Evaluation of agronomic traits, their correlation to yield and ratooning ability of near commercial sugarcane varieties under supplementary irrigated and rainfed conditions

A. L.C. De Silva

Division of Agronomy, Sugarcane Research Institute, Uda Walawe

Abstract

The objective of this study was to evaluate near commercial sugarcane varieties for long term cultivation under different growing conditions in Sri Lanka. The experiments were started in 2004 *Maha* season, are being continued to the end of 2009 at the Sugarcane Research Institute, Sri Lanka (6°21'N, 80°48'E). Six near commercial varieties (SL906237, SL924918, SL924997, SL925588, SL93938 and SL93945) along with two standards (SL88116 and Co775) were grown in two experiments under supplementary irrigated and rainfed conditions. Yields, cane yield traits (*NMS*, stalk weight, stalk height, stalk diameter, *NOI* and *LAI* at harvest), their correlations to yields in plant and ratoon crops, and ratooning ability were evaluated. Out of the six varieties tested, SL924918 and SL906237 were identified for possible recommendation to growers, on the basis of their superior cane and sugar yields in plant and 1st ratoon crops under both water regimes. However, SL924997 and SL925588 were comparatively superior on sugar yields under both water regimes. High levels of number of millable stalks per ha (*NMS*) and stalk weight showed significant positive correlation with cane yields and reduction of these traits in ratoons positively correlated with ratoon yield reductions. Moreover, it was varied for tested varieties under both water regimes. Therefore, in the selection of varieties with higher plant and ratoon yields, more emphasis on *NMS* and stalk weight would be of importance.

Key words: *Sugarcane, Agronomic traits, Ratoon crops, Irrigated, Rainfed*

Introduction

On a global scale, maximum average productivity of sugarcane has increased from 75 to 95 t cane ha^{-1} and from 5 to 12 t sugar ha^{-1} during the period 1960 to 2000 (Cock, 2003). However, in Sri Lanka, the average yield during the last decade has been 60 t cane ha^{-1} and 5 t sugar ha^{-1} (Anon, 2008). The low average cane yield is due mainly to low soil moisture availability under rainfed conditions (Dharmawardene and Krishnamurthi, 1992), although *SRI* has developed locally bred improved varieties with higher potential yields. At present approximately 90% of total cultivation of sugarcane in Sri Lanka is under rainfed conditions in dry and intermediate zones and the crop experiences frequent soil moisture deficit during a considerable part of the year. Furthermore, new sugarcane plantations of about 20,000 ha are proposed under rainfed conditions in Bibile, along with a new sugar factory. Hence, selection of varieties that have better agronomic and ratoon performances under rainfed conditions is the most promising pathway to increase sugarcane yield in Sri Lanka.

In addition, the low average cane yield is due to poor growth of ratoon crops. Ratoon cropping is a common practice in most sugarcane growing countries as it significantly reduces the cost of planting operations and seedcane, which is the largest proportion of cost of sugarcane production (Verma, 2002). However, the yield of ratoons is less than the yield of the plant crop (*PC*). A cane yield decline of 10-15% in ratoons is a common phenomenon throughout the world (Sundara *et al.*, 1992 and Sundara, 1997). In India, average yield decline from *PC* to 1st ratoon (R_1) is about 20-25% (Sundara, 1998). In Australia, it is about 15-18% (Berding *et al.*, 2005). A similar situation on ratoon yield decline could be observed in other countries including Sri Lanka. Therefore, the low yields in ratoon crops limit the economic productivity of sugarcane when several ratoons are practiced. Number of ratoons varying from 2-15 are taken in different sugarcane growing conditions. It is dependent on climatic and soil conditions, pest, disease and weed infestation, management practices, water availability and ratoonability (*RA*) of the cultivars (Verma, 2002).

Out of these complex causes for declining ratoon yields, management practices and *RA* of the varieties are the most important (Singh and Singh, 2002). Therefore, within similar environmental and management conditions, *RA* is an important genotypic factor which could be improved to enhance the sugarcane yields in Sri Lanka. Moreover, sugarcane cultivars show substantial variation in *RA* which is a cane yield related character and has a significant genetic correlation with stalk number of the *PC* (Milligan *et al.*, 1992 and Singh *et al.*, 2005). *RA* of sugarcane is defined as the ratio between cane or sugar yield at the 2nd ratoon crop (R_2) relative to the *PC* (Milligan *et al.*, 1992). The *RA* has also been quantified using the absolute cane and sugar yield at the 2nd ratoon crop (Mirzawan and Sugiyarta, 1999). In the ratoon crop, it is common that stalk number increases while weight per stalk decreases. High tiller density during early growth of ratoon crop leads to excessive competition and results in reduced weight of cane and death of some tillers. Lighter and less millable stalks due to tiller or stalk death are responsible for the lower cane yield in ratoon crops. Moreover, the traits, such as high *NMS* and stalk weight are indicative of better ratooning varieties (Milligan *et al.*, 1992; Ferraris *et al.*, 1993; Sundara, 1997; Mirzawan and Sugiyarta, 1999; Singh *et al.*, 2005 and De Silva, 2007). Therefore, these genetically correlated traits in sugarcane which show substantial variation could be used to select the better ratooning varieties. The objective of this study was to evaluate near commercial sugarcane varieties on the basis of agronomic and ratooning performances and correlate related traits and to select better varieties for long term cultivation under different growing conditions in Sri Lanka.

Materials and Methods

Field experiments were started in November 2004 and will be continued up to October 2009 at the Sugarcane Research Institute (SRI), Uda Walawe, Sri Lanka (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 (Panabokke, 1996). The average annual minimum and maximum temperatures are $22^0 \pm 1.4^0$ C and $33^0 \pm 1.6^0$ C. 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).

Two separate experiments under supplementary irrigated and rainfed conditions which contained six near commercial sugarcane (*Saccharum* hybrid L.) varieties (i.e. SL906237, SL924918, SL924997, SL925588, SL93938 and SL93945) along with Co775 and SL88116 as the standards were conducted in a *RCBD* design using three replicates. 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). After testing the maturity of cane samples with top:bottom ratio of brix values at one month intervals from seven months after planting, both irrigated and rainfed plots were harvested at 13 months (in December 2005) as the *PC*. After stubble shaving, the 1st ratoon crop (R_1) of irrigated and rainfed plots were ratooned in

January 2006. The R_1 crop of the irrigated trial was harvested in February 2007 whereas rainfed plots were harvested in March 2007 at 14 *MAP* because of delayed maturity. The second ratoon crops (R_2) of irrigated and rainfed were ratooned in March 2007 and irrigated plots were harvested in March 2008 whereas harvesting of rainfed plots is delayed up to August 2008. Therefore, this paper presents only the results of *PC* and R_1. However, experiments will be continued up to 3rd ratoon crops to evaluate ratoonability of near commercial varieties as well. Rainfall and pan-evaporation data during the experimental period were taken from the *SRI* weather station which is located close to the experimental site.

Cane yield, sugar yield and juice quality parameters, total biomass production and biomass partitioning in to the stalk and yield traits, i.e. number of millable stalks ha^{-1} (*NMS*), height, weight, diameter and number of internodes of the stalk, number of leaves per stalk, leaf length, leaf width and *LAI* were recorded in *PC* and R_1 at harvesting. Leaf area was measured by length and width method using a pre-calculated leaf area co-efficient. *RA* of sugarcane varieties was determined based on the ratio between cane yields at the R_1 crop relative to the *PC*. 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 traits were determined by simple linear correlation analysis. The *SAS* statistical computer package (2004) was used to analyse the data.

RESULTS AND DISCUSSION

Seasonal variation of rainfall and its impact in variation of cane yield

The annual average rainfall of 1276 mm in 2005 which was lower than the standard annual average rainfall (1450 mm) of the experimental site, affected the plant crop. However, normal annual rainfall of 1552 mm was received in the year 2006, which coincided with R_1 crop duration. Moreover, the highest seasonal total rainfall (*STRf*) of 1750 mm was received during the R_1 crop. A higher difference between *STRf* and seasonal total pan evaporation (*STPEv*) was recorded during the *PC* which indicates the significant environmental water deficit to this crop than the ratoon crop (Fig. 1).

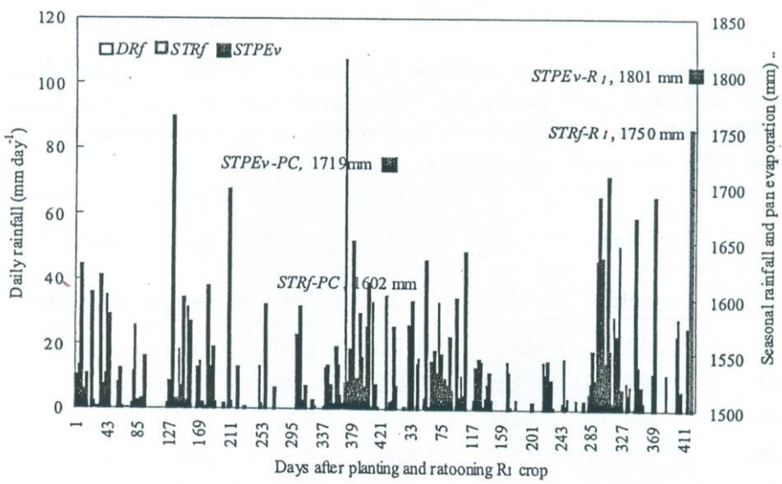

Fig.1. *Daily rainfall (DRf) from planting to harvesting of R_1 crop of the experiment (from 01/11/2004 to 28/02/2007) and seasonal total rainfall (STRf) and seasonal total pan evaporation (STPEv) in PC and R_1 crop durations. Source: Engineering Division, SRI.*

Rather than the *STRf*, distribution of rainfall (No. of rainy days where rainfall = or > 20 mm day^{-1} throughout the growing period) is important to maintain the growth and yield of sugarcane under rainfed conditions. Total number of rainy days in *PC* and R_1 crop durations were 152 and 171 respectively whereas the number of rainy days that rainfall = or >20 mm day^{-1} in *PC* and R_1 crop durations were 28 and 33 respectively (Fig. 1). Total durations of *PC* and R_1 crops under rainfed conditions were 13 and 14 months respectively whereas total durations of *PC* and R_1 crops under irrigated conditions were 13 months. Majority of near commercial sugarcane varieties under rainfed conditions responded to this variation in rainfall from *PC* to ratoon and showed higher cane yield in R_1 crop compared to the *PC* (Tables 2 and 4). In contrast all tested varieties showed lower yields and yield components in R_1 compared to the *PC* under irrigated conditions (Tables 1 and 3). Basically, these results confirmed that the yield in *PC* or yield reduction in ratoons is dependent on moisture availability under water limited conditions.

Variation in yield and yield traits

Cane yield, sugar yield and cane yield traits i.e. number of millable stalks per ha (*NMS*), weight per stalk, height per stalk, stalk diameter, number of internodes per stalk (*NOI*) and *LAI*, with the exception of cane yield in *PC* and R_1 under rainfed and irrigated conditions respectively, sugar yield and *LAI* in *PC* and R_1 under irrigated conditions and stalk height in R_1 under rainfed conditions, showed significant (p<0.05) varietal variations under both water regimes in all crop classes from *PC* to R_1 (Tables 1 - 4). In the *PC*, all the varieties tested with the exceptions of SL925588 for cane yield and SL93938 and SL93945 for sugar yield, showed superior yields than the standard variety Co775 under irrigated conditions (Table 1). In the R_1, all the varieties tested with the exceptions of SL93938 and SL93945 under irrigated and rainfed conditions respectively, recorded superior sugar yield than the standard variety Co775 under both water regimes (Tables 3 and 4). Moreover, the results revealed that SL924918 showed higher yields under both water regimes in all crop classes (Tables 1 - 4).

Table 1. *Cane yield (mt ha^{-1}), sugar yield (mt ha^{-1}), number of millable stalks per ha (NMS), weight per stalk (kg), stalk height (m), stalk diameter (mm), number of internodes per stalk (NOI) and leaf area index at harvesting (LAI) of near commercial sugarcane varieties in the PC under irrigated conditions.*

Variety	Cane yield	Sugar yield	*NMS*	Stalk weight	Stalk height	Stalk diameter	*NOI*	*LAI*
SL906237	116.50	13.86	118410	0.99	2.60	21.86	28.83	2.08
SL924918	127.08	12.58	90295	1.41	3.05	28.55	38.70	3.00
SL924997	106.76	12.89	108948	0.99	2.30	28.77	31.57	3.83
SL925588	91.62	12.27	100095	0.92	2.05	24.74	28.17	2.59
SL93938	99.62	9.44	90903	1.11	2.47	27.55	25.80	2.39
SL93945	101.12	8.25	105704	0.96	2.36	23.06	25.53	3.07
Co775	94.27	10.64	94147	1.02	2.52	25.51	29.00	2.86
Mean	105.28	11.42	101215	1.06	2.48	25.72	29.66	2.83
LSD (p=0.05)	25.27	4.87	15546	0.27	0.50	2.73	5.77	1.79

Note: *LSD* (p=0.05) for varietal comparisons within a respective variable.

Table 02 Cane yield (mt ha^{-1}), sugar yield (mt ha^{-1}), *NMS*, weight per stalk (kg), stalk height (m), stalk diameter (mm), *NOI* and *LAI* of near commercial sugarcane varieties in the *PC* under rainfed conditions.

Variety	Cane yield	Sugar yield	*NMS*	Stalk weight	Stalk height	Stalk diameter	*NOI*	*LAI*
SL906237	54.79	5.36	90565	0.61	1.92	23.85	22.76	1.92
SL924918	60.92	4.72	66640	0.92	2.13	31.36	31.60	2.87
SL924997	60.53	6.84	67789	0.89	1.89	30.62	26.67	2.20
SL925588	56.40	6.70	77926	0.73	1.76	23.32	24.33	1.77
SL93938	52.87	3.77	64409	0.82	2.13	28.46	25.67	1.26
SL93945	48.55	4.93	79481	0.62	1.91	23.39	24.27	1.42
SL88116	51.61	6.31	59476	0.86	1.57	29.26	25.07	2.03
Co775	57.89	6.32	66842	0.87	1.79	27.32	23.83	2.19
Mean	55.45	5.62	71641	0.79	1.89	27.20	25.52	1.96
LSD (p=0.05)	14.45	1.88	17212	0.14	0.24	3.18	3.71	0.69

Note: *LSD (p=0.05) for varietal comparisons within a respective variable.*

Table 03. *Cane yield (mt ha^{-1}), sugar yield (mt ha^{-1}), NMS, weight per stalk (kg), stalk height (m), stalk diameter (mm), NOI and LAI of near commercial sugarcane varieties in R_1 crop under irrigated conditions.*

Variety	Cane yield	Sugar yield	*NMS*	Stalk weight	Stalk height	Stalk diameter	*NOI*	*LAI*
L906237	86.48	11.36	110368	0.78	2.37	21.56	27.30	2.56
SL924918	89.55	11.14	77859	1.16	2.37	27.93	30.83	2.60
SL924997	70.25	9.36	74682	0.94	1.98	26.13	26.30	2.12
SL925588	69.51	9.92	94553	0.74	1.90	20.89	27.03	2.28
SL93938	80.97	8.69	86104	0.94	2.56	24.75	25.70	2.09
SL93945	82.19	9.06	106042	0.78	2.38	21.89	25.70	2.33
Co775	73.23	8.86	83942	0.87	2.06	25.75	24.60	2.36
Mean	78.88	9.77	90507	0.89	2.23	24.13	26.78	2.33
LSD (p=0.05)	16.89	2.91	16375	0.10	0.39	2.74	2.85	0.91

Note: *LSD* (p=0.05) for varietal comparisons within a respective variable.

The importance of traits in yield determination and correlation between them varied in different varieties within and between crop classes and water regimes. For example, in the *PC*, SL924918 which had the high stalk weight, stalk height and *NOI*, second highest stalk diameter and lowest *NMS*, recorded the highest cane yield under irrigated conditions. In contrast, SL906237 which had the highest *NMS*, second highest stalk height and lowest stalk diameter and *LAI*, recorded the second highest cane yield and the highest sugar yield under the same conditions. SL924918 which had the highest *NOI* and *LAI*, highest stalk weight and stalk diameter, second highest stalk height, recorded the highest cane yield under rainfed conditions (Table 2).

In the R_I, SL906237 and SL924918 which had significantly ($p<0.05$) higher *NMS* and stalk weight respectively, obtained significantly ($p<0.05$) higher sugar yield than Co775, and the highest and second highest cane yield respectively under rainfed conditions (Table 4). SL906237 which had the highest *NMS* and second highest *NOI* and *LAI*, and second lowest stalk diameter, recorded highest sugar yield and second highest cane yield under irrigated conditions. SL924918 which had the highest stalk weight, stalk diameter, *NOI* and *LAI*, and second lowest *NMS*, obtained the highest cane yield and second highest sugar yield under irrigated conditions (Table 3).

Correlation analysis in yield traits

In the different crop classes under different water regimes, cane yield had significant positive correlations with all yield traits with the few exceptions. Under irrigated conditions, cane yield showed a significant positive correlation with stalk weight, stalk height and *NOI* in all crop classes and *NMS* and *LAI* in R_I and *LAI* in *PC* (Tables 5 and 7). Under rainfed conditions, cane yield showed a significant positive correlation with stalk weight, stalk height and *LAI* in *PC* and R_I, and stalk diameter and *NMS* in *PC* and R_I respectively (Tables 6 and 8). Moreover, varieties SL906237, SL93945 and SL925588 which had highest, second highest and third highest *NMS* respectively and lowest, second lowest and third lowest stalk weight respectively under rainfed conditions in the *PC* (Table 2), showed a negative correlation between *NMS* and stalk weight under rainfed conditions. The results of linear correlation analysis of yield traits showed significant negative correlation in *NMS* with stalk weight and stalk diameter under both conditions (Tables 5 - 8).

Table 4. *Cane yield (mt ha^{-1}), sugar yield (mt ha^{-1}), NMS, weight per stalk (kg), stalk height (m), stalk diameter (mm), NOI and LAI of near commercial sugarcane varieties in the R_I crop under rainfed conditions.*

Variety	Cane yield	Sugar yield	*NMS*	Stalk weight	Stalk height	Stalk diameter	*NOI*	*LAI*
SSL906237	75.05	9.03	104826	0.72	2.14	21.77	26.00	2.48
SL924918	67.35	7.66	68059	0.99	2.11	26.52	32.13	2.44
SL924997	61.50	7.28	71776	0.86	1.87	27.15	27.33	2.28
SL925588	51.03	6.47	78940	0.64	1.87	22.14	29.77	2.16
SL93938	52.99	5.59	61909	0.85	2.13	24.55	25.57	1.47
SL93945	44.77	5.09	74953	0.60	2.03	21.57	25.87	2.10
SL88116	48.49	6.61	59070	0.82	1.71	26.81	26.67	1.83
Co775	45.21	5.44	60692	0.74	1.80	26.26	26.30	2.23
Mean	55.80	6.65	72528	0.78	1.96	24.60	27.45	2.12
LSD (p=0.05)	15.18	1.71	12581	0.11	0.36	2.64	3.22	1.09

Note: *LSD* (p=0.05) for varietal comparisons within a respective variable.

Table 5. *Linear correlation coefficients between agronomic traits of sugarcane in the PC grown under irrigated conditions.*

	Cane yield	*NMS*	Stalk weight	Stalk height	Stalk diameter	*NOI*	*LAI*
Cane yield		0.076 ns	0.737**	0.548*	-0.006 ns	0.530*	0.005 ns
NMS	0.076 ns		-0.610*	-0.384 ns	-0.436*	-0.101 ns	0.009 ns
Stalk weight	0.737**	-0.610*		0.711**	0.318 ns	0.531*	0.002 ns
Stalk height	0.548*	-0.384 ns	0.711**		0.004 ns	0.544*	0.020 ns
Stalk diameter	-0.006 ns	-0.436*	0.318 ns	0.004 ns		0.344 ns	0.298 ns
NOI	0.530*	-0.101 ns	0.531*	0.544*	0.344 ns		-0.064 ns
LAI	0.005 ns	0.009 ns	0.002 ns	0.020 ns	0.298 ns	-0.064 ns	

Note: **- Significant at $p<0.0001$; *- Significant at $p<0.05$; ns- Non-significant at $p=0.05$.

Table 6. *Linear correlation coefficients between agronomic traits of sugarcane in the PC grown under rainfed conditions.*

	Cane yield	*NMS*	Stalk weight	Stalk height	Stalk diameter	*NOI*	*LAI*
Cane yield		0.337 ns	0.499*	0.392*	0.377*	0.350 ns	0.553*
NMS	0.337 ns		-0.637*	0.086 ns	-0.558*	-0.315 ns	0.015 ns
Stalk weight	0.499*	-0.637*		0.232 ns	0.823**	0.581*	0.447*
Stalk height	0.392*	0.086 ns	0.232 ns		0.247 ns	0.489*	0.165 ns
Stalk diameter	0.377*	-0.558*	0.823**	0.247 ns		0.598*	0.395*
NOI	0.350 ns	-0.315 ns	0.581*	0.489*	0.598*		0.294 ns
LAI	0.553*	0.015 ns	0.447*	0.165 ns	0.395*	0.294 ns	

Note: **- Significant at $p<0.0001$; *- Significant at $p<0.05$; ns- Non-significant at $p=0.05$.

Table 7. *Linear correlation coefficients between agronomic traits of sugarcane in the R_1 crop grown under irrigated conditions.*

	Cane yield	*NMS*	Stalk weight	Stalk height	Stalk diameter	*NOI*	*LAI*
Cane yield		0.436*	0.456*	0.682*	0.109 ns	0.555*	0.421*
NMS	0.436*		-0.592*	0.221 ns	-0.662*	-0.050 ns	0.302 ns
Stalk weight	0.456*	-0.592*		0.388 ns	0.755**	0.596*	0.105 ns
Stalk height	0.682*	0.221 ns	0.388 ns		0.181 ns	0.382 ns	0.233 ns
Stalk diameter	0.109 ns	-0.662*	0.755**	0.181 ns		0.257 ns	0.078 ns
NOI	0.555*	-0.050 ns	0.596*	0.382 ns	0.257 ns		0.283 ns
LAI	0.421*	0.302 ns	0.105 ns	0.233 ns	0.078 ns	0.283 ns	

Note: **- Significant at $p<0.0001$; *- Significant at $p<0.05$; ns- Non-significant at $p=0.05$.

Table 8. *Linear correlation coefficients between agronomic traits of sugarcane in the R_1 crop grown under rainfed conditions.*

	Cane yield	*NMS*	Stalk weight	Stalk height	Stalk diameter	*NOI*	*LAI*
Cane yield		0.695**	0.485*	0.473*	-0.029 ns	0.365 ns	0.568*
NMS	0.695**		-0.288 ns	0.359 ns	-0.558*	0.022 ns	0.540*
Stalk weight	0.485*	-0.288 ns		0.211 ns	0.615*	0.457*	0.069 ns
Stalk height	0.473*	0.359 ns	0.211 ns		-0.321 ns	0.310 ns	0.109 ns
Stalk diameter	-0.029 ns	-0.558*	0.615*	-0.321 ns		0.159 ns	0.023 ns
NOI	0.365 ns	0.022 ns	0.457*	0.310 ns	0.159 ns		0.227 ns
LAI	0.568*	0.540*	0.069 ns	0.109 ns	0.023 ns	0.227 ns	

Note: **- Significant at $p<0.0001$; *- Significant at $p<0.05$; ns- Non-significant at $p=0.05$.

However, these traits had significant positive correlations with cane yield. Moreover, stalk weight had a significant positive correlation with stalk diameter and *NOI* under rainfed conditions and with stalk height and *NOI* under irrigated conditions. Therefore, the traits *NMS* and stalk weight should be considered in a suitable breeding program to break this negative relationship in selecting varieties for different growing conditions.

The contribution of yield traits to cane yield, as indicated by the partial R^2 value of multiple regression analysis for each trait, varied within and between crop classes and water regimes (Table 9). Except in R_1 under irrigated conditions, recorded highest R^2 values showed that stalk weight contributed most to the cane yield in all crop classes under irrigated and rainfed conditions. Stalk height contributed most to the cane yield in R_1 under

Table 9. *Partial R^2 values for multiple regression between cane yield and the respective yield traits of near commercial sugarcane varieties in PC and R_1 crops under irrigated and rainfed conditions.*

Yield traits	Regression coefficients (R^2) with cane yield			
	Irrigated		Rainfed	
	PC	R_1	*PC*	R_1
No. of stalks ha^{-1}	0.438	0.219	0.208	0.483
Stalk weight	0.542	0.200	0.555	0.512
Stalk diameter	0.001	*ns*	*ns*	0.001
Stalk height	*ns*	0.466	*ns*	*ns*
No. of internodes	0.004	0.102	*ns*	*ns*
LAI at harvest	*ns*	*ns*	0.206	0.001
PBS	0.001	*ns*	0.001	*ns*

Note: *ns* = Respective variables were not within the 0.500 significance level, *PBS* = Partitioning of biomass into the stalk. R^2 indicates the fraction of cane yield variation explained the variation of a given component factor.

irrigated conditions. However, the *NMS* was the component which had the second highest contribution to cane yield consistently in all crop classes under both water regimes. Moreover, De Silva (2007) recorded that the *NMS* was the component which had the highest contribution to cane yield in commercial sugarcane varieties in Sri Lanka under both water regimes. Thus *NMS* may be considered as the most reliable yield contributing trait. *NMS* is a better index for selection as it is a character which shows clear and significant genotypic variation (Singh *et al.*, 2005). Moreover, selection for *NMS* could easily be made without harvesting.

Ratoon yield reductions and ratoonability

Cane yield and stalk weight reductions from the *PC* to the R_1 showed significant ($p<0.05$) varietal variation under rainfed conditions (Table 11). However, all the varieties tested reduced cane yield and yield traits in R_1 compared to the *PC* with few exceptions under irrigated conditions (Table 10). In contrast, majority of varieties tested increased cane yield and many yield traits except mean stalk diameter in R_1 compared to the *PC* under rainfed conditions due to better rainfall during R_1 (Table 11).

Cane yield reductions from *PC* to R_1 were significantly positively correlated with reductions in *NMS* ($r^2 = 0.81$ with $p=0.0001$), stalk weight ($r^2 = 0.56$ with $p=0.004$) and *LAI* ($r^2 = 0.48$ with $p=0.01$) under rainfed conditions and reduction in *NMS* ($r^2 = 0.58$ with $p=0.005$) under irrigated conditions (Table 12). These results suggested that the traits, i.e. high stalk number and stalk weight are indicative of better ratooning varieties. This finding was generally in agreement with those reported by Milligan *et al.* (1992), Ferraris *et al.* (1993), Mirzawan and Sugiyarta (1999), Singh *et al.* (2005) and De Silva (2007). However, as *NMS* had significant negative correlations with stalk weight, it is suggested that selection for moderate stalk number in the younger crops would enhance plant and ratoon yields. Milligan *et al.* (1992) showed that stalk number in the younger crop was the only trait that was significantly correlated to ratoon yields, and yield in R_2 could be predicted by yield in R_1. However, the best improvement of yield in R_2 could be obtained by selection in the R_2.

Table 10. *Reductions in cane yield (mt ha^{-1}) and yield traits (NMS, stalk weight, LAI, stalk diameter and NOI) in different sugarcane varieties from PC to the R_1 crop under irrigated conditions.*

Variety	Reduction from plant crop to the 1st ratoon crop					
	Cane yield (mt ha^{-1})	*NMS*	Stalk weight (kg)	*LAI*	Stalk diameter (mm)	*NOI*
SL906237	30.03	8043	0.21	-0.48	0.30	1.53
SL924918	37.52	12436	0.26	0.40	0.61	7.87
SL924997	36.50	34266	0.06	1.70	2.64	5.27
SL925588	22.10	5542	0.18	0.32	3.84	1.13
SL93938	18.65	4799	0.18	0.30	2.80	0.10
SL93945	18.93	-338	0.18	0.74	1.18	-0.17
Co775	21.04	10205	0.14	0.50	-0.24	4.40
Mean	26.40	10708	0.17	0.50	1.59	2.88
LSD (p=0.05)	23.76	24246	0.21	2.47	3.97	7.00

Table 11 Reductions in cane yield (mt ha^{-1}) and yield traits (*NMS*, stalk weight, *LAI*, stalk diameter and *NOI*) in different sugarcane varieties from *PC* to the R_1 under rainfed conditions.

Variety	Reduction from plant crop to the 1st ratoon crop					
	Cane yield (mt ha^{-1})	*NMS*	Stalk weight (kg)	*LAI*	Stalk diameter (mm)	*NOI*
SL906237	-20.26	-14261	-0.11	-0.57	2.08	-3.24
SL924918	-6.43	-1419	-0.07	0.43	4.84	-0.53
SL924997	-0.97	-3988	0.03	-0.07	3.47	-0.67
SL925588	5.38	-1014	0.09	-0.39	1.18	-5.43
SL93938	-0.11	2501	-0.03	-0.22	3.91	0.10
SL93945	3.78	4528	0.02	-0.68	1.82	-1.60
SL88116	3.12	406	0.04	0.20	2.45	-1.60
Co775	12.68	6150	0.12	-0.04	1.06	-2.47
Mean	-0.35	-887	0.01	-0.17	2.60	-1.93
LSD (p=0.05)	12.53	19579	0.11	1.31	4.12	4.83

Note: *LSD* (p=0.05) for varietal comparisons within a respective variable. Negative values indicate that the respective values in the R_1 crop were higher than in the plant crop.

Table 12 Linear correlation coefficients between reductions in cane yield and yield traits of sugarcane varieties from *PC* to R_1 under both water regimes.

Reduced yield traits	Correlation coefficients with cane yield reduction from *PC* to R_1	
	Irrigated	Rainfed
NMS	0.58*	0.81**
Stalk weight	0.23^{ns}	0.56*
NOI	0.35^{ns}	-0.09^{ns}
LAI	0.29^{ns}	0.48*
Stalk diameter	-0.06^{ns}	-0.28^{ns}

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

In the current study, average cane yield from *PC* to R_1 and ratio between cane yields at the R_1 crop relative to the *PC* crop (R_1/*PC*) showed significant varietal variations under both water regimes. The variety SL924918 which had highest absolute cane yield in R_1 (Table 03) and the highest average cane yield from *PC* to R_1, obtained highest ratooning ability (*RA*) under irrigated conditions whereas SL93945 recorded highest ratio between cane yields R_1/*PC* (Table 13). Under rainfed conditions, SL906237 which had highest absolute cane yield in R_1 (Table 04), highest ratio between cane yields R_1/*PC* and highest average cane yield from *PC* to R_1, obtained highest ratooning ability (*RA*) (Table 13). The study revealed that out of the six near commercial sugarcane varieties that were evaluated SL906237 and SL924918 could be successfully used to replace the currently existing Co775 in commercial sugarcane cultivation in Sri Lanka.

Table 13. *Comparison of average cane yield of PC and* R_1, *and the ratio between cane yields at* R_1 *crop relative to the PC of different sugarcane varieties under irrigated and rainfed conditions.*

Variety	Average cane yield (t ha^{-1}) of *PC* and R_1 and cane yield ratio of R_1:*PC*			
	Irrigated		Rainfed	
	Average yield of *PC* and R_1	Yield ratio R_1:*PC*	Average yield of *PC* and R_1	Yield ratio R_1:*PC*
SL906237	101.49	0.74	64.92	1.41
SL924918	108.32	0.72	64.13	1.13
SL924997	88.51	0.66	61.02	1.02
SL925588	80.57	0.76	53.72	0.89
SL93938	90.29	0.82	52.93	1.01
SL93945	91.65	0.83	46.66	0.93
SL88116	*NE*	*NE*	50.05	0.95
Co775	83.75	0.78	51.55	0.78
Mean	92.08	0.76	55.62	1.01
LSD (p=0.05)	17.90	0.19	13.43	0.25

Note: *LSD* (p=0.05) for varietal comparisons within a respective variable. *NE* = SL88116 was not included for evaluation as a standard variety under irrigated conditions.

CONCLUSIONS

The present study showed that there is a significant ($p<0.05$) genotypic variation in the agronomic traits (*NMS*, stalk weight, stalk height, stalk diameter and *NOI* at harvest) than the cane and sugar yields under both conditions in all crop classes from *PC* to R_1. However, correlation of agronomic traits to determine cane yields varied under different sugarcane growing conditions in Sri Lanka. Moreover, among the six near commercial varieties tested in the present study, there was no variety in which all above traits were present at favourable levels. Different characters were responsible for higher yields in different varieties under different conditions. Consequently, yields of the six varieties tested under each condition showed a comparatively narrow range, thus indicating a relatively narrow genotypic variation for selecting varieties on the basis of yield alone. Based on these conclusions, the following approaches are recommended for selecting varieties for sugarcane-growing environments in Sri Lanka: (a) Selecting varieties on the basis of agronomic traits which have shown significant correlations with 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 presently narrow genetic base for cane yield.

ACKNOWLEDGEMENTS

This research was funded by the Sugarcane Research Institute (*SRI*). The director and board of governors of the *SRI*, and the assistance given by Dr. W.R.G. Witharama (Head of Agronomy Division) and the staff of the Agronomy Division of the *SRI* are gratefully acknowledged.

REFERENCES

Anon. (1975). Soil taxonomy. A basic system of soil classification, United States Department of Agriculture Washington D.C., USA. pp 753

Anon. (1991). Cultivation practices of sugarcane (in sinhala), advisory circular No. 1, Sugarcane Research Institute, Uda Walawa, Sri Lanka pp 2-13.

Anon. (2008). Economic and social statistics of Sri Lanka 2008. Central Bank of Sri Lanka. Colombo, Sri Lanka.

Berding, N., Hurney, A.P., Salter, B. and Bonnett, G.D. (2005). Agronomic impact of sucker development in sugarcane under different environmental conditions. *Field Crops Research* 92: 203-217.

Cock, J.H. (2003). Sugarcane growth and development. *International Sugar Journal* 105 (1259): 540-552.

De Alwis, K.A.N. and Panabokke, C.R. (1972). Handbook of the soils of Sri Lanka. *Journal of Soil Science Society of Sri Lanka* 2: 1-26.

De Silva, A.L.C. (2007). Investigation of growth, yield, ratooning ability and some important physiological attributes of a selected set of commercial sugarcane varieties in Sri Lanka under irrigated and rainfed conditions. *Unpublished MPhil. Thesis*, the University of Peradeniya, Sri Lanka.

Dharmawardene, M.W.N. and Krishnamurthi, M. (1992). *Outline Plan for Development of Sugar Industry of Sri Lanka*. Sugarcane Research Institute, Uda Walawe, Sri Lanka pp 30-34.

Ferraris, R., Chapman, L.S. and Ludlow, M.M. (1993). Ratooning ability of cane varieties: Interception of light and efficiency of light use. *Proceedings Australian Society of Sugar Cane Technologists* 15: 316-322.

Milligan, S.B., Gravois, K.A. and Martin, F.A. (1992). Inheritance of sugarcane ratooning ability and relationship of younger crop traits to older crop traits. *Proceedings XXI Congress International Society of Sugar Cane Technologists* 404-417.

Mirzawan, P.D.N. and Sugiyarta, E. (1999). Ratooning ability in sugarcane: direct *Vs* indirect selection based on clonal performance in younger crops. *Proceedings XXI Congress International Society of Sugar Cane Technologists* 467-473.

Panabokke, C.R. (1996). Soils and Agroecological Environments of Sri Lanka. Natural Resources, Science and Energy Authority of Sri Lanka pp 73-100

Sanmuganathan, K., (1992). Modeling growth of rainfed and irrigated sugarcane in the dry zone of Sri Lanka. *Unpublished MPhil. Thesis*, University of Newcastle, UK. pp 7-23.

Singh, R.K. and Singh, S.B. (2002). Stability in ratooning ability of early maturing sugarcane varieties for higher yield and recovery. *Indian Journal of Agriculture Science* 72 (12): 716-718.

Singh, R.K., Singh, S.P and Singh, S.B. (2005). Correlation and path analysis in sugarcane ratoon. *Sugar Tech.* 7(4): 176-178.

Sithakaran, V. S. (1987). Study of some physical properties of the research farm at Sugarcane Research Institute, UdaWalawa. *Unpublished BSc research report*, University of Peradeniya, Sri Lanka pp 34-43.

Sundara, B. (1997). Multiratooning potential of sugarcane varieties and management of multiratoons. *Indian Journal of Sugarcane Technology* 12(1): 24-26.

Sundara, B. (1998). *Sugarcane cultivation.* Vikas publishing house PVT LTD, New Delhi. pp 134-146.

Sundara, B., Sankaranarayanan and Batcha, M.B.G.R. (1992). Varietal characteristics affecting ratooning potential of sugarcane. *Sugarcane* 6:1-4.

Verma, R.S. (2002). Ratoon decline. *In: Sugarcane ratoon management*. International book distributing company, Lucknow, India. pp 199-203.