOMBIA: A COMPARATIVE STUDY

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ABSTRACT: Sugar cane in the valley of Cauca river, Colombia, is grown in approximately 250.000 ha. The predominant irrigation system is by furrows, used in over 80% of the area. Due to climatic change, rain distribution has become unpredictable. In addition, the increase of the area planted has caused a decrease in the availability of water per hectare. An experiment was developed aimed at finding alternative surface irrigations which could reduce water consumption during the growing cycle, without lowering productivity. It was carried out on a soil of fine francose texture, with a furrow slope of 0,6%, during three successive cuts (plant cane and two ratoons). In this experiment, different modalities of irrigation were compared, using two flows per furrow: traditional flow (3L /s per furrow) and low flow (0,5 L/s per furrow), in comparison to a control treatment without irrigation. Different irrigation modalities in every furrow were established taking into account the distribution of the harvest residue on the field. The following irrigation modalities were tested: every furrow (EF), four furrows irrigated by one without irrigation (4x1), two furrows irrigated by one without irrigation (2x1), one furrow irrigated by one without irrigation (Alternate Furrow: AF), two furrows irrigated in alternating way by tree without irrigation (2x3 alternating-alternating), and one furrow irrigated in alternating way by two without irrigation (1x2 alternating-alternating).

No differences were found in the use of water, or crop yield due to the flows used, for the same modality. However, the results showed differences in the amounts of water used, according to the modality of irrigation. Water saving was: 56% in 1x2 alternating –alternating, 52% in 2x3 alternating-alternating, 45% in AF, 19% in 2x1, and 5% in 4x1, compared to the modality of EF. Low flow irrigation in flat areas and fine-texture soils also showed to be viable.

KEYWORDS: irrigation by furrows, sugar cane, irrigation modalities.

EM CAMINHO AO MELHORAMENTO DA IRRIGAÇÃO POR SULCOS NA CANA DE AÇÚCAR DA COLÔMBIA: UM ESTUDO COMPARATIVO.

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RESUMO: A cana de açúcar no vale do rio Cauca (Colombia), é cultivada em cerca de 250000 ha. O sistema de irrigação predominante é a irrigação por sulcos é utilizado por mais de 80% da área semeada. Atribuível à mudança climática, a distribuição de chuvas tem se tornado cada vez mais incerto que, juntamente com o aumento da área cultivada, tem causado uma diminuição na disponibilidade de água para irrigação. Com o objetivo de estudar alternativas de irrigação de superfície, o que levaria a reduzir o consumo da água de irrigação para um ciclo da cultura, sem reduzir a produtividade da cultura, foi desenvolvida uma pesquisa na qual foram comparadas diferentes modalidades de irrigação, e dois caudais por sulco: o caudal tradicional (3 L/ s-sulco) e o caudal reduzido (0, 5 L/ s-sulco) em comparação com um controle sem irrigação.

As modalidades de irrigação utilizados foram estabelecidos considerando o arranjo dos resíduos das culturas no campo; os tratamentos avaliados foram: irrigação em todos os sulcos (SC), quatro sulco com irrigação por um sem irrigação (4x1), dois sulcos com irrigação por um sem irrigação (2x1), um sulco com irrigação por um sem irrigação (sulco alternado, SA), dois sulcos alternados entre eventos de irrigação por três sem irrigação (2x3 alternado-alternado) e um sulco de irrigação alternado entre eventos de irrigação por dois sulcos sem irrigação (1x2 alternado-alternado).

Os resultados não apresentaram diferenças nas quantidades de água utilizada, ou na produção da cultura para a mesma modalidade de irrigação; no entanto, foram encontradas diferenças entre as quantidades de água aplicada de acordo com a modalidade de irrigação. As poupanças foram: 56% em 1x2 alternado- alternado, 52% em 2x3 alternado-alternado, 45% em sulco alternado (SA), 19% na irrigação 2x1 e 5%, na irrigação 4x1, em comparação com o tratamento de irrigação em todos os sulcos. Além, foi estabelecida a viabilidade do caudal reduzido em áreas planas.

PALAVRAS-CHAVE: irrigação por sulcos, cana de açúcar, métodos de irrigação.

INTRODUCTION

In Colombia, sugar cane is grown in the Valley of Cauca River (250,000 ha), most of which (92%) has fine texture soils and 1% slope. The rest of the area (8%), is in the foothills where soils have slope above 3% and high stone contents, which limit water storage capacity of the soil. Frequent irrigation is required in the latter, (though there is not enough water

available for this purpose), being sprinkler irrigation, the most common system used in this area in spite of its high cost.

Irrigation with reduced furrow inflow rates (RFR) was developed by Cenicaña as an alternative sugar cane irrigation technique in foothills areas. RFR is considered a low-flow irrigation system since it uses 0,3 L/s per furrow, and uses gravity as its main power source, which makes it a low-cost and frequent-use alternative for fine-texture soils in areas where water sources are limited. Experiments showed that sugar cane irrigated with this system increased yield by 23% compared to a control crop without irrigation, and 9.3% compared to another crop using sprinkler irrigation. They also showed that the runoff was almost 1% of the volume applied, and total dissolved solids were the same at the beginning and end of the furrow. This means that RFR did not produce erosion in the foothill soil (Campos and Cruz, 2010).

Soils of the plains of the Valley of Cauca River are the most productive for sugar cane crops, due to their fine texture. Irrigation per furrow is the traditional irrigation (TI) used in over 80% of the area, using between 3 L/s and 6 L/s of water per furrow, and showing application efficiency of 40%. Water used in TI comes mainly from wells (which increases irrigation costs) even though these do not have the capacity to irrigate all the plain areas. Rain distribution has become unpredictable due to climatic changes, thus affecting the capacity of water sources in the area. In addition, the area used for sugar cane crops has been increasing at a staggering rate, reducing water availability even more. This paper is aimed at showing the effectiveness of the use of RFR in plain areas (with slope lower than 1%), reducing water consumption during the growing cycle, without affecting crop yield.

MATERIALS AND METHODS

An experiment of irrigation with RFR was carried out in Santa Anita farm at Manuelita Mill. This experiment was developed in three cuts: one plant cane and two ratoons, with the variety CC 01-1228, in a Mollisol soil (Manuelita) of fine francose texture, with furrows of 0.6% slope, 150 m of length, and 1,75 m of distance between furrows. Manuelita soil is characterized by francose texture in the first two horizons (42 cm and 25 cm deep respectively), no texture contrast that may limit water movement, high water storage capacity, and good moisture distribution.

The experimental design was done using whole random blocks, with five treatments and five replicates each. The experimental unit consisted of 10-furrow plots, taking the yield from the 5 central furrows. The five treatments received by the plant cane were: one control treatment

without irrigation (NI), two irrigation treatments with reduced furrow inflow rates (RFR), and two treatments with traditional irrigation (TI), all using every furrow (EF) and alternate furrow (AF) modalities. RFR used 0,37 L/s per furrow, and TI used 3,7 L/s per furrow.

Treatments for the first and second ratoon were done considering the harvest residues on the field. For the first ratoon, residues were distributed each two furrows (2x1), so the five treatments were done as follows: a control without irrigation (NI), a reduced furrow inflow rates at two furrows of irrigation by one without irrigation (RFR 2x1, at 0,6 L/s), a traditional irrigation at two furrows of irrigation by one without irrigation (TI 2x1, at 3,3 L/s), a reduced furrow inflow rates at one furrow irrigated in alternating way by two without irrigation (RFR1x2 a-a, at 0,6 L/s), and a traditional irrigation at one furrow irrigated in alternating way by two without irrigation (TI 1x2 a-a, at 3,3 L/s). For the second ratoon, harvest residues were distributed 4x1 (four furrows without harvest residue by one with residue). The treatments were as follows: a control without irrigation (NI), a reduced furrow inflow rates at four furrows of irrigation by one without irrigation (RFR 4x1, 0,5 L/s), a traditional irrigation at four furrows of irrigation by one without irrigation (TI 4x1, at 3,1 L/s), a reduced furrow inflow rates at two furrows of alternating irrigation by three without irrigation (RFR 2x3 a-a, at 0,5 L/s), and a traditional irrigation at two furrows of alternating irrigation by three without irrigation (TI 2x3 a-a, at 3,1 L/s).

The plant cane was harvested at 12 months, the crop received 640 mm of rainfall, two germination irrigations, and five irrigations with treatments; evaporation was 1520 mm. The first ratoon was harvested at 11.9 months, receiving 1036 mm of rainfall. There was a dry period between the 4th and 6th month, during which 5 irrigations were applied; evaporation was 1767 mm.

The second ratoon was harvested at 12.4 months, the crop received 976 mm of precipitation. Between the 5th and 9th month there was a water deficit, and during this period 5 irrigations were applied. Evaporation was 1924 mm.

During all three cuts, irrigations were programmed with tensiometers located in the field at depths of 10, 30 and 50 cm. Irrigation treatments were applied with equal frequency.

RESULTS AND DISCUSSION

In all three cuts, the period of highest water demand coincided with the dry season. As a result, the frequency of irrigation treatments was around 26 days.

The plant cane, regardless of the treatment used, yielded around 140 t/ha (Table 1), with no significant statistical differences. However, irrigation treatments increased yield by 40 t/ha compared to the control crop without irrigation. The total amount of water applied in the alternate irrigation treatments (3038 m³/ha RFR-AF and 3263 m³/ha TI-AF) was approximately half of that used in every-furrow irrigation (5888 m³/ha RFR-EF and 5500 m³/ha TI-EF). Having said that, it becomes clear that the alternate irrigation modality in fine-texture soils is an effective strategy for saving water without reducing crop yield. (Torres and Cruz, 1996).

In the first ratoon, there were no significant statistical differences in yield among irrigation treatments. However, compared to the control crop without irrigation, the increase of yield was over 20 t/ha. The volume of water applied to the 1x2 alternating-alternating treatments with reduced flow was 2743 m³/ha RFR1x2 a-a, and for the traditional flow was 2264 m³/ha TI 1x2 a-a, compared to the 2x1 irrigation treatments, which received 5466 m³/ha in RFR 2x1, and 3015 m³/ha in TI 2x1.

For the second ratoon, there were no significant statistical differences in yield among irrigation treatments. Treatments of 4x1 irrigation applied 5330 m³/ha of water in RFR 4x1, and 5460 m³/ha in TI 4x1, while at the 2x3 alternating-alternating the amounts were 2750 m³/ha in RFR2x3a-a, and 2660 m³/ha in TI2x3a-a.

In summary, no significant statistical differences in yield were found among the three cuts regardless of the irrigation flow used, but the difference in the volumes of water applied was significant. The following list shows the amounts of water used and the percentage of area irrigated in descending scale: every furrow (EF)-100%, 4x1-80%, 2x1-67%, alternate irrigation (AF)-50%, 2x3 alternating and alternating-40%, and 1x2 alternating-alternating-33% (Figure 1).

When comparing all the modalities of irrigation used and EF irrigation, water savings were found as follows: 56% in 1x2 alternating –alternating, 52% in 2x3 alternating-alternating, 45% in AF, 19% in 2x1, and 5% in 4x1.

On the other hand, when analyzing the percentage of irrigated areas against yield in tons of cane per hectare per month (TCHM), it was found that TI and RFR have similar results (Figure 2). The same happens when comparing the amount water applied in all modalities and TCHM in the two flow levels used (Figure 3). However, the maximum TCHM was found in the irrigation modality 2x1 (67%), for both flow levels.

CONCLUSIONS

In three consecutive cuts, *Irrigation with reduced furrow inflow rates (RFR at 0,3-0,6 L/s per furrow)* showed to be an effective irrigation alternative for fine francose textured soil.

In addition, in furrows with slope of 0.6% and length of 150 m, these conditions did not represent limitations for water to spread throughout the furrows even when using low flows.

The use of low flow between 0.37 - 0.6 L/s per furrow during the three cuts did not show significant statistical differences in the crop yield and the total amount of water applied, in comparison with the traditional flow of 3 L/s per furrow.

It is possible to obtain significant water savings using traditional irrigation or reduced flow by irrigating the crop area partially, especially using irrigation at 1x2 alternating – alternating (water saving: 56%).

The greatest efficiency of water use was obtained with reduced or traditional alternate furrow irrigation.

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Table 1. Results of harvest. Manuelita Mill, Santa Anita farm, variety CC 01-1228, plant cane, first and second ratoon.

| Cut | Treatment (% furrows irrigated) | t/ha | Δ^* t/ha | Volumen applied/irrigation (m ³ /ha) | Total volumen applied (m ³ /ha) | m ³ /tsc |
|---------------|---------------------------------|--------|-----------------|---|--|---------------------|
| Plant cane | Control without irrigation | 100 b | | | | |
| | RFR- EF (100%) | 134 a | 34 | 1178 | 5888 | 98 |
| | TI -EF (100%) | 140 a | 40 | 1100 | 5500 | 91 |
| | RFR - AF (50%) | 141 a | 41 | 608 | 3038 | 77 |
| | TI -AF (50%) | 140 a | 40 | 653 | 3263 | 79 |
| First ratoon | Control without irrigation | 118 b | | | | |
| | RFR - 2x1 (67%) | 143 a | 25 | 1093 | 5466 | 90 |
| | TI - 2x1 (67%) | 140 a | 22 | 603 | 3015 | 85 |
| | RFR-1x2 a-a (33%) | 142 a | 24 | 549 | 2743 | 84 |
| | TI-1x2 a-a (33%) | 138 a | 20 | 453 | 2264 | 80 |
| Second ratoon | Control without irrigation | 116 b | | 0 | 0 | |
| | RFR 4x1 (80%) | 145 a | 29 | 1070 | 5330 | 97 |
| | TI 4x1 (80%) | 143 a | 27 | 1090 | 5460 | 94 |
| | RFR 2X3 a-a (40%) | 137 ab | 20 | 550 | 2750 | 89 |
| | TI 2x3 a-a (40%) | 137 ab | 21 | 530 | 2660 | 86 |

* Increase of t/ha with respect to the control without irrigation.

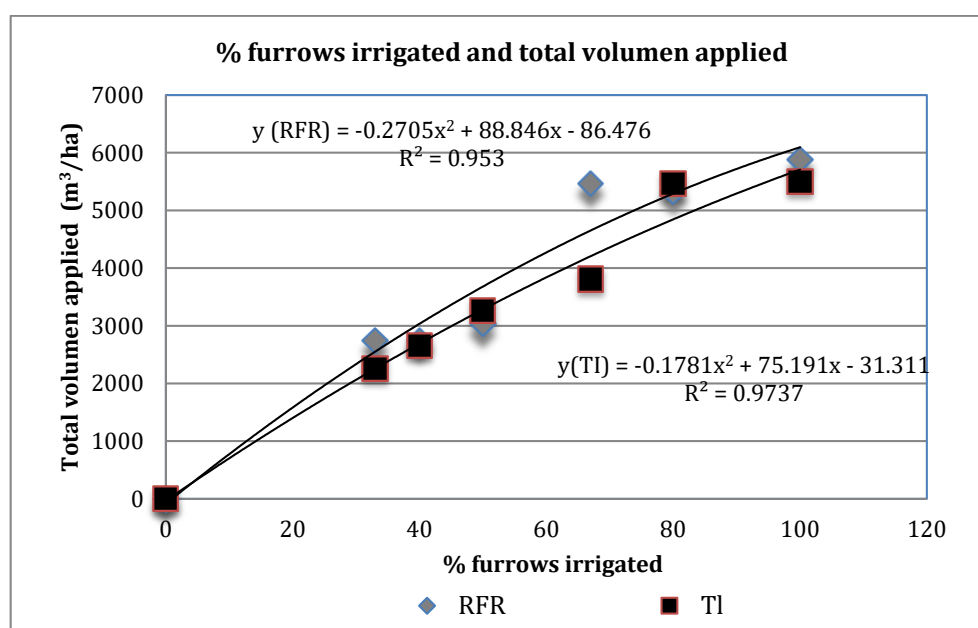


Figure 1. Percentage furrows irrigated y m³/ha irrigated in a crop cycle.

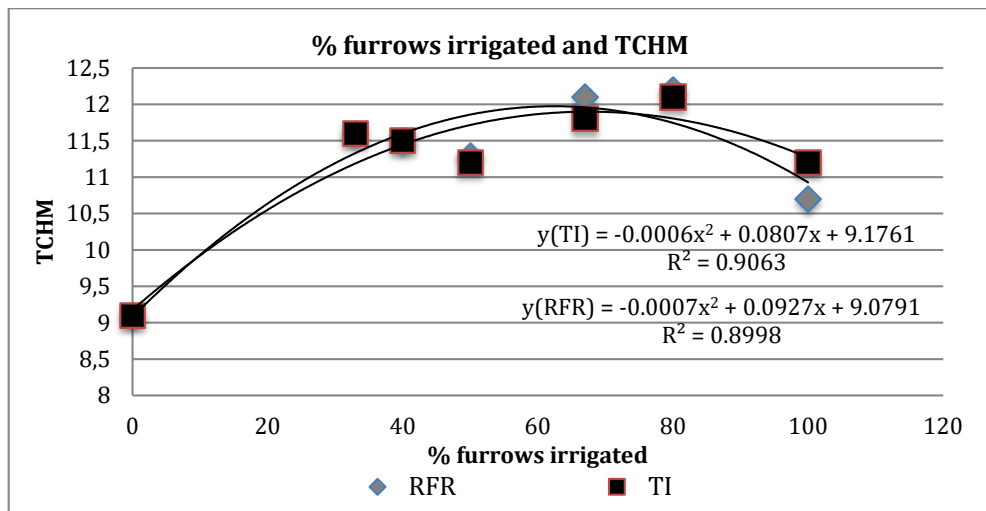


Figure 2. Percentage furrows irrigated and ton of sugarcane per hectare per month. (TCHM).

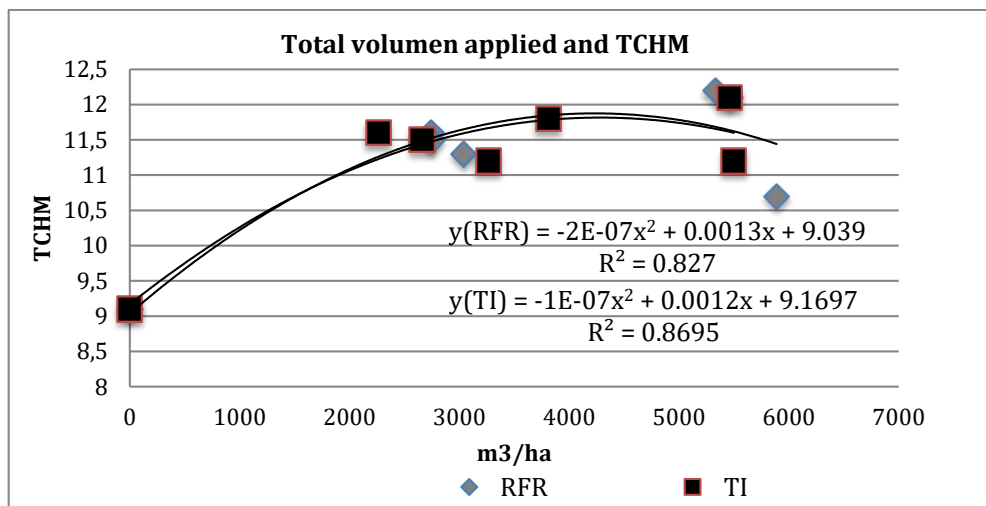


Figure 3. The amount water applied (m³/ha) and TCHM.