Evaluation of Alternate-row Furrow Irrigation Technique on the Growth and Performance of Sugarcane (Saccharum hybrid spp.) Grown in Reddish Brown Earth Soil in Sri Lanka

L.M.J.R Wijayawardhana, W.R.G Witharama and A.L.C.De. Silva

Sugarcane Research Institute, Uda Walawe, 70190, Sri Lanka

Corresponding Author: L.M.J.R Wijayawardhana - lmjrw@yahoo.com

ABSTRACT

A field experiment was conducted at the research farm of the Sugarcane Research Institute, Uda Walawe,Sri Lanka to find out the feasibility of reducing gross irrigation water requirement of irrigated sugarcane by practising alternate-row furrow irrigation method in Reddish Brown Earth soil (RBE). The effects of the three treatments, i.e., every furrow irrigation, alternate-row furrow irrigation and rain-fed on growth and performances of plant and ratoon yield were evaluated in randomised completely block design (RCBD) with 4 replicates. The results revealed that mean productivity of irrigation water use in alternate-row furrow irrigation method was 16 kg/m^3 and was 45% higher than that for every furrow irrigation. The alternate-row furrow irrigation method reduced the consumption of water by maha-and yala-planted sugarcane by 39% and 43% respectively without reducing sugarcane yield. In addition, sugarcane juice quality was improved significantly by alternate-row furrow irrigation method.

Keywords: Reddish Brown Earth soil, Sri Lanka, Sugarcane, Water productivity

INTRODUCTION

Furrow irrigation is the widely-adopted surface irrigation method for irrigating sugarcane in Sri Lanka. The maximum achievable field application efficiency of water by a furrow irrigated crop is around 60% (Ramos *et al*., 2011). In sugarcane cultivation in Sri Lanka, it has been estimated at 25-45% (Shanmuganathan, 1990).Low irrigation efficiency increases water wastage in farmers' fields, and causes water shortage to other irrigable land. On the other hand, available water for agricultural purpose has been constrained with the increasing demand for water from non-agricultural purposes like domestic consumption and industrial use. Also, the severity of this problem has aggravated further under the present scenario of changing climate. Moreover, shortage of irrigation water reduces productivity of sugarcane land. Efficient methods, such as, use of sprinklers, drip irrigation, etc., are available for irrigating sugarcane, but their high costs of installation, operation and maintenance are prohibitive for their adoption. Therefore, there is a need to introduce low-cost techniques to increase efficiency of irrigation without affecting productivity of sugarcane lands

Alternate-row furrow irrigation (skipped furrow irrigation), which has a higher water use efficiency is one of the effective methods to minimise wastage of irrigation water (Halim, 2013). Unlike sprinkler and drip irrigation methods, alternate-row furrow irrigation does not require additional cost or sophisticated technology. Bakker et al. (1997) reported that the alternate-row furrow irrigation with well-scheduled irrigation program was the best practice to irrigate sugarcane in Colombia. It has reduced the irrigation water requirement by 50% per irrigation cycle in addition to reduction of labour requirement for irrigation. In India, alternate-row furrow irrigation is practised for sugarcane (Shrivastava *et al*., 2011), and it saves irrigation water by 36% while increasing water use efficiency by 64% compared to every furrow irrigated sugarcane (Visha *et al*., 2014). Pandian, et.al. (1992) reported, 43-46% reduction in water use was achieved by alternate-row furrow irrigation in irrigated sugarcane in India. Naouri and Nasab (2011) have reported 27% saving of irrigation water by alternate-row furrow irrigation method without significant yield loss in sugarcane in Iran. However, Bakker *et al.* (1997) have noticed a reduction of sugarcane yield by 38 t/ha with alternate-row furrow irrigation compared to every-row furrow irrigated sugarcane in Australia. This gives evidence that the alternate-row furrow irrigation method does not perform equally well everywhere. Performance of alternate-row furrow irrigation method has a close relationship with the properties of soil in which the crop is grown. For an example, alternate-row furrow irrigated maize crop grown in soils with different textural classes gave different water use efficiencies (Sepaskhah & Khajehabdollahi, 2005). The predominant soil type found in commercial sugarcane-growing areas in Sri Lanka is Reddish Brown Earths (RBE), which has specific chemical and physical properties (Irrigation Department of Sri Lanka, 1988). The impermeable gravel layer found at sub surface soil horizon limits drainage characteristics of RBE (Punyawardhana, 2008). In sugarcane-growing soils at Uda Walawe, this gravel layer was found at 25-60 cm depth (Saputhantree, 2015). This impeded drainage condition may have a favourable impact on the alternate-row furrow irrigation as impermeable layer enhances lateral movement of soil water in subsurface soil towards non-irrigated rows.

Therefore, this study was conducted to examine growth, yield and irrigation water productivity of alternate-row furrow irrigation methods and compare with every furrow irrigation and rain-fed cultivation, in order to assess the feasibility to increase irrigation water productivity in sugarcane-growing areas in RBE soils in Sri Lanka.

MATERIALS AND METHODS

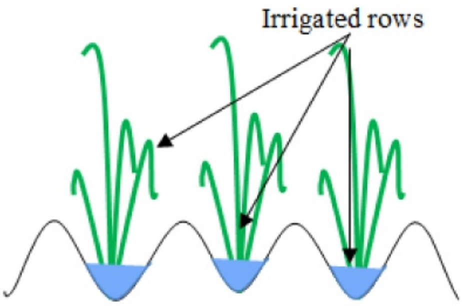
Description of the Study Area

The study was conducted from 2010 to 2014 in the research farm of the Sugarcane Research Institute (SRI), Uda Walawe, Sri Lanka (latitudes 60 24' N and 6025' N and longitudes 800 49' E and 800 50' E). The area belongs to the low-country dry zone (DL1a) (Punyawardana, 2008) and receives an annual rainfall of 1452 mm (Wijayawardhana, *et al*., 2014). Average annual ambient air temperature ranges from 28^0 C to 32^0 C (Witharama, *et al*., 2015). The rainfall is characterised by a bi-modal pattern of distribution where two-thirds of rainfall is received from September to January in maha season. The predominant soil group is Reddish Brown Earths (Panabokke, 1996; Punyawadhana, 2008).The top soil layer (10 20 cm depth) of the experimental location is characterised by sandy clay-loam in texture, bulk density, porosity and gravel content range from 1.4 g/cm^3 to 1.7g/cm3, 40% to 50% and 20% to 30% respectively. In sub-surface soil layer (40 cm 50 cm depth), the soil is sandy clay and sandy clay-loam in texture, bulk density, porosity and gravel content range from 1.4 g/cm^3 to 1.7 g/cm^3, 30%to 40% and10% to 30% respectively (Saputhanthree, 2015).

Experimental Procedures

An even land with uniform gradient was selected for the study. The land was ploughed to a depth of 20-30 cm and furrowed following the recommended procedure (SRI, 1991). The sugarcane seed setts were planted in the furrows. The spacing between two adjoining furrows was 1.37 cm. The furrows prepared were "V" in shape and the original depths were 18- 22 cm and they became 13-17 cm deep with 40-45 cm wide flat base after planting sugarcane. The field was laid out to make four blocks, each having three treatment plots. A treatment plot consisted of 25 m long 9 cane rows (308 m^2). The following three treatments were tested in RCBD experimental design with 4 replicates. The treatments were;

T1- Every furrow irrigation (EF)
T2- Alternate-row furrow irrigation (ARF)
T3 Rain-fed (RF): control



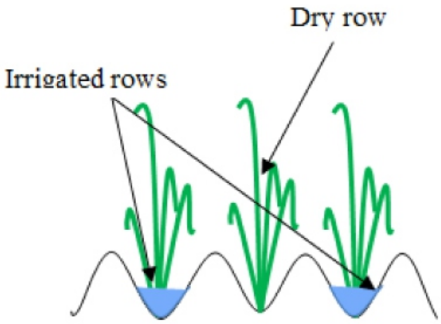


Figure 1: Every furrow irrigation Alternate-row furrow irrigation

In alternate-row furrow irrigation method, one furrow was skipped (left-out) and irrigation was given to every other furrows (Figure 1). Two types of alternate-row furrow irrigation methods are available, namely, fixed and variable alternate-row furrow irrigations. In the fixed furrow method, the furrows to be irrigated are decided at the beginning and the same alternate-row furrows are irrigated during the whole cropping cycle. In the variable alternate-row furrow method, every alternate furrows are irrigated, and the furrows kept un-irrigated are irrigated in the subsequent irrigation.

Variable alternate-row furrow irrigation method is difficult to be practised in sugarcane lands because non-irrigated furrows are used for keeping sugarcane residues and thrash. Therefore, the fixed alternate-row furrow irrigation method was practised in this study.

In order to avoid sub-surface soil moisture movement between different treatment plots and between adjoining other areas, a thick poly-ethylene sheet was placed vertically across soil profile to a depth of 100 cm around each treatment plot.

Planting and Crop Management

The experiments were conducted in both *maha* and *yala* cropping seasons. Field planting was coincided with the onset of rain in each season to assure maximum germination and field establishment of RF crop. The *maha* trial was planted in October 2010 and the *yala* trial was in April 2011, and both the experiments were continued until harvesting 2nd ratoon crop in 2014.The recommended practices were followed in establishing and maintaining both plant and ratoon crops (SRI, 1991).

Application of Irrigation Treatments

In plant crop, water was allowed to flow along the planted furrows as shown in Figure (1). But, in the case of ratoon crop, soil in-between the cane rows was heaped up either side of the cane rows to make original furrows into ridges and original ridges into furrows. Accordingly, water was allowed along the newly-formed furrows in-between the cane rows of ratoon crop.

Application of 60 mm at 9 day irrigation interval and optimum water discharge rate of 2.0 l/sec recommended to get maximum yield from irrigated sugarcane in Uda Walawe area (Katupitiya, 1986) was practised in this study. The discharge rate was estimated using bucket calibration method.

Estimation of Irrigation Performance Indices

The performance of alternate-row furrow irrigation method was evaluated by estimating following parameters:

a. Irrigation Depth

The depth of water applied into each plot by each irrigation event was calculated using the following equation (Halim, 2013).

$$d = Qt \times 1000/A \text{ --------------------------- } 01$$

Where: d = depth of irrigation applied,
Q = water flow rate at the inlet (L/min),
t = time of water allocated or cut-off time (min),
A = plot size (m^2)

b. Water Productivity

Water productivity was determined using the following formula:

$$WP = Y/Ir \text{ ---------------------------------- } 02$$

Where: WP=Water productivity (kg/m^3), Y =Yield (kg/ha), and Ir =Irrigation (m^3/ha).

Estimation of Sugarcane Yield and Quality Indices

The weight of cane harvested in each treatment plot excluding the border rows was measured to estimate cane yield. In addition, the number of cane stalks harvested from each treatment plots were recorded. The cane samples obtained from each treatment plots were analysed for brix, polarisation and fibre percentages to estimate POCS (pure obtainable cane sugar) as a quality parameter. These estimated sugarcane yield parameters were used to compare growth and performance of sugarcane under each treatment.

Statistical Analysis

The analysis of variance (ANOVA) procedure was used with DMRT mean separation method at 5% probability level for comparing the effects of the treatment on the crop parameters and the moisture parameters.

RESULTS AND DISCUSSION

Irrigation Application

In the maha-planted experiment, the average amounts of water consumption for one irrigation of plant crop and ratoon I crop by EF irrigation were 817 and 856 m^3/ha respectively. In irrigation by ARF, the water consumption of plant and ratoon I crops have reduced to 532 and 494 m^3/ha irrigation respectively (Table1). Similarly, in the yala-planted experiment, for each EF irrigation in plant crop, ratoon 1 and 11, water requirements were 775, 725 and 745 m^3/ ha respectively, and the respective levels of irrigation water requirement for ARF irrigation were 438, 398 and 448 m^3/ha. When the average water consumption of each of the irrigation event made for plant, ratoon I and II crops over both *maha* and *yala* seasons, the water consumption by ARF irrigation treatment was 462.0 m^3/ha; it was 41% less than the amount of water consumed by EF treatment (783.6 m^3/ha). Even though, the water was allowed only to half of the total number of furrows due to 50% of furrows are skipped in ARF irrigation treatment, the water consumption has not reduced by equal proportion (by half) compared with EF irrigation. This may be due to lateral movement of water at subsurface soil horizons. This phenomenon has been reported to be quite high in the fields irrigated with ARF method because two adjoining rows in both sides are dry. But, in EF method, since all furrows are used for irrigation, downward movement of water is greater than the lateral movement. Capillary action is another phenomenon which could be attributed to this difference (Mahomedand Imara, 2010).

Table 1: Irrigation application (m^3/ha) for each irrigation event of EF and ARF irrigation methods adopted to plant and ratoon crops of *maha* and *yala* - planted sugarcane

	maha-Planting				*yala*-Planting					
Irrigation event	Plant crop		Ratoon I		Plant crop		Ratoon I		Ratoon II	
	EF	ARF	EF	ARF	EF	ARF	EF	ARF	EF	ARF
1	754 ±14	521 ±07	911 ±11	541 ±11	752 ±09	399 ±09	997 ±03	565 ±06	838 ±17	474 ±12
2	821 ±14	342 ±06	927 ±10	501 ±10	794 ±20	307 ±19	644 ±17	447 ±08	844 ±17	413 ±17
3	927 ±12	656 ±06	831 ±12	564 ±1	695 ±11	437 ±9	668 ±18	372 ±09	811 ±14	480 ±13
4	918 ±04	481 ±12	871 ±10	486 ±10	775 ±15	252 ±19	679 ±11	427 ±05	788 ±08	571 ±18
5	851 ±08	591 ±15	769 ±8	504 ±8	647 ±09	232 ±14	654 ±07	376 ±03	732 ±17	569 ±7
6	951 ±12	598 ±13	859 ±11	532 ±11	731 ±14	298 ±18	746 ±17	387 ±8	662 ±12	476 ±17
7	800 ±11	511 ±18	839 ±7	446 ±7	826 ±18	572 ±9	635 ±19	351 ±10	810 ±13	482 ±19
8	740 ±11	554 ±12	926 ±21	553 ±21	818 ±9	470 ±8	644 ±4	307 ±2	674 ±10	527 ±17
9	600 ±9	532 ±8	856 ±13	544 ±13	842 ±12	472 ±9	784 ±6	349 ±3	772 ±13	466 ±11
10			744 ±1	541 ±12	833 ±8	627 ±12	664 ±13	378 ±6	662 ±14	352 ±14
11			816 ±13	405 ±14	788 ±8	547 ±9	714 ±18	360 ±9	601 ±11	312 ±16
12			892 ±17	393 ±17	799 ±11	649 ±12	707 ±14	428 ±7		
13			880 ±19	418 ±18			748 ±13	357 ±6		
14							689 ±16	418 ±8		
15							908 ±3	444 ±12		
Avg	817	532	856	494	775	438	725	398	745	448

Note: The *maha*-trial was panted in October 2010; the *yala*-trial was planted in April 2011. The duration of each crop cycle is 12 months.

Water Productivity (WP)

WP has increased substantially by adopting ARF method compared to EF method. The average WP of plant, ratoon I and Ratoon II crops over both *maha* and *yala* seasons were 11 kg/m^3 in EF irrigated plots and 16 kg/m^{3}in ARF irrigated plots. This is an increase of WP by 46% due to adoption of ARF irrigation method compared to EF irrigation. According to Srivasthava *et al*, (2011), WP of ARF irrigated sugarcane was 17 kg/m^{3}in India, and there was a 31% saving of irrigation water by ARF irrigation than every furrow irrigation.

Water saving by ARF irrigation was more in *yala*-planted crop (40% 45%) than that in *maha*-planted crop (35% 42%). In yala-planted experiment, the average water consumption over plant, ratoon I and ratoon II crops was 43% less in alternate-row furrow irrigation than that in every furrow irrigation. In maha-planted experiment, the irrigation water consumption averaged over plant and ratoon I crops by alternate-row furrow irrigationwas 39% less than that by the every furrow irrigation (Table 2).

Table 2: Annual total irrigation application (mm),water productivity (WP) and irrigation water saving (%) in EF and ARF irrigated plant and ratoon crops of maha- and yala-planted sugarcane

	***Maha*-planting**				***Yala*-Planting**					
	Plant crop		Ratoon 1		Plant crop		Ratoon I		Ratoon II	
	EF	ARF	EF	ARF	EF	ARF	EF	ARF	EF	ARF
Irrigation (mm/year)	736^{a} ±2.6	479^{b} ±3.5	1112^{a} ±7.9	643^{b} ±7.9	930^{a} ±3.4	526^{b} ±3.4	1088^{a} ±4.8	596^{b} ±5.5	819^{a} ±2.8	512^{b} ±2.9
WP (kg/m^3)	12^{b} ±0.6	18^{a} ±0.9	09^{b} ±0.3	16^{a} ±0.8	13^{a} ±1.5	16^{a} ±1.3	10^{b} ±0.5	15^{a} ±0.6	10^{a} ±0.5	13^{a} ±0.8
Water saving %		35.0		42.2		43.4		45.0		39.8

Notes: WP = Water productivity. Means were separated using DMRT at 5% probability level.

Sugarcane Yield and Juice Quality

In the *maha*-planted experiment, there was no significant reduction of cane yield between ARF irrigated plots and EF irrigated plots in plant crop and ratoon I. However, in RF plots, cane yield was significantly lower than that in the other two treatments, of ARF and EF irrigations (Table3). In plant crop, RF plots have shown a significant reduction of yield by 17 and 19% compared to ARF and EF irrigated plots respectively. In ratoon I, the cane yields of the RF plots have reduced by 23% and 15% compared to ARF and EF irrigated plots respectively (Table 3).

There were no significant differences of stalk densities between EF and ARF treatments in both plant and ratoon I crops. However, stalk densities have reduced significantly by about 19% in both plant and ratoon 1 crops RF fields compared to that in EF and ARF irrigated fields. In contrast, there was no significant difference in sugarcane juice quality, either brix or POCS values between two irrigation methods in the *maha*-planted experiments (Table 3).

Table 3: The estimated parameters of sugarcane yield and quality of plant and ratoon I crops of Maha (2010) planted experiment

	Plant crop			Ratoon I		
	EF	ARF	RF	EF	ARF	RF
Yield t/ha	90.9[a] ±4.4	85.8[a] ±4.3	71.9[b] ±1.5	103.2[a] ±3.7	101.5[a] ±4.8	74.8[b] ±0.6
Stalks/ha	78637[a] ±1356	76414[a] ±1709	62950[b] ±1945	96269[a] ±4897	86782[a] ±2570	73978[b] ±612
Brix %	20.8[a] ±0.49	21.1[a] ±0.07	21.9[a] ±0.24	18.3[b] ±0.23	18.1[b] ±0.36	19.7[a] ±0.42
POCS %	13.5[a] ±0.22	13.7[a] ±0.52	14.4[a] ±0.31	11.6[a] ±0.23	11.4[a] ±0.27	12.5[a] ±0.42

Note; Means were separated using DMRT at 5% probability level.

In the *yala*-planted experiment, there was no significant yield difference in both plant and ratoon 1 crops between ARF irrigated and EF irrigated plots. Also, the cane yield of RF crop also was not shown significant difference with ARF irrigation treatment. However, there were significant differences of cane yields between EF irrigated and RF treatments both in plant and ratoon I crops. But, this trend has changed in ratoon II. ARF irrigated plots showed significantly lower cane yield by 18% than EF irrigated plots, and RF plots showed significantly low yield by about 37% than the ARF irrigated plots. The yield decline in RF plot was 49 % compared to that in EF irrigated plots (Table 4).

The stalk densities between EF and ARF irrigated plots in plant and ratoon I and ratoon II crops was not significantly different in *yala*-planted experiments (Table 4). However, the stalk densities of plant crop of RF plots was 38% less and that in ratoon II crop. It was 34% less compared to EF irrigation treatment. The stalk densities between EF and ARF in plant crop, ratoon II and between any treatments in ratoon I were statistically not significant (Table 4).

In the *yala*-planted experiment, POCS (%) values showed significant differences between different irrigation treatments. In plant crop, POCS was significantly higher in ARF irrigated crop than that in EF irrigated and RF crops. The patterns were different in the other two crop classes. In ratoon I, POCS values were significantly higher in EF and ARF irrigation treatments than that in RF treatment whereas in ratoon II crop, POCS values were significantly higher in ARF irrigation treatment and RF treatment than that in EF irrigation treatment. Thus, the ARF treatment has contributed to significant improvement of sugar content (POCS %) in harvested cane in all three crop classes under EF irrigation and RF treatments. On average, the ARF irrigation treatment has increased POCS levels by 4% and 10% than EF and RF plots respectively. Thus, the ARF irrigation treatment is favourable for improving juice quality in harvestable cane. Generally, RF crops take longer time for maturity than the irrigated, often more than 12 months. Furthermore, the EF irrigated plots usually contain high moisture levels that could significantly reduce the sugar content.

Table 4: The estimated parameters of sugarcane yield and quality of both plant, ratoon I and II crops of yala 2011-planted experiment

	Plant crop			**Ratoon I**			**Ratoon II**		
	EF	ARF	RF	EF	ARF	RF	EF	ARF	RF
Yield (t/ha)	118.5[a] ±15.1	83.4[ab] ±6.9	58.6[b] ±2.5	104.1[a] ±5.7	89.1[ab] ±4.1	75.8[b] ±2.5	79.2[a] ±4.0	64.8[b] ±3.6	40.7[c] ±1.5
Stalks/ha	115246[a] ±1932	85051[ab] ±5479	70362[b] ±2745	94626[a] ±1829	91212[a] ±3027	90905[a] ±2113	80214[a] ±3301	72224[a] ±5749	52981[b] ±2531
Brix %	17.6[b] ±0.22	18.4[a] ±0.31	17.2[b] ±0.25	20.2[a] ±0.17	19.9[a] ±0.33	17.2[b] ±0.21	20.4[a] ±0.20	20.9[a] ±0.49	21.4[a] ±0.17
POCS %	11.2[b] ±0.21	11.9[a] ±0.29	10.8[b] ±0.22	13.5[a] ±0.27	13.4[a] ±0.25	10.8[b] ±0.31	14.3[b] ±0.13	15.3[a] ±0.35	15.4[a] ±0.20

Note; Means were separated using DMRT at 5% probability level.

CONCLUSIONS

The results of this study confirmed that the ARF irrigation method can be practised effectively to irrigate sugarcane fields in RBE soil in Sri Lanka. Adoption of this method helps saving irrigation water by 35-45% and increasing water productivity of the crop by 46% compared to that in EF irrigation. Quality of sugarcane grown by practising this method is higher than that under EF (4%) or RF conditions (10%).

ACKNOWLEDGEMENTS

The assistance given by Mr, W.G.N. Gamage, Mr D.M. Weerasiri, and Mr. N.K. Rupasena for collecting field data and managing field research plots is thankfully acknowledged.

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