Water Use Efficiency in Commercial Sugarcane Varieties under Irrigated and Rain-fed Conditions in Sri Lanka

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Introduction

Sugarcane is a sun-loving grass having C_4 photosynthetic path way with efficient water use. Few studies have analysed productivity in relation to water use efficiency (*WUE*) of sugarcane. The efficiency of biomass production under water stress is determined by the transpiration efficiency (T_E) which is the main and appropriate measure of WUE of a crop. *WUE* is defined as the amount of biomass produced per unit of water used. T_E is defined as the amount of biomass produced per unit of water transpired. Therefore, particularly under water limited conditions, both T_E and *WUE* quantify the efficiency of water use during the biomass production process in the plant. Moreover, considerable variation in these responses to water stress occurs among sugarcane varieties. The T_E varies with genotype, management conditions, CO_2 concentration and vapour pressure deficit of the growing environment. *WUE* can be increased by management practices such as higher planting densities and mulching which reduce soil evaporation. *WUE* of sugarcane ranges from 4.8 to 20.94 g cane kg^{-1} of water and it should not be constant due to the variation in vapour pressure deficit and stalk dry matter content. High values of *WUE* are obtained under well watered conditions (Robertson and Muchow, 1994; Inman-Bamber *et al.,* 1999a and Inman-Bamber *et al.,* 1999b). The objective of this study was to evaluate the WUE of commercial sugarcane varieties and thereby to identify sugarcane varieties which are efficient in utilizing soil moisture to grow under different sugarcane growing environment in Sri Lanka.

Materials and Methodology

A field experiment was conducted at the Sugarcane Research Institute (SRI), Uda Walawe (6°21'N latitude, 80°48'E longitude and 76 m altitude) where the annual average rainfall is about 1450 mm with a distinctly bimodal distribution. The experiment was conducted as a two-factor factorial, which contained 16 treatment combinations, composed of two main plot treatments as 'irrigated' ('well-watered') and 'rainfed' ('water-stressed') and eight commercial sugarcane (*Saccharum* hybrid L.) varieties as subplot treatments, in a split plot design. Each treatment combination was replicated thrice. Plot size was 9 m x 8.22 m, each of which contained 6 furrows spaced at 1.37 m.

Soil moisture content in each plot was measured fortnightly by gravimetrical method down to 1-m depth at 20-cm intervals. Runoff water from 73.98 m^2 area of an each plot was gathered into runoff-water collecting tanks buried in irrigated and rain-fed plots. The height of runoff water in the tanks was measured after each rainfall and the amount of runoff was calculated per unit area. A measured amount (2000 litre/plot/application) of water was supplied for the irrigated treatments only. The amount of rainfall was taken from SRI meteorological data and the soil water balance equation was used to compute evapotranspiration (*ET*) as $ET = RF + IR - RO - \Delta S - DR$ where RF=rainfall, IR=irrigation, RO=runoff, ΔS=change in soil moisture storage and DR=deep drainage. *DR* was assumed as a zero due to the soil moisture conditions did not exceed the field capacity level at 100 cm soil depth in all plots during the experimental period. *ET* values were calculated for the periods between successive destructive samplings to measure above-ground biomass accumulation (*ATBM*). Cumulative *ET* values (*CUMET*) were calculated by cumulating the respective periodic *ET* values throughout the season. Mean seasonal water use efficiency (*WUE*) was estimated as the slope of the linear regression fitted to the relationship between the respective *ATBM* and *CUMET* values for each plot.

Significance of treatment differences was tested by analysis of variance (*ANOVA*). Means were separated by using the Duncan Multiple Range Test (DMRT). Correlation between yield and other parameters were determined by correlation analysis. The SAS statistical computer package was used to analyse the data.

Results and Discussion

There was a significant (p=0.05) varietal variation in evapo-transpiration per day (ET_{dy}) and seasonal totals of evapo-transpiration (*ET*) under rain-fed conditions. Water deficits significantly reduced ET_{dy} and mean seasonal water use efficiency (*WUE*) in all the varieties tested (Table 1). However, *ET* increased in all varieties except M 438/59 and SLI 121 under rain-fed conditions because the duration of the rain-fed crop (392 days) was greater than the irrigated crop (325 days). *ET* varied from 1127 to 1454 kg m^{-2} and from 1177 to 1462 kg m^{-2} under irrigated and rain-fed conditions respectively. The ratio of evapo-transpiration to class A pan evaporation reached a maximum of 1.2 because the roughness of the tall cane crop increased. ET_{dy} varied from 3.47 to 4.48 mm day^{-1} and from 3.00 to 3.73 mm day^{-1} under irrigated and rain-fed conditions respectively (Table 1). In Hawaii the ET_{dy} ranged from 3.8 to 8.9 mm day^{-1}. The peak use of water was 8.1 to 8.6 mm day^{-1} during the grand growth period. It varied from 2.3 to 6.1 mm day^{-1} and from 1.3 to 6.8 mm day^{-1} depending on the physiological stage of development and atmospheric demand (Gascho and Shih, 1983).Also, ET_{dy} of irrigated sugarcane could be as high as 8 mm day^{-1} depending on atmospheric demand.

WUE ranged from 3.66 to 5.27 g of biomass kg^{-1} of water and from 2.15 to 2.92 g of biomass kg^{-1} of water under irrigated and rain-fed conditions respectively (Table 1). In agreement with the present findings, Gascho and Shih (1983) recorded that *WUE* ranged from 3.3 to 6.9 g kg^{-1} with the variation being due to differences in varieties, age, climatic conditions and experimental techniques. However, sugarcane in Hawaii and Queensland produced about 7-9 g biomass kg^{-1} of water under optimum conditions. Based on a harvest index of 0.39, Muchow *et al.* (1996) gave a sucrose yield of 2.7-3.5 g sucrose kg^{-1} of water used. High values of *WUE* were obtained under well watered conditions. Inman-Bamber *et al.* (1999a) showed thatirrigation increased *WUE* up to 27 g cane kg^{-1}. Although irrigation added only 9% to the total water input, it enhanced canopy development and increased rainfall efficiency and transpiration considerably. Total biomass at harvest was increased by 31% and cane yield by 41% because of improved dry matter partitioning to the stalk in the irrigated treatment (Inman-Bamber *et al.*, 1999b).

Table 1 Evapo-transpiration per day (ET_{dy}), seasonal total evapo-transpiration (*ET*) and mean seasonal water use efficiency (*WUE*) (± standard error) of different sugarcane varieties in the plant crop under irrigated and rain-fed conditions.

Variety	ET_{dy} (mm day^{-1})		*ET* (mm or kg m^{-2})		*WUE* (g dry wt.kg$^{-1}H_2O$)	
	Irrigated	Rain-fed	Irrigated	Rain-fed	Irrigated	Rain-fed
Co 775	3.96^{ab}	3.59^{ab}	1287.9^{ab}	1407.8^{ab}	4.90^{a}	2.92^{a}
M 438/59	4.04^{ab}	3.35^{bc}	1312.3^{ab}	1312.3^{bc}	4.37^{ab}	2.52^{a}
SL 71 03	4.22^{ab}	3.57^{ab}	1371.8^{ab}	1398.2^{ab}	4.13^{ab}	2.66^{a}
SL 71 30	3.47^{b}	3.25^{bc}	1127.3^{b}	1272.9^{bc}	5.22^{a}	2.76^{a}
SL 83 06	3.90^{ab}	3.52^{ab}	1266.9^{ab}	1380.6^{ab}	5.27^{a}	2.37^{a}
SL 86 13	3.63^{ab}	3.53^{ab}	1179.6^{ab}	1384.8^{ab}	4.61^{ab}	2.15^{a}
SL 88 116	3.88^{ab}	3.73^{a}	1262.0^{ab}	1462.4^{a}	4.84^{ab}	2.54^{a}
SLI 121	4.48^{a}	3.00^{c}	1454.5^{a}	1177.1^{c}	3.66^{b}	2.63^{a}
Mean	3.95	3.44	1282.8	1349.5	4.62	2.57

Note: Within a column, the means followed by the same letter are not significantly different at p=0.05

The importance of ET_{dy}, *ET* and *WUE* in yield determination varied with varieties within and between water regimes. Variety SLI 121 which had the highest ET_{dy}, *ET* and the lowest *WUE* recorded the lowest cane yield under irrigated conditions. It also had the lowest ET_{dy}, *ET* and cane yield under rain-fed conditions. Variety SL 88 116 which had the highest ET_{dy} and *ET* recorded the highest biomass and cane yield under rain-fed conditions. Variety SL 71 30 recorded the lowest ET_{dy} and *ET* under irrigated conditions. SL 83 06 which had the second highest biomass and third highest cane yield recorded the highest *WUE* under irrigated conditions. When yields under both water regimes were considered, cane yield showed significant positive correlations with ET_{dy} (r^2= 0.38 with p=0.0075) and *WUE* (r^2= 0.89 with p=0.0001). On the other hand, cane yield under irrigated conditions showed significant positive correlations with *WUE* (r^2= 0.66 with p=0.0004). Cane yield under rain-fed conditions showed significant positive correlations with *WUE* (r^2= 0.56 with p=0.0027).

Conclusion

The study showed that there is an adequate genotypic variation in *WUE* and related characters which determine cane yields under different sugarcane-growing environments of Sri Lanka. Moreover, SL 83 06 and Co 775 showed highest *WUE* under irrigated and rain-fed conditions respectively. High levels of cane yield, cane biomass and total biomass were ositively correlated well with *WUE* and varied for different varieties under different onditions. Therefore, it is recommended to identify the correlation between cane yield and *VUE* which could be used in breeding programmes to select for drought resistant varieties or different sugarcane-growing environments in Sri Lanka.

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