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Varietal Variation in Growth, Physiology and Yield of Sugarcane under Two Contrasting Water Regimes

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***ABSTRACT**. The objective of this study was to determine the effects of soil moisture deficits on growth, physiology and yield of sugarcane varieties in order to identify drought tolerant varieties and specific traits. The experiment was conducted in 2002/03 at the Sugarcane Research Institute, Sri Lanka (6°21'N, 80°48'E). Eight commercial varieties (SL 7103, SL 7130, SL 8306, SL 8613, SL 88116, SLI 121, M 438/59 and Co 775) were grown under irrigated (soil water potential > -0.05 MPa) and rainfed conditions. Vegetative growth, cane yield and yield components, stomatal conductance and transpiration rates, root length densities at different depths of the soil were measured. The improved Sri Lankan variety, SL88-116, showed the highest cane and sugar yields under both water regimes. Cane yields of all varieties under irrigation were significantly (P<0.05) greater (38-74%) than under rainfed conditions. High levels of stalk weight, leaf area index at harvest and the number of stalks per ha were correlated well with yields and varied for different varieties under rainfed conditions. Water conservation through lowering stomatal conductance, both at the individual leaf and canopy level, and developing higher root length densities in the 30-60 cm soil layer to ensure survival during the periods of significant water deficits in the top soil layer (0-30 cm) were identified as mechanisms responsible for achieving high sugarcane yields in the rainfed environments of Sri Lanka.*

INTRODUCTION

Sugarcane is grown in more than 70 countries of the world, and it contributes 72% to the world sugar production (Anon, 2003a). On a global scale, its average productivity has increased from 75 to 95 t cane ha^{-1} and from 5 to 12 t sugar ha^{-1} during the period from 1960 to 1999 (Cock, 2003). However, in Sri Lanka, cane and sugar production has declined, and the current domestic production of sugar is less than 7% of the national demand (Anon, 2003b).

At present more than 90% of the cultivation is mainly dependent on a single variety Co 775. It has the potential to produce a cane yield of about 140 t ha^{-1} under irrigation and 70 t ha^{-1} under rainfed conditions (Personal communication A. Sivanathan, 2003). However, Sri Lanka has never achieved the potential yield level. The average sugarcane yield during the last decade has been 58 t cane ha^{-1} and 4.9 t sugar ha^{-1} (Anon, 2003b; Anon, 2003c) which is well below the potential of the variety. The low cane yield is due mainly to low soil moisture availability under rainfed conditions (Dharmawardene and Krishnamurthi, 1992). In Sri Lanka, sugarcane is

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mostly grown under rainfed conditions in the dry and intermediate zones (Mettananda, 1990) and the crop experiences frequent soil moisture deficits during a considerable part of the year. This problem cannot be overcome by changing the date of planting because the duration of the crop is about 12 months.

Hence, development or screening of drought resistant varieties is the most promising way to increase sugarcane yield in Sri Lanka (Ludlow and Muchow, 1990). The objectives of this study were to (a) determine the effects of soil moisture deficits on growth, yield and physiology of selected sugarcane varieties and thereby identifying varieties having higher yield potential under rainfed conditions, and (b) identify physiological mechanisms responsible for achieving higher yields under rainfed conditions with a view to using them in future breeding programmes for the development of drought tolerant sugarcane varieties for Sri Lankan sugarcane-growing environments.

MATERIALS AND METHODS

A field experiment was conducted from April 2002 to September 2003 at the Sugarcane Research Institute (SRI), Uda Walawe, Sri Lanka (6^o21'N latitude, 80^o48'E longitude and 76 m altitude) where the annual average rainfall is about 1450 mm with a distinctly bimodal distribution (Panabokke, 1996). The average annual minimum and maximum temperatures were 22^0C and 32^0C. The evaporation from a free water surface averages about 5 mm per day (Sanmuganathan, 1992). The soil has been classified as Ranna series of *Reddish Brown Earth* (RBE), great group of Rhodustalfs (order Alfisols, suborder Ustalfa) soils and has a sandy clay loam texture (De Alwis and Panabokke, 1972; Anon, 1975). It is moderately well drained with a pH of 6.5 - 6.7. The bulk density of the soil ranges from 1.59 – 1.85 g cm^{-3} (Sithakaran, 1987). The respective soil water contents at saturation, field capacity and permanent wilting point are 30%, 20% (10 kPa) and 8% (1500 kPa), respectively (Sanmuganathan, 1992).

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 (i.e. SL 7103, SL 7130, SL 8306, SL 8613, SL 88116, SLI 121, M 438/59 and Co 775) as subplot treatments, in a split plot design. The irrigated treatment received irrigation (2 m^3 of water per irrigation) at 5-10 day intervals so that its soil water potential in the top 1 m was maintained above -0.05 MPa. One meter deep trenches were made between irrigated and rainfed plots to avoid the lateral movement of water. 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. The sugarcane was planted and maintained under recommended procedures (Anon, 1991).

Soil moisture content at each plot was measured gravimetrically at fortnightly intervals down to 1-m depth at 20-cm intervals. Variation of leaf area index (LAI) and accumulation of total biomass were measured by destructive sampling of five randomly selected stalks from two rows close to the two boarder rows on either side of the plot at approximately two week intervals. Leaf area was measured by length and width method using a pre-calculated leaf area co-efficient. Total biomass was obtained by oven drying the samples at 90^0C until a constant weight was obtained.

Stomatal conductance and instantaneous transpiration rate per unit leaf area were measured in leaves of top, middle and bottom parts of the canopy layers using a steady-state porometer (LI-1600, LI-COR, Inc. LTD., Lincoln, USA) at 6 and 9 months after planting (MAP). The measurements were done between 09:30 and 14:30 hours. Canopy stomatal conductance and instantaneous canopy transpiration rate were computed by summing the products of mean leaf stomatal conductance and partial leaf area index in the three canopy layers (Squire and Black, 1981). Root length density (RLD) down to 1-m soil depth at 10-cm intervals was measured at 184 days after planting by core sampler method (Schurman and Goedewaagen, 1971). Soil samples were taken within a diameter of 30 cm around the plant using a core sampler. Root separation from soil was done using a root washer. Root length was measured by the grid method (Marsh, 1971) and root length density was calculated as root length per unit soil volume.

The irrigated plots were harvested at 12 MAP. Rainfed plots were harvested at 16 MAP because of their delayed maturity. The middle two rows in each plot were harvested for yield analysis. In addition to cane yield and sugar yield, stalk population, total biomass, harvest index (HI), LAI at harvest, stalk diameter, weight, height were recorded, and the number of internodes per stalk was recorded in a sub-sample of 10 stalks.

The significance of treatment differences was tested by analysis of variance (ANOVA). Means were separated by using the least significant difference (LSD). Correlation between yield and yield components was determined by simple linear correlation analysis. The SAS statistical computer package was used to analyse the data.

RESULTS AND DISCUSSION

Variation of rainfall pattern and soil moisture content

The soil moisture content of the irrigated plots was greater than that of the rainfed plots throughout the experimental period (Table 1). There was an extremely lower rainfall than the 75% probable rainfall between the 2nd and 4th months, i.e. June – August in the life of the crop. This low rainfall created a substantial difference in the average soil moisture content in the top 1-m of the soil between the two water regimes. However, the total rainfall during the first 12 months of the experiment was greater (1871 mm) than the annual average rainfall (1450 mm) at the experimental site (Table 1).

Canopy development and biomass accumulation

When averaged across varieties, water deficits reduced LAI (Fig. 1a) and the biomass of sugarcane throughout the growing period (Fig. 1b). LAI from 56 to 276 days after planting *(DAP)* was significantly ($p<0.05$) higher in irrigated condition than under rainfed conditions. Also the total dry matter production from 104 *DAP* to harvesting was significantly ($p<0.05$) higher in irrigated conditions in comparison to rainfed conditions (Fig. 1b). The highest, LAI values of 7.3 under irrigation and 6.0 under rainfed conditions were achieved at 242 and 304 *DAP*, respectively. A rapid reduction of LAI was observed in both treatments after achieving their respective maxima. This was probably due to the onset of cane maturity, which is associated with an increased nitrogen demand and a higher rate of respiration (Wolf *et al*., 1988).

Varietal variation of total biomass, cane and sugar yield

Water deficits during the 3rd to 6th months of age significantly reduced total biomass at harvest, cane yield and sugar yield in all varieties (Table 3). When averaged across varieties, water deficits reduced mean total biomass at harvest, cane yield and sugar yield by 37%, 51% and 55%, respectively. Variety SL 88-116 showed the highest cane yield, sugar yield, and total biomass under both water regimes (Table 3). Variety SLI 121 showed significantly ($p=0.05$) lowest total biomass under both water regimes, and cane yield under irrigated conditions.

Table 1. Seasonal variation of soil moisture contents (% dry weight basis) in 1-m soil profile under irrigated ($SM\%_{Ir.}$) and rainfed ($SM\%_{Rf.}$) conditions, actual ($RF_{Ac.}$) and 75% probable rainfall ($RF_{Pr.}$) at the experimental site during first 12 months of the experiment.

Crop – age (month)	$SM\%_{Ir.}$	$SM\%_{Rf}$	$RF_{Ac.}$ (mm / month)	$RF_{Pr.}$ (mm / month)
1st (May-2002)	16.17 ± 1.48	14.76 ± 1.29	158.42	109.6
2nd (June-2002)	12.91 ± 1.66	11.98 ± 1.61	10.20	32.0
3rd (July-2002)	12.72 ± 2.13	9.61 ± 2.29	29.00	83.9
4th (Aug-2002)	12.81 ± 2.49	8.68 ± 1.69	32.50	81.3
5th (Sep-2002)	13.54 ± 2.01	6.62 ± 1.58	54.00	17.5
6th (Oct-2002)	14.62 ± 2.23	9.43 ± 1.49	264.30	49.9
7th (Nov-2002)	16.88 ± 2.14	13.56 ± 1.52	350.60	102.3
8th (Dec-2002)	15.57 ± 2.03	14.47 ± 1.44	68.50	332.4
9th (Jan-2003)	13.05 ± 1.38	11.99 ± 1.42	49.20	46.2
10th (Feb-2003)	13.91 ± 1.38	11.37 ± 1.21	60.30	25.3
11th (Mar-2003)	18.00 ± 1.27	16.81 ± 1.73	542.30	15.3
12th (Apr-2003)	16.86 ± 1.38	14.27 ± 2.02	251.70	161.2
Mean	14.75	11.96	155.91	88.14

Soil moisture values *(SM %)* are means ± SD of 120 observations (eight varieties in three replicates and five levels of soil depth) and average values for whole soil profile.

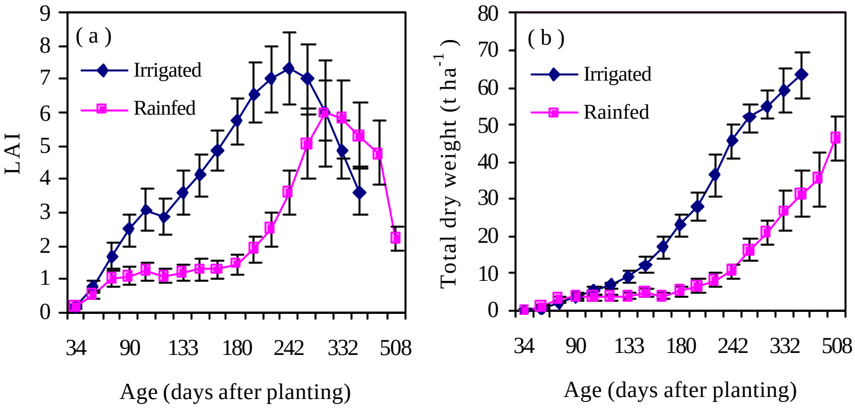

Fig. 1. **Seasonal variation of (a) leaf area index (LAI) and (b) total dry matter production with aging of sugarcane in response to water regimes.**
[Note: Each data point is the average of eight varieties and error bars indicate the standard deviation of means].

Table 2. **LAI at harvest (L_h), maximum LAI (L_m) and age of achieving L_m (days after planting - given within parentheses) of different sugarcane varieties under irrigated and rainfed conditions.**

Variety	LAI (L_h)		LAI (L_m)	
	Irrigated	Rainfed	Irrigated	Rainfed
SL 88-116	3.74 ± 0.9	2.02 ± 0.2	6.95 ± 0.8 (242)	5.75 ± 1.1 (304)
Co 775	3.35 ± 1.0	2.81 ± 0.2	7.09 ± 0.5 (195)	7.17 ± 1.9 (304)
SL 8306	3.95 ± 0.9	1.82 ± 0.4	7.93 ± 0.6 (276)	7.35 ± 0.8 (332)
SL 8613	4.44 ± 0.4	1.52 ± 0.1	8.35 ± 1.7 (242)	7.03 ± 2.5 (304)
SL 7130	3.61 ± 0.5	2.01 ± 0.2	7.87 ± 1.3 (242)	6.51 ± 2.1 (304)
M 438/59	3.60 ± 0.8	2.60 ± 0.6	7.53 ± 2.0 (242)	6.04 ± 1.6 (304)
SL 7103	3.14 ± 0.9	2.64 ± 0.1	7.40 ± 0.7 (242)	5.06 ± 1.2 (332)
SLI 121	3.13 ± 0.8	2.19 0.4	6.72 ± 1.4 (224)	4.95 ± 0.9 (304)
Mean	3.62	2.20	7.33	5.96
LSD_v	1.29	0.60		
LSD_w	0.34			

LSD_v = LSD (p=0.05) for varietal comparisons within a water regime; LSD_w = LSD (p=0.05) for comparison of mean ± SD values of water regimes.

Table 3. Total biomass (oven dried weight of cane, trash and leaves), cane yield (cane fresh weight) and sugar yield of different sugarcane varieties under irrigated and rainfed conditions.

	Total biomass (t/ha)		Cane yield (t/ha)		Sugar yield (t/ha)	
Variety	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed
SL 88-116	68.7±10.9	52.2±8.5	156.5±24.5	98.0±16.6	21.9±2.5	14.1±3.3
Co 775	66.3±5.9	51.9±5.8	147.8±19.9	97.8±12.6	17.9±2.7	13.7±1.8
SL 8306	67.2±6.1	46.3±3.6	145.5±4.4	88.7±4.9	19.3±1.5	11.7±0.6
SL 8613	61.5±4.4	41.3±1.7	137.6±11.7	78.8±13.3	19.1±4.3	10.3±2.3
SL 7130	66.2±11.8	46.3±9.5	137.0±15.9	91.5±17.9	18.1±4.4	12.0±1.8
M 438/59	60.7±12.1	44.7±8.5	135.8±15.9	93.2±12.5	17.4±2.2	12.0±2.9
SL 7103	60.2±9.2	48.7±9.1	135.4±18.0	97.6±17.0	17.3±2.1	13.5±2.2
SLI 121	54.9±1.7	39.0±7.0	125.2±4.6	79.3±14.2	17.9±0.9	11.2±1.9
Mean	63.25	46.32	140.12	90.61	18.60	12.30
LSD_v	10.89	9.97	23.48	19.77	4.12	3.48
LSD_w	3.43		7.17		1.26	

LSD_v = LSD (p=0.05) for varietal comparisons; LSD_w = LSD ± SD for comparison of water regimes.

Responses of yield parameters to water deficit

Leaf area index at harvest and maximum leaf area index (Table 2), number of stalks per ha, weight per stalk and height per stalk (Table 4), and stalk diameter and number of internodes per stalk (Table 5) showed significant ($p<0.05$) variations between varieties within and between both water regimes. However, harvest index was not significantly affected by either varieties or water deficits (Table 5).

All the above variables showed reductions under rainfed conditions in all varieties, with the exceptions of No. of stalks ha^{-1} in SL 7130, L_m in Co 775, HI in M 438/59 and SL 7103 and number of internodes in SLI 121.

When yields under both water regimes were considered, cane yield had significant and positive correlation with Number of stalks ha^{-1} (r^2 = 0.43 with p=0.0022), stalk weight (r^2 = 0.86 with p=0.0001), L_h (r^2 = 0.82 with p=0.0001), mean stalk diameter (r^2 = 0.29 with p=0.0485), number of leaves at harvest (r^2 = 0.61 with p=0.0001) and plant height at harvesting (r^2 = 0.69 with p=0.0001) (Table 6). Under rainfed conditions, cane yield showed significant positive correlations with stalk weight (r^2 = 0.73 with p=0.0001), L_h (r^2 = 0.50 with p=0.01) and plant height at harvesting (r^2 = 0.64 with p=0.0008) and a moderate positive correlation with Number of stalks ha^{-1} (r^2 = 0.31 with p=0.14) (Table 6). The importance of these characters in yield determination under rainfed conditions varied for different varieties. For example, SL 88-116, which showed the highest rainfed cane yield, had the highest stalk weight among the varieties tested (Table 3 and 4). A higher L_h rather than a higher stalk weight was responsible for the higher rainfed yield in Co 775. In contrast, the number of stalks ha^{-1} was lowest in SLI 121, which showed the second lowest rainfed cane yield.

Table 4. No. of stalks per ha, weight per stalk and height per stalk of different sugarcane varieties under irrigated and rainfed conditions.

Variety	No. of stalks ha^{-1}		Stalk weight (kg)		Stalk height (m)	
	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed
SL 88-116	72232±3687	65693±2540	2.2±0.2	1.5±0.3	3.18±0.2	2.72±0.2
Co 775	74513±4239	73145±6392	1.9±0.2	1.3±0.2	2.88±0.2	2.76±0.1
SL 8306	88656±4477	79988±9999	1.6±0.1	1.1±0.1	3.14±0.2	2.72±0.1
SL 8613	88656±9998	74513±7388	1.5±0.1	1.0±0.1	3.11±0.3	2.69±0.2
SL 7130	67518±9089	69495±7275	2.0±0.1	1.3±0.1	3.16±0.1	2.54±0.1
M 438/59	75426±2512	70560±5794	1.8±0.2	1.3±0.1	3.04±0.1	2.63±0.2
SL 7103	73905±8522	72385±9997	1.8±0.1	1.4±0.3	2.98±0.1	2.73±0.2
SLI 121	64477±526	57938±3444	1.9±0.1	1.4±0.3	2.53±0.2	2.25±0.3
Mean	75673	70465	1.87	1.29	3.00	2.63
LSD_v	9506	9494	0.26	0.27	0.29	0.32
LSD_w	3570		0.09		0.11	

LSD_v = LSD (p=0.05) for varietal comparisons; LSD_w = LSD ± SD for comparison of water regimes.

Responses of stomatal conductance and instantaneous transpiration rate to water deficits

The significant interactions between water regime and variety were shown on stomatal conductance and instantaneous transpiration rate in terms of both individual leaves in the top leaf layer (g_s, E_l) (Table 7) and the whole canopy (g_c, E_c) (Table 8). Soil water deficit decreased g_s, E_l, g_c, and E_c in a majority of varieties. When yields under both water regimes were considered, cane yield showed significant positive correlations with g_s (r^2 = 0.49 with p=0.05), E_l (r^2 = 0.51 with p=0.04), g_c (r^2 = 0.80 with p=0.0002) and E_c (r^2 = 0.74 with p=0.0001). This indicated that greater stomatal opening and efficient water use are pre-requisites for increasing overall sugarcane yields in this environment.

On the other hand, cane yield under rainfed conditions showed moderate negative correlations with g_s (r^2 = -0.53 with p=0.18), E_l (r^2 = -0.30 with p=0.47) and g_c (r^2 = -0.22 with p=0.60). This indicated that water conservation mechanisms (i.e. lowering of g_s and E_l) are needed in a variety to achieve higher yields under rainfed conditions. For example, the variety SL 88116 which showed the highest rainfed cane yield had the second lowest g_s and E_l and lowest g_c under rainfed conditions (Table 3). Conversely, SL 8613 which had the lowest rainfed cane yield had the second highest E_l, g_c and E_c under rainfed conditions.

Table 5. Harvest index (HI), stalk diameter and number of internodes per stalk of different sugarcane varieties under irrigated and rainfed conditions.

Variety	Harvest index		Stalk diameter (mm)		No. of internodes	
	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed
SL 88-116	0.62±0.04	0.60±0.03	33.5±3.0	30.6±1.5	30.2±2.7	30.0±2.3
Co 775	0.64±0.06	0.61±0.02	28.4±0.9	26.6±1.9	27.7±2.1	28.4±0.7
SL 8306	0.62±0.03	0.64±0.03	27.6±1.1	26.6±1.7	32.8±2.7	30.7±2.4
SL 8613	0.63±0.03	0.60±0.10	29.3±2.3	26.4±1.0	33.8±2.5	30.7±3.0
SL 7130	0.61±0.01	0.61±0.01	31.1±0.7	30.8±0.7	28.7±1.3	26.9±2.6
M 438/59	0.62±0.01	0.64±0.02	29.1±1.5	28.9±0.4	31.1±1.7	26.8±2.7
SL 7103	0.63±0.03	0.64±0.05	28.9±1.5	26.1±0.8	27.1±2.9	24.2±1.9
SL 121	0.67±0.02	0.61±0.02	32.3±1.4	30.8±3.1	22.2±2.0	23.1±2.7
Mean	0.63	0.62	30.04	28.36	29.18	27.60
LSD_v	0.05	0.08	3.10	3.02	4.03	4.45
LSD_w	0.02		0.99		1.39	

LSD_v = LSD (p=0.05) for varietal comparisons; LSD_w = LSD ± SD for comparison of water regimes.

Table 6. Pearson's correlation coefficients between cane yield and yield components of sugarcane when averaged across varieties and under irrigated and rainfed conditions.

	Correlation coefficients between cane yield and yield components		
	Overall	Irrigated	Rainfed
No. of stalks ha^{-1}	0.432^{*}	0.446^{*}	0.311^{ns}
Weight per stalk	0.862^{**}	0.450^{*}	0.732^{**}
Stalk diameter	0.286^{*}	0.098^{ns}	0.112^{ns}
Stalk height	0.690^{**}	0.211^{ns}	0.639^{*}
No. of leaves per stalk	0.608^{**}	0.146^{ns}	0.059^{ns}
LAI at harvest (L_h)	0.818^{**}	0.565^{*}	0.500^{*}

** Significant at p<0.0001; * Significant at p< 0.05; ^{ns} Non-significant at p=0.05.

Table 7. Stomatal conductance and instantaneous transpiration rate of top leaves of different sugarcane varieties under irrigated and rainfed conditions.

Variety	Mean stomatal conductance of top leaves, gs, (cm s-1)		Instantaneous transpiration rate of top leaves, El, (µg cm-2 [leaf area] s-1)	
	Irrigated	Rainfed	Irrigated	Rainfed
SL 88-116	0.195± 6.10	0.069±0.02	6.163±2.01	1.798±0.54
Co 775	0.142±0.06	0.057±0.02	5.028±2.95	1.765±0.72
SL 8306	0.173±0.04	0.103±0.04	4.387±1.90	3.498±0.18
SL 8613	0.079±0.05	0.108±0.04	2.793±1.14	3.912±0.18
SL 7130	0.072±0.01	0.132±0.03	1.792±0.22	4.588±2.24
M 438/59	0.177±0.14	0.095±0.03	4.178±0.30	1.992±0.37
SL 7103	0.172±0.07	0.077±0.03	4.647±1.52	2.183±0.90
SLI 121	0.147±0.05	0.112±0.05	4.457±1.18	2.613±1.32
Mean	0.145	0.094	4.181	2.794
LSD_v	0.100	0.060	2.706	1.885
LSD_w	0.028		0.814	

LSD_v = LSD (p=0.05) for varietal comparisons; LSD_w = LSD ± SD for comparison of water regimes.

Root length density

Root length density (RLD) varied significantly (p<0.0001) between different soil layers (Fig. 2). The top soil layer (0-30 cm) had greater RLD than the middle layer (30-60 cm) which in turn had greater RLD than the bottom layer (60-100 cm). Within each layer, there was a significant (p<0.05) variety x water regime interaction effect on RLD. The variety SL 88-116, which showed the highest rainfed cane yield (Table 3), had substantially greater RLD under rainfed conditions in the top and middle layers. This superior rooting ability of SL 88-116 was probably due to its inherent genetic make-up. In these two layers, except for SL 88-116, the majority of varieties had lower RLD under rainfed conditions than under irrigated conditions. In the bottom layer, a majority of varieties had greater RLD under rainfed conditions. It is notable that SL 88-116 had comparatively higher levels of RLD in the bottom layer under both rainfed and irrigated conditions. There was a significant (p<0.05) variety x water regime interaction on RLD of the entire soil profile (0-100 cm) as well. The comparative variation pattern of RLD in the entire soil profile was similar to that shown for the top soil layer. In all varieties except SL 88-116, there was a lower RLD under rainfed conditions. Total profile RLD showed a moderate positive correlation with cane yield (r^2 = 0.21 with p=0.14) when both irrigated and rainfed data were used in the correlation analysis. A higher total RLD allowed greater water absorption and thereby achieved higher cane yields through increased stomatal conductance and water use (as shown earlier from Tables 3, 7 and 8). On the other hand, rainfed cane yield showed a significant positive correlation with RLD in the middle soil layer (r^2 = 0.42 with p=0.04) and a moderate correlation with total RLD (r^2 = 0.26 with p=0.23). As water conservation mechanisms were needed to achieve higher yields under rainfed conditions (Tables 3, 7 and 8), it is highly probable that higher RLD in the middle soil layer was used as a means of absorbing water to maintain plant functions during periods of significant soil water deficits in the top soil layer rather than as a means of increasing water use and thereby increasing rainfed cane yields.

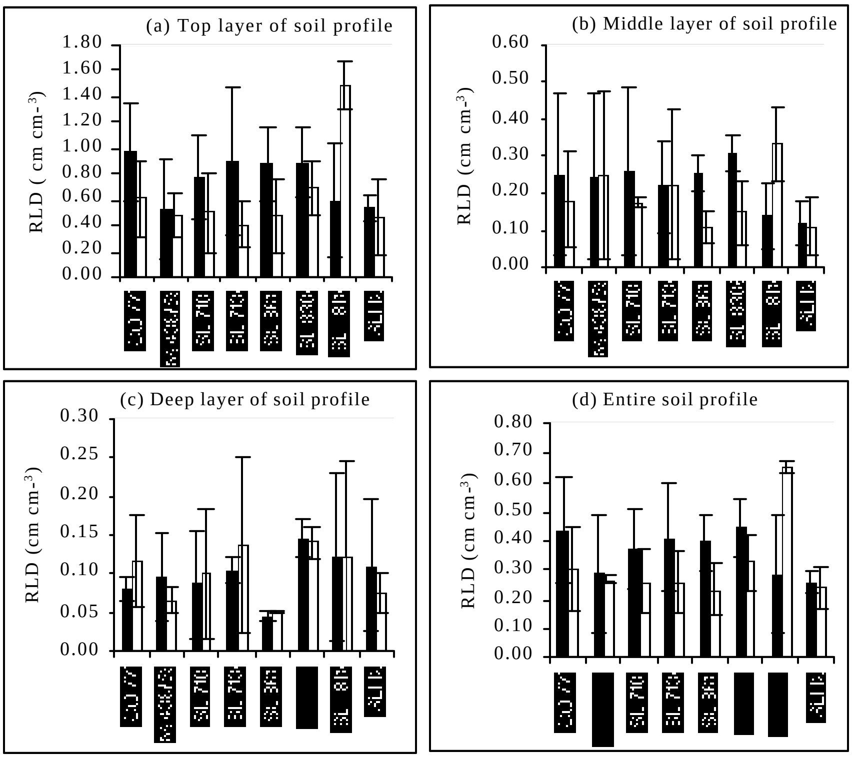

Fig. 2. **Root length density (RLD) in different layers of the soil profile at 184 days after planting in different sugarcane varieties under irrigated (solid bars) and rainfed (open bars) conditions. The error bars indicate the respective standard deviations.**

Table 8. Stomatal conductance and instantaneous transpiration rate of the overall canopy of different sugarcane varieties under irrigated and rainfed conditions.

Variety	Canopy stomatal Conductance, g_c, (cm s^{-1})		Instantaneous canopy transpiration Rate, E_c, (μg cm^{-2} [land area] s^{-1})	
	Irrigated	Rainfed	Irrigated	Rainfed
SL 88-116	1.251±0.60	0.279±0.10	37.93±15.06	10.25±6.61
Co 775	0.941±0.33	0.344±0.17	32.53±16.03	9.78±3.73
SL 8306	0.899±0.24	0.420±0.12	31.19±9.52	12.28±3.02
SL 8613	0.719±0.77	0.499±0.20	18.49±18.39	15.79±5.86
SL 7130	0.559±0.29	0.669±0.17	14.04±6.78	22.65±10.96
M 438/59	0.624±0.18	0.324±0.12	17.45±4.68	7.56±2.23
SL 7103	0.704±0.24	0.296±0.08	18.40±6.51	7.75±1.62
SLI 121	1.090±0.50	0.349±0.18	34.93±10.70	8.32±4.41
Mean	0.838	0.386	25.21	11.33
LSD_v	0.673	0.256	19.743	8.620
LSD_w	0.189		5.379	

LSD_v = LSD (p=0.05) for varietal comparisons; LSD_w = LSD ± SD for comparison of water regimes**.**

CONCLUSIONS

The present study showes that there is an adequate genotypic variation in the agronomic (mean stalk weight, LAI at harvest and number of stalks per ha) and ecophysiological characters (root length density and stomatal conductance), which determine cane yields under rainfed conditions in the sugarcane-growing environments of Sri Lanka. However, among the eight varieties tested in the present study, there was no single variety in which all above characters were present at favourable levels. Different characters were responsible for higher rainfed yields in different varieties. Consequently, yields of the eight varieties tested under rainfed conditions showed a comparatively narrow range, thus indicating a relatively narrow genotypic variation for selecting drought tolerant varieties on the basis of yield alone.

Based on these conclusions, the following approaches are recommended for development of drought tolerant varieties for sugarcane-growing environments in Sri Lanka: (a) Selecting varieties on the basis of agronomic and ecophysiological characters which have shown significant correlations with rainfed cane yield and using them in hybridisation programmes to obtain hybrids in which several characters are combined at favourable levels;, and (b) Introduction of foreign germplasm into breeding programmes to broaden the existing narrow genetic base for rainfed cane yield.

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